kSA BandiT
User Manual

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BandiT User Manual

Introduction

Contact Information

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Introduction

The kSA BandiT is a non-contact, non-invasive, optically-based real-time wafer temperature sensor. Typical substrate materials include GaAs, Si, InP, ZnSe, and ZnTe, and are measured using a NearIR spectrometer. kSA BandiT may also be used with a Visible spectrometer for SiC substrates and for GaN deposition on sapphire. Pyrometry is another method for measuring temperature in transmission mode (no light source) by measuring blackbody radiation.

BandiT provides an absolute temperature solution for low- and high-temperature wafer monitoring. BandiT works by detecting diffusely scattered light from the wafer and using that to measure the band gap absorption edge. Then, from the absorption edge, BandiT accurately determines the temperature. Hence, BandiT is insensitive to viewport transmission, stray light sources, and signal contribution from substrate heaters.

Using the NearIR spectrometer –

For high-temperature applications:

BandiT can use the substrate heater stage as the light source, operating in a single port geometry.

For low-temperature applications:

BandiT's light source mounts on one optical port, its detector mounts on a second (non-specular) port.

For MBE chambers:

BandiT is typically installed on the pyrometer port and an unused source port.

Using the Visible spectrometer –

The BandiT light source must be used for producing enough signal. Two ports are ideal, but contact us to discuss single-port configurations.

The BandiT is available in two models covering the spectral range 380 nm – 1400 nm (NearIR through Visible). Dual spectrometer units are also available for applications requiring the full spectral range.

BandiT can also take temperature via a pyrometer. Generally, this technique is less accurate than using band edge thermometry. However, the band-edge technique often fails when depositing a very absorbing layer, so the pyrometry technique is available for such situations.

Multi-wafer BandiT enables users to determine temperature on multiple wafers spinning on a platen. For Multi-wafer BandiT users, this help document includes pages specific to Multi-wafer BandiT features.

Notes:

1. Learn more about how to navigate this Help document by reading the Using Help topic.
2. Several How-To Guides are available that cover the procedures for executing BandiT's most commonly used routines.
3. For detailed information on the installation of the kSA BandiT system, please refer to the document titled kSA BandiT Install and Getting Started Guide, or contact us directly. For

information on the absorption-edge temperature measurement technique, please refer to the references on the following page.

4. In an effort to provide our customers with the latest capability (including measuring temperature of materials deposited on SiC substrates as well as GaN deposition on sapphire), kSA engineers are continually advancing kSA BandiT software. This Help Manual documents software version 1.14.

References

The kSA BandiT system analyzes the diffuse reflectance spectrum from semiconductor substrates for temperature measurement. This technique has been known for several years. However, recent progress in solid-state spectrometer performance has made the diffuse reflectance technique a viable and affordable technology for commercial semiconductor wafer temperature monitoring.

Please refer to the following references for additional information on diffuse reflectance spectroscopy:

Ri-an Zhao, Michael J. Chich, Petra Specht, and Eicke R. Weber, "In-situ Diffuse Reflectance Spectroscopy Investigation of Low-Temperature-Grown GaAs", App. Phys. Lett. **80**(12), 2002, pp. 2060-2062.

P. Thompson, Y. Li, J.J. Zhou, D.L. Sato, L. Flander, and H.P. Lee, "Diffuse Reflectance Spectroscopy Measurement of Substrate Temperature and Temperature Transient During Molecular Beam Epitaxy and Implications for Low-Temperature III-V Epitaxy", App. Phys. Lett **70**(12), 1997, pp 1605-1607.

C. Lavoie, S.R. Johnson, J.A. Mackenzie, T. Tiedje, and T. van Buuren, "Diffuse Optical Reflectivity Measurements on GaAs during Molecular-Beam Epitaxy Processing", J.V.S.T. A **10**(4), 1992, pp. 930-933.

S.R. Johnson, C. Lavoie, T. Tiedje, and J.A. Mackenzie, "Semiconductor Substrate Temperature Measurement by Diffuse Reflectance Spectroscopy in Molecular-Beam Epitaxy", J.V.S.T B **11**(3), 1993, pp. 1007-1010.

M. K. Weilmeier and K. M. Colbow, "A New Optical Temperature Measurement Technique for Semiconductor Substrates in Molecular Beam Epitaxy", Can. J. Phys. **69**, (1991) pp 422-426

System Schematic

The kSA BandiT system communicates with its hardware components via a single USB connection. As a result, the BandiT system can run from a laptop, and is extremely easy to connect to the rack mount unit. Here is a schematic of the BandiT hookup:

The main hardware components of BandiT are the following:

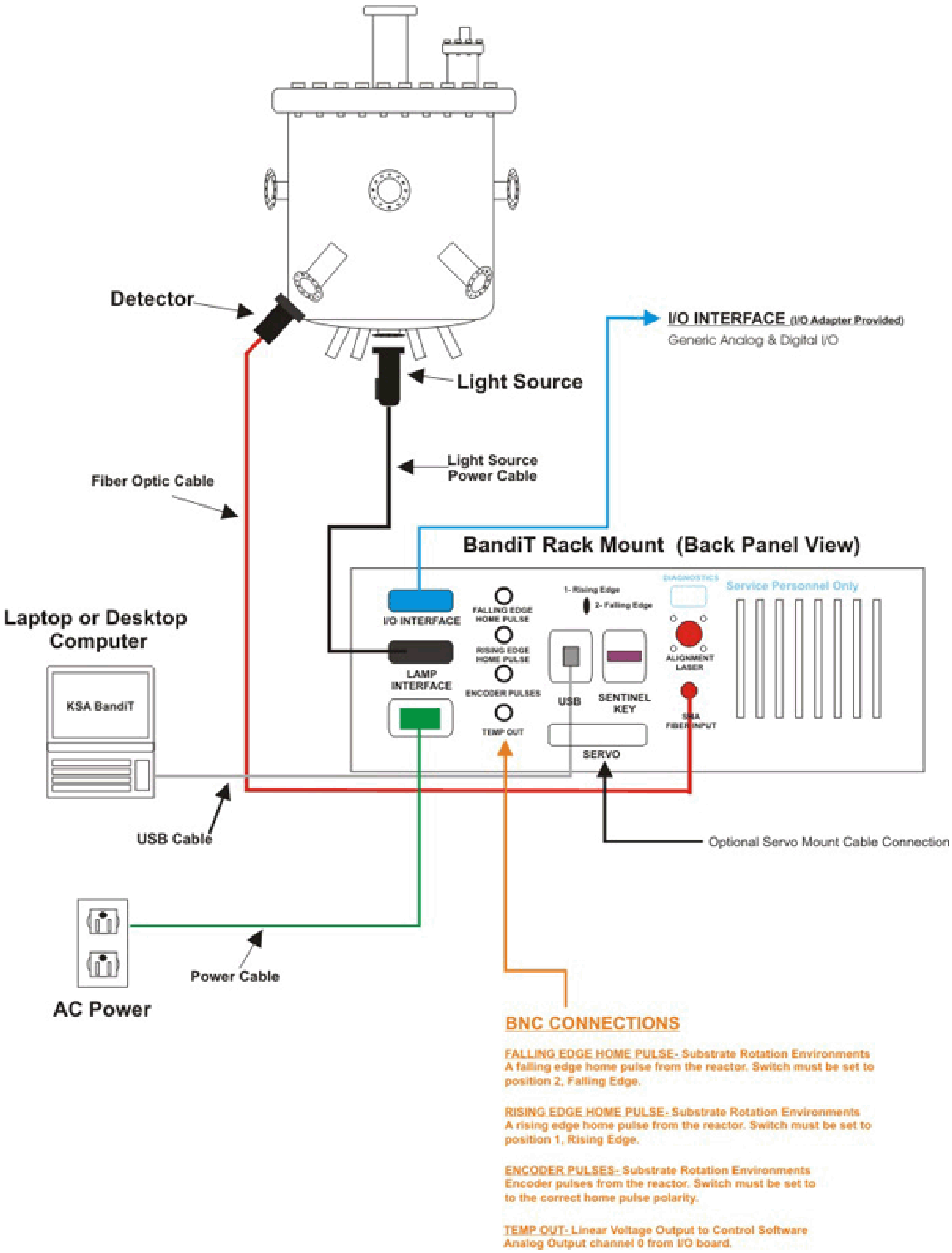
- Solid-state spectrometer
- Light source (optional)
- Alignment laser
- Detector assembly with dual 400 um fiber optic
- DT9806 USB data acquisition module

The kSA BandiT software communicates with and controls all the components listed above. From a user standpoint, external data access is made possible through the PMD1208FS board, via BNC and D-sub type connections on the back of the BandiT 19" rack mount assembly. Please refer to the document kSA BandiT Install and Getting Started Guide supplied with the BandiT system for details on wiring and connecting.

Notes:

1. ***(Fixed Temperature Output)*** The standard method for externally reading the BandiT temperature is to connect to the "Temp Out" BNC on the back panel of the BandiT 19" rack mount assembly. The signal emanating from this connector is mapped as follows:
   0 – 800°C BandiT Temperature = 0 – 10V analog output.
   Internally, this signal is emanating from Channel 0 of the PMD1208FS board.
2. ***(Fully Configurable Output)*** Temperature output is both voltage configurable and temperature-range configurable from a software standpoint. Please see the Device Output Control Advanced Acquisition Option.

The schematic diagram below shows BandiT connected to a system and computer.



Using Help

There are several ways to navigate this Help file. Below is a picture of the many options.

Note that the ***current topic*** will always appear in the upper right-hand corner of each page with the navigation route to the page.

Select:

Hide button to show/hide the *Contents*, *Index*, and *Search* panel

Back button to jump back to a previously-viewed topic

Forward to move forward to a previously viewed topic

Print button to print a page or a section and sub-sections of the help file

Throughout this Help file, click blue words (←try it!) for more information or to jump to that topic.

Most users do not read Help files straight through from beginning to end, but prefer to jump from topic to topic based on interest or need. For this reason, the ***Back*** button is probably the most useful feature because it allows the user to jump back to the previous topic even when it is not the previous page.

For example, to return to any previous topic you viewed before jumping to this Using Help topic, click the ***Back*** button.

Precautions and Care

To keep the BandiT system operational and keep those who use it from harm, please take the following precautions:

Warning
This symbol indicates:

- the possibility of minor injury
- the possibility of damage to the system or its accessories
- possible problems relating to the quality of the process

Hazard
This symbol indicates the possibility of:

- very serious injury
- fatality
- considerable damage to property

Laser Radiation
Avoid exposure to the laser beam

Wear Protective laser goggles/glasses

Water and Moisture — The system should not be used near water, or in any area where excessive moisture or condensation may come in contact with system components.

Ventilation — System components should be mounted in well-ventilated areas. Ensure that there is adequate airflow above the rack controller (intake) and to the fan side (exhaust) of the rack controller. Also ensure that there are no obstructions to the lamp housing air intake fan or the exhaust vents.

Heat — Do not place flammable materials on or near the lamp housing at any time. Always allow time for the lamp and all surfaces surrounding the bulb to cool before attempting to replace lamp.

Lamp — Never stare into the lamp output. The lamp output contains focused infrared radiation and long-term exposure to the lamp output should be avoided.

Power — Connect all cables before plugging in the BandiT system. Ensure the unit is plugged into a properly grounded outlet. The system uses a high current supply to power the lamp, so never connect or disconnect the lamp power cable or service the lamp in any manner unless the system power is OFF. As a further safety precaution, always unplug the rack controller when replacing or servicing the lamp.

Laser — Never look directly at the focused beam from the detector and always use laser goggles when aligning the system. The alignment laser used in the BandiT system is a CLASS IIIA laser (only CLASS I lasers present no eye hazard). The laser interlock should always be set to OFF when the laser is not in use.

Servicing — Do not service the unit beyond that which described in this manual. The rack controller contains no user-serviceable parts.

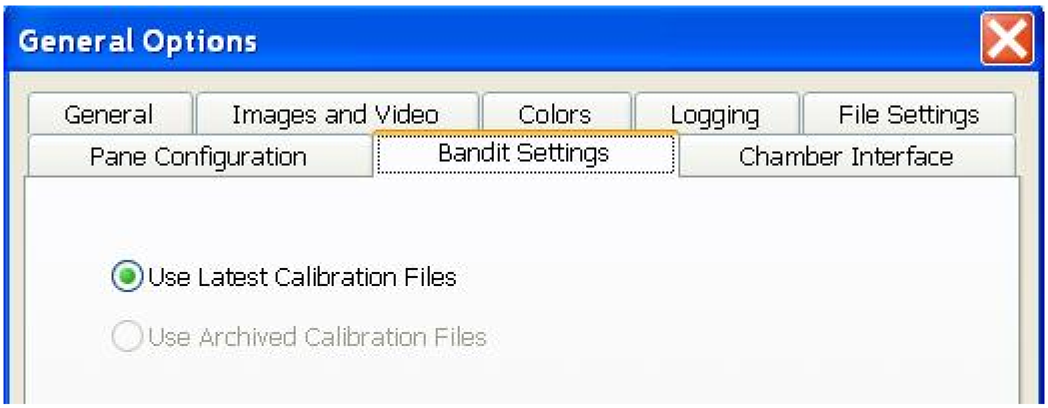
I/O Interface — Before making connections, refer to Rack Mount Controller Installation for a complete functional description of each pin in the BNC and DB-15 I/O connectors found on the BandiT rack controller.

Setup

General Options

BandiT Settings

The ***BandiT Settings*** tab is available by selecting ***General Options*** under the Options menu.



Select either

Use Latest Calibration Files – these come with the system and/or are downloaded from k-Space's web site

or

Use Archived Calibration Files – this becomes enabled only if the user has stored a folder called CalibrationArchive (all one word) in the program folder (i.e., …kSA\PROGRAM\kSA BandiT\Program\). The latest calibration files give the best temperature fit, so, in general, archived calibration files should not be used. But there are circumstances when some users have desired the use of archived calibration files. So this option allows for that functionality.

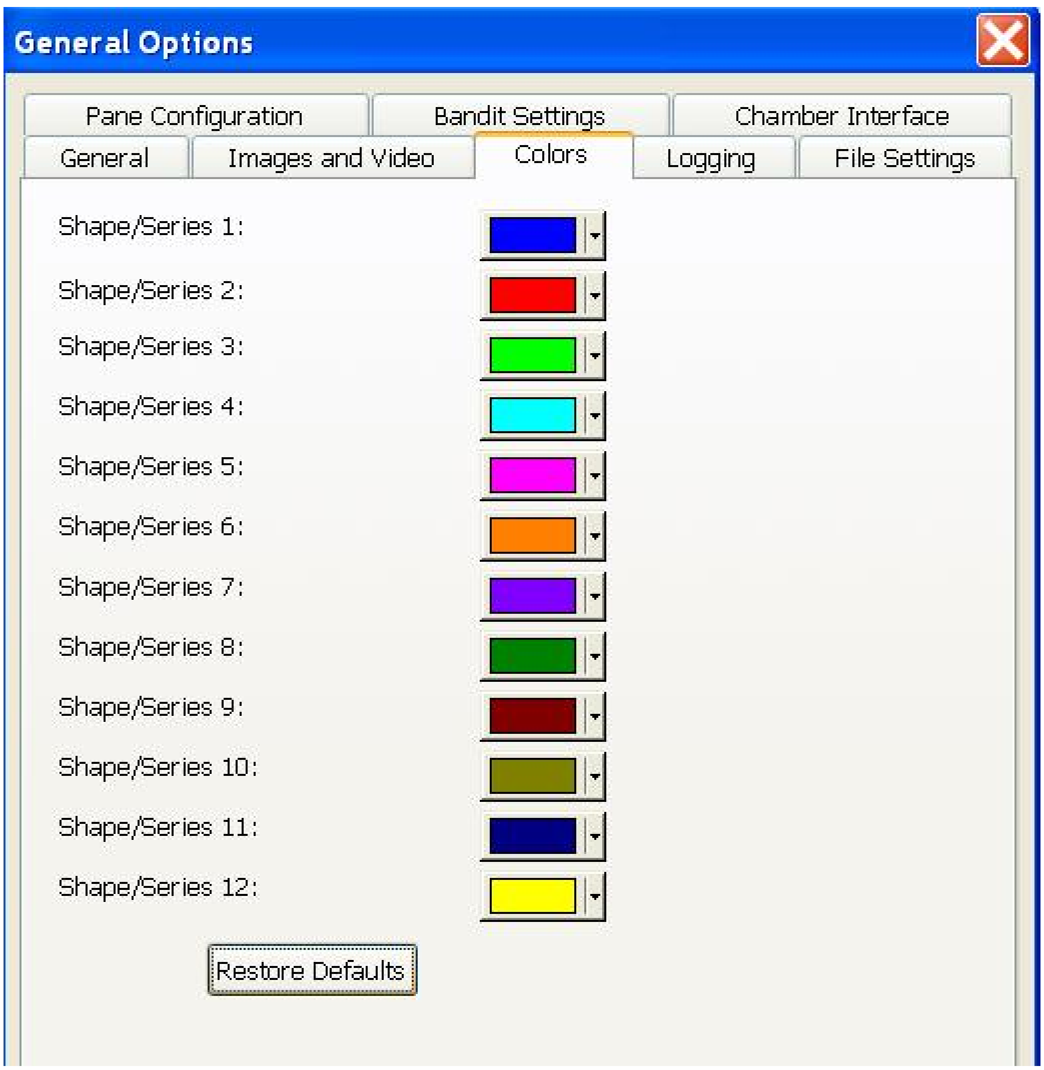
Chamber Interface

The ***Chamber Interface*** tab is available by selecting ***General Options*** under the Options menu.

This allows for software interface through TCPIP.

Colors

The ***Colors*** tab is available by selecting ***General Options*** under the Options menu.



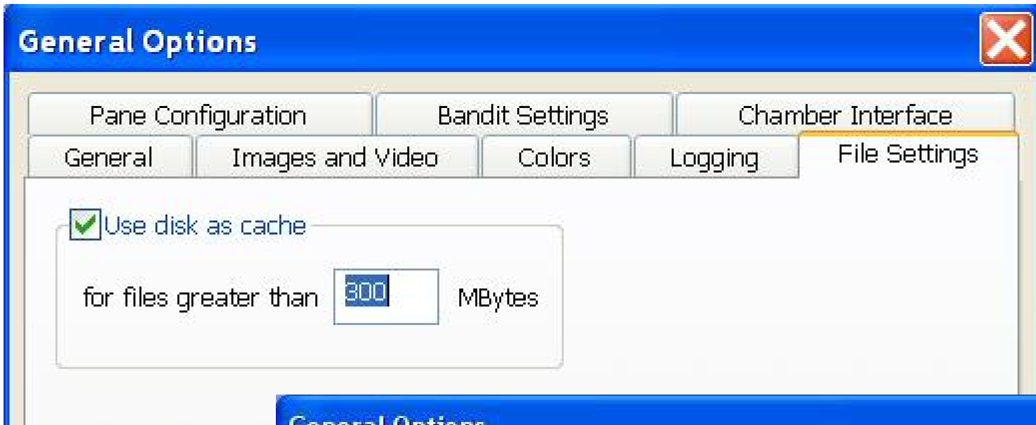
Select the color for each ***Shape/Series***. Default selections are shown above.

General Note:

After the software cycles through the twelve colors, it repeats. For example, if performing thirteen Line Profiles on a single image, both the first and the thirteenth line will be red (given the above color choices).

File Settings

The ***File Settings*** tab is available by selecting ***General Options*** under the Options menu.

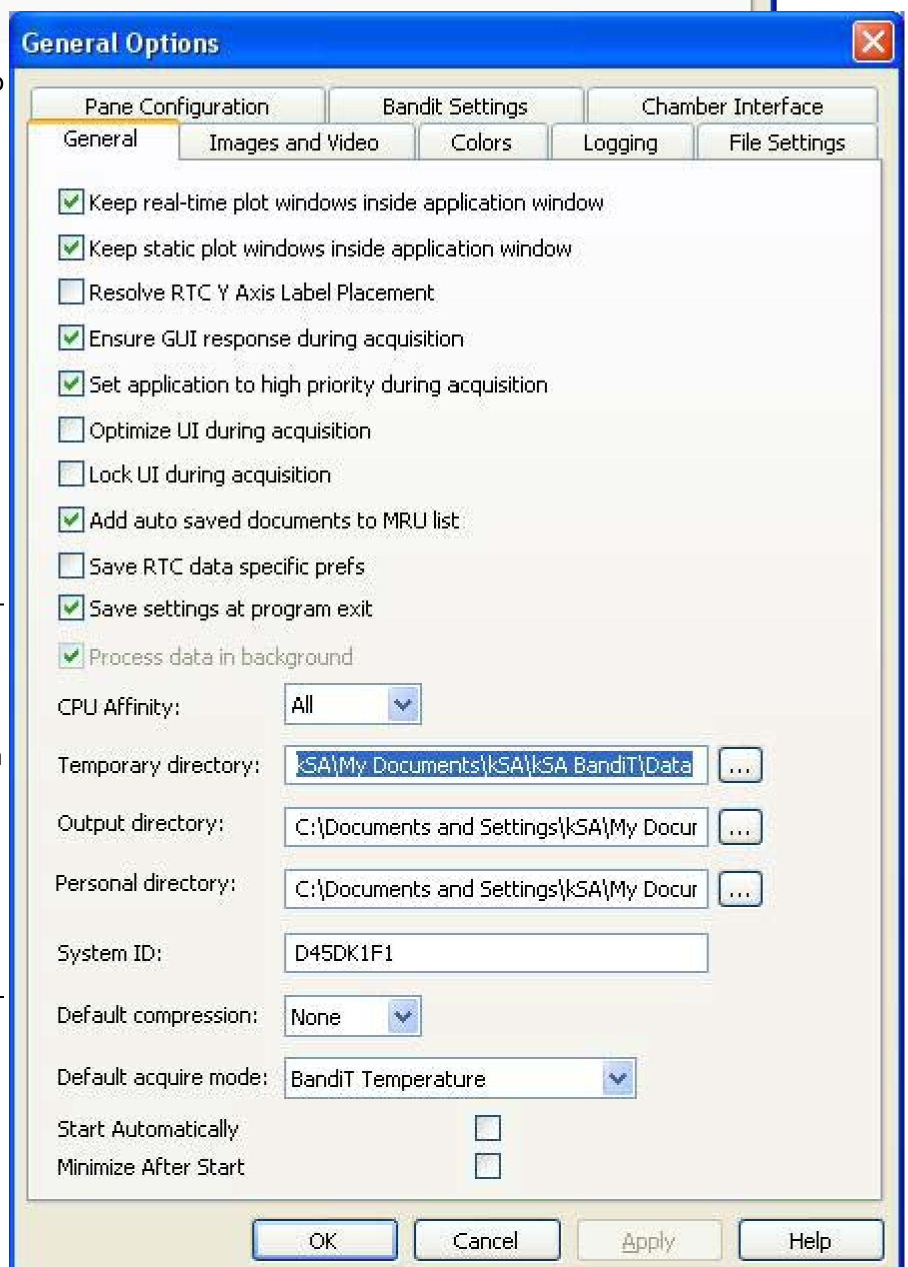


Select ***Use Disk as Cache*** to cache data to disk during acquisition

Specify file size.

General

The ***General*** tab is available by selecting ***General Options*** under the Options menu.



Select:

> ***Keep real-time plot windows inside application window*** – to keep the real-time plot windows inside the application window. If this is not checked, then you can drag the real-time plot windows outside the main application window.
>
> ***Keep static plot windows inside application window*** – to keep the static plot windows inside the

application window. If this is not checked, then you can drag the static plot windows outside the main application window.

Resolve RTC Y Axis Label Placement – in general leave unchanged. If Y-Axis labels are not centered on plots, changing this option (either from checked to unchecked or vice versa) should center it.

Ensure GUI response during acquisition – so that the program responds to user commands promptly during acquisition. Unless absolute timing precision is needed, the user can leave this box checked. To ensure maximum data throughput during acquisition, leave this box unchecked.

Set application to high priority during acquisition – to give the kSA application the highest priority within the *Windows* environment during acquisition. In the operating system vernacular, this is setting its "Priority Class" to "High," meaning that only real-time events (such as moving the mouse and refreshing the screen) are done before the kSA application acquisition task. Generally, this is not checked. But for BandiT, it should be.

Optimize UI during acquisition – to reduce the priority of the user-interface during acquisition. This will lead to less data interruption, as moving windows around can slightly affect acquisition.

Lock UI during acquisition – to keep the user-interface from working during acquisition. This prevents the user from moving any window or clicking any button until acquisition is complete.

Add auto-saved documents to MRU list – kSA software auto-saves documents generated by the program if the user has selected the auto-save checkbox in the Document Generation advanced acquisition option. Check this option to add these auto-saved documents to the Most-Recently Used list (found under the File menu at the top of the application window).

Save RTC data specific prefs – kSA software builds dynamic real-time charts (RTCs) that update, for example, the scale of the X and Y axis depending on the data. These preferences may be changed by the user, but default back to the dynamic mode once the chart is closed. Checking this box keeps those user-specified preferences the next time those charts are opened.

Save settings at program exit - this is normally checked so that the current programme settings are always saved when the programme is exited. If it is unchecked then the user will need to save settings manually.

Process data in background - this should always be checked as it causes data processing to be done in the background when processor power is available and not take up processor power that is needed to run the acquisition. If this is not checked it is possible for the acquisition to be interrupted. This can only be changed when there is no acquisition mode open, if it is greyed out, close the current acquisition mode.

Specify:

CPU Affinity - select a specific CPU for processing if required

Temporary Directory – where the program places temporary files

Output Directory – where the program saves files

Personal Directory - where the program saves files such as logging files

System ID – defaults to the computer name, but may be changed for archival purposes

Default Compression – set either to *None* for no compression or to *Z-Lib* as a loss-less compression. Note that compression takes system resources and therefore can interrupt acquisition.

Default acquire mode – an acquisition mode that opens when the software opens. Select one of:

BandiT Dark Background – to obtain a calibration of the spectrometer dark background at various spectrometer exposure times

BandiT Temperature – to obtain substrate temperature and (optionally) spectra data

BandiT Reference - used to take a reference scan when using a Visible Spectrometer

Bandit Roughness Calibration - used to calibrate the system for roughness measurements

Bandit Pyrometry Calibration - used to calibrate the temperature acquired by Pyrometry to the real BandiT temperature

Blackbody Calibration - used to calibrate the temperature acquired by Blackbody measurements

Phase Delay Selection - used to set the phase delay for a sample on a rotating platen

BandiT Temperature Scan - used by k-Space when configuring calibration files

BandiT Substrate Calibration - used by k-Space when configuring calibration files

Flat Field Correction - used to create a flat field correction file specific to each Spectrometer for use in Blackbody Pyrometry - this file will normally be provided by k-Space when the instrument is shipped

Spectrometer Calibration - used to calibrate the Spectrometer - this is normally done by k-Space before the instrument is shipped and it is not usually necessary for users to do this.

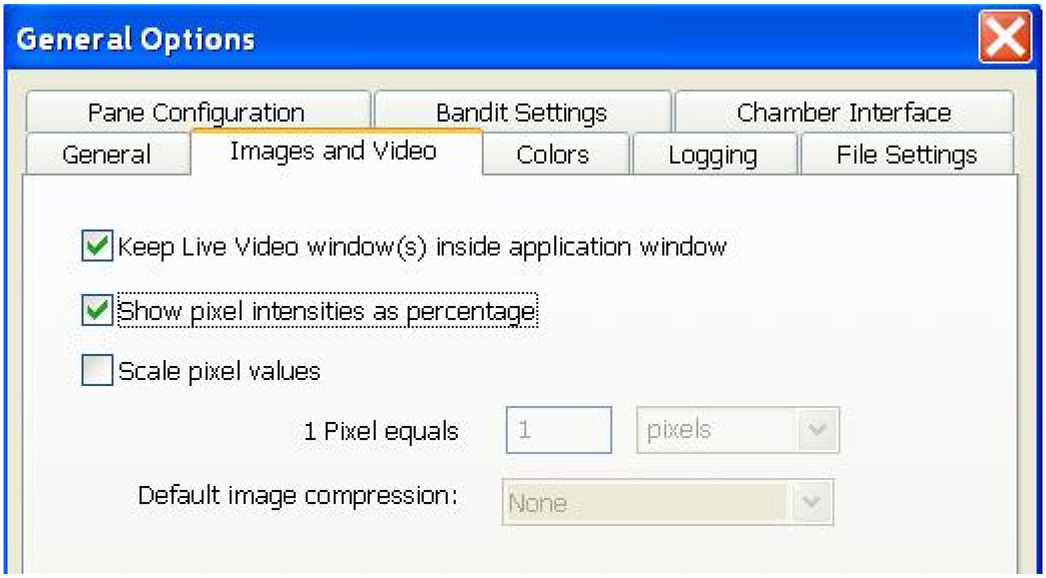
With a ***Default acquire mode*** selected, choose:

Start Automatically – to begin data acquisition with program start-up

Minimize After Start – to reduce the acquisition window to only its banner with program start-up

Images and Video

The ***Images and Video*** tab is available by selecting ***General Options*** under the Options menu.



Select:

Keep Live Video window(s) inside application window – to keep the Live Video window within the main application window. Unchecking this box will allow the user to drag the Live Video window outside the main application window. Note that for BandiT, this option does not matter because the only image possible is a pyrometric oscillation image (used for measuring growth rate) and there is no live video window.

Show pixel intensities as percentage – toggle between pixel intensity as a percentage of the maximum possible pixel intensity or the raw signal count in digital numbers. For example, with a 12-bit camera, a raw signal count of 2048, when expressed in terms of a percentage, is 50%.

Scale pixel values – if acquiring something of a known size, select this option to scale it to the acquired number of pixels

With ***Scale pixel values*** selected, select:

1 Pixel equals – a number and any units of measurement (centimeters, feet, inches, microns, meters, and millimeters).

Default image compression – select either none or ZLib, which is a loss-less compression option. This option is disabled in BandiT.

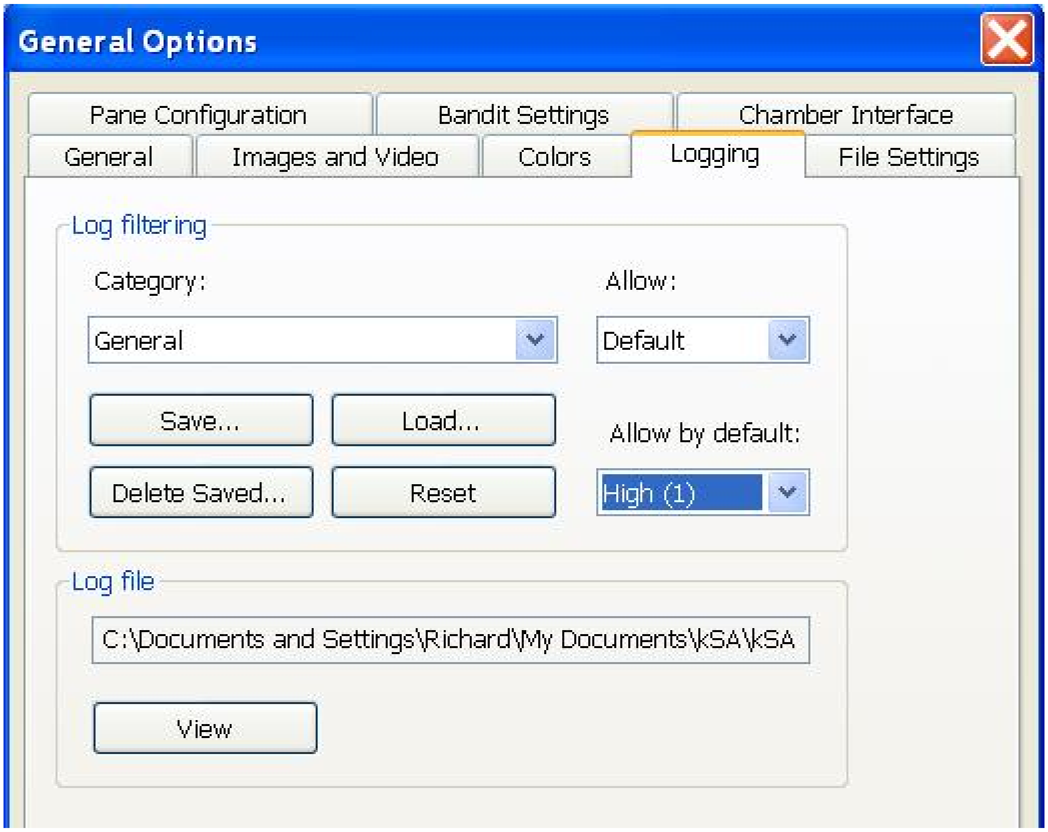
Logging

The ***Logging*** tab is available by selecting ***General Options*** under the Options menu. The software can keep a record (log) of many details every time the program runs. It is useful both for recording software use and for capturing the reasons for errors, if any occur. Note that program errors prompts a pop-up window; logging allows the user to see why the error occurred. The log is saved as a text (*.txt) file.

There are five thresholds of logging:

- None – for no logging at all
- High (1) – to capture high-level details such as start/stop times, acquisitions, system information, and any program errors
- Medium (2) – to capture all *High (1)* details as well as any program warnings
- Low (3) – to capture all *Medium (2)* details as well as any program notes

- All – to capture all system information



For each ***Category*** –

- *General*
- *User commands*
- *External/command prompt commands*
- *Software license*
- *Acquisition*
- *Plotting*
- *I/O boards and other devices*
- *Images*
- *Image filters*

Specify:

Allow – what threshold level of logging to allow

Allow by default – to specify which threshold level is default. Under the ***Allow*** drop-down menu is a ***Default*** selection, which selects the value chosen here.

Save/Load - Save and Load logging preferences by using these buttons.

Delete Saved - to delete all saved log files

Reset - to reset all logging levels to Medium

Log File – where the log file is saved

Click the ***View*** button to see the log.

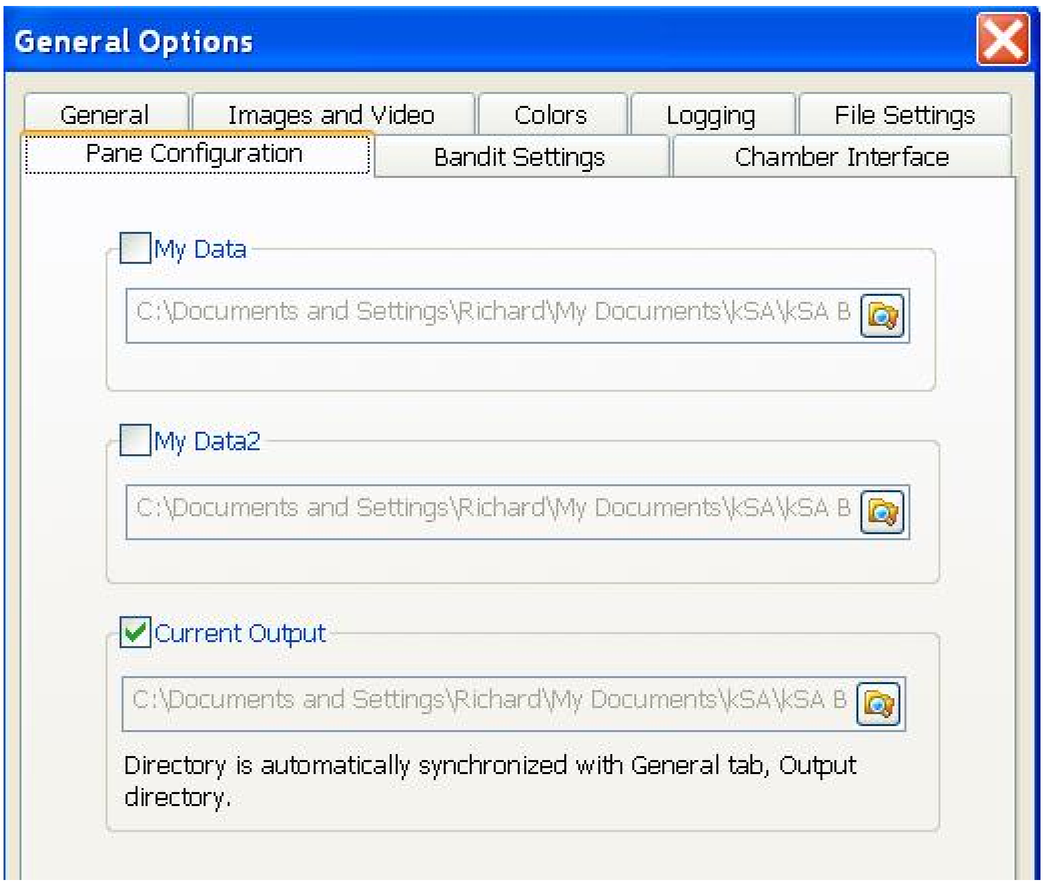
Pane Configuration

The ***Pane Configuration*** tab is available by selecting ***General Options*** under the Options menu.

Pane Configuration allows the user to select which folders will be displayed in up to three panes open in the BandiT application window.

The ***Current Output*** folder is automatically synchronised with the Output directory set in the General tab of the General options. The ***My Data*** folders can be selected by using the browse buttons, for example to set the locations where data has been archived.

Tick the check box by each folder selection so that the folder can be opened in a pane in the BandiT application window. The panes can then be temporarily shown or hidden using the View menu.



Input Output Devices

Configure Input/Output Devices

Installed in the BandiT Rack Mount Controller is a USB Input/Output Board (for example Model, DT9802 or DT9806). This board allows the software to send/receive analog and digital signals. Once the board is properly installed on the host computer; it will need to be configured in the BandiT software.

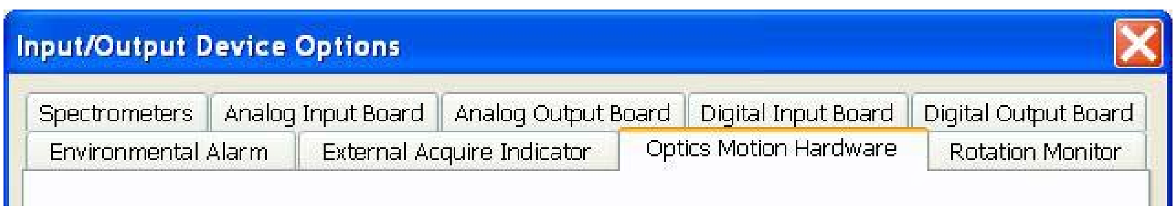
1. Open the BandiT software by double-clicking on the desktop icon.
2. Select Options / Input/Output Devices. This will open the Input/Output Device Options dialog.

3. Configure the tabs Analog Input, Analog Output, Digital Input and Digital Output for the DT9802 or DT9806. The Board Number should be 0.
4. Once each tab is configured, select Apply and then close the BandiT program.

Input/Output Devices

The ***Input/Output Device Options*** (found under the Options menu) allow configuration of the various data acquisition boards present including mapping board channels to voltage ranges that match any input/output devices needed for process control or data acquisition. These boards perform analog input/output, digital input/output, counter/timer functions, and other functions depending on the system and whether capability has been activated on the USB Security Key. The various types of input/output (I/O) boards are divided using multiple tabs on this dialog:

There are ten options:



Analog Input Board

Analog Output Board

Digital Input Board

Digital Output Board

Environmental Alarm

External Acquire Indicator

Options Motion Hardware

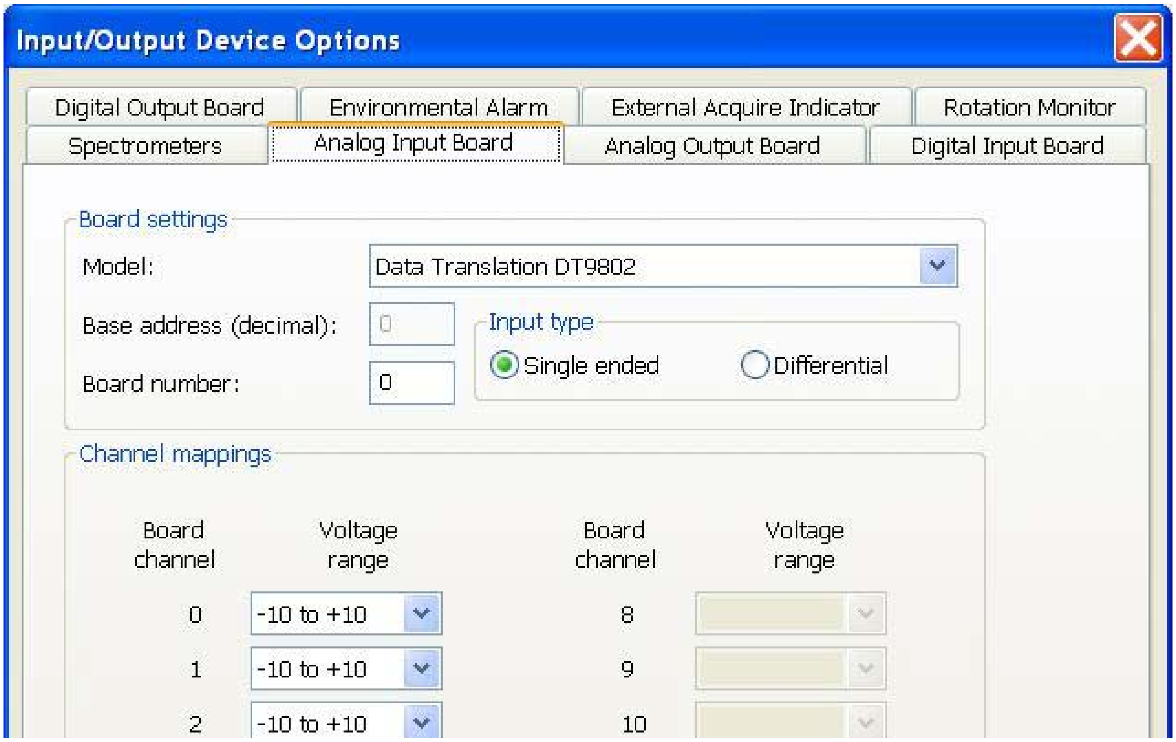
Process Step Input

Rotation Monitor

Spectrometers

Analog Input Board

Analog Input Board is one of the Input/Output Device options found under the Options menu. The system supports various analog input boards for real-time analog input (e.g., voltage for triggers).



Specify:

Board Settings

Model – choose from among the following analog input board types:

- *Computer Boards CIO-DAS08* – ISA legacy
- *Computer Boards CIO-DAS08/Jr/16* – ISA legacy
- *Computer Boards CIO-DAS08/Jr/16-AO* – ISA legacy
- *Computer Boards PCIM-DAS1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DAS6014*
- *Data Translation DT9802*
- *Data Translation DT9806*
- Use *[None]* when no analog input board is installed.

Base address(decimal) or ***Board number*** (depending on *Model*) – if it is a *Measurement Computing Board*, run the *InstaCal* control software, which will specify a board number. Input that here.

Input type (available depending on *Model)* – choose:

Single ended – which measures the voltage between the input signal and ground.

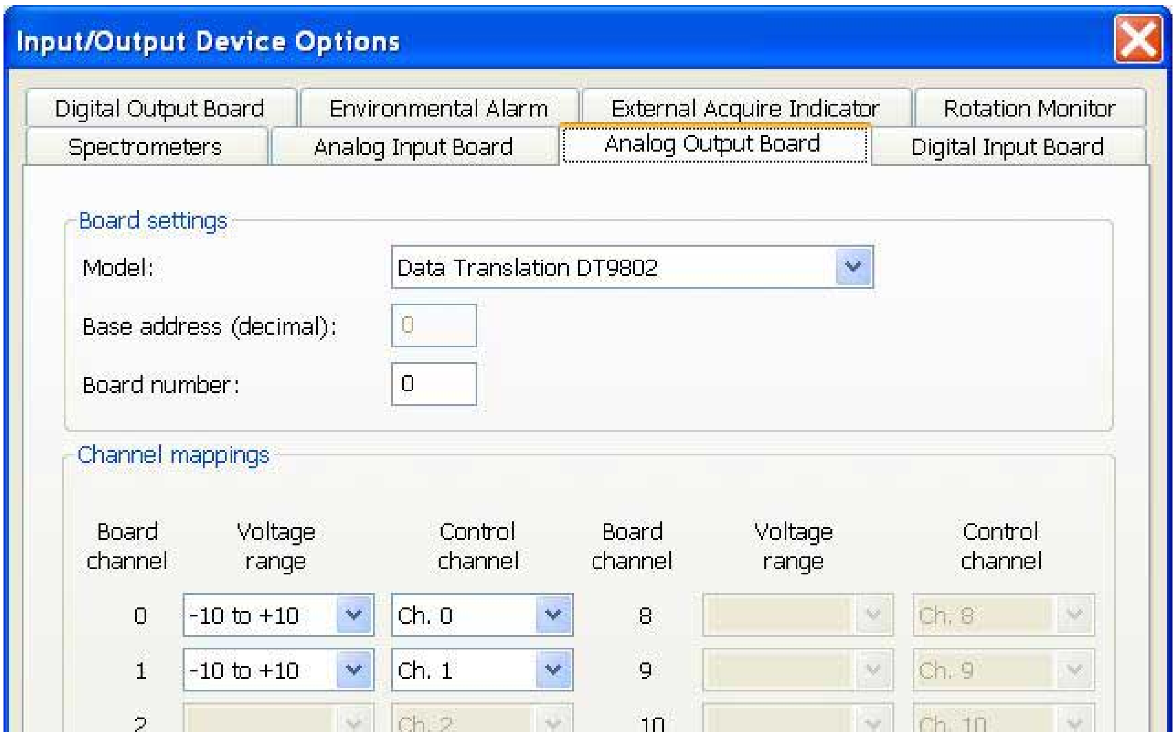
Differential – which measures the difference between two distinct input signals (also used for when the system has a floating ground). More immune to EMI (Electro-Magnetic Interference) For low-noise applications, differential input is the preferred analog input method because induced noise is largely negated with a differential signal.

Channel mappings

Voltage range – (Note the ranges available depend on *Model*) – these default to the proper setting and should not, in general, need to be changed

Analog Output Board

Analog Output Board is one of the Input/Output Device options found under the Options menu. The system supports various analog output boards for real-time analog output e.g., voltage for output trigger (internally to detector or to other acquisition devices).



Specify:

Board settings

Model – choose from among the following analog output board types:

- *Keithley Metrabyte DAC-02* – ISA legacy
- *Computer Boards CIO-DAC02/16* – ISA legacy
- *Computer Boards CIO-DAC16/16* – ISA legacy
- *Computer Boards CIO-DAC08/16*– ISA legacy
- *Computer Boards CIO-DAS08/Jr/16-AO* – ISA legacy
- *Computer Boards PCI-DDA08/16*
- *Computer Boards PCIM-DAS1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DDA02/16*
- *Computer Boards PCI-DAS6014*
- *Computer Boards USB-3101*
- *Data Translation DT9802*
- *Data Translation DT9806*
- Use *[None]* when no analog input board is installed.

Base address(decimal) or ***Board number*** (depending on *Model*) – if it is a *Measurement Computing Board*, run the *InstaCal* control software, which will specify a board number. Input that here.

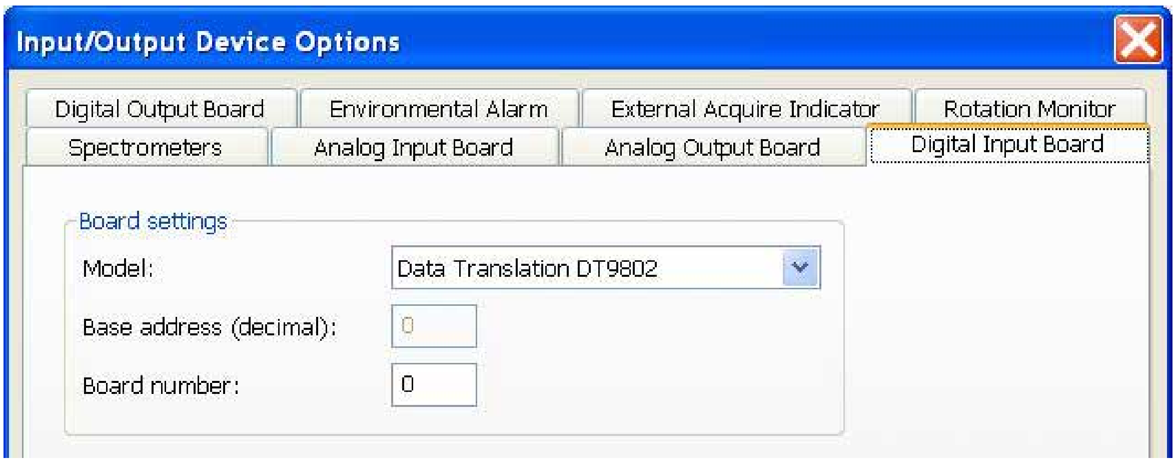
Channel mappings

Voltage range – (Note the ranges available depend on *Model*) – these default to the proper setting and should not, in general, need to be changed

Control channel – these default to the proper setting and should not, in general, need to be changed unless additional input/output is required for a very specific process control

Digital Input Board

Digital Input Board is one of the Input/Output Device options found under the Options menu. The system supports various digital input boards for real-time digital input (e.g., voltage for input trigger). Digital boards are becoming the standard because they are less susceptible to Electro-Magnetic Interference (EMI).



Specify:

Board settings

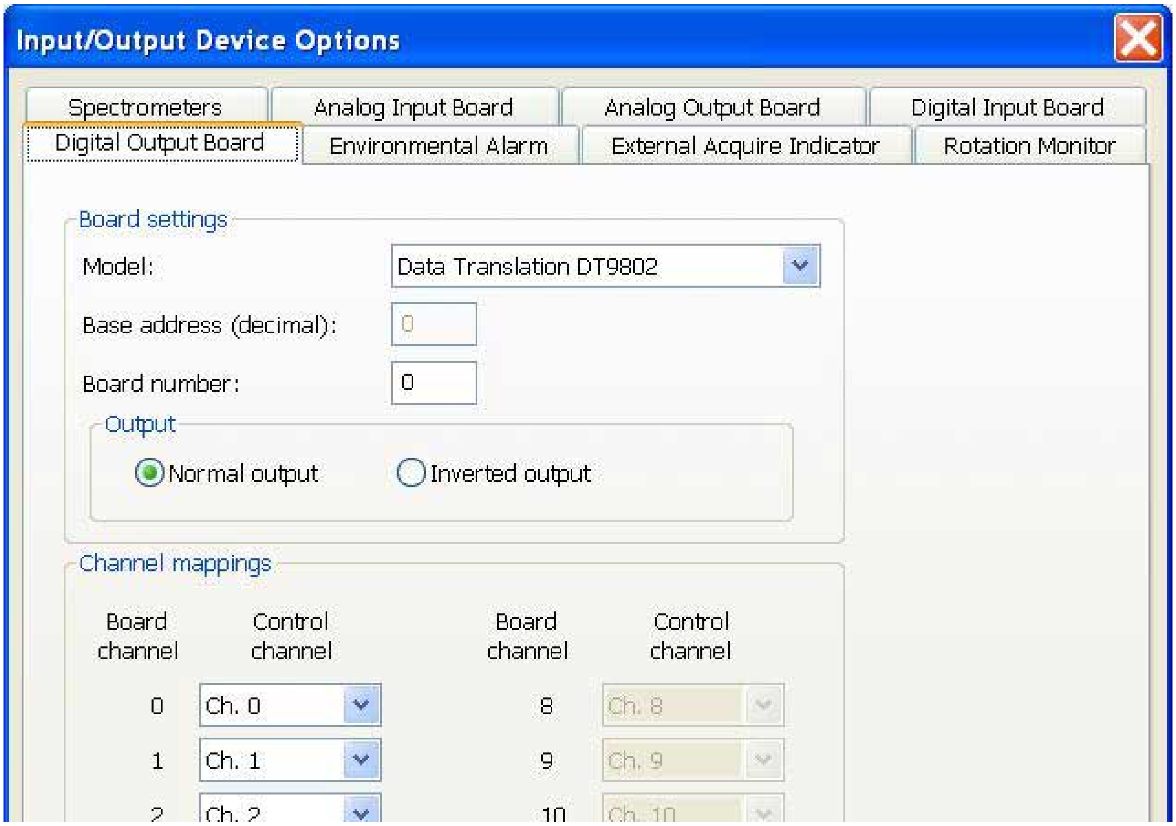
Model – choose from among the following digital input board types:

- *Computer Boards CIO-DAS08/Jr/16* –ISA legacy
- *Computer Boards CIO-DAS08/Jr/16-AO* – ISA legacy
- *DT3153 Frame Grabber* – legacy board
- *PIO/CIO-12/24* – legacy
- *PXD Frame Grabber*
- *Data Translation DT302*
- *Computer Boards PCIM-DAS1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DIO24*
- *Computer Boards PCI-DDA02/16*
- *Computer Boards PCI-DAS6014*
- *Data Translation DT9802*
- *Data Translation DT9806*
- *Computer Boards USB3101*

Base address(decimal) or ***Board number*** (depending on *Model*) – specified by manufacturer's installation instructions when properly installing the digital input board

Digital Output Board

Digital Output Board is one of the Input/Output Device options found under the Options menu. The system supports various digital output boards for real-time digital output (e.g., voltage for output trigger for an external event). Digital boards are becoming the standard because they are less susceptible to Electro-Magnetic Interference (EMI).



Specify:

Board settings

Model – choose from among the following digital output board types:

- *PIO/CIO 12/24* – ISA legacy
- *Computer Boards PCI-DIO24* – legacy
- *Computer Boards CIO-DAS08/Jr/16* – ISA legacy
- *Computer Boards CIO-DAS08/Jr/16-AO* – ISA legacy
- *DT Frame Grabber* – legacy
- *PXD Frame Grabber*
- *Computer Boards PCIM-DAS1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DDA02/16*
- *Computer Boards PCI-DAS6014*
- *Computer Boards USB-3101*
- *Data Translation DT9802*

- *Data Translation DT9806*

Base address(decimal) or ***Board number*** (depending on *Model*) – specified by manufacturer's installation instructions when properly installing the digital output board

Output – choose:

Normal output – sending out signal from low to high

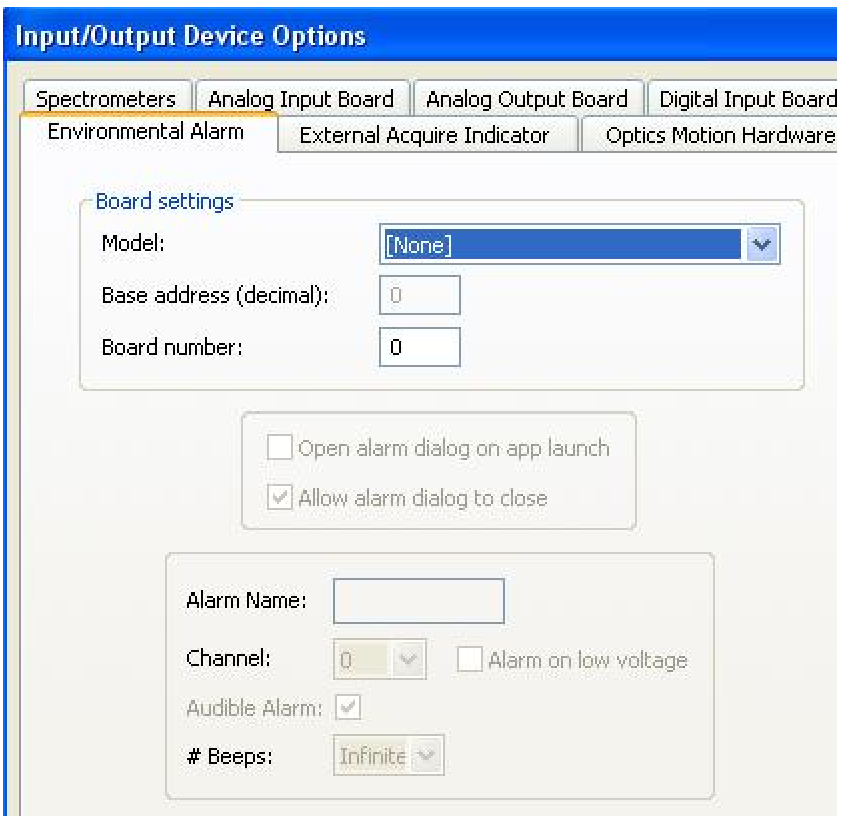
Inverted output – sending out signal from high to low

Channel mappings

Control channel – these default to the proper setting and should not, in general, need to be changed unless additional input/output is required for a very specific process control

Environmental Alarm

The Environment Alarm is a customer specified feature, one of the ***Input/Output Devices*** found under the ***Options*** menu. It can accept a digital input from any system to signal BandiT to pause or resume depending on whether the alarm is triggered.



Specify:

Board settings Model – choose from available board types:

Board settings Base address(decimal) or ***Board number*** (depending on Model) – specified by manufacturer's installation instructions

Alarm - a name for this alarm

Channel: – channel to be used for this alarm. This channel number can then be used as the input channel in the Pause/Resume Trigger Option of the Advanced Acquisition Options

#Beeps - select the numbers of beeps to sound on alarm

Check:

Open alarm dialog on app launch - to open the alarm dialog when the application is launched

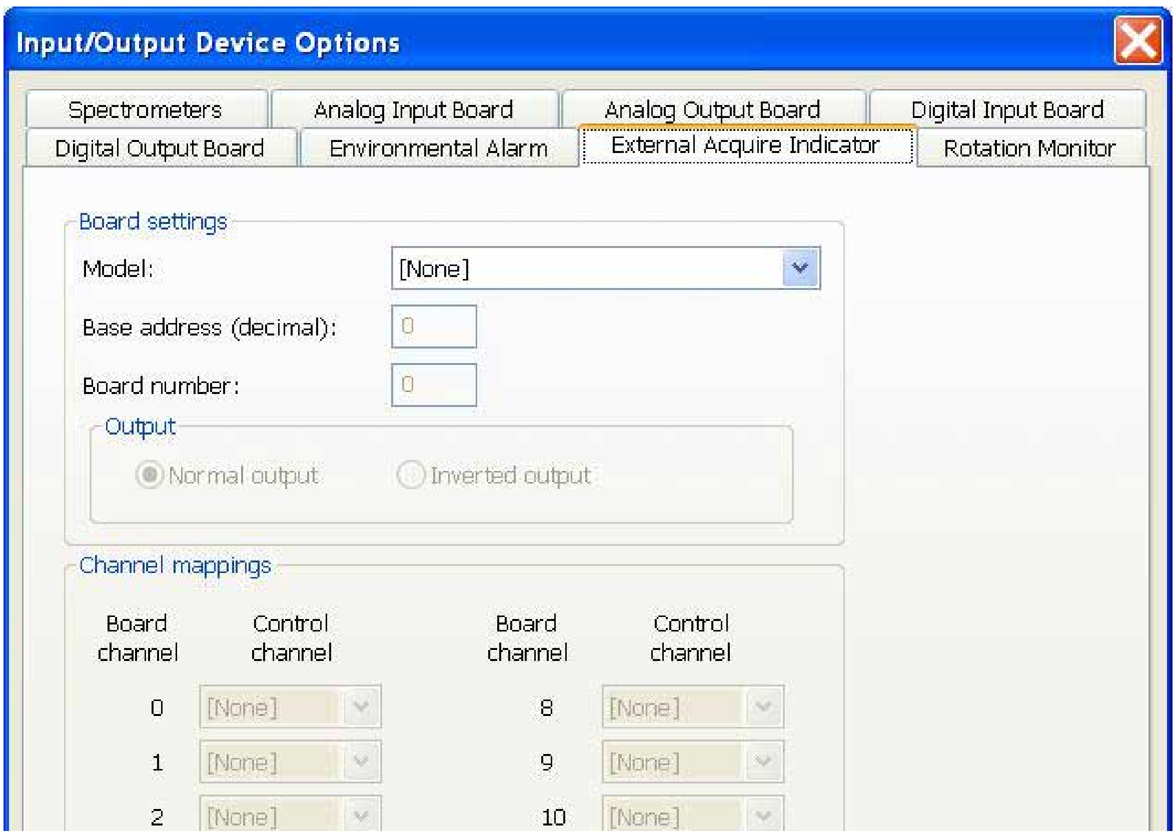
Allow alarm dialog to close - allow the user to close the alarm dialog box

Alarm on low voltage - if the alarm will be triggered by low voltage

Audible Alarm - to get an audible alarm, and then select the number of beeps for this alarm so that the alarm can be easily identified

External Acquire Indicator

External Acquire Indicator is one of the Input/Output Device options found under the Options menu. It is used for mapping a signal to a specific analog input channel.



Specify:

Board settings

Model – choose from among the following board types:

- *PIO/CIO 12/24* – ISA legacy
- *Computer Boards PCI-DIO24*

- *Computer Boards CIO-DAS08/Jr/16* –ISA legacy
- *Computer Boards CIO-DAS08/Jr/16-AO* –ISA legacy
- *DT Frame Grabber*
- *PXD Frame Grabber*
- *Computer Boards PCIM-DAS 1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DDA02/16*
- *Computer Boards PCI-DAS6014*
- *Computer Boards USB-3101*

Base address(decimal) or ***Board number*** (depending on *Model*) – specified by manufacturer's installation instructions when properly installing the digital output board

Output – choose:

Normal output – sending out signal from low to high

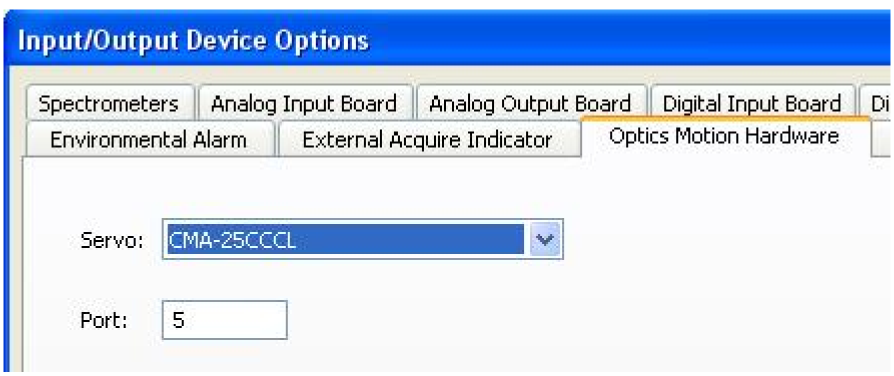
Inverted output – sending out signal from high to low

Channel mappings

Control channel – select a channel for *Acquiring*.

Optics Motion Hardware

Optics Motion Hardware is one of the Input/Output Device options found under the Options menu. It is used to map the board monitoring the motion of the optics to a port number which is then monitored by the Rotation Monitor.



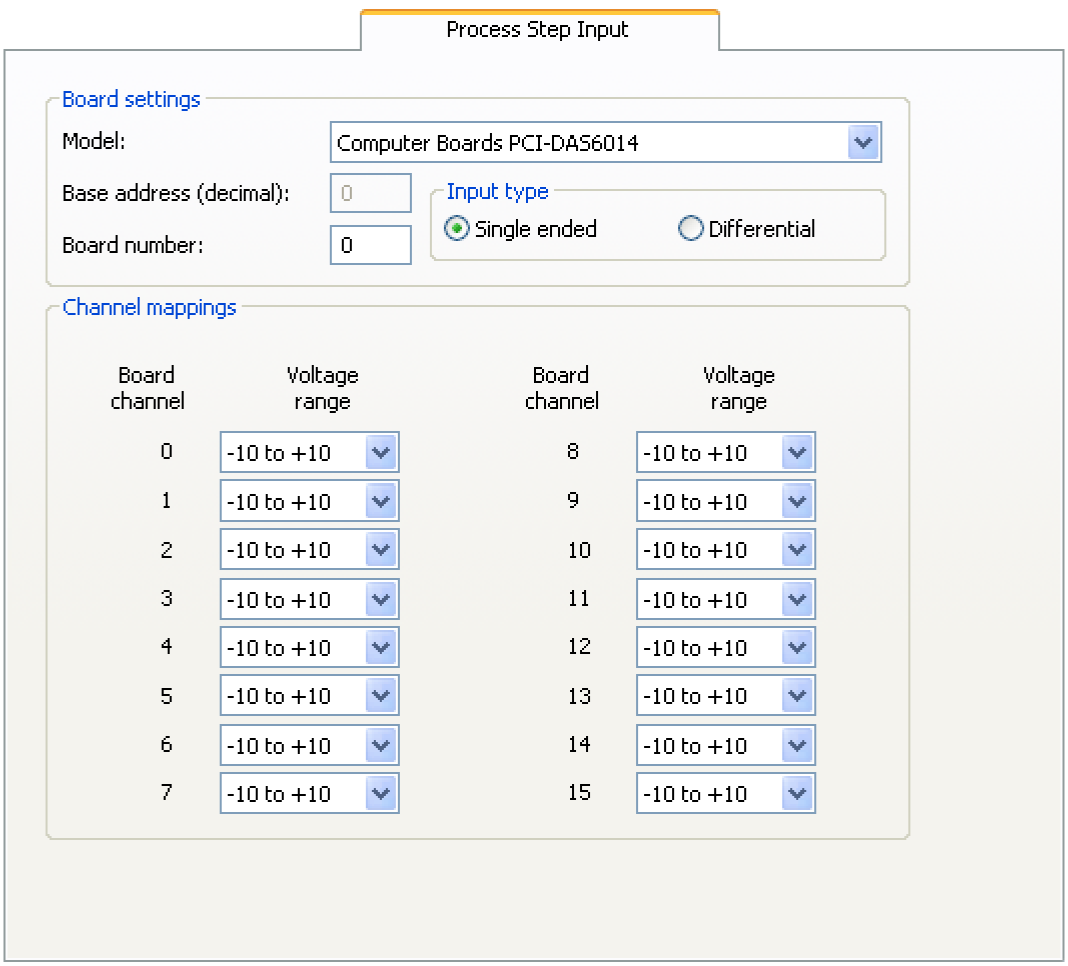
Select the ***Servo*** board in use in the system.

Specify the ***Port*** number that is assigned to the board by the Windows computer system.

The ports that are in use can be checked by going to the ***Control Panel*** on the BandiT computer system, selecting ***System*** and then ***Device Manager***. Expanding the section Ports (COM & LPT) will show all the connected ports which might be similar to the image below.

Process Step Input

Process Step Input is one of the Input/Output Device options found under the Options menu. It typically only available in systems equipped for multi-wafer applications as it is used to process the analog input signal specifically for processing stepcode signals that indicate a new procedure or process has begun during acquisition.



Specify:

Board settings ***Model*** – choose from among the following board types:

- *Computer Boards CIO-DAS08*—ISA legacy
- *Computer Boards CIO-DAS08/Jr/16* –ISA legacy

- *Computer Boards CIO-DAS08/Jr/16-AO* –ISA legacy
- *Computer Boards PCIM-DAS 1602/16*
- *Computer Boards USB-PMD1208FS*
- *Computer Boards PCI-DAS6014*

Base address(decimal) or ***Board number*** (depending on *Model*) – specified by manufacturer's installation instructions when properly installing the board

Input type (available depending on *Model)* – choose:

Single ended – which measures the voltage between the input signal and ground.

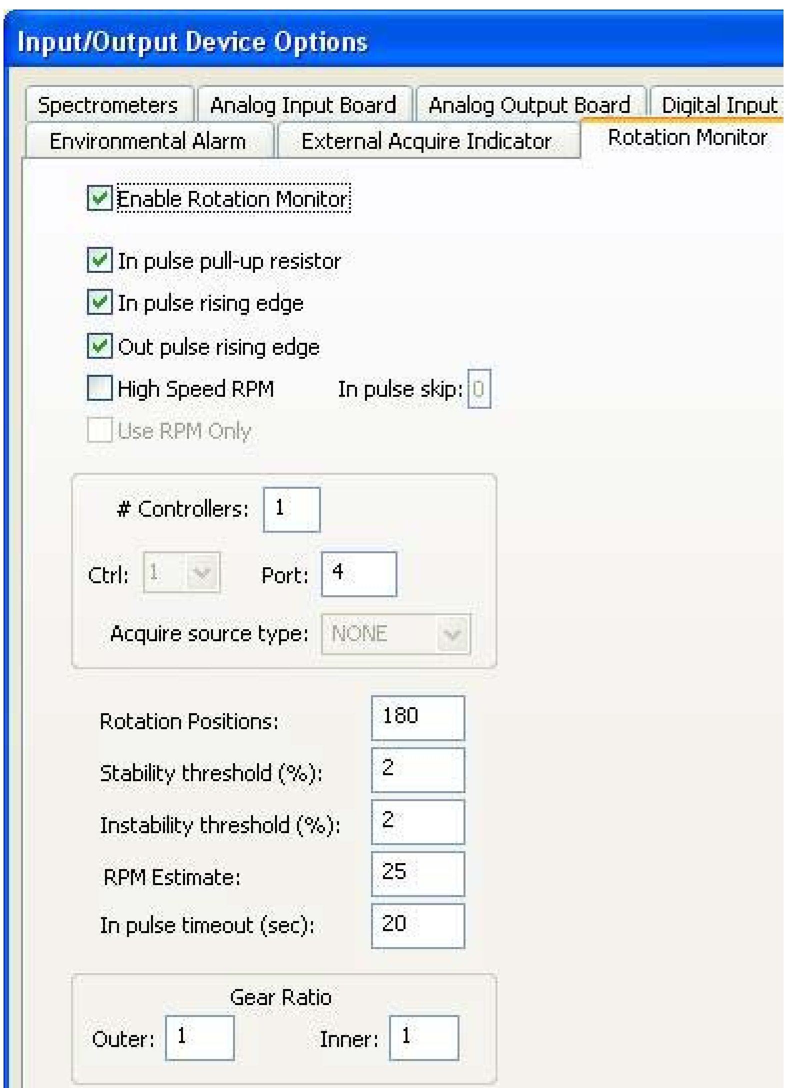
Differential – which measures the difference between two distinct input signals (also used for when the system has a floating ground). More immune to EMI (Electro-Magnetic Interference). For low-noise applications, differential input is the preferred analog input method because induced noise is largely negated with a differential signal.

Channel mappings ***Voltage range*** – (Note the ranges available depend on *Model*) – these default to the proper setting and should not, in general, need to be changed

Rotation Monitor

Rotation Monitor is one of the Input/Output Device options found under the Options menu. It is usually used in Multi-Wafer BandiT systems to monitor the rotating platen and trigger acquisition of data for each sample on the platen.

The Rotation Monitor menu is used if the BandiT system has the Teensy rotation controller. Go to Check Hardware Rotation Board to check whether the system has this controller before enabling it.



Check:

Enable Rotation Monitor - To activate the Rotation Monitor. An error will occur if no trigger is provided indicating a home pulse from a rotating platen. If this happens check that you have this controller, as above.

In Pulse Pull Up Resistor - Configured for anticipated trigger system that may not be at least 3.8V (TTL high). Should always be enabled.

In Pulse Rising Edge - This is the home pulse that is coming into BandiT and is dependent on if the platen trigger is active high or low. Check this box if the trigger pulse is active high (so normally low voltage and the trigger rises to above 3.8V) for the rising edge of incoming pulse. Deselect if the trigger is active low to trigger on the falling edge.

Out Pulse rising Edge - Deselect the box to trigger on the falling edge.

High Speed RPM - For rotation speeds over 50 RPM.

In pulse - This is a sampling function. Specifies how many rotations BandiT will skip between accepting a home pulse trigger.

Use RPM Only - Use only the RPM without an incoming trigger.

Specify:

 # Controllers - Allows for inputs from multiple defined controllers. If multiple controllers exist specify which controller goes to which port and also the Acquire source type. Only special combined kSA systems have the option of multiple controllers. This will be greyed out for normal systems.

Port - Specify the port number that is assigned to the Teensy controller. See Check Hardware Rotation Board to find the port number.

Rotation Positions - Determines the resolution of the rotation monitor. 100 positions will give a position every 3.6 degrees on the platen. A maximum of 180 positions is possible. NOTE: updates may soon allow more rotation positions.

Stability threshold - % tolerance of what BandiT considers a calculated stable RPM to lock on to. Data Acquisition will not take data if the calculated RPM is unstable.

Instability threshold - % tolerance of RPM that will pause the data acquisition. Currently, just set the instability threshold to be the same as the Stability threshold value.

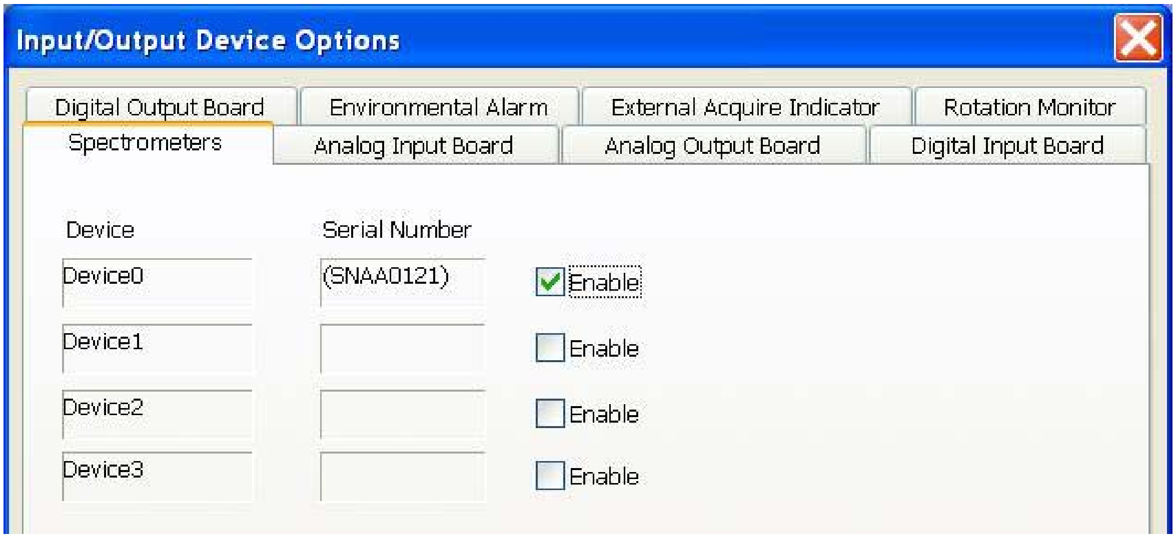
RPM estimate - Anticipated RPM, to help the system converge faster. The software will correctly calculate the RPM of any rotation, but a more accurate estimate specified here will help the software calculate a stable RPM faster.

In Pulse Timeout (sec) - The allowed time duration to detect a home pulse. An error will occur if no home pulse is found within the specified timeout.

Gear Ratio - Most systems detect the rotation home pulse directly from the rotation shaft connected to the rotating platen. However, if there are additional gears and/or the home pulse is not triggered off of the rotating platen gear, then a ratio must be specified.

Spectrometers

Spectrometers is one of the Input/Output Device options found under the Options menu. It shows the Spectrometer devices included in the BandiT rack. Check the ***Enable*** check box to choose the Spectrometer(s) that will be used.



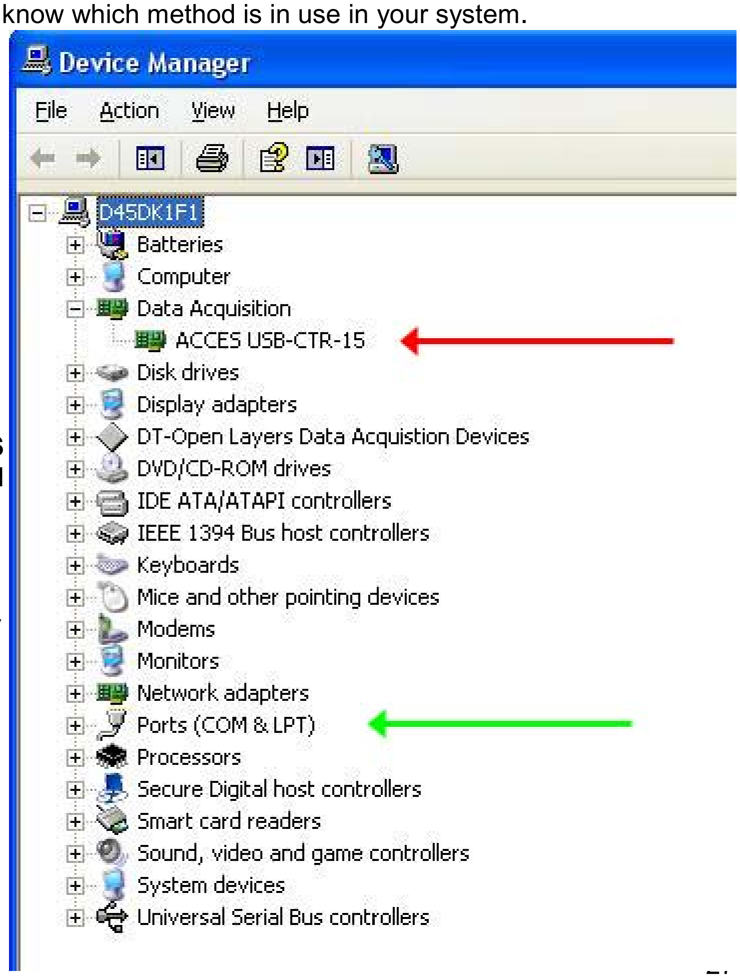
If no Spectrometers are shown here it may be that they have not been fully installed on the computer. Go to Configure Spectrometer for information about checking Spectrometer configuration and drivers.

Check Hardware Rotation Board

BandiT has two different methods of tracking rotation of a platen. Older systems use a ***Counter Timer Board***, while newer systems use a ***Teensy USB controller***. These hardware methods have different software control menus so it is important to know which method is in use in your system.

Go to the ***Control Panel*** on the BandiT control computer and open ***System***:

and then ***Device Manager***, as shown on the right:



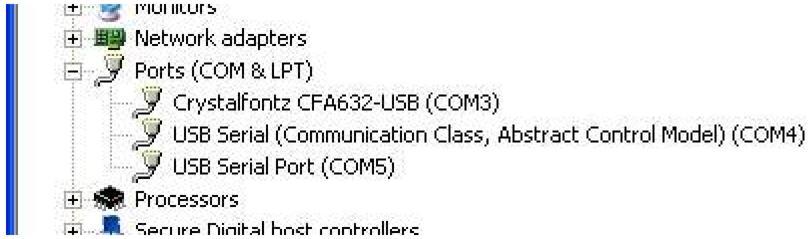
Counter Timer Board

This is installed as a Data Acquisition module labelled **"ACCES USB-CTR-15"** as shown with the red arrow on the right.

The software control menus for the Counter Timer Board are found by right clicking the ***Live Spectrometer*** window and selecting Properties. Select Home Pulse Monitor and Position Monitor and click the ***Enable*** check box in each menu to activate them.

Teensy USB Controller

This is installed under the Ports section labelled as **"USB Serial (Communication Class, Abstract Control Model) (COM4)"**, would appear where the green arrow is on the right, and is shown below.



The software control menu for the Teensy Controller is found by selecting the Options Menu and then Input/Output Devices, then selecting the Rotation Monitor tab. Click the ***Enable*** check box to activate the Rotation Monitor.

More information about setting up the rotation monitoring for each device can be found by clicking the links above for the appropriate device.

Spectrometer

Align Spectrometer

Follow these steps to align spectrometers (10º to 60º from normal).

Using the Alignment Laser

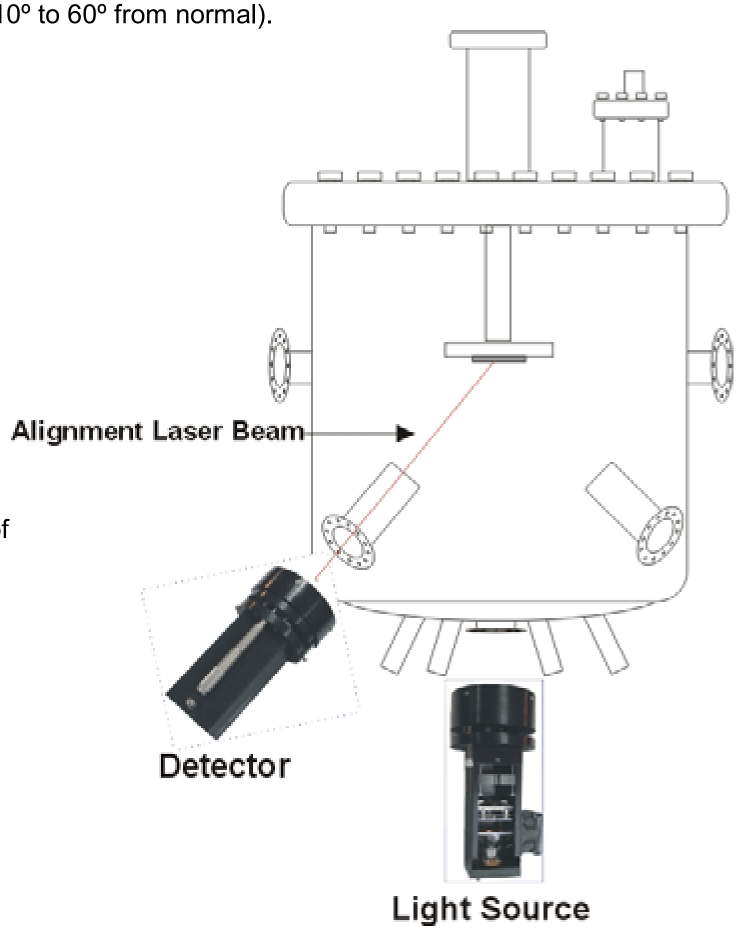
(Note: Users without optical access to the chamber should skip this section.)

The alignment laser is a Class IIIA laser (wavelength 630-660nm, max. output 4 mW), so please follow all laser safety guidelines.

The BandiT system has an integrated laser inside the rack mount which helps users with optical access align the detector to the sample. The alignment laser illuminates the area of the sample where the detector is directed. It does not demonstrate the area of detection on a wafer.

At this point in the installation, the detector should be securely mounted to the flange and the optical fiber should be in place. If not, follow the steps in the Tilt and Rotate Detector Installation section to install and mount it to the detector and controller.

(Note: If the optical fiber supplied does not have the second leg, you will need to move the fiber from the SMA Fiber Input to the Alignment Laser SMA fitting.)

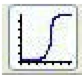


After ensuring all the proper connections are made, turn ***On*** the Laser Power and turn the ***Laser Interlock to On***. Both are found on the front of the BandiT rack:

On the wafer, look for a dim laser spot. If it is hard to locate, rotate the ***Micrometer*** on the detector so the spot moves to the platen's edge. It may be that the laser beam through the detector lens is too diffuse. Use the ***Focusing Lens*** on the detector to focus it, see Align Tilt and Rotate Detector for more information. When finished, turn off the ***Laser Interlock***, and then turn off the ***Laser Power.***

Configure Spectrometer

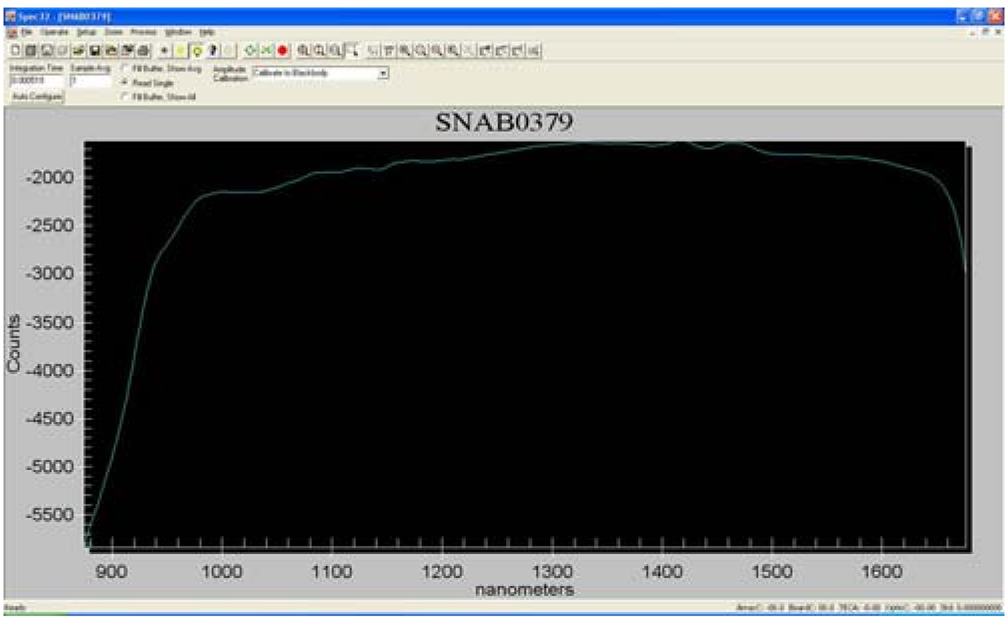
The first time that a Spectrometer is connected to the BandiT computer system, or if a new Spectrometer is connected to the system, the software will need to be configured to use it.

Connect the new rack to the BandiT computer and allow all the hardware devices to install themselves as described in First Power On. Several devices will be found and will install, wait until all new hardware devices are installed. Then start the BandiT software and check that the Spectrometer has been correctly found by selecting View/Spectrometer from the main menu or by clicking the  icon on the toolbar. If it hasn't several error messages will be displayed, close the BandiT software and follow the instructions below to get the ***Spectrometer Setup***.

After connecting to a new Spectrometer the BandiT software will give you the option to copy any recipes that you have saved from a different Spectrometer. Select the Spectrometer you want to copy from using the down arrow, checking the recipe by using the ***View*** button. Click ***OK*** to copy the recipe.

Get Spectrometer Setup from Spec32

Go to My Computer, open the C: drive and open the folder CDI32. Run the program Spec32.exe. This should find the Spectrometer and show a screen similar to the one below, showing the spectral range of the Spectrometer. If it doesn't see ***Install Spectrometer Drivers*** below.



Go to File, Save Setup and save the new Spectrometer in Device0 with the filename the same as the Spectrometer, SNAB0379 in the case above. This saves the setup as a number of files in the folder Device0. This folder can then be saved in the KSA area by copying it to:

C:\Program Files\KSA\KSA BandiT\PROGRAM\Spectrometers\

and renaming it to the Spectrometer name.

Start the BandiT software, which should now find the Spectrometer.

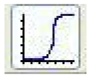
Install Spectrometer Drivers

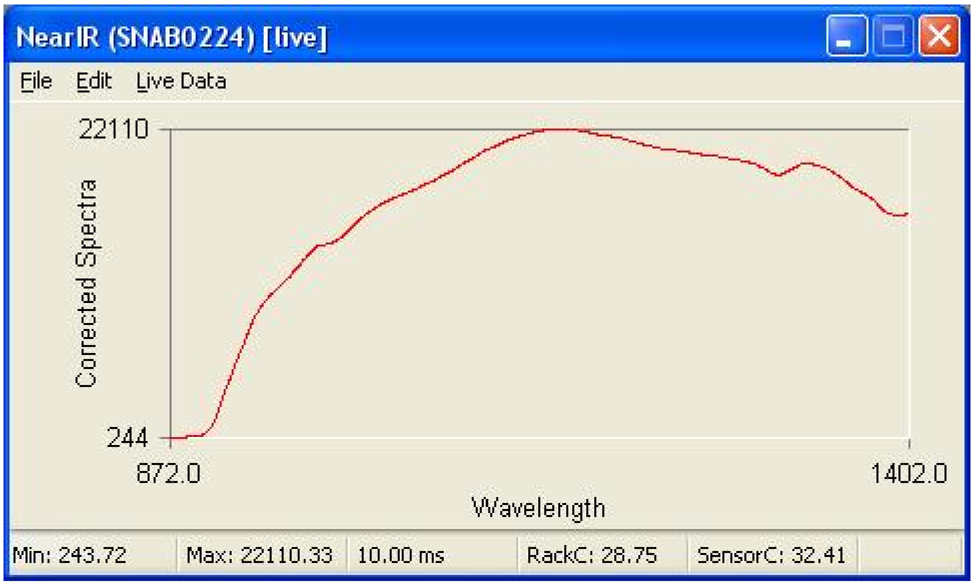
If the program Spec32 does not find the Spectrometer, it may be that the drivers for this Spectrometer have not been correctly installed. If this is the case you will get an error message from Spec32.

To install drivers run the program instdrvgui.exe which is in the same folder as Spec32.exe. This should install any drivers that you need. Run Spec32 again and it should find the Spectrometer.

If the BandiT software can still not see the Spectrometer then Contact us.

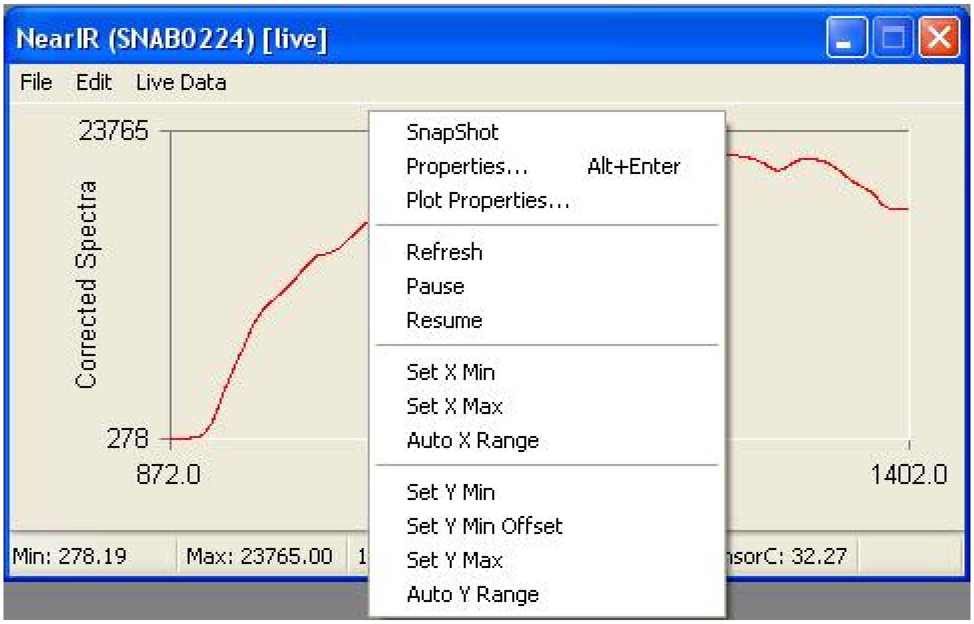
Live Spectrometer

The kSA BandiT system utilizes a solid-state spectrometer for acquiring and viewing the diffuse reflectance spectra from the substrate. To view the live spectrometer data, select View/Spectrometer from the main menu or click the  icon on the toolbar.

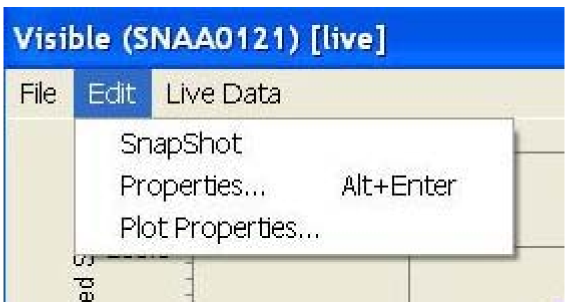


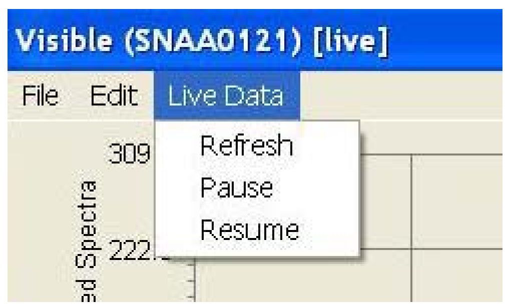
The ***Status Bar*** (at the bottom of the spectrometer live data window) always displays the minimum spectra intensity, maximum intensity, spectrometer integration time (10.00 msec as shown above), and the device temperatures, if enabled in the Spectrometer tab of Spectrometer Properties. Up to three temperatures can be displayed "Rack" temperature is the temperature of the internal spectrometer board (28.75°C as shown above), the "Sensor" temperature is the temperature of the array (32.41°C as shown above) and the "Optic" temperature is the temperature of the optic which is not available for un-cooled spectrometers for example most NIR spectrometers. If the ***Status Bar*** is not displayed, select it under the View menu.

To change the spectrometer settings, right-click the ***Live Spectrometer*** window.



Or use the Edit Menu and the Live Data Menu which bring up some of the same options, as shown below:





Select:

Snapshot - to take a snapshot of the current Spectrometer Spectrum into a file

Properties - to change the Spectrometer Properties

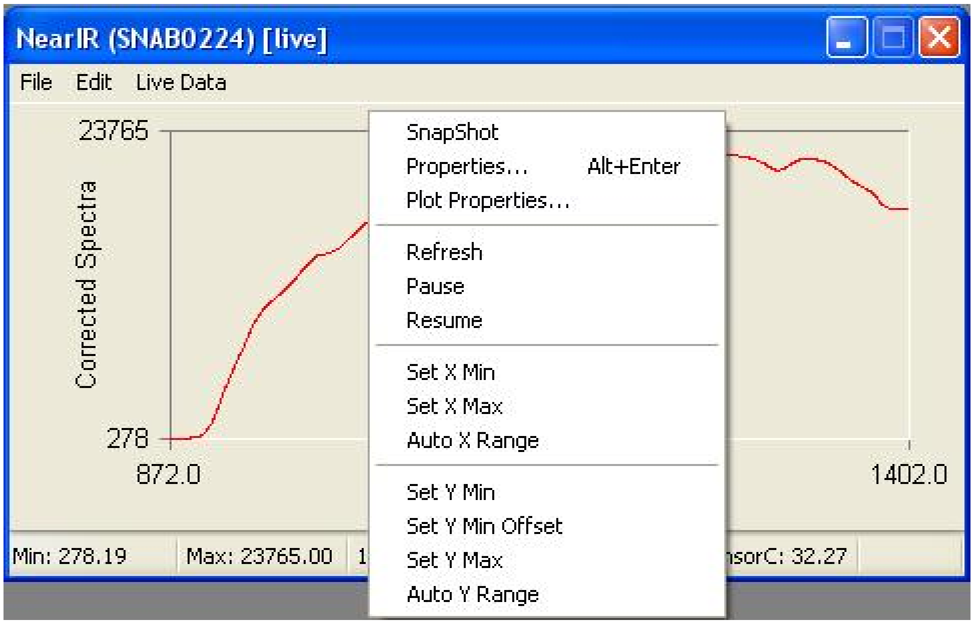
Plot Properties - to change the plot properties of the current plot.

Pause, Resume and Refresh - to pause or resume the live display of the Spectrometer output

Use the ***Set X Min***, ***Set X Max*** etc. to set the range of data displayed on this plot. Position the cursor at the boundary that you want to use for X Min or X Max and then right click and select the appropriate command. And range boundaries set can be reset by clicking ***Auto X Range*** or ***Auto Y range***.

Spectrometer Properties

Right-clicking the Live Spectrometer window and selecting ***Properties*** brings up the Spectrometer Properties dialog.



Select:

- Advanced – to change the number of skipped frames during a data acquisition
- Averaging – to change the number of spectra to be averaged during a data acquisition
- Data Sets - specify parameters for data sets
- Home Pulse Monitor – to specify the parameters of triggering the home pulse during rotation
- Spectrometer – to change the acquisition properties of the spectrometer
- Wavelength Filter - to specify the parameters for the wavelength filter

Advanced

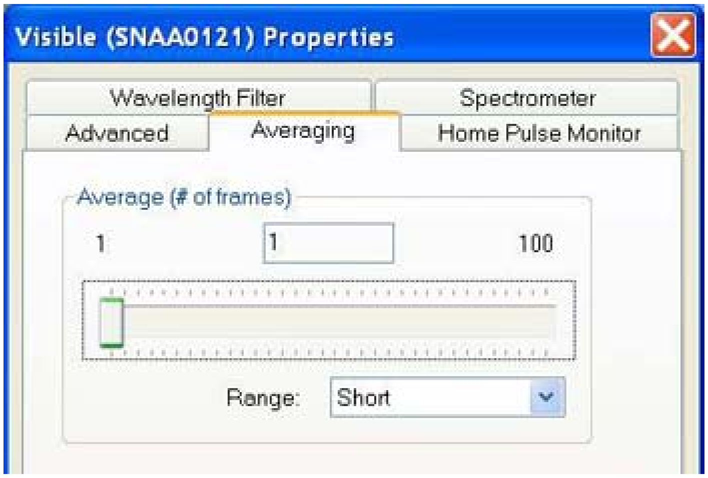
Right-clicking the Live Spectrometer window and selecting Properties brings up the Spectrometer Properties. Use the ***Advanced*** tab to specify the number of skipped frames during a data acquisition. This is useful for reducing the amount of data without changing the other acquisition parameters. This can also be done by setting a Delay in the Advanced Acquisition Options.

Specify the ***Skip frames*** number for the number of frames BandiT skips between acquired frames.

Averaging

Right-clicking the Live Spectrometer window and selecting *Properties* brings up the Spectrometer Properties.

Use the ***Averaging*** tab to change the number of spectra to be averaged during a data acquisition. Averaging frames reduces the amount of data and reduces noise by the square root of the number of frames averaged.



Specify:

> ***Average (# of frames)*** – the number of frames to average together in order to generate a data spectra. Each pixel from each frame is averaged individually.
>
> ***Range*** – the range of values for averaging. Choose *Short*, *Medium*, or *Long* from the drop down box to change the range for the *Average (# of frames)*.

Data Sets

Accessed from Spectrometer Properties use the ***Data Sets*** tab to identify data sets with names. In Multi-wafer BandiT a data set is assigned to each marker and only information collected at that marker is saved in the corresponding .kdt file. To allow proper post acquisition analysis it is crucial that each data set is identified so that the user knows which wafer or which position on a wafer is stored in the file.

Specify:

Number of data sets - the number of data sets required

Data set names - select the number of the data set from the drop down menu and enter a unique name that identifies the wafer or wafer position

Device output control - check ***Enable*** to allow device output control and click the Mappings button to set up the parameters for each Output Device.

External digital input data set detection - this is an advanced feature contact kSA for implementation

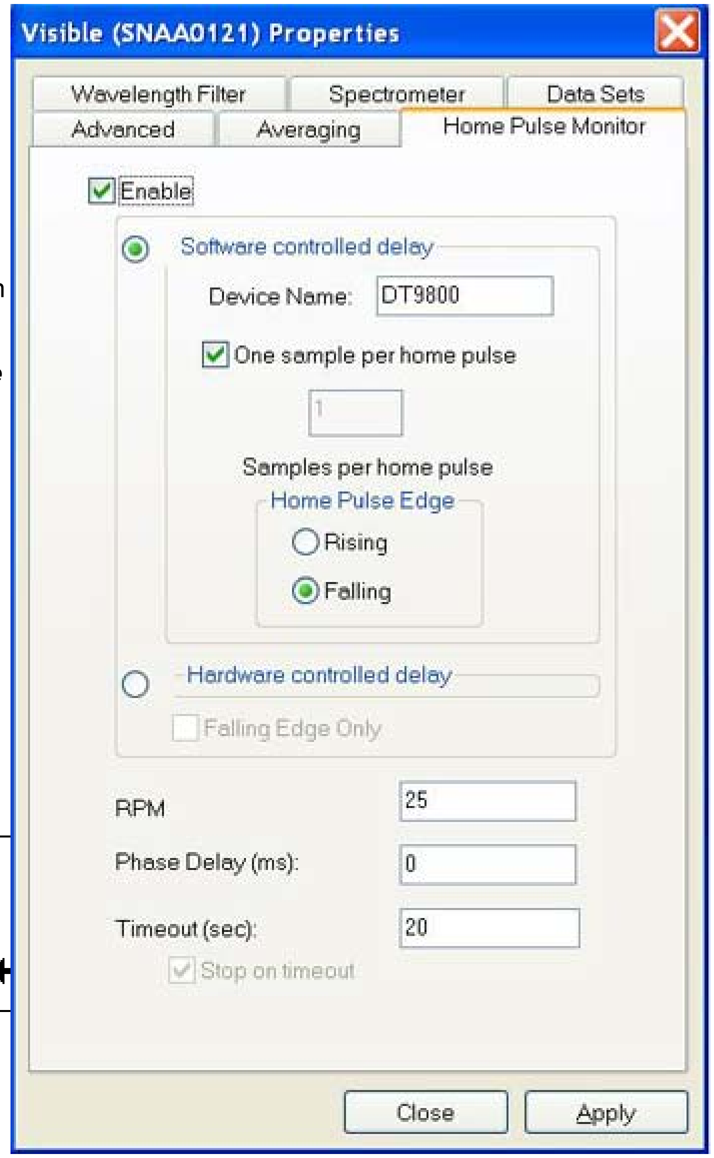
Home Pulse Monitor

Right-clicking the Live Spectrometer window and selecting ***Properties*** brings up the Spectrometer Properties.

Use the ***Home Pulse Monitor*** tab to specify the parameters of the home pulse during rotation if the system uses the ***"Counter Timer Board"*** to monitor rotation. Go to Check Hardware Rotation Board to check whether the system has this board.

Learn more about triggering temperature acquisition and how to set up the Home Pulse Monitor in the topic How-To Trigger Temperature Measurement.

With the ***Enable*** checkbox ticked, select:

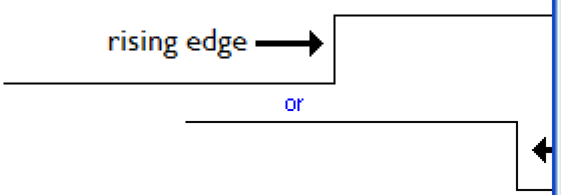


Software Controlled Delay and specify:

Device Name – this is the name of the I/O device. For most users this will be CB(0,1) For users with the DT9806 the name will be different. This will be normally be specified by the k-Space engineer who sets up the system. Details for finding the correct name can be found at the end of this page.

With the ***One sample per home pulse*** checked, the ***Samples per home pulse*** box is greyed out and 1 is used as the ***Samples per home pulse*** no matter what number is displayed. Uncheck the box to specify more samples per home pulse (in positive integers). Use this to take a number of consecutive samples (as fast as possible) when the home pulse is received (once per rotation).

Home Pulse Edge – select ***Rising*** or ***Falling*** depending on whether the pulse is as a rising or falling edge.



or

Hardware Controlled Delay and specify:

Falling Edge Only - ****

RPM – revolutions per minute of the wafer. This should be set to the maximum RPM expected.

Phase Delay (ms) – time in milliseconds after the trigger pulse is detected before the data point is gathered. Use this to gather data from another position on the wafer other than the center. The ***Phase Delay*** can be set by using the Phase Delay Selection Acquisition

Timeout (sec) – number of seconds before acquisition stops if no data point is gathered

Stop on timeout: for now, this option is default checked and cannot be changed. On timeout, the Live Spectrometer will be stopped/paused until the user manually resumes.

How to find the Device Name

Determine whether the kSA BandiT system has a DT9800-series or Measurement Computing PMD-1208FS board.

To do this, open the Computer's Device Manager (found on the Control Panel, System, Device Manager).

If "DT-Open Layers Acquisition Devices" (or some close variant) is listed, then the system has a DT9800-series board. Click the + icon to find the name of the device (e.g., DT9806(01)). Enter that name exactly as it appears into the ***Device Name*** box. Note that some systems will not have any parenthesis for the name (e.g., DT9806).

If it is not a DT9800-series board, then (except in a few specialty cases), it is a Measurement Computing Board. Click Start → All Programs, and run the InstaCal program (it may be listed under "Measurement Computing"). In the InstaCal window, find the Measurement Computing board and note the board number. In the ***Device Name*** box, enter CB(<boardnumber>,1), where <boardnumber> is the number reported by the InstaCal software.

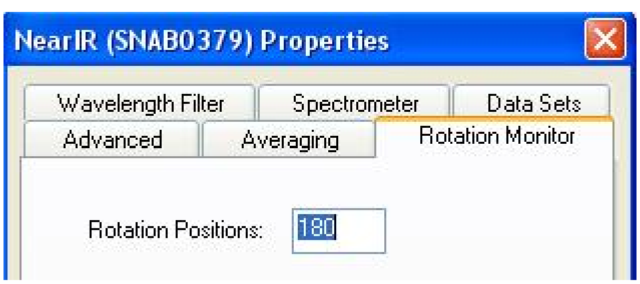
For example, CB(0,1) would be entered if InstaCal reported that the board number is 0.

If after clicking ***Apply*** a dialog appears stating that the Home Pulse monitor could not be found, then the device name is wrong. Please ensure that the device name is entered exactly as described above. If you need further assistance with this step, please contact us.

Rotation Monitor

Right-clicking the Live Spectrometer window and selecting ***Properties*** brings up the Spectrometer Properties.

Use the ***Rotation Monitor*** tab for multi-wafer BandiT if the system uses the ***"Teensy"*** to monitor rotation. Go to Check Hardware Rotation Board to check whether the system has this board. The Rotation Monitor menu sets the number of positions to track across the rotating platen.



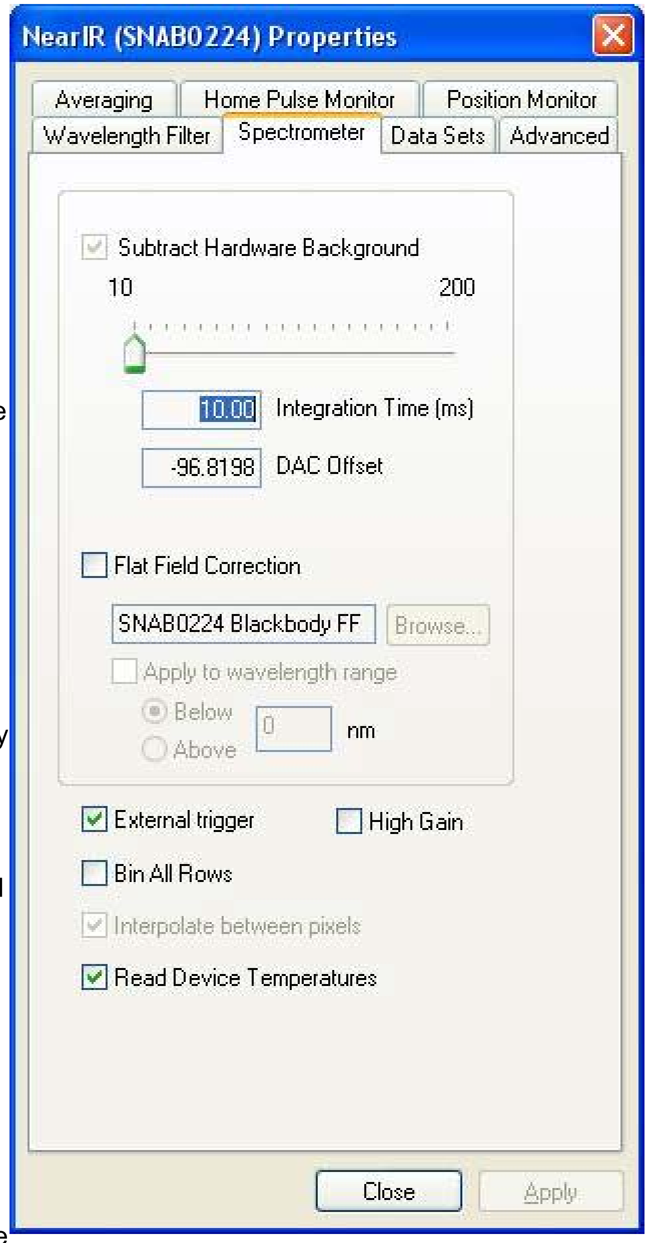
Specify:

Rotation Positions - the number of rotation positions on the platen. This determines the resolution of the rotation monitor. 100 positions will give a position every 3.6 degrees on the platen. A maximum of 180 positions is possible.

Spectrometer

Right-clicking the Live Spectrometer window and selecting *Properties* brings up the Spectrometer Properties.

Use the ***Spectrometer*** tab to change the acquisition properties of the spectrometer.



Specify:

Subtract Hardware Background – to subtract the dark background from every raw spectra acquired. Note that the software subtracts the appropriate dark background given any changes in the spectrometer integration time.

Integration Time (ms) – this is the amount of time that the spectrometer collects signal before digitizing and reading out this signal. The typical range of integration times for kSA BandiT spectrometers is 10 - 300msec. Use *Integration Time* to decrease (low values) or increase (high values) the intensity. The integration times available here are those that are set when the latest Dark Background was taken. If the range or the step sizes do not match your requirements you will need to take a new Dark Background.

DAC Offset – (not user-adjustable) – this is determined internally by the BandiT software and is based on the minimum dark background for each integration time.

Flat Field Correction - Flat Field Correction is only needed when performing Blackbody Pyrometry. Check this box and select the Flat Field Correction file that corresponds to your Spectrometer. the default directory is C:\Program Files\kSA\kSA BandiT\PROGRAM\Spectrometers\SNABnnnn, and the file will normally be named "SNABnnnn Blackbody FFC.kdt", where SNABnnnn is the spectrometer's serial number.

Optionally select to apply the correction to only part of the wavelength range.

Check:

External Trigger – spectrometer data can only be acquired when an external trigger input signal is sensed on the trigger input line of the spectrometer. This is a legacy option for kSA BandiT built before August, 2006. See more information in the topic How-To Trigger Temperature Measurement. Please contact us for details on wiring for external trigger input.

High Gain – put the spectrometer in a high gain mode. In this mode, the spectrometer is much more sensitive and can better detect weak signals. However, the high gain mode also results in high noise, so the signal-to-noise (S/N) ratio is reduced.

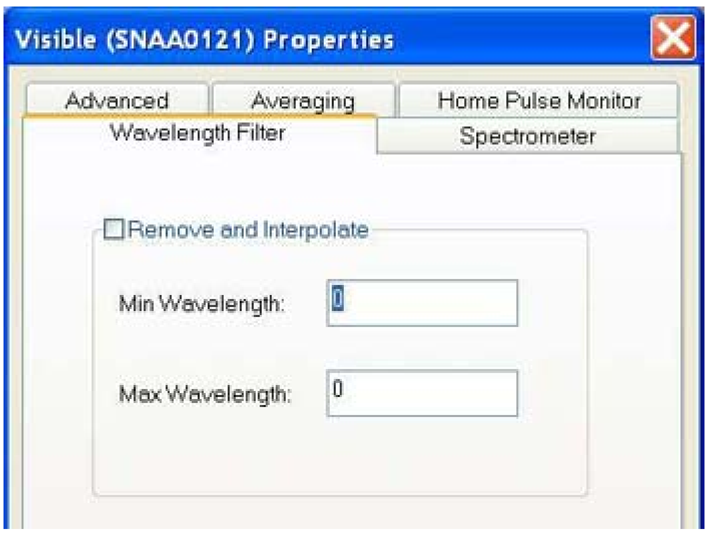
Bin All Rows – (Default: unchecked) – checking this option is a hardware function that adds up all the rows on the CCD for increasing speed (visible to about 4 ms integration) but decreases signal-to-noise (because it adds dummy rows (non-image information) from the CCD). Do not check this option in triggered mode as it will not clear the CCD non-imaged rows and noise may increase over time.

Interpolate between pixels – not user selectable (Default: ON) – interpolates between raw pixels from CCD detector

Read Device Temperatures - (Default: Checked) - reads the real time temperature of the embedded thermocouples inside the Spectrometer and displays them at the bottom of the Live Spectrometer window. This real time display of the temperature can be disabled to optimize performance, but the temperatures will still be recorded in the kdt file. Up to three temperatures can be displayed "Rack" temperature is the temperature of the internal spectrometer board, "Sensor" temperature is the temperature of the array and the "Optic" temperature is the temperature of the optic although this is not available for un-cooled spectrometers for example most NIR spectrometers.

Wavelength Filter

Accessed from Spectrometer Properties the ***Wavelength Filter*** is used to select which portion of the Spectrometer source to use as source data for BandiT. It can be useful if there is something contaminating the spectrum, for example if an Argon emission line is contaminating the spectrum the Wavelength Filter can be used to "Remove and Interpolate" the region of peaks (e.g. 908-916 for the 912 emission line). Bandit removes the region and interpolates the spectrum, smoothing out the line. It is also useful during Black Body measurements, for example for filtering out a bandedge.



Check ***Remove and Interpolate*** to enable the filter

Specify:

Min Wavelength - the lower wavelength to filter

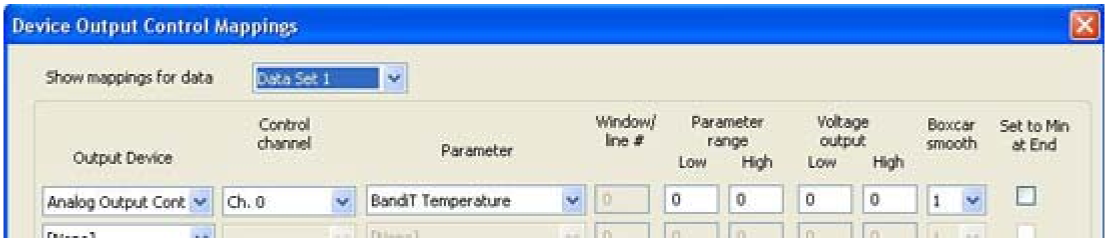
Max Wavelength - the upper wavelength to filter

Device Output Mappings

This is accessed from the Data Sets tab of the Spectrometer Properties by clicking the ***Mappings*** button.

Use ***Device Output Control Mappings*** to map any real-time parameter—including BandiT temperature —to a configurable analog output channel.

In the example shown below, Channel 1 is used to map the BandiT temperature: 0 – 800°C maps to 0 – 10V output.



Specify:

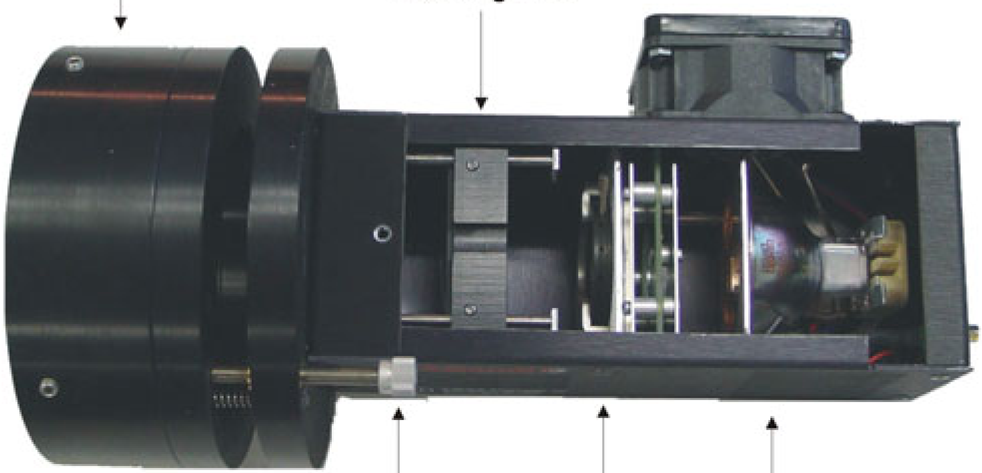
> ***Output Device*** – through which output signals can be made. This device is typically a data acquisition board with digital or analog output channels. If the device is detected by the k-Space software, it will be present in the *Output device* dropdown box.
>
> ***Control channel*** – of the of the selected device that you want to use for signal output. The *Control channel* dropdown list will list only those channels currently available on the selected *Output device*.
>
> ***Parameter*** – to be mapped to the output channel. For example, it could be the BandiT temperature, band-edge wavelength, elapsed time, etc. All available data parameters will be listed in the *Data parameter* dropdown box.
>
> ***Window/line #*** – if the acquisition mode utilizes window or line regions, then this parameter selects which region to use for the data output mapping. Note that this parameter is not available in some acquisition modes, in which case this parameter text box will be disabled (such as above).
>
> ***Parameter range*** – to define the range of parameter values mapped to the output channel. In the example above, the temperature range is 0°C (min) to 800°C (max). Many other parameters are available.
>
> ***Voltage output*** – to define the voltage range to which the *Parameter* is mapped. Common ranges include 0-10V, 0-5V, and -5-+5V.
>
> ***Boxcar Smooth*** – to employ a simple, common data smoothing routine whereby a given data point is smoothed, or averaged, into the data surrounding it. As an example, for a 3-point boxcar smooth, each data value is averaged with its nearest neighbor data point on each side, replacing the original data value with this "smoothed" average. Note that the boxcar smooth value must be an odd number. When 1 is chosen, no smoothing is done.
>
> ***Set to Min at End*** - will set the specified mapped minimum voltage after the acquisition is complete. This is useful to keep active high boards in the 'off' state when not in use.

Note: For smoothing on analog outputs, the software waits until it gets the boxcar smooth number of data points, and then averages these numbers to smooth the data.

Light Source

Standard Light Source

BandiT has a few different light source options, including a liquid light guide. The most common is a halogen bulb (shown in the image below).



The standard light source is shipped fully assembled (including halogen bulb). Before mounting the light source to the view port, please follow these steps to make sure the bulb is seated correctly:

1. Carefully unpack the light-source housing and inspect it for any damage caused by shipping.

2. Next, remove the cover and inspect the optics.

3. The socket connector lever should be in the forward position. The lever allows removal of the lamp.

4. The lamp should be seated in the lamp assembly. Be sure to press down firmly so that the bulb is completely seated in the socket.

5. Replace the cover.

Signal strength is best if BandiT's light source is mounted on a ***normal incidence*** view port. If such a port is not available, then please choose another port with the smallest angle from normal as possible. Bench tests have shown that signal strength is reduced only by 30% at angles as large as 60 degrees from normal, which is sufficient for accurate temperature measurement. But, of course, the greater the range of signal strength, the greater the precision in temperature measurement.

Mounting to the view port:

Typically, BandiT comes supplied with both 4.5" and 2.75" mounting rings. A 4.5" ring comes attached to the light source, so if mounting the light source to a 2.75" view port, change the mounting ring. Then, using the four 10-32 set screws located around the 4.5" mounting ring, secure the light-source housing to the view port. For exact alignment and focus of the light source on the view port see Align Light Source.

Configure Light Source Controller

BandiT's light source is completely controlled through the software so it is important to ensure the interface is properly set up.

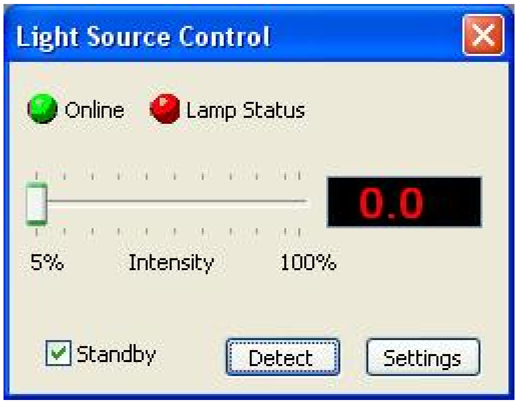
Follow these steps to ensure the lamp interface is properly set up:

1. If the Main Power switch is not already On from the software installation procedure, verify that all cables are connected and then turn on the Main Power.

2. Turn On the Lamp Power. The lamp may come on depending on the default conditions of the lamp driver board.

3. If the BandiT application is not already open from the software installation procedure, open it by double-clicking on the kSA BandiT icon on the desktop. The application should open in the default condition with no windows open. If it does not, then close all windows within the application.

4. From the top of the application go to the View menu and select Light Source Control.



5. Click the Detect button. The indicators should be green, intensity set at 5%, and the lamp placed in standby:

6. Take the light source out of Standby mode and use the slider to increase the intensity. Ensure the lamp's intensity is corresponding with the change in the slider.

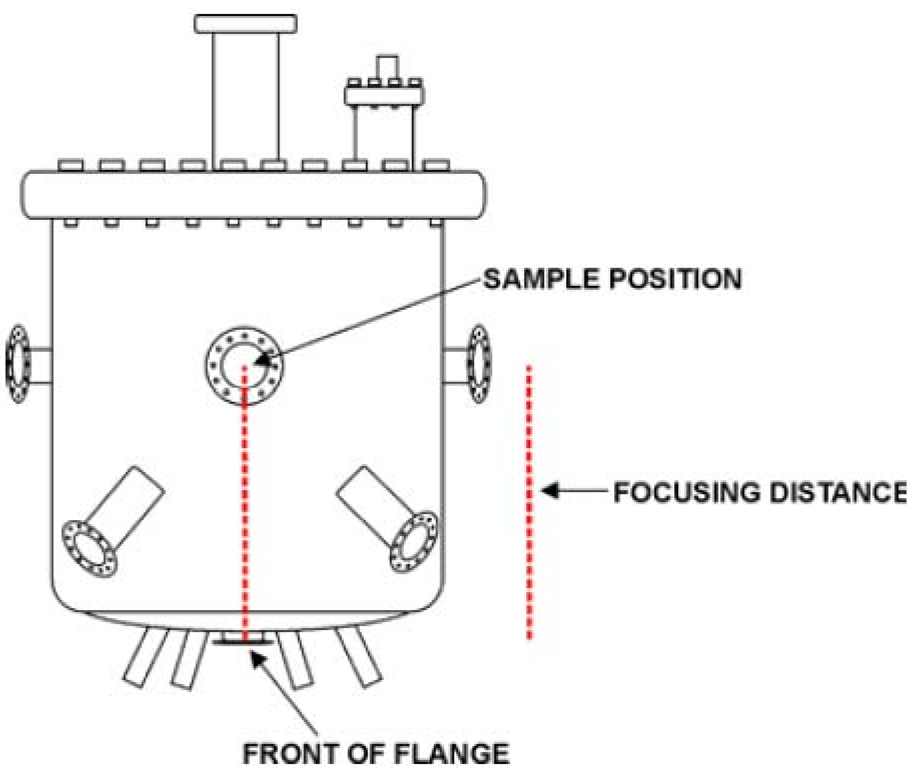
7. Return the intensity slider to 5% and place the lamp in Standby mode.

Align Light Source

After the light source has been properly mounted and tested, focus and align the unit following these steps:

1. Remove the light source from the view port and set the unit on a workbench or flat surface facing a wall.

2. Determine what the Focusing Distance is from the light source to the sample. The Focusing Distance will be the distance



from the front of the light source to the center of the sample (see diagram on right).

3. Using the lamp control window in the BandiT application, take the lamp off of standby mode and set the intensity to the minimum (5%).

4. Remove the top cover of the light source.

5. Move the light source so it is the same distance from the wall as the Focusing Distance.

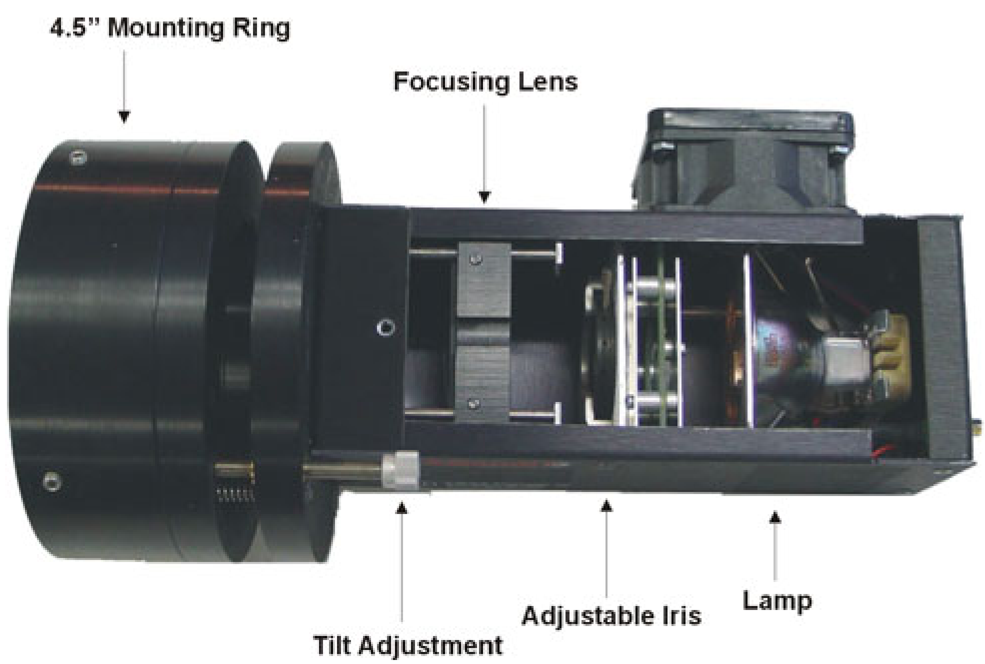
6. Set the Adjustable Iris diaphragm to a desired position. Keep in mind that the larger the opening of the iris, the more the sample will heat up at lower temperatures.

7. Using the light spot on the wall as a guide, set the focus using the Focusing Lens.

8. To keep the focus from changing, tighten the set screws in the Focusing Lens to the guide rail.

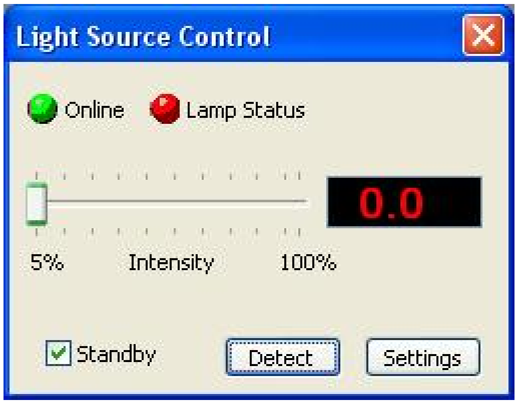
9. Using the lamp control window in the BandiT application, return the lamp to standby mode.

10. Remount the light source to the view port.



Light Source Control

Light Source Control is opened by using the  icon on the toolbar or by using the View menu.

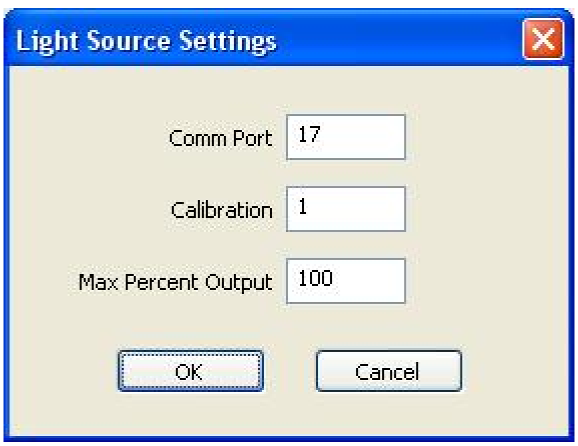


Click the ***Detect*** button to detect the light source - the indicators Online and Lamp Status should turn green.

Use the ***Intensity*** slider to increase/decrease the light source intensity - it can be left at about 5% when not in use.

Click ***Standby*** to put the light source into Standby mode - the light source will normally be left in standby mode when not in use.

Click ***Settings*** to open the settings dialog box as shown below:



Comm Port - is the Communication port used for communicating with the light source

Calibration - the factory-configured value that is based on the lamp controller. In general, this will not need to be changed by the user.

Max Percent Output - allows for less than 100% of the lamp output to be used if required

Tilt and Rotate Detector

Tilt and Rotate Detector

The Tilt and Rotate Detector is available in two formats Manual and Motorized.

The Manual Detector has a Micrometer that can be used to align the detector onto the wafer at the desired position.

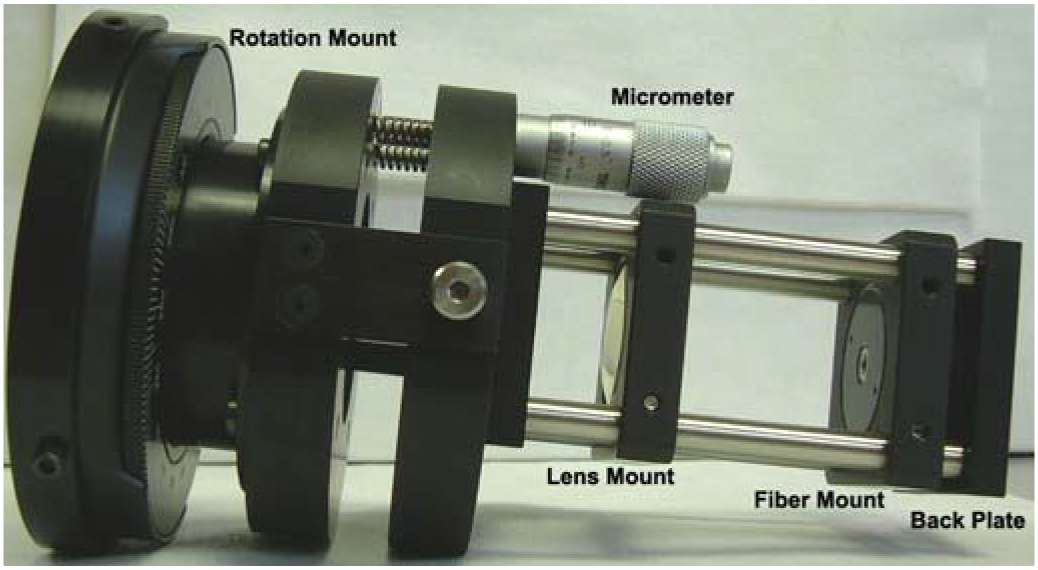
The Motorized Detector has a Servo motor which is powered from the BandiT rack and controlled by the BandiT software. This is required to enable the Full Platen Temperature Scan (a BandiT Multi-Wafer Acquisition mode) to be used.

Tilt and Rotate Detector Installation

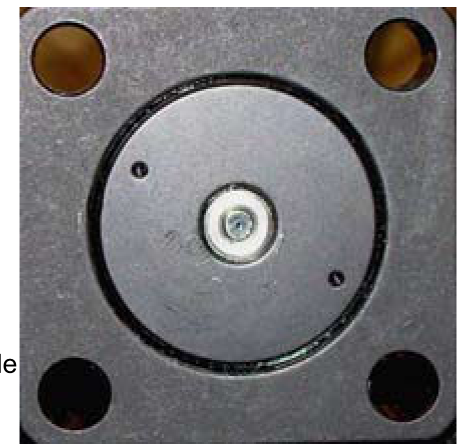
The tilt and rotate detector effectively collects light and its design allows users the ability to adjust where the detector is collecting light reflected from or transmitted through the sample.

1. Carefully unpack the detector and inspect it for any damage caused by shipping.

2. Next, remove the covers and inspect the lens. The curved side of the lens should be facing towards the front of the detector.



Before mounting the detector on the view port, you will want to install the optical fiber into the fiber mount. In order to attach the fiber, the detector first must be partially disassembled. Please follow these steps to attach the optical fiber into the detector:



1. With covers removed, unscrew the back plate from the rails.

2. Loosen the set screws from the fiber mount and slide the mount off the rails.

3. Locate the optical fiber in the accessories packaging and remove the end cap on one end.

4. Taking care not to scratch the end of the optical fiber, guide the fiber into the SMA fitting (located in the Fiber Mount) and rotate the mount until the fiber is flush to the front of the mount (see example picture on the right).

5. Connect all the components back onto the rails of the detector. Finally, connect the top and bottom housing covers to the detector.

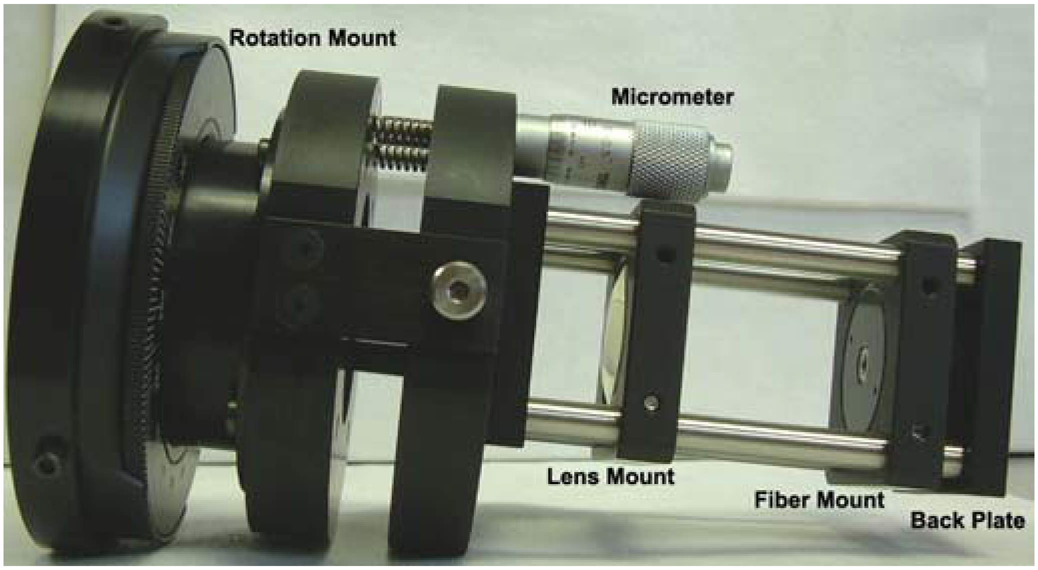
Mounting to the view port:

Typically, BandiT comes supplied with both 4.5” and 2.75” mounting rings. A 2.75” ring comes attached to the detector, so if mounting the light source to a 4.5” view port, change the mounting ring. Then, using the four 6-32 set screws located around the 2.75” mounting ring, secure the detector housing to the view port. For exact alignment and focus of the detector see Align Tilt and Rotate Detector.

The ***Motorized*** version of the Tilt and Rotate Detector will also need to be connected to the Servo port on the back of the BandiT rack. The Servo motor is powered and controlled from the BandiT rack so it is important that the interface is correctly set up, see Detector Motion Configuration for more details.

Align Tilt and Rotate Detector

(Note: All Tilt/Rotate Detectors are pre-focused at a distance of 2 feet. If the sample-to-viewport distance is greater than 2 feet, focus adjustments for the detector may be needed.)



To align the detector and focus the input, follow these steps:

If you have optical access to the chamber

1. Connect and turn on the Alignment Laser and look for a red laser spot on the wafer. If it is not visible try adjusting the ***Micrometer*** a little.
2. If the spot is large and diffuse the ***Focusing Lens mount*** and ***Fiber Input mount*** will need to be adjusted in order to focus the laser spot. Remove the detector covers loosen the set screws around the ***Focusing Lens mount*** and slide them until the light is focused. If necessary adjust the ***Fibre Input mount*** as well. Then, tighten all the set screws. The goal is to have a sharply focused spot that is the same size (or slightly larger) than the fiber input (which is quite small).
3. The ***Micrometer*** can be adjusted to align the detector with the required position on the wafer.
4. Turn off the Alignment Laser.

If you do not have optical access to the chamber

1. If you have not adjusted the ***Micrometer*** using the alignment laser or do not have optical access to the chamber, then adjust the ***Micrometer*** so there is no observable tilt between the detector and the mounting ring.
2. Using the lamp control window in the BandiT application, take the lamp off standby mode and set the intensity to the minimum (5%).
3. Both the ***Focusing Lens mount*** and ***Fiber Input mount*** may need to be adjusted in order to focus the light coming into the detector. The goal is to have a sharply focused spot that is the same size (or slightly larger) than the fiber input (which is quite small).
4. With the detector covers removed, place a business card or other small piece of paper flush with the Fiber Input. If the light coming through the focusing lens is too large or is not focused on the paper, then loosen the set screws around the Focusing Lens mount and slide them until the light is focused. Then, tighten all the set screws.
5. Once the light is focused, tighten all the set screws.

Detector Motion Configuration

The ***Motorized Tilt and Rotate Detector*** is completely controlled through the BandiT software and it is important that it is correctly set up. Follow these steps to check the Detector:

1. Go to Options, Input/Output Devices and open the Optics Motion tab. Check that the Servo selected corresponds with that installed on your detector and that the COM port is the one that Windows has assigned to the Servo board.

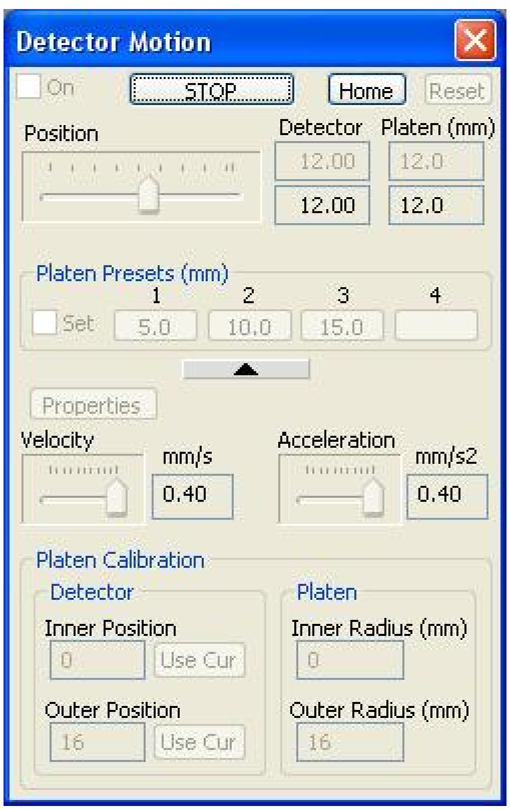
2. Use the  icon on the toolbar or select ***Detector Motion*** from the View menu to open the Detector Motion dialog.

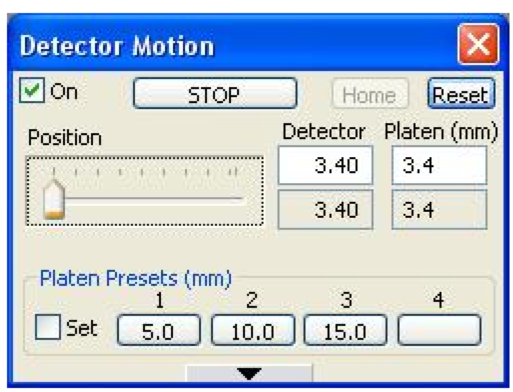
3. Click ***Home*** on the Detector Motion dialog and ensure that the Detector comes on and move the ***Position*** slider to confirm that the motor can move.

Detector Motion Control

Detector Motion is opened by using the  icon on the toolbar or by using the View menu.

This is used to control the motorized Tilt and Rotate Detector which can scan across the platen and is required during Full Platen Temperature Acquisition (a BandiT Multi-Wafer Acquisition mode).



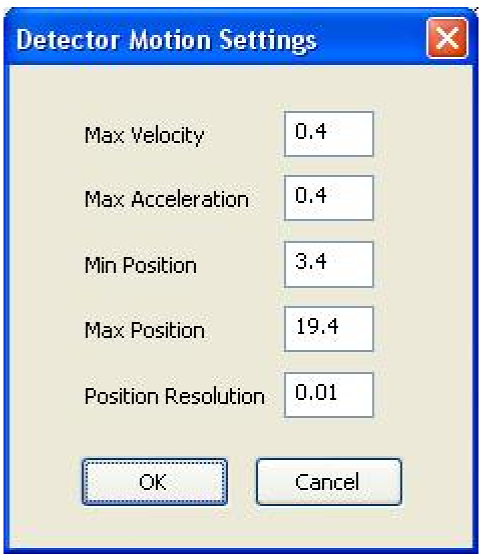


When first opened the Detector Motion dialog opens in the ***Reset*** state as shown on the left.
Click ***Home*** to turn the Detector Motion ***On*** and activate the rest of the controls.
The arrow button in the centre can be used to show/hide the platen properties and calibration part of the screen as shown in the right hand image.

Position - With the Detector Motion On set the ***Position***, use the slider to select a radius for the detector to move to, or type the require radius value into the ***Detector*** box. The motor will then move to drive the Tilt and Rotate Detector to the specified radius. It can be stopped at any time by clicking ***STOP***.

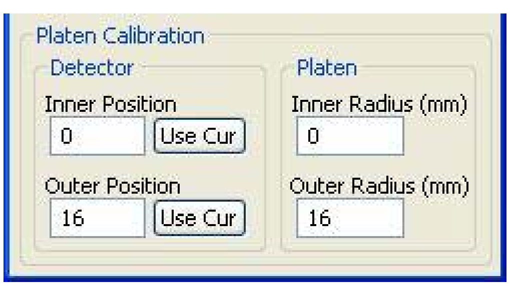
Platen Presets - The Platen Presets are used so that the detector can be moved to a specified position either by clicking the Preset button on this dialog box, or automatically at the end of the Full Platen Temperature scan. To set the Preset buttons, drive the detector to the required position, check the ***Set*** box and then click the Preset button that you want to set. Up to four different positions can be Preset. Once set these cannot be cleared but they can be set to new positions.

Clicking the ***Properties*** button brings up the dialog box below. The ***Maximum Velocity***, ***Acceleration*** and Maximum and Minimum ***Positions***, and the ***Position Resolution*** for the Servo motor that is installed in your Detector will be set automatically when the Servo board is initialized, but they can be changed here if required.



Velocity and ***Acceleration*** can be selected using the sliders on the Detector Motion dialog up to the maximum velocity specified in the Detector Motion Settings.

Platen Calibration - use this to calibrate the Detector positions with the actual Platen Radius. The number of positions available on the detector will depend on the model in use. If it is a Goniometer model then 0 will be in the centre of the movement and positions will be defined +/- this, for example from -30 to +30 positions. The Platen dimensions are in mm. In the Full Platen Temperature Acquisition mode the scan parameters are set in mm, for the actual platen radius not in detector positions.



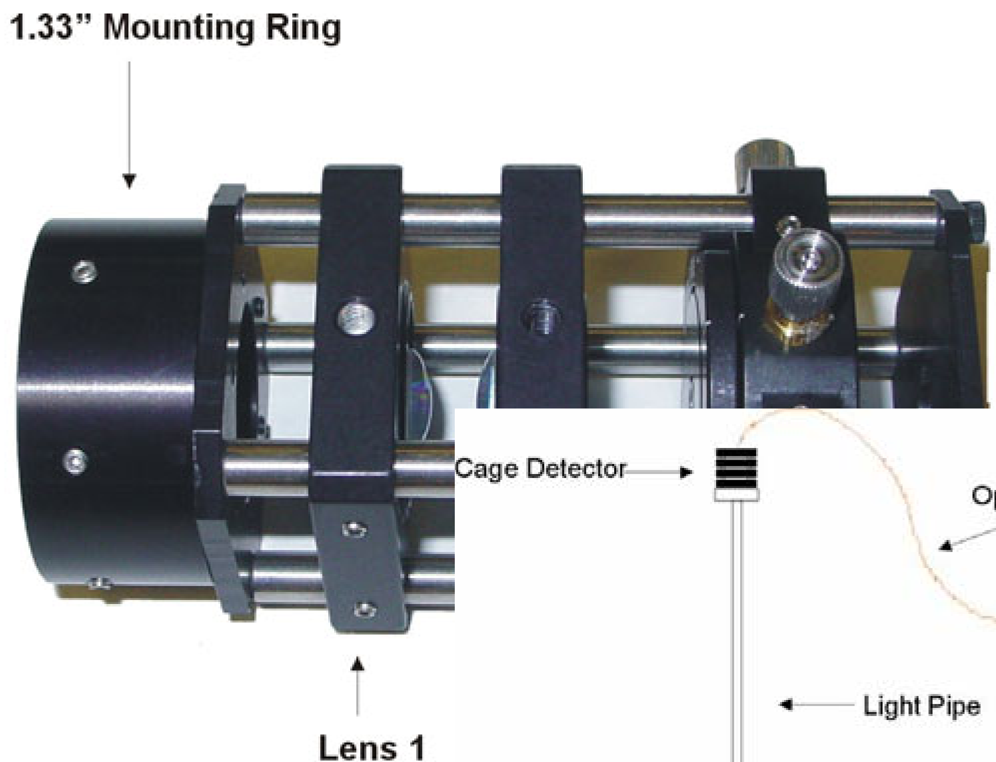
Specify the ***Inner*** and ***Outer Radius*** of the Platen in mm. Specify the ***Inner*** and ***Outer Positions*** of the Detector that correspond to the Platen radius.

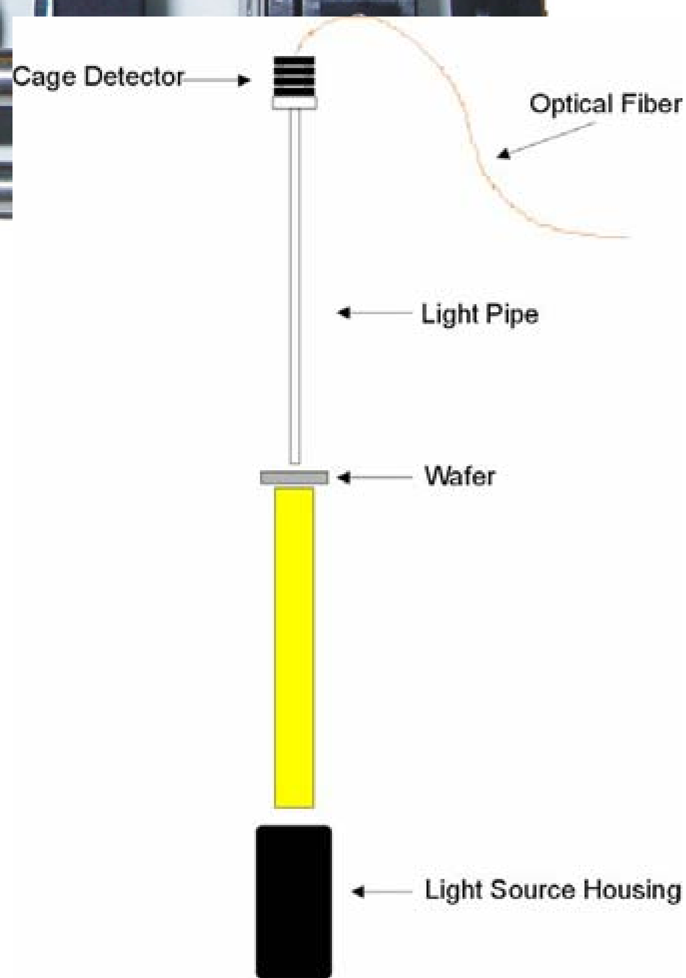
The ***Use Cur*** button can be used to take the Current Position of the Detector.

CAR Port Unit

CAR Port Detector Installation

Designed for use specifically on Veeco's GEN II and GEN III reactors configured with a light pipe facing the backside of the wafer, the CAR port detector unit is used for transmission mode only. Because the light source unit must be mounted on the pyrometer port—illuminating the wafer at all times—the substrate heater cannot be used as a light source.





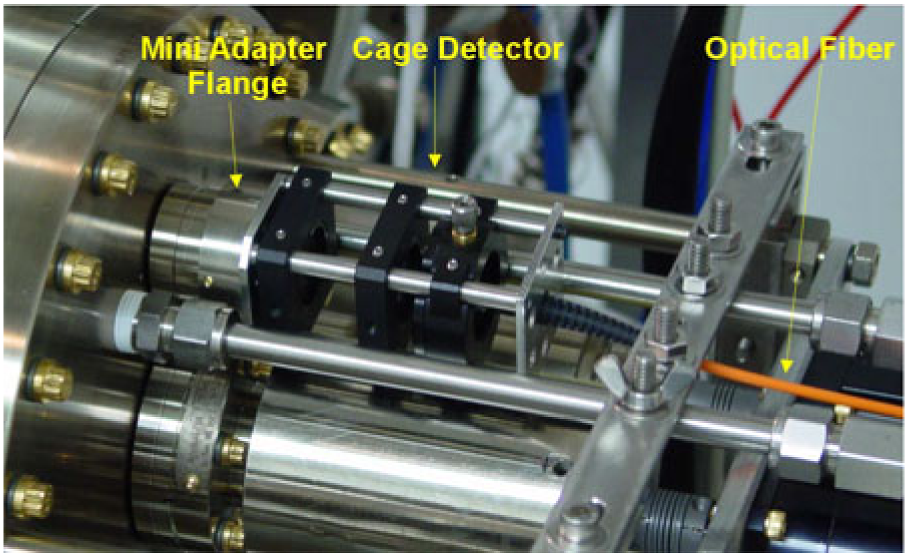
Included with the CAR port single-axis tilt detector assembly, please find:

- 2 12mm acromat lens
- 1 x/y fiber translation stage
- 1 optical fiber

Carefully unwrap the cage detector and inspect the unit. If the lens needs to be cleaned, do so before mounting it on the chamber. Use only clean alcohol and dry with clean laboratory-grade compressed air, argon, or nitrogen.

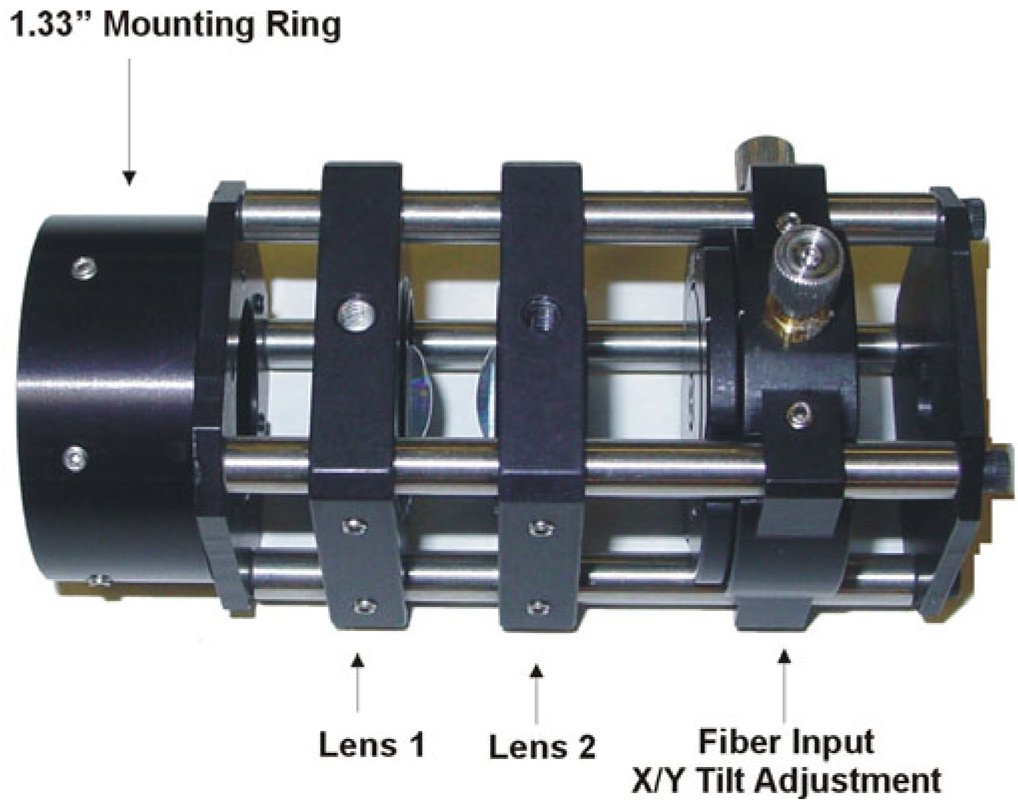
Next, please find in the accessories box the 10-meter dual optical fiber. Carefully unpack it and do not remove the end caps. Taking care not to scratch the end of the fiber, feed the single end into the SMA connector in the x/y translation stage.

Finally, mount the complete assembly to the CAR port flange and secure it using the four set screws around the perimeter of the mini adapter.



Align CAR Port Detector

At this point, the detector should be securely mounted to the view port and the optical fiber should be in place. If not, follow the steps in the CAR Port Detector Installation section to install it.



Then follow the steps below to align the detector.

1. Take whatever steps are necessary so that light is coming into the detector.
2. Loosen the 4 set screws around each lens.
3. Move ***Lens 1*** until it is positioned against the front mounting plate, then tighten its set screws.
4. Position ***Lens 2*** close to ***Lens 1***, but do not allow the lenses to touch. The goal is to have a sharply focused spot that is the same size (or *slightly* larger) than the fiber input (which is quite small).
5. Place a business card or other small piece of paper flush with the ***Fiber Input***. If the light coming through the ***Lens 2*** is too large or is not focused on the paper, then move ***Lens 2*** until the light is focused. If that is not possible, then pull ***Lens 1*** slightly back from the front mounting plate and try again until the light is focused.
6. Once the light is focused, tighten all the set screws.
7. In the BandiT application under the ***Acquire*** menu, select BandiT Temperature Acquisition and open the Real-time Bandit Spectra Real Time Chart. Use the fine adjustment on the on the sides of the ***Fiber Input X/Y Tilt Adjustment*** to maximize the signal detected in the ***Real-time BandiT Spectra*** window.

Rack Mount Controller

Rack Mount Controller Installation

The BandiT controller is a standard 19-inch, 5.25-inch height rack mount. Install the controller in a well-ventilated rack and ensure that the top cover vents are not obstructed. To ensure proper airflow, please also install a spacer between the top of the BandiT controller and any other equipment in the rack.

Important note: turn off main power before making the next set of connections.

Follow these steps to install the controller:

1. Install the laser interlock key on the front of the controller.
2. For those using a light source, connect the black lamp power interface cable to the back of the controller (labeled ***Lamp Interface***) and to the light source housing.
3. Connect the supplied USB cable to the back of the controller (labeled ***USB***) and to the computer's USB port.

4. Connect the optical fiber from the detector housing to the SMA fiber input on the back of the controller.
5. Connect the I/O Adapter Cable to the back of the controller (labeled ***I/O-Interface***).
6. Connect the USB sentinel key to the back of the controller (labeled ***Sentinel Key***).

   *Note: the **USB Sentinel Key** is your software license. It is important not to lose it. It may be inserted into a USB hub, but do not connect more than one computer to the hub, or, if having more than one system, then installing more than two keys to the same hub. It will not work and/or may disable some of the functionality because the options on one USB Security Key will override the other.*
7. Ensure that the ***Main Power***, ***Laser Interlock***, ***Laser Power***, and the ***Lamp Power*** switches on the front of the controller are all in the OFF position (rocker switch down), then plug in the AC power cord.

I/O Interface and BNC Connections:

The BandiT system can be configured to read and output a variety of analog and digital signals. Most users will use the analog voltage output BNC labeled “Temp Out” to send a linear voltage output to MBE control software. Alternatively BandiT can generate a TC voltage output on the I/O interface connector. ***However it is not generally a good idea to use BandiT as a direct feedback control to the substrate temperature controller.*** When the BandiT system is unable to detect a band edge and is unable to make a temperature measurement, then the output will be 0 volts and 0°C (unless *Disregarded data below threshold* is selected, which is in the Compute Band Edge Configuration Option).

I/O Interface (DB-15 female):

Pin	Signal
1	Analog Input High (Channel 0)
2	Analog Input Low (Channel 0)
3	Analog Output 1 High
4	Analog Output 1 Low

5	Digital Input 0
6	Digital Input 1
7	Digital Output 0
8	Digital Output 1
9	Digital GND
10-15	N/C

BNC Connections:

The remaining three BNC connections (Falling Edge H.P., Rising Edge H.P. Encoder Pulese) are for BandiT user's using the multi-wafer software option. The reactor's home pulse and encoder pulses (if available) connect to the appropriate BNC.

- ***Falling Edge Home Pulse*** - Used for timing with substrate rotation. A falling edge (5V-0V) pulse from the reactor.
- ***Rising Edge Home Pulse*** - Used for timing with substrate rotation. A rising edge (0V-5V) pulse from the reactor.
- ***Encoder Pulses*** - Used for timing with substrate rotation. Pulse polarity does not matter.

Switch Setting:

To the right of the BNC connections there is a switch for controlling the correct home pulse polarity received into the BandiT rack. This switch is only to be used if the system is being triggered for substrate rotation applications. The switch setting will correspond to the same home pulse (rising or falling) connected to one of the BNC connectors.

Servo Connector:

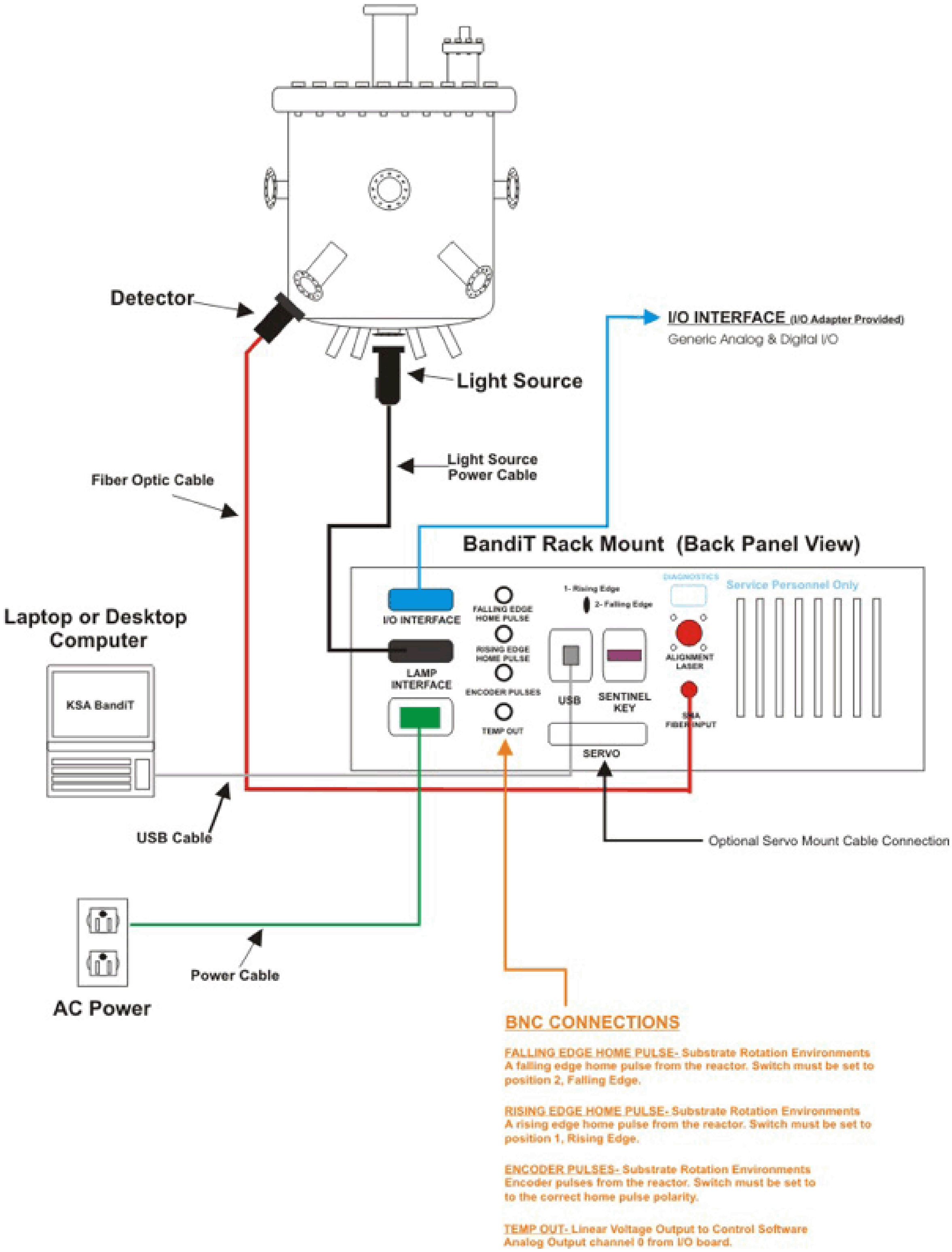
The SERVO connector supplies power and controls the BandiT servo detector mount. This is only used if the Multi-Wafer Scanning option is purchased.

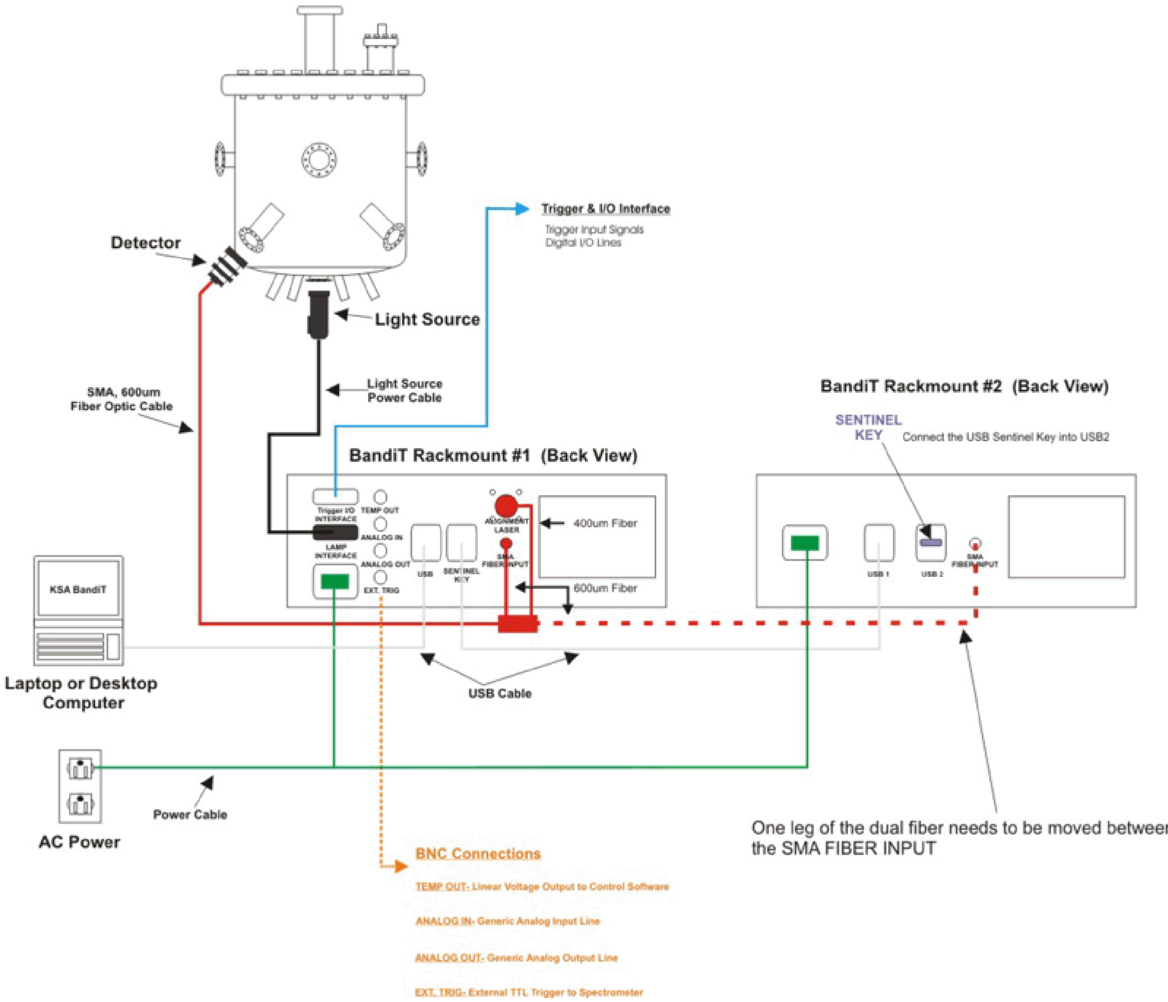
Diagnostic Connector:

The DIAGNOSTIC connector is to be used only by properly trained k-Space Associates, Inc. personnel. No connections should be made to this connector, unless instructed by a k-Space Associates representative.

Schematic diagrams

BandiT Systems are available in both one and two rackmount units. The diagrams below show schematic diagrams of both of these systems with the cable connections to the deposition chamber, computer and power. They also show differing configurations of the back panel that may be seen in different BandiT systems.





System recommendations:

- Although the BandiT system is not sensitive to changes in transmission from coated view ports, it cannot measure the temperature when ports become so coated that it cannot detect the signal. So, to keep the ports in operation as long as possible, we suggest heated view ports to minimize the rate of coating.
- To ensure the most accurate temperature measurement, use a shutter on the detector port to block chamber light from entering the spectrometer during BandiT Dark Background calibration (described in further detail later in this guide).

Alignment Laser

The BandiT system rack is supplied with an integrated Alignment Laser which is very useful for aligning the optics to the sample. The alignment laser illuminates the area of the sample where the detector is directed. It does not demonstrate the area of detection on a wafer.

To use the laser remove the fiber optic cable from the SMA Fiber Input socket and connect it instead to the Alignment Laser socket. Some systems have an optical fiber with a second leg, in which case there is no need to move the fiber as this second leg will be connected to the Alignment Laser.

Take great care when using the laser. Never look directly at the focused beam from the detector and always use laser goggles when aligning the system. The alignment laser used in the BandiT system is a CLASS IIIA laser (only CLASS I lasers present no eye hazard).

Insert the key into the Laser Interlock on the front panel of the BandiT rack and turn it to ON, then switch on the Laser Power. The laser will now be shining down the fiber optic cable into the Detector on your system.

When Alignment is complete, turn off the Laser Power, switch OFF the Laser Interlock and move the fiber optic cable back to the SMA Fiber Input socket.

Software

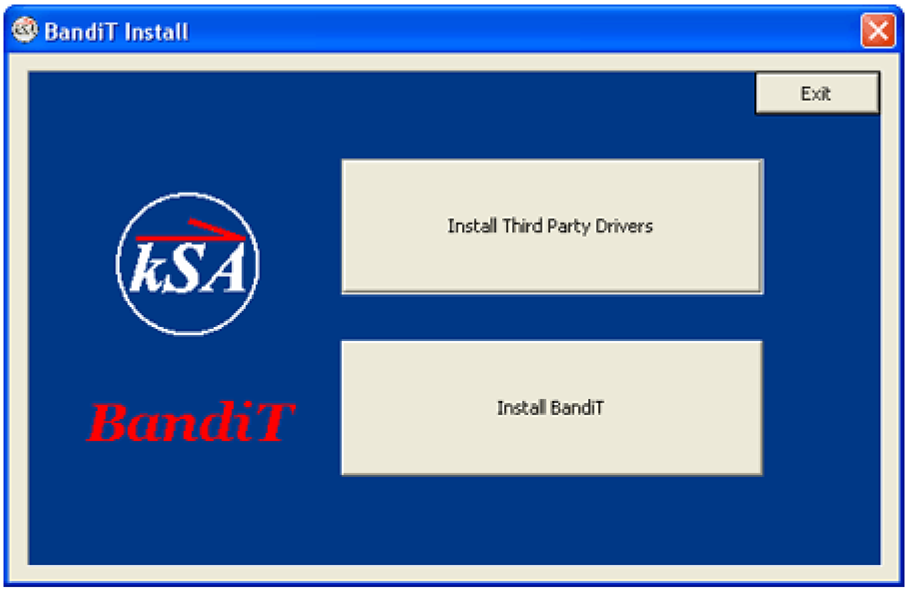
Software Installation

The BandiT software application and 3rd party device drivers are all located on the BandiT installation CD. Follow the installation instruction below to ensure that the software and device drivers install properly. If you come across any errors during the software installation, please contact k-Space Associates for technical assistance.

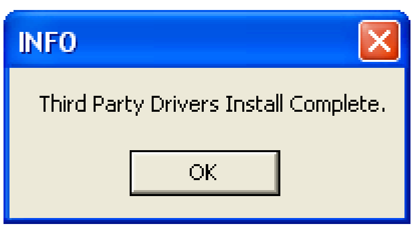
If you have already attached cables between the BandiT rack controller and the computer, please detach them and be sure the rack controller power is off. Several device drivers should be loaded before the hardware is detected.

Install Third Party Device Drivers First

Before beginning the software installation, please close all other applications. Then insert the CD into the computer's CD-drive. Installation should begin automatically. If it does not, double click on the CD-ROM icon to open it and then run BanditInstallStartup.exe from the CD. Doing so will bring up the following dialog box.



When the screen above appears, first select Install Third Party Drivers (This installation will automatically load all the drivers needed for the BandiT system). A new dialog will appear. Click OK to start. Then please be patient as many screens will appear and you may hear system alerts: do not click anything until the following pop-up window appears:

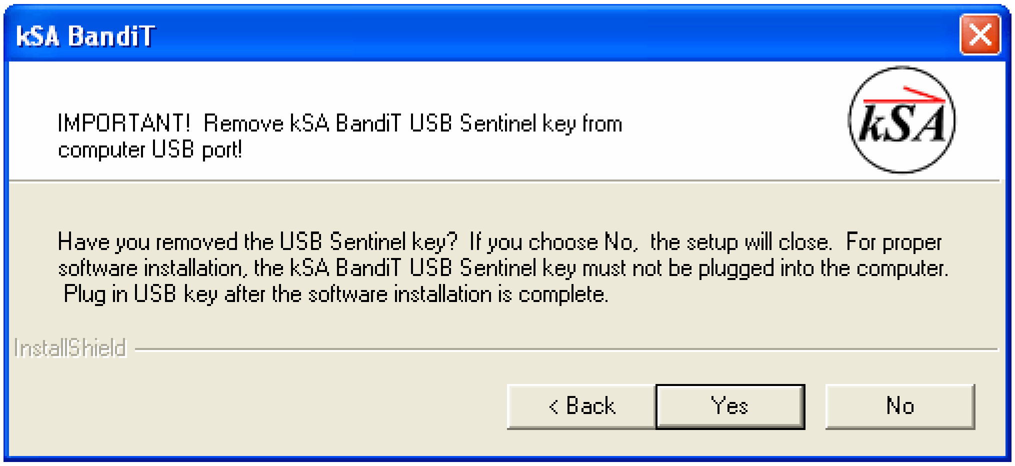


Click OK to close that pop-up window.

Install BandiT

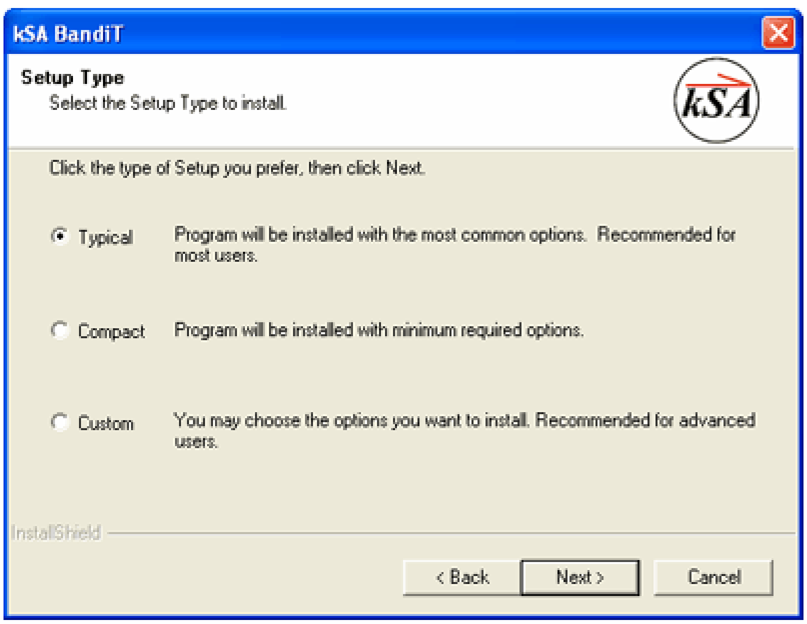
After the third party device drivers are installed, the next step is to load the BandiT application software. Follow through the installation instructions to load the BandiT software properly. Click the Install BandiT button to begin.

Important note: do not insert the USB Sentinel Key until after the BandiT software has been loaded and the computer has been restarted. This is so important that we have built in a prompt during the installation of the BandiT software:

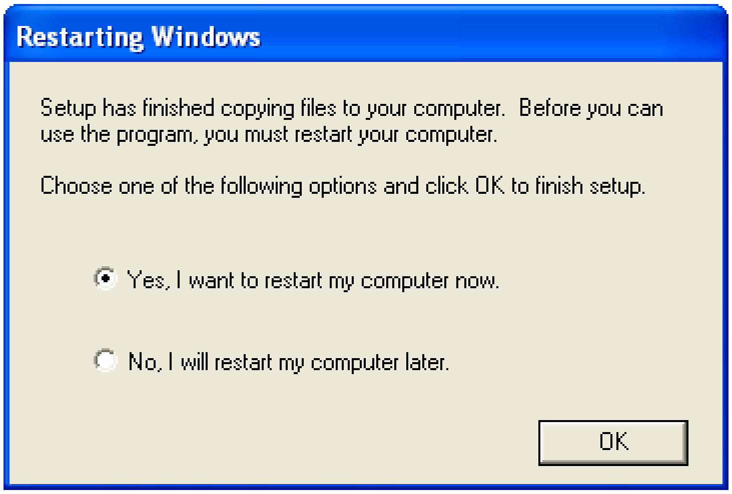


During the installation, you will be asked to choose among three setup types:

- ***Typical*** – installs all components (this is the recommended choice)
- ***Compact*** – installs only the application (no help manual, no samples, etc.)
- ***Custom*** – installs components as selected by user



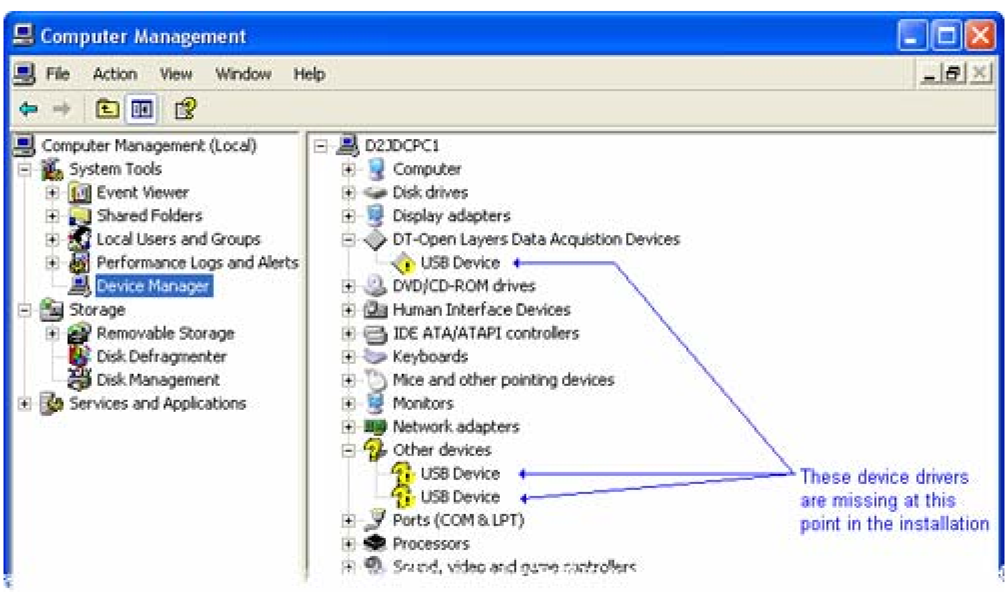
When installation is complete, the computer needs to be restarted for changes to take effect. Restart the computer.



Now the BandiT software installation is complete.

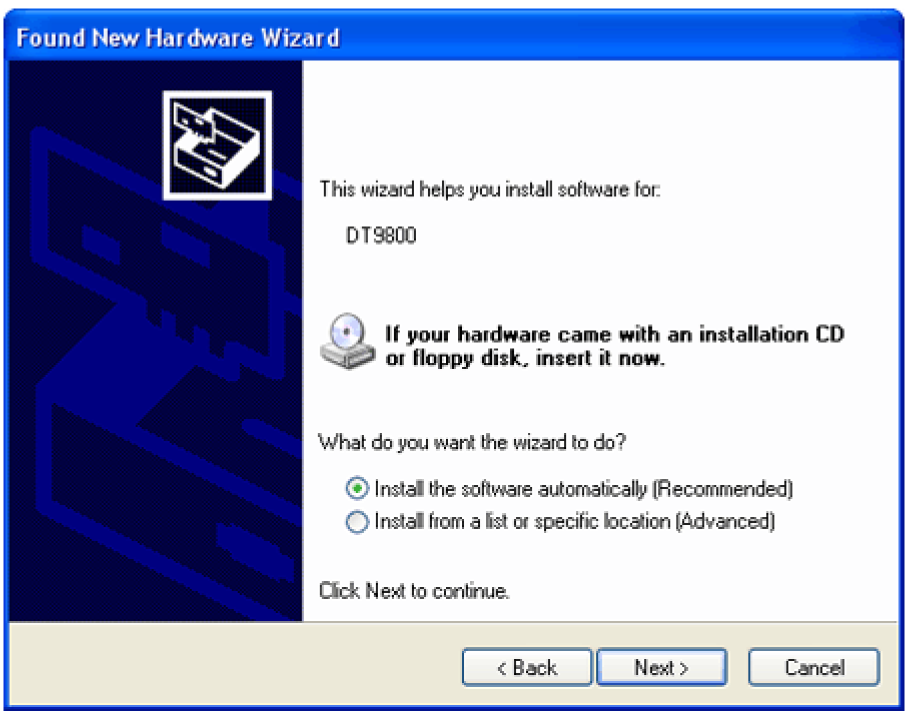
Power on the BandiT Rack

Turn on the BandiT's MAIN POWER switch on the front of the rack, but do not yet start the software. The computer will recognize the new devices and ask you to load drivers. At this point, you may want to open the Device Manager (Control Panels / System / Hardware / Device Manager). Before the drivers are loaded, it will look like

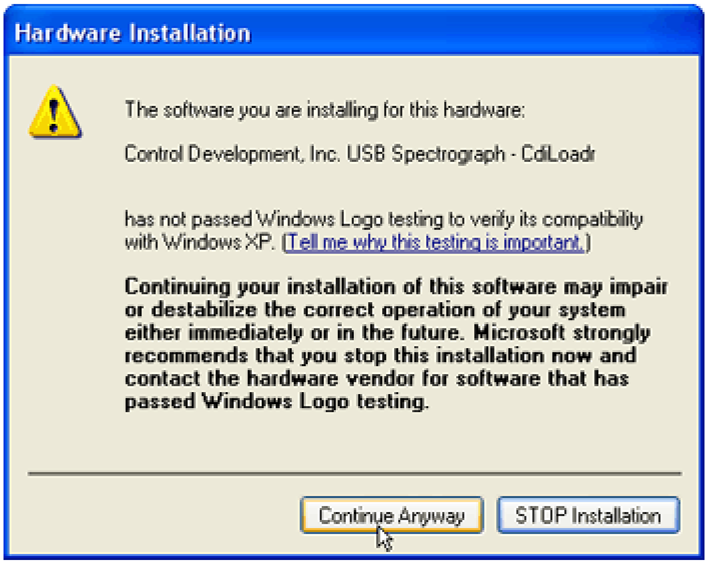


Windows Hardware Wizard will start up. Because there are many components within the BandiT rack, this will happen many times. Whenever the dialog shown in Figure 8 appears during the installation process, please select "No, not this time" and then click Next.

Each time this screen appears, select “Install the software automatically” and then click Next.



After each hardware device driver has loaded, click Finish. This process will be repeated several times, and may include the dialog box shown below appearing as well.



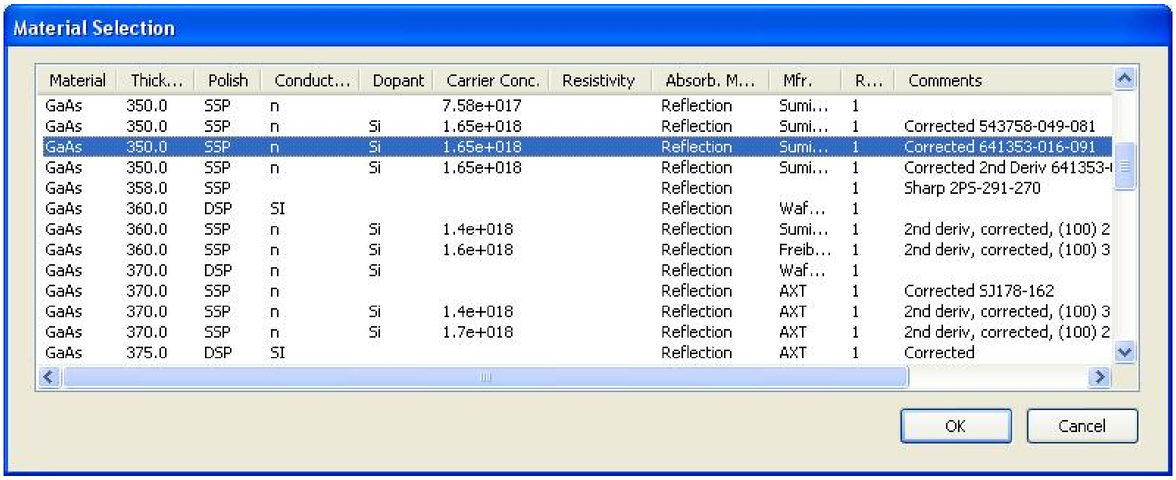
Each time this dialog box appears, select "Continue Anyway." k-Space Associates has thoroughly tested the hardware's compatibility. When all the BandiT hardware has been installed, the Device Manager should no longer have any question marks or exclamation points as it did before. If not, then please contact k-Space Associates.

Substrate Material

Select Substrate Material

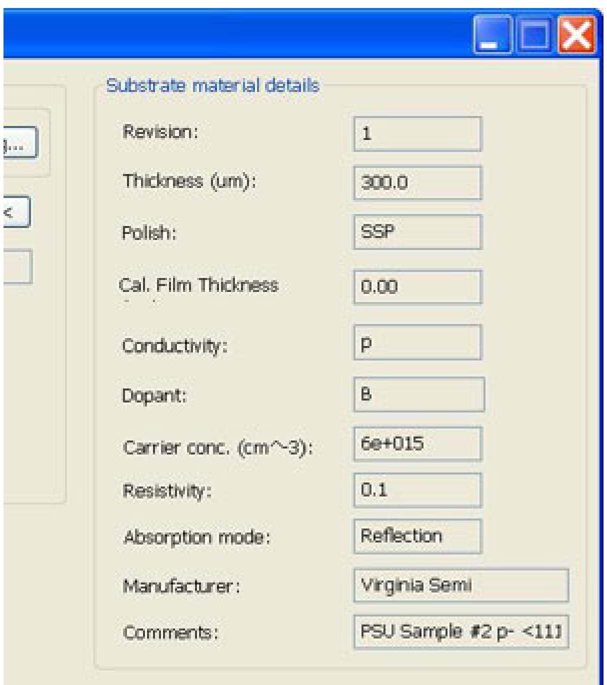
Whatever Acquisition mode is being used it is necessary to select the ***Substrate Material***.

Use the drop down arrow to select the base ***Substrate Material***, then use the ***Select*** button to open the table of materials for which there are calibration files. Select the one that best matches your substrate.



It may be the case that the Library does not contain the exact specification of the substrate material being used. Generally, the closest match will produce perfectly acceptable results, but if higher precision is required, it is possible to apply small correction terms using either 3) Band Edge Correction or 4) Temperature Correction. A final option is that k-Space can provide a calibration service for wafers that are not already listed in the Library.

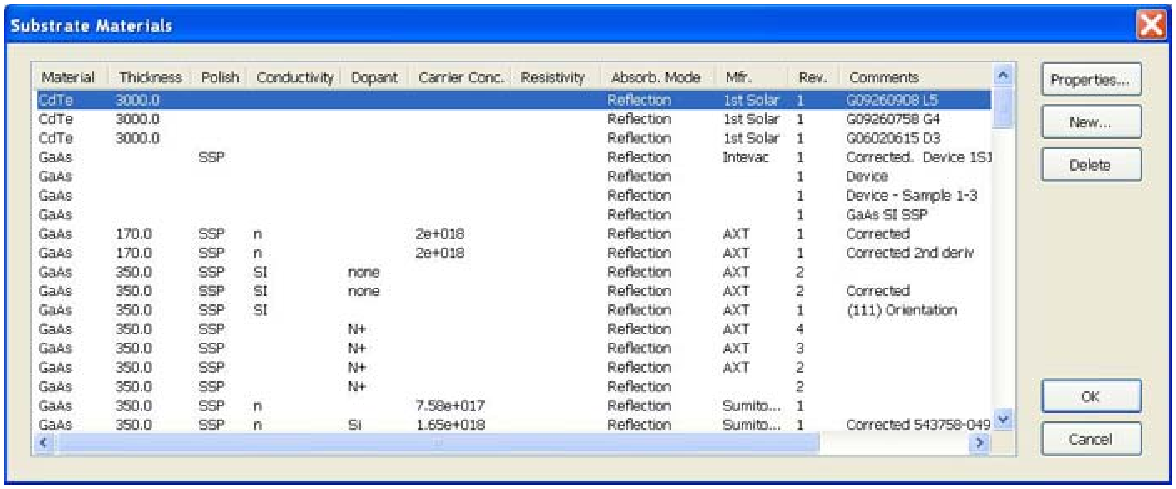
The details of the material selected can be seen in the Acquisition window by using the >> button.



Substrate Materials Setup

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

Input/View/Alter the properties substrate materials used in BandiT Temperature acquisition by using this dialog found under the Options menu.



Material	Thickness	Polish	Conductivity	Dopant	Carrier Conc.	Resistivity	Absorb. Mode	Mfr.	Rev.	Comments
CdTe	3000.0						Reflection	1st Solar	1	G09260908 L5
CdTe	3000.0						Reflection	1st Solar	1	G09260758 G4
CdTe	3000.0						Reflection	1st Solar	1	G06020615 D3
GaAs		SSP					Reflection	Intevac	1	Corrected. Device 1S1
GaAs							Reflection		1	Device
GaAs							Reflection		1	Device - Sample 1-3
GaAs							Reflection		1	GaAs SI SSP
GaAs	170.0	SSP	n		2e+018		Reflection	AXT	1	Corrected
GaAs	170.0	SSP	n		2e+018		Reflection	AXT	1	Corrected 2nd deriv
GaAs	350.0	SSP	SI	none			Reflection	AXT	2	
GaAs	350.0	SSP	SI	none			Reflection	AXT	2	Corrected
GaAs	350.0	SSP	SI				Reflection	AXT	1	(111) Orientation
GaAs	350.0	SSP		N+			Reflection	AXT	4	
GaAs	350.0	SSP		N+			Reflection	AXT	3	
GaAs	350.0	SSP		N+			Reflection	AXT	2	
GaAs	350.0	SSP		N+			Reflection		2	
GaAs	350.0	SSP	n		7.58e+017		Reflection	Sumito...	1	
GaAs	350.0	SSP	n	Si	1.65e+018		Reflection	Sumito...	1	Corrected 543758-049

Click the ***Properties*** button to view the full list of properties of each substrate material, or click ***New*** to create one. Either button brings up a new window with the following options:

File – view/choose the raw data file used for calibration

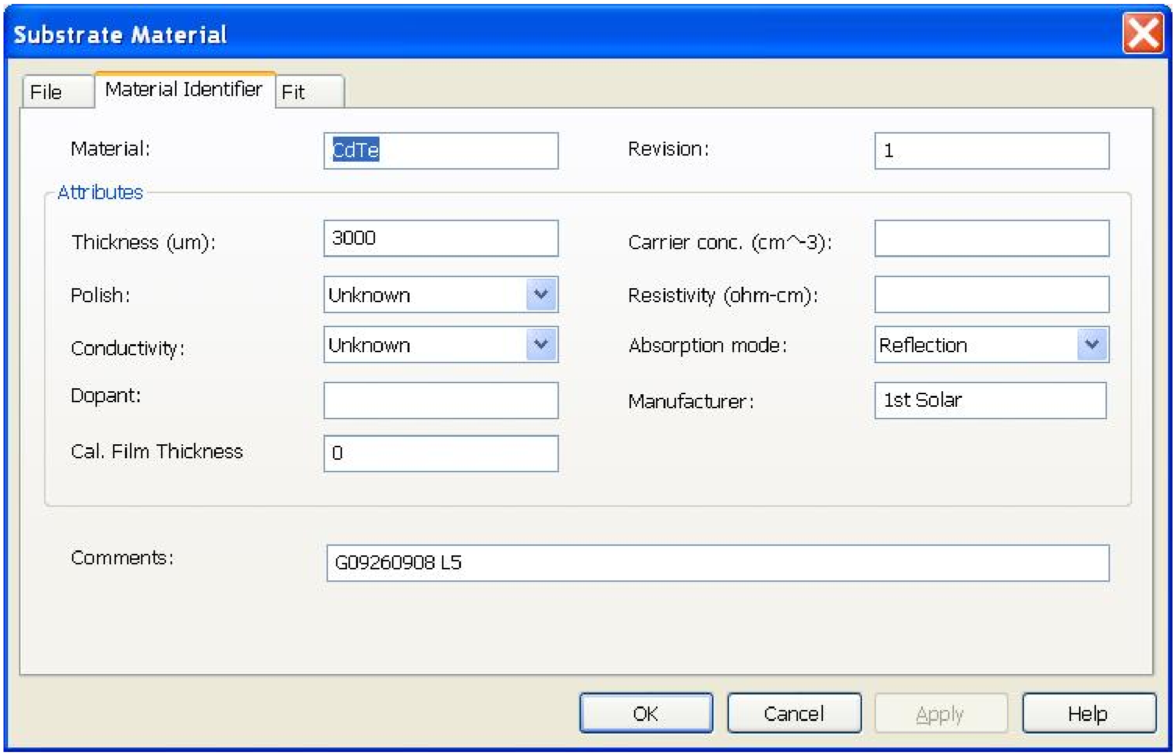
Material Identifier – view/choose the material and material attributes

Fit – view/choose/create a new fit to the raw data, and/or change fit properties

Material Identifier

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

Clicking the *Properties* button from the Substrate Materials Setup window brings up the *Material Identifier*. Use this property to view/choose the material and material attributes.



Specify:

Material – the substrate material

Revision – separates the files when calibration is done more than once using the same parameters

Thickness (im) – thickness of the substrate

Polish – choose either *Unknown*, *SSP*, or *DSP*. (SSP = Single-Sided Polish, DSP = Double-Sided Polish)

Conductivity – choose either *Unknown*, *n*, *p*, or *SI*

Dopant – this substance (e.g., boron) has been added in small amounts to a pure semiconductor material to alter its conductive properties. Type in the name of the dopant.

Carrier conc. (cm^3) – the carrier concentration of the substrate in cubic centimeters

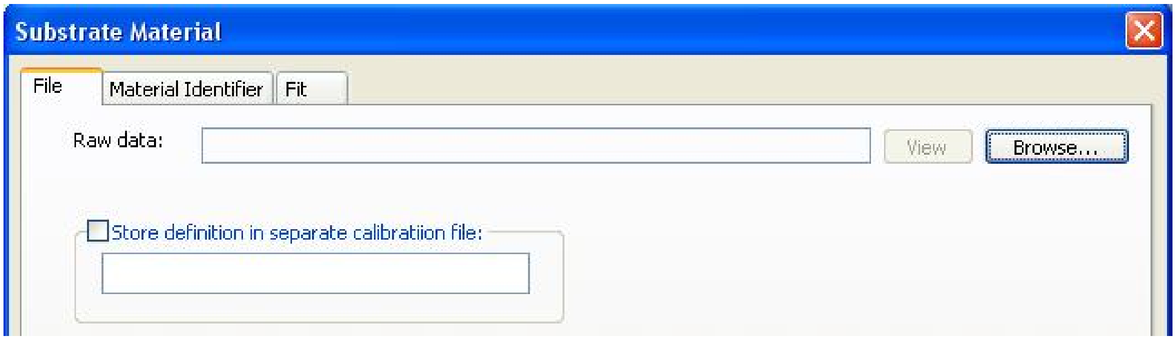
Resistivity (ohm-cm) – the intrinsic property of a material that is measured as its resistance per unit length for a uniform cross section

Absorption mode – choose either *Unknown*, *Reflection*, or *Transmission* for specifying how the BandiT system acquired the data

File

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

Clicking the ***Properties*** button from the Substrate Materials Setup window brings up the ***File***. Use this property to view/choose the raw data file to be used for calibration.



Click the ***View*** button to see a plot of the raw data.

Click ***Browse*** to select a raw data file

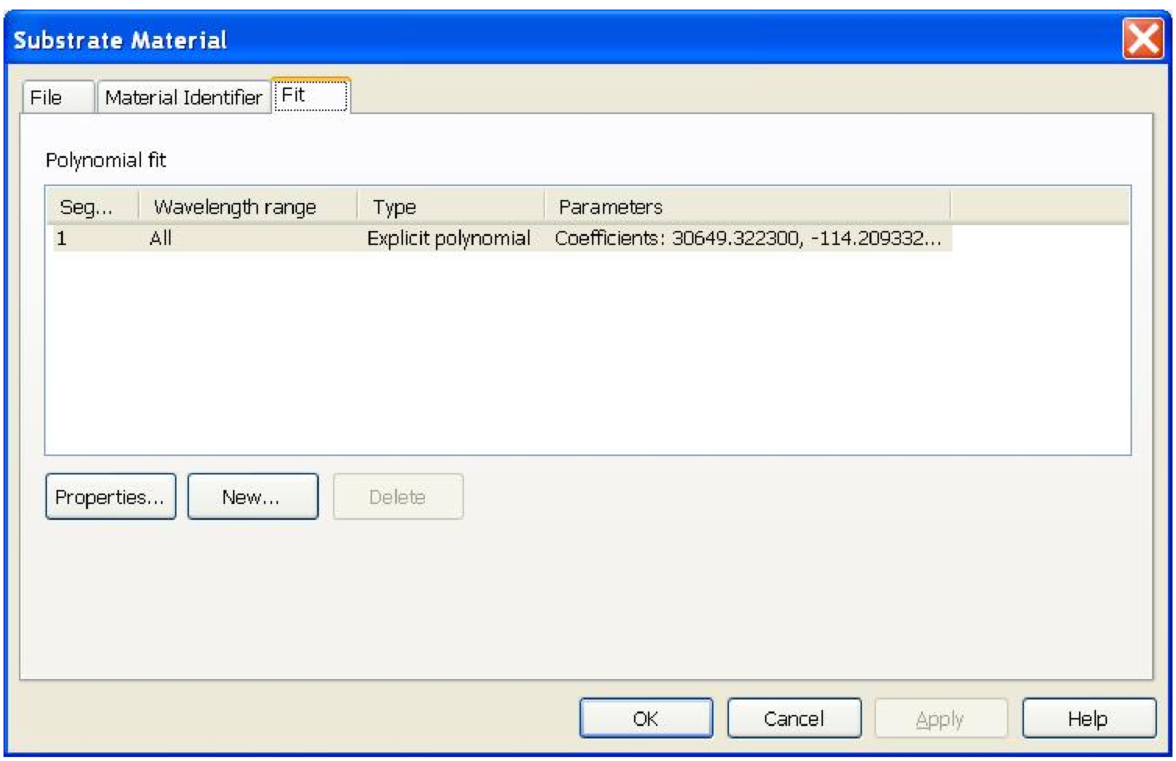
When this window is opened from the ***New*** button on the Substrate Material Setup:

Check ***Store definition in separate calibration file*** and enter a new file name into the box to create a new calibration file

Fit

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

Clicking the *Properties* button from the Substrate Materials Setup window brings up the *Fit.* Use this property to view/choose/create a new fit to the raw data, and/or change fit properties.



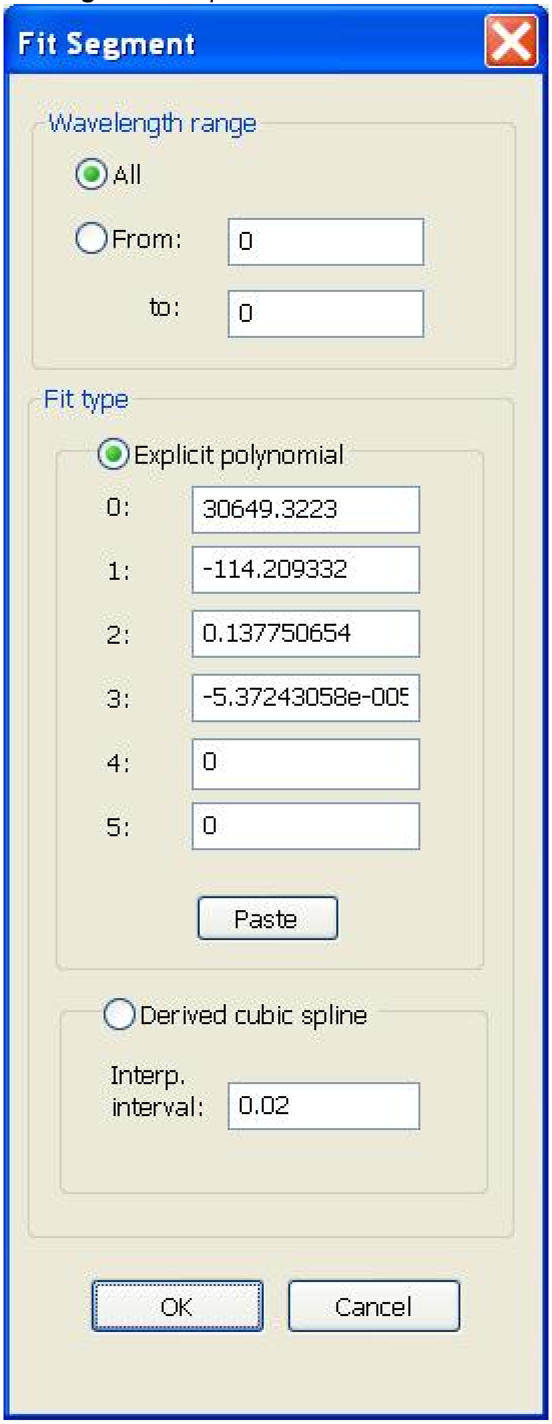
Click the ***Properties*** button to view/change the wavelength range, toggle the type between *Explicit polynomial* or *Derived cubic spline*, and specify fit parameters.

Click the ***New*** button to specify new fitting segments.

Fit Properties

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

From Fit, click the ***Properties*** or ***New*** button to bring up the ***Fit Segment*** *Properties*.



For ***Wavelength range***, choose:

All – to fit the entire range of data

From… to – to select a subset of data. The units are nanometers.

For ***Fit type***, choose:

Explicit polynomial – to fit the raw data to an explicit polynomial

Specify:

0 for the constant value in the polynomial, ***1*** for the linear constant, ***2*** for the quadratic, and so on

Click the ***Paste*** button to paste these values from the Windows® clipboard (copied from a plot that has had Poly Fit w/ extrapolation analysis done on it – use the *View Output Pane* by right-clicking the plot and then copy the coefficients from the bottom of the chart.

or

Derived cubic spline – to fit the raw data to a derived cubic spline function.

Specify:

Interp. Interval – (interpolation interval) this is the interval size for filing in connecting points of data, i.e., not simply to smooth between two regions of data but to interpolate between them

Menus Options and Toolbars

Main Controls

Navigate the program's many features by using global controls, accessing menu and view options, clicking buttons on toolbars, and setting properties.

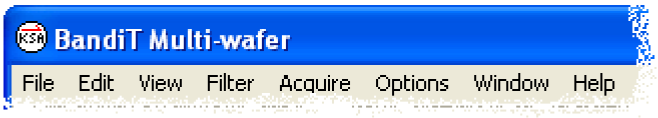
Global controls

Right-click – view and change properties and other options of any window in the program by right-clicking it.

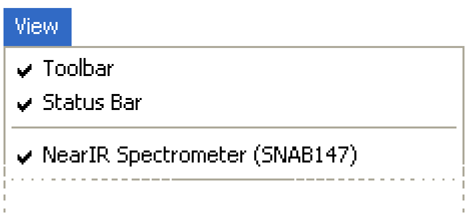
Double-click – view the properties of any image, movie, or live video window by double-clicking it.

Keyboard – use standard keyboard conventions. For example, select *File* by pressing Alt+F.

Menu options – located along the top of the application window, these options change based on which file or acquisition mode is active



View options – the most commonly used ***menu option***. Options change based on which file or acquisition mode is active.



Toolbars allow for quick accessibility to the most useful controls:

Main Toolbar – for general options, acquisition, plots and help

kdt Toolbar – controls the most frequently used features of the *.kdt file

Properties help in setting up the system, viewing images or movies, and changing how data is plotted.

General Notes:

1. Setting invalid parameters prompt error messages. Acquisition/Analysis will not proceed until valid input parameters are set. Invalid parameters include attempting to acquire more data than the computer can store.
2. Inputted parameters are retained, so the most recent used value remain even if the program is restarted.

Main Toolbar

The main toolbar is along the top of the kSA application window.

Standard: Open / Save / Cut / Copy / Paste / Print / Zoom-in / Zoom-out.

These are standard Windows® options. Notice that the *Cut* and *Paste* options will never be highlighted. Copy is available, and copies to clipboard for pasting in documents in other applications.

BandiT toolbar: Live Spectrometer / Light Source / Detector Motion / Dark Background / Reference / Phase Delay Selection / Temperature

These are the BandiT controls, the three on the left open the control windows for the Spectrometer, Light Source and Detector Motion. The four on the right open the Acquisition modes to acquire a Dark Background; to acquire a Reference; to calculate Phase Delay Selection; to acquire BandiT Temperature.

Help: Context-Specific Help / User Manual (this file)

Click the Arrow/? button and then click anywhere in the program window. Doing so will bring the user to a page in this Help File, specified by what is clicked.

Note: While this Help File is comprehensive (with a page for each dialog, menu item, analysis tool, plot property, etc.), not every button, window banner, menu item, or background is mapped to a mouse click. This is because the program relies on dynamic dialog creation. So, for example, clicking for help on any of the real-time charts brings the user to the same page in this help file, from which the user can easily navigate to the particular topic of interest.

kdt Toolbar

The *.kdt Toolbar is available by selecting a *.kdt file and then selecting the View/Status Bar from the main menu.

The toolbar gives the user control over the most often used features of *.kdt files.

From left to right –

The first six icons act just like the controls on a Digital Video Disk (DVD) player, with jump to beginning, back one frame, play, pause, forward one frame, and jump to end.

Loop – enable this button and the file will repeat from the beginning after it reaches the end. Note that this is for playback only. To loop the source for BandiT Temperature Acquisition, use the ***Loop*** checkbox at the top of the BandiT Spectra Acquire Source plot property, found by right-clicking the *.kdt window and selecting ***Properties***. Note that for multi-wafer BandiT, there is no such thing as a multi-wafer *.kdt, so it cannot be used as a source for multi-wafer BandiT temperature acquisition – this is because a separate *.kdt is created for each marker.

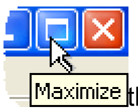
Snapshot – click this button to take a single frame from the *.kdt file – results in a single spectra data plot (for ***BandiT Spectral Data***) and a single point (for ***BandiT Computed Data***). See chart tabs below.

To change the speed of playback, right-click the *.kdt window and select ***Properties***. Then use options found in the Playback tab.

At the bottom of the window up to three tabs allow selection of the two chart types: BandiT Computed Data and BandiT Spectral Data and Spreadsheet Data. For *.bsrf files, these tabs toggle between a spreadsheet view and the single spectra.

Menu Options

Menu options change based on which window is active. The blue banner at the top of the window indicates which window is active, and the bottom right corner of the window (View/*Status bar*) shows how much a window is magnified or reduced.



the window to full-screen size in order to see the entire status bar.

When program ***opens***, the user has the following menu options:

Open a saved image or plot by using the ***File*** menu option.

Or use the ***Acquire*** menu option to access the Acquisition Modes.

Opening or acquiring an ***image*** or ***plot*** changes the menu options:

Notice that ***Analysis*** appears. The analysis available depends on whether an image or plot is selected.

For menu options that do not change based on Acquisition Mode (available via the ***Acquire*** menu) there are the standard Windows® options:

File – Open / Close / Save / Save As / Export / Batch Export / Print / Print Preview / Print Setup / Exit

This menu option also shows the last four files that the user accessed.

Edit – Copy / Properties (Undo / Cut / Paste are not available)

Window – to toggle between active windows and arrange windows on the screen

Help – user manual (this file), registration, contact and support information, and version

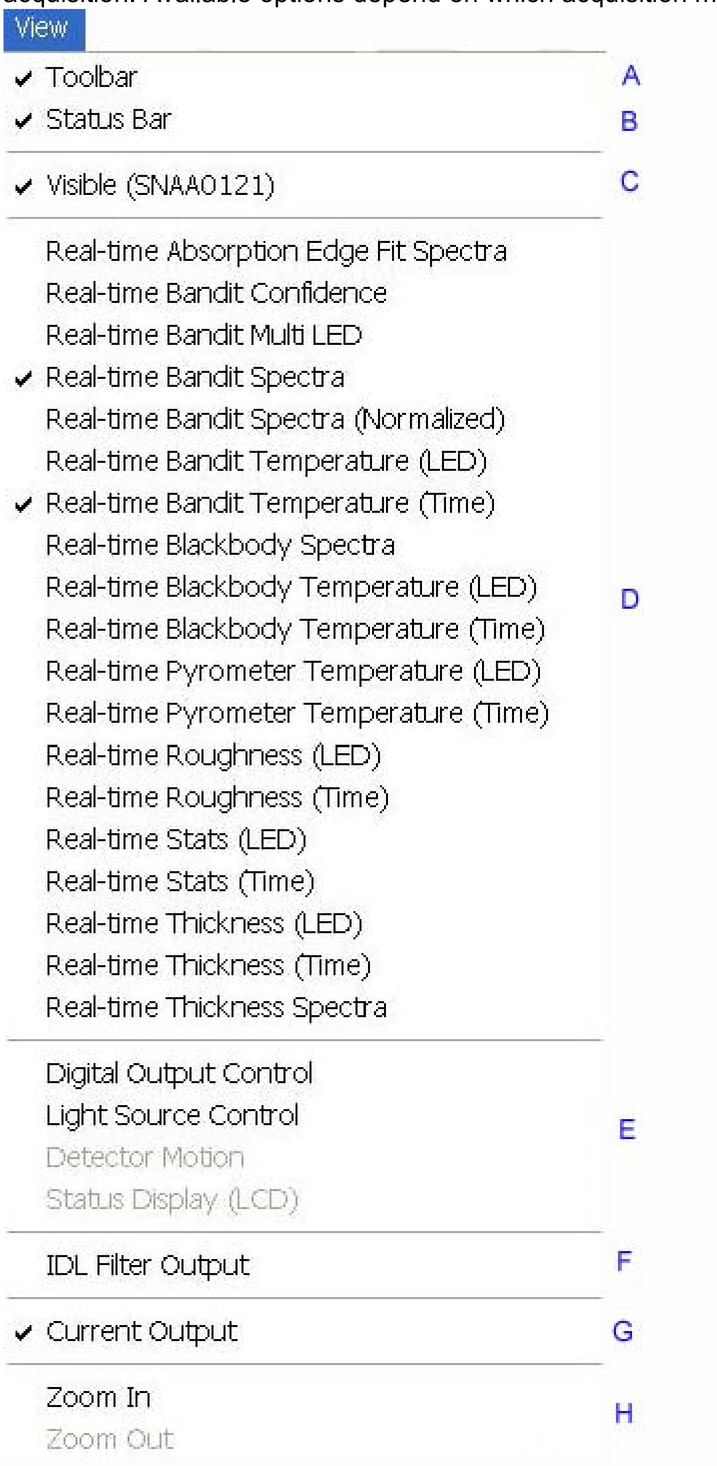
The View menu item is used to control what is open on the screen during acquisition. Real Time Charts are opened from here.

The Options menu item is for options in the program itself.

The ***Filter*** menu item is always present, however functionality depends on which window is active.

View Options

View options allow the user to see various features of the kSA software and real-time charts during acquisition. Available options depend on which acquisition mode is selected.



A. Show/hide toolbars; depends on which window is active.

B. Show/hide the bottom of a window (called the *Status Bar*) when available. If no window is selected, the program's status bar is toggled.

C. Show/hide the Spectrometer. There will be as many spectrometers as are hooked up and active in the system.

D. Show/hide available Real-Time Charts.

E. Show/hide available controls:Digital Output Control, Light Source Control and Detector Motion. Note that *Status Display (LCD)* will never be available to the user.

F. Show/hide IDL Filter Output.

G. Show/hide Current Output

H. *Magnify or Reduce* the active window. Clicking the magnifying glass icons available on the the Main Toolbar does the same thing.

Options

BandiT has several kinds of options available from the Options menu:

General Options – Colors, General, Images and Video, Logging, BandiT Settings.

Input/Output Devices – analog/digital options and how the software will interact with installed PCI boards

Substrate Materials Setup – for inputting/viewing file, material identifier, and fit for substrate materials used in BandiT Temperature acquisition.

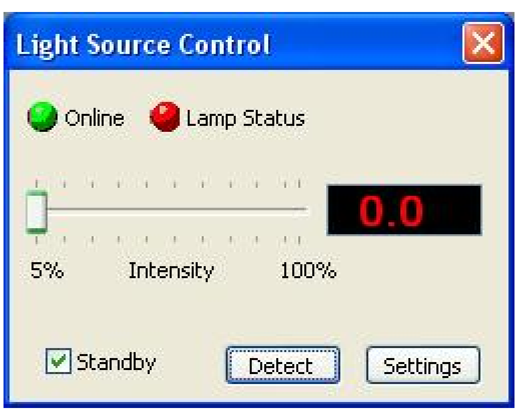
Logging - sets the level of logging that will be used, can be set at High, Medium or Low, see Logging for more information.

Save Settings - saves the current program settings.

Load Settings - loads previously saved program settings

Light Source Control

The lamp control is found by selecting View/Light Source Control from the main menu. It is used to control the lamp that provides the light that is, in turn, reflected off the sample and collected by BandiT's optics.



If both the ***Online*** and ***Lamp Status*** indicators are green, then –

use the slider or click in the box and type in a number to vary the ***Intensity*** of the light

check the ***Standby*** button to keep the filament hot but emitting less than 5% intensity – this is useful for Acquiring Dark Background as well as preserving lamp life.

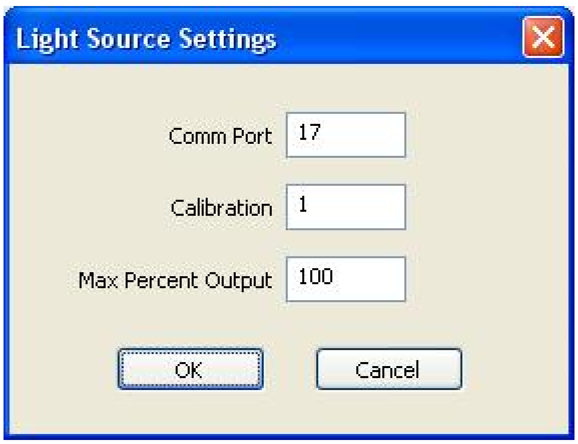
The rest of this topic addresses the *Online* and *Lamp Status* indicators.

The indicator ***Online*** turns green to indicate that the software is communicating with the lamp controller.

After ***Online*** turns green, the indicator ***Lamp Status*** turns green to indicate that the lamp is functioning correctly. Of course, if it remains red then the lamp may need a new bulb.

If both indicators are red, click the ***Detect*** button and the software will automatically determine the Comm Port for communications (see ***Lamp Settings*** below). If the ***Online*** indicator is still red, then please refer to the document kSA BandiT Install and Getting Started Guide supplied with the BandiT system for details on wiring and testing the system.

Clicking the ***Settings*** button brings up this dialog:



Specify:

Comm Port – the communications port on the computer to which the lamp controller is connected

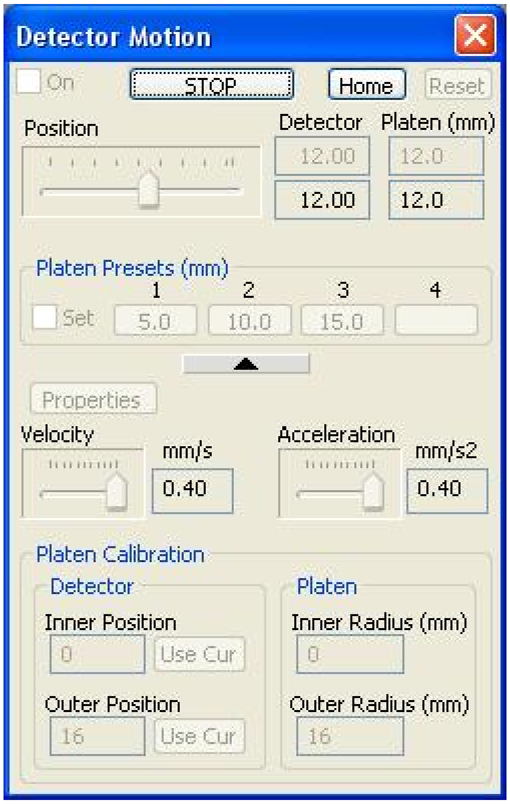
Calibration – the factory-configured value that is based on the lamp controller. In general, this will not need to be changed by the user.

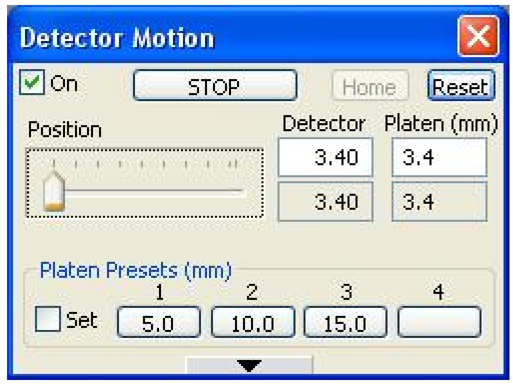
Max Percent Output - the maximum output as a percentage of total lamp output

Detector Motion Control

Detector Motion is opened by using the  icon on the toolbar or by using the View menu.

This is used to control the motorized Tilt and Rotate Detector which can scan across the platen and is required during Full Platen Temperature Acquisition (a BandiT Multi-Wafer Acquisition mode).



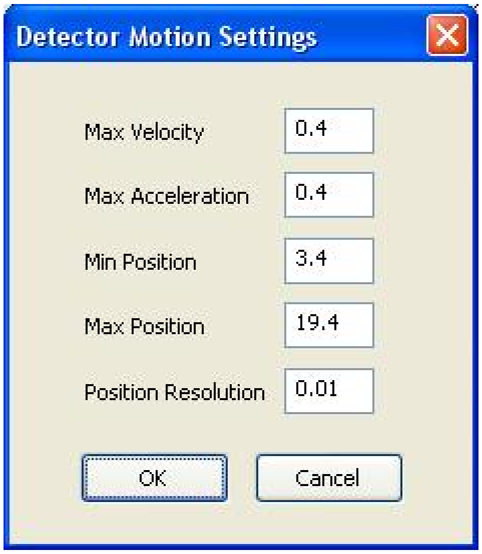


When first opened the Detector Motion dialog opens in the ***Reset*** state as shown on the left.
Click ***Home*** to turn the Detector Motion ***On*** and activate the rest of the controls.
The arrow button in the centre can be used to show/hide the platen properties and calibration part of the screen as shown in the right hand image.

Position - With the Detector Motion On set the ***Position***, use the slider to select a radius for the detector to move to, or type the require radius value into the ***Detector*** box. The motor will then move to drive the Tilt and Rotate Detector to the specified radius. It can be stopped at any time by clicking ***STOP***.

Platen Presets - The Platen Presets are used so that the detector can be moved to a specified position either by clicking the Preset button on this dialog box, or automatically at the end of the Full Platen Temperature scan. To set the Preset buttons, drive the detector to the required position, check the ***Set*** box and then click the Preset button that you want to set. Up to four different positions can be Preset. Once set these cannot be cleared but they can be set to new positions.

Clicking the ***Properties*** button brings up the dialog box below. The ***Maximum Velocity***, ***Acceleration*** and Maximum and Minimum ***Positions***, and the ***Position Resolution*** for the Servo motor that is installed in your Detector will be set automatically when the Servo board is initialized, but they can be changed here if required.



Velocity and ***Acceleration*** can be selected using the sliders on the Detector Motion dialog up to the maximum velocity specified in the Detector Motion Settings.

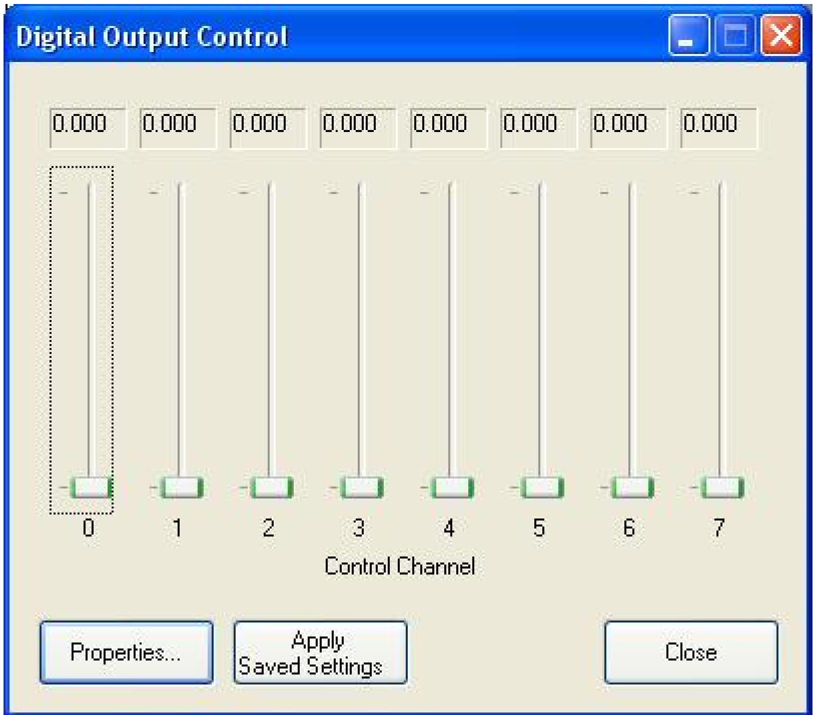
Platen Calibration - use this to calibrate the Detector positions with the actual Platen Radius. The number of positions available on the detector will depend on the model in use. If it is a Goniometer model then 0 will be in the centre of the movement and positions will be defined +/- this, for example from -30 to +30 positions. The Platen dimensions are in mm. In the Full Platen Temperature Acquisition mode the scan parameters are set in mm, for the actual platen radius not in detector positions.

Specify the ***Inner*** and ***Outer Radius*** of the Platen in mm. Specify the ***Inner*** and ***Outer Positions*** of the Detector that correspond to the Platen radius.

The ***Use Cur*** button can be used to take the Current Position of the Detector.

Digital Output Control

The ***Digital Output Control*** is found by selecting View/Digital Output Control from the main menu. This allows control of the Digital Outputs from the BandiT system.



Click ***Properties*** to bring up the ***Saved Settings*** menu where each channel can be set and the settings saved.

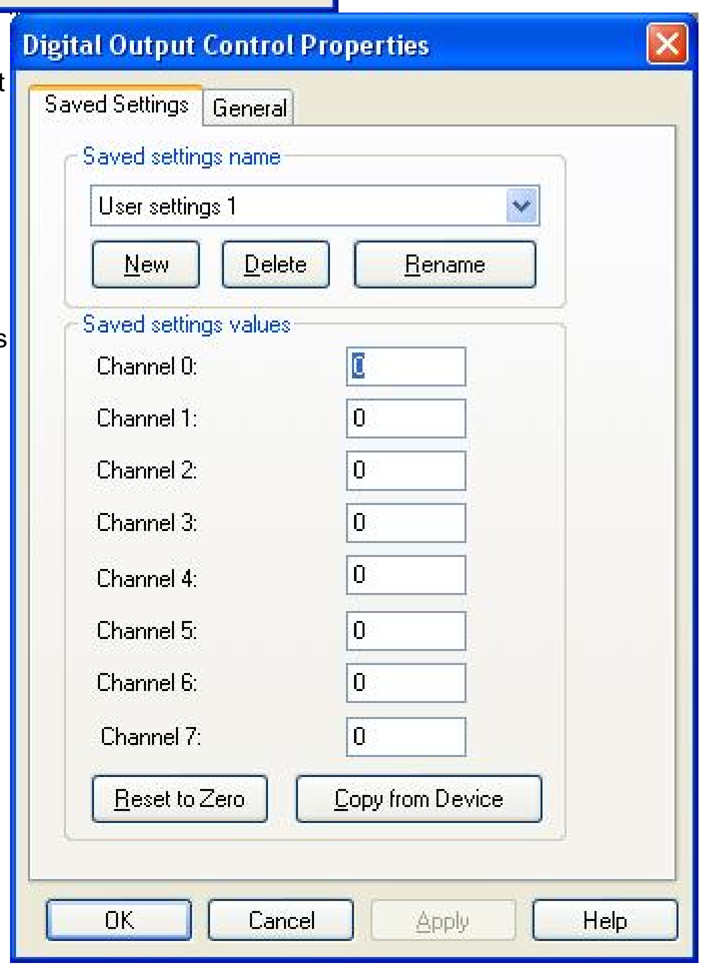
Saved settings name - select a set of saved settings from the drop down list or click :

> ***New*** - to create a new set with a new name.
>
> ***Delete*** - to delete a set of saved settings
>
> ***Rename*** - to rename the current set of settings

Saved settings values - values can be entered manually for each channel or by clicking:

> ***Reset to Zero*** - to reset all values to zero
>
> ***Copy from Device*** - to copy the current settings from the output device

Click the ***General*** tab to specify the ***Device response time*** as shown below:



The set of ***Saved Settings*** that has been selected can be Applied by click ***Apply Saved Settings.***

Types of Properties

There are three main kinds of properties. Each can be accessed by right-clicking the window of interest and selecting ***Properties***.

Spectrometer Properties – to view/change how the spectrometer acquires data

Image Properties – add comments and view/change other scan mode image properties – in BandiT, the only images are those created by generating a pyrometric scan image for growth-rate analysis. Please see the help topic Pyrometric Oscillations, an advanced acquisition option, or the guide How-To Measure Growth Rate.

Plot Properties – to view/change how the data is plotted

Quick Start and How To Guides

Quick Start

Please see the document titled kSA BandiT Install and Getting Started Guide to set up the system. That guide includes step-by-step instructions for the following operations.

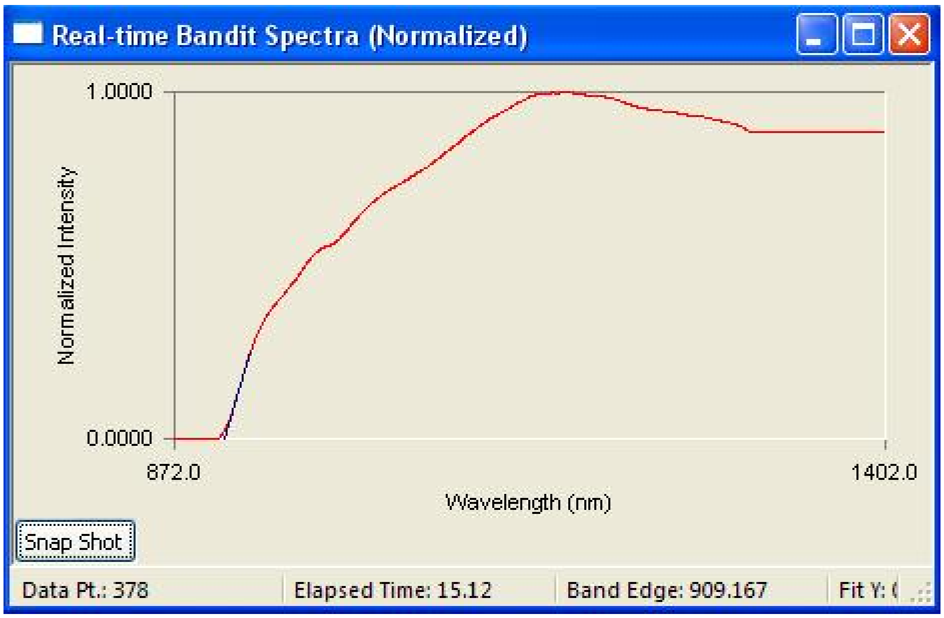
1. Install Software on the computer that will control the system
2. Install Hardware using the Schematic diagrams to help with connections
    1. Standard Light Source
    2. Tilt and Rotate Detector or CAR Port Detector
    3. BandiT Rack
3. Power on the BandiT rack and wait for devices to install
4. Configure the Input/Output Devices
5. Acquire a Dark Background - without acquiring a background, the kSA BandiT system will not operate properly.
6. Configure the Light Source Controller
7. Align the Light Source
8. Align the Spectrometer
9. Align Tilt and Rotate or CAR Port Detector

The system is now fully set up and should be checked to ensure that it is configured correctly as follows:

- From the Acquire menu, select BandiT Temperature.
- That brings up the BandiT Temperature Acquisition Window:
- Ensure the Spectra source has defaulted to your type of spectrometer.

- Select the Substrate Material that you are using, and then click the Select button to choose the proper calibration file.
- Click the ***Continuous (no data saved)*** button.
- Before clicking Start, click the ***Config*** button.
- Within the Configuration Options, choose the Automatic Intensity Control tab.
- Click the ***Enable Auto Intensity Control*** and use the defaulted values.
- Then click OK at the bottom of the window and the Configuration Options dialog will close.
- Under the View menu, select Real-time BandiT Spectra (Normalized).
- Then click the Start button in the BandiT Temperature Acquisition window.

In the ***Real-time Bandit Spectra (Normalized)*** window, a shape similar to this below should appear, with a "Band Edge" extending up about 20% from the bottom, as pictured below.



Now the system is all set up and ready to go because BandiT is acquiring a "Band Edge."

(Note: users often keep many Real-Time Charts open (including Real-time BandiT Temperature) during acquisition. Note also that these measurements have been performed without substrate rotation. Further information on the role of rotation can be found at How-To Trigger Temperature Measurement .)

If you encounter any problems in completing these steps, please contact us.

Next, learn how to perform the most commonly-used routines in the kSA BandiT by reading the How-To Guides.

How-To Guides

There are several How-To Guides that cover the procedures for executing BandiT's most commonly-used routines.

How-To Acquire a Dark Background - to take the dark background reading of the Spectrometer

How-To Measure Temperature – this is the most common use of kSA BandiT

How-To Capture an Individual Spectrum – to acquire a single spectrum for analysis or for saving for reference

How-To Capture Continuous Spectra – to acquire spectra continuously for a specified interval

How-To Measure Film Thickness - to acquire the thickness of films

How-To Measure Growth Rate – a post-acquisition analysis procedure for determining the rate of growth

How-To Acquire a Dark Background

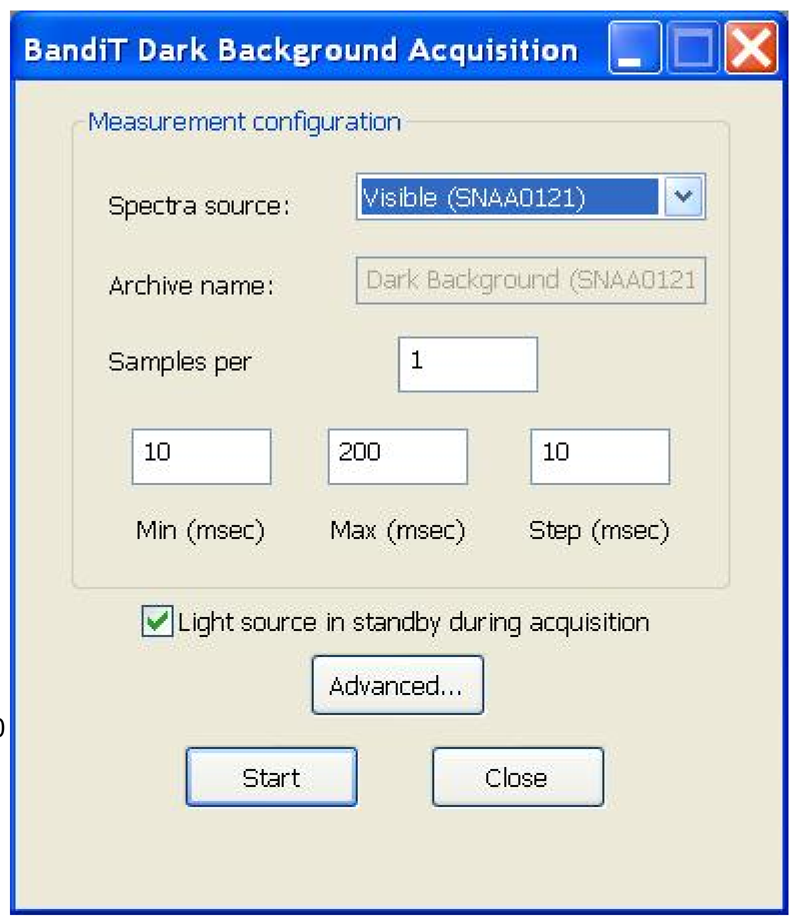
The first time the BandiT software is run it should prompt you to acquire a dark background. If your computer was supplied by k-Space, this may already have been done, but it will need to be done again at regular intervals. Some users do this before each temperature acquisition, or at least once a day.

Taking a dark background at the various spectrometer integration times results in clean, noise-free spectra for analysis because the dark backgrounds will be subtracted automatically from the live spectra. It is important to generate a dark background that includes all the integration times that you will want to use for BandiT temperature acquisition as only those included in the dark background will be possible for acquisition.

It is important that all light is eliminated from the chamber when the Dark Background is acquired. Remove the fiber out of the SMA Fiber Input and cover the SMA fitting or cover the detector so no light can get into the spectrometer. Make sure that the Light Source is not switched on or is in standby mode and that the substrate heater is turned off as this may contribute some radiation to the chamber.

Select BandiT Dark Background from the ***Acquire*** menu or by using the

icon on the toolbar.



Specify:

Spectra source – this is the spectrometer. If more than one spectrometer is set up on the system, choose the one that will be used for temperature acquisition.

Archive Name - The archive is named automatically by the software and is shown here for reference.

Samples per - Samples per datapoint. Typically this is set at 1.

Min (msec) -- the minimum desired integration time (in milliseconds) for the spectrometer. Typically this is 10 msec.

Max (msec) – the maximum desired integration time (in milliseconds) for the spectrometer. Typically this is 200 msec.

Step (msec) – the integration time step size for the spectrometer, in milliseconds. A step size of 10 msec will yield available spectrometer integration times in intervals of 10 msec.

Make sure the check box ***Light source in standby during acquisition*** is checked.

Typically, the values shown above yield plenty of range and resolution for proper temperature measurement. These will result in spectrometer integration times of 10, 20, 30, …, 190, 200 (msec) being available for temperature acquisition.

Click ***Start*** to run the acquisition.

When acquisition is complete, the Status Bar at the bottom of the kSA BandiT application window will read "Acquisition complete." Click the Close button on the acquisition window

Single Wafer Temperature

How-To Measure Temperature

The most common use of BandiT is measuring temperature. Note that these guides are written for single-wafer BandiT.

Choose which procedure depending on material and spectrometer, or measure via pyrometry:

BandiT NearIR – for narrow band-gap substrates such as GaAs, InP, and Si using kSA BandiT's NearIR spectrometer

BandiT Visible – for wide band-gap substrates such as SiC or depositing GaN on sapphire using kSA BandiT's Visible spectrometer

BandiT Pyrometry – for simulating a single wavelength conventional pyrometer (used without a light source), by converting the black-body radiative intensity from the sample into a temperature reading. Note that such intensity is usually only significant in the ***Near IR*** wavelength range, so the corresponding spectrometer must be used.

BandiT Black-Body Pyrometry - for making a wide wavelength-range pyrometric measurement, by fitting the radiated black-body intensity distribution to the temperature-dependent Planck equation. Again, this is only useful with a Near IR spectrometer, and does not need a light source.

For externally triggered temperature acquisition please refer to How-To Trigger Temperature Measurement

BandiT NearIR

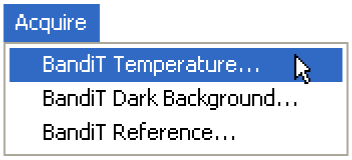
This is one of four ways of How to measure temperature using BandiT. This procedure outlines how to measure temperature using kSA BandiT's NearIR spectrometer for substrates GaAs, InP, and Si.

1. Acquire a Dark Background

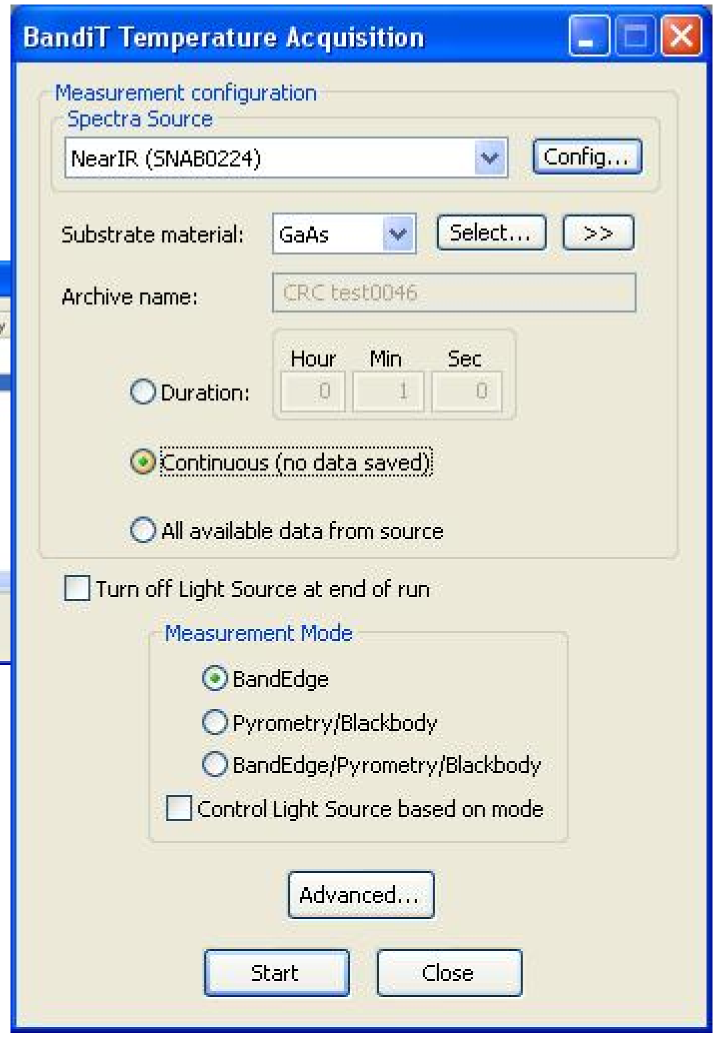
The first step in any BandiT temperature acquisition is always to acquire a BandiT Dark Background. While the software does prompt the user to acquire a dark background, if that has not yet been done, then please take a look at the BandiT Dark Background topic in this help manual.

2. Select Substrate Material

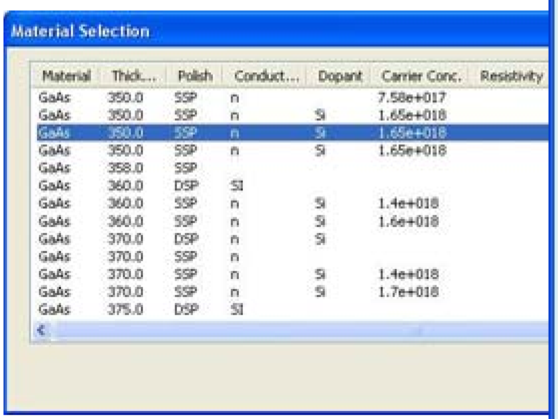
After acquiring a dark background, select ***BandiT Temperature*** from the Acquire menu.



That brings up the BandiT Temperature Acquisition window.



Specify the ***Substrate material*** (typically GaAs or InP) and use the ***Select*** button to open the table of materials, selecting the one that best matches your substrate.



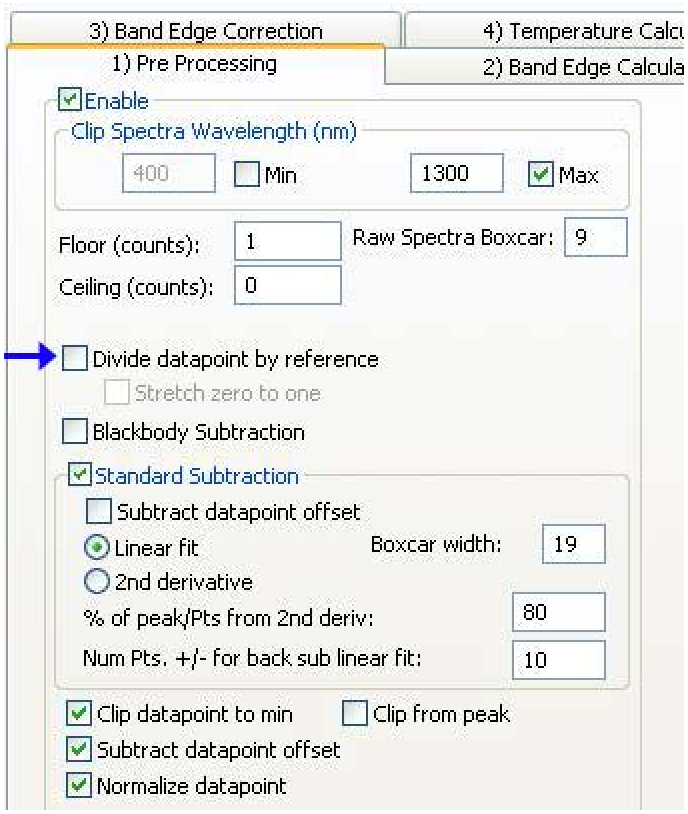
The details of the material selected can be seen in the Acquisition window by using the >> button.

It may be the case that the Material Selection Library does not contain the exact specification of the substrate material being used. Generally, the closest match will produce perfectly acceptable results, but if higher precision is required, it is possible to apply small correction terms using either 3) Band Edge Correction or 4) Temperature Calculation (see How-To Apply Corrections). A final option is that k-Space can provide a calibration service for wafers that are not already listed in the Library.

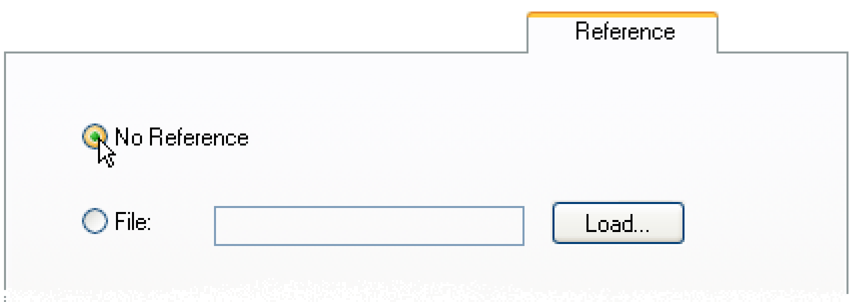
3. Set Configuration Options

Next click the ***Config*** button to bring up the ***Configuration Options***. This is where all the parameters for controlling the temperature acquisition process are set including the Band Edge settings for pre-processing and calculating the Band Edge, Pyrometry settings, Thickness and Roughness. Check that are set to your requirements.

Select the Band Edge tab to open the Band Edge configuration options and then load a Recipe for the substrate if desired. Then select 1) Pre-Processing. Please ensure the checkbox ***Divide datapoint by reference*** is not ticked



under the Reference tab, please ensure that *No Reference* is selected.



Click ***OK*** to close the Configuration Options.

4. Check Advanced Acquisition Options

There are many advanced acquisition options available for specifying parameters of the acquisition. Click the ***Advanced*** button to specify such parameters as BandiT I/O Settings, Document Generation and Triggers.

Recommendations: If choosing not to run in continuous mode and have selected a ***Duration*** longer than five minutes, it is recommended that you select ***Minimum data output (default)*** in the BandiT I/O Settings tab. (Note that such data cannot subsequently be re-analysed off-line, which requires full data storage.) Storing raw and fully processed BandiT files mean the files can become so large that they cannot be reopened without increasing the amount of RAM in the system. Also, for any duration longer than five minutes, it is recommended that you select ***Store Incrementally*** in the Document Generation tab. Checking this option yields an occasional, very small disruption in data acquisition rather than the larger disruptions that can occur when the system has filled its RAM and must write it all to disk before continuing data collection. A further method of reducing the amount of data stored is to record only a fraction (say 1 in 10) of the available data points. This is achieved by right-clicking on the spectrometer window, selecting ***Properties*** and opening the Advanced tab. Enter an integer in the 'Skip frames' box (e.g. 9 for a 1 in 10 reduction) and close the window.

At this point, most users simply need to click the ***Continuous (no data saved)*** radio button which does as it says and does not save any data.

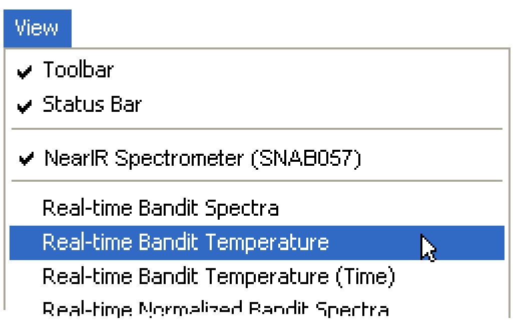
The ***Duration*** radio button sets the maximum amount of time for which the temperature reading can be taken, and data stored; however, the acquisition can still be stopped at any earlier time. These data files can become so enormous that the system may not be able to re-open them - see Recommendations above.

The ***All available data from source*** is enabled when the ***Spectra source*** is a previously saved *.kdt file that is open on the desktop. These *.kdt files are created by acquiring for a specific ***Duration***. Find more on this topic in the How-To Capture Continuous Spectra topic.

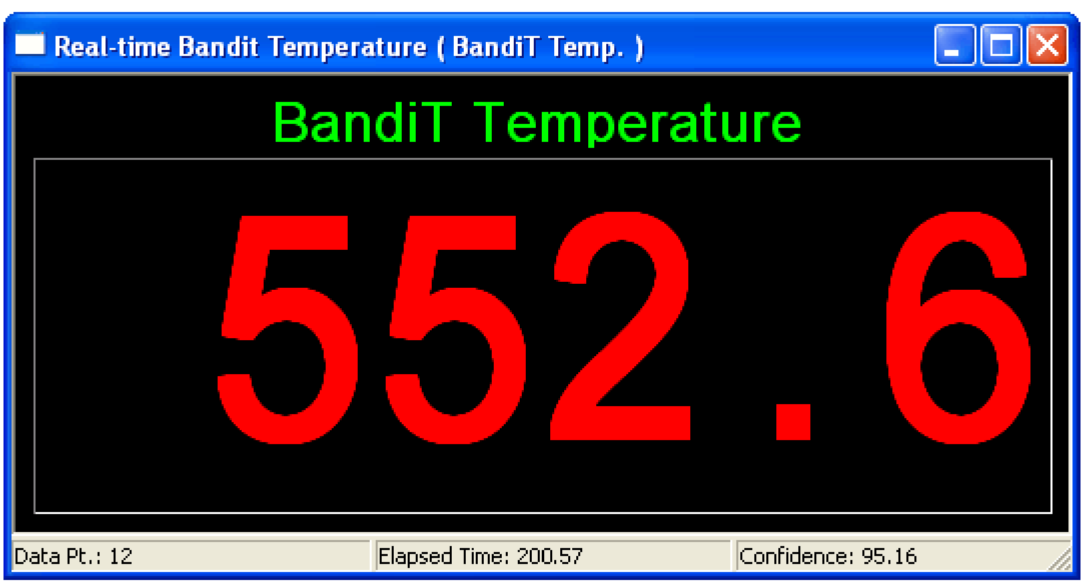
Learn more about the various options in the BandiT Temperature Acquisition topic.

5. Open Real Time Charts and Start Acquisition

The View menu lists the data which can be shown in real time. Click to select the required displays, for example ***Real-Time Bandit Temperature (LED)***.



That brings up the following window with the temperature given in degrees Celsius (°C).



Click the Start button to start the Temperature Acquisition. During acquisition, the ***Start*** button becomes a ***Pause*** button. Pausing acquisition causes the same button to become a ***Resume*** button.

The Status bar (View/Status bar) at the bottom of the window displays the data point, elapsed time (in seconds), and confidence in the fit.

BandiT Visible

This is one of four ways of how to measure temperature using BandiT. This procedure outlines how to measure temperature using kSA BandiT's Visible spectrometer for SiC or for depositing GaN on sapphire.

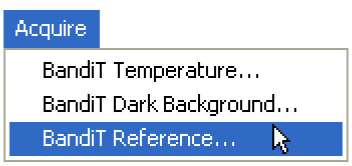
1. Acquire a Dark Background

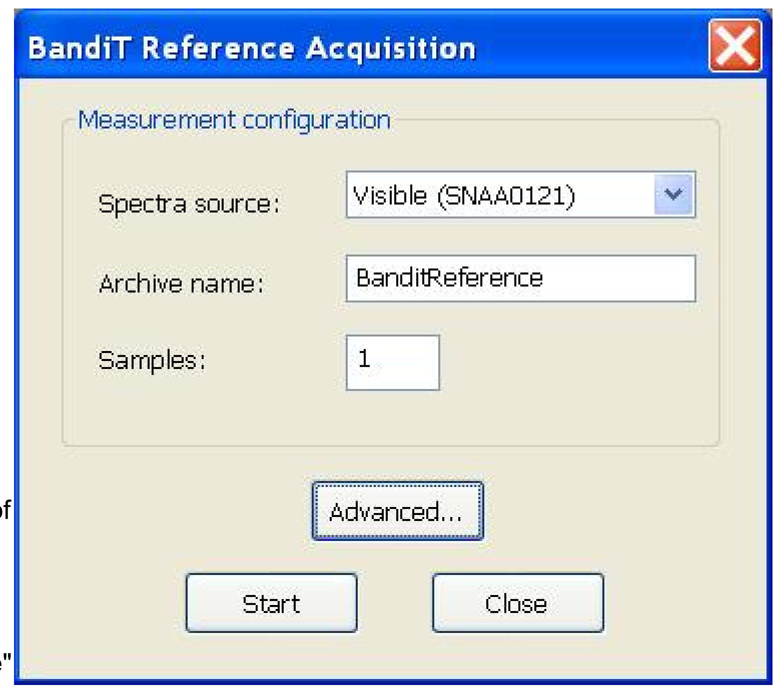
The first step in any BandiT temperature acquisition is always to acquire a BandiT Dark Background. While the software does prompt the user to acquire a dark background, if that has not yet been done, then please take a look at the BandiT Dark Background topic in this help manual.

2. Acquire a BandiT Reference

After acquiring a dark background, select ***BandiT Reference*** from the ***Acquire*** menu or click the 

icon on the toolbar. This acquisition mode is used to acquire a spectrum of the lamp intensity so that this can be used to normalize the spectra acquired during the BandiT temperature acquisition. As the aim is to acquire information about the lamp intensity this should be done either without a wafer present or at low temperature.





This brings up the BandiT Reference Acquisition window as shown on the right.

The ***Spectra source*** should be a visible spectrometer as there is no need to take a reference for NearIR acquisition.

Specify the ***Archive name*** - the format of this is determined by the Document Generation tab in the ***Advanced Acquisition Options*** (found by clicking the ***Advanced*** button). The document name may be set as "Manual Run Name" in the Document Generation in which case the Archive name box will be white and will allow you to enter the name manually as is shown in the example on the right. Alternatively if the Archive name box is grey then the name will have been set automatically in Document Generation. To change this click ***Advanced*** and select Document Generation.

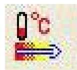
Also in the ***Advanced*** window, click the General tab and specify the number of samples to collect (one is usually enough). Then select Delay to ensure no delay is set (use the drop-down ***Delay type*** menu to check no delay is set for any of the three types).

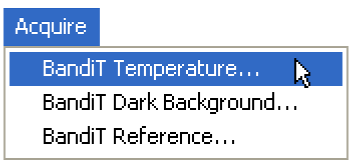
After specifying the parameters, click ***Start.***

When acquisition is complete, the reference file opens (e.g., "BanditReference.bsrf" based on the name given above) and should be saved (if not already automatically saved via the Document Generation tab selections).

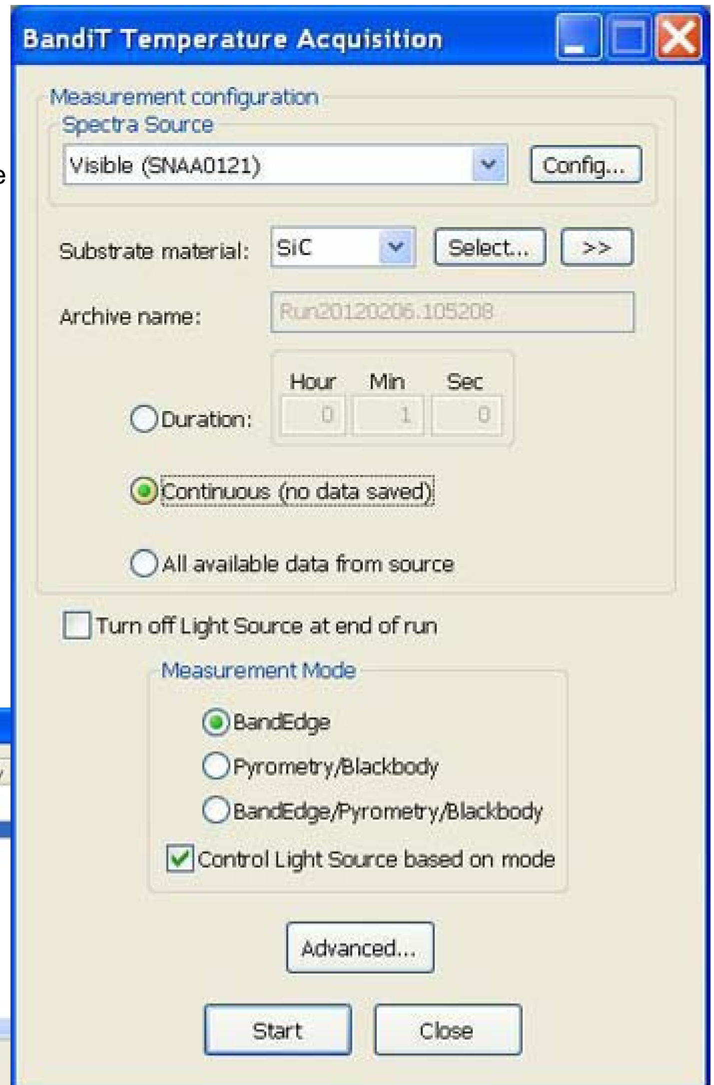
Close the ***BandiT Reference Acquisition*** window.

3. Select Substrate Material

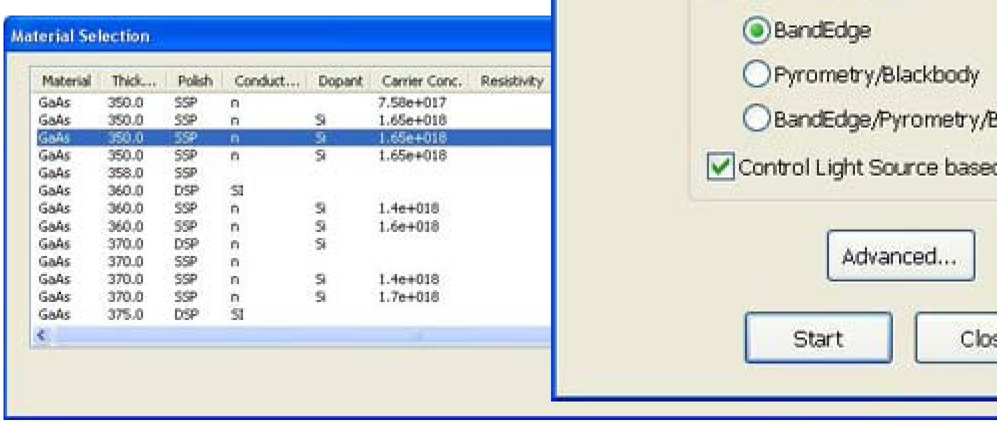
Select ***BandiT Temperature*** from the ***Acquire*** menu or click the  icon on the toolbar.



This brings up the BandiT Temperature Acquisition window as shown on the right.



Specify the ***Substrate material*** (SiC or GaN, typically) and use the ***Select*** button to open the table of materials, selecting the one that best matches your substrate.



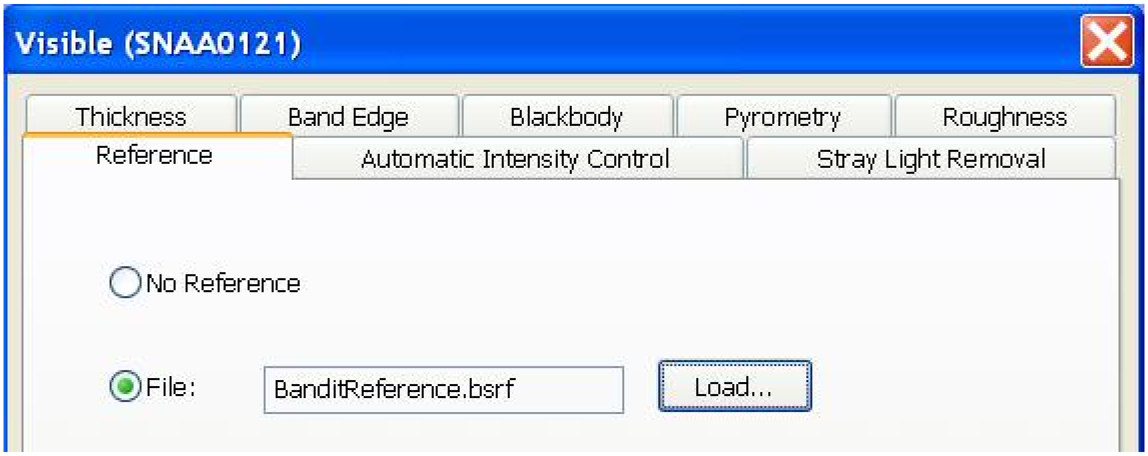
The details of the material selected can be seen in the Acquisition window by using the >> button.

It may be the case that the Library does not contain the exact specification of the substrate material being used. Generally, the closest match will produce perfectly acceptable results, but if higher precision is required, it is possible to apply small correction terms using either 3) Band Edge Correction or 4) Temperature Correction (see How-To Apply Corrections). A final option is that k-Space can provide a calibration service for wafers that are not already listed in the Library.

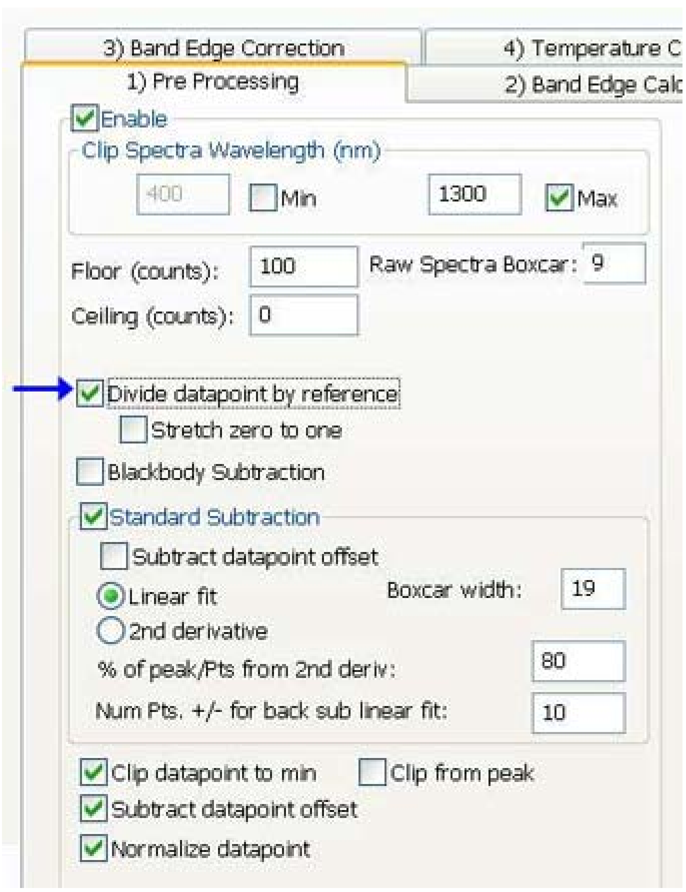
4. Set Configuration Options

Next click the ***Config*** button to bring up the Configuration Options***.*** This is where all the parameters for controlling the temperature acquisition process are set including the Band Edge settings for pre-processing and calculating the Band Edge, Pyrometry settings, Thickness and Roughness. Check that are set to your requirements.

Select the Reference tab and select the reference just taken:



Select the ***Band Edge*** tab to open the Band Edge configuration options and then select ***1) Pre-Processing***. Ensure that the check box ***Divide datapoint by reference*** is ticked.



Then click ***OK*** to close this window and return to the ***BandiT Temperature Acquisition*** window.

5. Check Advanced Acquisition Options

There are many advanced acquisition options available for specifying parameters of the acquisition. Click the ***Advanced*** button to specify such parameters as BandiT I/O Settings, Automatic Intensity Control and Triggers.

> ***Recommendations***: If choosing not to run in continuous mode and have selected a ***Duration*** longer than five minutes, it is recommended that you select ***Minimum data output (default)*** in the BandiT I/O Settings tab. (Note that such data cannot subsequently be re-analysed off-line, which requires full data storage.) Storing raw and fully processed BandiT files mean the files can become so large that they cannot be reopened without increasing the amount of RAM in the system. Also, for any duration longer than five minutes, it is recommended that you select ***Store Incrementally*** in the Document Generation tab. Checking this option yields an occasional, very small disruption in data acquisition rather than the larger disruptions that can occur when the system has filled its RAM and must write it all to disk before continuing data collection. A further method of reducing the amount of data stored is to record only a fraction (say 1 in 10) of the available data points. This is achieved by right-clicking on the spectrometer window, selecting ***Properties*** and opening the Advanced tab. Enter an integer in the 'Skip frames' box (e.g. 9 for a 1 in 10 reduction) and close the window.

At this point you need to select a data acquisition mode, most users simply need to click the ***Continuous (no data saved)*** radio button, which does as it says and displays the data as it is collected but does not save it.

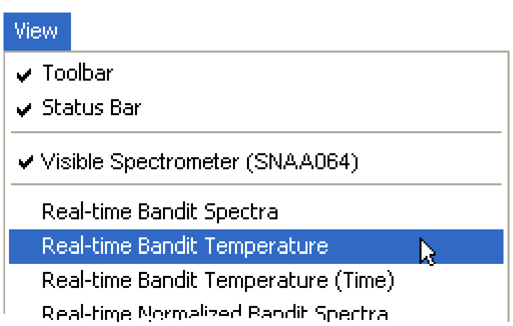
The ***Duration*** radio button sets the maximum amount of time for which the temperature reading can be taken, and data stored; however, the acquisition can still be stopped at any earlier time. These data files can become so enormous that the system may not be able to re-open them - see Recommendations above.

The ***All available data from source*** is enabled when the ***Spectra source*** is a previously saved *.kdt file that is open on the desktop. These *.kdt files are created by acquiring for a specific ***Duration.*** Find more on this topic in the How-To Capture Continuous Spectra topic.

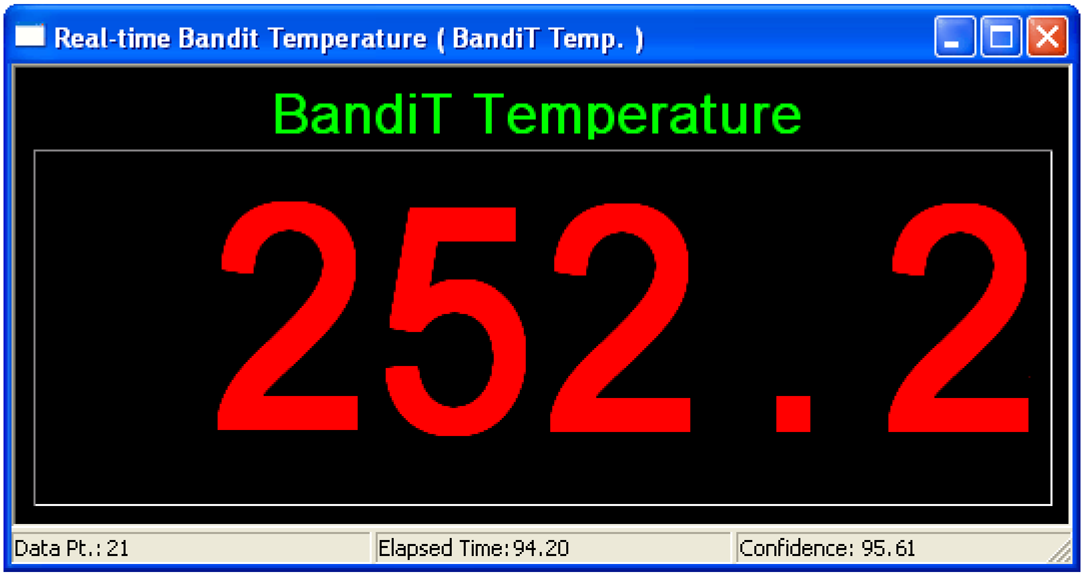
Learn more about the various Advanced Acquisition Options in the BandiT Temperature Acquisition topic.

6. Open Real Time Charts and Start Acquisition

The View menu lists the data which can be shown in real time. Click to select the required displays, for example ***Real-Time Bandit Temperature (LED)*** or ***Real-time Bandit Spectra***.



That brings up the following window with the temperature given in degrees Celsius (°C).



Click the ***Start*** button to start the Temperature Acquisition. During acquisition, the ***Start*** button becomes a ***Pause*** button. Pausing acquisition causes the same button to become a ***Resume*** button.

The Status bar (View/Status bar) at the bottom of the window displays the data point, elapsed time (in seconds), and confidence in the fit.

BandiT Black-Body Pyrometry

This is one of four ways of how to measure temperature using BandiT. This procedure outlines how to measure temperature by performing non-linear least squares fitting of a blackbody thermal radiation curve to spectra in real time. This allows a measurement of the temperature which is independent of the band edge method.

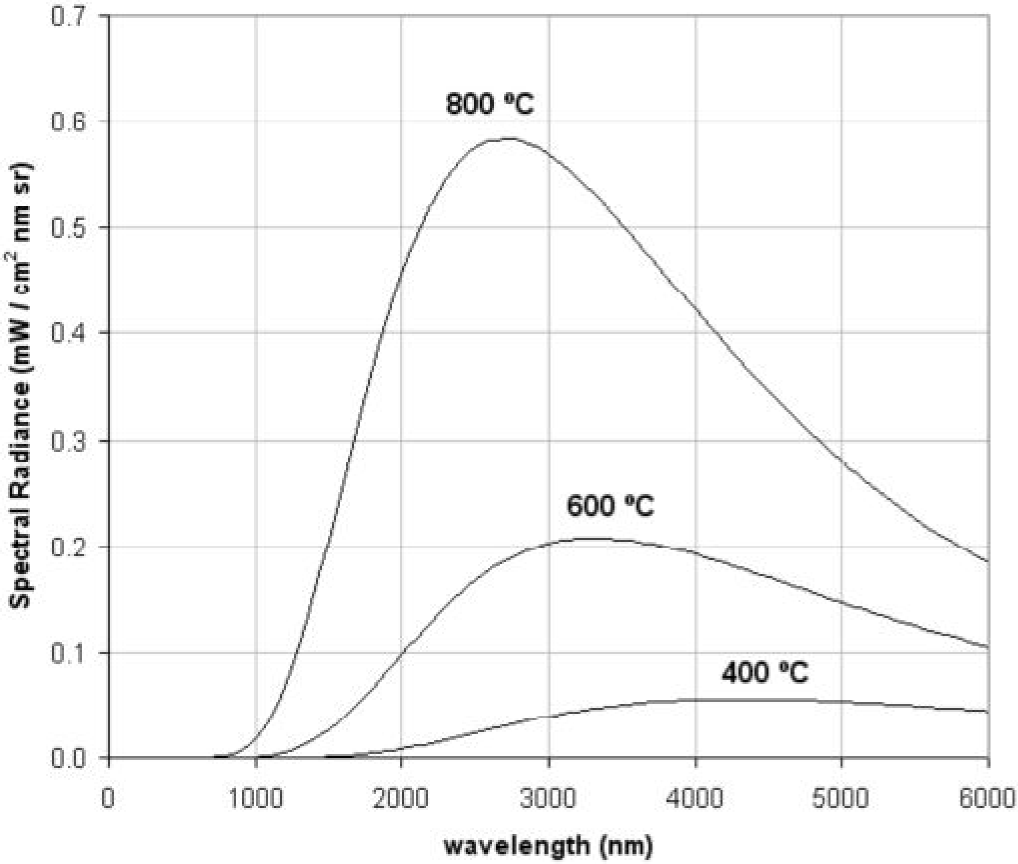
Generally, this technique is inferior to using a band edge thermometry. However, the band-edge technique often fails when depositing a very absorbing layer, so the Pyrometry technique (such as the Black-Body Pyrometry described here or the conventional Pyrometry method) is available for such situations. The Blackbody technique allows measurement over a wide wavelength while conventional Pyrometry is restricted to a narrow wavelength.

Important note: do not use a light source when using this technique to measure temperature. Because this technique is signal-level dependent, any light source will add potentially variable signal and so affect the temperature conversion, which will lead to an improper temperature reading.

This guide assumes the system is calibrated to read the correct temperature using transmission mode (without a light source) using one of BandiT's spectrometers. See How-To Measure Temperature.

1. Technical background

Spectral radiance is the fundamental measure of the amount of light that can reach a detector from a diffuse source. It is defined as the emitted power per unit area of emitting surface, per unit solid angle, per unit wavelength. The image below is a plot of the spectral radiance of a blackbody for several different temperatures commonly used in semiconductor processing. Note that the peak shifts to shorter wavelengths as the temperature increases.



This behavior can be expressed mathematically in the form of Wien's displacement law:

$$\lambda_{\max} = \frac{b}{T}$$

Here T is the temperature (in Kelvin), and b is a constant which equals $\frac{hc}{4.96511\, k_B} \approx$ 2.8978×106 nm-K. Note that in the temperature range of interest for typical semiconductor processing, the peak lies in the mid-IR portion of the spectrum. Thus, for the most part, BandiT spectral data comes from the short-wavelength exponential tail below the peak. This often poses a challenge, as the signal intensity is relatively weak in this region.

According to Planck's law, the spectral radiance I (λ, T) of a blackbody at a given temperature is given by:

$$I(\lambda, T) = \varepsilon T.F.\, \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda k_B T} - 1} + C$$

In fitting a function of the form described in Planck's law to spectra there are four adjustable parameters: the material's emissivity ε, the tooling factor T.F., the temperature T (in Kelvin), and an optional constant background C. The tooling factor incorporates system-dependent geometrical and sensitivity factors, and therefore must be determined empirically.

The tooling factor can be determined by calibrating to a blackbody curve at a known temperature (e.g. from a band edge measurement, RHEED transition, or Si/Al eutectic). In this case the temperature is held fixed at the known value, and the tooling factor is allowed to vary to obtain the best fit. Once the tooling factor is known, a blackbody fit can then be performed in real-time during BandiT data acquisition. In this case, the tooling factor is held fixed, and the temperature is allowed to vary to obtain the best fit. This is the so-called "Locked" mode of operation. This approach assumes that the tooling factor and sample emissivity do not change after calibration.

Alternatively, in cases where this assumption may not be valid, the "Free Fit" mode of operation can be used. In this mode both the temperature and tooling factor are allowed to vary in order to obtain the best fit. In principle, this approach is insensitive to viewport coatings as the tooling factor can vary over time to accommodate the resulting decrease in signal intensity. The same holds true for the emissivity.

However, in practice the best results are typically obtained by calibrating at the highest practical temperature and locking the tooling factor. If the calibration temperature is not known via some other means, a free fit can be done to determine it. Then the tooling factor can be determined as described above. This is the so called "Self-Calibration" method (Figure 2).

Whichever mode is chosen, the non-linear least squares fitting routine requires initial guesses for the four adjustable parameters in Equation 2. The routine is sensitive to the accuracy of these values; if they differ too much from the actual values, the fitting routine will fail to converge. In order to minimize this occurrence, "Auto" mode may be selected. In this mode, approximate values of these parameters are automatically calculated and used as the initial guesses.

A simplified version of the Planck expression can be used to obtain these values. This is the so-called "Wien approximation" (Equation 3). This approximation is valid in the limit that hc / λkT >> 1. This applies when the wavelength is well below the peak of the spectral radiance in Figure 1, which is typically the case at low temperatures.

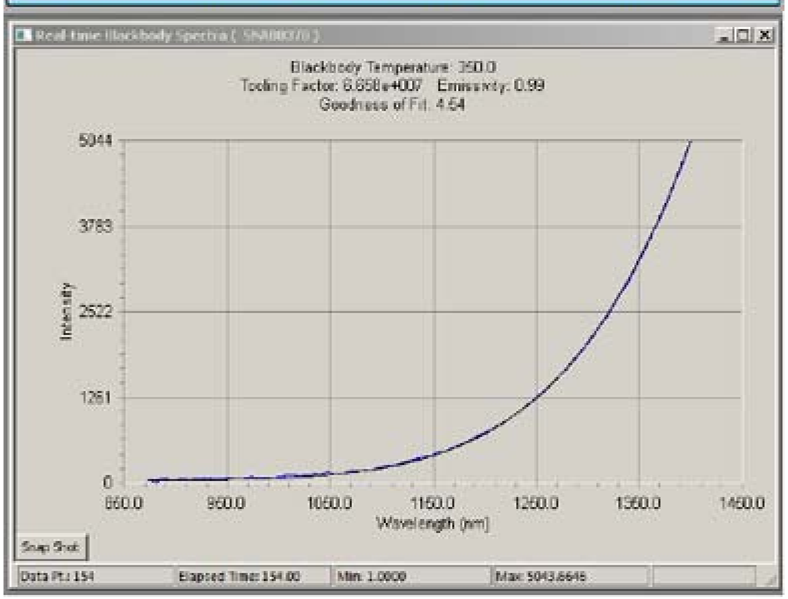
$$I(\lambda) \cong \varepsilon T.F.\frac{2hc^2}{\lambda^5} e^{-hc/\lambda k_B T} + C \quad \left(hc/\lambda k_B T >> 1\right)$$

Neglecting the background C, and performing a suitable transformation, this can be expressed as a linear function of 1/λ (Equation 4).

$$\ln\left(\lambda^5 I\right) \cong \ln\left(2hc^2 \varepsilon T.F.\right) - \frac{hc}{k_B T}\frac{1}{\lambda}$$

Thus a simple linear least-squares fit can be performed to the transformed spectra. The tooling factor can be extracted from the intercept, and the temperature from the slope. These values can then be used as the initial guesses in fitting to the full Planck expression (Equation 2). Note that this works well in many, but not all circumstances. If for some reason the fitting routine fails to converge when using "Auto" mode, then starting guesses will have to be manually entered in the usual fashion.

In addition to providing initial guesses for the fit to Equation 2, the linearized spectra provide a better visual representation of any deviations from an ideal blackbody curve across the spectral range. This allows the user to improve the robustness of the fit by excluding portions of the spectrum. This is particularly useful at low temperatures, where noise can have a significant impact at the shorter wavelengths where the expected blackbody intensity is quite low. The images below show the Real-time Wien linearization chart and the corresponding conventional fit to a low temperature Blackbody (note the deviation from linearity at short wavelengths).



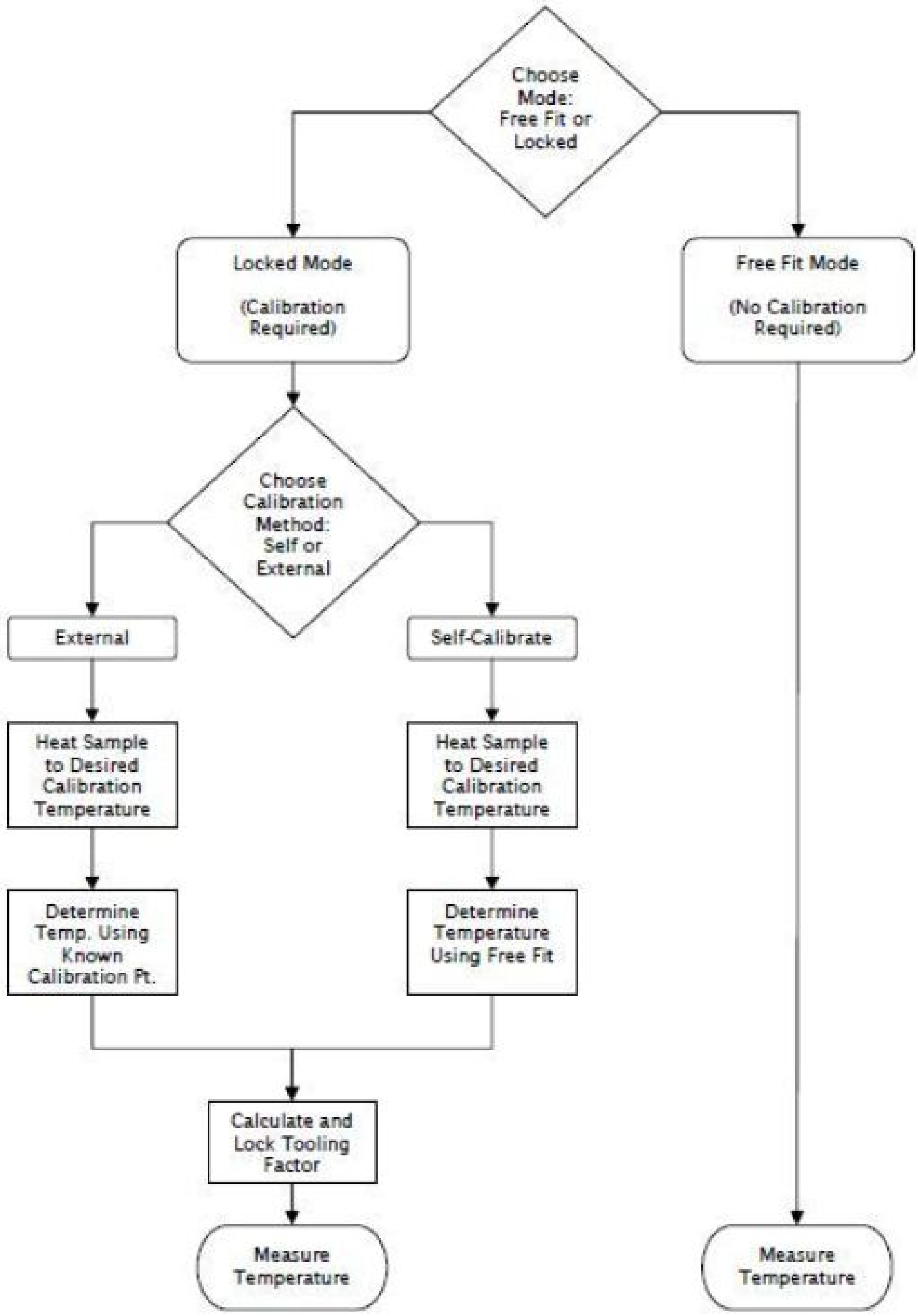
2. Choose Measurement Mode

The choice of measurement mode, either ***Free Fit*** or ***Locked*** determines the processes that are required in order to calculate the Blackbody temperature.

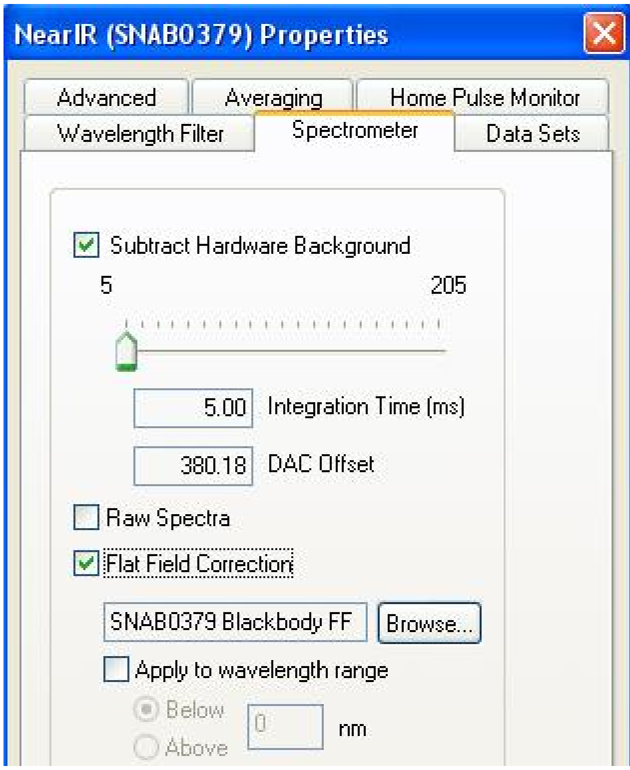
Locked mode is used where a temperature can be measured by some means, for example conventional BandiT Band Edge mode, and then the Tooling Factor can be obtained during the Calibration process. The Tooling factor can then be "Locked" during acquisition so that Blackbody temperature can be measured.

Free Fit mode is used where it is not possible to measure a temperature using the conventional BandiT Band Edge mode, for example when measuring Antimonide materials where an absorption edge is outside the spectrometer range. In this case there is no known temperature to use to calibrate the Tooling Factor and both the temperature and tooling factor are allowed to vary in order to obtain the best fit.

The flow chart below shows the sequence of processes:



The steps that follow below describe the ***Locked Mode*** which requires the use of the Calibration Procedure.



3. Enable Flat Field Correction (FFC)

The spectrometer output has been corrected to yield a flat response as a function of wavelength. This correction is unique to each individual spectrometer. Before attempting to calibrate blackbody, make sure this correction is enabled.

Right-click anywhere in the live spectrometer window and select ***Properties***. Select the Spectrometer tab, and verify that the ***Flat Field Correction*** checkbox is enabled. If not, select the Browse button and select the appropriate FFC file for the spectrometer in question. When finished, select OK to return to the live spectrometer window.

4. Set Chamber Temperature

Select ***BandiT Temperature*** from the ***Acquire*** menu or the  icon from the toolbar. This brings up the BandiT Temperature Acquisition.

In the BandiT Temperature Acquisition window, make sure that ***Continuous (no data saved)*** mode is selected and that ***BandEdge/Pyrometry/Blackbody*** is selected. Also, tick the ***Control Light Source based on mode***, which ensures the light source stays off.

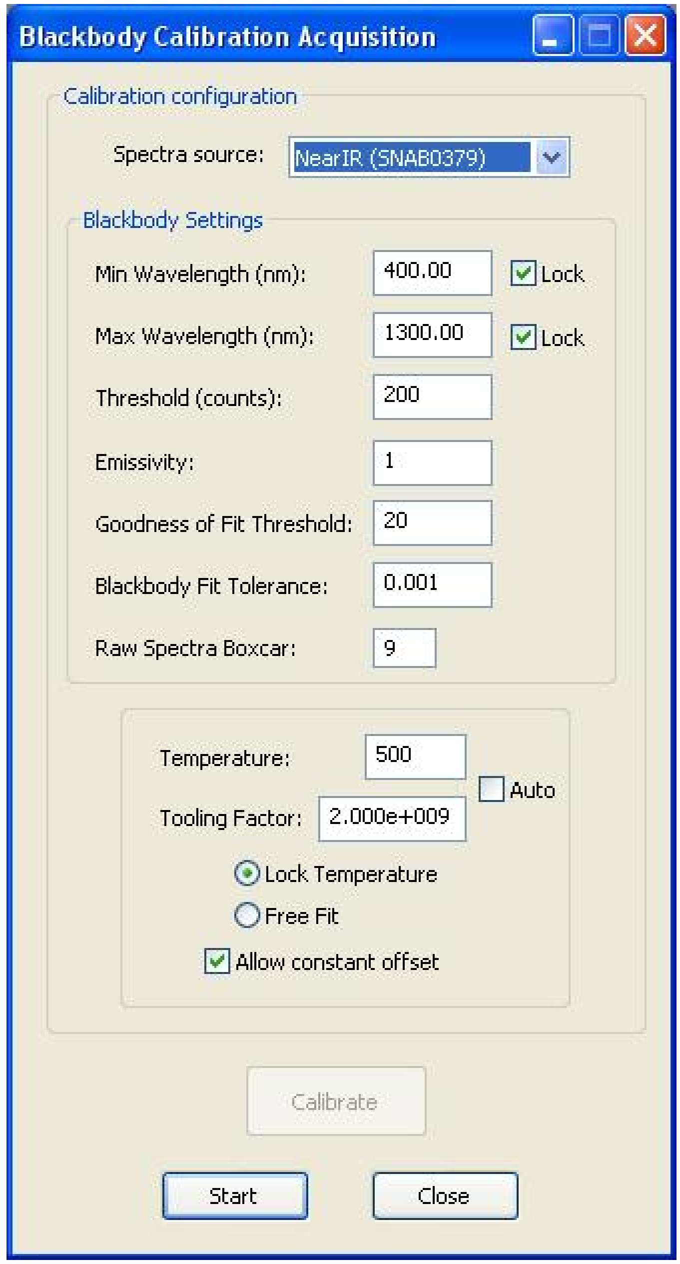
Next, open the Real-Time Bandit Temperature (LED) Real Time Chart from the View menu.

Now, click ***Start*** on in the ***BandiT Temperature Acquisition*** window and ramp up the chamber temperature until it reads the BandiT temperature that you want to use for calibration in the ***Real-time BandiT Temperature (LED)*** window.

Then, leave the temperature where it is and press the ***Stop*** button in the acquisition window and close the Temperature Acquisition mode.

5. Calibration

In order to run in ***Locked mode*** the ***Tooling Factor*** must be calibrated first. To do this open the Blackbody Calibration Acquisition mode from the ***Acquire*** menu. Also open the Real-time Blackbody Spectra Real Time Chart from the ***View*** menu.



Select the ***Spectra source*** from the pull-down menu.

Enter the desired ***wavelength range*** over which to perform the blackbody fit. Entering zeros will cause the software to automatically select the spectrometer's min and max wavelengths. The values can be locked using the check boxes. Alternatively, if one or both boxes are unchecked, the software will attempt to optimize the goodness of fit by successively reducing the range each time the Calibrate button is pressed.

Enter the ***Threshold***, which specifies the minimum number of counts for performing a blackbody fit. Spectra which don't have at least this many counts will be ignored.

Enter the calibration sample's ***Emissivity***. If not known, a value of 1 can be entered. In this case the emissivities of the subsequent samples will need to be expressed relative to that of the calibration sample, instead of entering the actual values.

Enter the ***Goodness of Fit Threshold***. This allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. The default value is 20, meaning spectra which have reduced chi-squared greater than this value will be ignored.

Enter the ***Blackbody Fit Tolerance***. The fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations (default is 1.0E-3).

Enter the ***Raw Spectra Boxcar*** value (must be odd, default is 9). This specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the spectra before attempting to fit.

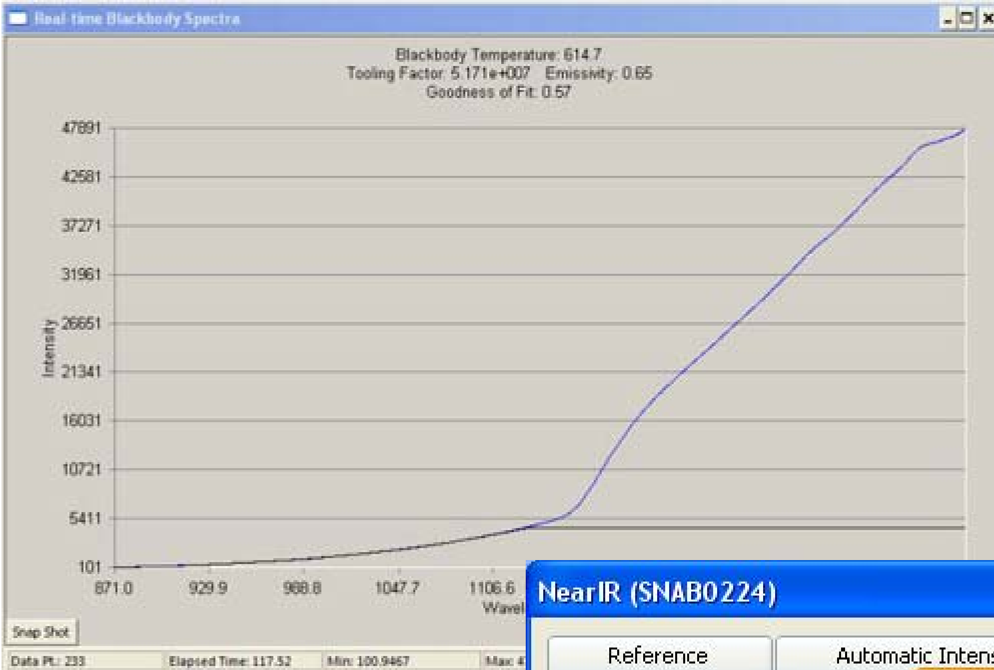
Enter the Calibration mode. Select ***Lock Temperature*** if the calibration temperature is known, or ***Free Fit*** to self-calibrate.

Enter the calibration ***Temperature*** (ºC). If self-calibrating, enter an estimate of the temperature to be used as an initial guess by the fitting routine. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate. If ***Auto*** mode is selected, this will be calculated automatically.

Enter an estimate of the ***Tooling Factor*** to be used as an initial guess by the fitting routine. If ***Auto*** mode is selected, this will be calculated automatically. Selecting ***Allow constant offset*** permits the constant C to be calculated automatically. Otherwise, it is forced to zero.

Select ***Start***. The software will determine the temperature by attempting to fit a blackbody curve to the source spectra in real-time using the most recently saved tooling factor and emissivity values. These values can be found in the BandiT Temperature Acquisition settings. The Real-time Blackbody Spectra

Real Time Chart displays the source data in blue and the resulting fit in black. At the top of the window it displays the temperature, tooling factor, emissivity, and the goodness of fit statistic (i.e. the reduced chi-squared). If the goodness of fit statistic exceeds the threshold value, a message will appear. Pressing ***Calibrate*** will cause the fitting routine to attempt to perform a fit according to the current settings. If successful, the corresponding tooling factor will be calculated. If needed, the wavelength range can be adjusted for optimum results. Every time ***Calibrate*** is pressed, the settings are automatically saved.



6. Set Up Blackbody Processing Recipe

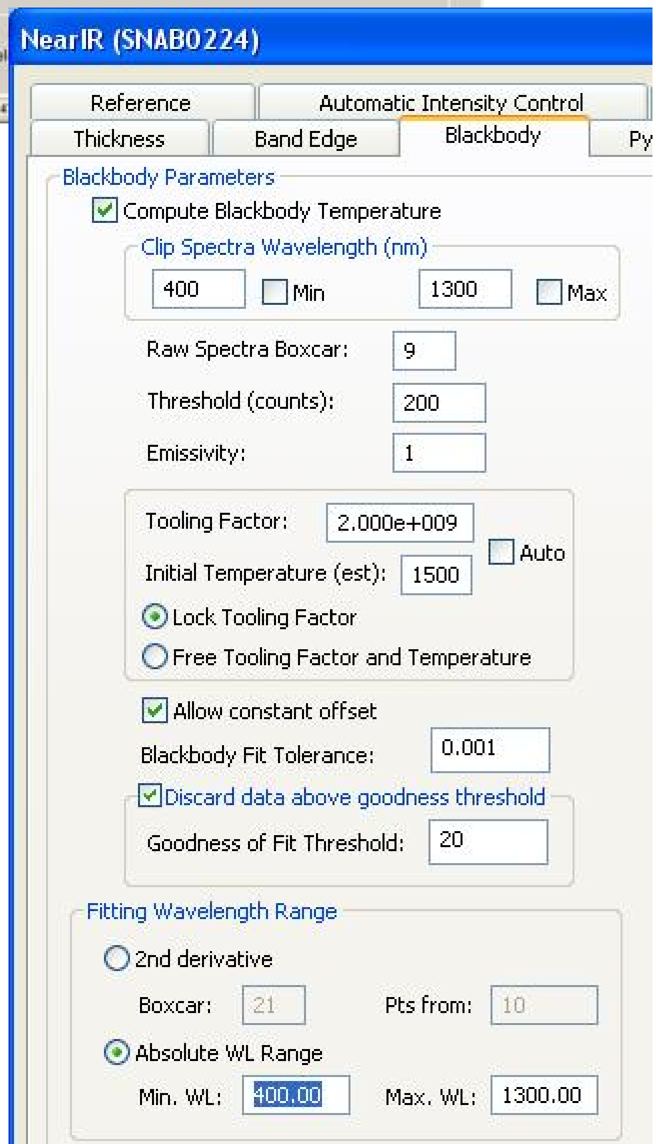
Select ***BandiT Temperature*** from the ***Acquire*** menu or the  icon from the toolbar. This brings up the BandiT Temperature Acquisition.

Ensure that ***BandEdge/Pyrometry/Blackbody*** is selected. Also, tick the ***Control Light Source based on mode***, which ensures the light source stays off.

Select ***Config*** to open the Configuration Options and then select the Blackbody tab.

Select ***Compute Blackbody Temperature*** to enable blackbody fitting.

The user has the option to clip the raw spectrum below a min wavelength, and/or above a max wavelength. This is intended to allow the removal of noisy portions of the spectrum which may exist under certain circumstances.



Enter the ***Raw Spectra Boxcar*** value (must be odd, default is 9). This specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the spectra before performing attempting to fit.

Enter the ***Threshold***, which specifies the minimum number of counts for performing a blackbody fit. Spectra which don't have at least this many counts will be ignored.

Enter the sample's ***Emissivity***. Note that this is not necessarily the same as the emissivity used in the calibration procedure. This allows the user to perform the calibration on a sample which is different than the sample under test. If a value of 1 was entered during calibration, the sample's emissivity will need to be expressed relative to that of the calibration sample, instead of entering the actual value.

Enter the mode. Select ***Lock Tooling Factor*** if it is desired to run in Locked mode, or ***Free Tooling Factor and Temperature*** if Free Fit mode is desired.

Enter the ***Tooling Factor***. If a calibration was performed as described above, this will already contain that value. If in ***Locked mode***, this will be the value used for all calculations. If in ***Free Fit mode***, this will be the initial guess, unless ***Auto*** is selected, in which case it will be calculated automatically.

Enter an ***Initial Temperature estimate***. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate. If ***Auto*** mode is selected, this will be calculated automatically.

Selecting **Allow constant offset** permits the constant C in to be calculated automatically. Otherwise, it is forced to zero.

Enter the ***Blackbody Fit Tolerance***. The fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations (default is 1.0E-3).

Selecting ***Discard data above goodness threshold*** allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. Spectra which have reduced chi-squared greater than the entered ***Goodness of Fit Threshold*** will be ignored. The default value is 20.

Specify the ***Wavelength Range***. This can be fixed, or the upper limit can be adjusted dynamically relative to the sample's band edge. In this way the measurement is restricted to the "above-gap" portion of the spectrum where the sample is opaque. This is based on the "knee" in the spectrum, which is located at the peak of the 2nd derivative, i.e. the wavelength where the slope is increasing most rapidly. If this ***2nd derivative*** option is selected, the smoothing and number of data points to offset from the knee must be specified.

When satisfied with all the settings, select ***OK*** to return to the Temperature Acquisition window.

7. Acquire Blackbody Temperature

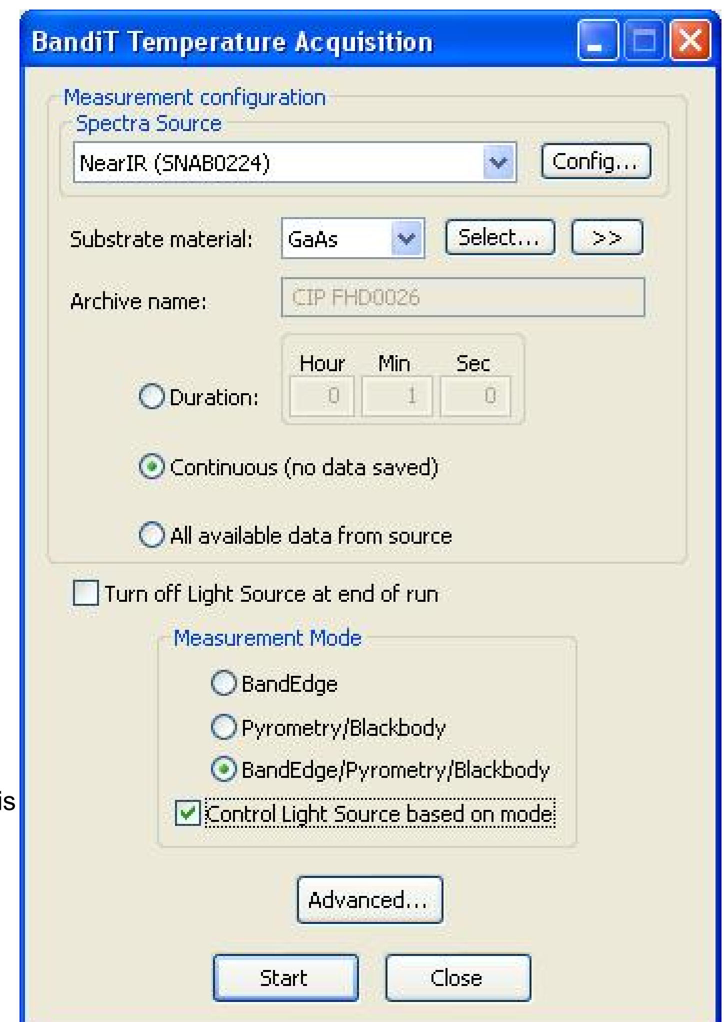
Once the spectra processing recipe has been set up, acquisition can begin by selecting ***Start*** in the BandiT Temperature Acquisition window. During data acquisition, in addition to the live spectrometer window, the user may view a number of real-time charts and stats which provide useful information. These can be accessed from the View menu. For example, the Realtime Blackbody Spectra chart which displays the raw data and the resulting fit, as shown above during Calibration, Realtime Blackbody Temperature (LED), and Real-time Blackbody Temperature (Time) which plots the blackbody temperature versus time as shown below.

BandiT Pyrometry

This is one of four ways of how to measure temperature using BandiT. This procedure outlines how to measure temperature using the intensity of black-body radiation over a narrow wavelength. Generally, this technique is inferior to using a band edge thermometry. However, the band-edge technique often fails when depositing a very absorbing layer, so the Pyrometry technique (either a conventional method described here, or the Black-Body Pyrometry method) is available for such situations.

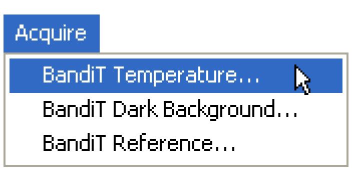
Important note: do not use a light source when using this technique to measure temperature. Because this technique is signal-level dependent, any light source will add potentially variable signal and so affect the temperature conversion, which will lead to an improper temperature reading.

This guide assumes the system is calibrated to read the correct temperature using transmission mode (without a light source) using one of BandiT's spectrometers. See How-To Measure Temperature.



1. Set Chamber Temperature

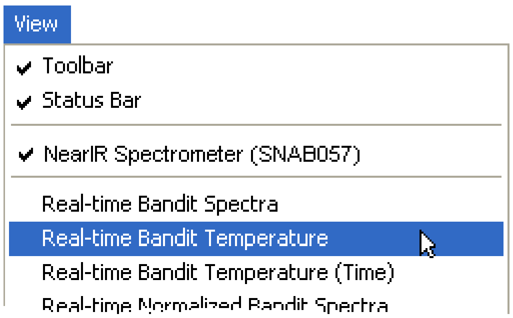
Select ***BandiT Temperature*** from the ***Acquire*** menu or the  icon from the toolbar.



This brings up the BandiT Temperature Acquisition window as shown on the right.

In the ***BandiT Temperature Acquisition*** window, make sure that ***Continuous (no data saved)*** mode is selected (as shown) and that ***BandEdge/Pyrometry/Blackbody*** is selected. Also, tick the ***Control Light Source based on mode***, which ensures the light source stays off.

Next, select ***Real-Time Bandit Temperature (LED)*** from the View menu.



Now, click ***Start*** on in the ***BandiT Temperature Acquisition*** window and ramp up the chamber temperature until it reads a BandiT temperature of, for this example, 500°C in the ***Real-time BandiT Temperature (LED)*** window.

Then, leave the temperature where it is and press the ***Stop*** button in the acquisition window.

2. Calibrate the system for Pyrometry

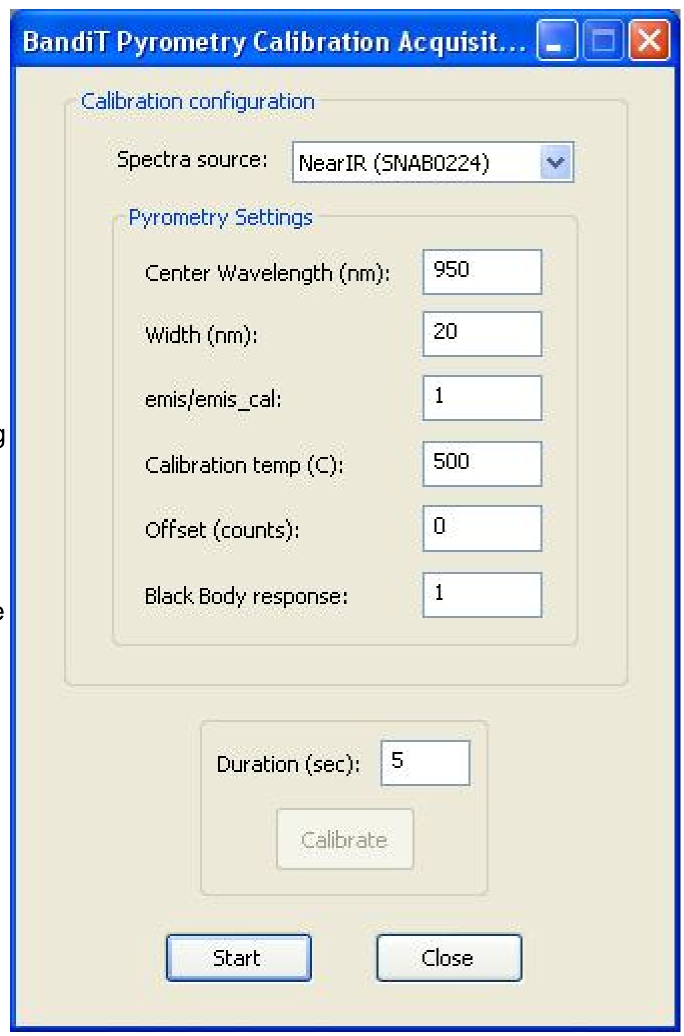
Next calibrate the system for Pyrometry.

Open the ***BandiT Pyrometry Calibration*** acquisition mode from the ***Acquire*** menu.

In this window, set the material-dependent ***Center Wavelength,*** here it is set at 950 nm and set the ***Width*** which is the overall width around the centre wavelength that bandit will use to detect blackbody radiation, here set to a width of 20 nm, so the algorithm is looking between 940 and 960nm. It is important that the wavelength range chosen is within the absorbing range of wavelengths for the material being measured, otherwise erroneous results may be obtained. This is the wavelength that BandiT will use when looking for blackbody radiation.

Leave the other numbers as they are, except the ***Calibration temp (C)***, which should be the current system temperature (500 in this example).

Note that emis/emis_cal is 1 because in this case we're calibrating the pyrometry temperature based on the temperature of the material being measured. Learn more about this in the Pyrometry tab topic.



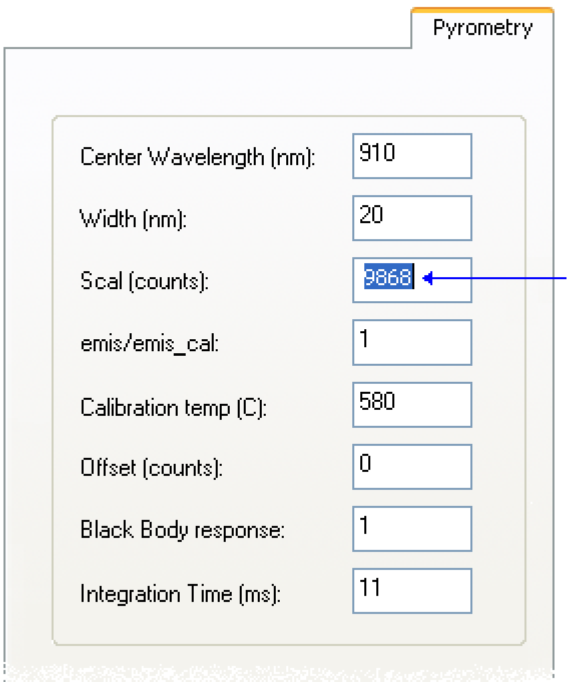
Set a ***Duration*** of a few seconds, this is the time that will be used to perform the calibration.

Click ***Start*** to start the acquisition process and then click ***Calibrate***. The system will show "Calibrating" in the task bar . When the calibration is complete click ***Stop*** and then ***Close*** to finish the acquisition and close the dialog box.

The system is now set up to use Pyrometry of the selected wavelength to measure the BandiT Temperature.

3. Check Config Options

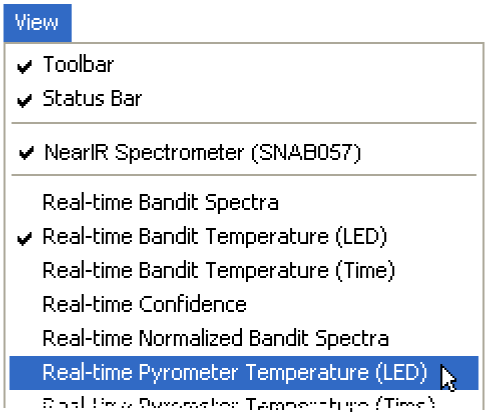
Open the ***BandiT temperature Acquisition*** mode , click on the ***Config*** button and select the Pyrometry tab.



You will see that the ***Scal (counts)*** value has been entered automatically by the Calibration procedure. This is the signal calibration, and will be a large number (many thousands to several million, depending on signal strength). The Calibration system will also have set the ***Integration Time*** to the Spectrometer integration time during the calibration procedure.

5. Acquire Temperature via Pyrometry

At this point, the system is calibrated to use Pyrometry for measuring temperature. To check, select Real-Time Pyrometer Temperature (LED) and the Real-time BandiT Temperature (LED) from the View menu.



Next, again select ***Continuous (no data saved)*** in the ***BandiT Temperature Acquisition*** window.

Click ***Start***. Both the ***Real-time BandiT Temperature (LED)*** window and ***Real-time Pyrometry (LED)*** window should have the same temperature (or very nearly the same – within a degree or two at most).

That's it! Use the ***Real-time Pyrometry Temperature (LED)*** window to view the temperature via Pyrometry.

How-To Trigger Temperature Measurement

If the system has not yet been set up to gather temperature, go to the How-To Measure Temperature guide and work through steps to acquire a dark background, a BandiT reference if required and to set up the parameters for Temperature acquisition.

Once the system is set up to gather temperature, temperature measurements can be acquired via kSA BandiT:

Continuously – for NearIR, Visible, and via Pyrometry

Externally triggered – for NearIR and Visible (legacy – before August, 2006)

Externally triggered with software control – for NearIR and Visible

This how-to manual describes each type of temperature measurements and the steps needed to implement an external trigger (with and without software control). It should be noted here that this capability is for "Single-Wafer BandiT," which can be configured to capture the temperature measurement of any single wafer in a platen, but not more than one wafer except through continuous mode (capturing all data from whatever is placed in front of the BandiT system). k-Space Associates also offers "Multi-Wafer BandiT," which gathers data from each wafer as it rotates in front of the BandiT system, omitting contributions from the platen.

1. Continuously

Continuously measuring temperature has been described in the other How-To Measure Temperature Guides and is currently the only way to set up the system to measure via pyrometry. For the Near IR and Visible spectrometers running on a standard desktop PC, the "continuous" setting usually results in about 40 measurements per second. The main performance limiter is the integration time of the spectrometer, which is running in an asynchronous reset mode and polling for a new spectrum as fast as the system can operate. For example, an integration time of 25 ms yields the 40 measurements per second. Note that these measurements are initiated by software and are prone to a small amount of jitter.

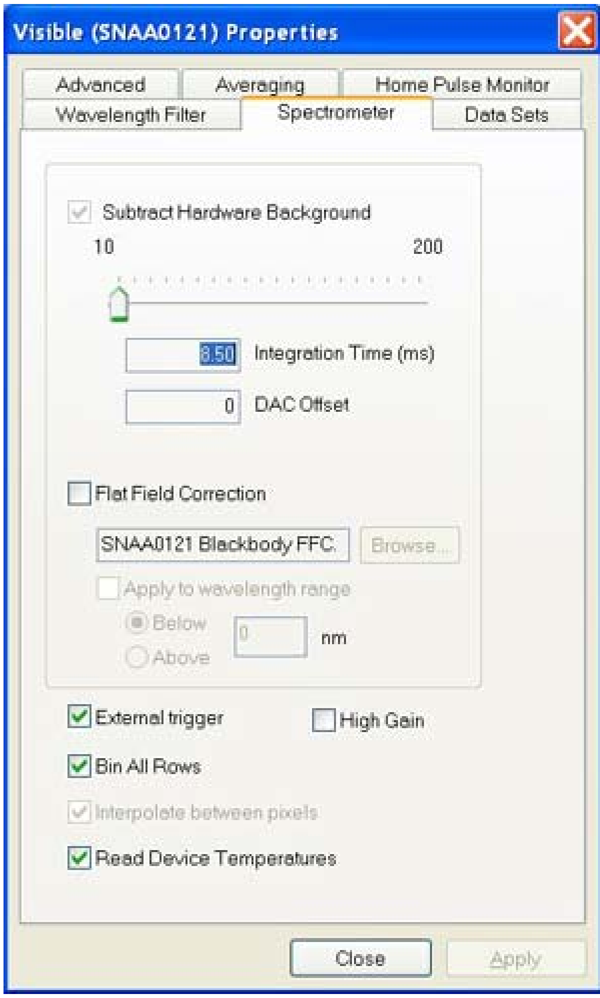
2. Externally Triggered

Externally triggered acquisition utilizes the trigger line of the spectrometer and gathers a temperature measurement the moment a trigger is received. This is a legacy feature for systems that shipped before August, 2006, and is configured in just a few steps:

1. Connect the external TTL-signal to the BNC connection labeled "Ext. Trig" on the back of the kSA BandiT rack.

2. From the BandiT software main menu, select ***View*** and click the Spectrometer name to open the Spectrometer [live] window.

3. On the Spectrometer [live] window, right click on the window and select ***Properties***.



4. Select the ***Spectrometer*** tab and tick the ***External Trigger*** check box at the bottom of this tab.

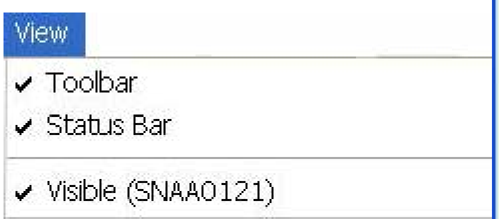
5. Click ***Apply.*** The spectrometer is now configured to take data only when an external trigger is received.

3. Externally Triggered Through Software Control

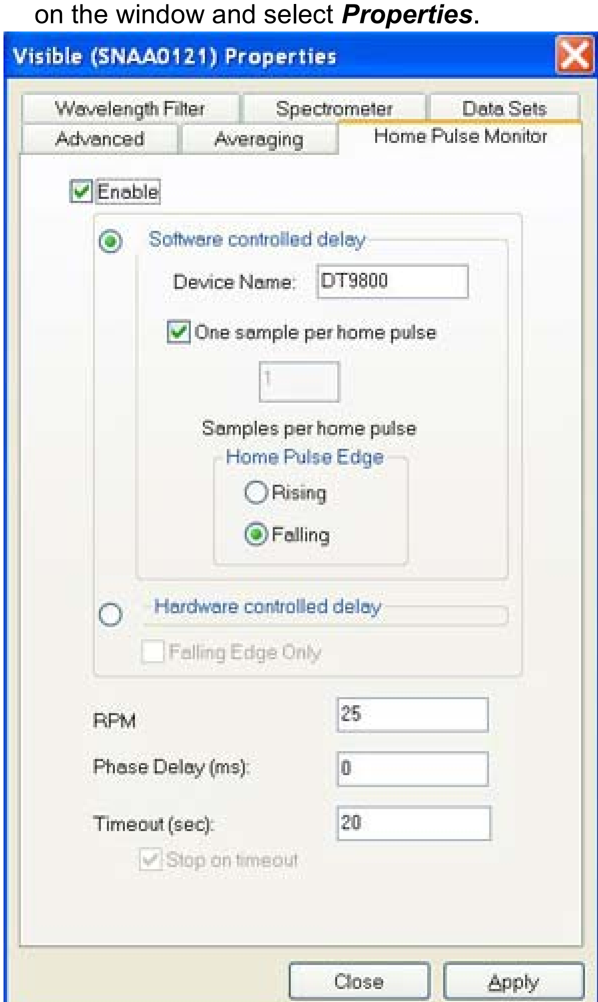
Externally triggered through software control means setting in a delay after receiving a trigger and gathering one or multiple data samples. This option is useful for gathering the temperature measurement across a single wafer as it spins by the BandiT system in a platen. (Note that k-Space also offers "Multi-wafer BandiT," which performs this same temperature measurement for ***each*** wafer as it spins by the BandiT system.) Please follow the steps below to configure the system for software control of external triggers:

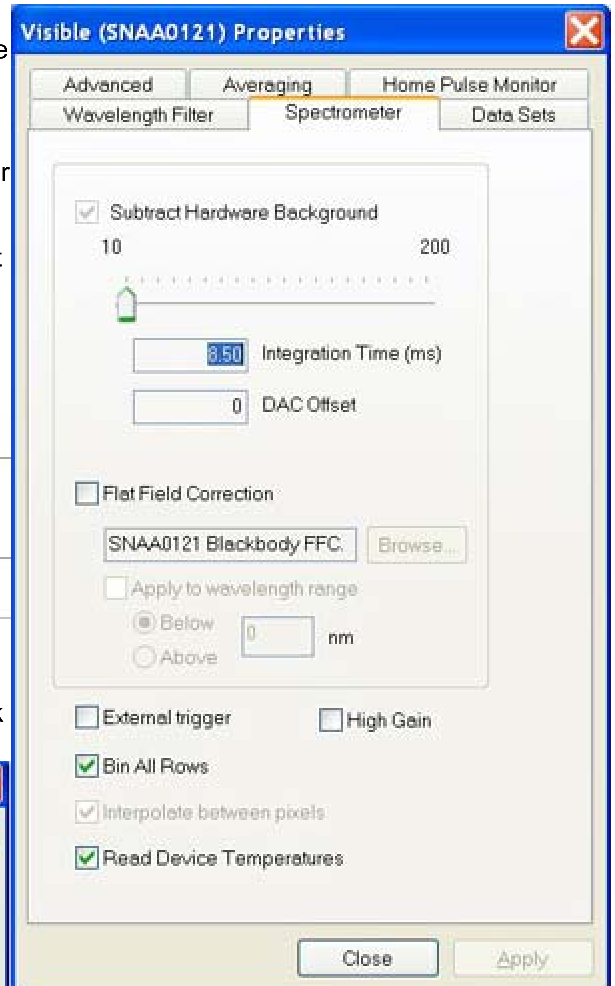
1. Depending on your system (older models use pin X on the 15-pin connector, all recent systems use BNC connection labeled "Ext. Trig"), connect the external TTL-signal to the back of the kSA BandiT rack. If you need further assistance in this, please contact us.

2. From the BandiT software main menu, select ***View*** and click the Spectrometer name to open the Spectrometer [live] window.



3. On the Spectrometer [live] window, right click on the window and select ***Properties***.





ct the ***Spectrometer*** tab and be sure the ***External Trigger*** check box is ***not*** ticked at the bottom of this tab - as shown on the right.

5. Next, select the ***Home Pulse Monitor*** tab and tick the ***Enable*** checkbox.

For the ***Device Name*** – determine whether the kSA BandiT system has a DT9800-series or Measurement Computing PMD-1208FS board.

To do this, open the Computer's Device Manager (found on the Control Panel, System, Device manager).

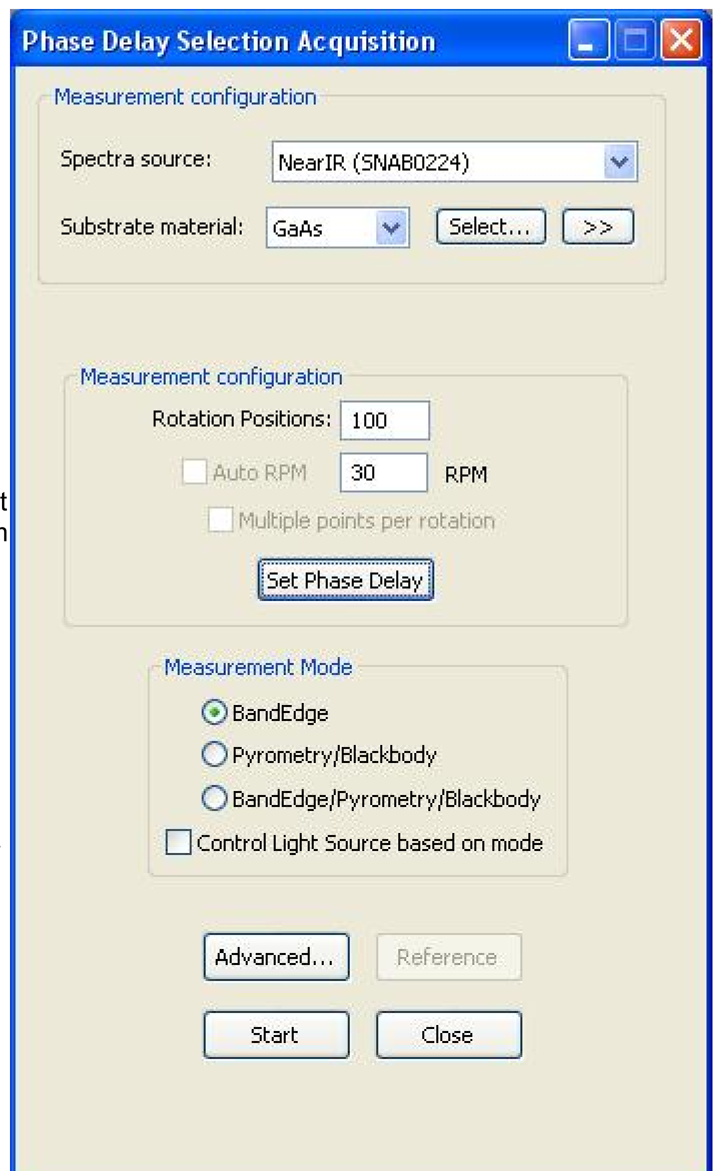
If "DT-Open Layers Acquisition Devices" (or some close variant) is listed, then the system has a DT9800-series board. Click the + icon to find the name of the device (e.g., DT9806(01)). Enter that name exactly as it appears into the ***Device Name*** box. Note that some systems will not have any parenthesis for the name (e.g., DT9806).

If it is not a DT9800-series board, then (except in a few specialty cases), it is a Measurement Computing Board. Click Start → All Programs, and run the InstaCal program (it may be listed under "Measurement Computing"). In the InstaCal window, find the Measurement Computing board and note the board number. In the ***Device Name*** box, enter CB(<boardnumber>,1), where <boardnumber> is the number reported by the InstaCal software.

For example, CB(0,1) would be entered if InstaCal reported that the board number is 0.

For the other parameters of this dialog, please see the descriptions in the Home Pulse Monitor topic.

6. Click ***Apply***. If a dialog appears stating that the Home Pulse monitor could not be found, then the device name is wrong. Please ensure that the device name is entered exactly as described above. If you need further assistance with this step, please contact us.



4. Select Phase Delay

The ***Phase Delay*** in the Home Pulse Monitor menu shown above is the delay after the ***Home Pulse*** has been detected and before the temperature is measured. This can be set up using the Phase Delay Selection Acquisition mode.

Open Phase Delay Selection from the ***Acquire*** menu or by using the  icon on the toolbar.

One type of hardware to monitor rotation must be installed and enabled in the BandiT system for the Phase Delay Selection acquisition to work. Go to Check Hardware Rotation Board to locate and enable the correct option for your system.

Select ***Spectra source*** and ***Substrate material*** as usual for BandiT Temperature Measurement.

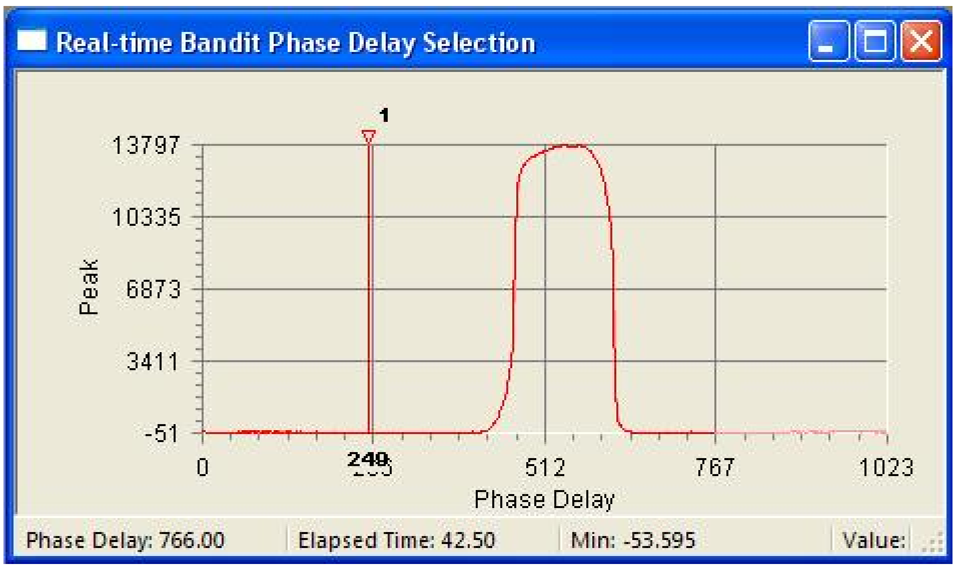
Enter the number of ***Rotation Positions*** that will be tracked by the system. The number of positions chosen depends on a combination of the rotation speed, exposure time and the processing that is being done. For most purposes a range between 100 and 128 will be sufficient. If the platen is very large then a larger number of positions would be needed to get the resolution high enough.

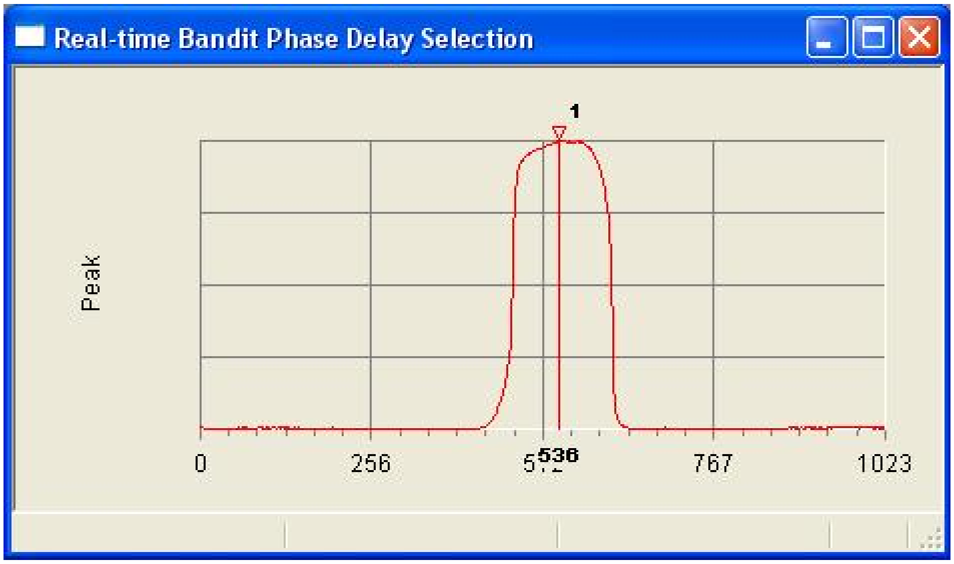
Enter the ***RPM,*** revolutions per minute, of the sample rotation stage, if known.

If the Hardware Rotation method can detect the RPM the ***Auto RPM*** check box will become available, select it to allow the automatic synchronisation to RPM.

Open the Real-time Bandit Phase Delay Selection Real Time Chart from the View menu. This Real-Time Chart should be set to plot the ***Peak Intensity*** against the rotation positions. If it is not, right click the plot and select ***Properties*** and then ***Plot value***, and select ***Peak Spectra Intensity*** from the drop down list.

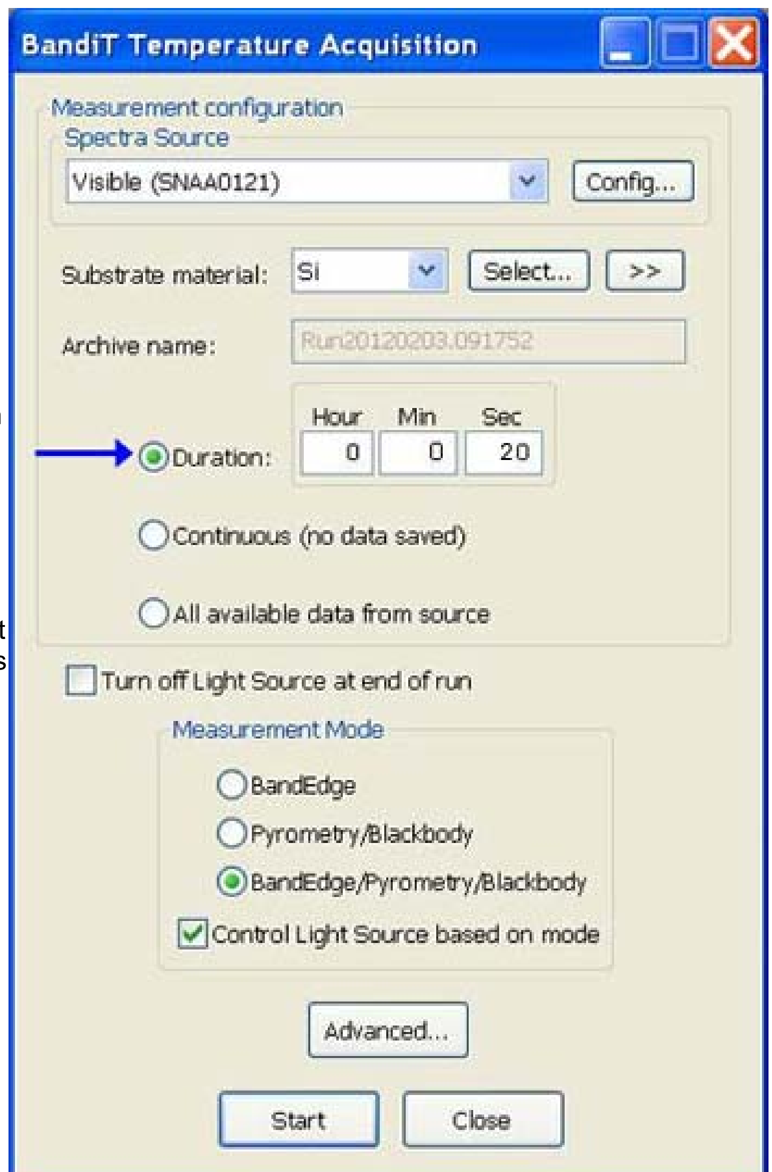
Click ***Start***. The Real-time BandiT Phase Delay Selection chart will start to update with an active trace which will re-trace itself as the sample rotates. Let it stabilise so that it retraces itself reliably as shown in the first image below, then click ***Stop***. It is now possible to move the red marker from the left hand side of the chart by clicking and dragging the triangle at the top of the marker line. Move this marker to the position of greatest peak intensity - this will be the location where data will be collected - as shown in the lower image.





When the marker is in the correct position click ***Set Phase Delay***. The delay (in ms) will be entered into the Phase Delay field in the Home Pulse Monitor screen, found by right clicking the Live Spectrometer window and selecting ***Properties***. From this point onwards the system will be triggered to only take a snapshot of data when the stage rotation reaches the marker.

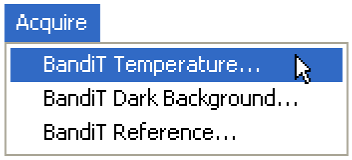
The system will now acquire the specified number of samples after the specified delay after receiving the home pulse. Please refer to the How-To Measure Temperature guide for more information on temperature measurement.



How-To Capture Continuous Spectra

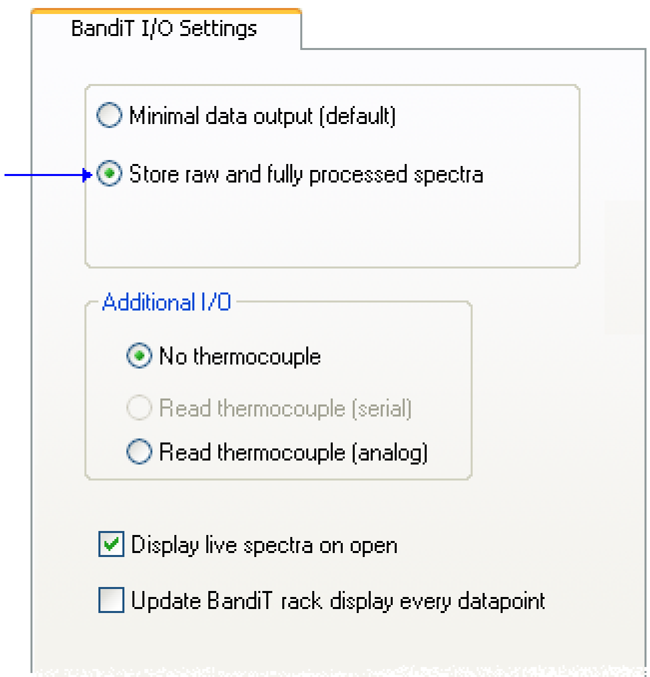
Capturing a spectrum continuously for a specified interval is useful because it can be used as if it were a data source for analysis. This makes it easy to analyze at any time because it can be stored for future reference. It also makes it easier for us to troubleshoot your temperature analysis: contact us and then send us the full *.kdt movie. Then we can replay it and analyze it, seeing the data exactly as it was acquired.

To capture a continuous spectra of a specified interval, first select BandiT Temperature from the ***Acquire*** menu.

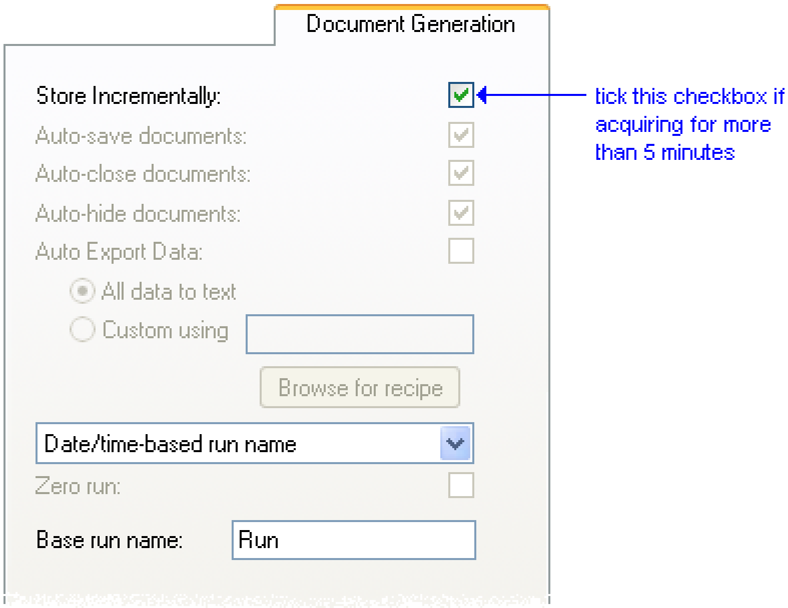


Next, choose ***Duration*** and specify an acquisition time period, for example 5 minutes as shown on the right.

Then click the ***Advanced*** button. That brings you to the Advanced Acquisition Options. Next, select the BandiT I/O Settings tab and choose ***Store raw and fully processed spectra***.



If acquiring for more than 5 minutes, then click over to the Document Generation tab and click the ***Store Incrementally*** button. This also will automatically select ***Auto-save***, ***Auto-close***, and ***Auto-hide*** and prevent the user from disabling those selections.



That's because storing raw and fully processed spectra means saving enormous files that will interrupt acquisition significantly if the system only saves when RAM is full. Storing incrementally means the system will regularly take data from RAM and store it to disk. While this will cause slight disruptions in acquisition, they may not be noticeable at all. And even if it is, the disruptions will be regular and small. Most modern machines have enough RAM to store five minutes worth of this kind of data before needing to store it to disk.

Important Note: files can be so large that it literally may take minutes for one to open. Also, it is possible to generate files—using the ***Store Incrementally*** option—that are so large that they cannot be re-opened until more RAM is made available (or purchased!).

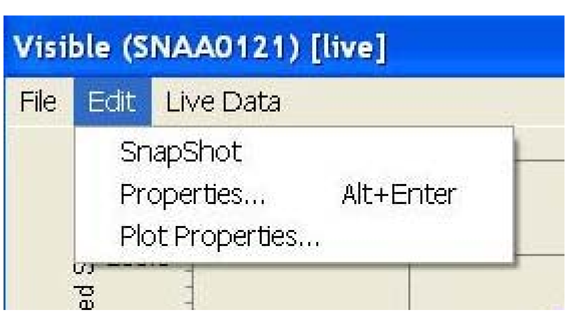
Click the ***OK*** button at the bottom of the ***Advanced Acquisition Options*** window to return to the ***BandiT Temperature Acquisition*** window.

Then click the ***Start*** button. At the end of acquisition, a *.kdt file has been archived as specified in the Document Generation Advanced Acquisition Option. Open it and, using the *.kdt toolbar, play the file as a movie. You can also use it as an acquisition source.

How-To Capture an Individual Spectrum

Capturing individual spectra is useful for analysis and for saving for future reference.

To capture an individual spectrum, simply select ***SnapShot*** from the Edit menu on the Live Spectrometer window, as shown below.



A new window will open up with a single spectrum.

How-To Measure Growth Rate

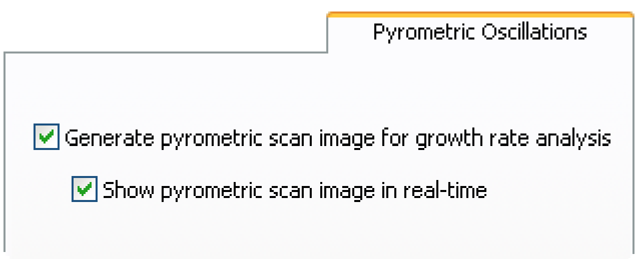
The kSA BandiT system has the ability to determine deposition rate from pyrometric interference oscillations in radiated light from the sample surface. These oscillations occur when a film is being deposited with different index of refraction from the under layer or substrate.

Specifically, when the sample is hot enough to emit blackbody radiation, this radiation is emitted in all directions. Radiation that is emitted back into the sample is reflected off the interface between the film and the substrate (provided there is a refractive index difference at this interface). This reflected radiation then interferes with radiation that is forward-emitted from the surface. BandiT collects this interference, allowing users to observe the oscillations in intensity at any given wavelength. Growth rate may be extracted by fitting these oscillations to simple optics equations.

Requirements for this type of analysis with the BandiT system are:

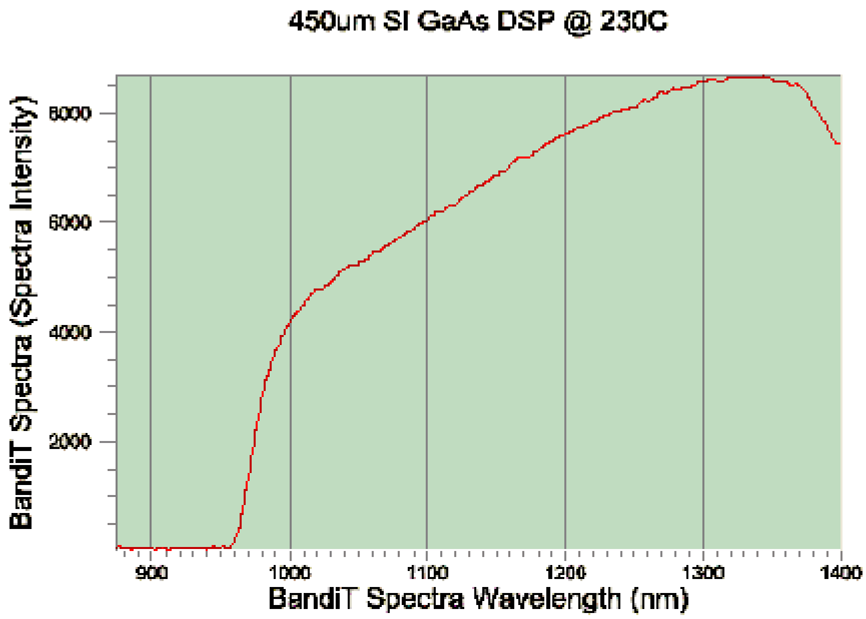
- a film and substrate of different material composition,
- a semi-transparent film and substrate (this requirement is satisfied by most semiconductor materials), and
- a sufficiently thick film, on the order of 2000 Å or more.

To measure growth rate, first execute the same steps in the How-To Capture Continuous Spectra, but do not yet click OK at the bottom of the ***Advanced Acquisition Options*** window after specifying ***Store raw and fully processed data***. Instead, select the Pyrometric Oscillations tab and click ***Generate pyrometric scan image for growth rate analysis***. To see the image being created during acquisition, click the ***Show pyrometric scan image in real-time***.

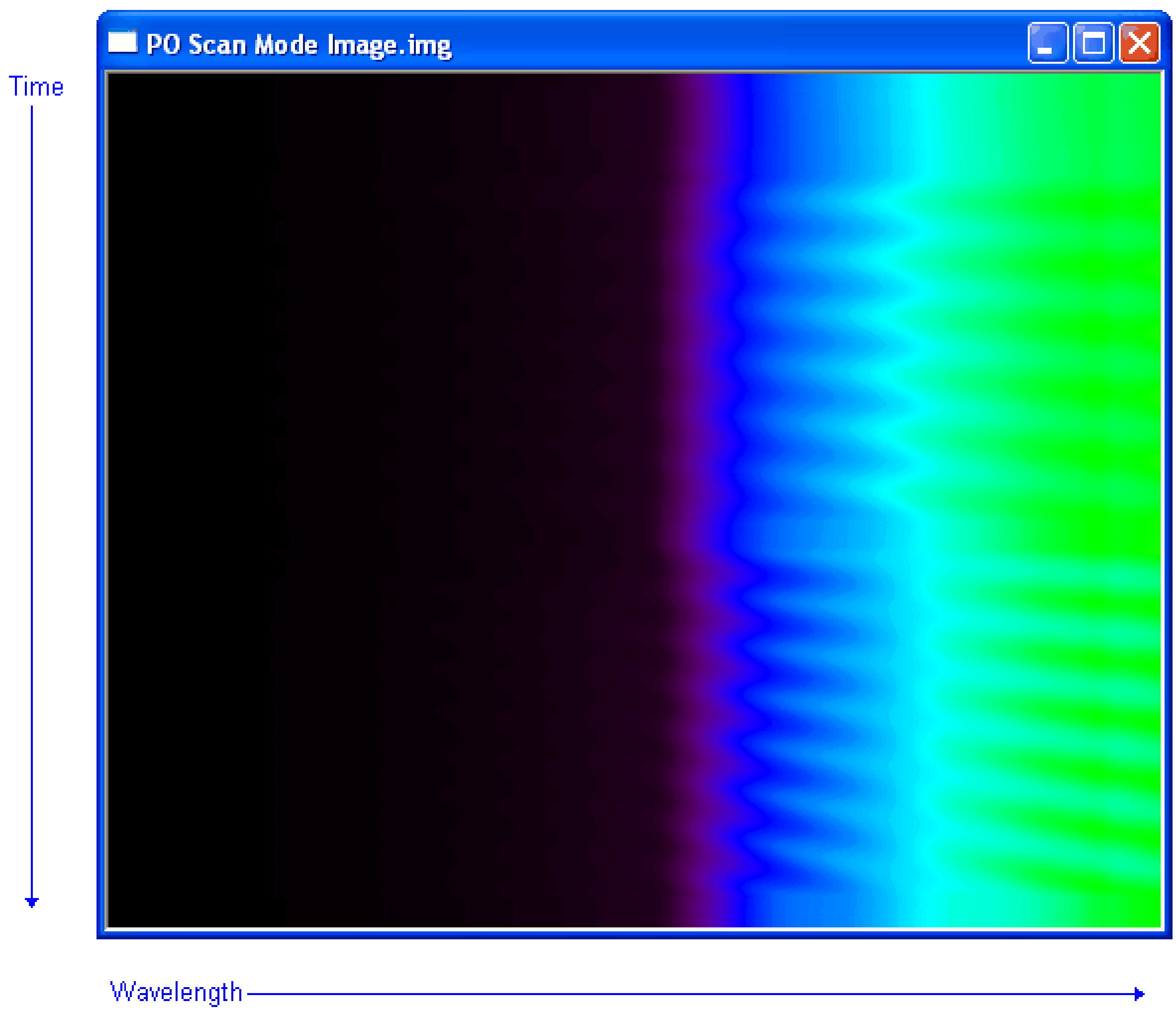


Click the ***OK*** button at the bottom of the ***Advanced Acquisition Options*** window to return to the ***BandiT Temperature Acquisition*** window.

Next click the ***Start*** button. That will start acquisition. A typical kSA BandiT spectra is shown below. This spectra shows the collected light intensity at each wavelength in the range from 870nm-1400nm. Spectra in this range is typical for monitoring the temperature of GaAs, Si, and InP substrates.



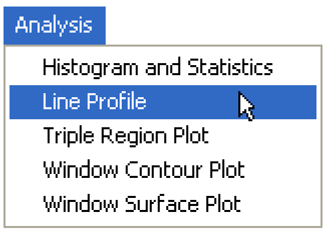
At the end of acquisition, locate and click the BandiT Scan Mode Image window. (The following image has had IDL 40 [palette](#) applied to it.)



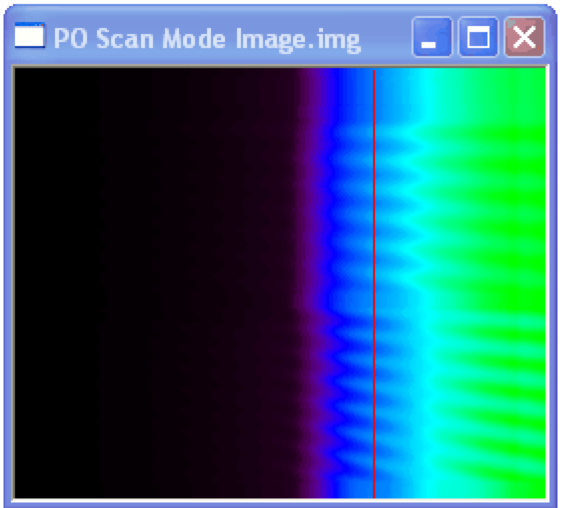
Looking from left to right, the absorption edge of the substrate material corresponds to the color change from black (above the band gap where absorption occurs) to violet, blue and green (below the band gap where the sample is transparent).

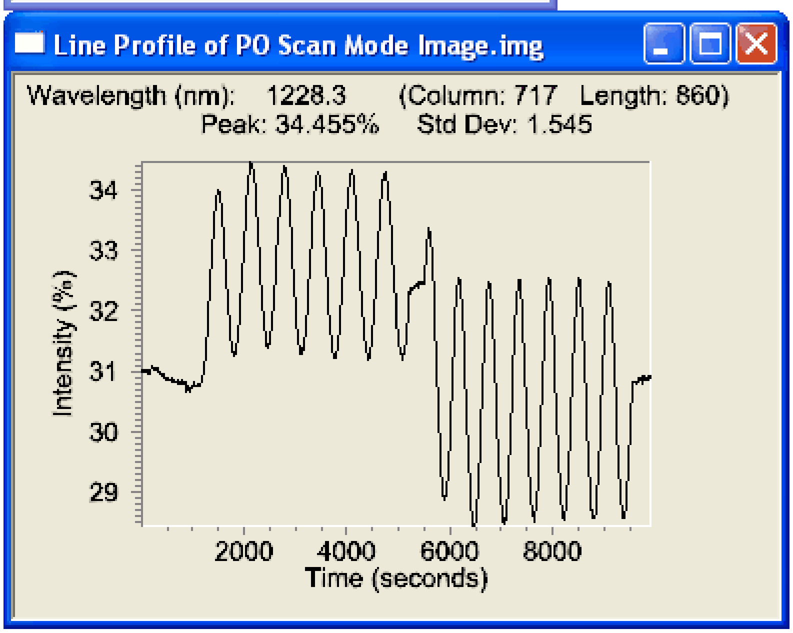
Looking from the top to the bottom of the image (in the colored area), first notice that there are no oscillations. That's because all shutters were closed. Then a shutter was opened and some growth occurred (oscillations data begins about a sixth of the way down). Then the shutter was closed (about half way down). Then a different shutter was opened and growth occurred at a different rate (different rate and amplitude of oscillations). This is easily seen with a Line Profile, which is needed for analysis.

From the ***Analysis*** menu, select Line Profile.



With a vertical ***Line Profile*** of a Scan Mode Image, the plot shows the time-dependence of intensity at each wavelength within the range of the spectrometer.



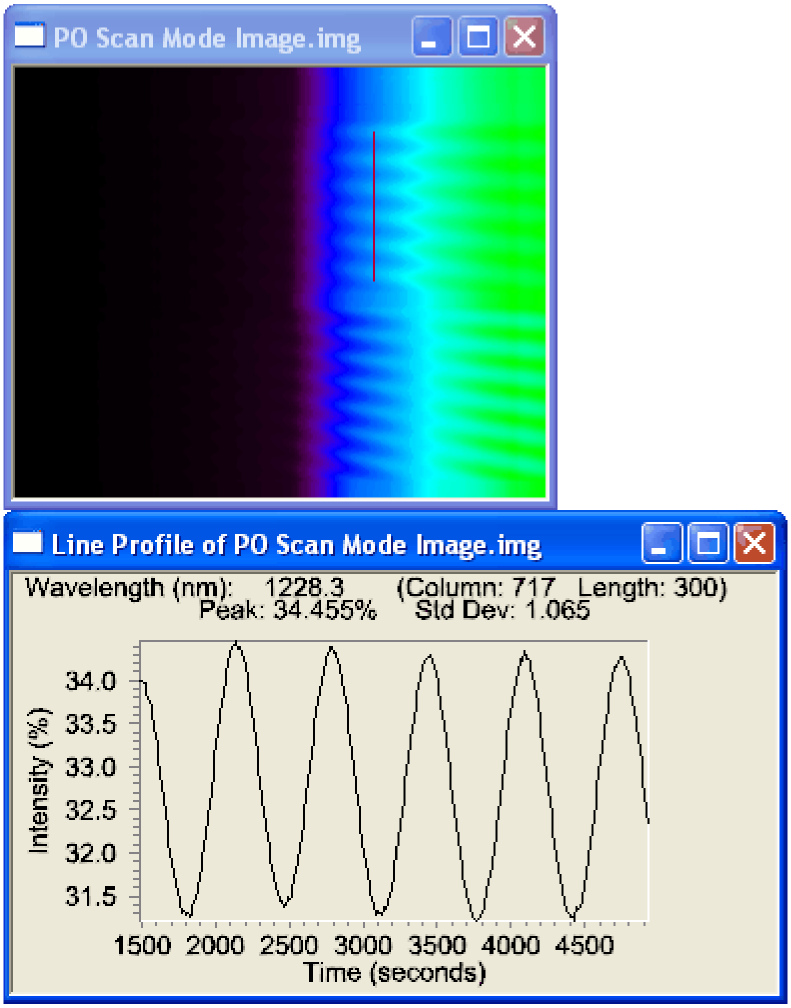


For the data run shown here, deposition of GaAs on AlGaAs began at approximately 1150 seconds. Growth was then stopped at 5200 seconds, and commenced again at 5500 seconds with the deposition of AlGaAs on GaAs. Deposition of the AlGaAs layer stopped at 9600 seconds.

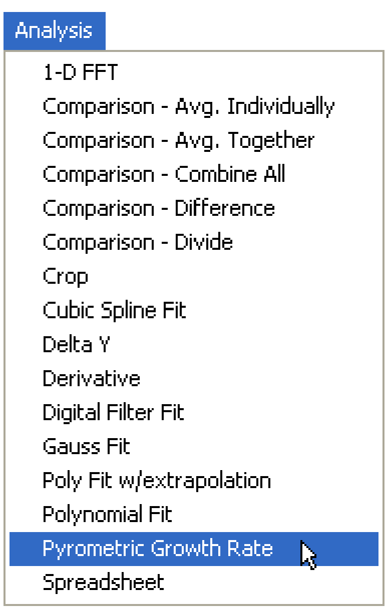
The ***Line Profile*** is at wavelength 1228 nm. Simply move the vertical ***Line Profile*** across the image to see similar data at different wavelengths. In doing so, however, the range of the Intensity axis will change.

For growth rate determination, choose the largest intensity amplitude possible: as above, the range between maximum and minimum may only be a couple of percentage points. It is also important only to choose one set of oscillations (so that it only measures one deposition process) and does not contain any data when growth was not occurring. This can be done in two ways:

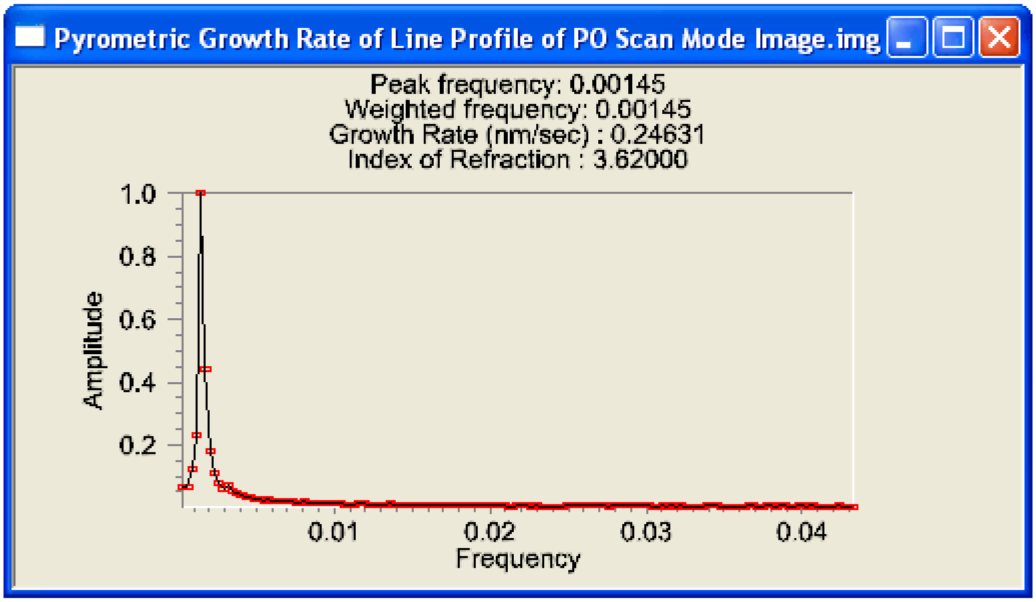
- Place the cross-hairs on the ***Line Profile*** window to the immediate left of the oscillation data. Right-click and select ***Set X Min***. The graph will be cropped to that value. Right-click on the value to the immediate right of the oscillation data and select ***Set X Max***. Then the ***Line Profile*** will only include the oscillation data.
- Reduce the size of the line itself on the ***Scan Mode Image***, which automatically adjusts the ***Line Profile***. For example, the portion selected below is the GaAs growth rate, a subset of the full data set.



Next, with the ***Line Profile*** window highlighted, select the ***Pyrometric Growth Rate*** from the ***Analysis*** menu.



Right-click the ***Pyrometric Growth Rate*** window and select properties. In the plot below, the Index of Refraction parameter is set to 3.62, markers are placed on the data Series, and Discrete Fourier Analysis (DFT, recommended) is chosen in the Fourier Transform plot property.



The growth rate is determined from this equation:

$$G = \frac{1}{T} \cdot \frac{\lambda}{2\eta}$$

where

G = growth rate

T = period (determined by the frequency analysis of the acquired data set)

λ = wavelength (depends on the placement of the line in the *Line Profile*)

η = index of refraction

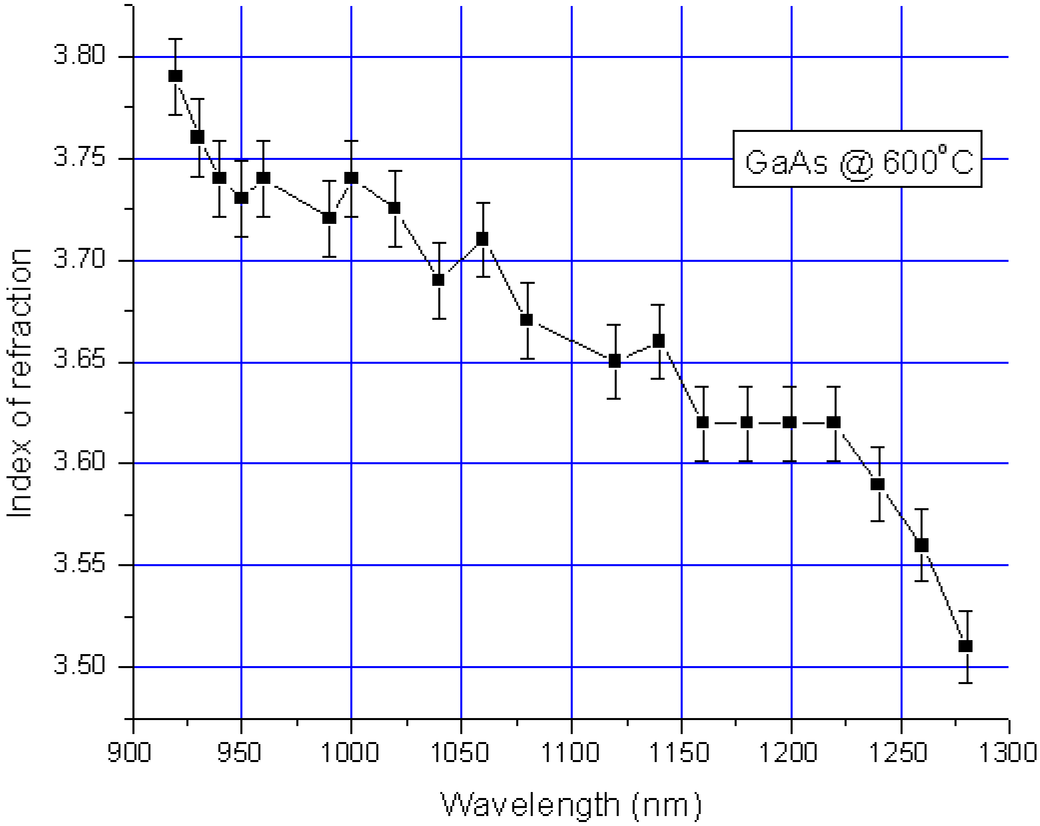
This is because the emitted radiation reflects off the interface between the film and the substrate and interferes with radiation emitted directly outward from the surface. A peak intensity occurs whenever the optical path length of the film is a multiple of the wavelength of light. That is, a peak in detected intensity occurs at thickness intervals of (λ/2η), where η is the index of refraction of the film. It follows that the oscillation period will be

$$T = \frac{1}{G} \cdot \frac{\lambda}{2\eta},$$

which is trivially manipulated to give the equation above.

Only the index of refraction (η) is unknown. A direct way to determine η is by taking simultaneous pyrometric interference data and RHEED oscillation data. By determining *G* from RHEED and *T* from the pyrometric interference data, one can solve for η. Furthermore, one can determine the dispersion curve for η at a given wavelength by solving for η at every wavelength.

A dispersion curve for η for GaAs is shown below (determined using the methodology described here) in the wavelength range 900-1280nm.



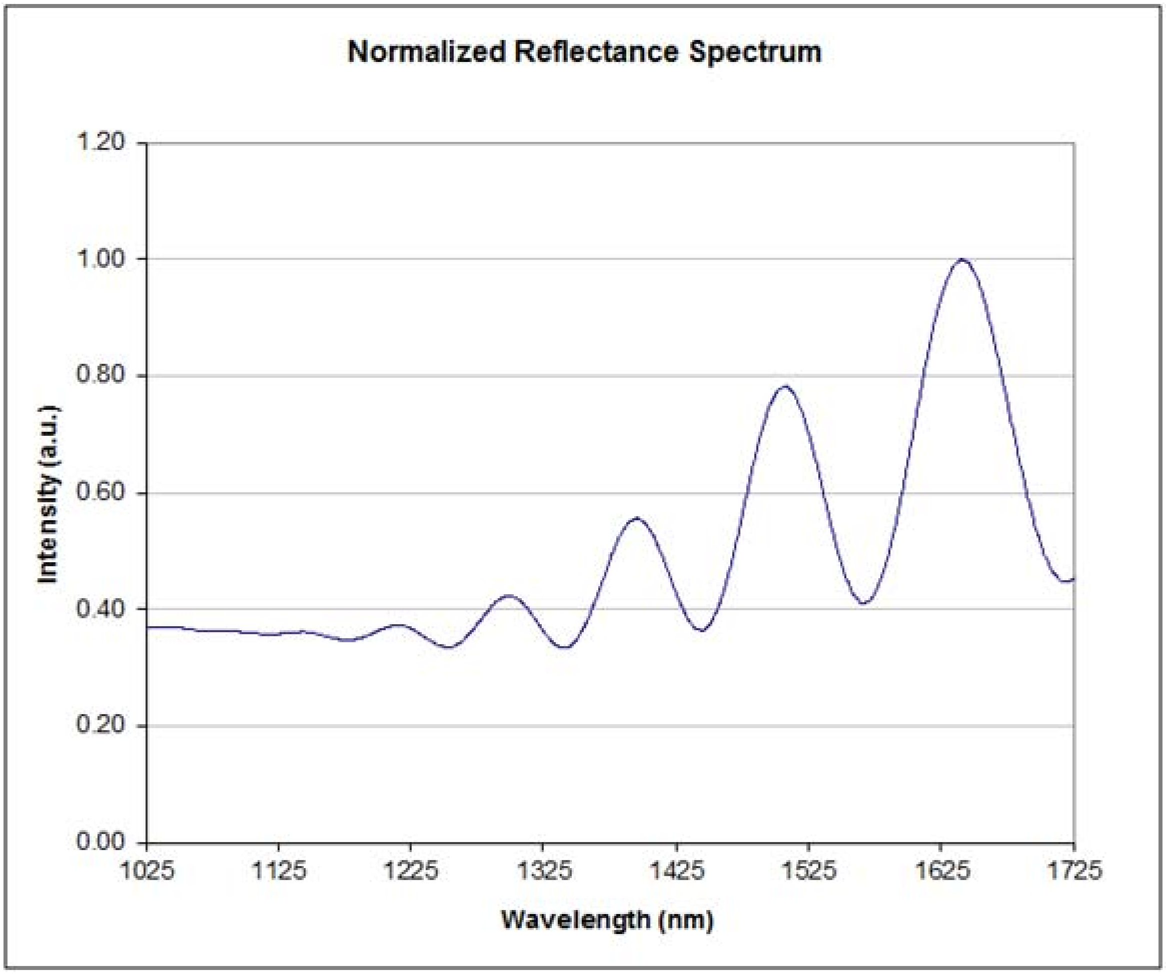
Once η is determined for a given wavelength and temperature, then the equation above may be used to accurately determine growth rate with BandiT. Absolute rates accurate to within 2-3% should be obtainable.

How-To Measure Film Thickness

In addition to band edge thermometry, BandiT software has the capability of using the interference patterns observed in the reflectance spectrum from a thin film to obtain thickness information. (Note that to see such oscillations, there needs to be a refractive index difference between the film and substrate, preferably with that of the film being higher.) This can be exploited to determine a film's thickness by comparing the wavelengths of the extrema of these oscillations, provided the index of refraction is known as a function of wavelength. This is to be distinguished from the use of temporal reflectivity oscillations over a narrow wavelength range to calculate film thickness during growth.

1. Technical Background

As one approaches the absorption edge from the below-gap direction (i.e. long wavelengths), absorption starts to become significant and the spectral oscillations therefore become damped. Thus these measurements are best done as far below gap as is practical (i.e. at wavelengths greater than the absorption edge wavelength).



The image above shows a plot of the below-gap portion of a normalized reflectance spectrum from a GaAs film. It has been normalized using a reference spectrum in order to remove the effects of the spectral variation of the light source output. The spectrometer output has also been corrected to yield a flat response as a function of wavelength. The spectrum has been scaled so that the maximum value is unity. In the below-gap portion of the spectrum (where the film's absorption is small), the film thickness can be determined using the following expression:

$$d_i = \frac{\lambda_i}{4\pi n_i}\left[m\pi + \delta\right]$$

In this equation:

$\boldsymbol{\lambda_i}$ - are the wavelengths of the extrema, which are found from the zero crossings of the first derivative of a digitally smoothed spectrum.

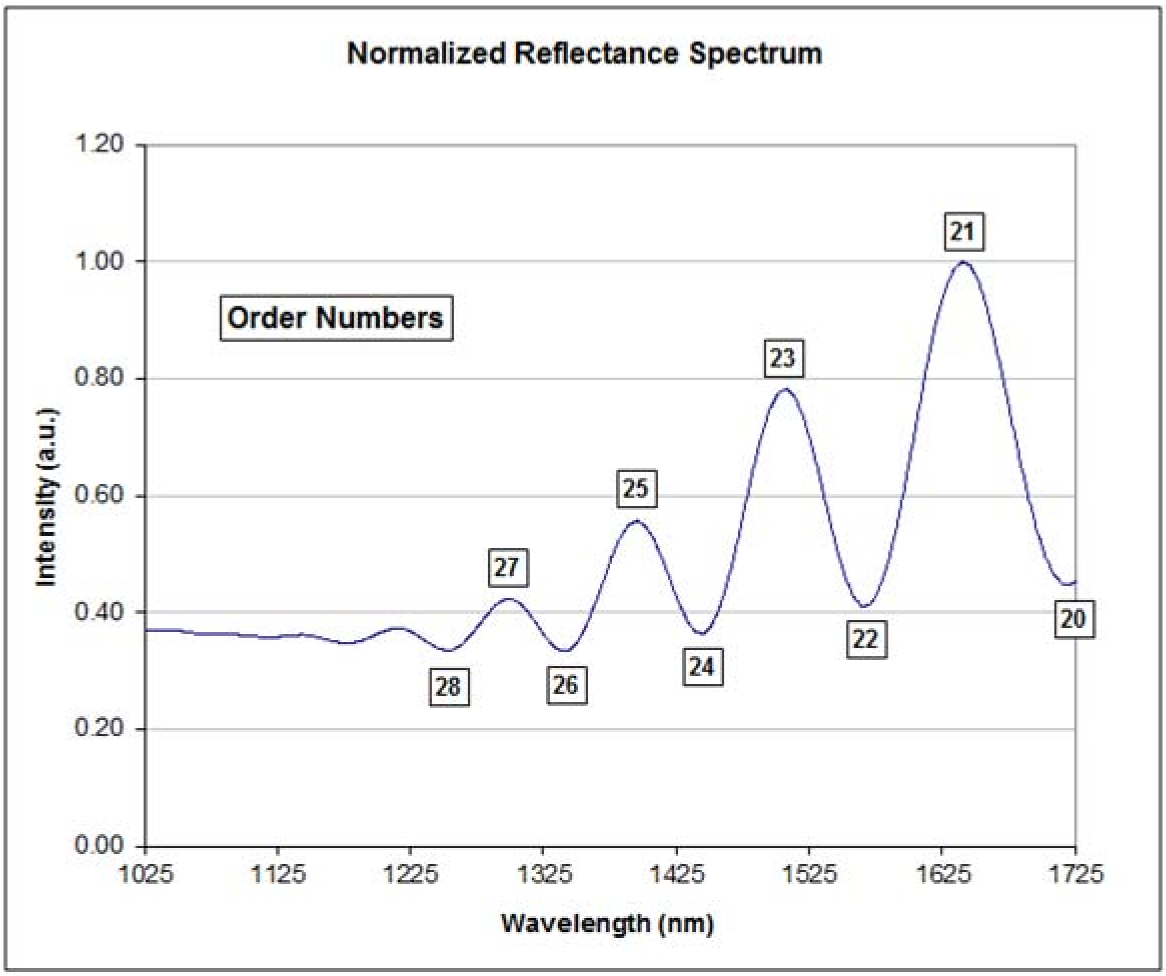
$\boldsymbol{n_i}$ - represents the indices of refraction at those wavelengths

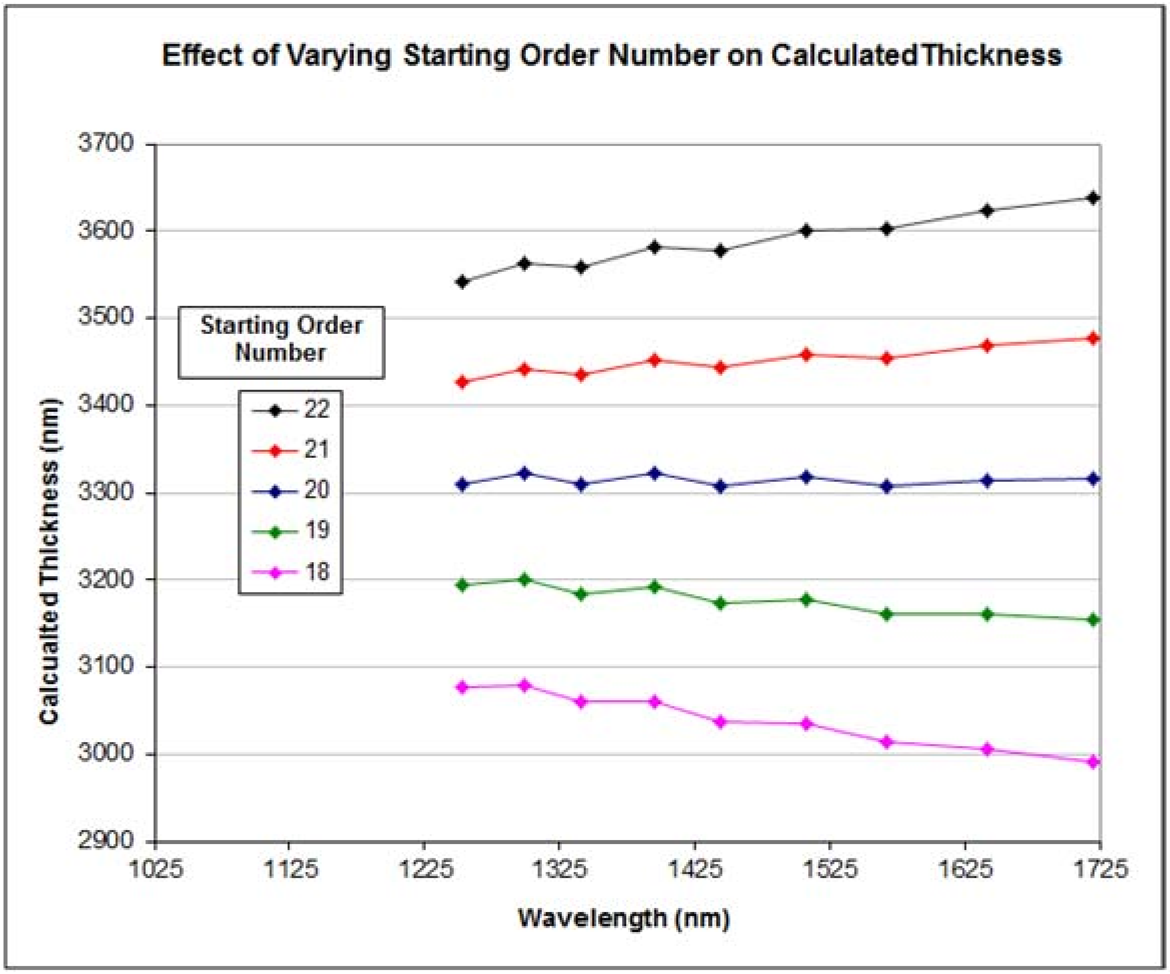
$\boldsymbol{d_i}$ - the resulting thickness values.

Thus, a thickness value is obtained for each extremum. Note that this method requires only the wavelengths of the interference peaks and valleys, and therefore does not rely on knowledge of absolute reflectance values. It assumes the measurements are done at normal incidence, but nonnormal incidence can be accounted for by scaling the results as described in the next section of this document.

m - represents the integer order number at each extremum. As can be seen in the annotated spectrum below, the order increases by unity (i.e. the phase changes by π) from one extremum to the next with decreasing wavelength. The order numbers are calculated using an iterative method by selecting the set of m values that minimizes the spread in the calculated thickness values (see graph below).

δ - represents a phase shift due to the film/substrate interface. Likewise, the optimum delta value is determined by minimizing the spread in the individual thickness values. These values are averaged to get the final thickness result, with the standard deviation giving a figure of merit. As can be seen in the graph below, the best figure of merit (i.e. the least variation in the calculated thickness using all the extrema) is obtained using a starting order of m=20 (blue curve).



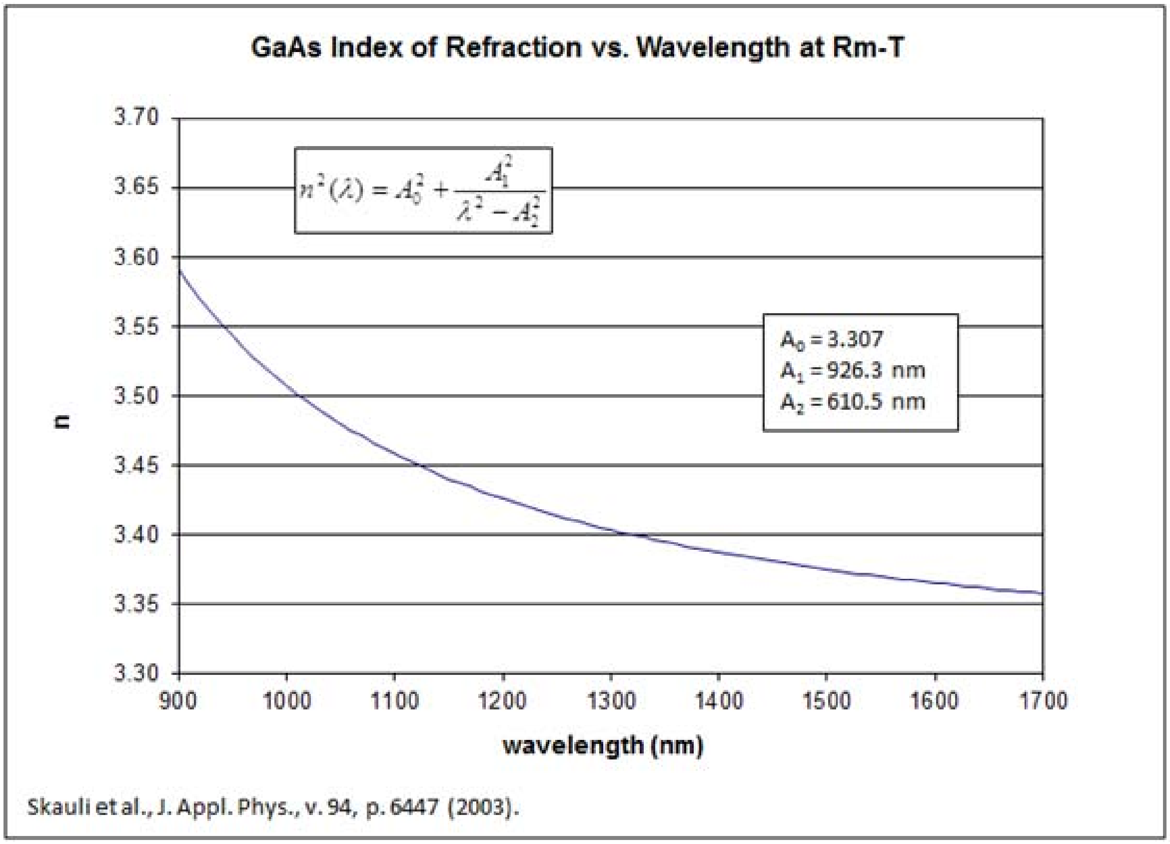


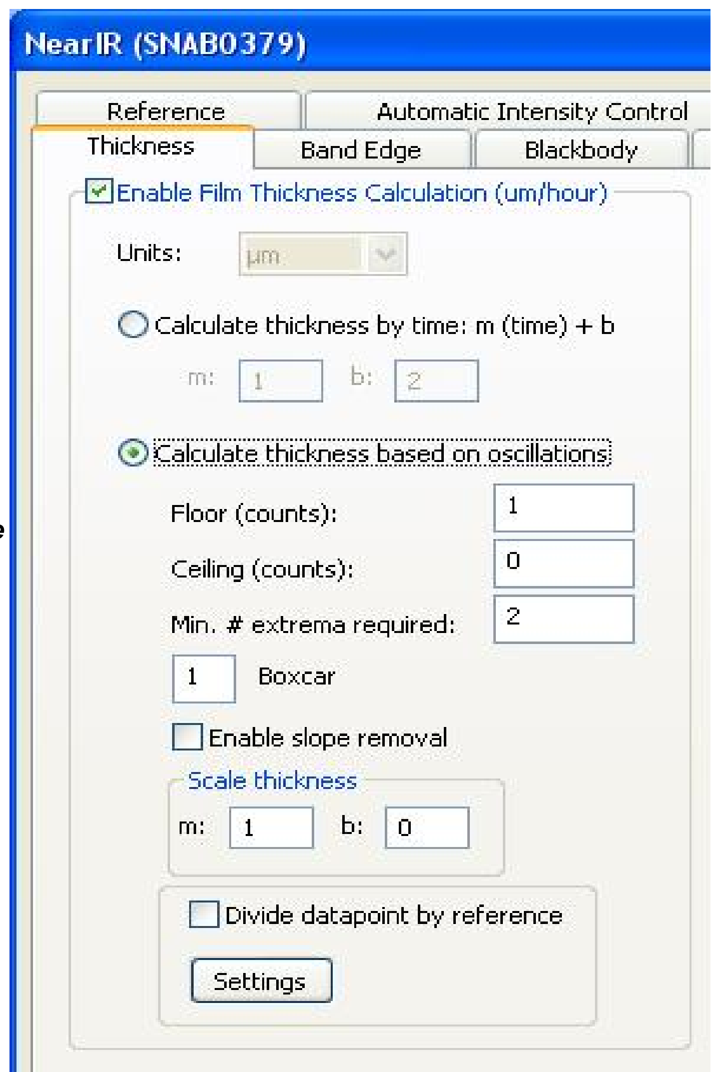
The index of refraction at each extremum is calculated using a Sellmeier dispersion curve of the form given in the equation below. This form has been found to work well over the wavelength range of interest.

$$n^2(\lambda) = A_0^2 + \frac{A_1^2}{\lambda^2 - A_2^2}$$

This has three free Sellmeier parameters: A_0(dimensionless), A_1 (nm), and A_2 (nm).

A non-linear least squares fitting routine is used to extract these parameters from a given dispersion curve. The image below shows an example of such a curve for GaAs at room temperature. Note that these values are temperature dependent; therefore for best accuracy a dispersion curve corresponding to the film growth temperature should be used.





2. Calculating and Collecting Film Thickness Data

Open the ***BandiT Temperature Acquisition*** Mode from the ***Acquire*** menu or by using the  icon on the toolbar.

Click the ***Config*** button to open the Configuration Options dialog and select the Thickness tab.

Tick the ***Enable Film Thickness Calculation*** box so that the data will be calculated and collected and then select the method of calculation, either by elapsed time - ***Calculate thickness by time*** - or by spectral interference oscillations - ***Calculate thickness based on oscillations***.

If you select ***Calculate thickness by time*** enter the values for ***m*** and ***b***

m: Growth rate in units/hr.

b: Starting thickness in the specified units.

If you select ***Calculate thickness based on oscillations*** enter the values for these parameters:

Floor (counts) - Any raw spectra which have maximum intensity below this noise floor value will be ignored. This is intended to reject spectra which contain only noise. *Default: 1,000 cts.*

Ceiling (counts) - Any raw spectra which have maximum intensity above this noise ceiling value will be ignored. This is intended to reject spectra which might saturate the spectrometer. *Default: 60,000 cts.*

Min. # extrema required - Any spectra having fewer than this number of extrema will be ignored. *Default: 4.*

Boxcar - Specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the thickness result (must be odd). For example, a setting of N results in each data point being averaged with the (N-1)/2 neighboring data points on either side. *Default: 1 (i.e. no smoothing).*

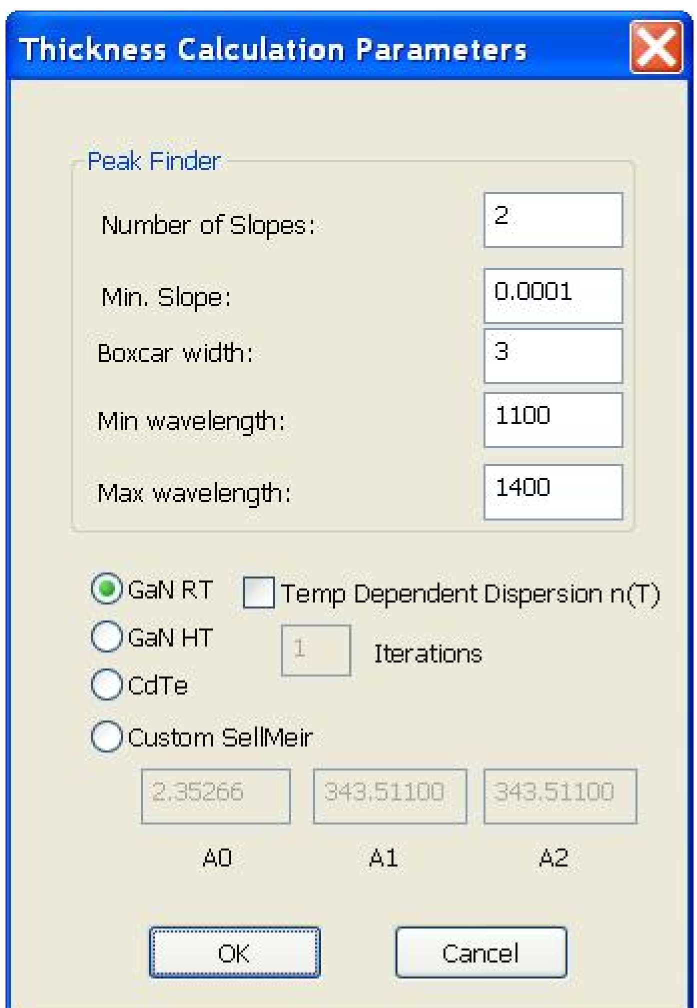
Enable slope removal - If this is enabled, the software will attempt to remove any background slope over the wavelength range specified in the Settings dialog. This is intended to improve the accuracy of the extrema wavelength measurement by providing a flat baseline.

Scale thickness - Performs a linear scaling of the thickness with scaling factor m and offset b. The scaled thickness is obtained via the equation: t' = m * t + b.

m: Scaling factor (dimensionless). *Default: 1.*

b: Thickness offset in the specified units. *Default: 0.*

Divide datapoint by reference - If this is enabled, the raw spectrum will be divided by a saved reference spectrum. This is intended to normalize the spectrum to remove the effects of spectral variation of the light source output. This provides a flatter baseline and makes determination of the wavelengths of the extrema more accurate. Reference spectra can be acquired from any surface giving a diffuse reflection. Commonly used materials include sapphire wafers(SSP) and PBN. Note that it is critical that the reference be taken at the same lamp power that will be used during data acquisition, as the shape of the lamp's output spectrum is strongly power-dependent. The desired reference file can be specified in the Reference tab in the Configuration Options.



Click the ***Settings*** button to enter the settings for analysis of the spectra. This opens the Thickness Calculation Parameters dialog box as shown below.

Number of Slopes - Specifies the minimum number of consecutive data points required with slope having the same sign (either increasing or decreasing) before a potential extremum is considered valid. The purpose of this setting is to filter valid extrema from background noise. *Default: 20.*

Min. slope - Specifies the minimum slope required before a potential extremum is considered valid. The purpose of this setting is to filter out small extrema which may be due to background noise. *Default: 5E-5.*

Boxcar - Specifies the number of points used by the digital smoothing filter that is applied to the spectrum before analysis (must be odd). For example, a setting of N results in each data point being filtered using the (N-1)/2 neighboring data points on either side. *Default: 65.*

Min wavelength - Minimum wavelength for analysis (nm).

Max wavelength - Maximum wavelength for analysis (nm).

Select the dispersion curve corresponding to the film material. The user has the option to select from a preset list, or manually enter the three Sellmeir parameters A0 (dimensionless), A1 (nm), and A2 (nm). For more information see the Technical Background section earlier in this How-To Guide.

When all the required parameters have been set, close the Configurations Options dialog boxes using the OK button.

Use the View Menu to open some Real-Time Charts to see the acquisition of the data you require. You might want to open:

- Real-Time Thickness Spectra - which shows the thickness intensity against wavelength, the normalized reflectance spectrum, similar to the first plot in this How-To Guide
- Real-Time Thickness (Time) - which shows a plot of thickness against elapsed time
- Real-Time Thickness (LED) - which gives a numeric read-out of calculated thickness

Note that the saved data files will contain the thickness (in the specified units), and the fit sigma (in nm), as described in the technical background section, which is a figure of merit of the quality of the fit.

Acquisition

Acquisition Modes

Acquisition Modes

BandiT has a number of Acquisition modes which can be access via the Acquire menu and also from the BanditT toolbar.

BandiT Temperature - toolbar icon  - used to acquire BandiT temperature

BandiT Dark Background - toolbar icon  - used to take a dark background before any other acquisition

BandiT Reference - toolbar icon  - used to take a reference scan when using a Visible Spectrometer

Bandit Roughness Calibration - used to calibrate the system for roughness measurements

Bandit Pyrometry Calibration - used to calibrate the temperature acquired by Pyrometry to the real BandiT temperature

Blackbody Calibration - used to calibrate the temperature acquired by Blackbody measurements

Phase Delay Selection - toolbar icon  - used to set the phase delay for a sample on a rotating platen

BandiT Temperature Scan - used by k-Space to configure BandiT calibration files

BandiT Substrate Calibration - used by k-Space to configure BandiT calibration files

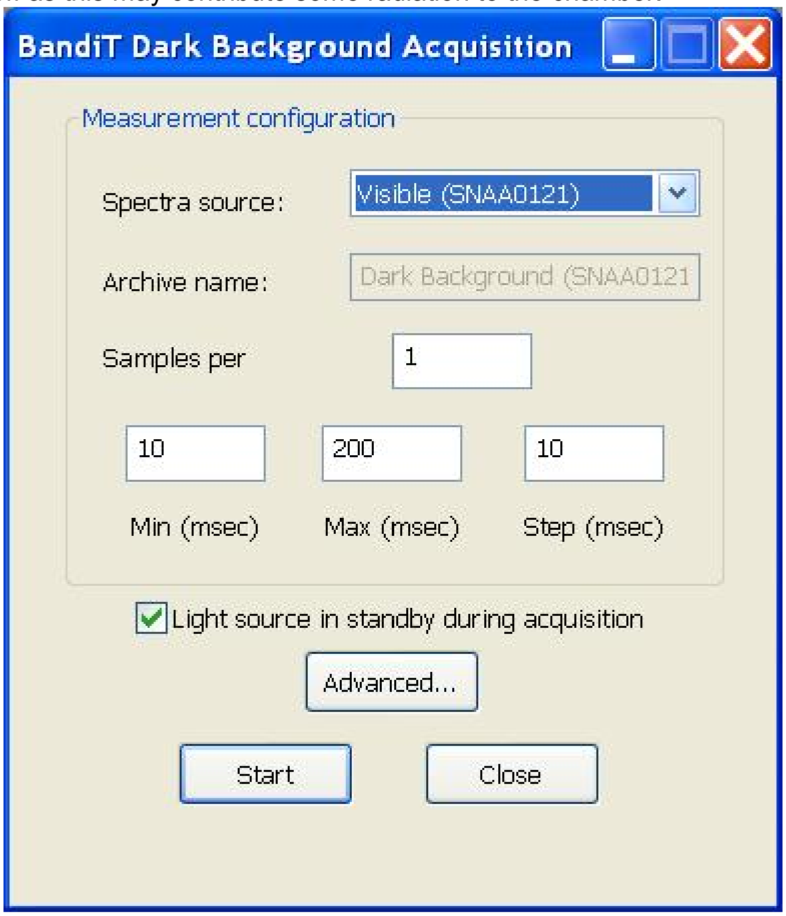
Flat Field Correction - used to create a flat field correction file specific to each Spectrometer for use in Blackbody Pyrometry - this file will normally be provided by k-Space when the instrument is shipped

Spectrometer Calibration - used to calibrate the Spectrometer - this is normally done by k-Space before the instrument is shipped and it is not usually necessary for users to do this.

BandiT Dark Background

Available from the  icon on the toolbar or under the ***Acquire*** menu, use the ***BandiT Dark Background*** acquisition mode to obtain a calibration of the spectrometer dark background at various spectrometer integration times. Taking a dark background at the various spectrometer integration times results in clean, noise-free spectra for analysis because the dark backgrounds will be subtracted automatically from the live spectra. It is important to include all the integration times that you will want to use, as these are the only ones that will be available in the BandiT Temperature Acquisition mode.

It is important that all light is eliminated from the chamber when the Dark Background is acquired. Remove the fiber out of the SMA Fiber Input and cover the SMA fitting or cover the detector so no light can get into the spectrometer. Make sure that the Light Source is not switched on or is in standby mode and that the substrate heater is turned off as this may contribute some radiation to the chamber.



Note: These are the default values and should be sufficient for most systems.

Specify:

Spectra source – this is the spectrometer. If more than one spectrometer is set up on the system, choose the one that will be used for temperature acquisition.

Archive Name - The archive is named automatically by the software and is shown here for reference.

Samples per - Samples per datapoint. Typically this is set at 1.

Min (msec) -- the minimum desired exposure time (in milliseconds) for the spectrometer. Typically this is 10 msec, although for fast data acquisition, a minimum of 5 msec may be entered. Values below 10 msec may result in too low a signal for proper analysis.

Max (msec) – the maximum desired exposure time (in milliseconds) for the spectrometer. Typically this is 200 msec, although longer exposure times may be needed. Note that as exposure times get longer, the background noise also grows, and noisy spectra may result when choosing very long exposure times (> 300 msec).

Step (msec) – the exposure time step size for the spectrometer, in milliseconds. A step size of 10 msec will yield available spectrometer exposure times in intervals of 10 msec.

For example, consider the following parameters:

Min exposure time = 10 msec

Max exposure time = 200 msec

Step = 10 msec

As a result, available spectrometer integration times for temperature acquisition are (in msec) 10, 20, 30, …, 190, 200.

Tick ***Light Source in standby during acquisition*** - to ensure that the light source is in standby mode to eliminate as much light as possible in the chamber.

Click ***Advanced*** to open the Advanced Acquisition Options to check BandiT I/O Settings.

Click the ***Start*** button and kSA BandiT will acquire and store a Spectrometer Dark Background, subtracting it automatically from the live spectra that will be used for acquiring data.

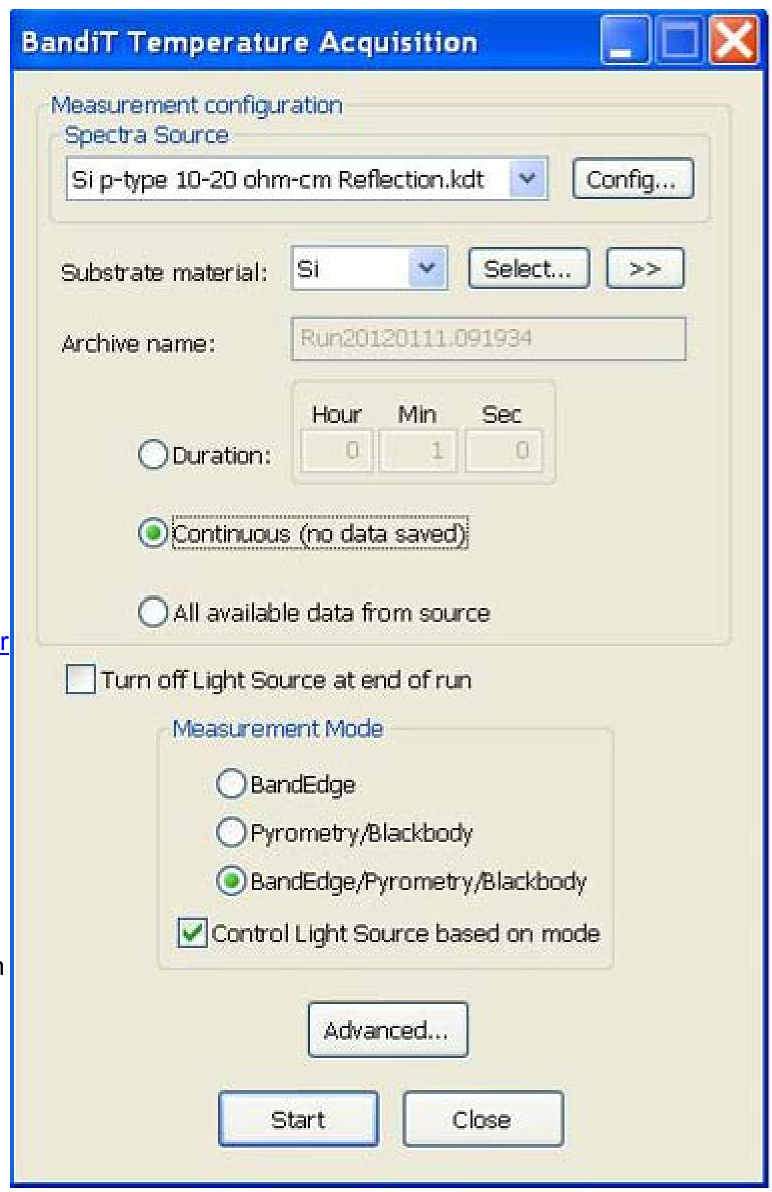
General Note:

Entering a *Min*, *Max*, and *Step* defines the possible exposure times for acquisition. Typically, the values shown above yield plenty of range and resolution for proper temperature measurement.

Single Wafer

BandiT Temperature

The most common mode of operation for the kSA BandiT system is the ***BandiT Temperature*** mode, available under the ***Acquire*** menu or by using the  icon in the toolbar. In this mode, substrate temperature may be acquired continuously without data storage, or temperature and (optionally) spectra data may be acquired for a user-selectable amount of time.



Specify Measurement configuration:

Spectra source – this can be a live spectrometer, multiple spectrometers, or a previously acquired *.kdt data file. Selecting a *.kdt file allows for playback of a previously acquired data set.

When choosing to use a *.kdt data file - open the file first only then is the radio button ***All available data from source*** enabled.

> To perform ***Continuous (no data saved)*** acquisition, check the ***Loop*** checkbox in the BandiT Spectra Acquire Source, found by right-clicking the *.kdt file and selecting ***Properties***. Note that the *Loop* button in the *.kdt toolbar only affects playback, not acquisition. So it does not matter whether it is clicked or not.

Click ***Config*** - to open the Configuration options menu where all the parameters for band edge calculation, pyrometry, automatic intensity control etc. are specified

Substrate material – use the drop-down list to choose the type of substrate. Then click the ***Select*** button to view the material table for that material, see Select Substrate Material for more details. At any time, click the **>>** button to view the selected substrate material details in the acquisition window itself:

Archive name – is editable in the Document Generation tab of the Advanced Acquisition Options, selected by clicking the ***Advanced*** button.

Choose one of:

> ***Duration*** – amount of time in hours, minutes and seconds for acquisition
>
> ***Continuous (no data saved)*** – acquire data continuously without storing any data. Typically, this mode is used simply to see the temperature and not the time evolution of the temperature.
>
> ***All available data from source*** – only available when *.kdt files are selected as the *Spectra source*, above. This option allows reprocessing of a file when it is selected as the source.

Choose Measurement Mode:

> ***BandEdge*** – kSA's band-edge thermometry
>
> ***Pyrometry*** – generally inferior to kSA's band-edge thermometry, but the band-edge technique often fails when depositing a very absorbing layer, so the pyrometry technique is available for such situations. Do not use a light source when using this technique as it is signal-level dependent and any light source will add potentially variable signal and affect the temperature conversion and lead to an improper temperature reading.
>
> ***Both BandEdge and Pyrometry*** – for dual measurement. This is recommended only for acquiring via transmission as any light source will add potentially variable signal and so affect the temperature conversion, which will lead to an improper temperature reading.

Tick the ***Control Light Source based on mode*** checkbox to ensure that the light will only be on during *BandEdge* and will not be on (i.e., in standby mode) with either of the two pyrometry modes above.

Tick the ***Turn off Light Source at end of run*** checkbox to turn off the light source when the run ends.

Click:

> ***Advanced*** – to access the Advanced Acquisition Options to specify BandiT I/O settings, Configurable Temperature Output, and Triggers

Click the ***Start*** button to begin acquisition. During acquisition, the ***Start*** button becomes a ***Pause*** button. Pausing acquisition causes the same button to become a ***Resume*** button.

BandiT keeps track both of Elapsed Time and of Adjusted Elapsed Time. Adjusted elapsed time captures time spent only in acquisition (so it is shorter than Elapsed Time if the ***Pause*** button was clicked during acquisition). When plotting data over time (in BandiT Computed Data plots), select Elapsed Time or Adjusted Elapsed time using the Data tab (found by right-clicking the plot and selecting *Properties*.)

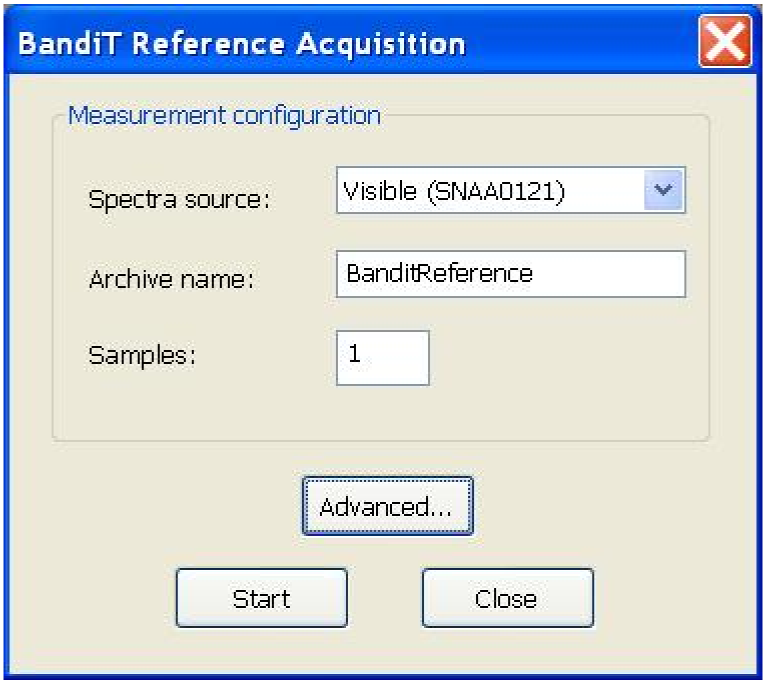
Click the ***Close*** button to close this dialog.

BandiT Reference

Available from the 

icon on the toolbar or from the ***Acquire*** menu, use the ***BandiT Reference Acquisition*** mode to obtain a reference for acquiring via a Visible spectrometer. Learn more about the step-by-step procedure for using this acquisition mode in the How-To Measure Temperature: BandiT Visible help topic.

The BandiT Reference file records the spectrum of the lamp intensity so that this can then be used to normalize the acquired spectrum. This provides a flatter baseline and makes determination of the wavelengths of the extrema more accurate. Reference spectra can be acquired from any surface giving a diffuse reflection. Commonly used materials include sapphire wafers(SSP) and PBN. Note that it is critical that the reference be taken at the same lamp power that will be used during data acquisition, as the shape of the lamp's output spectrum is strongly power-dependent.



Specify Measurement configuration:

Spectra source – this should be a visible spectrometer as there is no need to take a reference for NearIR acquisition.

Archive name - this can be entered manually here or use the Document Generation tab in the Advanced Acquisition Options (found by clicking the *Advanced* button) to have the system generate one automatically.

Samples - one sample is usually sufficient.

After specifying the parameters, click ***Start.***

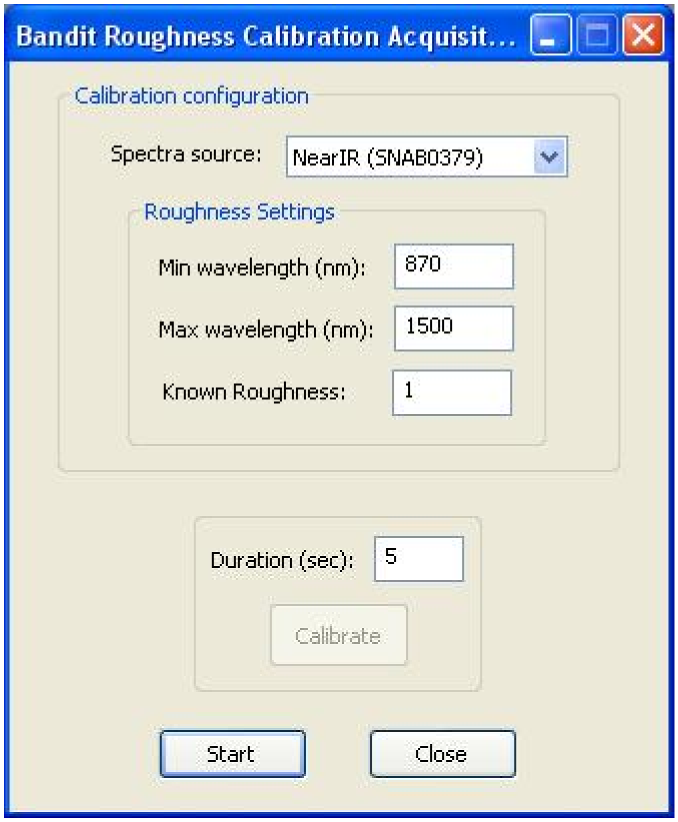
When acquisition is complete, the reference file opens (e.g., "BanditReference.bsrf" based on the name given above) and should be saved (if not already automatically saved via the Document Generation tab selections).

Bandit Roughness Calibration

The ***Bandit Roughness Calibration*** Acquisition mode, available under the Acquire menu, is used to calibrate the system to allow collection of roughness data for samples. Typically an increase in roughness of a sample increases the diffuse scatter of light collected into the spectrometer and the roughness calibration assigns a particular roughness metric to the above gap intensity. Calibration of at least two points is needed with NIST roughness standards. Once calibrated BandiT can provide a qualitative metric for surface roughness.

Specify:

> ***Spectra source*** - select the spectrometer to use
>
> ***Min. wavelength*** - the minimum wavelength to use when calculating roughness
>
> ***Max wavelength*** - the maximum wavelength to use when calculating roughness
>
> ***Known Roughness*** - enter known roughness
>
> ***Duration (sec)*** - the time that the system should use for calibrating the roughness

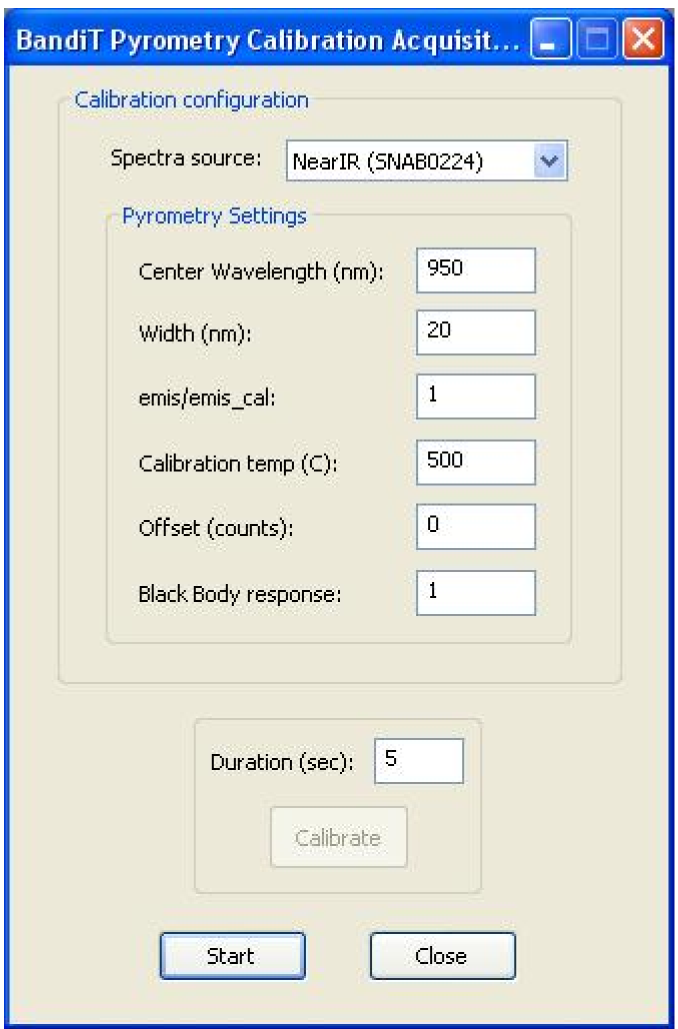


Click:

> ***Start*** - to start the acquisition. This also enables the Calibrate button.
>
> ***Calibrate*** - to start the calibration which will run for the number of seconds specified. During calibration "Calibrating" is displayed in the taskbar.

When calibration is complete click ***Stop*** to stop the acquisition mode and ***Close*** to close the window. The calibration process sets the ***Roughness Scale Factor*** in the Configuration Options Roughness tab.

Bandit Pyrometry Calibration



The ***Bandit Pyrometry Calibration*** Acquisition mode, available under the ***Acquire*** menu, is used to calibrate the system for BandiT Pyrometry.

BandiT Pyrometry mode simulates a single wavelength conventional pyrometer (used without a light source), by converting the black-body radiative intensity from the sample into a temperature reading. Note that such intensity is usually only significant in the Near IR wavelength range, so the corresponding spectrometer must be used. More information about how to perform the system calibration can be found in BandiT Pyrometry.

Select ***BandiT Pyrometry Calibration*** from the ***Acquire*** menu to open the dialog box shown on the right.

Select the ***Spectra Source*** using the drop down menu.

Specify ***Pyrometry Settings***:

> ***Center Wavelength (nm)*** – this is the material-dependent primary wavelength that BandiT should search for when looking for black-body radiation
>
> ***Width (nm)*** – this is the overall width around the ***Center wavelength*** that BandiT will search for black-body radiation. For example, with a width of 100, the algorithm will search 50 nm on either side of the ***Center wavelength*.**
>
> ***emis/emis_cal*** – this is the material emissivity divided by the emissivity calibrated. The general rule is that if the system is calibrated based on the same temperature as you are going to measure, then this value is 1. If calibrating using a different temperature, then this parameter will have another value.
>
> > For example, when calibrating the system using the procedure outlined in BandiT Pyrometry, this number is 1. That's because the same material (say GaAs with emissivity 0.68) used in calibrating the pyrometer will be the same material measured via Pyrometry (so 0.68/0.68 = 1) at the temperature (580°C). Other users may calibrate using blackbody emissivity, which is typically rounded up to one. Then emis_cal = 1 and the measured emissivity in the chamber (say of GaAs) is another number (say 0.68), meaning emis/emis_cal is 0.68/1 = 0.68.
>
> ***Calibration temp (C)*** – this is the temperature within the chamber and should also be the temperature as read by using BandiT's transmission mode (in the Real-time BandiT Temperature window).
>
> ***Offset (counts)*** – this is a tweaking option, and typically should be left at 0
>
> ***Black Body response*** – each spectrometer has a slightly different response as a function of intensity. For NearIR spectrometers, this value is very close to one. For visible spectrometers, this value is close to 0.5. As a part of calibrating the system, a k-Space engineer provides this value.
>
> ***Duration (sec)*** - the time that the system should use for calibrating the pyrometry temperature.

Click:

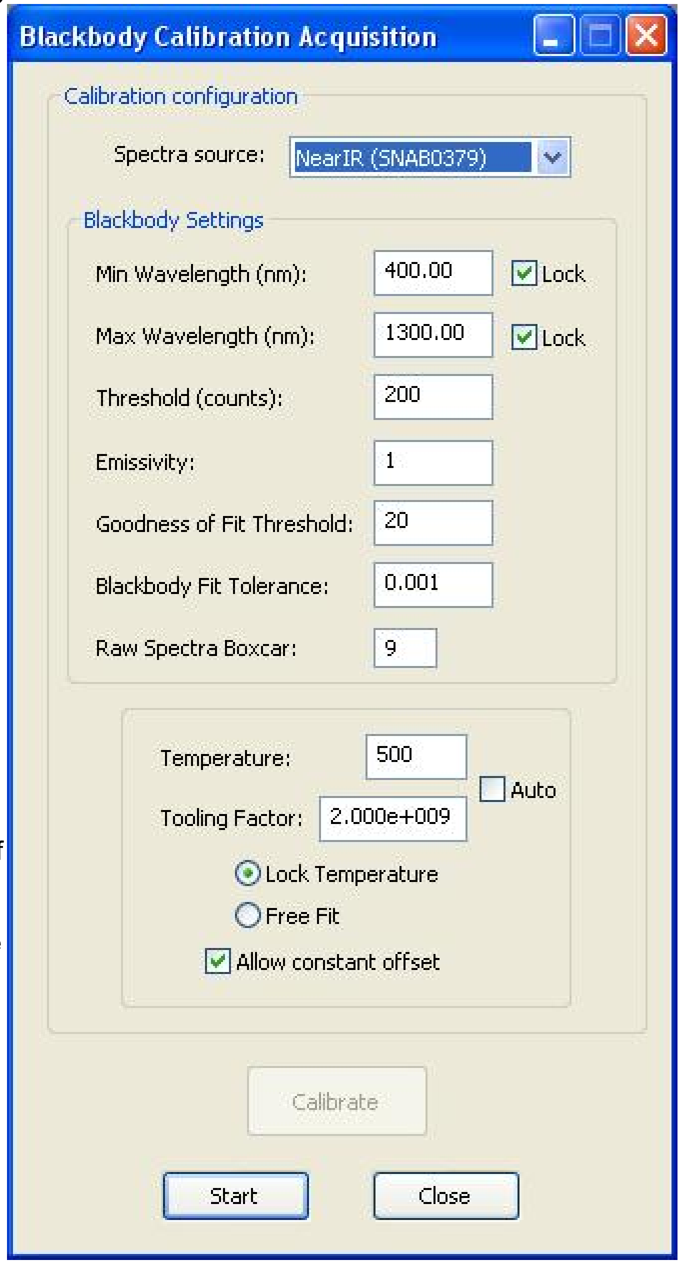
> ***Start*** - to start the acquisition. This also enables the Calibrate button.
>
> ***Calibrate*** - to start the calibration which will run for the number of second specified. During calibration "Calibrating" is displayed in the taskbar.

When calibration is complete click ***Stop*** to stop the acquisition mode and ***Close*** to close the window. The calibration process sets the ***Scal*** and ***Integration time*** in the Configuration Options Pyrometry tab.

Blackbody Calibration

The Blackbody Calibration Acquisition mode is used to Calibrate the Tooling factor if Blackbody temperature is going to be acquired in Locked Mode. See BandiT Blackbody Pyrometry for more information about using Blackbody mode.

Select ***Blackbody Calibration*** from the ***Acquire*** menu, which will bring up the window shown on the right.



Select the ***Spectra Source*** using the drop down menu

Specify ***Blackbody Settings*** as follows:

Min / Max Wavelength range - Enter the desired wavelength range over which to perform the blackbody fit. Entering zeros will cause the software to automatically select the spectrometer's Min and Max wavelengths. The values can be locked using the ***Lock*** check boxes. Alternatively, if one or both boxes are unchecked, the software will attempt to optimize the goodness of fit by successively reducing the range each time the ***Calibrate*** button is pressed.

Threshold - the minimum number of counts for performing a blackbody fit. Spectra which don't have at least this many counts will be ignored.

Emissivity - the calibration sample's emissivity. If not known, a value of 1 can be entered. In this case the emissivities of the subsequent samples will need to be expressed relative to that of the calibration sample, instead of entering the actual values.

Goodness of Fit Threshold - this allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. The default value is 20, meaning spectra which have reduced chi-squared greater than this value will be ignored.

Blackbody Fit Tolerance - the fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations (default is 1.0E-3).

Raw Spectra Boxcar - (must be odd, default is 9). This specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the spectra before attempting to fit.

Temperature - the calibration temperature (ºC). If self-calibrating, enter an estimate of the temperature to be used as an initial guess by the fitting routine. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate. If ***Auto*** mode is selected, this will be calculated automatically.

Tooling Factor - an estimate of the tooling factor to be used as an initial guess by the fitting routine. If ***Auto*** mode is selected, this will be calculated automatically.

Select:

Lock Temperature - if the calibration temperature is known, to use the External Calibration Method

or **_Free Fit_** - to use the Self-Calibrate Method (see BandiT Blackbody Pyrometry for more information)

Allow constant offset - to allow the constant C to be calculated automatically, if not checked the constant is forced to zero (see BandiT Blackbody Pyrometry for more information).

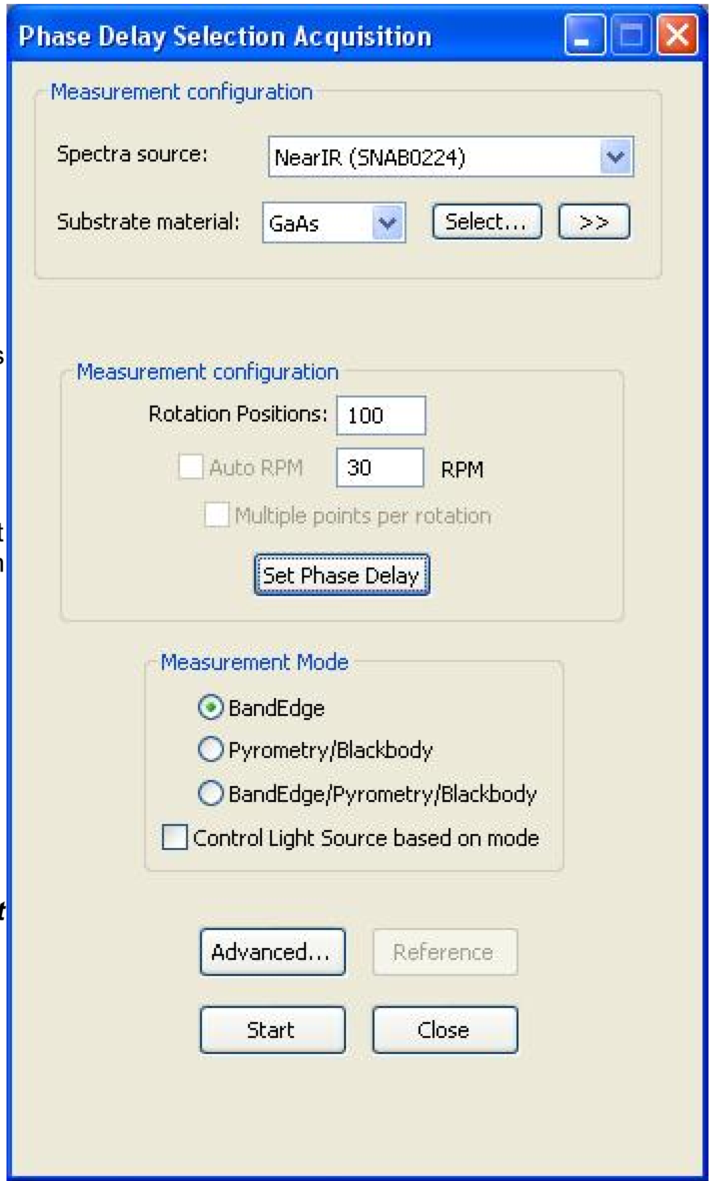
Using the View menu open the Real-time Blackbody Spectra chart.

Click:

Start - The software will determine the temperature by attempting to fit a blackbody curve to the source spectra in real-time using the most recently saved tooling factor and emissivity values. The real-time chart displays the source data in blue and the resulting fit in black. At the top of the window it displays the temperature, tooling factor, emissivity, and the goodness of fit statistic (i.e. the reduced chi-squared). If the goodness of fit statistic exceeds the threshold value, a message will appear.

Calibrate - will cause the fitting routine to attempt to perform a fit according to the current settings. If successful, the corresponding tooling factor will be calculated.

If needed, the wavelength range can be adjusted for optimum results. Every time **_Calibrate_** is pressed, the settings are automatically saved.



Phase Delay Selection

This Acquisition mode is used when a sample is rotating during acquisition. Available from the  icon on the toolbar or under the **_Acquire_** menu **_Phase Delay Selection_** allows for the selection of the phase delay position so that acquisition is triggered when the sample is in the correct position during the rotation.

One type of hardware to monitor rotation must be installed and enabled in the BandiT system for the Phase Delay Selection acquisition to work. Go to Check Hardware Rotation Board to locate and enable the correct option for your system.

Select:

Spectra Source - the Spectrometer that will be used.

Substrate material - Specify the **_Substrate material_** and use the **_Select_** button to open the table of materials, selecting the one that best matches your substrate. The details of the material selected can be seen in the Acquisition window by using the >> button. See Select Substrate Material for more information.

Specify:

Rotation Positions - The number of rotation positions tracked by the system.

RPM - The revolutions per minute of the sample rotation stage, if known.

Auto RPM - if the Hardware Rotation method can detect the RPM this check box will become available, select it to allow the automatic synchronisation to RPM.

Multiple points per rotation - this check box will become available if the hardware allows for selection of multiple points.

Measurement Mode - Select the measurement mode that you will be using for data acquisition.

In this mode View:

Real-time Bandit Phase Delay Selection – this Real-Time Chart should be set to plot the ***Peak Intensity*** against the rotation positions. If it is not, right click the plot and select ***Properties*** and then ***Plot value***, and select ***Peak Spectra Intensity*** from the drop down list.

Click:

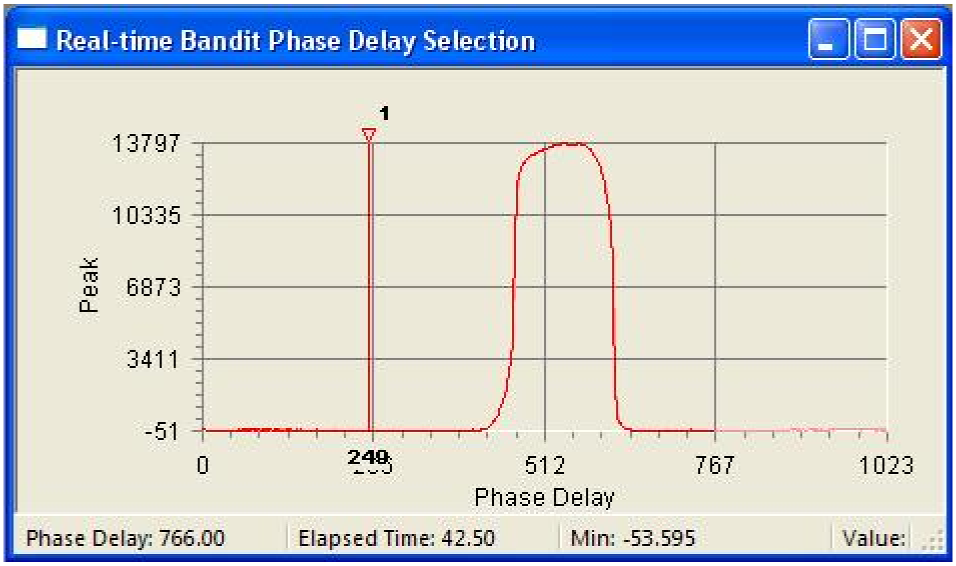
Advanced – to choose a number of Advanced Acquisition Options, including prompting windows and triggers

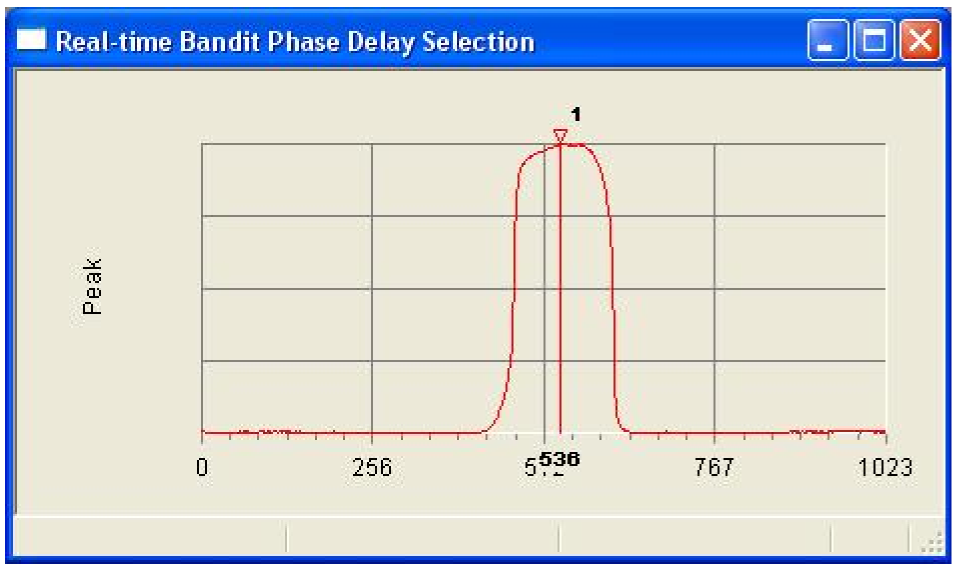
Start – to begin the phase delay acquisition; a new window may appear to prompt you to Start if such a prompt is set in the Prompts tab. Click the Advanced button to change this option

Once ***Start*** is clicked, the ***Start*** and ***Close*** buttons become ***Pause*** and ***Stop***.

Once ***Pause*** is clicked, the ***Pause*** button becomes ***Resume***. (During ***Pause***, the Phase Delay marker line cannot be moved, acquisition must be stopped first.)

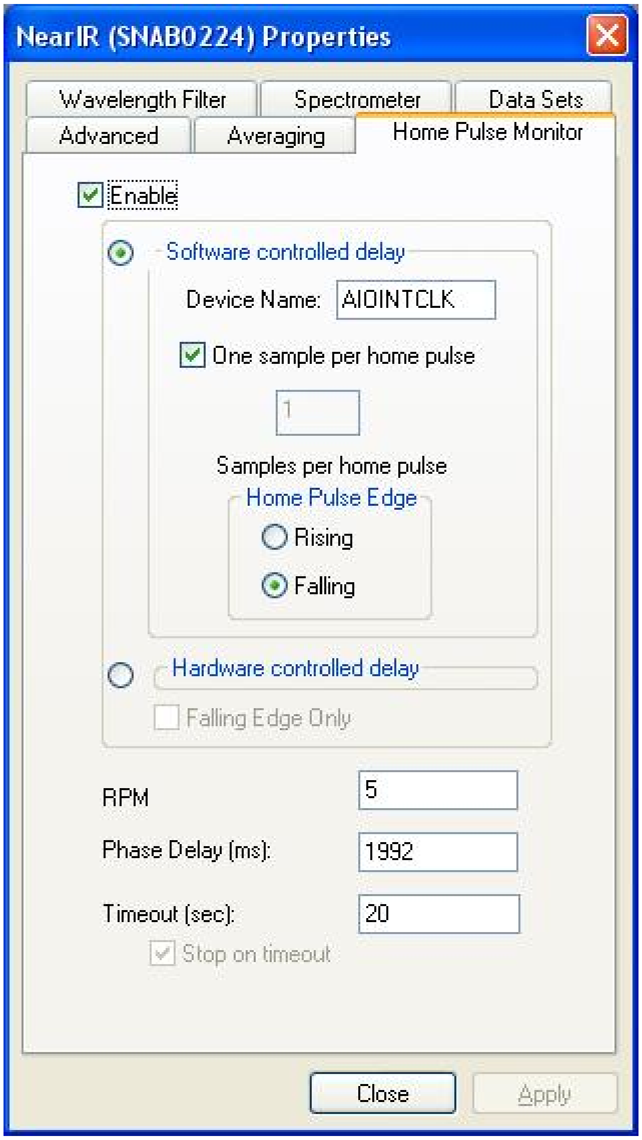
The Real-time BandiT Phase Delay Selection chart will start to update with an active trace which will re-trace itself as the sample rotates. Let it stabilise so that it retraces itself reliably as shown in the first image below, then click ***Stop***. It is now possible to move the red marker from the left hand side of the chart by clicking and dragging the triangle at the top of the marker line. Move this marker to the position of greatest peak intensity - this will be the location where data will be collected - as shown in the lower image.





When the marker is in the correct position click ***Set Phase Delay***.

Set Phase Delay - Click this when the position marker has been moved to the correct position. The delay (in ms) will be entered into the Phase Delay field in the Home Pulse Monitor screen, found by right clicking the Live Spectrometer window and selecting ***Properties.*** From this point onwards the system will be triggered to only take a snapshot of data when the stage rotation reaches the marker.

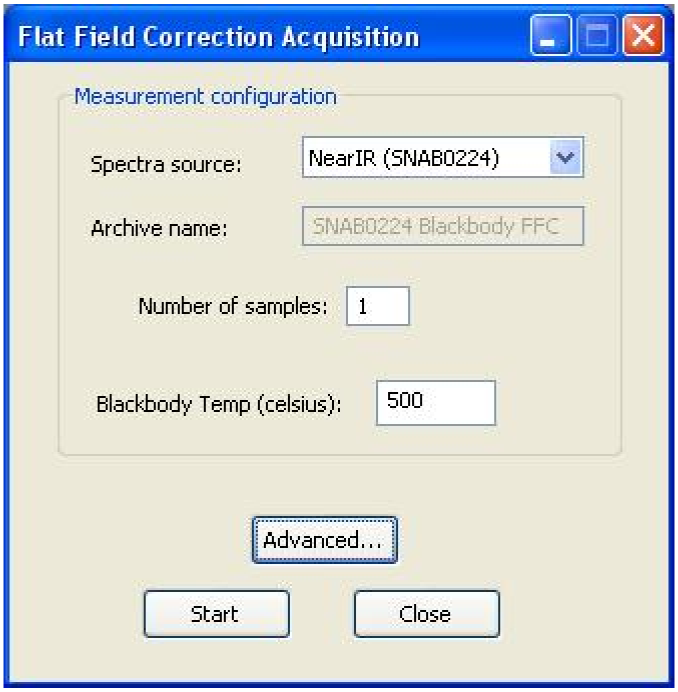


Flat Field Correction

The Flat Field Correction Acquisition Mode is used to generate a Flat Field correction file which is specific to each Spectrometer and corrects the spectrometer output to yield a flat response as a function of wavelength. This is used when using BandiT for Black-Body Pyrometry.

This correction file will normally be supplied by k-Space when the system is delivered from the factory and most customers would not need to use this mode.

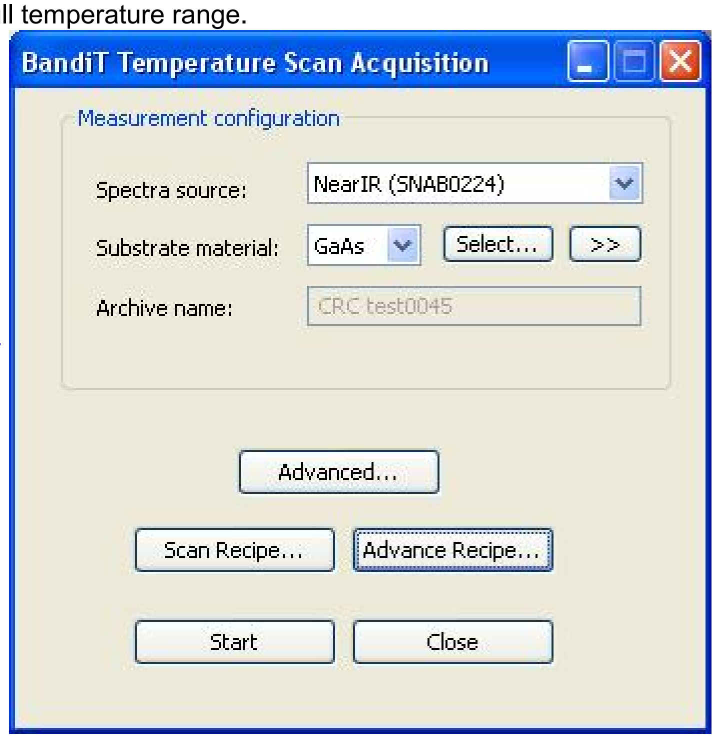
A special Blackbody source is required to do this calibration.



BandiT Temperature Scan

This is used by k-Space to configure the BandiT calibration files. It is not generally used by a BandiT user.

BandiT Temperature Scan is an acquisition mode found under the ***Acquire*** menu and is used when creating Substrate Calibration files. A Eurotherm controller is used to control the chamber temperature so that the calibration can be achieved for the full temperature range.



Select:

Spectra Source - the Spectrometer that will be used.

Substrate material - use the drop-down list to choose the type of substrate. Then click the ***Select*** button to view the material table for that material, see Select Substrate Material for more details. At any time, click the **>>** button to view the selected substrate material details in the acquisition window itself:

Archive name - this can be entered manually here or use the Document Generation tab in the Advanced Acquisition Options (found by clicking the ***Advanced*** button) to have the system generate one automatically.

Click:

Advanced – to access the Advanced Acquisition Options and Configuration options to specify BandiT I/O settings, Configurable Temperature Output, Triggers, and to set all the parameters for band edge calculation, pyrometry, automatic intensity control etc.

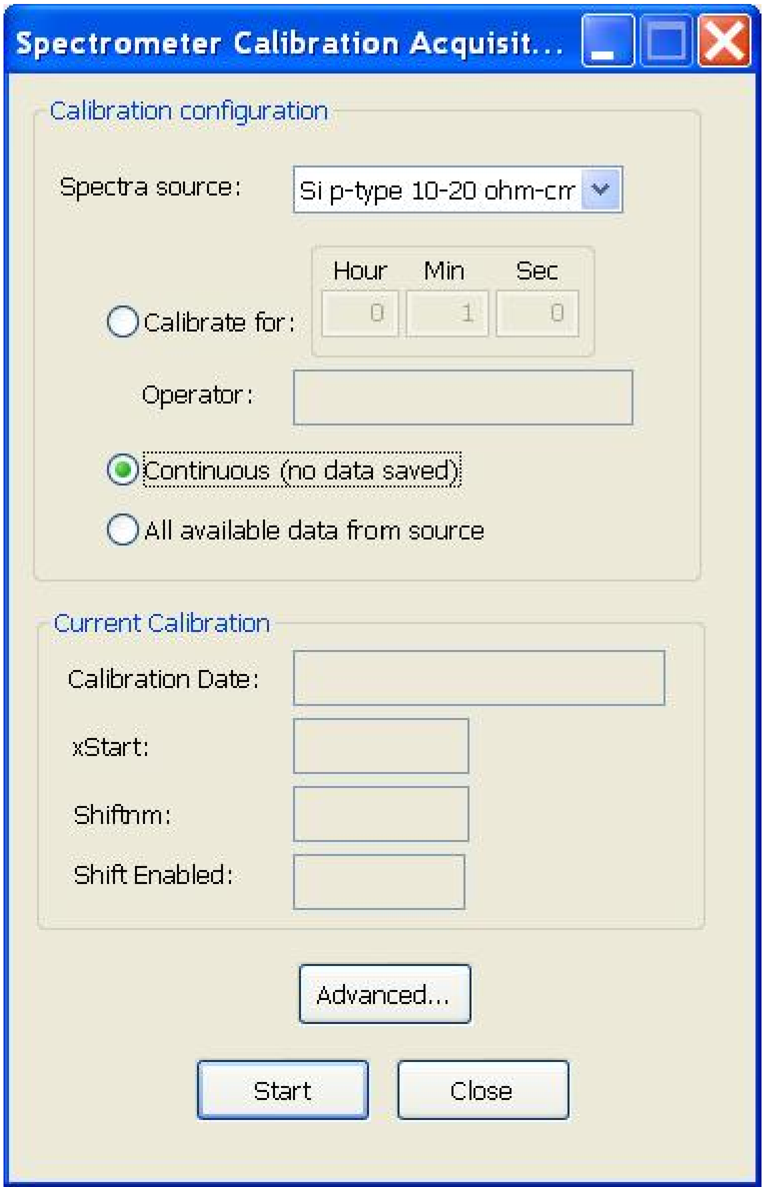
Scan recipe - to open the Thermal Scan Recipe dialog box as shown below to set the temperatures, dwell time and ramp rate.

Spectrometer Calibration

This Acquisition Mode is used to verify or adjust the BandiT spectrometer wavelength calibration. In this procedure, the wavelengths of various spectral lines from a Hg-Ar line source are measured and compared to tabulated values. This information is used to calculate the offset, Δ that minimizes the discrepancies at the individual wavelengths. The corrected wavelengths are then given by:

$$\lambda' = \lambda + \Delta$$

The results are used to automatically edit the existing spectrometer setup file



IMPORTANT: be sure to allow the spectrometer to warm-up for at least 30 minutes before attempting to calibrate. Also allow the Hg-Ar line source to warm-up for at least 10 minutes for the output signal levels to stabilize.

After allowing a sufficient warm-up period for both the spectrometer and Hg-Ar line source, connect the line source to the spectrometer fiber input. Adjust the spectrometer integration time to get a strong signal (typically 300 msec). Be sure to enable averaging to obtain a clean spectrum with good signal-to-noise (typically 4x averaging).

Specify:

Calibration configuration:

Spectra Source - Select the desired Spectra Source from the pull-down menu. You can choose a live spectrometer, or any open data file.

choose one of:

Calibrate for - to acquire spectral data for the specified period of time (default: 2 min). This is the mode to use if collecting data from a Live Spectrometer. This will prompt you to enter the identification of the Operator performing the calibration.

Continuous - to run the calibration without saving any data and without making any adjustment.

All available data from source - to use all the data in a stored *.kdt file

Click Advanced and verify the settings for your particular spectrometer in the Advanced Settings dialog box. When you are satisfied with the settings, select OK to return to main dialog.

From the View menu, select these Real-Time Charts:

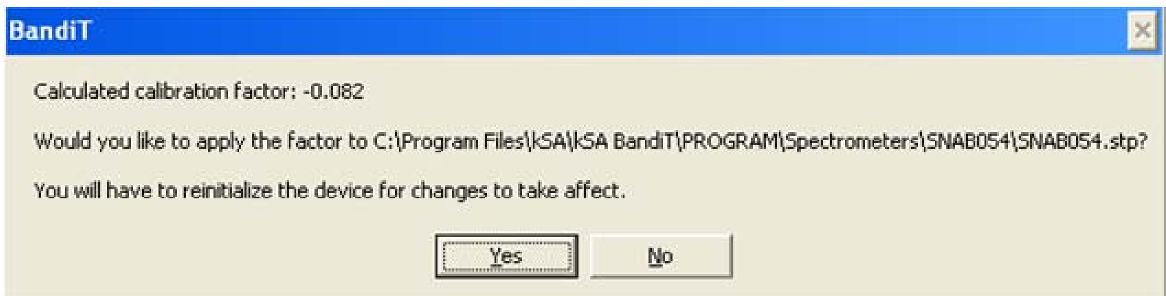
Real-Time Calibration Averages to view the current and running average values for up to three spectral lines

Real-Time Calibration Peak (Time) to view a strip chart for a given spectral line

Real-Time Calibration Spectra to view the spectra with the selected line(s) indicated.

Click ***Start*** to start the calibration process.

If connected to a live spectrometer, a dialog box will appear as shown below when the acquisition is completed. If Yes is selected, the spectrometer's setup file will be updated with the new settings and the spectrometer re-initialized in order for the new settings to take effect. A backup copy of the setup file will also be created. In addition, a log file will be created in order to track the calibration history.



If instead an existing data file was used as the acquisition source, a dialog box summarizing the results will appear as shown below.

Substrate Calibration

This is used by k-Space to configure the BandiT calibration files. It is not generally used by a BandiT user.

This Acquisition mode is used to create calibration files for new substrate materials, so that they can be included in the Library for other users to use.

Configuration Options

Configuration Options

These are found by clicking the ***Config*** button once you have selected an acquisition mode.

(Note that in earlier versions of BandiT, these options were found under the ***Advanced*** button)

Automatic Intensity Control – automate the lamp control and spectrometer integration time

Pyrometry – used for measuring temperature via black-body radiation

Reference – specify/acquire reference file needed for measuring GaN deposition and SiC substrates

Band Edge – fine-tune the fitting of the absorption edge spectra

Stray Light Removal – update the BandiT Dark Background during acquisition

Thickness - enable thickness calculation and set up parameters

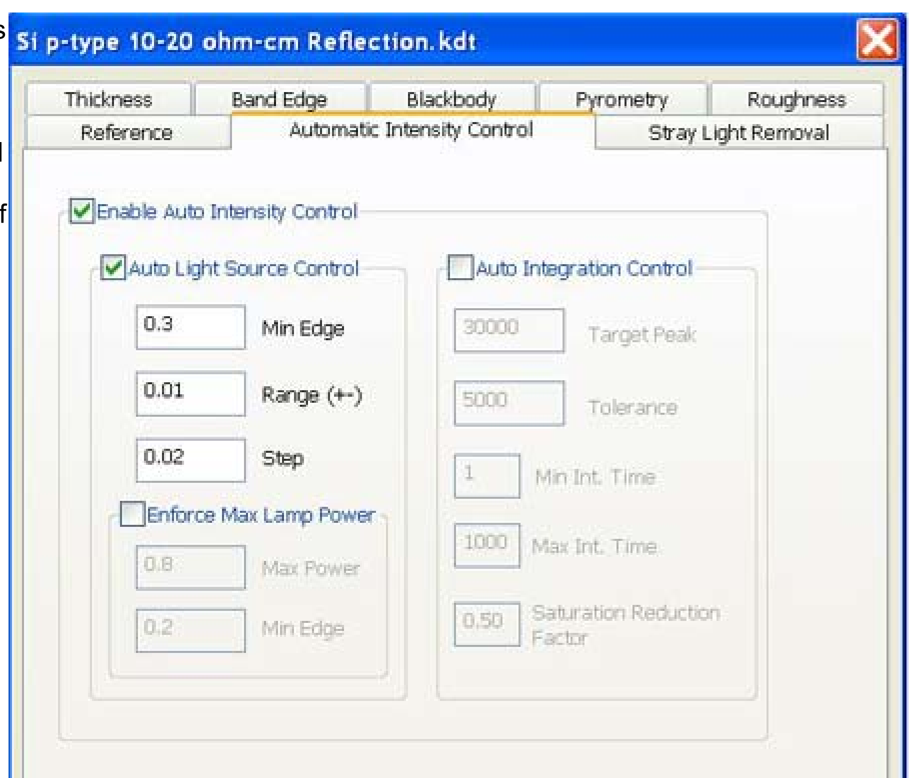
Roughness - enable roughness calculation and set up parameters

Blackbody - enable blackbody computation and set up parameters

Automatic Intensity Control

This is an Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window.

It is used for automating the lamp control and spectrometer integration time when measuring single wafer temperatures.



During acquisition, conditions change. For example, there may be more or less light because of changes in temperature, heater, material thickness, etc.. Use this option to keep the intensity of the signal stable.

Check:

Enable Auto Intensity Control to allow the system to use measurements of the minimum edge (Normalized BandiT Spectra) and peak (BandiT Spectra signal) to adjust automatically the lamp and/or integration separately or together as needed to keep the signal stable. The software first adjusts the lamp. If it does not reach the ***Target Peak***, then it will use ***Automatic Integration Control*** (if it is enabled).

Auto Light Scource Control – for handing the Light Source Control over to the software check this box then:

Specify:

Min Edge – to set the decimal value (between 0 and 1) of how much of the Normalized BandiT Spectra is to be used for the linear fit. During acquisition, this value is seen in the lower right corner of the Real-Time Normalized BandiT Spectra, labeled *Fit Y*. Visually, this is the amount up the Y-axis traversed by the green fitting line.

Range (+-) – to set the range on both sides of the ***Min Edge***.

For example, a value of 0.01 and a ***Min Edge*** of 0.3 means that the ***Min Edge*** is allowed to vary between 0.29 and 0.31.

Step – to set the lamp power step that the system uses to adjust the ***Min Edge***. The system will increase or decrease lamp power in steps specified here, reaching a minimum of 0 and a maximum of 1, unless another ***Max Power*** value is specified (as described below).

Check:

Enforce Max Lamp Power – to limit the lamp power so that it never exceeds a maximum value and never is set to a value that causes the minimum edge to be below a specified value. This is used to prevent saturation and prolong lamp life. It can be disabled independently of ***Automatic Lamp Control*** and ***Automatic Integration Control***. But if disabling ***Automatic Integration Control***, then be sure to enable this option.

Specify:

Max Power – to set the maximum lamp power as a decimal value between 0 (off) and 1 (maximum power)

Min Edge – to set the minimum edge as a limit for lamp brightness. This lower-limit parameter is meaningful only if it is set within the ***Range*** of the ***Min Edge*** set above.

Auto Integration Control – for handing the integration time (specified in the Spectrometer Properties) over to the software. The ***Automatic Intensity Control*** function can only work within the range and resolution of the Dark Background. It can only use Integration times that are included in the Dark Background so it is important to make sure that sufficient steps are included. Check this box then:

Specify:

Target Peak – to set the desired count for the Spectrometer. This value will be used for the ***Automatic Lamp Control***, whether or not the ***Automatic Integration Control*** is enabled.

Tolerance – to set the range on both sides of the ***Target Peak***.

For example, a value of 5000 and a ***Target Peak*** of 30000 means that the ***Target Peak*** is allowed to vary between 25000 and 35000.

Min Int. Time – to set the minimum time for integration.

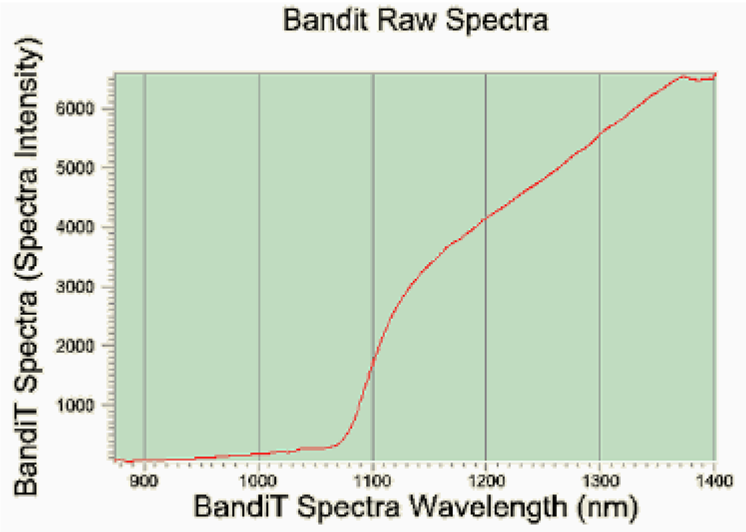
Max Int. Time - to set the maximum time for integration.

Saturation Reduction Factor - to set a reduction factor to avoid saturating the Spectrometer

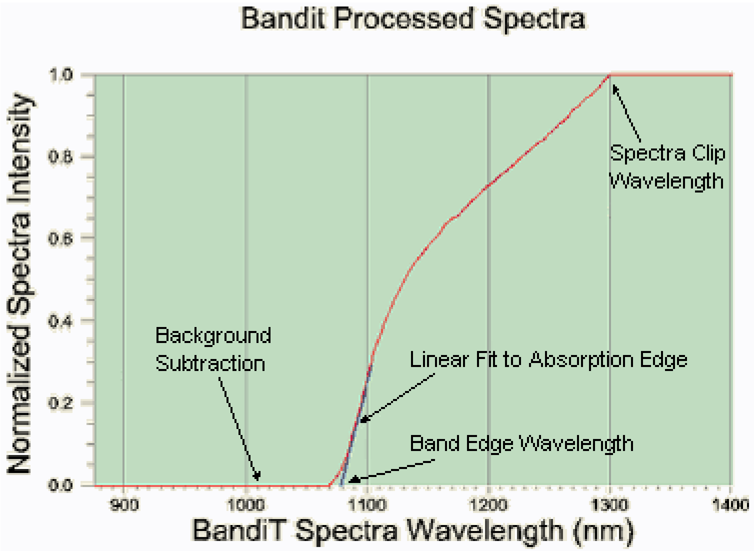
Band Edge

This is an Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to fine-tune the fitting of the absorption edge spectra.

Before the BandiT software processes the absorption spectra data, the data is in its raw format, as shown below:



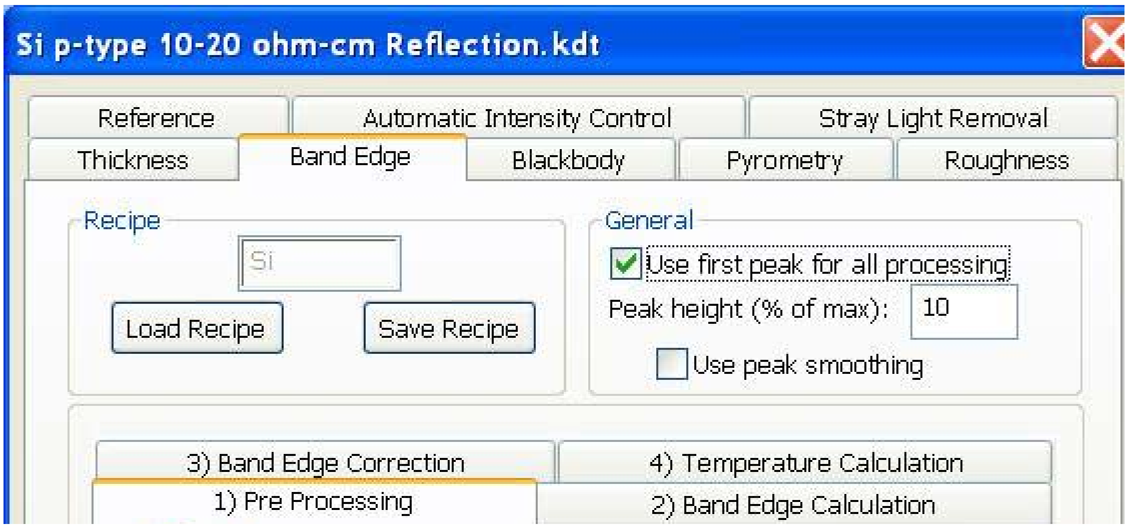
The spectra processing algorithm performs several operations on the original raw spectra data. First, it performs background subtraction of the data. Then it determines a band edge wavelength—or "knee wavelength" as it is commonly known—by fitting to the linear portion of the absorption edge, as shown by the blue line in the figure below.



In general, the default settings for all spectra processing parameters are sufficient for most substrate temperature measurement. While this Help file does discuss each of the parameters, adjusting these parameters requires a good understanding of the proprietary kSA BandiT fitting algorithm, which is *not* discussed in this Help manual. For further information regarding the fitting algorithm, please contact us.

Note that future versions of BandiT will allow temperature calculation from wavelength integration instead of band edge. Such options will need to be adjusted on a case-by-case basis, and those parameters are documented here as well in grey text.

Now, to the dialog itself:



Many users will have saved a Recipe, which when loaded will specify all the parameters in this dialog. Use the ***Load Recipe*** to pull up a previously saved recipe. Or, if specifying these parameters for the first time, click the ***Save Recipe*** when finished, this will save the current settings of all the parameters on the Band Edge menu. Users will normally have a recipe for each wafer.

(Note that the parameters will remain as specified so long as BandiT is exited normally. Users with only a single recipe need not take the step of saving the recipe, as the latest-input parameters will be saved and reloaded each time the application is opened.)

For ***General***, check:

> ***Use first peak for all processing*** - If this is enabled BandiT will use the first peak (i.e. the lowest wavelength) rather than the maximum peak found in the first derivative. This is useful when the BandiT Spectra contains oscillations in the steepest part of the graph, to the right of the band edge which may cause the algorithm to select an inflection point other than the one associated with the band edge. This may cause the peak derivative value used for calculations to switch (and perhaps jump back and forth depending on the oscillations of the ripple). This is useful if either 1) Pre-processing or 2) Band Edge Calculation is enabled. *Default: Disabled*
>
> With *Use first peak for all processing* checked, specify:
>
>> ***Peak height (% of max)*** - this specifies the minimum level a peak must attain before it is considered valid, so that the first peak detected will not be due to noise. For example a value of 15 means that any peak smaller than 15% of the maximum derivative peak height will be ignored. *Default: 15%*
>>
>> ***Use peak smoothing*** - If this is enabled, the software will attempt to reject any spurious noise spikes. It does this by rejecting any peak candidates which don't have at least three

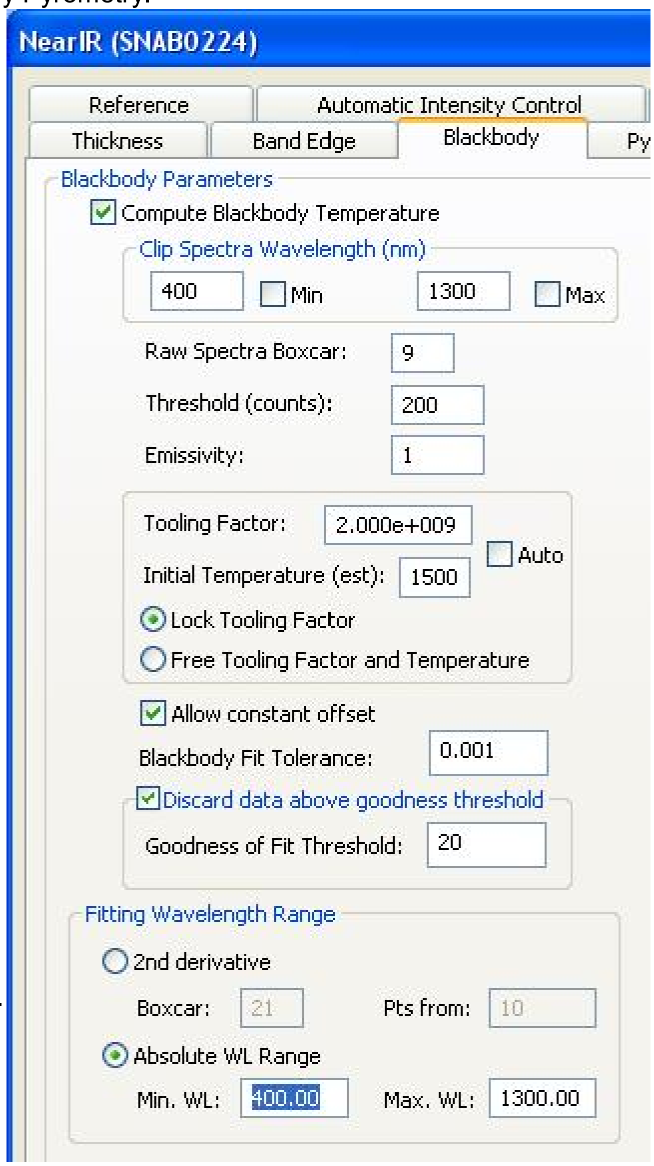
consecutive data points on each side with slope of the same sign (i.e. either increasing or decreasing). *Default: Enabled.*

In the following pages, learn about:

1. Pre-Processing
2. Band Edge Calculation
3. Band Edge Correction
4. Temperature Calculation

Blackbody

This is a Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used when measuring temperature using Blackbody Pyrometry.



Select ***Compute Blackbody Temperature*** to enable the blackbody fitting.

Specify:

Clip Spectra Wavelength - to clip the raw spectrum below a ***Min*** wavelength, and/or above a ***Max*** wavelength. This is intended to allow the removal of noisy portions of the spectrum which may exist under certain circumstances.

Raw Spectra Boxcar - this specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the spectra before performing attempting to fit. (*must be odd, default 9*)

Threshold - the minimum number of counts for performing a blackbody fit. Spectra which don't have at least this many counts will be ignored.

Emissivity - enter the sample's emissivity. ***Note:*** that this is not necessarily the same as the emissivity used in the calibration procedure. This allows the user to perform the calibration on a sample which is different than the sample under test. If a value of 1 was entered during calibration, the sample's emissivity will need to be expressed relative to that of the calibration sample, instead of entering the actual value.

Tooling Factor - if a calibration was performed, this will already contain that value. If in Locked mode, this will be the value used for all calculations. If in Free Fit mode, this will be the initial guess, unless Auto is selected, in which case it will be calculated automatically.

Initial Temperature (est) - enter an initial temperature estimate. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate. If Auto mode is selected, this will be calculated automatically.

Select:

Lock Tooling Factor - to run in Locked mode

or ***Free Tooling Factor and Temperature*** - to run in Free fit mode (see How-to Use BandiT Black-Body Pyrometry for more information)

Allow constant offset - to allow the constant C to be calculated automatically. Otherwise, it is forced to zero. (see How-to Use BandiT Black-Body Pyrometry for more information)

Discard data above goodness threshold - to allow rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. Spectra which have reduced chi-squared greater than the entered Goodness of Fit Threshold will be ignored.

Enter:

Blackbody Fit Tolerance - The fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations (*default is 1.0E-3*).

Goodness of Fit Threshold - threshold above which spectra will be ignored (*default value is 20*)

Fitted Wavelength Range - specify either:

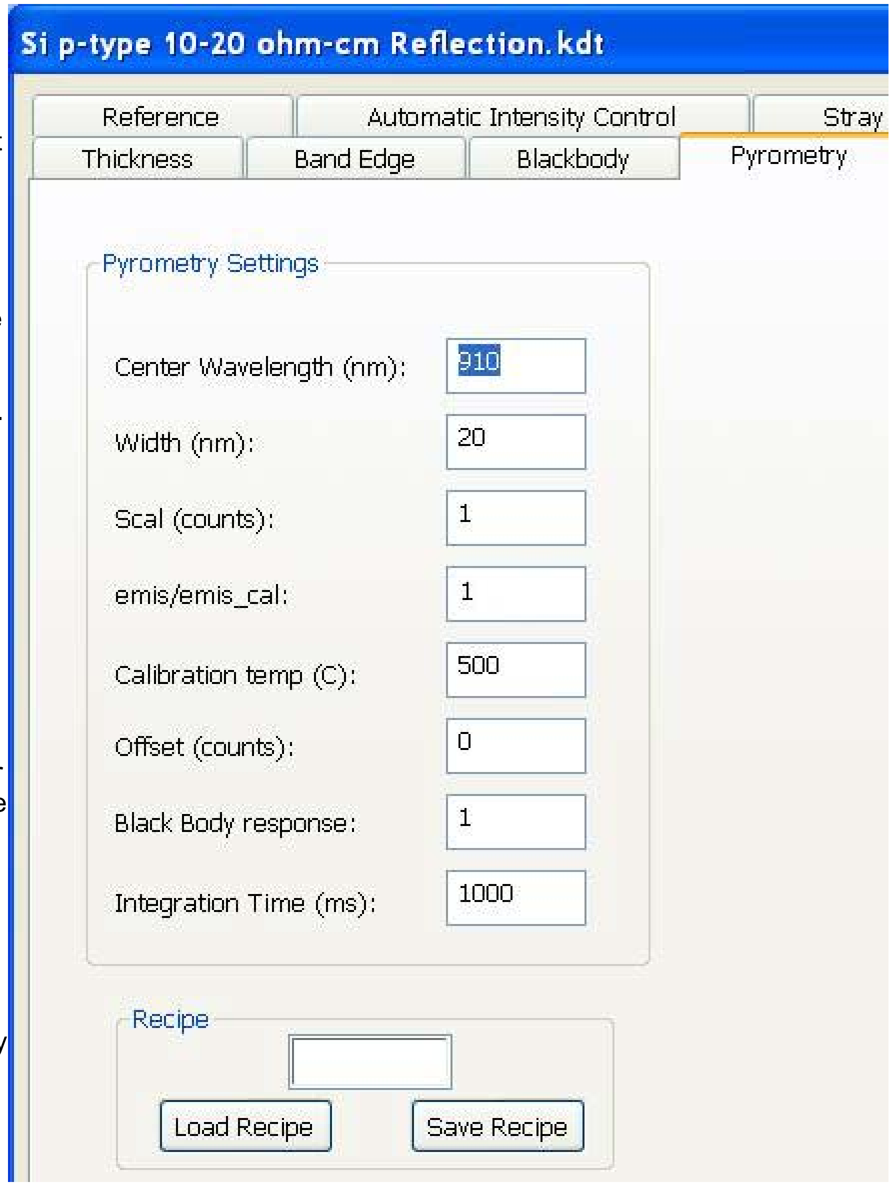
Absolute Wavelength Range, with Min and Max wavelengths

or ***2nd derivative*** allow the upper limit to be adjusted dynamically relative to the sample's band edge. This is based on the “knee” in the spectrum, which is located at the peak of the 2nd derivative, i.e. the wavelength where the slope is increasing most rapidly. If this 2nd derivative option is selected, the smoothing and number of data points to offset from the knee must be specified.

Pyrometry

This is a Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used when measuring temperature via blackbody radiation. This technique requires transmission mode and so make sure the light source is off (or in "standby" mode) as it will increase the noise in the signal and may hide it entirely.

Specify Pyrometry Settings:



Center Wavelength (nm) – this is the material-dependent primary wavelength that BandiT should search for when looking for black-body radiation

Width (nm) – this is the overall width around the ***Center wavelength*** that BandiT will search for black-body radiation. For example, with a width of 100, the algorithm will search 50 nm on either side of the ***Center wavelength***.

Scal (counts) – signal calibration, the Acquisition mode BandiT Pyrometry Calibration can be used to obtain the number for Scal. This will be a large number (many thousands to several million, depending on signal strength).

emis/emis_cal – this is the material emissivity divided by the emissivity calibrated. The general rule is that if the system is calibrated based on the same temperature as you are going to measure, then this value is 1. If calibrating using a different temperature, then this parameter will have another value.

For example, when calibrating the system using the procedure outlined in How-To Measure Temperature via Pyrometry, this number is 1. That's because the same material (say GaAs with emissivity 0.68) used in calibrating the pyrometer will be the same material measured via Pyrometry (so 0.68/0.68 = 1) at the temperature (580°C). Other users may calibrate using blackbody emissivity, which is typically rounded up to one. Then emis_cal = 1 and the measured emissivity in the chamber (say of GaAs) is another number (say 0.68), meaning emis/emis_cal is 0.68/1 = 0.68.

Calibration temp (C) – this is the temperature within the chamber and should also be the temperature as read by using BandiT's transmission mode (in the Real-time BandiT Temperature window).

Offset (counts) – this is a tweaking option, and typically should be left at 0

Black Body response – each spectrometer has a slightly different response as a function of intensity. For NearIR spectrometers, this value is very close to one. For visible spectrometers, this value is close to 0.5. As a part of calibrating the system, a k-Space engineer provides this value.

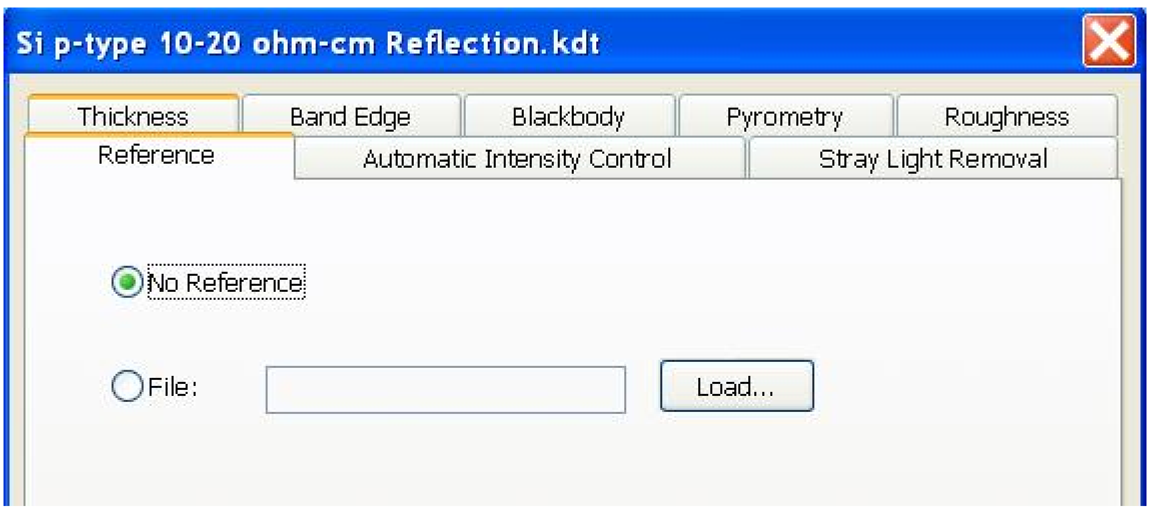
Integration time (ms) – this is the current integration time of the spectrometer window. This will be entered by the BandiT Pyrometery Calibration procedure.

Recipe - the current settings can be saved by clicking ***Save Recipe***, this will prompt for a file name. Pyrometry recipe files have the file extension .pyro

Saved settings can be used in future by clicking ***Load Recipe*** and selecting the appropriate file.

Reference

This is an Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to specify a reference spectra that is divided into the BandiT Spectra. A reference is necessary when using BandiT for measuring temperature for GaN deposition on sapphire or for depositing on to SiC. This is done using kSA BandiT's visible spectrometer. See the BandiT Visible topic for how to measure temperature for these materials.



Select either:

No Reference – and BandiT subtracts off a dark background

or

File – to specify a file (acquired via BandiT Reference acquisition in multi-wafer BandiT) for GaN or depositing on to SiC. For more information about the *.bsrf, please see the File Formats topic.

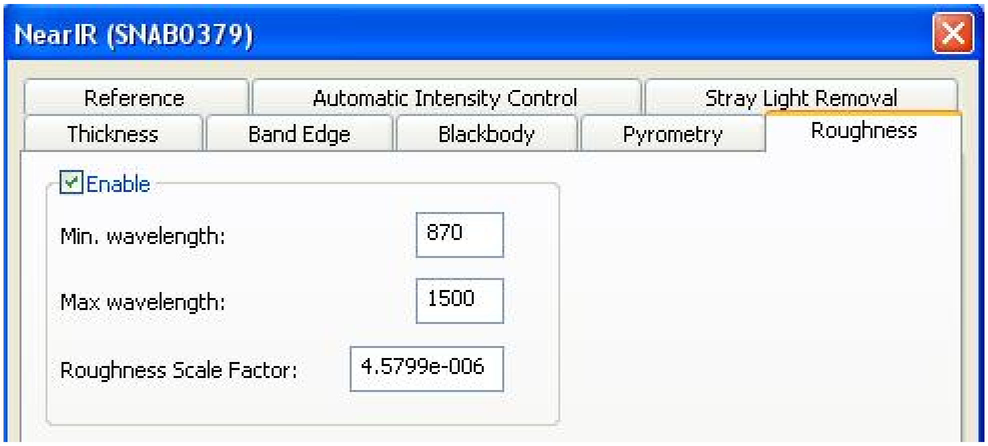
Click:

Load - to select the file to use

Roughness

This is a Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to set up the wavelength over which roughness data will be collected.

Click ***Enable*** to allow Roughness measurements to be made.



Specify:

Min. wavelength - the minimum wavelength to use when calculating roughness

Max wavelength - the maximum wavelength to use when calculating roughness

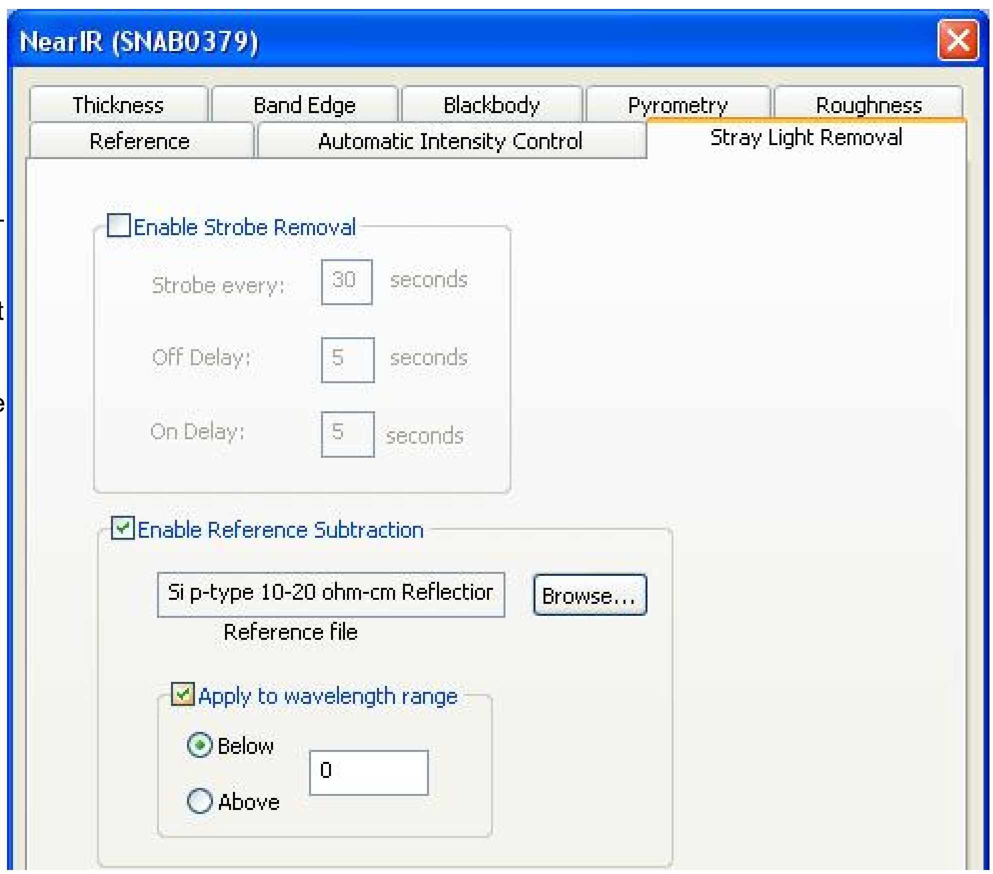
Roughness Scale Factor - The scale factor can be calculated automatically by using the Bandit Roughness Calibration Acquisition mode. Or you can enter a scale factor here.

If the numbers to be displayed on the Real-time Roughness (LED) chart are too large the display will show #.### instead of numbers, in this case the scale factor should be adjusted or re-calibrated using the Bandit Roughness Calibration Acquisition mode.

Stray Light Removal

This is an Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to update the BandiT Dark Background during acquisition—helping to make the system immune to ambient light in the chamber. This is useful when making frequent changes in the deposition chamber—such as rapid changes in temperature, adding or subtracting light through viewports, etc.. Indeed, most users report that they have not used this option, preferring to keep deposition chamber conditions more stable.

Check:



Enable Strobe Removal, and specify:

Strobe every – to set how often the system will wait before beginning a cycle to acquire a new dark background. Ideally, keep this value as large as possible, but it will depend on how often or rapidly changes are occurring in the deposition chamber.

Off Delay – to set how long the system waits to acquire a new dark background after the lamp goes into standby mode. Usually two seconds is sufficient to allow the lamp filament to cool down enough so that its intensity is below 5%.

On Delay – to set how long the system waits to resume temperature measurements (subtracting off the updated dark background) after the lamp is powered back up. Usually two seconds is sufficient to allow the lamp filament to return to previous levels.

Enable Reference Subtraction and specify:

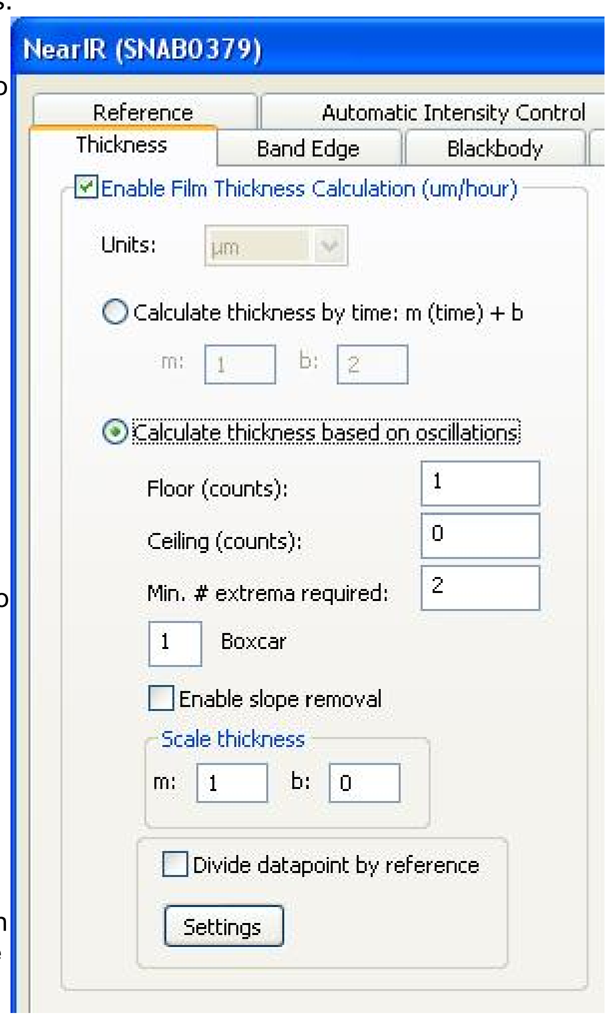
Reference File - Select a Bandit reference file using the Browse button.

Apply to wavelength range - check this to apply to only part of the wavelength range

Below or ***Above*** - check ***Below*** or ***Above*** and enter a wavelength value

Thickness

This is a Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to configure the film thickness calculation settings.



Enable Film Thickness Calculation - select this to enable the film thickness to be calculated by one of two methods: elapsed time or spectral interference oscillations.

Units - Specify the thickness units to be used. Default: µm.

Select one of the following two options:

Calculate thickness by time - to calculate thickness based on elapsed time using a known growth rate and starting thickness.

m: Growth rate in units/hr.

b: Starting thickness in the specified units.

Calculate thickness based on oscillations - to calculate thickness based on interference oscillations - for more information see How-To Measure Film Thickness

Floor (counts) - Any raw spectra which have maximum intensity below this noise floor value will be ignored. This is intended to reject spectra which contain only noise. *Default: 1,000 cts.*

Ceiling (counts) - Any raw spectra which have maximum intensity above this noise ceiling value will be ignored. This is intended to reject spectra which might saturate the spectrometer. *Default: 60,000 cts.*

Min. # extrema required - Any spectra having fewer than this number of extrema will be ignored. *Default: 4.*

Boxcar - Specifies the number of points used to perform a moving average, a.k.a. boxcar smoothing of the thickness result (must be odd). For example, a setting of N results in each data point being averaged with the (N-1)/2 neighboring data points on either side. *Default: 1 (i.e. no smoothing).*

Enable slope removal - If this is enabled, the software will attempt to remove any background slope over the wavelength range specified in the Settings dialog. This is intended to improve the accuracy of the extrema wavelength measurement by providing a flat baseline.

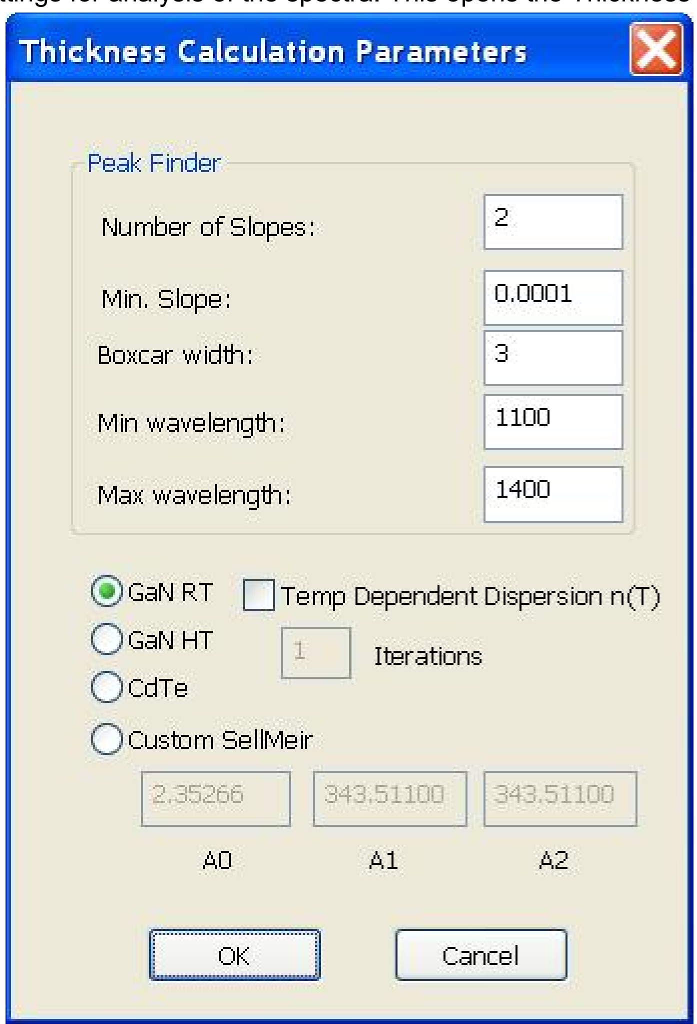
Scale thickness - Performs a linear scaling of the thickness with scaling factor m and offset b. The scaled thickness is obtained via the equation: $t' = m * t + b$.

m: Scaling factor (dimensionless). *Default: 1.*

b: Thickness offset in the specified units. *Default: 0.*

Divide datapoint by reference - If this is enabled, the raw spectrum will be divided by a saved reference spectrum. This is intended to normalize the spectrum to remove the effects of spectral variation of the light source output. This provides a flatter baseline and makes determination of the wavelengths of the extrema more accurate. Reference spectra can be acquired from any surface giving a diffuse reflection. Commonly used materials include sapphire wafers(SSP) and PBN. Note that it is critical that the reference be taken at the same lamp power that will be used during data acquisition, as the shape of the lamp's output spectrum is strongly power-dependent. The desired reference file can be specified in the Reference tab in the Configuration Options.

Click the ***Settings*** button to enter the settings for analysis of the spectra. This opens the Thickness Calculation Parameters dialog box as shown below.



Number of Slopes - Specifies the minimum number of consecutive data points required with slope having the same sign (either increasing or decreasing) before a potential extremum is considered valid. The purpose of this setting is to filter valid extrema from background noise. *Default: 20.*

Min. slope - Specifies the minimum slope required before a potential extremum is considered valid. The purpose of this setting is to filter out small extrema which may be due to background noise. *Default: 5E-5.*

Boxcar - Specifies the number of points used by the digital smoothing filter that is applied to the spectrum before analysis (must be odd). For example, a setting of N results in each data point being filtered using the (N-1)/2 neighboring data points on either side. *Default: 65.*

Min wavelength - Minimum wavelength for analysis (nm).

Max wavelength - Maximum wavelength for analysis (nm).

Select the dispersion curve corresponding to the film material. The user has the option to select from a preset list, or manually enter the three Sellmeir parameters A0 (dimensionless), A1 (nm), and A2 (nm). For more information see How-To Measure Film Thickness.

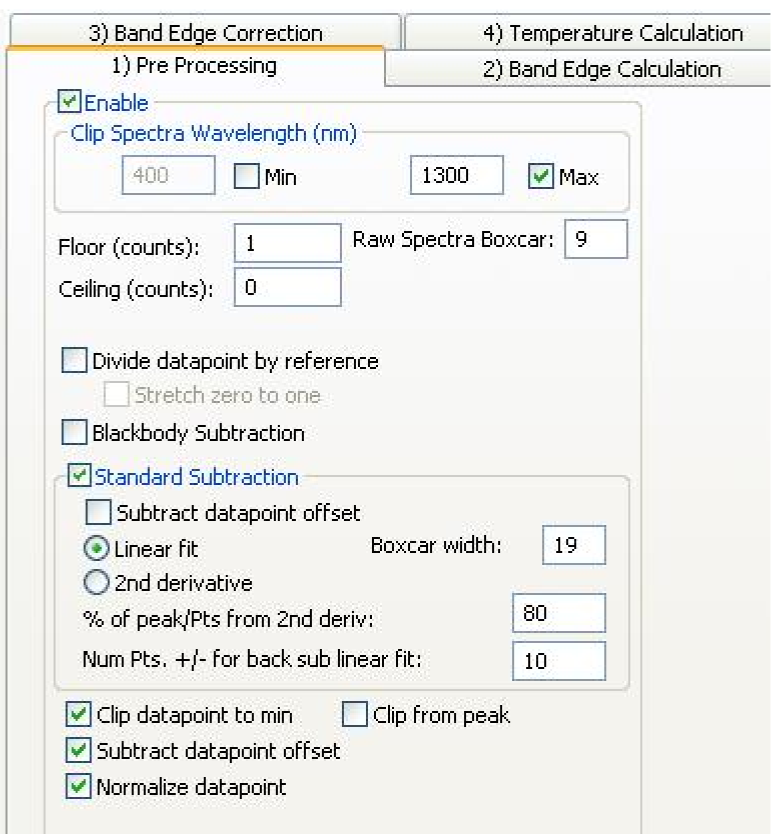
Spectra Pre-Processing

This is a part of the Band Edge Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window.

Perform *Pre-processing* to process the raw absorption spectra before fitting a band edge. Typically, the raw spectral data is smoothed, normalized, and background subtracted. Smoothing removes short-range variations, or "noise", and therefore functions as a low-pass filter. Background subtraction is performed in some cases in order to enhance a weak band edge.

Specifically:

- The pre-processing first boxcar smooths the raw spectra.
- Then, it is clipped at an user-defined upper wavelength.
- Beyond that upper wavelength, all data is set to the intensity equal to the user-defined upper wavelength.
- Next, its 1st derivative is taken and boxcar smoothed and peak found – thus determining the inflection point in the smoothed spectra.
- Using the inflection point, the pre-processing algorithm makes a linear fit and extrapolates it to the x-axis.
- A background subtraction of the entire spectra data is then taken, using the value at the x-axis intersection of the linear fit.
- The spectra data to the left of the x-axis intersection position is clipped.
- Finally, the resultant spectra is normalized to the peak value of the spectra.



With ***Enable*** selected, the software will perform the selected pre-processing operations on the raw spectra. *Default: Enabled.*

Specify:

Clip Spectra Wavelength (nm) - Clips the spectra outside of a user-defined wavelength range. This is typically done to eliminate the possibility of finding false inflection points.

Min – (default: OFF) – select this checkbox to clip the raw spectra data at the specified wavelength. For example, setting this value to 400 nm will result in all the data to the left of 400 nm to be set to the value at 400 nm. This is typically done on GaN or SiC. We only need to clip to a minimum when dividing by a reference to eliminate noise. *Default: Disabled*

Max – (default: ON, 1300nm (for GaAs)) – select this checkbox to clip the raw spectra data at the specified wavelength. For example, setting the clipped wavelength to 1300 nm will result in all data to the right of 1300 nm set to the value at 1300 nm. This is typically done to eliminate false peak finding due to strong IR signal at longer wavelengths. This can be seen, for example, at high temperatures when the substrate heater is outputting significant IR radiation. Using the Clip Spectra feature will ensure that erroneous fitting to the long wavelength structure does not happen. *Default: Enabled, 1250nm*

Floor – to set the intensity (in raw counts of the raw absorption spectra data) below which pre-processing will not occur. For example, any peaks found with intensities below the noise floor will be ignored in the pre-processing. *Default: 250 counts*

Ceiling - any raw spectra which have maximum intensity above the noise ceiling value will be ignored. This is intended to reject spectra which saturate the spectrometer. *Default: 70,000 counts.*

Raw Spectra Boxcar – the pre-processor smooths the raw spectra using a moving average, a boxcar, with the specified number of data points (which must be odd). For example, a setting of N results in averaging each data point with the (N-1)/2 neighboring data points on either side. *Default: 9 pts.*

Divide datapoint by reference – select this checkbox to divide a reference spectra into the acquired raw spectra. This is done, for example, to eliminate structure in the spectra of the light source and would be done by dividing out a reference spectra taken directly of the light source. Use this option only when using a visible spectrometer (depositing GaN on sapphire or using SiC). *Default: OFF*

Stretch zero to one – if this is enabled, the software will scale the reference-divided spectrum such that the maximum value is one, and the minimum value is zero. *Default: Disabled.*

Blackbody Subtraction - if this is enabled, the software will attempt to fit a blackbody curve and then subtract it off. This is sometimes used at high temperatures if there is a significant amount of blackbody radiation in the above-gap portion of the spectrum, and is therefore not applicable here. *Default: Disabled.*

Standard Subtraction - if this is enabled, the software will attempt to subtract the background signal from the raw spectra using one of two methods. *Default: Enabled.*

Subtract datapoint offset - if this is enabled, the software will first shift the entire spectrum such that the minimum value is zero. *Default: Disabled.*

Linear fit – This method performs a linear least squares fit to a portion of the spectrum centered at or below the inflection point. The fitted line is extended down, and every point to the left of where it crosses the wavelength axis is set to the value at that wavelength. *Default: Enabled.*

2nd derivative - this alternate method is based on the peak in the second derivative (i.e. “knee”), rather than the inflection point. In this case every point more than a specified distance left of the knee is set to the value at that wavelength. A 2nd derivative calibration file from k-Space is needed to be able to use this subtraction method, select a suitable file from the ***Substrate Material*** selection on the main Acquisition dialog box. Default: Disabled.

Boxcar width – The first derivative is calculated numerically and smoothed using a moving average, a boxcar, with the specified number of data points (must be odd). For example, a setting of N results in averaging each data point with the (N-1)/2 neighboring data points on either side. *Default: 19 pts.*

% of peak / ***Pts from 2nd deriv*** – If Linear Fit is selected, the fitted portion of the spectrum is centered at the point whose first derivative value equals this percentage of the maximum value. If instead, 2nd Derivative is selected, this value represents the offset from the knee. For example, a value of 10 means that every point more than 10 points left of the knee is set to the value at that wavelength. *Default: 85 %.*

Num Pts. +/- for back sub linear fit – (only for linear fit) – the number of points on both sides of the 2nd derivative that are used to find the best line fit (using least-squares fit). Choose a larger value for a longer line (if the graph has only one clear inflection point) and a shorter value to avoid fitting if there are multiple inflection points (the software chooses the first inflection point from the left). For example, a setting of 9 results in fitting the 9 neighboring data points on either side of the data point in question. *Default: 9 pts.*

After the optional background subtraction the following settings are applied:

Clip data point to min – If this is enabled, the software will clip all data points to the left of the minimum value to the minimum value. This checkbox should always be selected so that this happens. *Default: Enabled*

Clip from peak - if this setting and background subtraction are enabled, the minimum value used for clipping is restricted to one that lies to the left of the inflection point. *Default: Enabled.*

Subtract data point offset –If this is enabled, the software will shift the entire spectrum such that the minimum value is zero. *Default: Enabled.*

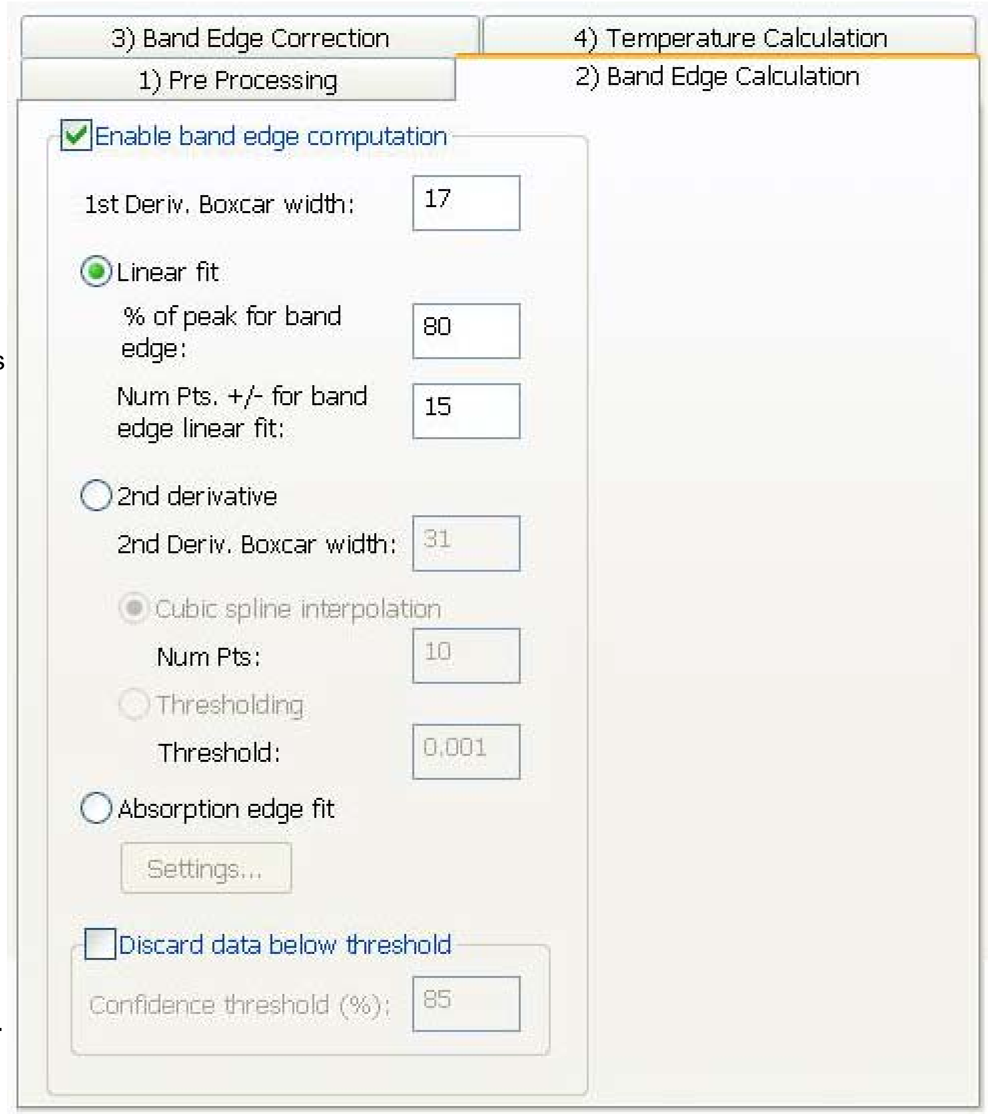
Normalize data point – If this is enabled, the software will normalize the spectrum such that the peak value is one. This is the final step in the pre-processing algorithm. *Default: Enabled.*

Band Edge Calculation

This is a part of the Band Edge Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window.

This tab contains the settings used to calculate the band edge wavelength from the pre-processed spectra (as determined by the settings in the Pre Processing tab).

Enable band edge computation -- If this is enabled, the software will compute the band edge wavelength value using one of the two main methods described below. The first method is based on the inflection point; the second method is based on the knee wavelength. *Default: Enabled.*



Specify:

> ***1st Deriv. Boxcar*** – In either method the first derivative is calculated numerically and smoothed using a moving average, a boxcar, with the specified number of data points (must be odd). For example, a setting of N results in averaging each data point with the (N-1)/2 neighboring data points on either side. *Default: 17 pts.*

For fitting the band edge, Select:

> ***Linear fit*** - This method performs a linear least squares fit to a portion of the spectrum centered at or below the inflection point. The fitted line is extended down until it crosses the wavelength axis. The band edge wavelength is defined as the point of intersection. *Default: Enabled*.

> > ***% of peak for band edge*** – The fitted portion of the spectrum is centered at the point whose first derivative value equals this percentage of the maximum value. To use the inflection point, select 100. For a value less than the peak, select a smaller percentage. For example, 80 means the band edge is set to be the spectra value that is 80% of the 2nd derivative peak height, i.e., 20% *down* (to the left) in the height of the peak in the 2nd derivative. *Default: 85%.*

> > ***Num Pts. +/- for band edge linear fit*** –Number of points used in the linear least squares fit. For example, a setting of 7 results in fitting the 7 neighboring data points on either side of the data point in question. *Default: 7 pts.*

or

2nd derivative - This alternative to the Linear Fit method is based on the knee wavelength. It is typically used if the presence of oscillations makes a linear fit difficult. There are two variants of this method. *Default: Disabled.*

2nd Deriv. Boxcar width – The second derivative is calculated numerically from the first derivative and smoothed using a moving average, a boxcar, with the specified number of data points (must be odd). For example, a setting of N results in averaging each data point with the (N-1)/2 neighboring data points on either side. Used to find the peak in the 2nd derivative (knee wavelength). *Default 31 pts*

Cubic spline interpolation – This variant defines the band edge wavelength as the peak of the second derivative, or knee. It first fits a cubic spline and interpolates a number of data points between the original points. *Default: Disabled.*

Num Pts - Specifies the number of data points to be interpolated between the original points. *Default: 10 pts.*

Thresholding - This variant defines the band edge wavelength as the point where the second derivative crosses a certain threshold value. This approach is intended to further reduce the sensitivity to oscillations. *Default: Disabled.*

Threshold - Specifies the second derivative threshold value. *Default: 0.001.*

or

Absorption edge fit - This alternative to the Linear Fit method is also based on the knee wavelength. It is typically used if the presence of oscillations makes a linear fit difficult. Rather than finding the knee numerically, it attempts to perform a non-linear least squares fit to the spectra. *Default: Disabled*.

Click Settings to specify the settings for this fit.

Check:

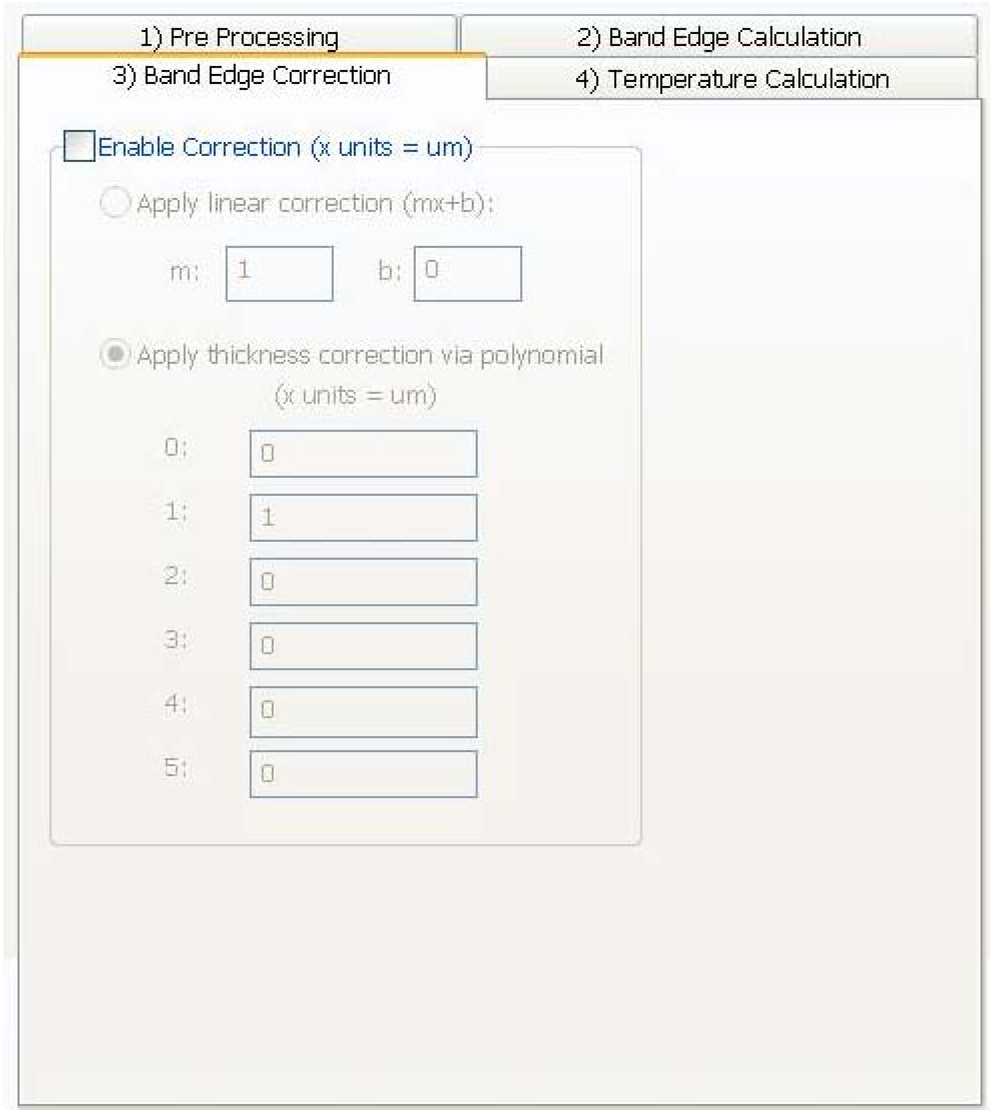
Discard data below threshold – In the case of a linear fit, the software calculates a confidence level (expressed as a percentage) based on the goodness of fit to the data. If this setting is enabled, the software will discard band edge wavelength values for which the calculated confidence is below a user-specified threshold level. Note that this only applies if the linear fit is selected. This is particularly useful when the user knows that reflected light may be obscured or altered during the acquisition process (e.g., reflected light off of a rotating platen for multiple wafers is a common reason). *Default: Enabled.*

Confidence threshold – Minimum confidence value for accepting a band edge linear fit. This sets the confidence-level below which the Real-Time Confidence meter will show red (indicating a poor fit) and above which it will show a green (indicating a good fit). *Default: 95 %.*

Band Edge Correction

This is a part of the Band Edge Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window. It is used to correct the Band Edge calculation made in the previous tab. In other words, this tab allows the user to tweak the *Band Edge Wavelength* value – the intercept of the absorption edge wavelength fit and the Band Edge Wavelength. This is seen in the *BandiT Processed Spectra* chart in the aforementioned Band Edge topic as the intercept between the blue line and the x-axis.

(*Note that temperature also has its own linear correction – described in 4) Calculate Temperature.*)



Enable Correction - If this is enabled, the software will apply a correction to the calculated band edge wavelength value using one of the two methods described below. *Default: Disabled.*

Choose:

Apply linear correction (mx+b) – performs a linear scaling of the band edge wavelength with scaling factor m and offset b. The corrected band edge wavelength, λ', is obtained via the equation: $\lambda' = m*\lambda + b$. *Default: Disabled.*

m – slope of the linear correction *Default: 1*

b – offset of the linear correction (nm) *Default: 0*

or

Apply thickness correction via polynomial – performs a film-thickness-dependent band edge wavelength correction (this will affect the final computed temperature) A correction term, Δλ, is calculated from the film thickness, t (expressed in microns), using up to a 5th order polynomial. The corrected band edge wavelength, λ', is obtained from the calculated film thickness via the equation: $\lambda' = \lambda + \Delta\lambda$, where $\Delta\lambda = a_0 + a_1*t + a_2*t^2 + \ldots + a_5*t^5$. *Default: Disabled.*

0 – the constant added to the polynomial

1 – the coefficient of the 1st degree term of the polynomial

2 – the coefficient of the 2nd degree term of the polynomial

…

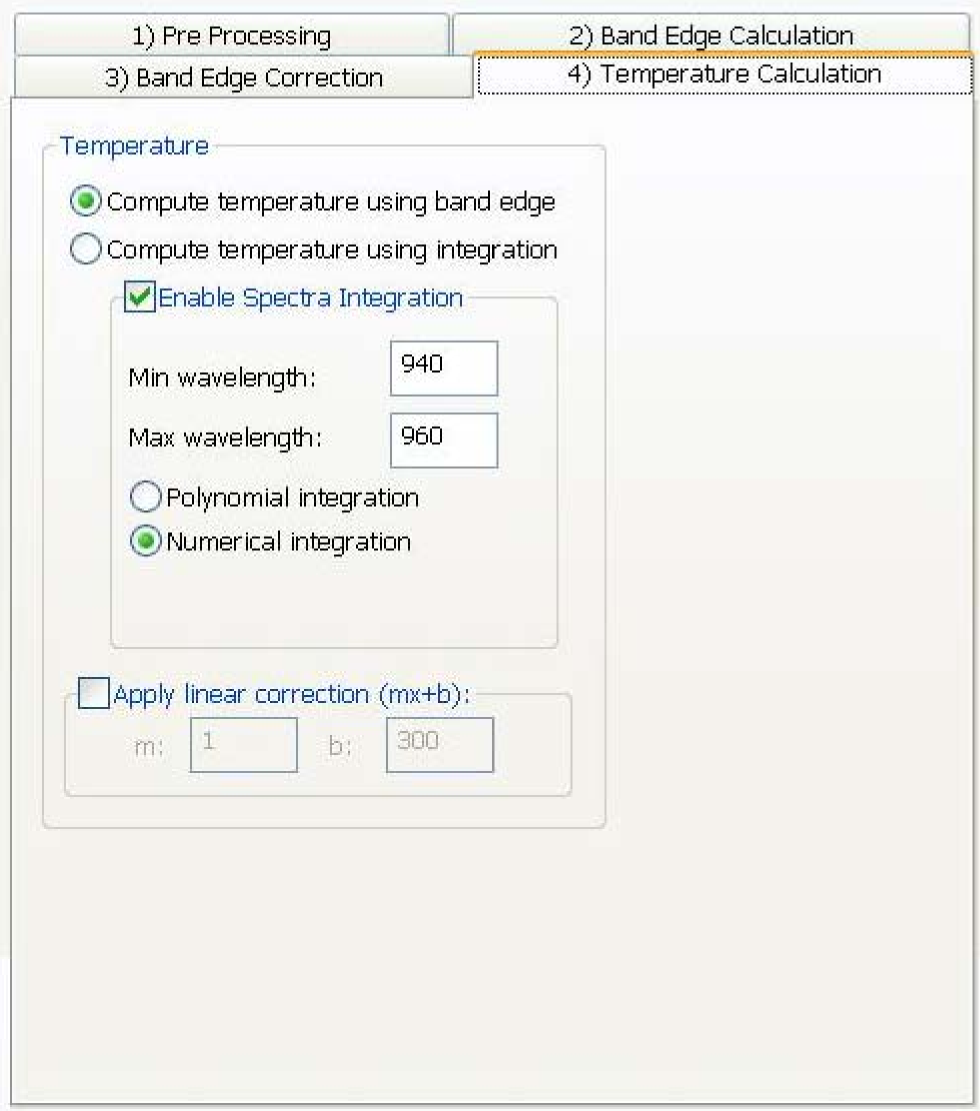
5 – the coefficient of the 5th degree term of the polynomial

Temperature Calculation

This is a part of the Band Edge Configuration Option found by pressing the ***Config*** button in the Acquisition Mode window.

BandiT computes temperature using Band Edge data, but k-Space is investigating temperature calculation via spectra Integration (the area under the curve). At the time of this manual being written, no calibration files are available for users using spectra integration. However, users can still enable spectra integration while computing temperature using band edge, if desired.

Choose:



Compute temperature using band edge – the software will use a user-specified substrate material calibration file to convert band edge wavelength to temperature. This is the default method k-Space Associates has developed to compute temperature. *Default: Enabled.*

or

Compute temperature using integration – an alternate temperature calculation method which is based on integrating the spectral curve. This computes the integrated value (sum of the area beneath the spectra wavelength) in the *.kdt file between two user-specified wavelengths because it automatically enables ***Spectra Integration***. No calibration files are available for users using spectra integration. *Default: Disabled*.

Check:

Enable Spectra Integration - Both temperature calculation methods allow the user to integrate the spectral curve. This option allows users to take advantage of the existing material-dependent band edge wavelength calibration files while also collecting data on the area under the spectral curve for refining the temperature calculation. *Default: Disabled.*

Specify:

Min. wavelength – set the lower limit for integration. *Default: 880 nm*

Max. wavelength – set the upper limit for integration. *Default: 950 nm*

Then, choose either:

Polynomial integration – Select this option to fit the spectrum with a polynomial, and then compute the integral using the polynomial. *Default: Disabled.*

or

Numerical integration – Select this option to directly integrate the spectral data. *Default: Disabled.*

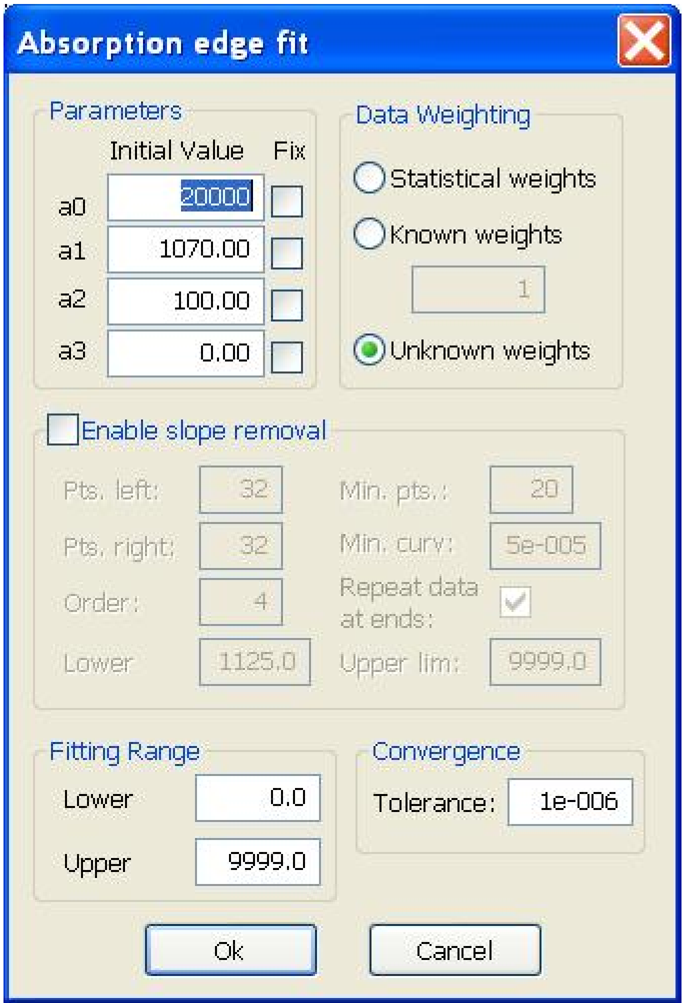
Lastly, check:

Apply linear correction (mx+b) - to perform a linear scaling of the temperature with scaling factor m and offset b. The corrected band edge temperature, T', is obtained via the equation: T'=m*T+b. *Default: Disabled*.

m - scaling factor (dimensionless). Default: 1

b - offset (°C). Default: 0 °C

For example, suppose during calibration that a plot of Pyrometer temperature vs. BandiT computed temperature does not go through the origin or have the correct slope. Use the linear correction to alter the slope and intercept so that future BandiT Temperature calculations will also be corrected.



Absorption Edge Fit Settings

The ***Absorption edge fit*** settings menu is accessed from the Band Edge Calculation tab of the Band Edge configuration option.

The Absorption Edge Fit is an alternative to the Linear Fit method of Band Edge calculation also based on the knee wavelength. It is typically used if the presence of oscillations makes a linear fit difficult. Rather than finding the knee numerically, it attempts to perform a non-linear least squares fit to the spectra.

Specify ***Parameters*** for the non-linear least squares fit - initial estimates that are near to the optimal values will improve the possibility of getting a good fit:

a0 - Amplitude

a1 - Inflection Point

a2 - Transition Width

a3 - Baseline Offset

Check

Enable Slope removal - and specify the points and limits to be removed, to remove any slope from the below-gap portion of the spectrum before the fitting takes place

Advanced acquisition options

Advanced Acquisition Options

These are found by clicking the ***Advanced*** button once you have selected an acquisition mode.

Options include:

BandiT I/O Settings – set what data is stored from the acquisition

Data Binning - sort data into separate bins

Delay - set delays before data is collected or between data points

Device Output Control - specify signals for external devices

Documentation Generation – set how documents are named and saved

General – set the number of samples per data point and other general program functionality

Inputs - specify analog or digital inputs

Pause/Resume Trigger- use input signals to pause and resume acquisition

Prompts – enable/disable prompts before and after acquisition

Pyrometric Oscillations – generate a scan mode image for growth-rate analysis

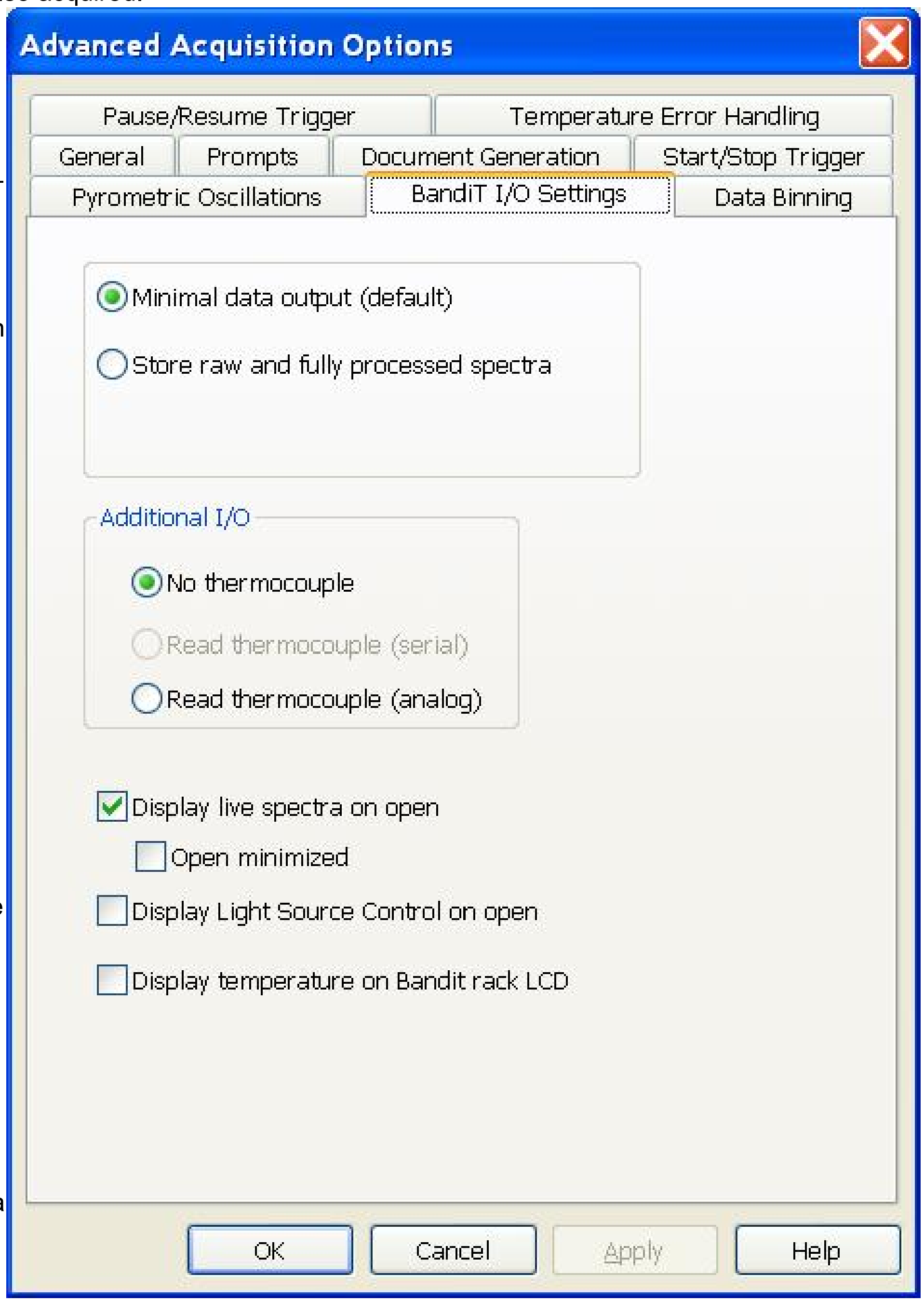
Start/Stop Trigger – use input signals to start and stop acquisition

Temperature Error Handling – specify how the software handles temperature analog output data

BandiT I/O Settings

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window.

It is used to configure what data is stored from the acquisition, as well as whether additional data input (via a thermocouple) is also acquired.



Specify:

> ***Minimal data output (default)*** – to store only the BandiT processed data, i.e., entire spectra will not be stored. This option also minimizes data storage requirements and maximizes the number of data points that can be stored.
>
> or
>
> ***Store raw and fully processed spectra*** – to store all acquired data, including the raw and normalized spectrometer spectra. Selecting this option can result in very large data files. If needing all data over a long period of time, a delay between data points is recommend, so that acquisition does not occur at the maximum data rate. To create a delay, use the Spectrometer Properties Advanced tab to skip frames or use the Delay Advanced Acquisition Option.

For *Additional I/O*, specify:

> ***No thermocouple*** – to ignore thermocouple data and not store it

or

Read thermocouple (serial) – to read the thermocouple value as a serial input. This depends on the port. Please contact k-Space for the data format.

or

Read thermocouple (analog) – to read the thermocouple value as analog (i.e., voltage) value.

Check:

Display live spectra on open - to display the spectrometer live spectra window automatically upon opening the application.

Open Minimized to have the spectra window minimized on open

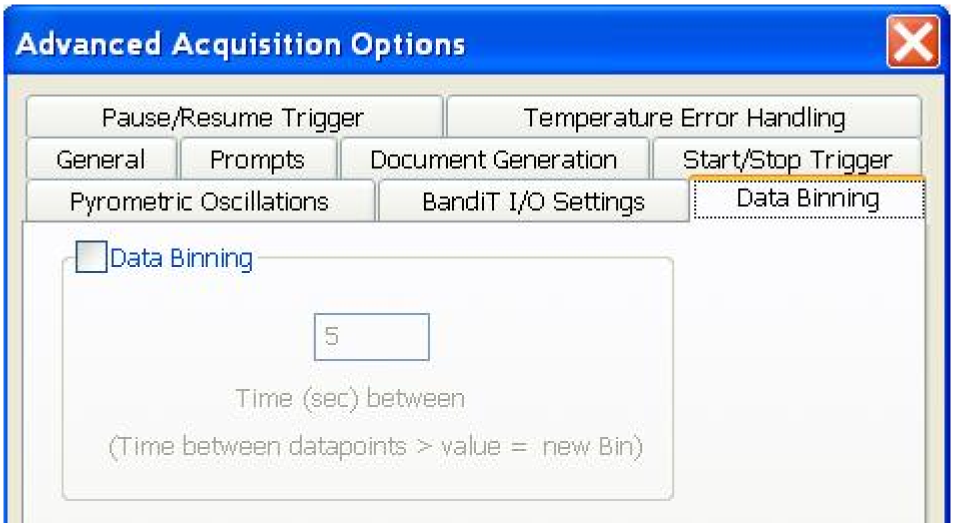
Display Light Source Control on Open - to open the Light Source Control window

Display temperature on Bandit rack LCD - this keeps the rack display updated at the same rate as the computer readout. This can slow acquisition slightly.

Data Binning

This is an Advanced Acquisition Option found by pressing the ***Advanced*** button in the Acquisition Mode window.

If enabled ***Data Binning*** allows the system to distinguish between bursts of data by counting the time between bursts. A burst can be a triggered event for example with the Pause/Resume Trigger, or can be detected as times when the Spectrometer is over saturated or recording zero intensity for example between wafers on a rotating platen. Each burst of data is then directed into a new bin. There must be a measurable time gap for this to work.

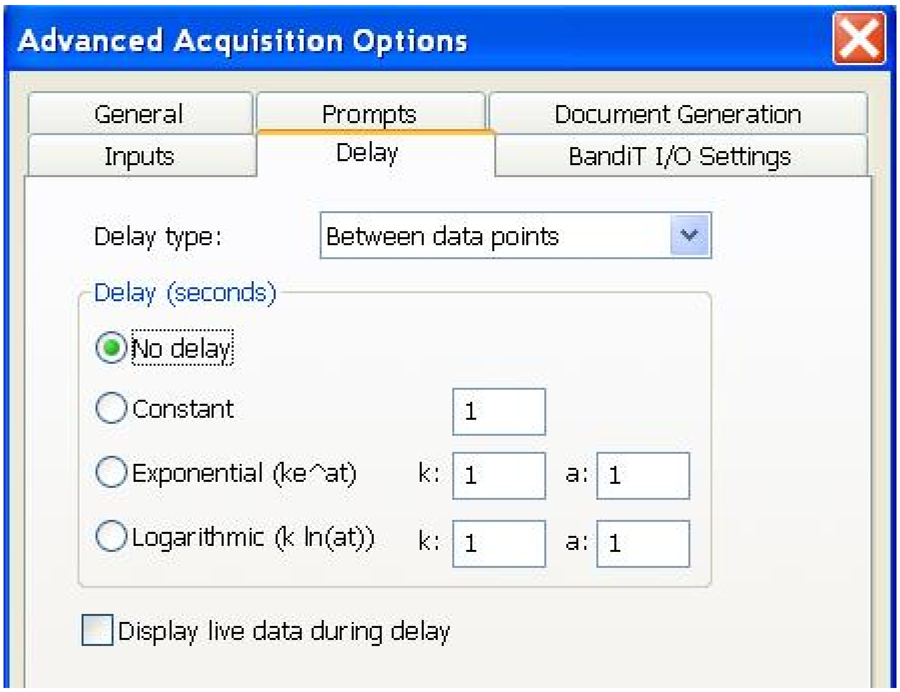


Check ***Data Binning*** to enable the function and enter a ***Time*** in seconds which will be used as the trigger to direct data to be saved in a new bin.

Delay

This is an Advanced Acquisition Option found by pressing the ***Advanced*** button in the Acquisition Mode window.

Use a delay to leave time between data points. Users may want to take advantage of the different types of delays and exponential or logarithmic settings. For example, exponential settings may be useful for a user who wants to capture data many times at the beginning of a process but needs fewer and fewer data points as time passes.



Note: each ***Delay type*** is independent of the other. So, for example, you can have a constant delay of 1 second before the first data point and an exponential delay (or choose a constant again or a logarithmic) with (k=5 and a = 2) between each data point and a constant delay (again, or choose an exponential or logarithmic) between samples of 10 seconds. In order to ensure there is no delay of any kind, then you must ensure that ***No delay*** is selected under each delay type.

Select:

For ***Delay type***, choose –

Between data points – to specify a delay between each data point acquired

Before first data point – to specify a delay before the first data point is acquired

Between samples – to specify a delay between each sample of acquired data. (Set ***Samples per data point*** in the General Advanced Acquisition Option.)

For ***Delay (seconds)***, choose –

No delay

Constant – specifies a delay of a constant value in seconds. This is similar to skipping frames, but is more exact because frame skipping depends on computer speed, which changes from computer to computer and can change during acquisition.

Exponential (ke^at) – using this delay option means that the software samples the data in time intervals that follow the dependent value of an exponential curve—slowly at first and then faster and faster. Use this option if capturing a process where the most important part happens at the end of the process. Note that the software only allows the parameter *a* to be positive.

Logarithmic (k ln(at)) – using this delay option means that the software samples the data in time intervals that follow the dependent value of a logarithmic curve—quickly at first and then slower and slower. Use this option if capturing a process where the most important part happens at the beginning of the process.

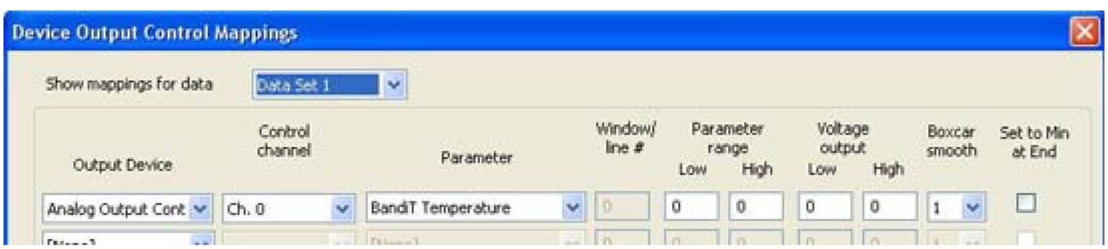
Check the ***Display live data during delay*** box in order to keep the data in the spectrometer window live. Un-checking the box means that the last sampled data point remains on the Live Spectrometer window until the next sample is acquired.

Device Output Control

This is an Advanced Acquisition Option found by pressing the ***Advanced*** button in the Acquisition Mode window, so long as Data sets are not enabled (because mapping may be specified for each data set, which is set when specifying the data sets. Please see the Data sets topic for more information). In addition, viewing this option may require hooking up an output control device.

Use this option to enable and specify settings for sending signals to external devices.

After enabling, click the ***Edit output mappings*** button to open the ***Device Output Control Mappings*** dialog:



Specify:

Output Device – through which output signals can be made. This device is typically a data acquisition board with digital or analog output channels. If the device is detected by the k-Space software, it will be present in the *Output device* dropdown box.

Control channel – of the of the selected device that you want to use for signal output. The *Control channel* dropdown list will list only those channels currently available on the selected *Output device*.

Parameter – to be mapped to the output channel. For example, it could be the BandiT temperature, band-edge wavelength, elapsed time, etc. All available data parameters will be listed in the *Data parameter* dropdown box.

Window/line # – if the acquisition mode utilizes window or line regions, then this parameter selects which region to use for the data output mapping. Note that this parameter is not available in some acquisition modes, in which case this parameter text box will be disabled (such as above).

Parameter range – to define the range of parameter values mapped to the output channel. In the example above, the temperature range is 0°C (min) to 800°C (max). Many other parameters are available.

Voltage output – to define the voltage range to which the *Parameter* is mapped. Common ranges include 0-10V, 0-5V, and -5-+5V.

Boxcar Smooth – to employ a simple, common data smoothing routine whereby a given data point is smoothed, or averaged, into the data surrounding it. As an example, for a 3-point boxcar smooth, each data value is averaged with its nearest neighbor data point on each side, replacing the original data value with this "smoothed" average. Note that the boxcar smooth value must be an odd number. When 1 is chosen, no smoothing is done.

Set to Min at End - will set the specified mapped minimum voltage after the acquisition is complete. This is useful to keep active high boards in the 'off' state when not in use.

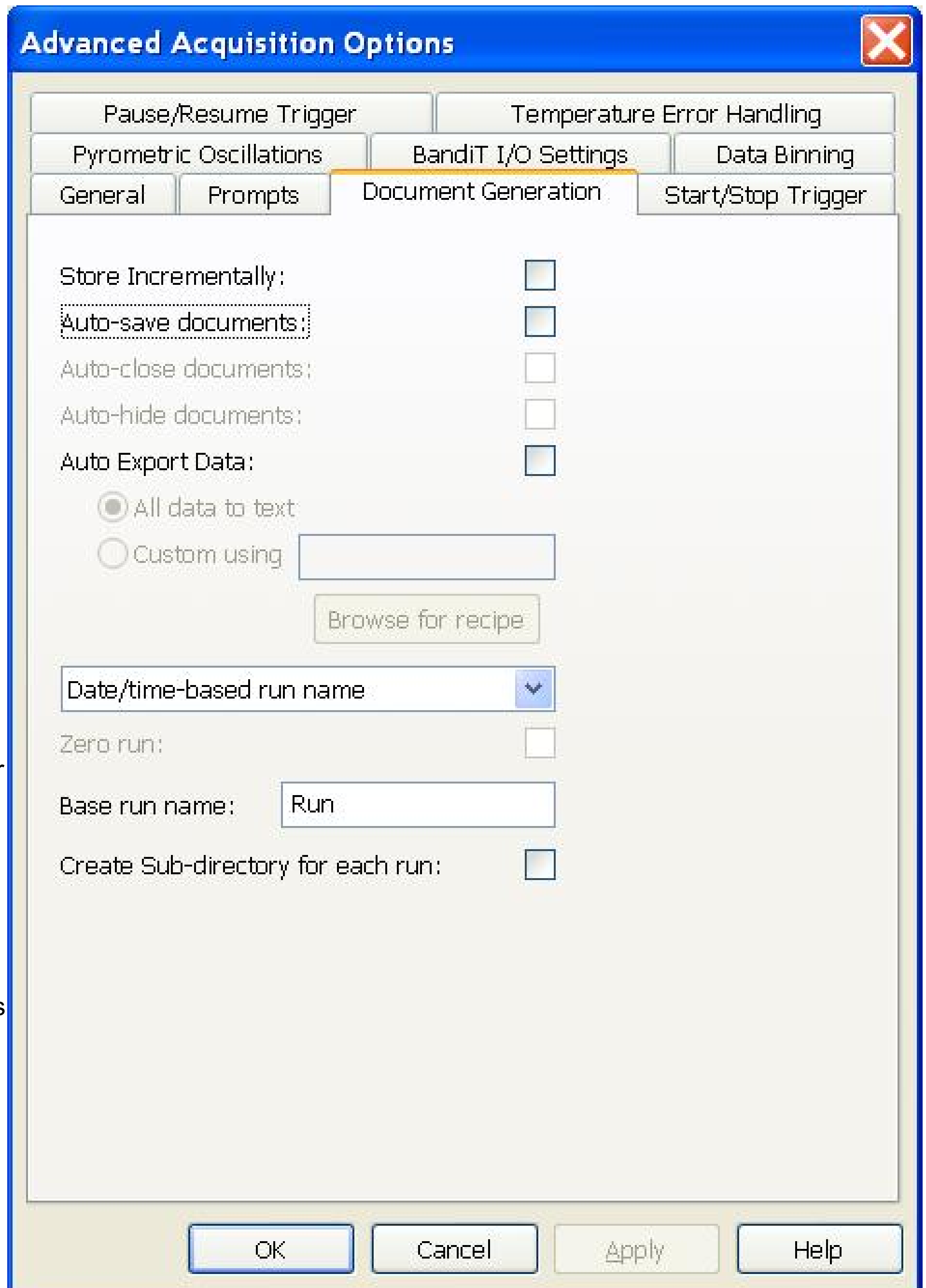
Note: For smoothing on analog outputs, the software waits until it gets the boxcar smooth number of data points, and then averages these numbers to smooth the data.

Document Generation

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. Use this option to set how documents are named and saved.

Check:

Store Incrementally – when acquiring for a long time (more than 5 minutes), it is generally a good idea to store data in smaller packets rather than saving only when the system's RAM is full. With this option checked, small



delays occur regularly and large delays are avoided.

Note that checking *Store Incrementally* automatically selects *Auto-save documents*, *Auto-close documents*, and *Auto-hide documents*, preventing the user from changing these options.

Auto-save documents – images are automatically saved in RAM, but selecting this option automatically saves them to disk as well. Note that the kSA Log is saved automatically unless no logging is selected in the General Options Logging.

With *Auto-save documents* checked,

Auto-*close documents* – to have documents close as soon as acquisition is complete.

With *Auto-close documents* checked,

Auto-hide documents – to briefly flash the data file on the screen while it is being saved. This is a visual aid to remind the user that the document has been saved and closed.

Auto-export data to text – causes all the acquired data also to be stored to another file type in addition to the kSA *.kdt file. Note that auto-exporting data (such as to ASCII *.txt files) can make very large files and can take considerable time to save. In general it is a good idea to store data in the native *.kdt format (binary) as it requires less disk space and saves faster, and then, if needed, export the data after acquisition.

By using the drop-down window, select how data files will be named. Choose:

Manual run name – for typing in the name in the acquisition window for each image/movie

Auto-incrementing run name – type in a Base run name and for each new acquisition the software adds one to the number (up to 9999). For example, with a Base run name of "Run," the first acquired image is Run0001, the second is Run0002, etc. Or click the ***Zero run*** checkbox to start the count at 0000.

Date/time-based run name – type in a Base run name and for each new acquisition the software uses the computer's date/time-stamp to uniquely name the file. For example, with a Base run name of "Run," a possible acquired image may be:

Run20061204.135940

where

20061204.135940 = year-month-day . hour-minute-second

So in this case, the file was generated at:

13:59:40 p.m. on December 4, 2006

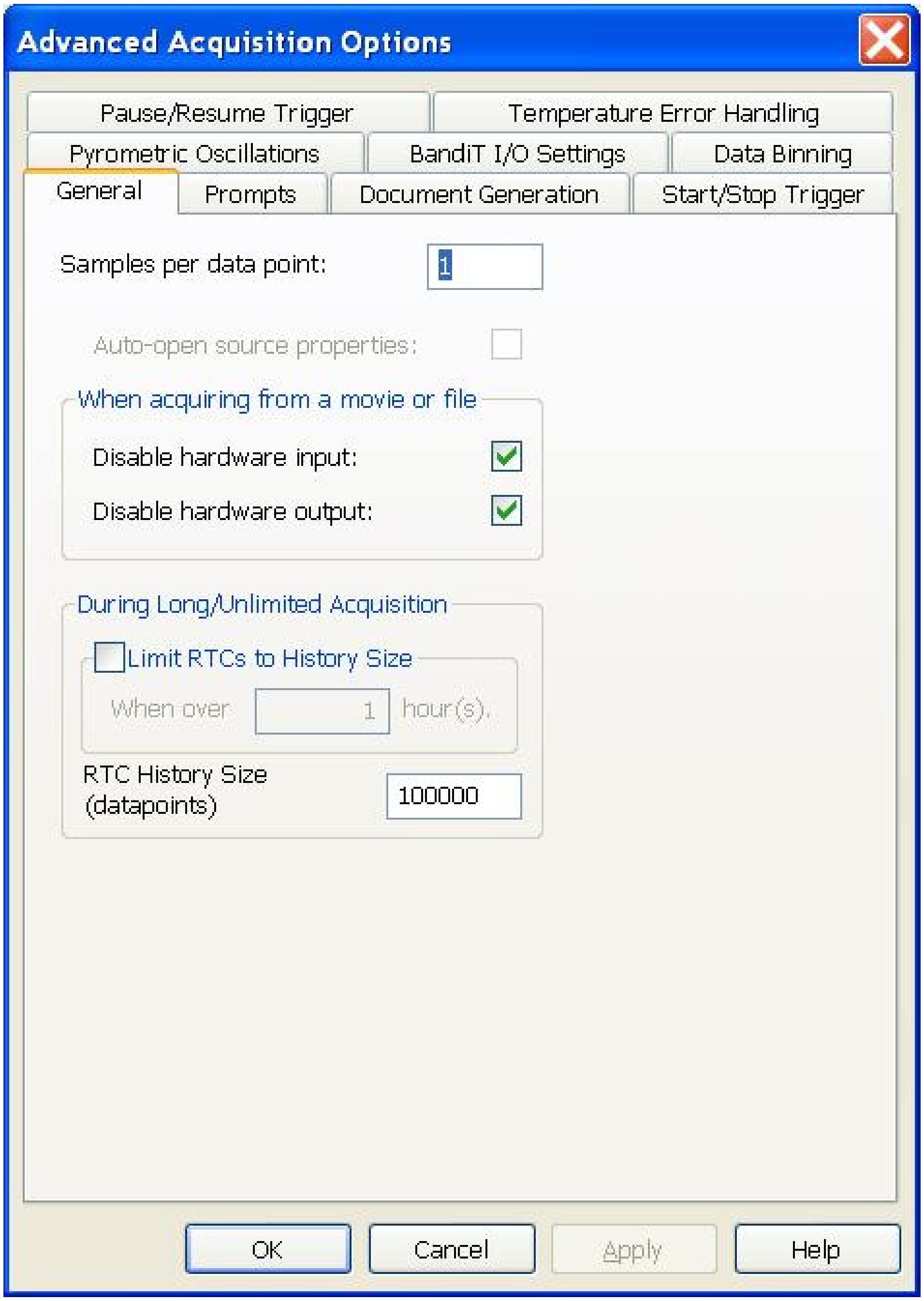
Base run name – type in a Base run name for use with the Auto-incrementing or Date/time based options.

Check:

Create Sub-directory for each run - to have each run saved in it's own sub directory.

General

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. Use this option to set the number of samples per data point and other general program functionality.



Specify:

Samples per data point – number of measurements to take for each data point. For example, if set to 5, then five measurements will be averaged together to make one data point. Note that this is different than sampling or averaging at the level of the data source: sampling of the data source is averaging the source signal, not averaging the processed or derived data point.

Auto-open source properties – checking this option means that the properties of the acquisition source opens whenever an acquisition mode is selected. It is disabled in kSA BandiT.

When acquiring from a movie or file, check

Disable hardware input – to ignore any inputs (like triggers). When acquiring data from a file (as opposed to from a live data source), checking the *Disable hardware input* checkbox will ensure that no analog or digital input signals will be read during the acquisition.

Disable hardware output – to keep from sending any outputs (like triggers). When acquiring data from a file (as opposed to from a live data source), checking the *Disable hardware output* checkbox ensures that no analog or digital output signals are sent during the acquisition. This is useful, for example, when replaying a data file on the acquisition computer, and no output control is desired.

During Long/Unlimited Acquisition, check

Limit RTCs to History Size - to limit the amount of data that Real Time Charts display, during very long or continuous data acquisition

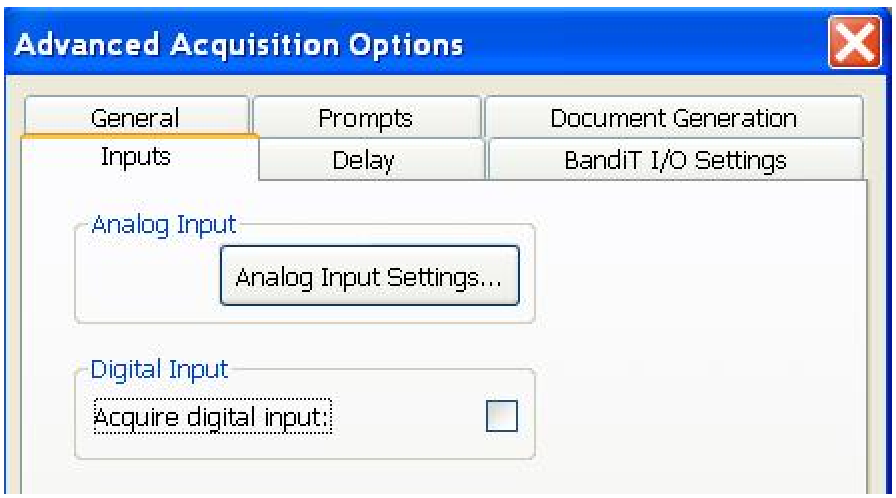
specify

When over - enter the number of hours over which the data will be limited

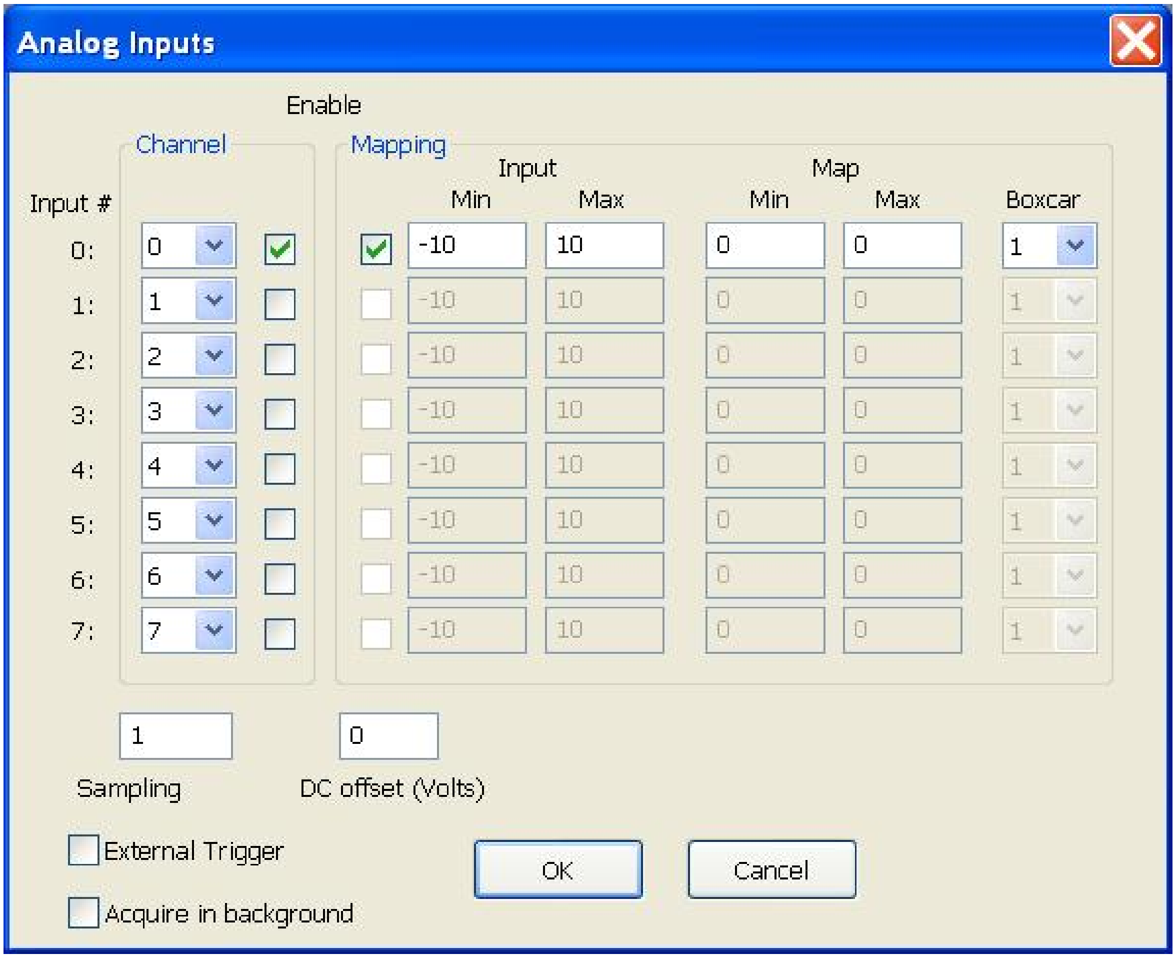
RTC History Size (datapoints) – the number of data points that the Real-Time Charts (RTCs) will display

Inputs

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. Use this option to enable input signal(s) for triggering and other acquisition options.



Clicking the ***Analog Input Settings*** button brings up the following dialog:



For each input number, specify

Channel – ***enable*** each by ticking the checkbox next to each drop-down option. In general, input numbers should be set to input channels (called *Board channels* in the Analog Input Board – while there are boards with sixteen input channels, only the first eight channels can be mapped at this time).

Enabling each channel enables the corresponding map checkbox:

> Mapping – ***enable*** each map and then type in the ***Input Min*** and ***Max*** that describes the voltage limits received by the system. Then select the ***Map Min*** and ***Max*** for the linear scale map and choose a ***Boxcar*** value from the drop-down box for smoothing (1 means no smoothing).

Sampling – this is the number of times the system reads an input signal before giving a value. Increasing this number means less noise, but will slow down acquisition.

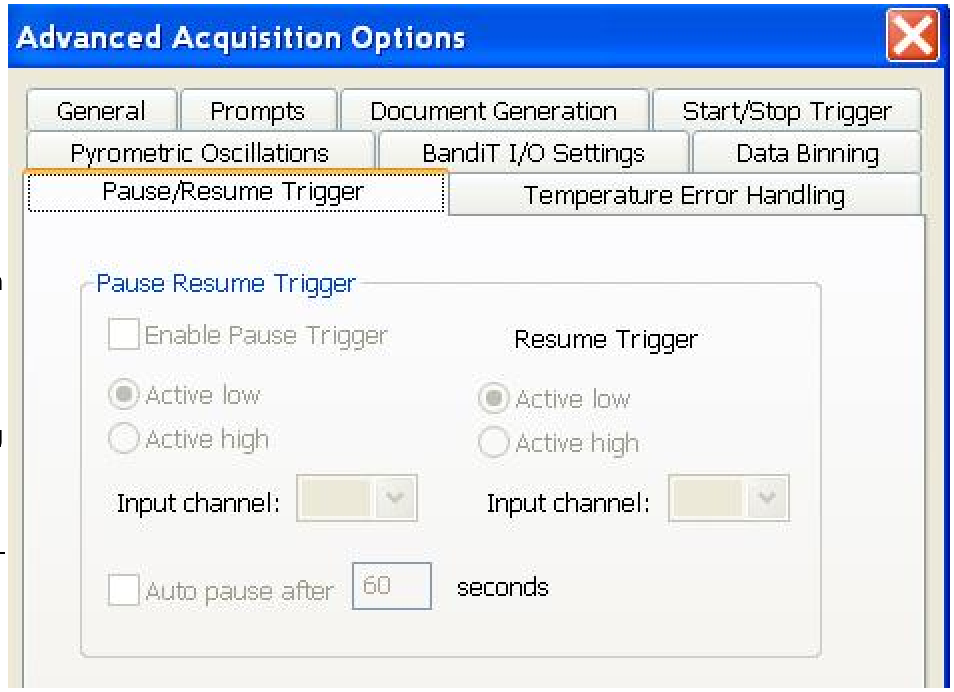
Check:

> ***External trigger*** - If an external trigger is present
>
> ***Acquire in background*** - to acquire data in the background

Check the ***Acquire digital input*** button to enable digital inputs. No special mapping is required, but please ensure that the Digital Input Board is set up properly.

Pause Resume Trigger

This is an Advanced Acquisition Option found by pressing the ***Advanced*** button in the Acquisition Mode window. Enable Pause/Resume trigger in order to start and stop acquisition based on a hard-wired input signal (usually into the digital input board). Note that the options in this window will be enabled only if the hardware supports it.



With ***Enable Pause Trigger*** checked, choose either:

> ***Active low*** or ***Active high*** for selecting whether the trigger activates on a high voltage or a low voltage. This depends on the output signal from the device sending the start trigger signal.
>
> Then use the drop-down window to specify the ***Input channel***, with options set in the Digital Input Board (Options menu, Input/Output Boards) and the Inputs tab in the Advanced Acquisition Options.

Options for **Resume *Trigger*** are automatically enabled when the ***Enable Pause Trigger*** is checked. Then choose:

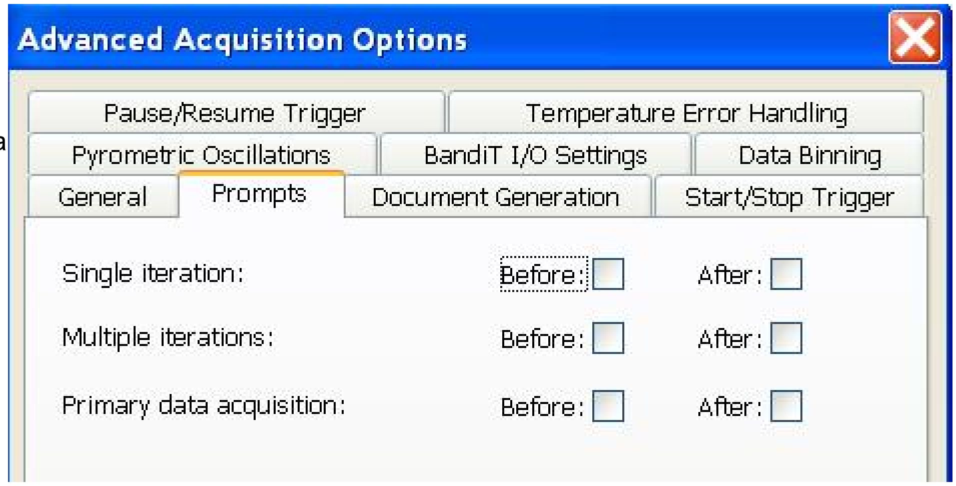
> ***Active low*** or ***Active high*** for selecting whether the ***Resume trigger*** activates on a high voltage or a low voltage. This depends on the output signal from the device sending the resume-trigger signal. Because the ***Resume trigger*** signal may or may not be from the same device as the ***Pause trigger*** signal, both options are available. If both signals do come from the same device, then generally the ***Pause*** activation (e.g. high) will be opposite from the ***Resume*** activation (e.g. low).
>
> Then use the drop-down window to specify the ***Input channel***, with options set in the Digital Input Board (Options menu, Input/Output Boards) and the Inputs tab in the Advanced Acquisition Options.

Select:

> ***Auto pause after*** - to automatically pause acquisition after a number of seconds, and specify the number of seconds required

Prompts

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. Use this option to turn on/off prompts before and after acquisition.



Check ***Before*** or ***After*** or both if you want prompts before or after

Overall acquisition – for a window prompt that signals the beginning/end of overall acquisition

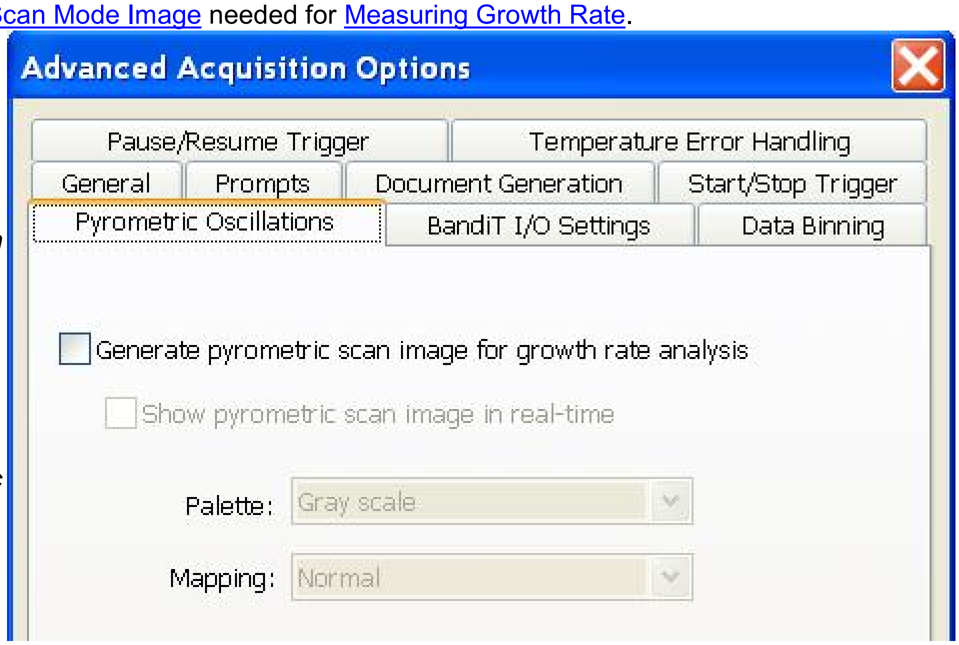
Background data – for a window prompt that signals that beginning/end of acquiring background data

Primary data acquisition – for a window prompt that signals the beginning/end of data acquisition. This dialog is different from the *Overall acquisition* prompt only if there is a sub loop of acquisition.

Pyrometric Oscillations

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window.

It is used to generate a Scan Mode Image needed for Measuring Growth Rate.



Check:

Generate pyrometric scan image for growth rate analysis to make a Scan Mode Image.

With the above checkbox selected, check ***Show pyrometric scan image in real-time*** to see the image being created in real time.

Select:

Palette - the palette is false coloring; it only changes how the image is displayed. Pick among a large number of palettes. The color can be changed after the image is generated by right clicking the image and selecting Properties.

Mapping - choose:

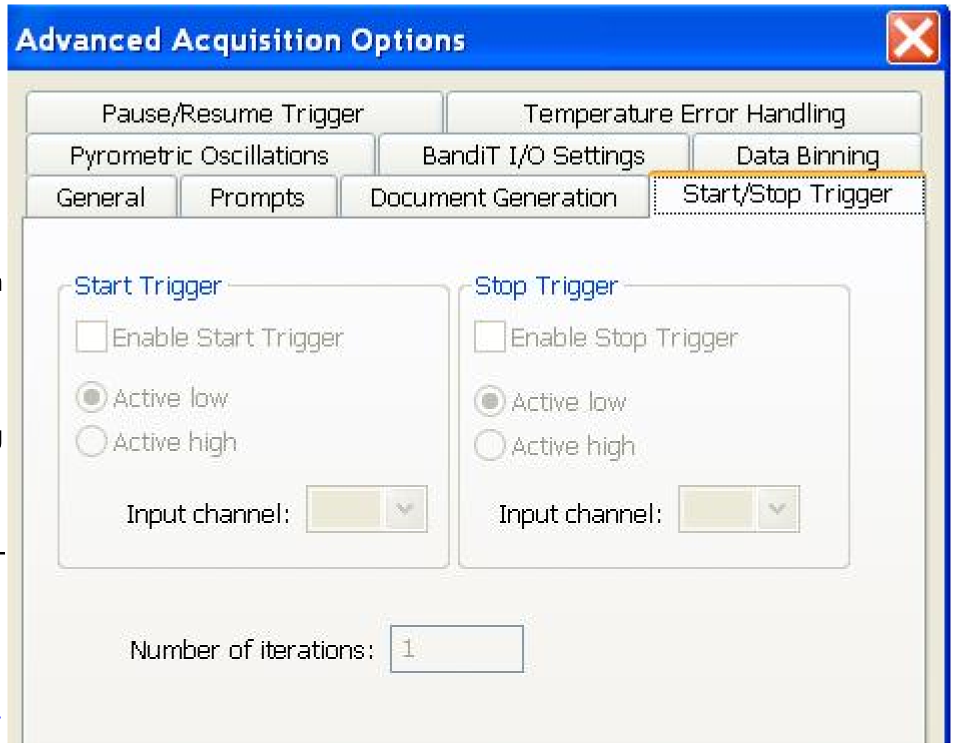
Normal – how the data comes in

Eight Most Significant Bits – for displaying a subset of the data, keeping only the most significant eight bits that make up the image. This option has the effect of reducing the number of shades in the image to an amount that the human eye can distinguish.

Maximized – for displaying the data scaled over eight bits, or 256 levels, so that the brightest part of the image is white and the darkest part black.

Start/Stop Trigger

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. Enable Start/Stop trigger in order to start and stop acquisition based on a hard-wired input signal (usually into the digital input board). Note that the options in this window will be enabled only if the hardware supports it.



With ***Enable Start Trigger*** checked, choose either:

Active high or ***Active low*** for selecting whether the trigger activates on a high voltage or a low voltage. This depends on the output signal from the device sending the start trigger signal.

Then use the drop-down window to specify the ***Input channel***, with options set in the Digital Input Board (Options menu, Input/Output Boards) and the Inputs tab in the Advanced Acquisition Options.

Options for ***Stop trigger*** are automatically enabled when the ***Enable Start Trigger*** is checked. Then choose

Active high or ***Active low*** for selecting whether the *Stop trigger* activates on a high voltage or a low voltage. This depends on the output signal from the device sending the stop-trigger signal. Because the *Stop trigger* signal may or may not be from the same device as the *Start trigger* signal, both options are available. If both signals do come from the same device, then generally the *Start* activation (e.g. high) will be opposite from the *Stop* activation (e.g. low).

Then use the drop-down window to specify the ***Input channel***, with options set in the Digital Input Board (Options menu, Input/Output Boards) and the Inputs tab in the Advanced Acquisition Options.

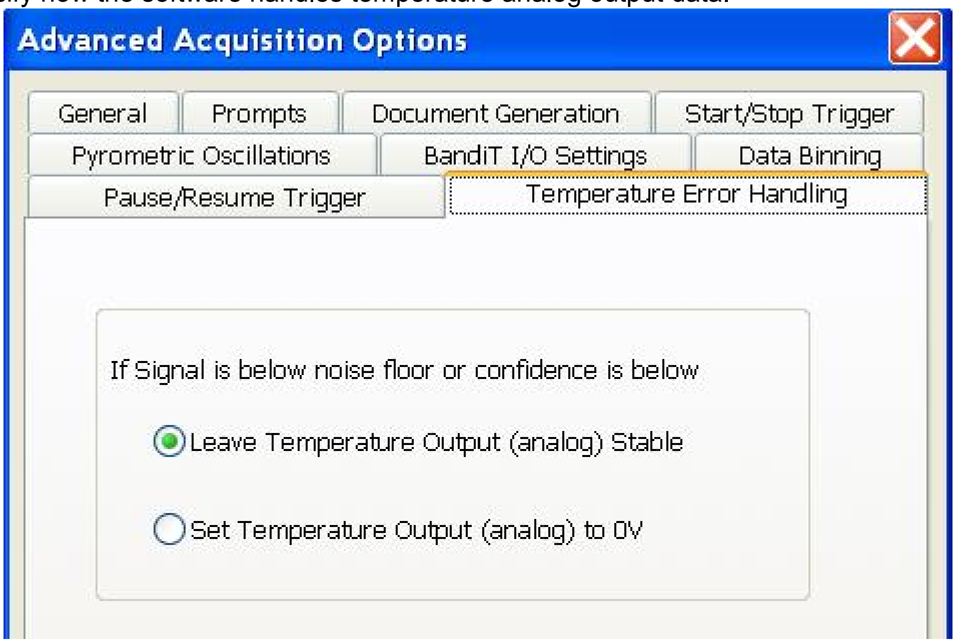
A stop trigger may not be needed if, for example, the acquisition duration is set for only a certain amount of time or number of data points/images.

Specify:

Number of iterations - the number of cycles to complete

Temperature Error Handling

This is an Advanced Acquisition Option found by pressing the *Advanced* button in the Acquisition Mode window. It is used to specify how the software handles temperature analog output data.



Select either:

Leave Temperature Output (analog) Stable – (default selected) – to keep the temperature analog output at the last good data point (before signal fell below noise floor or the fit falls below the confidence threshold – values set in the Spectra Processing advanced acquisition option).

For example, some users map temperature output as an analog voltage via the Device Output Control and use it to help control chamber temperature. Such users would probably want to ***Leave Temperature Output (analog) Stable*** so that if there's a period in which BandiT doesn't fit the data that the analog output remains stable, keeping the input into the chamber-temperature controller the same. If it were set to zero, that potentially would cause the temperature controller to respond as if the chamber temperature had suddenly gone to zero and raise the temperature!

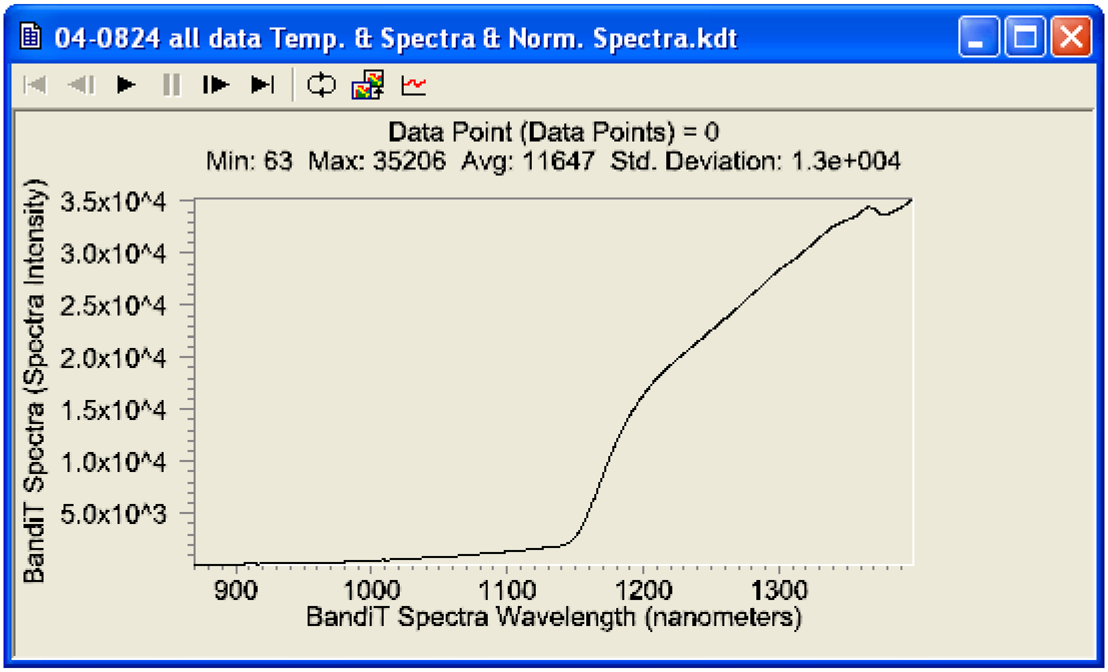
or

Set Temperature Output (analog) to 0V – to set the temperature analog output to zero. Users may want to select this option as the temperature output analog data suddenly going to zero clearly shows when the signal falls below noise floor or the fit falls below the confidence threshold. This option is for users who are not using the temperature analog output value as an input into the chamber-temperature controller.

Scan Mode Image

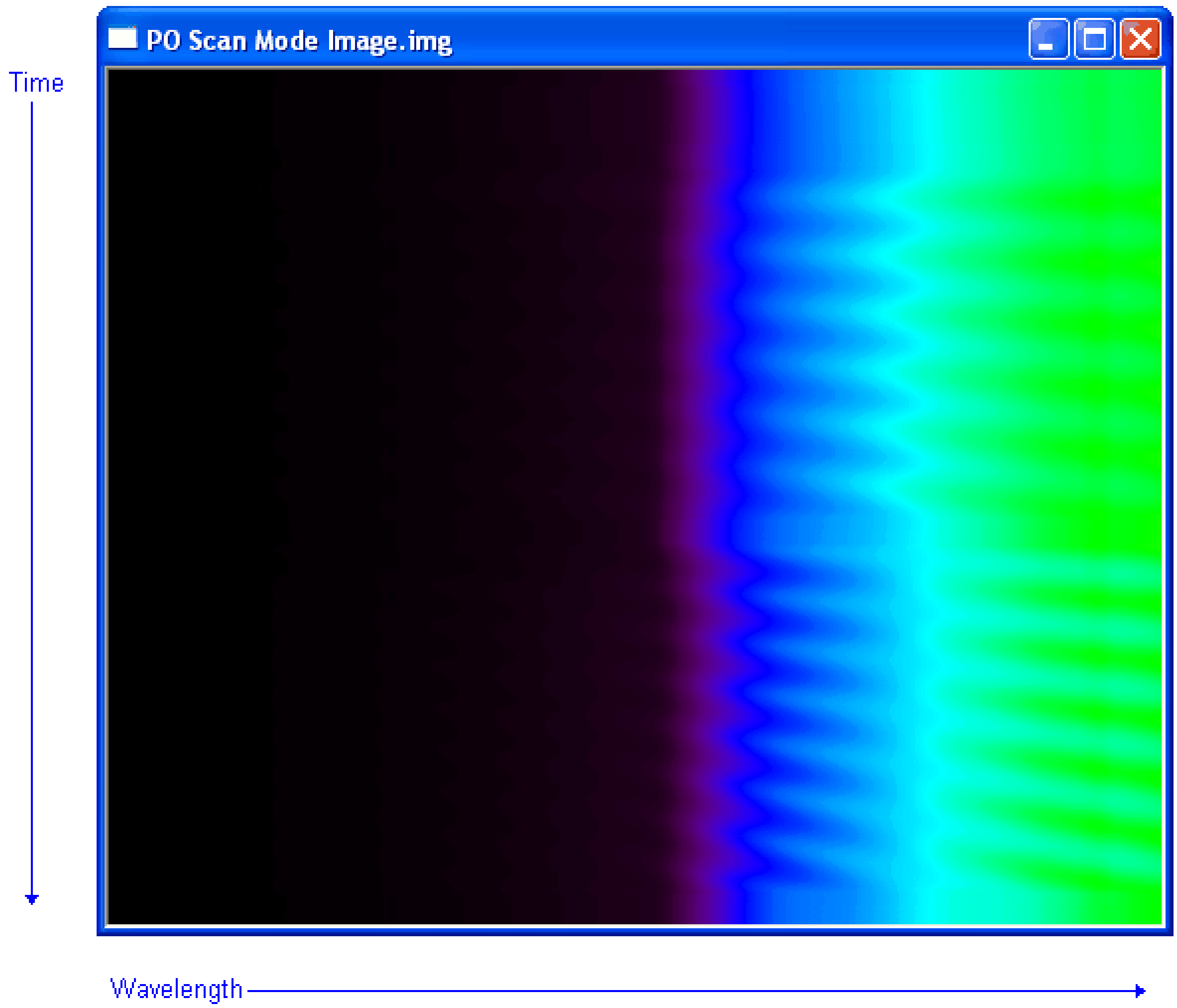
A ***Scan Mode Image*** is created when ***Generate Pyrometric Scan Mode Image*** is selected in the Pyrometric Oscillations advanced acquisition option.

The Scan Mode Image is created by taking the Spectra Intensity versus wavelength.



and mapping it on to a color palette. A horizontal line is generated from each plot.

Then, subsequent lines are stacked – one below another – to create the Scan Mode Image.



This image can be analyzed with a Line Profile and used to Measure Growth Rate.

General Notes:

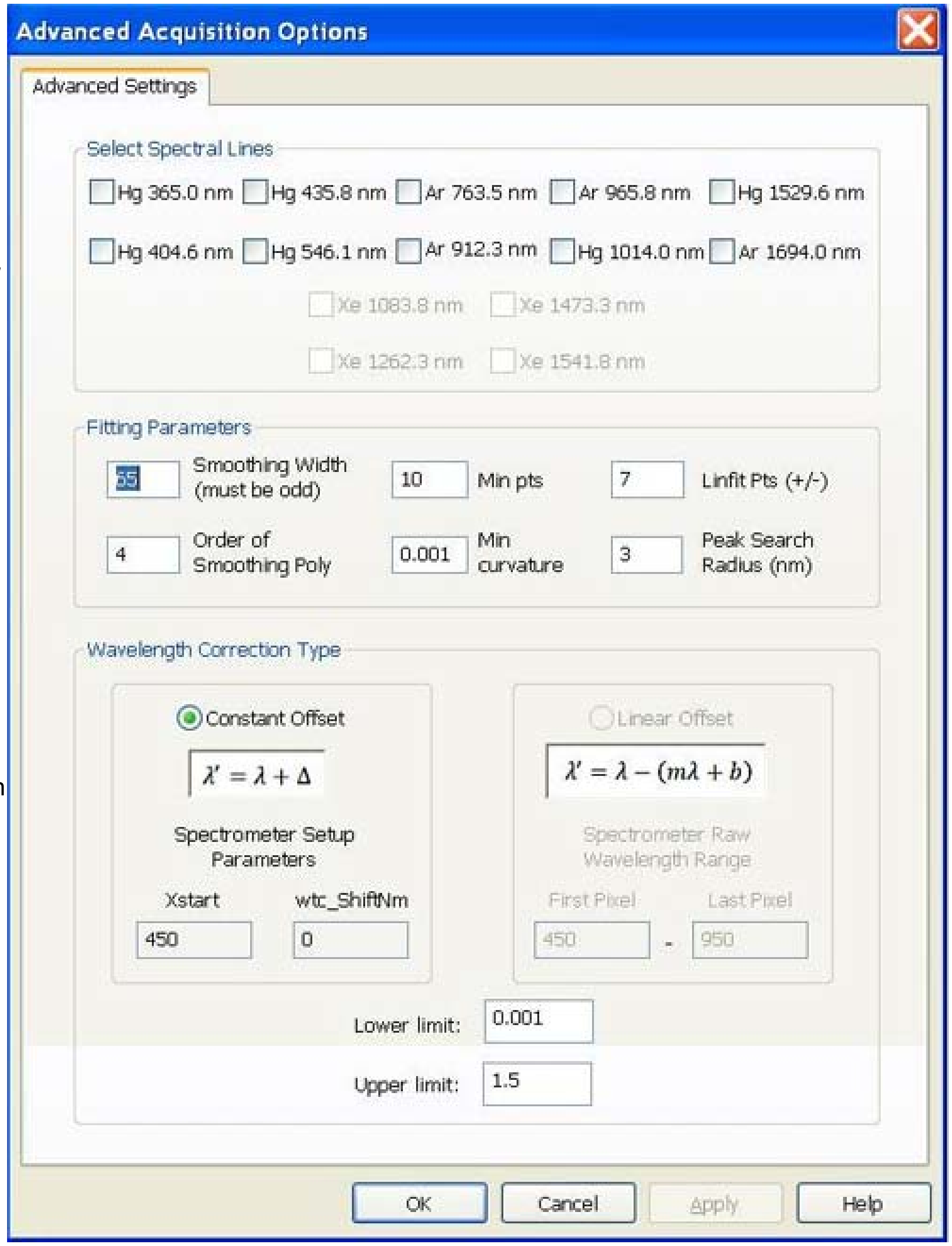
A Scan Mode image has its own set of image properties.

Advanced Settings

The Spectrometer Calibration acquisition mode precisely determines the center wavelength(s) of the selected spectral line(s) and calculates a spectrometer offset based on the published* wavelength value(s).

This is accomplished by first smoothing the spectrum using a polynomial-based digital smoothing filter. The first derivative is then computed and the data point nearest to the zero crossing is located. The zero crossing value is refined by performing a least squares linear fit to a number of neighboring data points on either side.

Specify:



Select Spectral Lines - Spectral line(s) to be used to determine the spectrometer offset. *Default: 1013.976 nm.*

Fitting Parameters:

Smoothing Width - Total number of points used by the digital smoothing filter (must be odd). For example, a setting of N results in smoothing each data point with the (N-1)/2 neighboring data points on either side. *Default: 65 pts.*

Order of Smoothing Poly - Order of the smoothing polynomial (zero for boxcar). *Default: 4.*

Min pts - Minimum number of consecutive data points with slope having the same sign (i.e. either increasing or decreasing) required before a candidate peak is considered valid. This is intended to reject any spurious noise spikes. *Default: 10 pts.*

Min curvature - Minimum curvature (i.e. second derivative value) required in order for a candidate peak to be considered valid. This is intended to reject small peaks. *Default: 0.001.*

Linfit Pts (+/-) - Number of points used in the linear fit. For example, a setting of 7 results in fitting the 7 neighboring data points on either side of the data point nearest to the zero crossing in the first derivative. *Default: 7 pts.*

Peak Search Radius (nm) - Radius of the peak search window. For example, a setting of 3 results in candidate peaks more than 3 nm from the target wavelength being rejected. *Default: 3 nm.*

Wavelength Correction Type: Type of correction to be applied. *Default: Constant Offset*

Spectrometer Setup Parameters - These are read-only parameters which detail the particular spectrometer's setup.

XStart: Starting wavelength in nm.

wtc_ShiftNm: Overall wavelength shift to be applied relative to original factory settings, in nm.

Lower limit (nm) - Minimum allowable wavelength shift. Default: 0.001 nm.

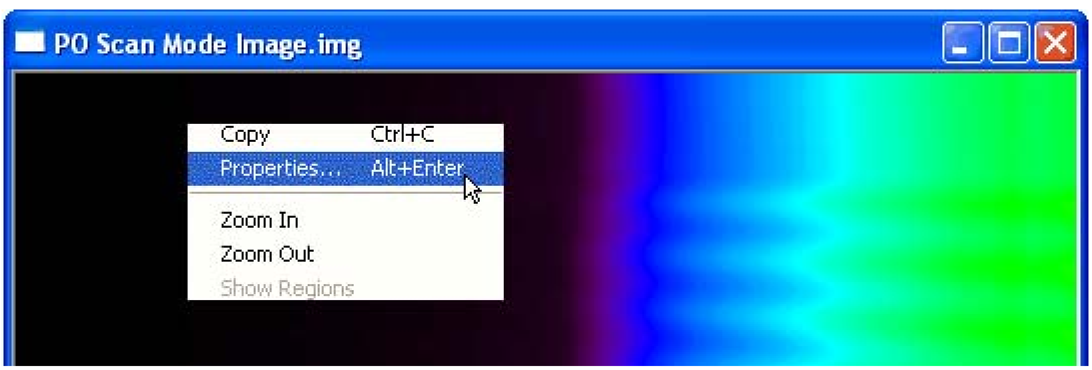
Upper limit (nm) - Maximum allowable wavelength shift. Default: 1.5 nm.

* http://physics.nist.gov/PhysRefData/Handbook/element_name.htm

Image properties

Image Properties

Image Properties describe the image; they do not change it. However, the properties dialog window does allow the user to add to the properties or change how the image is viewed. Double-click or right-click to view.



There are four image properties:

Comments

General

Palette

Scan Mode

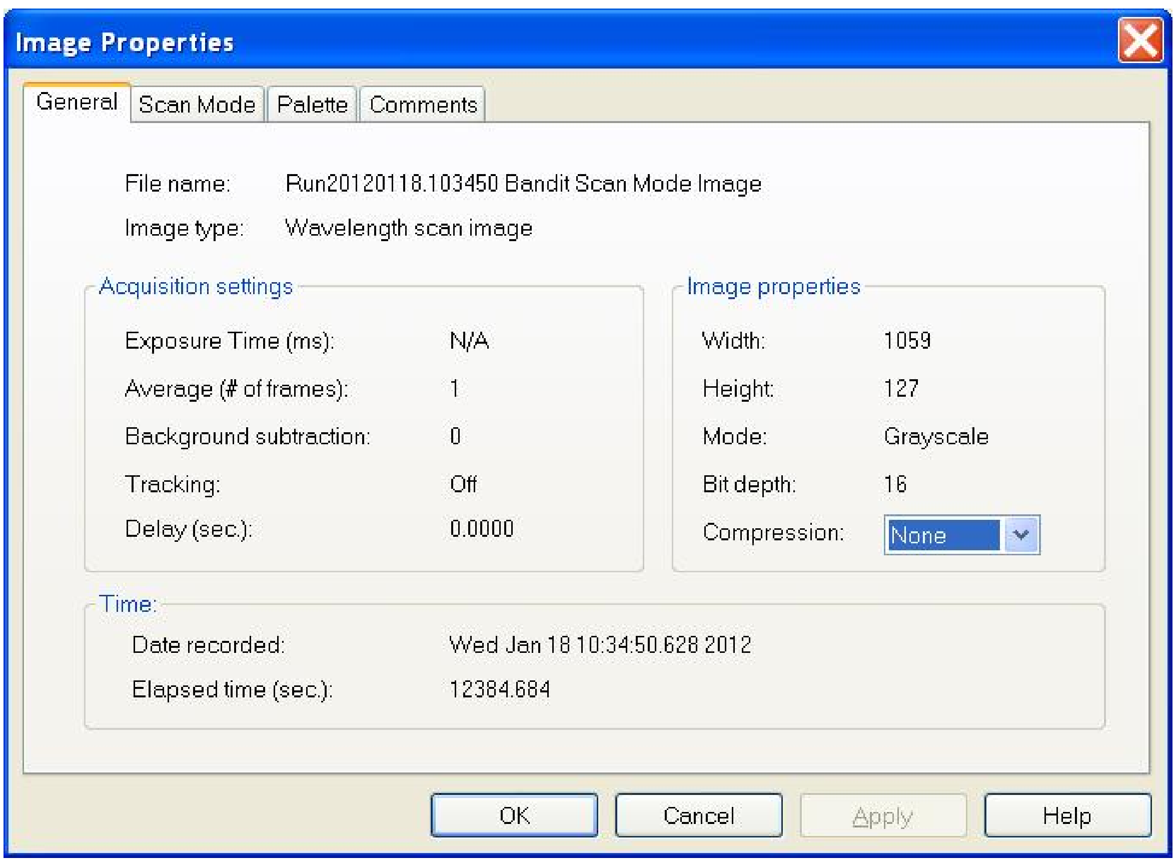
Comments

This is one of the Image Properties found by double-clicking an image or movie or by right-clicking and selecting *Properties* from the popup window.

Comments – a text box that allows user-entered comments to be save *with* files saved in kSA proprietary formats. Use this feature, for example, to document that an image was acquired at a substrate temperature of 550°C on GaAs (100).

General

This is one of the Image Properties found by double-clicking an image or by right-clicking and selecting *Properties* from the popup window.



File name – change the way the program names files in the Document Generation tab, found by clicking the Advanced button on the acquisition mode dialog.

Image type – this is set as "Wavelength scan image" in BandiT.

Acquisition settings – are not meaningful in BandiT because the only images are Scan Mode Images created from spectra versus wavelength data.

Image Properties –

Width – number of pixels in the width of the image. This is also the number of wavelengths.

Height – number of pixels in the height of the image. This is also the number of data points acquired.

Mode – color or grayscale, depending on how the image is generated

Bit depth – sometimes depends on how the image was acquired. With a bit depth of 8, for example, there is a maximum of 2^8 = 256 grayscale intensities (black to white) or 256 total colors.

Compression – is set to "None" for images generated in BandiT.

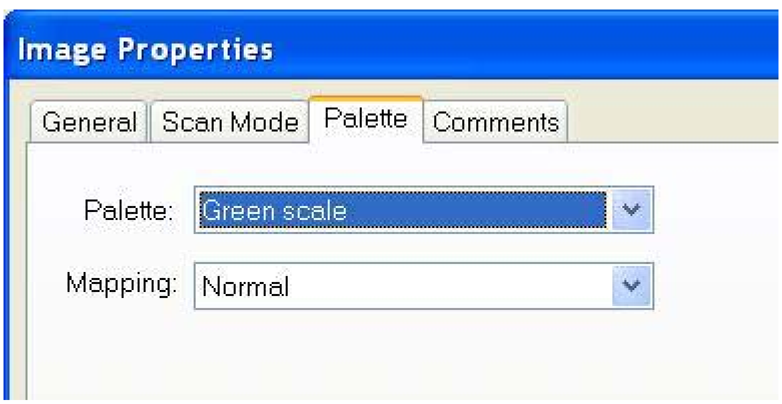
Time –

Date recorded – often this is part of the ***File name*** too (see above).

Elapsed time – gives the amount of time it took to create the image. This is the total time taken for temperature acquisition.

Palette

This is one of the Image Properties found by double-clicking an image or movie or by right-clicking and selecting *Properties* from the popup window.



Palette – the palette is false coloring; it only changes how the image is displayed. Pick among a large number of palettes.

Mapping – choose:

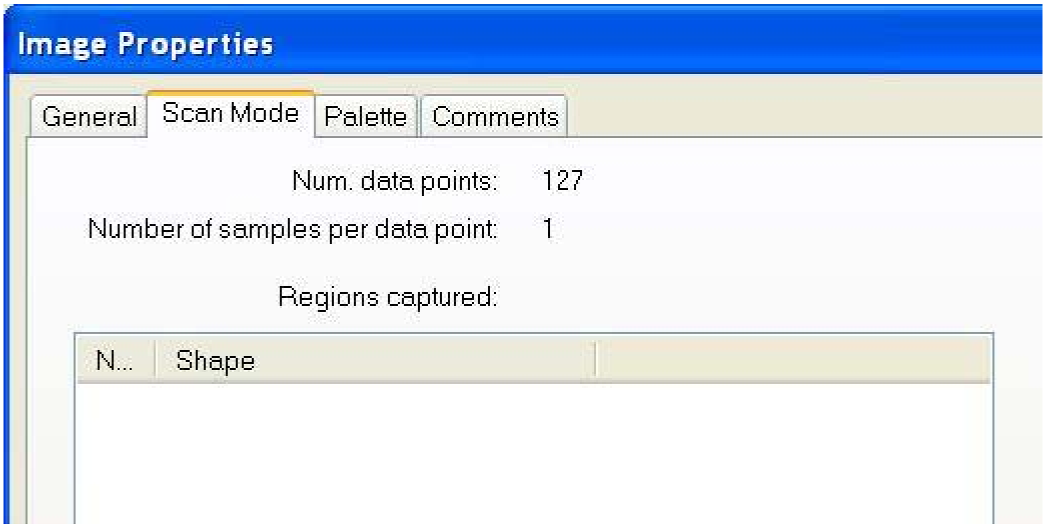
Normal – how the data comes in

Eight Most Significant Bits – for displaying a subset of the data, keeping only the most significant eight bits that make up the image. This option has the effect of reducing the number of shades in the image to an amount that the human eye can distinguish.

Maximized – for displaying the data scaled over eight bits, or 256 levels, so that the brightest part of the image is white and the darkest part black

Scan Mode

This is one of the Image Properties found by double-clicking an image or movie or by right-clicking and selecting ***Properties*** from the popup window. Only Scan Mode Images have the ***Scan Mode*** property.



Num. data points – This depends on the duration settings in the acquisition window.

Number of samples per data point – change this property in the General tab of the Advanced Acquisition Options.

Regions captured – this will always be blank in BandiT.

Analysis

Analysis

Analysis tools are interactive and continuous, meaning that the user can change the input at anytime during analysis and get a different output. For example, analysis done on an image often requires some type of re-sizable object (line, rectangle, etc.). While manipulating this object with the mouse, the corresponding data related to that object is continuously plotted in the accompanying chart window(s). In this manner data analysis is made fast, simple, and visual.

There are two types of analysis:

Real-time charts (RTCs) – allow the user to view raw and processed data during acquisition.

Post-acquisition analysis – allow the user to perform analysis on data after acquisition.

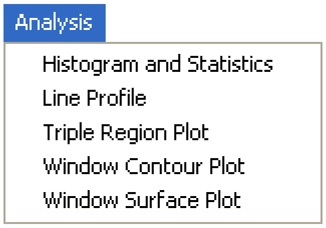
Post-Acquisition Analysis

There are two kinds of post-acquisition analysis:

- of an image
- of a 2-D plot

Click on an ***image window***.

Then click on the Analysis menu for image-based analysis options.



Histogram and Statistics – intensity versus window position

Line Profile – intensity versus line position

Triple Region Plot – original, contour, and surface plot together as one plot

Window Contour Plot – original image separated by intensity-based contour lines

Window Surface Plot – three-dimensional intensity plot

Click on a ***2-D plot window***.

Then click on the Analysis menu to for data-based analysis options.

1D FFT – Fast-Fourier Transform or Discrete Fourier Transform, as well as weighting options

Blackbody Fit

Blackbody Fit Lock Temp

Blackbody Fit Lock Tooling

Comparison - Avg. Individually

Comparison - Avg. Together

Comparison - Combine All

Comparison - Difference

Comparison - Divide

Contour Analysis

Crop

Cubic Spline Fit

Delta Y

Derivative

Digital Filter Fit

Exponential Fit

Extrema Count

Gauss Fit

Growth Rate Damped Sine Fit

Knee Fit

Lowpass Filter

Poly Fit w/ extrapolation

Polynomial Fit

Pyrometric Growth Rate

Sampling

Savitzky-Golay

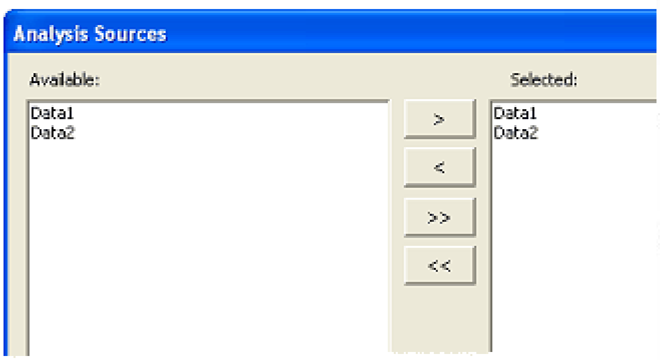
Scale by Poly

Spreadsheet

Surface Analysis

Analysis Sources

A common dialog used for all the comparison analysis tools available for 2-D data plots. Use the buttons in the middle to move the analysis sources from *Available* to *Selected*.



Real Time Charts

Real-Time Charts

Real-Time Charts (RTCs) allow the user to view raw and processed data during acquisition. Use the mouse to re-scale or move them during acquisition.

Choose an acquisition mode from the Acquire menu. Then use the View menu to choose from among the RTCs. The charts available will depend on the acquisition mode, not all charts can be used in all modes.

Real-time Absorption Edge Fit Spectra - shows the goodness of fit when using absorption edge fit as the method of Band Edge calculation

Real-time Bandit Confidence – confidence in the computed BandiT Temperature

Real-time Bandit Multi LED - numeric display of Band Edge, Pyrometry and Blackbody temperatures

Real-time Bandit Phase Delay Selection - used to help select the trigger delay when a single wafer is on a rotating platen

Real-time Bandit Spectra – resizable plot useful for displaying the unprocessed spectra value

Real-time Bandit Spectra (Normalized) -- completely processed data and band-edge fit

Real-time Bandit Temperature (LED) – displays the real-time computed BandiT temperature (°C)

Real-time Bandit Temperature (Time) – plots computed BandiT Temperature (°C) versus time

Real-time Blackbody Spectra - plot of the Blackbody spectra

Real-time Blackbody Temperature (LED) - displays the computed Blackbody temperature (°C)

Real-time Blackbody Temperature (Time) - plots the Blackbody temperature (°C) against time

Real-time Pyrometer Temperature (LED) – displays the real-time pyrometer temperature (°C)

Real-time Pyrometer Temperature (Time) – plots the pyrometer temperature (°C) against time

Real-time Roughness (LED) - displays the computed roughness

Real-time Roughness (Time) - plots roughness against time

Real-time Stats (LED) - numeric display of a selected data value

Real-time Stats (Time) - plots selected values against time

Real-time Thickness (LED) - displays the computed thickness

Real-time Thickness (Time) - plots the computed thickness against time

Real-time Thickness Spectra - plots the Normalized Reflectance Spectrum with the Interference Oscillations

These Real-time charts are used during Spectrometer Calibration only:

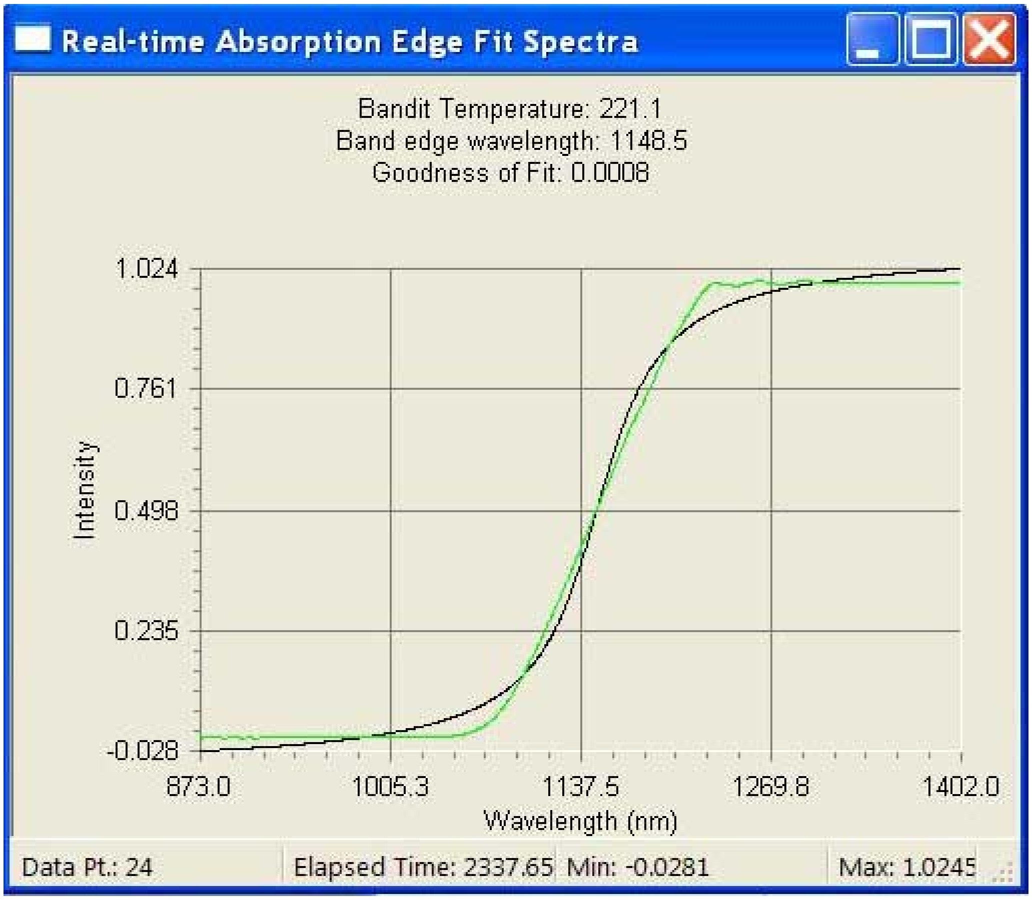
Real-time Calibration Averages - plots the current and running average values for up to three spectral lines

Real-time Calibration Peak (Time) - plots a strip chart for a given spectral line

Real-time Calibration Spectra - plots the spectra with the selected line(s) indicated

Real-time Absorption Edge Fit Spectra

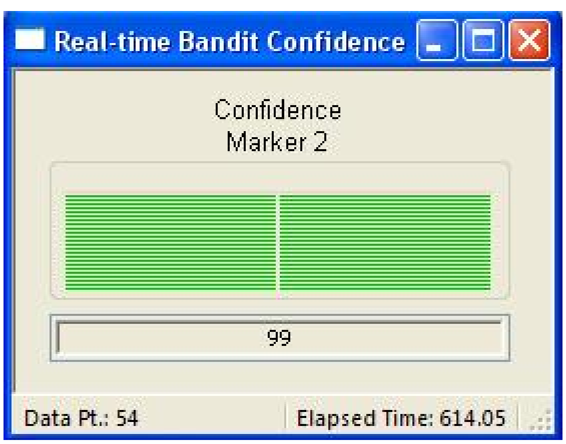
The ***Real-time Absorption Edge Fit Spectra*** Real Time Chart is available when the Absorption Edge fit is selected as the method of Band Edge Calculation in the Acquisition mode Configuration Options.



The Bandit Temperature, Band edge wavelength and Goodness of fit can be seen at the top of the plot window.

Real-Time Confidence

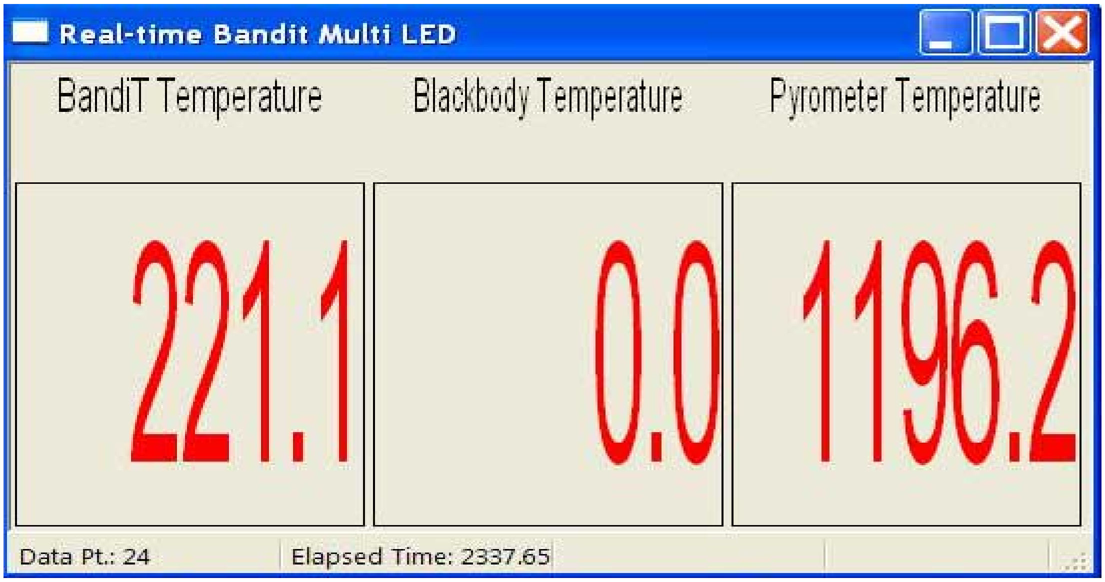
The confidence meter is found by selecting View/Real-Time Confidence from the main menu. It is used to display the level of confidence in the computed BandiT Temperature.



In the window above, the confidence in the fit is at 99%, displayed in two places so that the user can reduce the width of the window. Here, 99 corresponds to green, indicating that the confidence is greater than the ***Confidence threshold*** set in the BandiT Spectral Processing Advanced Acquisition Option. If the confidence falls below that threshold, the indicator turns to red. (A standard confidence for Band Edge fit is 85%.)

Real-Time Bandit Multi LED

The ***Real-time Bandit Multi LED*** Real Time Chart gives a useful display of the different temperatures being measured using Band Edge, Pyrometry and Blackbody Pyrometry, when all methods of measurement are being used.

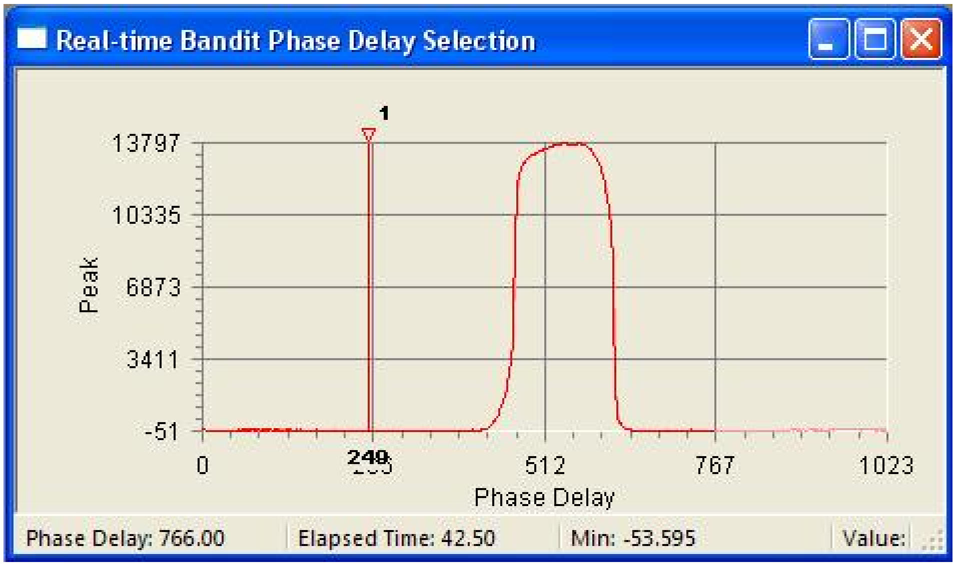


Real-Time Bandit Phase Delay Selection

The ***Real-time Bandit Phase Delay Selection*** Real Time Chart is used when a single wafer is on a rotating platen, to select the phase delay position so that acquisition is triggered when the sample is in the correct position during the rotation.

To change the value that is plotted, right click the chart and select Properties and then select the Plot Value tab. Choose the value to plot from the drop down list.

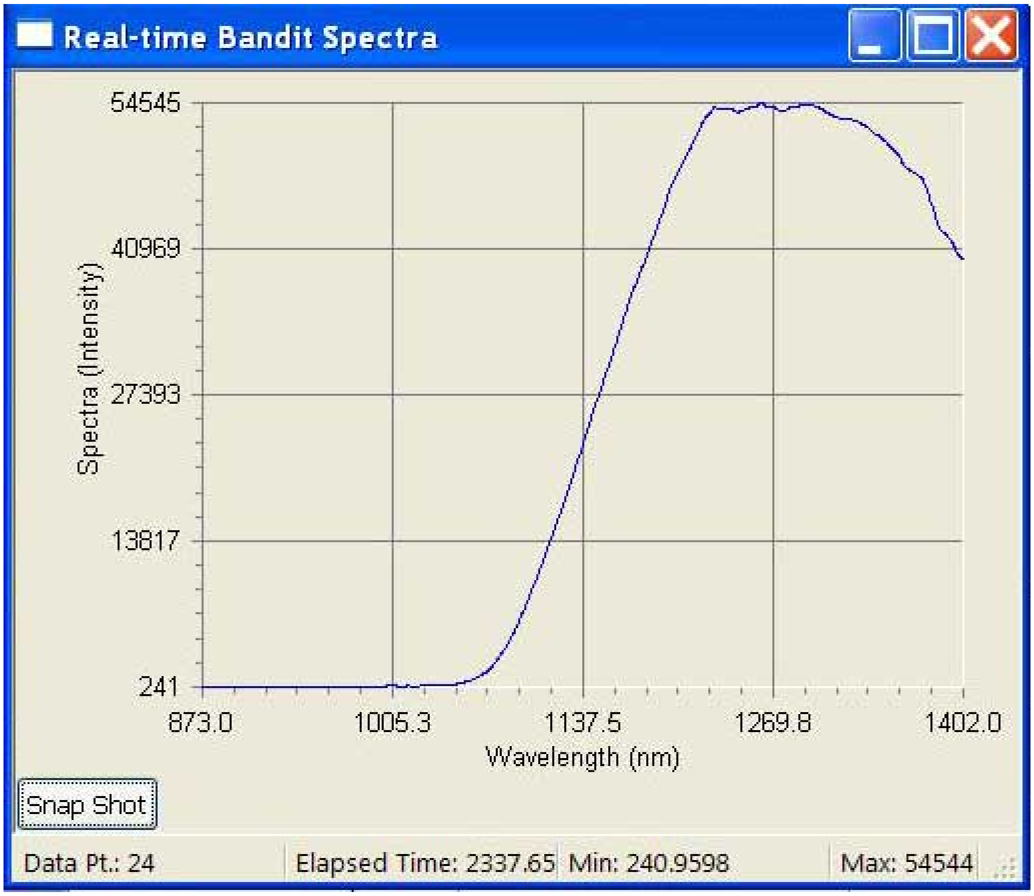
When acquisition starts the system will try to lock on to the RPM of the rotating platen, eventually after a few rotations of the platen the trace will begin to overwrite itself so that the dark line draws exactly over the light line, as shown in the example below. A single marker is displayed and can be moved to the desired position by clicking and dragging the red triangle at the top of the marker line. The chosen position will then be used to trigger data collection in subsequent acquisition modes.



For more information about using this Real-Time Chart go to the Phase Delay Selection Acquisition mode or the How-To Trigger Temperature Meaurement guide.

Real-Time BandiT Spectra

The ***Real-Time BandiT Spectra*** is a Real-Time Chart (RTC) that plots Spectra (Intensity) versus Wavelength (nm). It is useful for displaying the unprocessed spectra value. While the Live Spectrometer window gives the same view, it cannot be resized. This window can be resized.



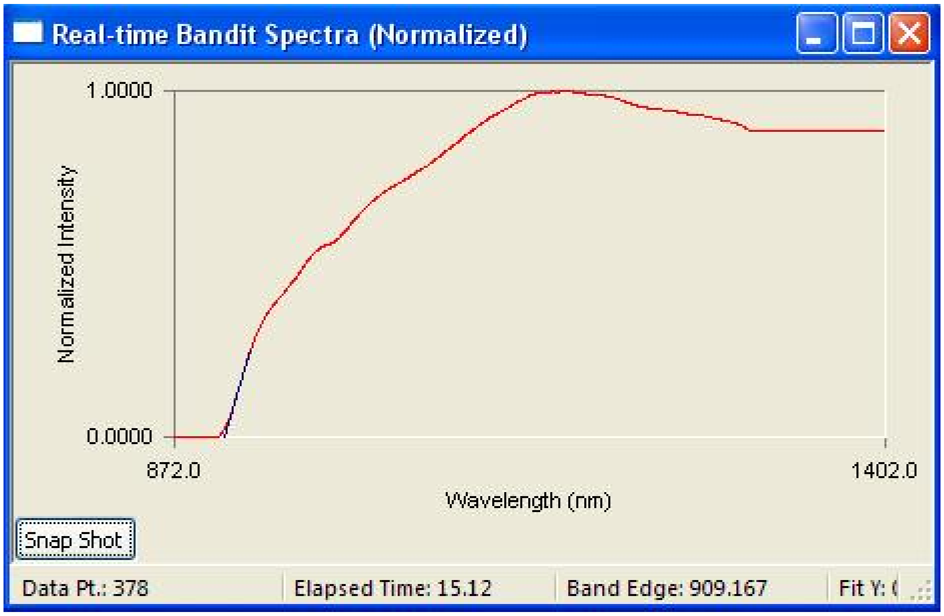
Along the bottom of the window is the ***Status** bar* (View/Status bar), which displays the number of data points collected thus far, elapsed time, and minimum spectra intensity value.

Right-click the plot and select Properties (or simply double-click) to apply data filters change the X/Y axis, and specify labels and colors.

Snap Shot - Click the ***Snap Shot*** button at any time to take a snap shot of the current spectra.

Real-Time Normalized BandiT Spectra

The ***Real-Time Normalized BandiT Spectra*** is a Real-Time Chart (RTC) that plots Normalized Intensity versus Wavelength (nm). It is useful for showing the completely processed and normalized data (red) and the band-edge fit (blue) of that particular spectra data value.



Along the bottom of the window is the ***Status bar*** (View/Status bar), which displays the number of data points collected thus far, elapsed time, band edge, and Fit Y. Band edge gives computed band edge for temperature calculation. Fit Y gives the length of the fit line along the Y-axis. See the Automatic Intensity Control topic for specifying this value, where it is called the *Min Edge*.

Right-click the plot and select Properties (or simply double-click) to apply data filters, specify X/Y axis, and change labels and colors.

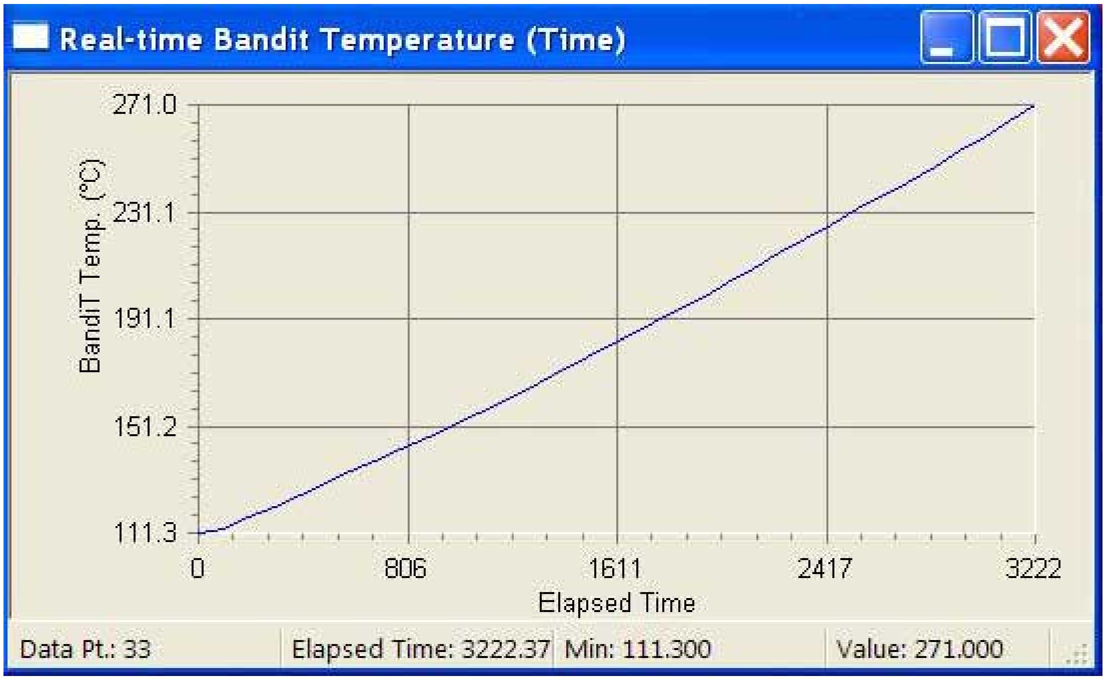
Real-time Bandit Temperature (LED)

The ***Real-Time BandiT Temperature (LED)*** is a Real-Time Chart (RTC) that displays the pyrometry temperature in degrees Celsius (°C).

Right-click the read-out and select Properties (or simply double-click) to change the plot value, data (marker to plot), and colors.

Real-Time BandiT Temperature (Time)

The ***Real-Time BandiT Temperature (Time)*** is a Real-Time Chart (RTC) that plots the computed BandiT Temp. (°C) versus time or data point.



Along the bottom of the window is the ***Status*** *bar* (View/Status bar), which displays the number of data points collected thus far, elapsed time, and min/max temperature.

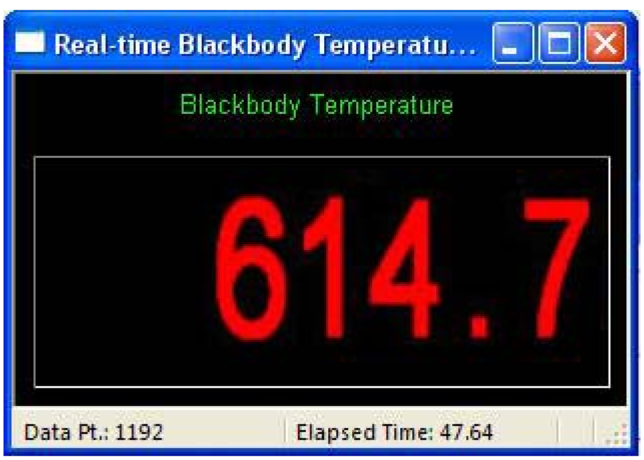
Right-click the plot and select Properties (or simply double-click) to apply boxcar smoothing, specify auto-scrolling and X/Y axis, and choose labels and colors.

Real-Time Blackbody Spectra

The ***Real-time Blackbody Spectra*** Real Time chart displays the raw blackbody data and the resulting fit, the source data in blue and the resulting fit in black. At the top of the window it displays the temperature, tooling factor, emissivity, and the goodness of fit statistic.

Real-Time Blackbody Temperature (LED)

The ***Real-Time Blackbody Temperature (LED)*** is a Real-Time Chart (RTC) that displays the blackbody temperature in degrees Celsius (°C).



Right-click the read-out and select Properties (or simply double-click) to change the plot value, data (marker to plot), and colors.

Real-Time Blackbody Temperature (Time)

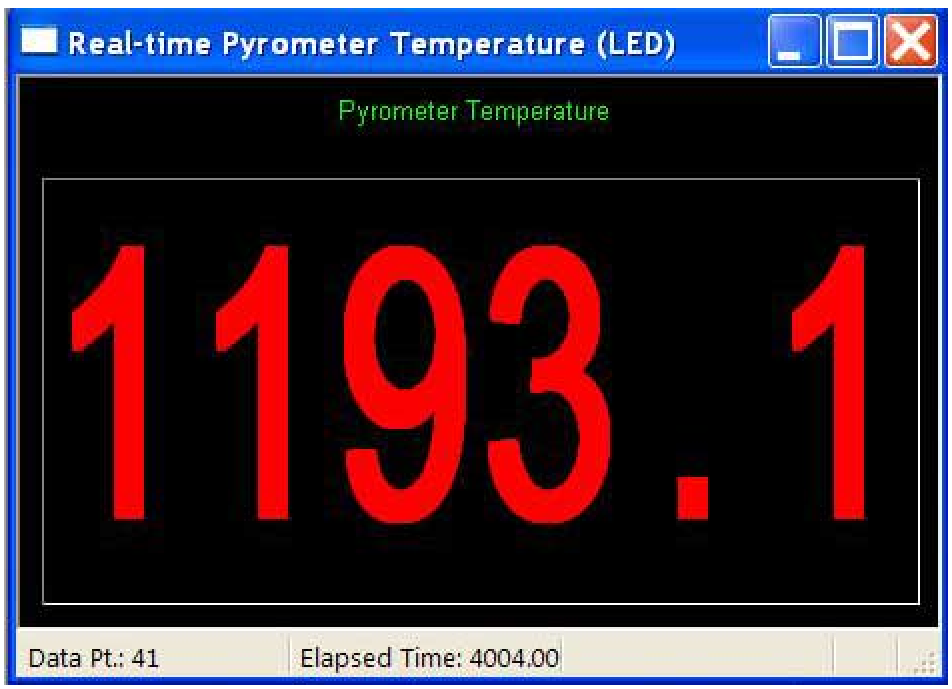
The ***Real-Time Blackbody Temperature (Time)*** is a Real-Time Chart (RTC) that plots the Blackbody temperature (°C) versus time or data point.

Along the bottom of the window is the ***Status bar*** (View/Status bar), which displays the number of data points collected thus far, elapsed time, and min/max temperature.

Right-click the plot and select Properties (or simply double-click) to apply boxcar smoothing, specify auto-scrolling and X/Y axis, and choose labels and colors.

Real-time Pyrometer Temperature (LED)

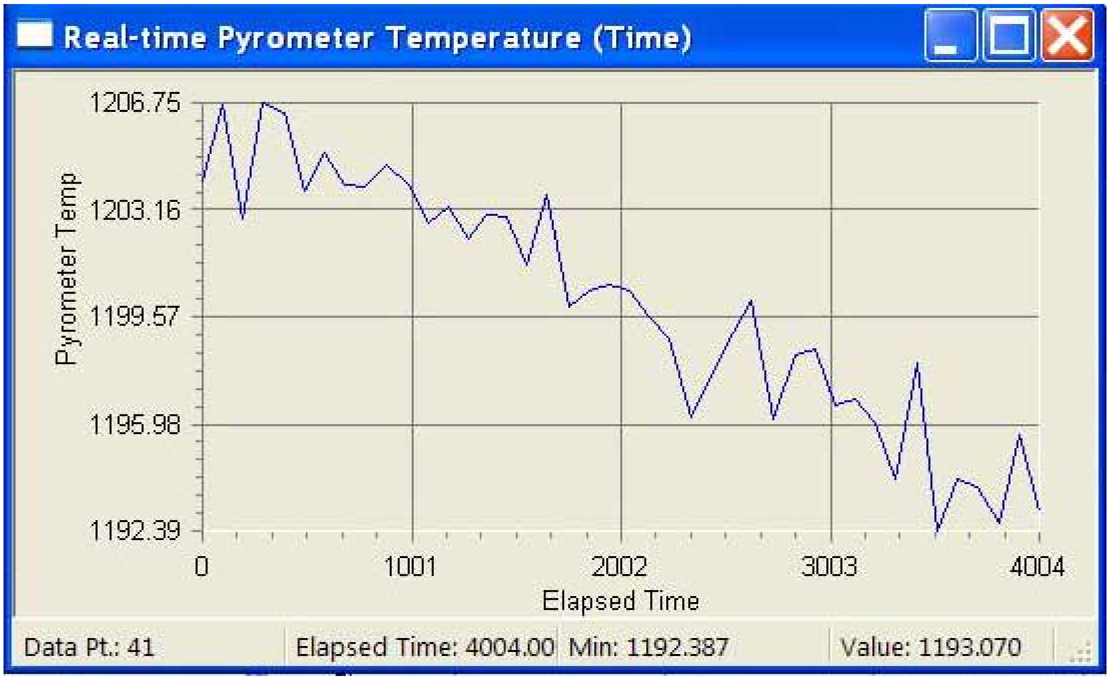
The ***Real-Time Pyrometer Temperature (LED)*** is a Real-Time Chart (RTC) that displays the pyrometry temperature in degrees Celsius (°C).



Right-click the read-out and select Properties (or simply double-click) to change the plot value, data (marker to plot), and colors.

Real-time Pyrometer Temperature (Time)

The ***Real-Time Pyrometer Temperature (Time)*** is a Real-Time Chart (RTC) that plots the pyrometer temperature (°C) versus time or data point.

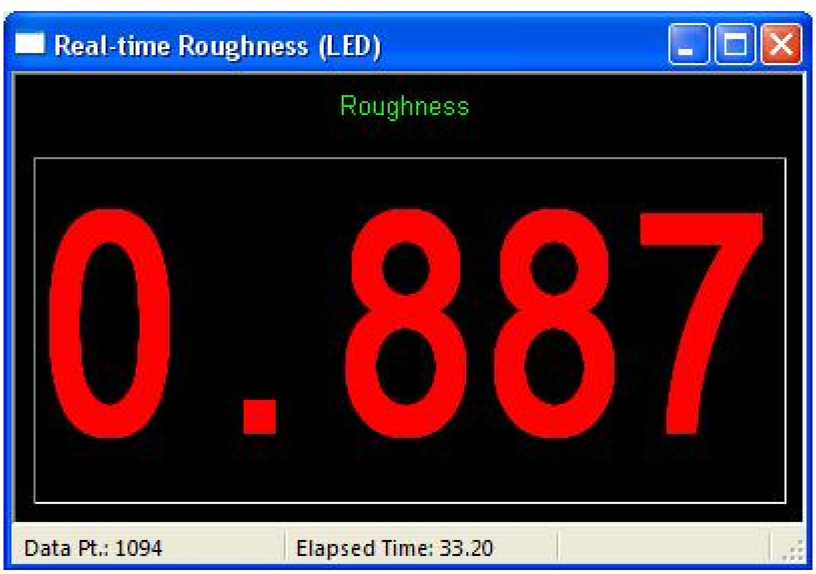


Along the bottom of the window is the ***Status bar*** (View/Status bar), which displays the number of data points collected thus far, elapsed time, and min/max temperature.

Right-click the plot and select Properties (or simply double-click) to apply boxcar smoothing, specify auto-scrolling and X/Y axis, and choose labels and colors.

Real-Time Roughness (LED)

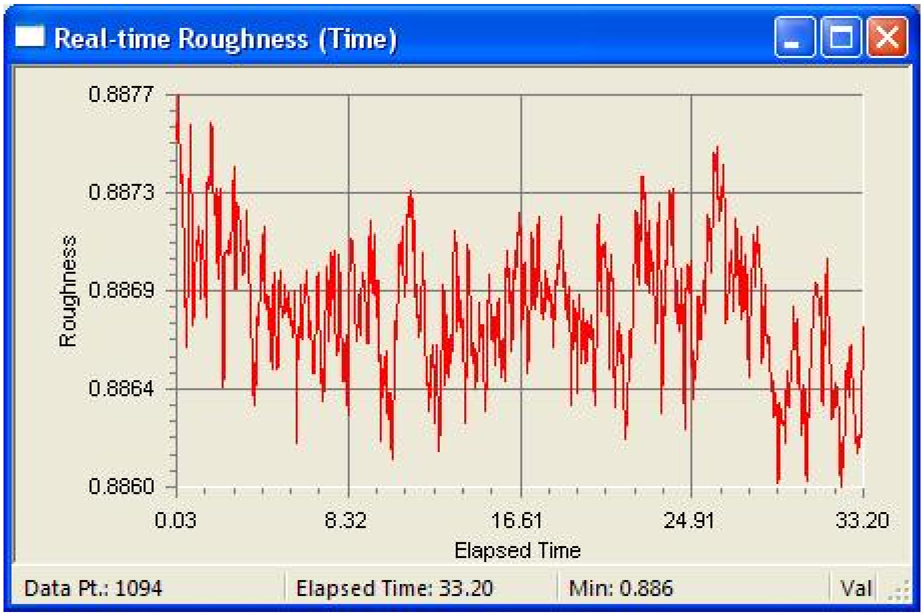
The ***Real-Time Roughness (LED)*** is a Real-Time Chart (RTC) that displays the roughness of the sample in ****



If the numbers to be displayed on the Real-time Roughness (LED) chart are too large the display will show #.### instead of numbers, in this case the scale factor should be re-calibrated using the Bandit Roughness Calibration Acquisition mode, or adjusted using the Roughness Configuration option.

Real-Time Roughness (Time)

The ***Real-Time Roughness (Time)*** Real Time Chart plots Roughness against elapsed time.

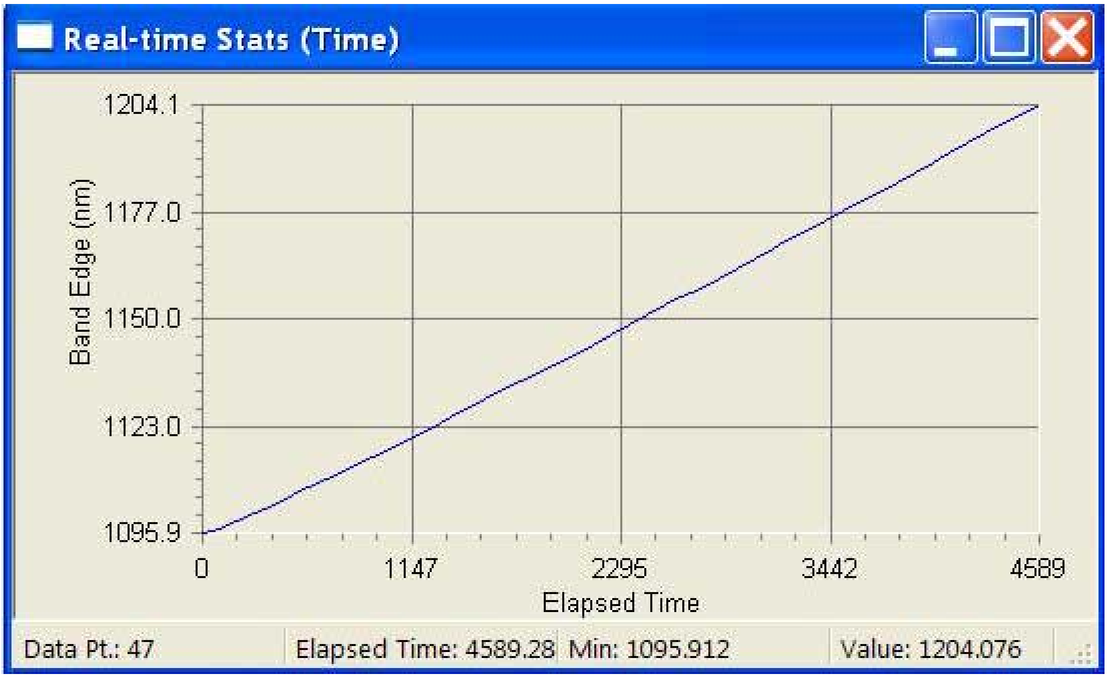


Real-Time Stats (LED)

The ***Real-time Stats (LED)*** Real Time Chart is used to give a numeric readout of a number of different values. To change the value that is displayed, right click the chart and select Properties and then select the Plot Value tab. Choose the value to plot from the drop down list.

Real-Time Stats (Time)

The ***Real-time Stats (Time)*** Real Time Chart is used to is used to plot a number of different values against time. To change the value that is plotted, right click the chart and select Properties and then select the Plot Value tab. Choose the value to plot from the drop down list.

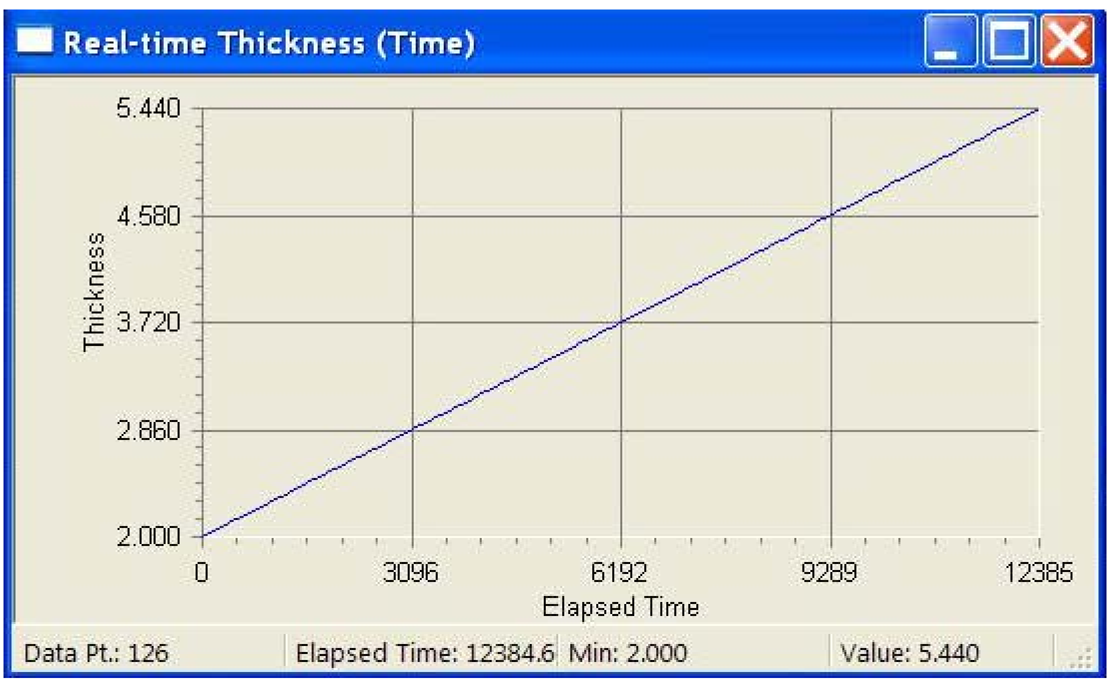


Real-Time Thickness (LED)

The ***Real-Time Thickness (LED)*** Chart gives a numeric readout of the calculated film thickness.

Real-Time Thickness (Time)

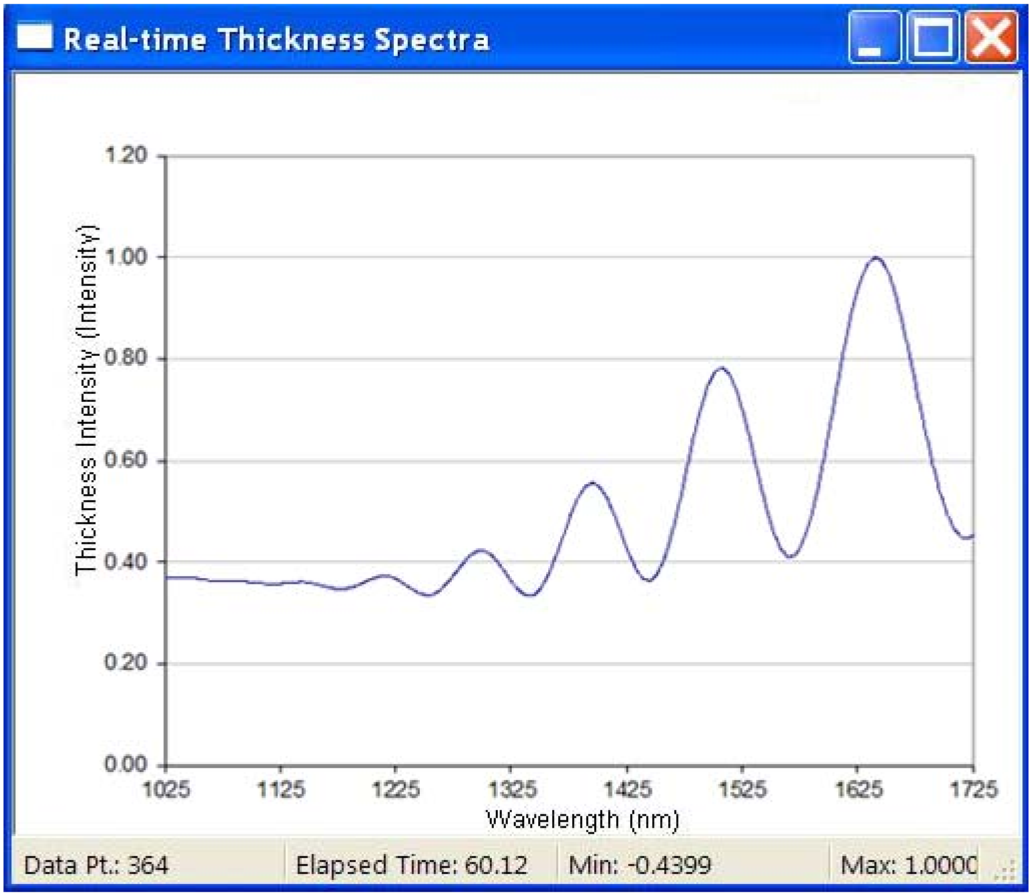
The ***Real-Time Thickness (Time)*** chart plots the calculated film thickness against time during acquisition.



Real-Time Thickness Spectra

BandiT software has the capability of using the interference patterns observed in the reflectance spectrum from a thin film to obtain thickness information. This can be exploited to determine a film's thickness by comparing the wavelengths of the extrema of these oscillations, provided the index of refraction is known as a function of wavelength.

The ***Real-Time Thickness Spectra*** Chart shows the Normalized Reflectance Spectrum with the Interference Oscillations.



Real-Time Calibration Averages

The ***Real-time Calibration Averages*** Real Time Chart shows the current and running average values for up to three spectral lines.

This is used only in the Spectrometer Calibration Acquisition mode when a BandiT spectrometer wavelength needs to be verified or adjusted.

Real-Time Calibration peak (Time)

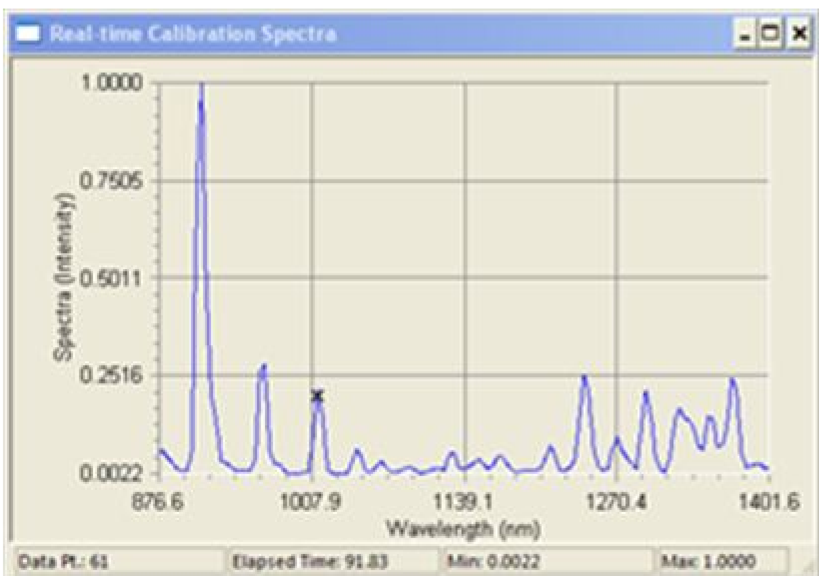
The ***Real-time Calibration Peak (Time)*** Real Time Chart shows a strip chart for a given spectral line

This is used only in the Spectrometer Calibration Acquisition mode when a BandiT spectrometer wavelength needs to be verified or adjusted.

Real-Time Calibration Spectra

The ***Real-time Calibration Spectra*** Real Time Chart shows the spectra with the selected lines marked with an x.

This is used only in the Spectrometer Calibration Acquisition mode when a BandiT spectrometer wavelength needs to be verified or adjusted.



Plots

1D FFT

This is a tool found under the Analysis menu that is available for 2-D data plots. Fast Fourier Transform (FFT) analysis is available for any 2D line plot. The kSA system utilizes the FFT algorithm from Numerical Recipes in C, Cambridge, 1991.

Note that FFT analysis differs from the FFT image filter, which filters images.

After performing FFT, right-click the plot and select *Properties*. Fourier Transform properties allow the user to toggle between FFT and Discrete Fourier Transform, mirror the data set (for improving accuracy), and choose weighted average parameters.

General note:

FFT analysis can be performed on any data set (independent of the units of the data set).

Technical notes:

1. The discussion below assumes the data set has units of time. This is for simplicity because then the Fourier-transform set has units of frequency.

Performing FFT squares the real and imaginary component of each frequency value, adds them together, and then takes the square root of the result.

Resultant = $\sqrt{(real)^2 + (imaginary)^2}$

Then the resultant is plotted as a function of frequency (i.e. the power spectrum).

Because frequency is the inverse of time, the more closely spaced the data set is in time, the less resolved the Fourier transform data set is in frequency space. The frequency resolution of the Fourier transform spectrum is given by

Resolution = $\frac{1}{\Delta \cdot (scans)}$

where

Δ= time interval between data points in original (time domain) data set

scans = # of data points in original (time domain) data set, rounded up to the nearest power of 2

2. To increase the frequency resolution of the FFT it is best to include as many scans (data points) as possible for the FFT analysis.
3. The FFT routine works on data sets that are powers of 2, so it is good practice to enter a data set that is close to a power of 2, but not exceeding it. The software will fill in zeros where necessary, and exceeding a power of 2 means the software will fill in a large number of zeros. That will yield a large dc component to the frequency spectrum. This dc component will not alter the other Fourier component peaks in any way, but simply will make the dc amplitude larger, possibly making it the largest amplitude component.

Blackbody Fit

This is a tool found under the Analysis menu that is available for 2-D data plots. This performs a non-linear least squares fitting of a blackbody thermal radiation curve to acquired spectra to determine temperature.

The Blackbody fit requires use of a spectrometer which has been flat field corrected using the Flat Field Correction Acquisition mode. This Flat Field Correction needs to be enabled in the Spectrometer Properties found by right clicking the Live Spectrometer window.

When Blackbody Fit is used in Analysis mode the integration time, emissivity are tied into the Tooling Factor. This differs from the case when Blackbody is used during Acquisition mode where the integration time and emissivity are independent of the Tooling Factor.

Use the Blackbody Fit plot properties to specify the properties for the fit.

Blackbody Fit Lock Temp

This is a tool found under the Analysis menu that is available for 2-D data plots. This performs a non-linear least squares fitting of a blackbody thermal radiation curve to acquired spectra using a fixed temperature parameter specified by the user.

A temperature is specified and BandiT superimposes the expected black body curve of the specified temperature over the current data plot. This is used to manually close in on a correct temperature for a spectrometer snapshot or kdt file. The Goodness of fit is calculated and displayed for reference.

The Blackbody fit requires use of a spectrometer which has been flat field corrected using the Flat Field Correction Acquisition mode. This Flat Field Correction needs to be enabled in the Spectrometer Properties found by right clicking the Live Spectrometer window.

Use the Blackbody Fit Lock Temp plot properties to specify the properties for the fit.

Blackbody Fit Lock Tooling

This is a tool found under the Analysis menu that is available for 2-D data plots. This performs a non-linear least squares fitting of a blackbody thermal radiation curve to acquired spectra using a fixed Tooling Factor specified by the user.

A specific Tooling Factor is used to superimpose the black body curve over the current data plot. A Goodness of fit is calculated and displayed for reference. This can be used to manually improve the goodness of fit of the superimposed curve. When Blackbody Fit is used in Analysis mode the integration time, emissivity are tied into the Tooling Factor. This differs from the case when Blackbody is used during Acquisition mode where the integration time and emissivity are independent of the Tooling Factor.

The Blackbody fit requires use of a spectrometer which has been flat field corrected using the Flat Field Correction Acquisition mode. This Flat Field Correction needs to be enabled in the Spectrometer Properties found by right clicking the Live Spectrometer window.

Use the Blackbody Fit Lock Tooling plot properties to specify the properties for the fit.

Comparison - Avg. Individually

This tool is found under the Analysis menu for 2-D data plots. It uses the Analysis Sources dialog for selecting the plots for comparison and computes the average values of each chart separately. The resultant chart has a plot of the averages versus source plot number, i.e., the horizontal axis is the source plot number (in the order that the plots were selected for averaging) and the vertical axis is the average of the entire plot.

Note that each chart selected must have at least two data points.

Comparison - Avg. Together

This tool is found under the Analysis menu for 2-D data plots. It uses the Analysis Sources dialog for selecting the plots for comparison and computes the point-by-point average (mean) of the plots and displays it in a new plot.

Note that the plots must have the same X-axis values and at least two data points.

This tool preserves series too. That means that plots with multiple series will be averaged series-by-series, so that the resultant plot will have the same number of series as the originals – series one is averaged point-by-point with series one in each of the plots, series two is averaged point-by-point with series two in each of the plots, and so on.

Comparison - Combine All

This tool is found under the Analysis menu for 2-D data plots. It uses the Analysis Sources dialog for selecting the plots for comparison and creates a chart with data from all the selected plots together on the same chart.

For example, selecting five plots and using the *Comparison - Combine All* tool results in one plot with five series plotted together on the same chart.

Comparison - Difference

This tool is found under the Analysis menu for 2-D data plots. It uses the Analysis Sources dialog for selecting the plots for comparison and plots the point-by-point difference between two source plots with the same X-axis. Order matters, with the second plot being subtracted from the first.

Comparison - Divide

This tool is found under the Analysis menu for 2-D data plots. It uses the Analysis Sources dialog for selecting the plots for comparison and plots the point-by-point quotient of two source plots with the same X-axis. Order matters, with the second plot being divided into the first.

Contour Analysis

Contour Analysis is an analysis tool for post-acquisition analysis of a Scan Mode Image. It performs a generic Contour Analysis algorithm on the current image.

Window Contour Plot

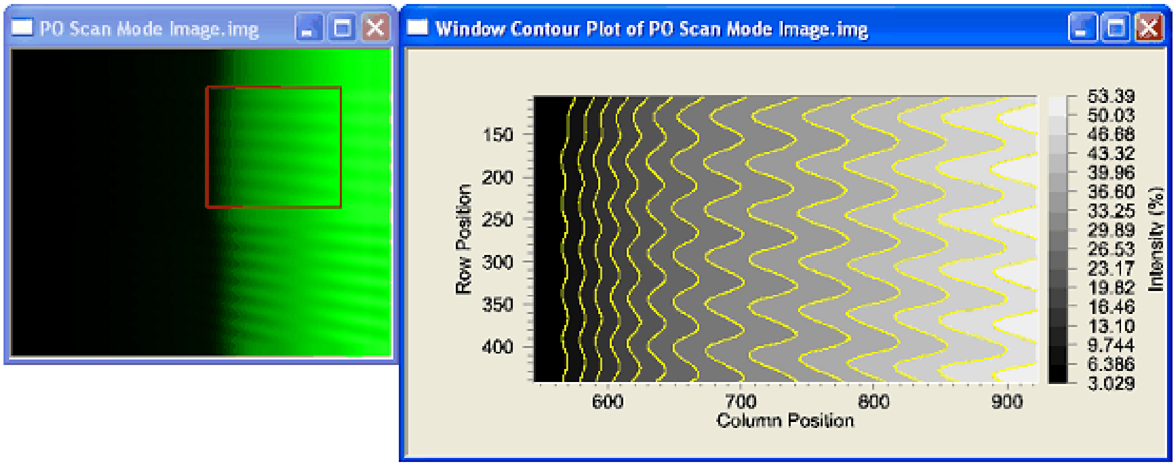
Contour Plot is an analysis tool for post-acquisition analysis of a Scan Mode Image.

This analysis tool plots intensity as a function of window position. The window position is determined by a rectangle or ellipse, which is placed on top of an image. The analysis is interactive, meaning that changing the characteristics of the window (position, length, or width) changes the plot.

Below is a picture of a Contour Plot performed on a test image:

- the red rectangle is profiled by the plot;

- the areas inside the red rectangle of different intensity are separated by yellow lines in the Contour Plot.



Right-click the Contour Plot window and select Properties to change such things as –

- plotting boundaries and mesh-size used to create the plot;
- whether the data is processed (e.g., smoothed) before it is displayed.

To change general display options (such as raw versus percent intensity), choose the Options/General menu and select options in the images and video tab.

Crop

This is a tool found under the Analysis menu that is available for 2-D data plots. It reduces the number of pixels plotted. Choosing this tool immediately plots a cropped-data version of the same 2-D data plot with the plot title "Trim Left: [number] Trim Right: [number]." The numbers specify the data (pixels) excluded from the plot, counting from the left and right edges of the original plot.

Use the Crop tab in the Plot properties to specify the number of pixels to be excluded. (Right-click the processed 2-D data plot (labeled with "Crop") and select Properties.)

Cubic Spline Fit

This is a tool found under the Analysis menu that is available for 2-D data plots.

In *Cubic Spline Fit*, the spline does not have to pass exactly through every point, but instead the spline's first and second derivatives must be continuous.

Use the Cubic Spline Fit plot property to specify the *Spline Fit interval*. Keep the interval smaller than the data interval points for interpolation or make it larger for smoothing purposes.

Delta Y

This is a tool found under the Analysis menu that is available for 2-D data plots. It plots the difference in Y-values (the dependent variable) between successive data points. Use this tool as an alternative to the Derivative analysis tool.

Derivative

This is a tool found under the Analysis menu that is available for 2-D data plots.

It has its own Derivative plot property to specify parameters. Because the tool uses data points rather than a function, this tool actually calculates ***Δy/ Δx*** *(Delta Y* divided by *Delta X*) and connects resultant data points with a straight line. Compare this tool with the Delta Y analysis tool.

Digital Filter Fit

This is a tool found under the Analysis menu that is available for 2-D data plots. Use the Digital Filter Fit plot property to specify parameters for constructing highpass, lowpass, bandpass, and bandstop filters

Exponential Fit

This is a tool found under the Analysis menu that is available for 2-D data plots. It applies a generic exponential fit algorithm that attempts to fit an exponential curve of the form:

$$f(\lambda) = a_0 e^{a_1 \lambda} + a_2$$

to a spectrum.

Use the Exponential Fit plot properties to specify initial guesses for the three parameters.

Extrema Count

This is a tool found under the Analysis menu that is available for 2-D data plots. It counts maxima and minima of the current data plot.

Use the Extrema Count plot properties to specify details.

Gauss Fit

This is a tool found under the Analysis menu that is available for 2-D data plots.

It gives the calculated fitting parameters of the non-linear least-squares fitting function:

$$f(x) = A_0 e^{\frac{-z^2}{2}} + A_3 + A_4 x + A_5 x^2$$

where

$$z = \frac{x - A_1}{A_2}.$$

It has its own Gauss Fit plot property to specify parameters.

Growth Rate Damped Sine Fit

This is a tool found under the Analysis menu that is available for 2-D data plots. This applies a generic Damped Sine Fit to the current data plot to calculate growth rate.

Use the Growth Rate Damped Sine Fit plot properties to specify the parameters for the fit.

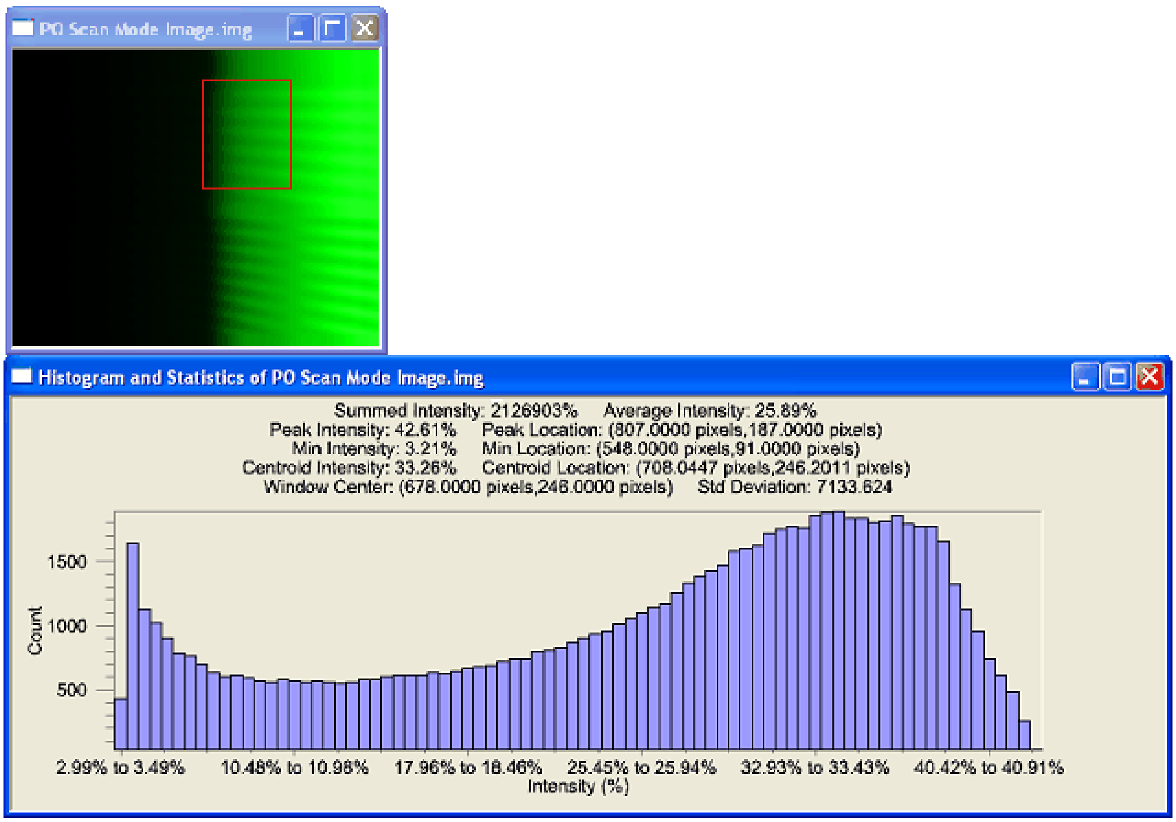
Histogram and Statistics

Histogram and Statistics is an analysis tool for post-acquisition analysis of a Scan Mode Image.

This analysis tool plots the Count versus Intensity as a function of window position. The window position is determined by a rectangle or ellipse, which is placed on top of an image. The analysis is interactive, meaning that changing the characteristics of the window (position, length, or width) changes the plot.

Below is a picture of Histogram and Statistics performed on a test image:

- the red rectangle gives the boundaries (including the boundary) of the data being profiled;
- the histogram plots count versus intensity.



Right-click the *Histogram and Statistics* window and select Properties to change such things as –

- plotting boundaries and colors used to create the plot;
- fonts and labels.

To change general display options (such as switching from *raw count* to *percent intensity*), choose the Options/General menu and select options in the Images and Video tab.

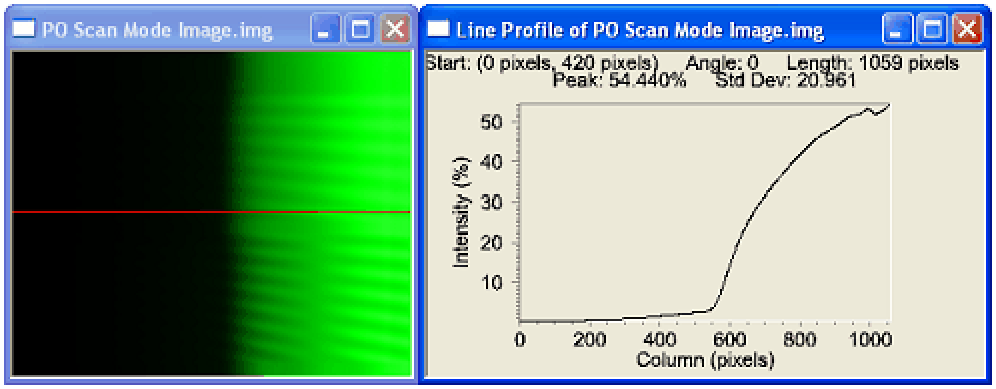
Line Profile

Line Profile is an analysis tool for post-acquisition analysis of a Scan Mode Image.

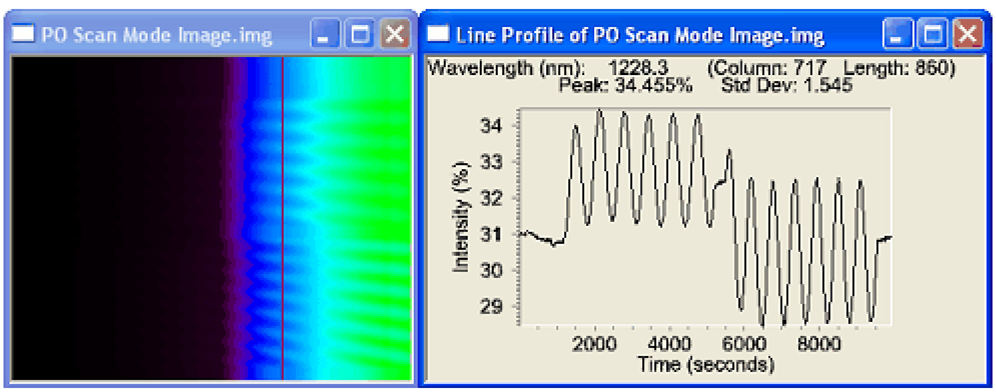
This analysis tool plots intensity as a function of position. The position is determined by a line, which is placed on top of an image. The analysis is interactive, meaning that changing the characteristics of the line (orientation, length, or width) changes the plot.

Below is a picture of a line profile performed on an image:

- the red line crossing the green image is the line that is profiled;
- the areas beneath the red line of higher intensity corresponds with the peaks in the Line Profile.



Below is a line profile of a Scan Mode image with a vertical red line. Note the horizontal axis is time. (See Technical Note below.)



Any number of line profiles can be done on the same movie/image. Click on the image and again click on the *Line Profile* icon to bring up another line profile window.

Right-click the Line profile window and select Properties to change such things as –

- how and what data is displayed;
- whether the data is processed (e.g., Boxcar smoothed) before it is displayed.

To change general display options (such as raw versus percent intensity), choose the Options/General menu and select options in the Images and Video tab.

Technical notes:

1. If a line profile is placed vertically on a Scan Mode image, the Line Profile automatically changes from intensity versus pixel number to intensity versus time. This is because traversing straight down a Scan Mode image represents the time evolution of the acquisition.

2. Changing the line's thickness (double-click the line to do so) will average out the data beneath the line. This is another way to improve the smoothness of the line profile (other than applying data filters).

Lowpass Filter

This is a tool found under the Analysis menu that is available for 2-D data plots. It applies a generic Low Pass Filter, that will pass below a specified cut off, to the current plot.

Use the Lowpass Filter plot properties to specify the Frequency to use.

Poly Fit w/ extrapolation

This is a tool found under the Analysis menu that is available for 2-D data plots. It performs a Polynomial Fit (up to 5th degree) and allows the user to increase the range over which the polynomial is plotted.

Use the Poly Fit w/ extrapolation plot property to specify the coefficients used for plotting and to increase the range beyond the data (for data extrapolation).

Polynomial Fit

This is a tool found under the Analysis menu that is available for 2-D data plots. It uses matrix inversion to do a least squares polynomial fit to the data.

Use the Polynomial Fit plot property to specify the degree of the polynomial:.

$f(x) = c_0 + c_1 x + c_2 x^2 + \cdots$ up to 22nd degree.

Compare with Poly Fit w/ Extrapolation, which allows plotting of the polynomial beyond the data range.

Pyrometric Growth Rate

This is a tool found under the *Analysis* menu that is available for 2-D data plots. It is used for determining thin film growth rate by performing a Fourier transform and then using BandiT's algorithm. The resulting plot is of the Fourier transform (either DFT or FFT, using the Fourier Transform plot property) with the growth rate displayed in the plot title.

It has its own Index of Refraction plot property, and both it and the use of this analysis tool are described more in the topic How-To Measure Growth Rate.

Sampling

This is a tool found under the Analysis menu that is available for 2-D data plots. It applies a generic sampling algorithm.

Savitzky-Golay

This is a tool found under the Analysis menu that is available for 2-D data plots. It applies a Savitzky-Golay digital smoothing polynomial (DISPO) filter to the current plot.

The main advantage of this type of filter is that it tends to preserve spectral features with higher moments which are typically 'flattened' by other smoothing techniques (such as moving average, for example). It performs a local polynomial regression of specified order on a specified number of adjacent points in order to determine the smoothed value at each point. An advantage of this technique is that derivatives may be trivially calculated from the smoothing polynomial.

Use the Savitzky-Golay plot property to specify the parameters of the fit.

Scale by Poly

This is a tool found under the Analysis menu that is available for 2-D data plots. It applies a generic scale by polynomial algorithm the degree of which is determined by a number of user specified coefficients.

Use the Scale by Poly plot property to specify the coefficients.

Spreadsheet

This is a tool found under the Analysis menu that is available for 2-D data plots that displays plotted data in a spreadsheet, with the independent variable(s) in the first column(s) on the left and the dependent variable(s) in the remaining column(s) on the right.

Right-clicking the spreadsheet and selecting *Properties* yields only a subset of the choices available for the plot, allowing the user only to change spreadsheet-specific properties rather than plot-specific properties.

The spreadsheet can be exported as a Text File (*.txt), Excel File (*.xls) or HTML File (*.html) by selecting File/Export in the main menu.

Surface Analysis

Surface Analysis is an analysis tool for post-acquisition analysis of a Scan Mode Image. It performs a generic Surface Analysis algorithm on the current image.

Window Surface Plot

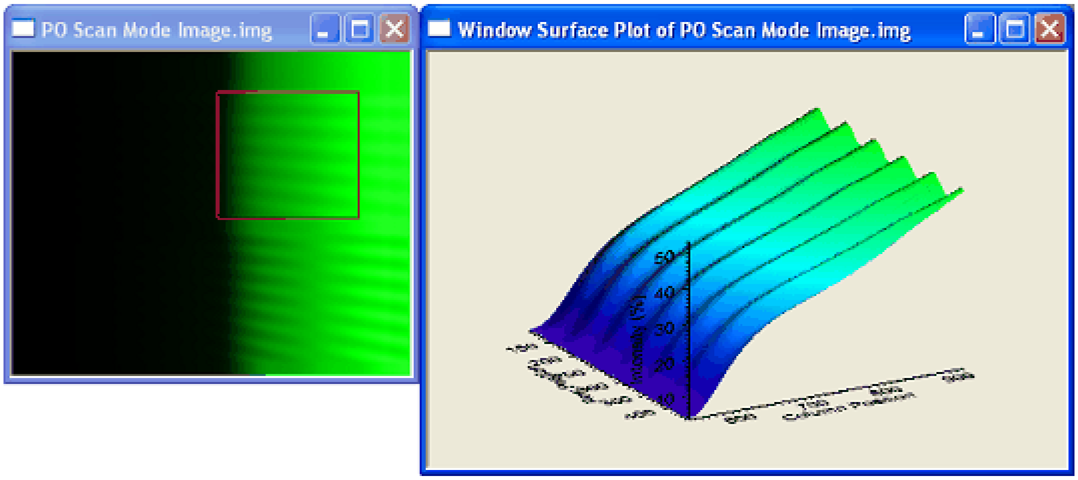
Surface Plot is an analysis tool for post-acquisition analysis of a Scan Mode Image.

This analysis tool plots intensity as a function of window position. The window position is determined by a rectangle that is placed on top of an image. The analysis is interactive, meaning that changing the characteristics of the window (position, length, or width) changes the plot. Surface Plot is particularly useful for bringing out weak features difficult to see in a 2-D image.

The Surface plot can also be rotated by clicking anywhere on the plot window and dragging with the mouse. This allows the surface to be viewed from all sides.

Below is a picture of a Surface Plot performed on a test image:

- the red rectangle is profiled by the plot;
- the areas inside the red rectangle of higher intensity corresponds with the higher values along the Z-axis in the Surface Plot.



Right-click the Surface Plot window and select Properties to change such things as –

- plotting boundaries (rectangle) and mesh-size used to create the plot;
- whether the data is processed (e.g., smoothed) before it is displayed.

To change general display options (such as raw versus percent intensity), choose the Options/General menu and select options in the Images and Video tab.

Triple Region Plot

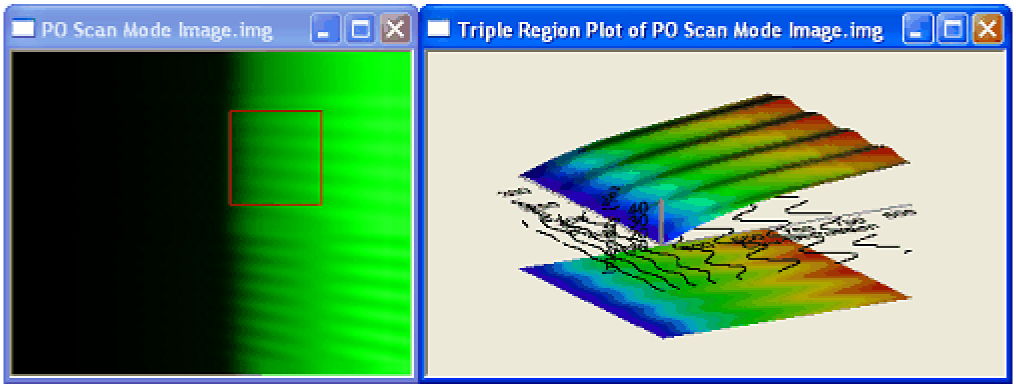
Triple Region Plot is an analysis tool for post-acquisition analysis of a Scan Mode Image.

Triple Region Plot analysis plots a Surface Plot, Contour Plot and the original image as a function of window position. The window position is determined by a rectangle or ellipse, which is placed on top of an image. The analysis is interactive, meaning that changing the characteristics of the window (position, length, or width) changes the plot.

The Triple Region plot can also be rotated by clicking anywhere on the plot window and dragging with the mouse. This allows the surface to be viewed from all sides.

Below is a picture of a Triple Region Plot performed on a test image:

- the red rectangle is profiled by the plot;
- the areas inside the red rectangle –
    - of higher intensity corresponds with the peaks in the Surface Plot (top plot)
    - of different intensities are separated by lines in the Contour Plot (middle plot)
    - is copied from the image for reference purposes (bottom plot)



Right-click the Triple Region Plot window and select Properties to change such things as –

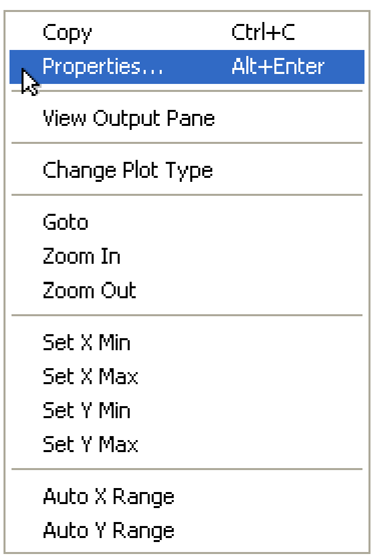
- plotting boundaries and mesh-size used to create the plot;
- whether the data is processed (e.g., smoothed) before it is displayed.

To change general display options (such as raw versus percent intensity), choose the Options/General menu and select options in the images and video tab.

Plot Properties

Plot Properties

Both Real-Time Charts and post-acquisition analysis tools have plots. Each plot has different sets of properties that can be modified and applied. Right-click a plot and select ***Properties*** to view the plot properties of that particular plot.



The full list of plot properties is as follows:

- Auto-Scrolling
- BandiT Computed Data
- BandiT Spectra Acquire Source
- BandiT Spectral Data

- Blackbody Fit
- Blackbody Fit Lock Temp
- Blackbody Fit Lock Tooling
- Boxcar Smooth
- Colors
- Contour
- Crop
- Cubic Spline Fit
- Data
- Data Filters
- Derivative
- Digital Filter Fit
- Exponential Fit
- Extrema Count
- Factory Calibration Acquire Source
- File
- Fonts
- Fourier Transform
- Gauss Fit
- Growth Rate Damped Sine Fit
- Index of Refraction
- Labels
- Line
- Lowpass Filter
- Parameters
- Playback
- Plot Value
- Refresh Rate
- Poly Fit w/ extrapolation
- Polynomial Fit
- Rectangle
- Samples
- Sampling
- Savitzky-Golay
- Scale by Poly
- Series
- Shape
- Source
- Surface
- X/Y/Z Axis

General Notes:

1. Find specific data values by simply clicking the plot and placing the mouse cross-hairs on the point of interest. The coordinates are given in the right lower portion of the kSA application window (in the Status bar). Maximize the application window and be sure the Status bar is selected (find it under the View menu).
2. Control-click-and-drag across a range of interest on a plot to zoom-in on those particular plot values.

Auto-Scrolling

This is a plot property most often associated with Real-Time Charts because it specifies how the data is to be displayed on the chart when the total amount of data is not known.

Specify:

Disabled – turn off auto-scrolling. Plots data by continually scaling plot.

Continuous – scrolling continuously

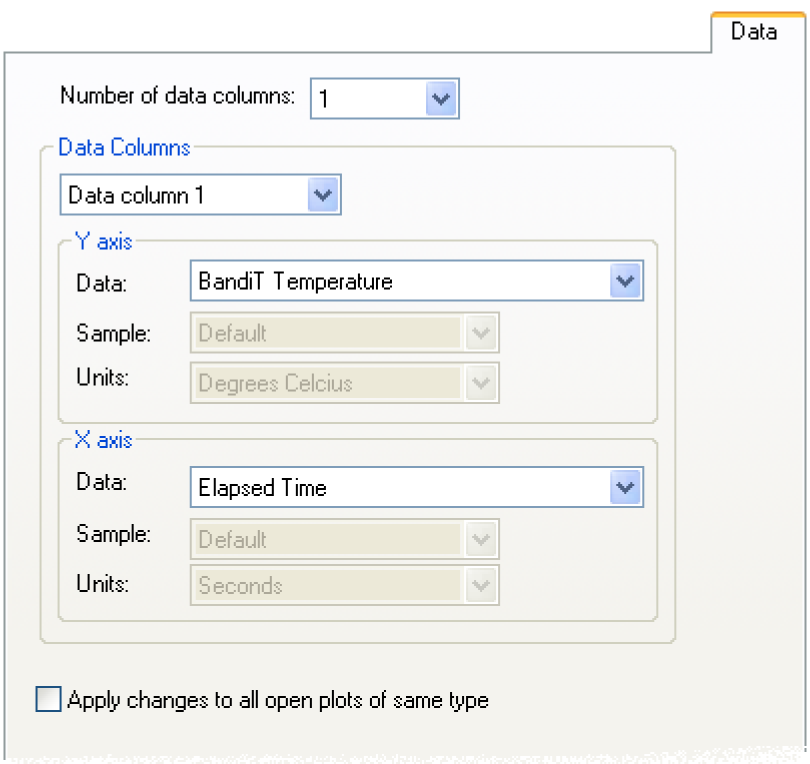
Intervals – data plotted across window and scrolls at end of window to next interval

BandiT Computed Data

This is a plot property. It is used for specifying which data is plotted. See also Bandit Spectral Data and kSA's proprietary file formats.

BandiT Computed Data may be called BandiT's "narrow-column" data, e.g., data such as temperature (a single value) is considered a data point. It is the only type of data stored when selecting *Minimal data output (default)* in the BandiT I/O Settings Advanced Acquisition Option.

To switch to the other data format (if it was stored during acquisition), close the plot property and click the *Toggle Charts* button in the *.kdt Toolbar.



Specify:

Number of Data Columns – up to 4 series of data may be plotted on the same plot. This is useful particularly for plotting two different Y-axis data against the same X-axis data, such as *BandiT Temperature* and *Analog Input* (used to control a process) versus *Elapsed Time*.

For each ***Series***, specify for *Y axis* and *X axis*:

For ***Data***, select the data values for each axis, such as –

- *Elapsed Time*
- *Data Point*
- *BandiT Temperature*
- *Band Edge Wavelength*
- *TC Temperature* – available for all calibration files
- *Confidence*
- *Number of Wavelengths*
- *Peak Spectra Intensity*
- *Spectrometer Integration Time*
- *Percent of Full Light Intensity*

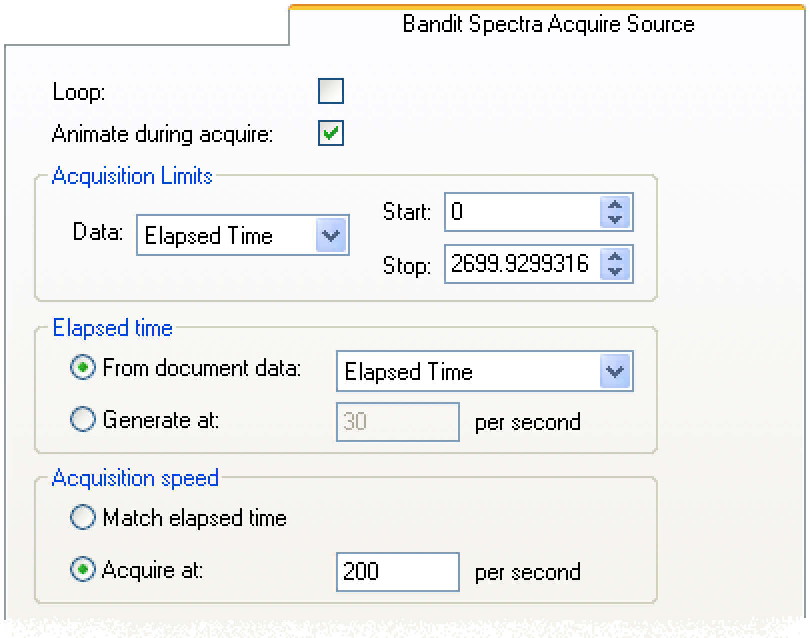
Sample – this will always read "Default" and remain disabled in kSA's BandiT

Units – of the *Data* that has been selected above. It will be disabled if there is only one unit choice.

Check the ***Apply changes to all open plots of same type***, and changes made in this properties dialog will apply to all open plots of the "narrow-column" data type.

BandiT Spectra Acquire Source

This is a plot property that is used only when a *.kdt file is chosen as the Source in BandiT Temperature Acquisition. It is used to configure the way data is viewed as if it is live. A similar plot property is the Factory Calibration Acquire Source, but that is used only when making calibration files, so most users will not use it.



Check:

Loop – for looping the *.kdt file for acquisition. This checkbox must be selected to loop the file. The *Loop* button on the *.kdt toolbar only loops playback.

Animate during acquire – to view the *.kdt file play during acquisition

Specify ***Acquisition Limits***:

Data – choose *Elapsed Time* or *Data Point* and then use the arrows with ***Start*** and ***Stop*** to set the lower and upper bound from which data is acquired. This trims the data, allowing the user to begin and end acquisition at any point.

Note that the *Start* and *Stop* values increment based on the values in the *.kdt, so data points are numbered sequentially and elapsed time is as recorded. For elapsed time, this means that the number of decimal places may mean that the beginning (or end) of the value is hidden while using the arrows buttons, so simply place the cursor in the box and use the arrow keys on the keyboard to view either end of the number.

(For example, in the *Stop* field pictured above, the end of the number 2699.9299316 is not displayed – the whole number is 2699.92993164063, and while scrolling through the data only .92993164063 is displayed.)

The ***Elapsed time*** specifies whether the spectra will be time-compressed in the new acquisition.

From document data – and the elapsed time will be generated from whatever data value is selected. Usually, users select *Elapsed Time*, which means that the new *.kdt acquisition elapsed time values will match those of the source *.kdt file.

or

Generate at – and the overall amount of data in the *.kdt file will be divided by this number, with the new acquisition will be as though it took place in the resultant number of seconds. The units are data points per second.

For example, suppose a *.kdt file has 8000 data points that were generated over the course of 9999 seconds. Setting *Generate at* to 1000 means that the new *.kdt file will have all 8000 data points in a file that has a total elapsed time of 8000/1000 = 8 seconds.

The ***Acquisition speed*** specifies how fast the spectra is available for processing during a new acquisition. Choose:

Match elapsed time – and the data will be available for processing at the same speed at which it was originally acquired

or

Acquire at – and the data (e.g. 200 spectra per second) will be available at a user-specified speed

BandiT Spectral Data

This is a plot property. It is used for specifying which spectral data is plotted. See also BandiT Computed Data and kSA's proprietary file formats.

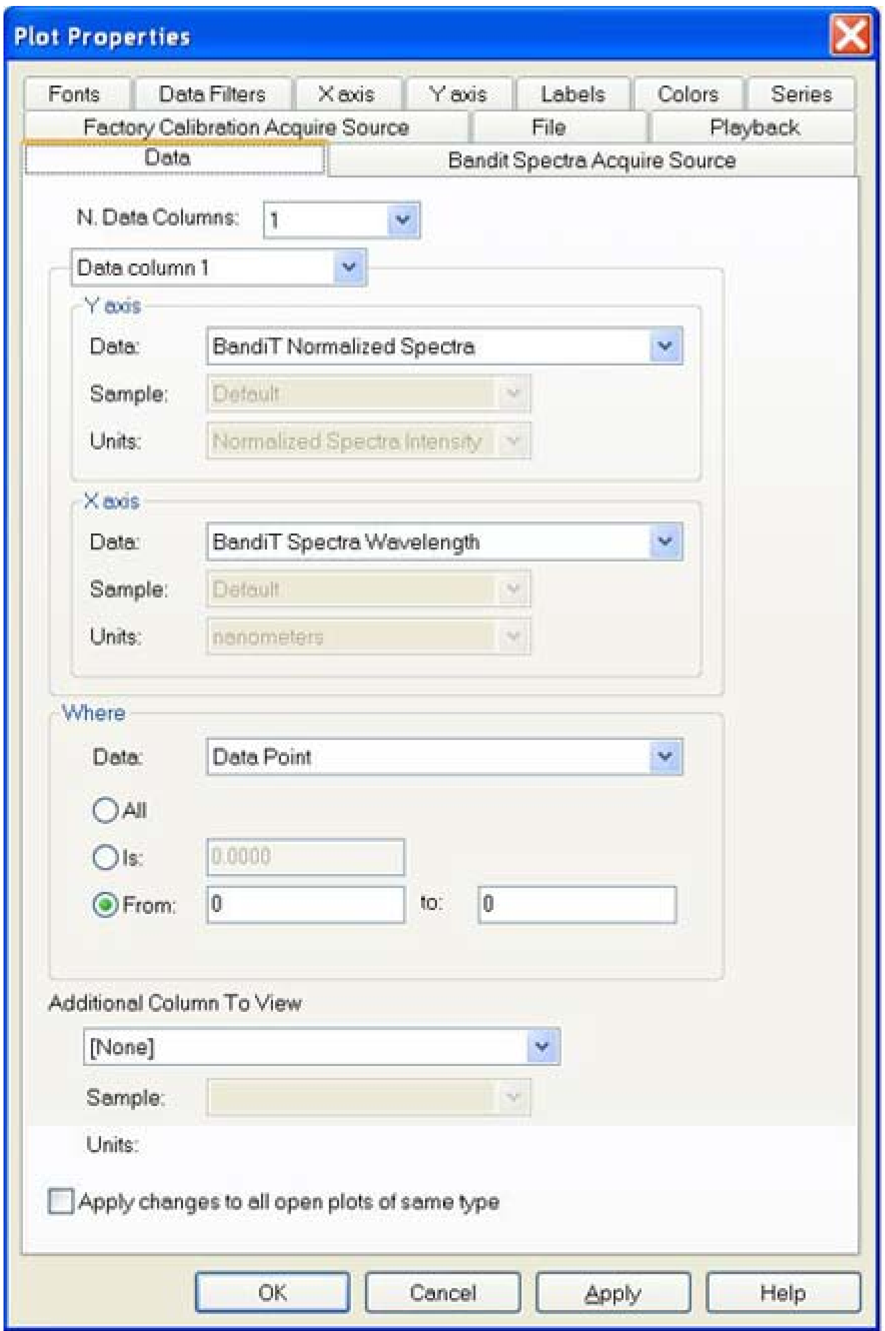
BandiT Spectral Data may be called BandiT's "wide-column" data, e.g., data such as spectra (multiple values) may be considered one data point. Both it and the *BandiT Computed Data* are stored when selecting *Store raw and fully processed spectra* in the BandiT I/O Settings Advanced Acquisition Option.

To switch to the other data format, close the plot property and click the other tab at the bottom of the chart.

Specify:

N. Data Columns – up to 4 columns of data may be plotted on the same plot. This is useful particularly for plotting two (or more) different Y-axis data against the same X-axis data. BandiT regularly does this in the Real-Time Normalized BandiT Spectra, plotting *BandiT Fit Linear Fit X Pos*, *BandiT Fit Linear Fit Y Pos*, and the *BandiT Normalized Spectra*.

For each ***Data column***, specify for ***Y axis*** and ***X axis***:



For ***Data***, select the data values for each axis, such as –

- *Band Gap Linear Fit X/Y Pos*
- *BandiT Normalized Spectra*
- *BandiT Spectra*
- *BandiT Spectra Wavelength*

Sample – this will always read "Default" and remain disabled in kSA's BandiT

Units – of the *Data* that has been selected above. It will be disabled if there is only one unit choice.

For ***Where***, specify the type and range of data plotted:

Data – select what type of data is to be used for the range

For example, in the dialog above, BandiT Spectra vs. Bandit Spectra Wavelength is plotted *Where* the *Data* plotted is *From* 0 *to* 10, meaning the first 11 data points are plotted together on one graph.

Choose one:

All – for plotting the whole range of *Data*. Selecting this option can take several minutes to plot if there is a lot of data.

Is – for plotting a particular spectra based on the *Data* value selected

From – for plotting a specific range of *Data*

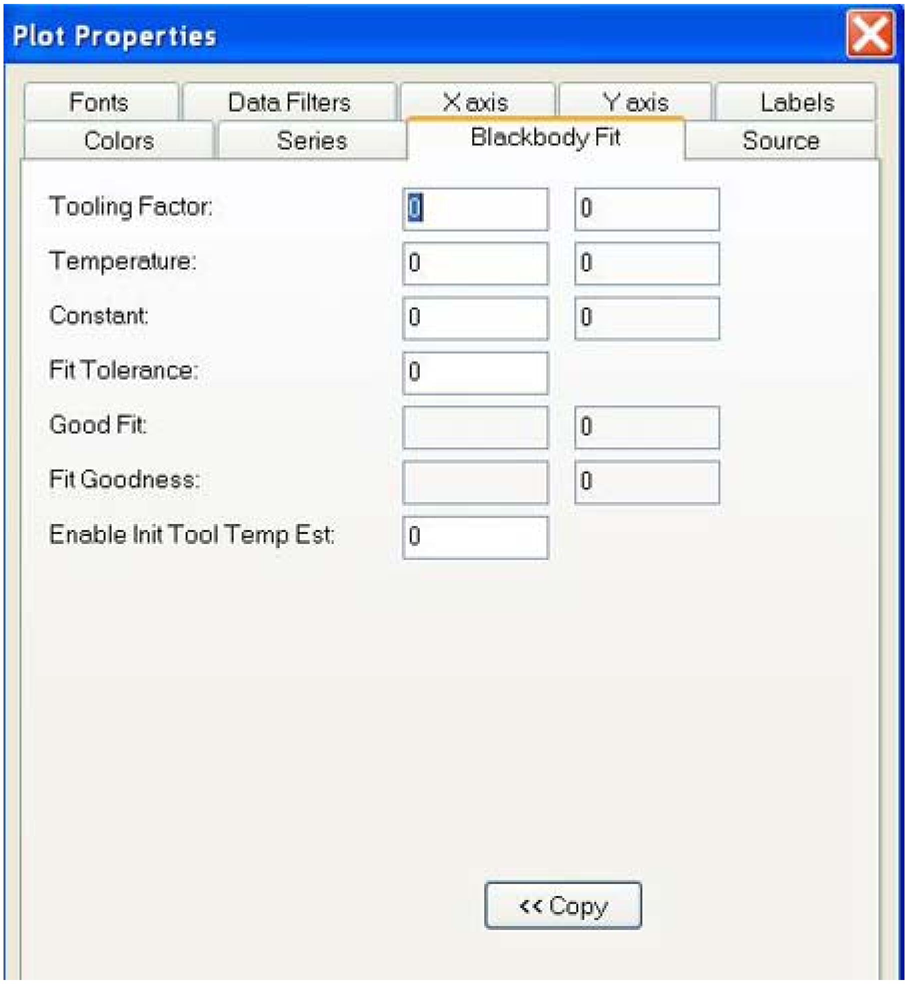
Specify ***Additional Column To View*** in order to place another title in the plot header that specifies the value.

Check the ***Apply changes to all open plots of same type***, and changes made in this properties dialog will apply to all open plots of the "wide-column" data type.

Blackbody Fit

This is a plot property unique to plots analyzed with the Blackbody Fit post-acquisition analysis tool. Temperature and Tooling Factor can both vary during the fitting of the Blackbody curve.

When Blackbody Fit is used in Analysis mode the integration time, emissivity are tied into the Tooling Factor. This differs from the case when Blackbody is used during Acquisition mode where the integration time and emissivity are independent of the Tooling Factor.



Specify the parameters for the plot in the left hand column. The parameters used in the last attempt are displayed in the right hand column and can be copied across using the ***<<Copy*** button. This is useful when using multiple iterations to obtain the best fit.

Tooling Factor - an estimate of the tooling factor to be used as an initial guess by the fitting routine.

Temperature - an estimate of the temperature to be used as an initial guess by the fitting routine. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate.

Constant - enter a value for the background constant, optional, enter 0 for no constant

Fit Tolerance - the fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations

Good Fit - this allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. The default value is 20, meaning spectra which have reduced chi-squared greater than this value will be ignored.

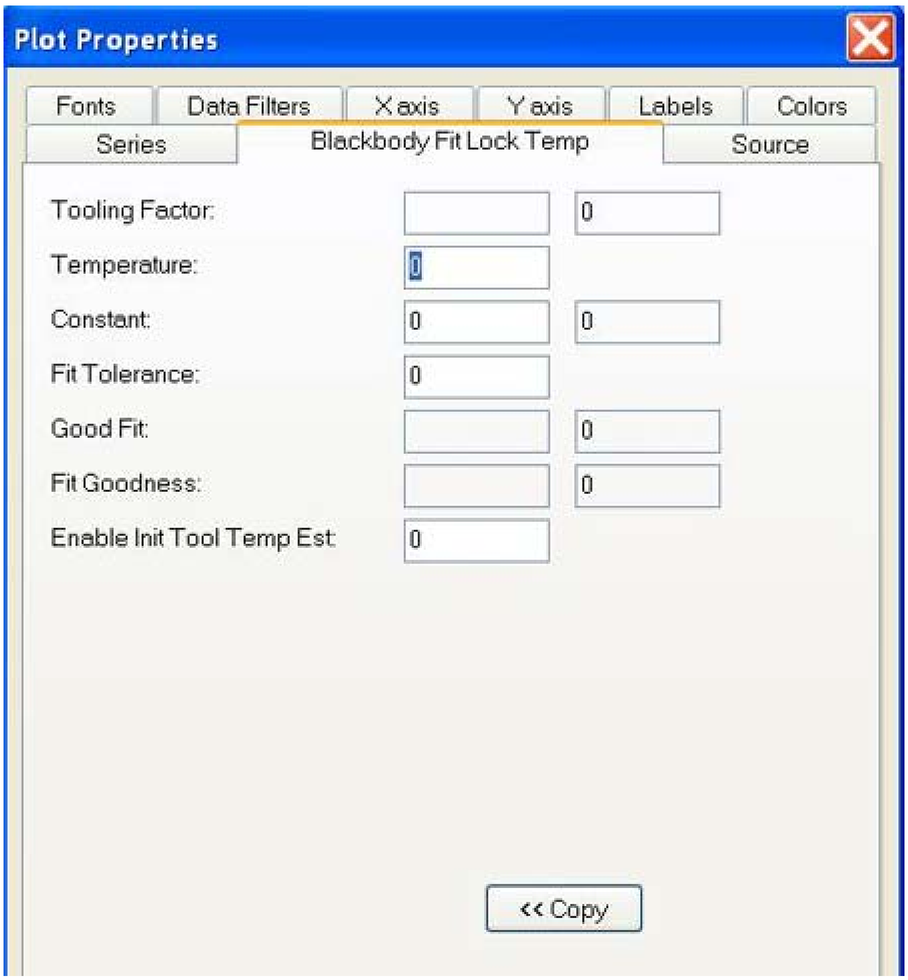
Fit Goodness - the goodness of fit that is obtained is displayed

Enable Init Tool Temp Est -

Blackbody Fit Lock Temp

This is a plot property unique to plots analyzed with the Blackbody Fit Lock Temp post-acquisition analysis tool. Specify a ***Temperature*** which will be used to superimpose the expected blackbody curve for that temperature over the current data plot. The ***Goodness of fit*** of the curve will be displayed.

When Blackbody Fit is used in Analysis mode the integration time, emissivity are tied into the Tooling Factor. This differs from the case when Blackbody is used during Acquisition mode where the integration time and emissivity are independent of the Tooling Factor.



Specify the parameters for the plot in the left hand column. The parameters used in the last attempt are displayed in the right hand column and can be copied across using the ***<<Copy*** button. This is useful when using multiple iterations to obtain the best fit.

Tooling Factor - an estimate of the tooling factor to be used as an initial guess by the fitting routine.

Temperature - the temperature that is to be used when calculating the Blackbody curve. This is locked and will not vary during the fitting process

Constant - enter a value for the background constant, optional, enter 0 for no constant

Fit Tolerance - the fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations

Good Fit - this allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. The default value is 20, meaning spectra which have reduced chi-squared greater than this value will be ignored.

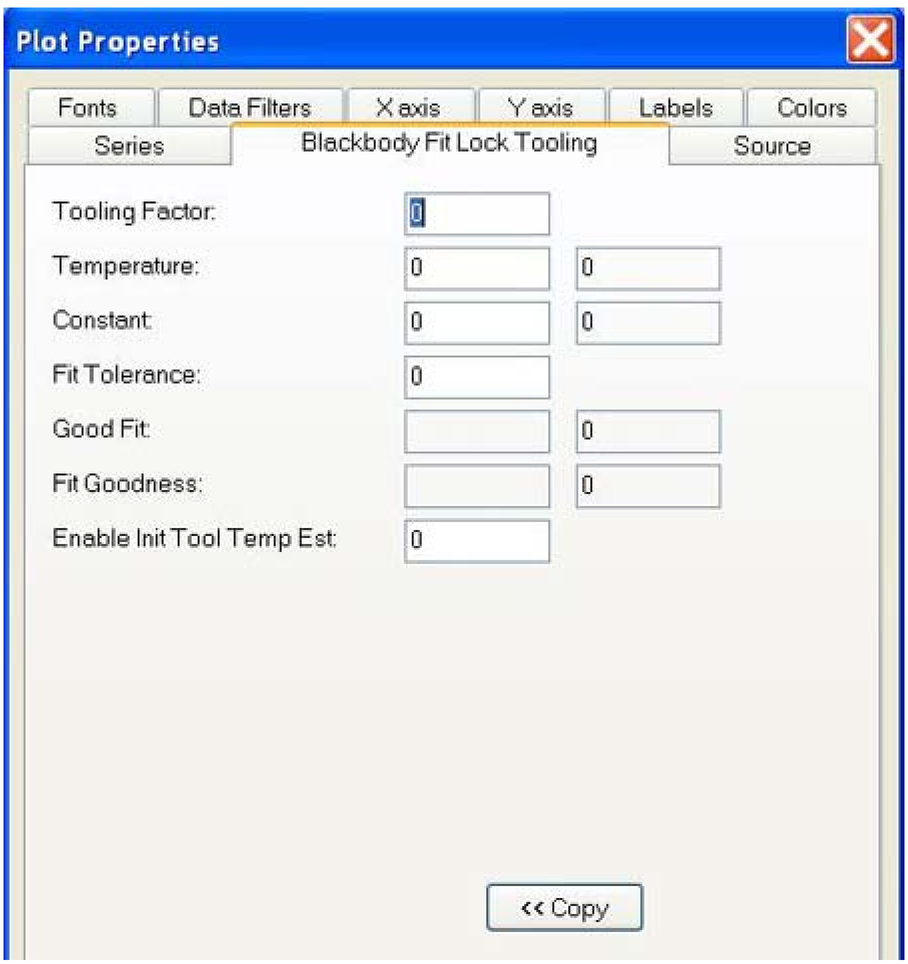
Fit Goodness - the goodness of fit that is obtained is displayed

Enable Init Tool Temp Est -

Blackbody Fit Lock Tooling

This is a plot property unique to plots analyzed with the Blackbody Fit Lock Tooling post-acquisition analysis tool. Specify a ***Tooling Factor*** which will be used to superimpose the expected blackbody curve for that temperature over the current data plot. The ***Goodness of fit*** of the curve will be displayed.

When Blackbody Fit is used in Analysis mode the integration time, emissivity are tied into the Tooling Factor. This differs from the case when Blackbody is used during Acquisition mode where the integration time and emissivity are independent of the Tooling Factor.



Specify the parameters for the plot in the left hand column. The parameters used in the last attempt are displayed in the right hand column and can be copied across using the ***<<Copy*** button. This is useful when using multiple iterations to obtain the best fit.

Tooling Factor - enter the Tooling Factor this is to be used when fitting the Blackbody curve

Temperature - an estimate of the temperature to be used as an initial guess by the fitting routine. Note that the results are fairly sensitive to the initial guess. Typically, it should be within ~20%, but the routine tends to be more forgiving if this represents an over-estimate rather than an under-estimate.

Constant - enter a value for the background constant, optional, enter 0 for no constant

Fit Tolerance - the fitting routine stops when chi-squared decreases by less than this tolerance value upon successive iterations

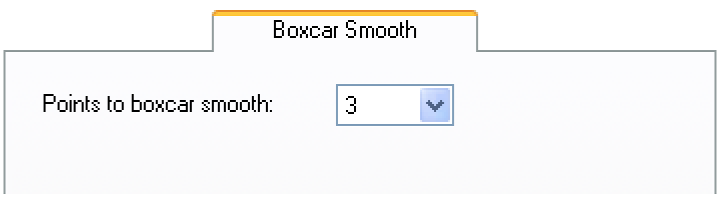
Good Fit - this allows rejection of spectra with poor fits, as measured by the reduced chi-squared statistic. The default value is 20, meaning spectra which have reduced chi-squared greater than this value will be ignored.

Fit Goodness - the goodness of fit that is obtained is displayed

Enable Init Tool Temp Est -

Boxcar Smooth

This is a plot property.



Specify ***Points to boxcar smooth*** to choose the width of the side of the smoothing window. For example, 3 specifies a 3 by 3 smoothing window with 9 total elements. The smoothed element will be in the middle of that box.

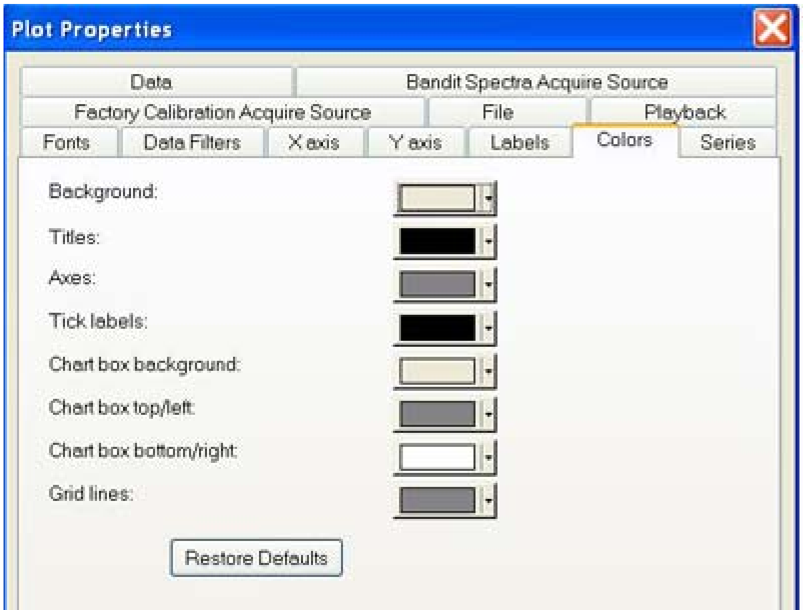
For no smoothing, choose 1 from the drop-down box.

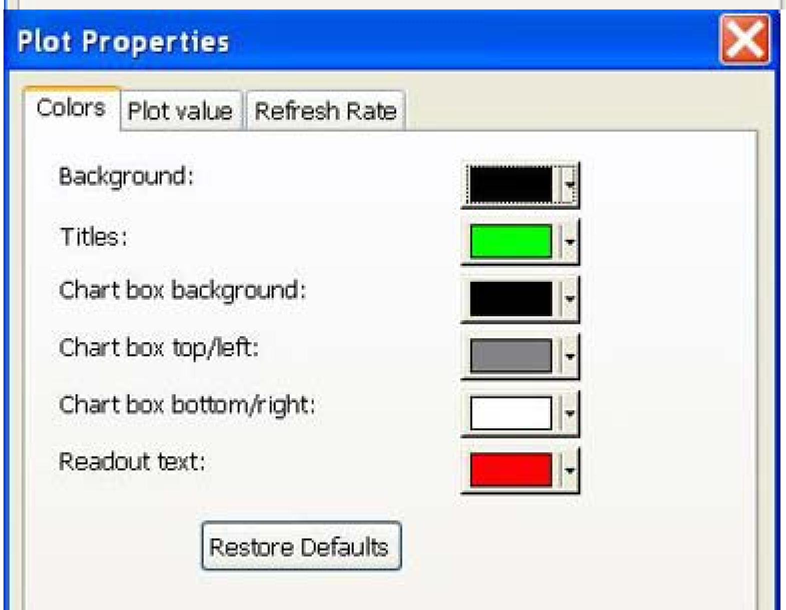
Smoothing can also be done using the 2-D data filter Boxcar Smooth.

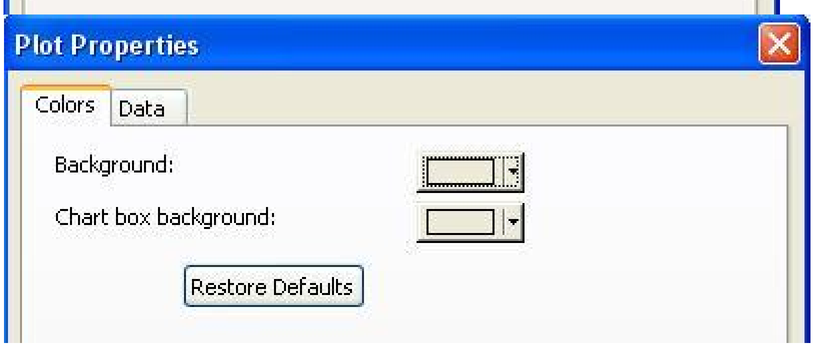
Colors

This is a plot property used to change the colors of the plot. Every color is available.

The number of elements available for coloring varies with the plot as shown in the examples below.







Additional color and palette options are available in the Contour and Surface properties for the following plots:

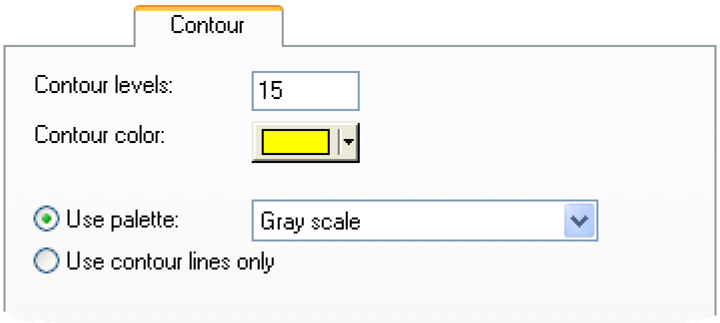
Contour Plot

Surface Plot

Triple Region Plot

Contour

This is a plot property available only for the Contour Plot and the Triple Region Plot.



Specify:

Contour levels – to divide the Z-Axis data into more/fewer parts. See the Z-Axis for setting the range and scale factor.

Contour color – to choose the color of the contour lines

Choose *either*

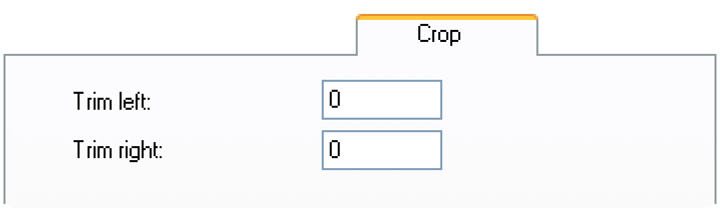
Use palette – to view the image with the contour lines. Using this option, specify the palette. Note that the palette only changes how the data is displayed.

or

Use contour lines only – to hide the image and show only the contour lines

Crop

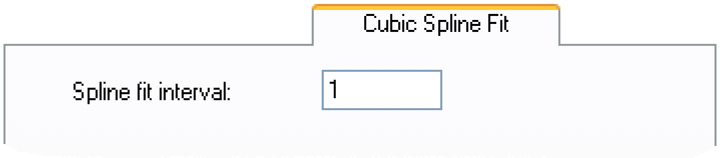
This is a plot property unique to cropped 2-D data plots created using the crop post-acquisition analysis tool.



Specify the number of columns to be trimmed from the left and right to create the new, cropped data plot.

Cubic Spline Fit

This is a plot property unique to plots analyzed with the Cubic Spline Fit post-acquisition analysis tool.



Specify the ***Spline fit interval*** –

for interpolation by typing in a value less than the data interval. Decimal values are acceptable.

for smoothing by typing in a value larger than the data interval.

Data

This is a plot property. In BandiT, there are several types of data, each with their own plot property:

BandiT Computed Data – for plots of "narrow-column" data, e.g., data such as temperature (a single value) is considered a data point

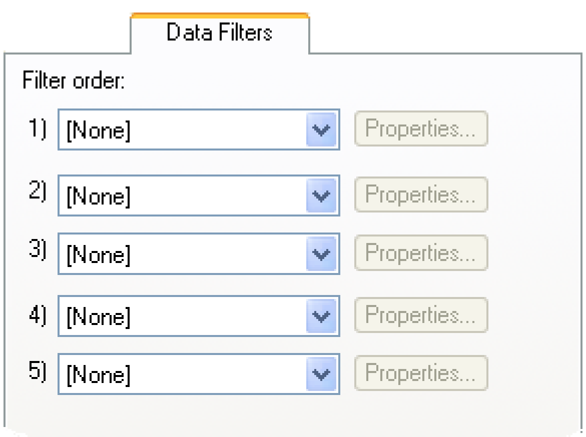
BandiT Spectral Data – for plots of "wide-column" data, e.g., data such as spectra (multiple values) may be considered one data point.

Bandit Platen Data - for plots of the platen surface in the Real-time Platen Surface Plot

Multiple Markers LED Data - For plots of numeric readouts from multiple markers on a rotating platen

Data Filters

This is a plot property that is available for many plots. It applies Data Filters that affect the plot (replacing the original data with the filtered data), but does not affect the data nor how the data are gathered. The number of filters available depends on the plot: 2-D plots have many filters; 3-D plots have a few.

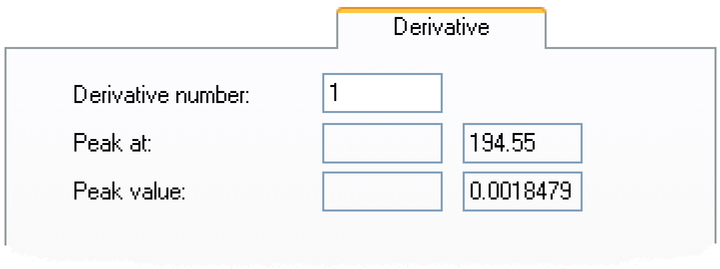


Choose up to five filters. They will be applied in order, i.e., the output of the first filter is the input to the second filter, and so on.

Click the ***Properties*** button to select the properties for each Data Filter.

Derivative

This is a plot property unique to plots analyzed with the Derivative post-acquisition analysis tool.

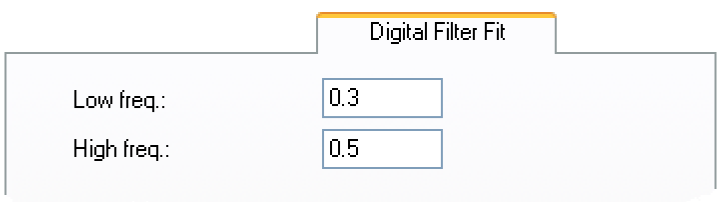


Specify a ***Derivative number*** to take that order of derivative. The ***Peak at*** (in same units as X-axis, horizontal) and ***Peak value*** (in same units as Y-axis, vertical) are not alterable and are given based on the derivative taken.

Because the tool uses data points rather than a function, this tool actually calculates ***Δy/Δx*** *(Delta Y* divided by *Delta X*) and connects resultant data points with a straight line – for the first derivative. It does likewise for other orders of derivatives.

Digital Filter Fit

This is a plot property unique to plots analyzed with the Digital Filter Fit post-acquisition analysis tool. It is used to construct highpass, lowpass, bandpass, and bandstop filters.



Specify:

Low freq. – the lower frequency of the filter as a fraction of the Nyquist frequency

High freq. – the upper frequency of the filter as a fraction of the Nyquist frequency

The following conditions are necessary for various types of filters:

No Filtering: ***Low*** = 0 and ***High*** = 1

Low Pass: ***Low*** = 0 and 0 < ***High*** < 1

High Pass: 0 < ***Low*** < 1 and ***High*** = 1

Band Pass: 0 < ***Low*** < ***High*** < 1

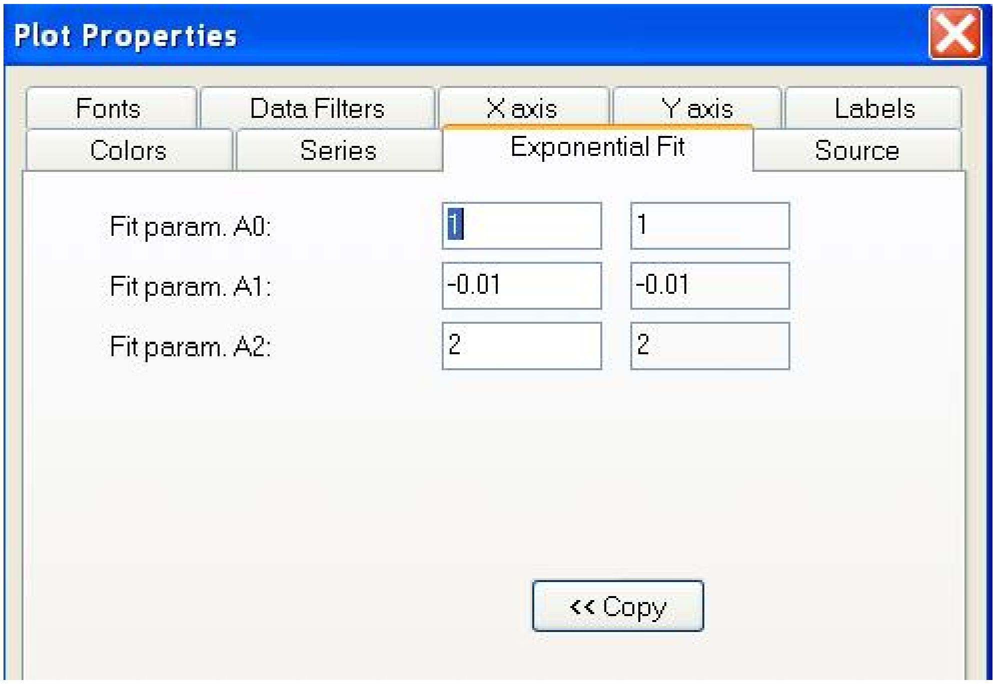
Band Stop: 0 < ***High*** < ***Low*** < 1

Exponential Fit

This is a plot property for the Exponential Fit plot which applies a generic exponential fit algorithm that attempts to fit an exponential curve of the form:

$$f(\lambda) = a_0 e^{a_1 \lambda} + a_2$$

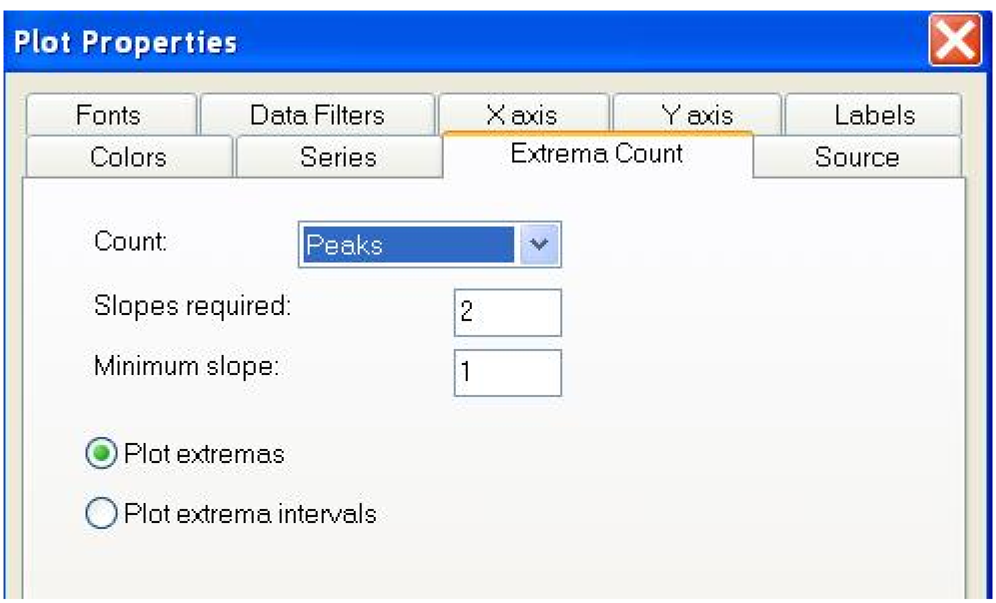
to a spectrum.



Specify initial starting points for the three parameters A0, A1 and A2.

Extrema Count

This is a plot property used to specify parameters for the Extrema Count Plot.



Specify:

Count - use the drop down list to select what to count

Slopes required - enter the number of slopes required

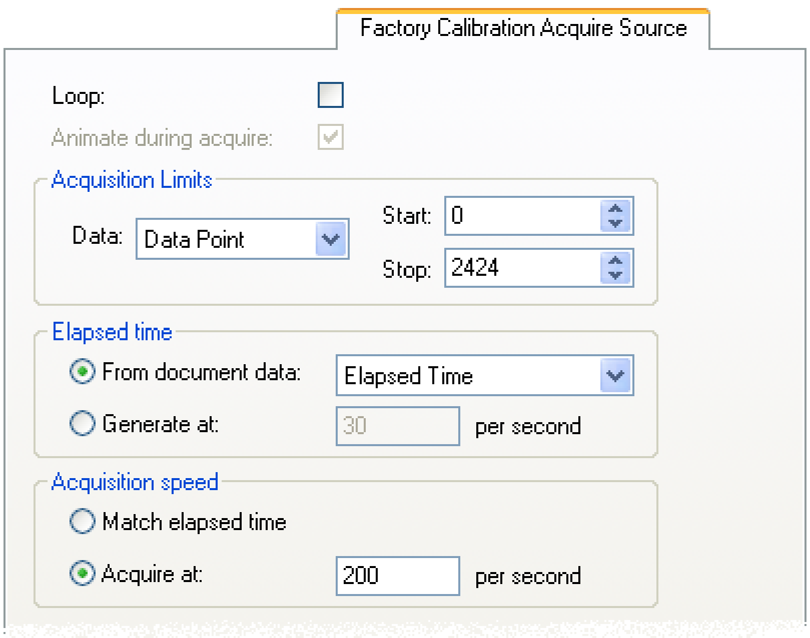
Minimum slope - enter minimum slope

Select Plot extremas or Plot extrema intervals.

Factory Calibration Acquire Source

This is used by k-Space to configure the BandiT calibration files. This is not generally used by a BandiT user.

This is a plot property. It is used only to make calibration files, so most users will not use it. Instead, users may use a similar plot property called BandiT Spectra Acquire Source to configure the way data is viewed as if it is live.



Check:

Loop – for looping the *.kdt file for acquisition. This checkbox must be selected to loop the file. The Loop button on the *.kdt toolbar only loops playback.

Animate during acquire – to view the *.kdt file play during acquisition, this is default selected and can no longer be changed.

Specify ***Acquisition Limits***:

Data – choose *Elapsed Time* or *Data Point* and then use the arrows with ***Start*** and ***Stop*** to set the lower and upper bound from which data is acquired. This trims the data, allowing the user to begin and end acquisition at any point.

Note that the *Start* and *Stop* values increment based on the values in the *.kdt, so data points are numbered sequentially and elapsed time is as recorded. For elapsed time, this means that the number of decimal places may mean that the beginning (or end) of the value is hidden while using the arrows buttons, so simply place the cursor in the box and use the arrow keys on the keyboard to view either end of the number.

The ***Elapsed time*** specifies whether the spectra will be time-compressed in the new acquisition.

From document data – and the elapsed time will be generated from whatever data value is selected. Usually, users select *Elapsed Time*, which means that the new *.kdt acquisition elapsed time values will match those of the source *.kdt file.

or

Generate at – and the overall amount of data in the *.kdt file will be divided by this number, with the new acquisition will be as though it took place in the resultant number of seconds. The units are data points per second.

For example, suppose a *.kdt file has 8000 data points that were generated over the course of 9999 seconds. Setting *Generate at* to 1000 means that the new *.kdt file will have all 8000 data points in a file that has a total elapsed time of 8000/1000 = 8 seconds.

The ***Acquisition speed*** specifies how fast the spectra is available for processing during a new acquisition. Choose:

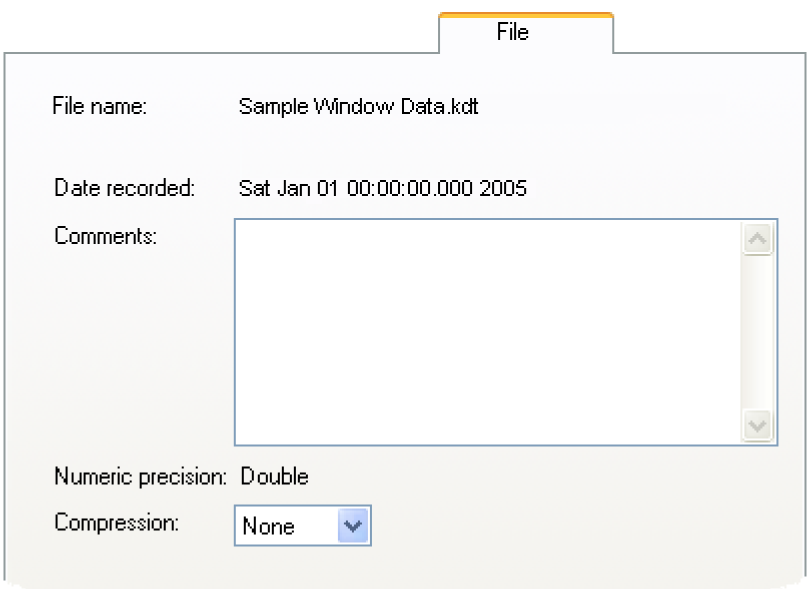
Match elapsed time – and the data will be available for processing at the same speed at which it was originally acquired

or

Acquire at – and the data (e.g. 200 spectra per second) will be available at a user-specified speed

File

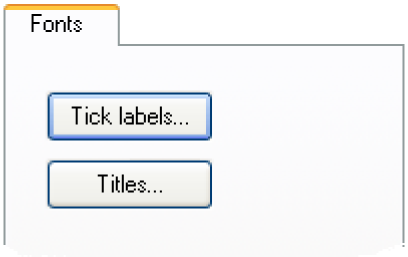
This is a plot property that enables the user to comment on the plot/spreadsheet and store those comments with the file (so long as it is not exported, but saved in k-Space's proprietary *.kdt format).



Change the ***Compression*** to ZLib for loss-less compression, thereby reducing file size, but taking slightly longer to re-open.

Fonts

This is a plot property that allows the user to change the font, font style, size, and script of the labels and titles on all charts. The functionality is similar to that of a word processor: the number of fonts available depend on the number installed on the system.

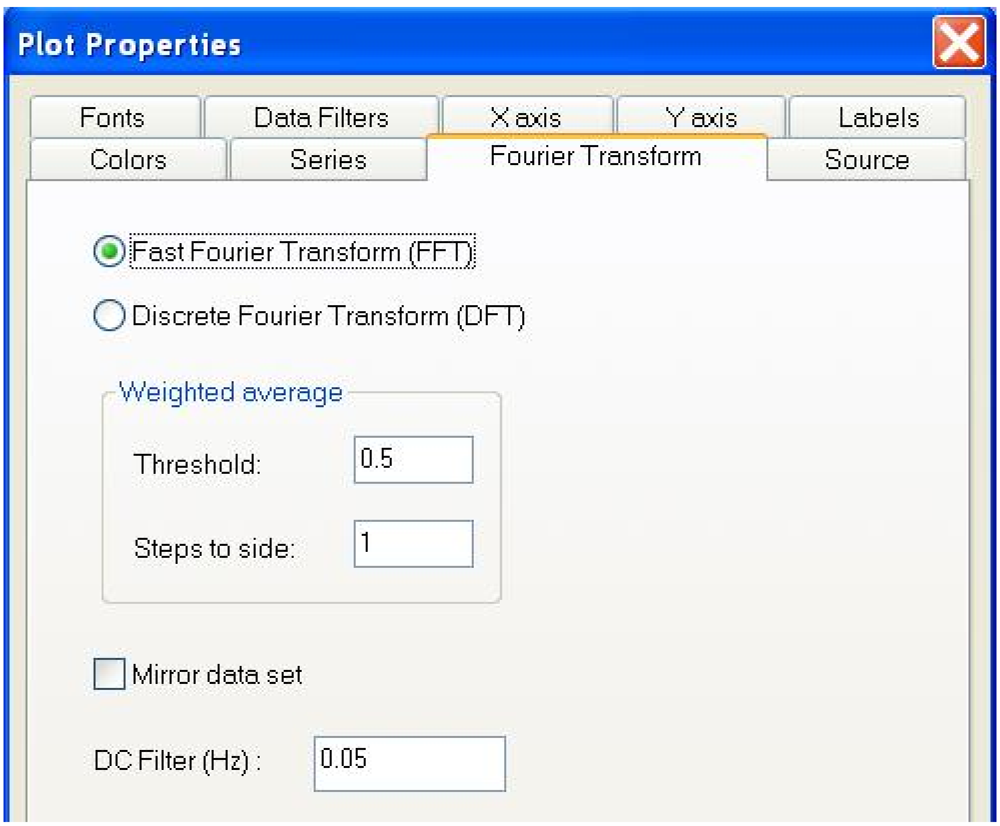


To change the font characteristics of the axis numbers, click the ***Tick labels*** button.

To change the font characteristics of anything else, click the ***Titles*** button.

Fourier Transform

This is a plot property for plots generated using FFT tools available under the Analysis menu.



Select:

FFT or ***DFT*** – While very fast, the Fast Fourier Transform (FFT) algorithm may introduce numerical error into the calculation. This is because FFT requires data sets that are a power of two in length. Zeros are added to data sets to get the proper length, and this can lead to small errors in determining the frequency. The Discrete Fourier Transform (DFT) does not have this deficiency. Unless the data set is very large data set (or a very slow computer), it is best to use the Discrete Fourier Transform (DFT) for analysis. While slower, DFT provides more accurate analysis of the frequency.

The ***Weighted average*** – takes the shape of the power spectrum peak frequency into account, calculating a weighted average frequency based on this shape. If the peak frequency profile is perfectly symmetric, then the weighted average frequency and the peak frequency are identical.

Specify:

Threshold – height of the peak profile below which a weighted average is not calculated. For example, a threshold of 0.5 means that the weighted average is calculated for the top 50% of the peak profile. The threshold value is useful for eliminating asymmetries in the peak profile.

Steps to side – the number of data points to each side of the peak that are used in the weighted average calculation. For example, a value of 1 means that the weighted average algorithm will take 1 data point to each side of the peak (as long as they are above the threshold value).

Check:

Mirror data set – to mirror the intensity data set about itself, thereby doubling the number of data points fed into the Fourier transform. In most cases this yields a cleaner Fourier transform. However, sometimes this yields additional harmonics that may result in an erroneous peak. The best way to check this is to first disable this checkbox, look at the peak frequency, and then turn on Mirror data set. The new peak should be within 5% of the old one.

Set:

DC Filter(Hz) - set the level of DC filter to use.

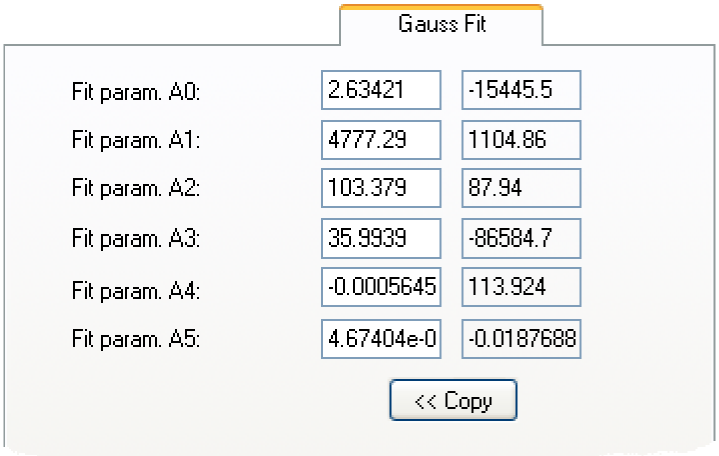
Gauss Fit

This is a plot property unique to plots analyzed with the Gauss Fit post-acquisition analysis tool. It gives the calculated fitting parameters of the non-linear least-squares fitting function:

$$f(x) = A_0 e^{\frac{-z^2}{2}} + A_3 + A_4 x + A_5 x^2$$

where

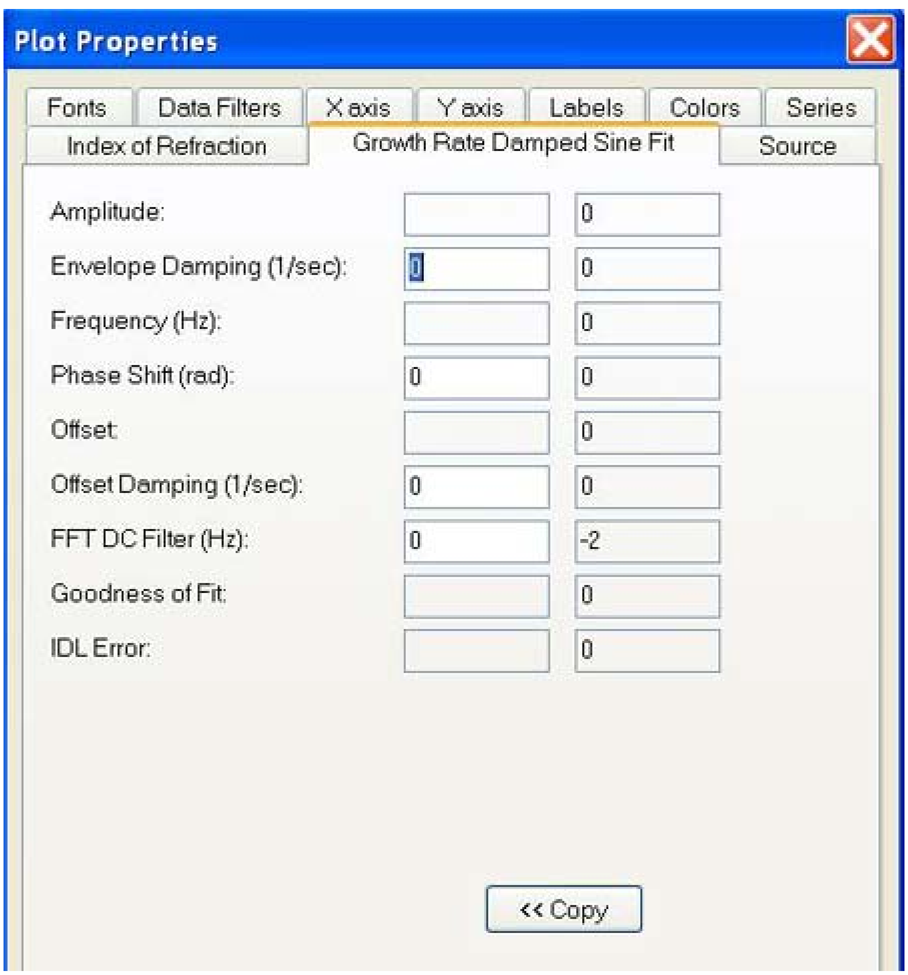
$$z = \frac{x - A_1}{A_2}.$$



Click the <<*Copy* button to copy the values from the shaded values (determined by the program) to the user-specified boxes. This will allow the same fitting parameters to be used on the next Gauss Fit.

Growth Rate Damped Sine Fit

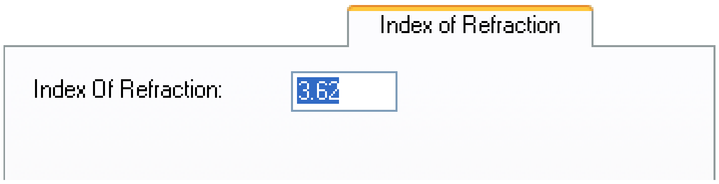
This is a plot property unique to the Growth rate Damped Sine Fit analysis plot.



Specify the parameters for the plot in the left hand column. The parameters used in the last attempt are displayed in the right hand column and can be copied across using the ***<<Copy*** button. This is useful when using multiple iterations to obtain the best fit.

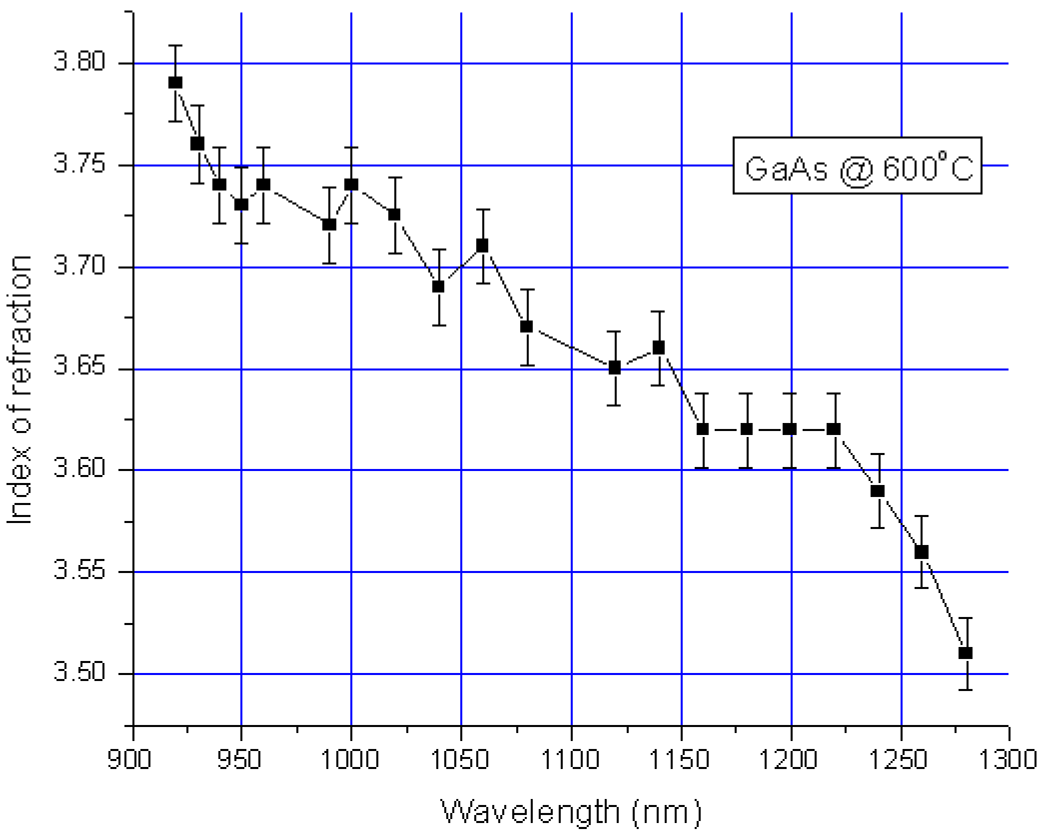
Index of Refraction

This is a plot property. It is used for Pyrometric Growth Rate analysis window, which is BandiT's method for determining growth rate.



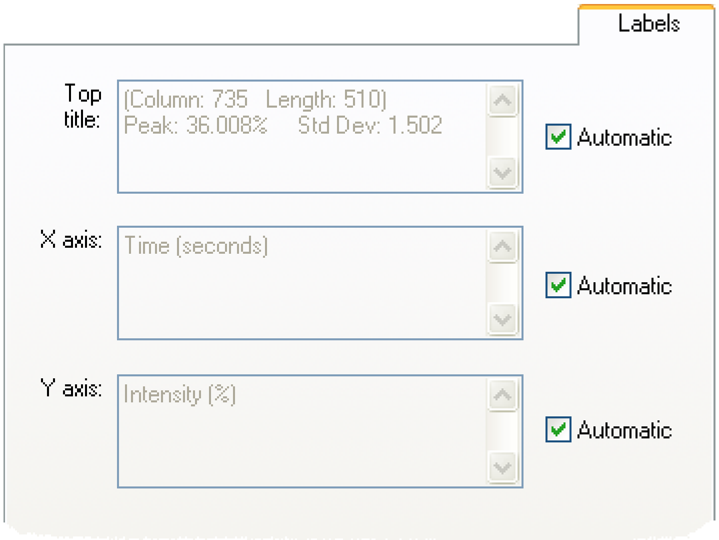
Specify the ***Index Of Refraction*** given the temperature and material. See more on this topic in the How-To Determine Growth Rate guide. There, it describes how to determine the *Index of Refraction* for a whole range of wavelengths given a temperature and material.

For example, here is a graph of the Index of Refraction versus Wavelength for GaAs at 600°C.



Labels

This is a plot property that allows the user to change how the axes and title are labeled.

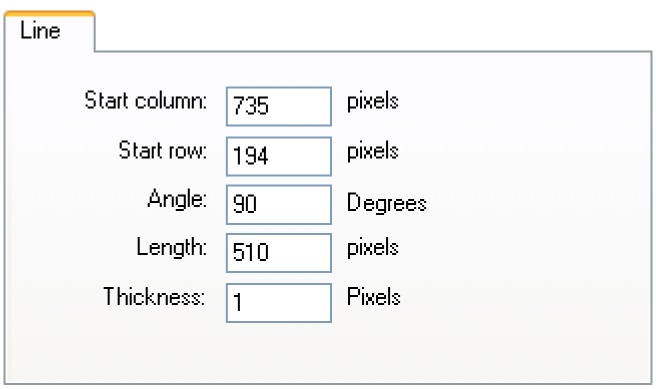


Using the ***Automatic*** setting selects the units chosen in the Data property. Deselect *Automatic* to rename the axis or title.

The ***Top title*** default is blank for the 3-D plots (Surface Plot, Contour Plot, Triple Region Plot), changing when non-default values are chosen in other properties (such as Samples). It defaults to specific data in 2-D plots (e.g., Histogram and Statistics, Line Profile).

Line

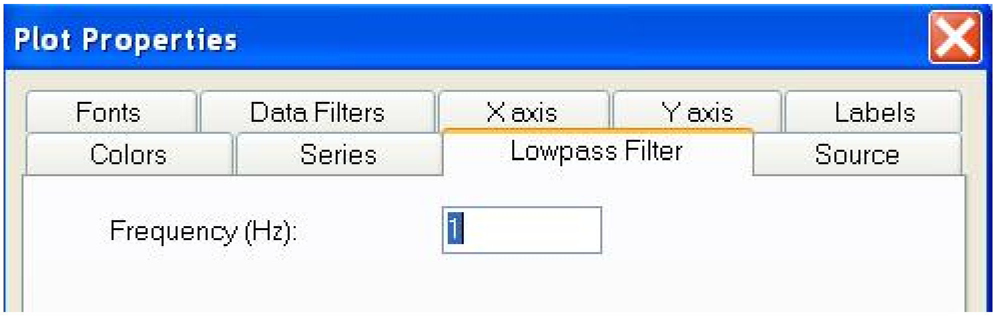
This is a plot property. But it also appears as a pop-up window when a line is double-clicked in an acquisition mode analysis tool (like Line Profile) for changing the line's properties.



Note in particular that changing the thickness averages (mean) the data beneath the line. So the thicker the line, the more data that is averaged.

Lowpass Filter

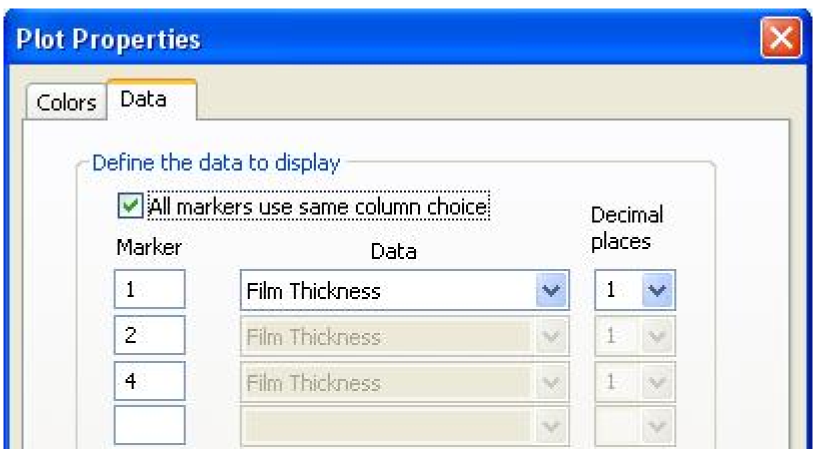
This is a plot property for the Lowpass Filter analysis plot.



Specify the ***Frequency*** to use for the filter.

Multiple Markers LED Data

This is a Plot Property which is used to determine which data is displayed in Multiple Marker LED Real-Time Charts.



Specify

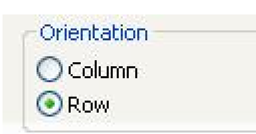
Marker - the number(s) of the markers that you want to display

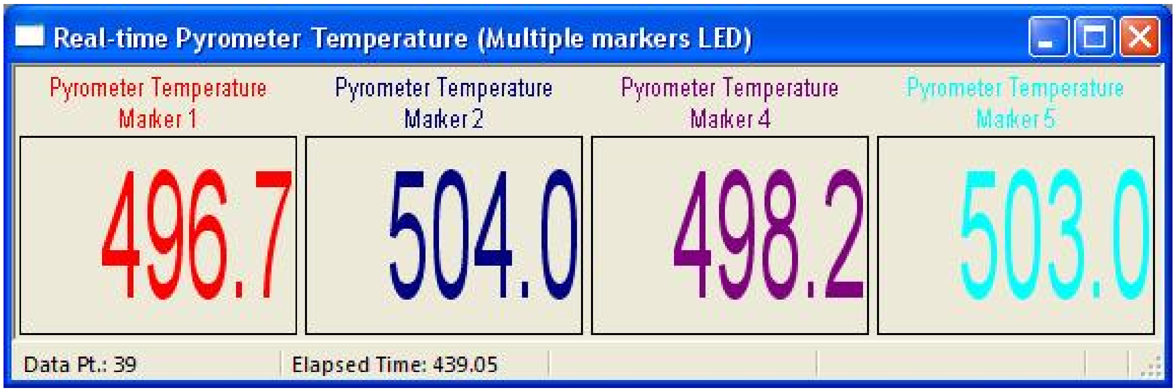
Select:

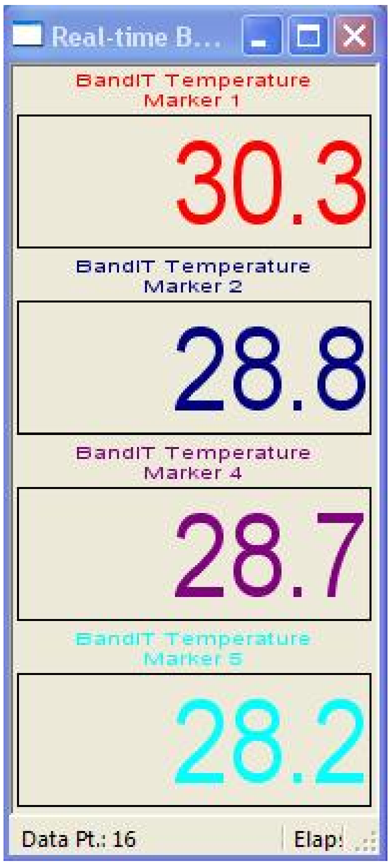
Data - the data to be displayed for each marker. Check the ***All markers use the same column choice*** to use the same data for each marker.

Decimal Places - choose the number of decimal places to display for each marker

Orientation Column or ***Row*** - to display the multiple LED values in a column or a row, see the examples below.

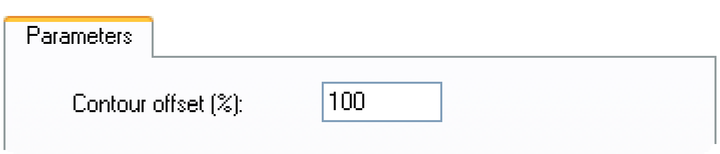






Parameters

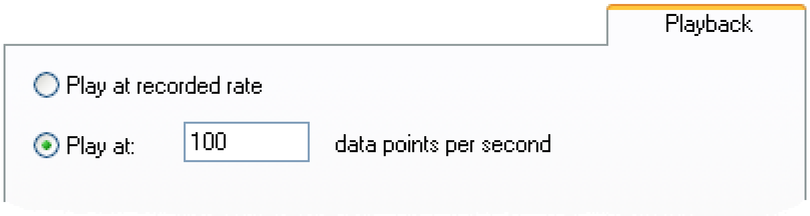
This is a plot property that is used to separate the Contour part of the Triple Region Plot from the other regions.



Specify the ***Contour offset (%)*** to 100 to maximize or 0 to minimize the distance between the plots.

Playback

This is a plot property. It is used to change the playback speed of a *.kdt file. The *.kdt Toolbar is used to control all other aspects of playback.



Specify either

Play at recorded rate – to play the file at the rate at which it was recorded. Of course, this option includes delays between acquisition points.

or

Play at – to choose the rate in units of data points per second

Plot Value

This is a plot property that is used to specify what value appears in some Real-Time Charts, including Real-Time Stats (Time) and Real-Time Stats (LED).

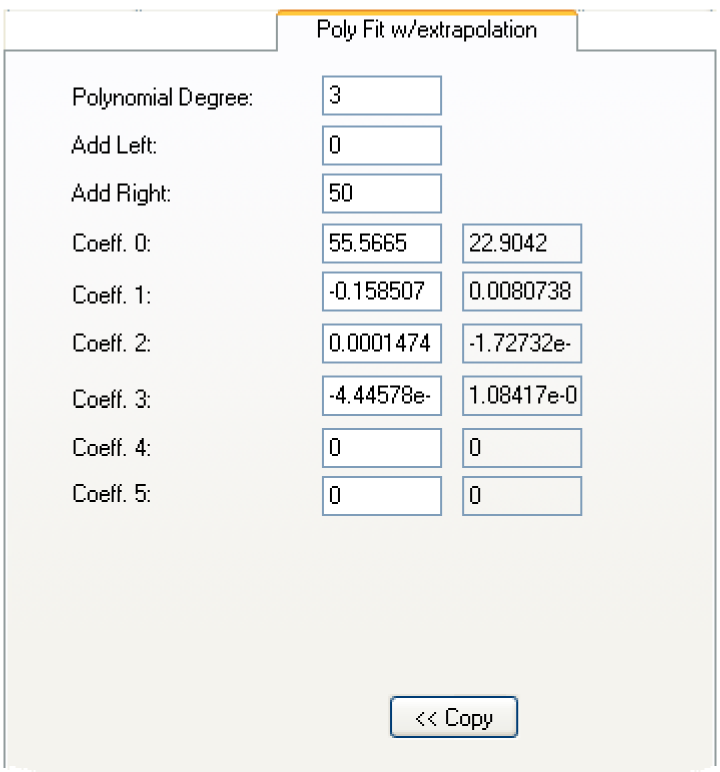
Specify the ***Plot*** to choose one of several possible values. A partial list follows:

- Elapsed Time
- Data Point
- Acquire in Progress
- Data Set
- Samples per Data Point
- Adjusted Elapsed Time
- BandiT Temperature
- TC Temperature
- Confidence

- BandiT Spectra
- Number of Wavelengths
- BandiT Normalized Spectra
- Bandit Spectra Wavelength
- Band Gap Linear Fit X/Y Pos
- Number of Linear Fits
- Band Edge Wavelength
- Peak Spectra Intensity
- BandiT Fit Spectra
- BandiT Fit Spectra Width
- BandiT Background Width
- Spectrometer Integration Time
- Pyrometry Value
- Percent of Full Light Intensity
- Integrated Intensity – *when implemented*
- Analog Input
- Analog Input 0 – up to 8 total Analog Input Channels
- Digital Input 1 – up to 15 total Digital Input Channels

Poly Fit w/ extrapolation

This is a plot property unique to plots analyzed with Poly Fit w/ extrapolation post-acquisition analysis tool. It performs a Polynomial Fit (up to 5th degree) and allows the user to increase the range over which the polynomial is plotted.



Specify:

Polynomial Degree – for the highest degree term. For example, if *Polynomial Degree* is set to 4, then the software will fit the data to a fourth degree function, e.g.,

$$f(x) = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4$$

Add Left – to increase the functions domain to the left of the data by this number of units

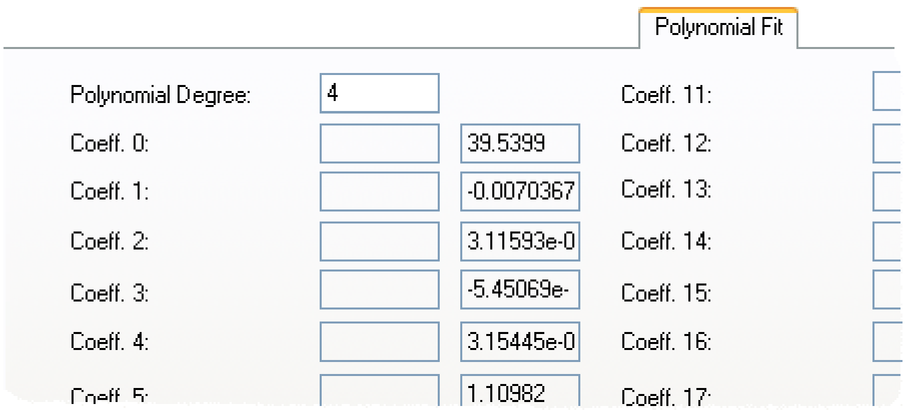
Add Right – to increase the function's domain to the right of the data by this number of units

Coeff. – for the coefficients of the Polynomial Fit (which uses matrix inversion)

Click the ***<<Copy*** button and the calculated values will be copied over to the user-specified values – which are the ones actually used to plot the fit.

Polynomial Fit

This is a plot property unique to plots analyzed with Polynomial Fit post-acquisition analysis tool.

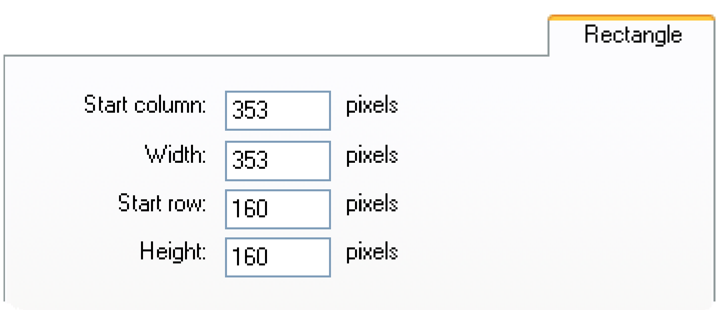


Specify the ***Polynomial Degree*** for the highest degree term. For example, if *Polynomial Degree* is set to 4, then the software will fit the data to a fourth degree function, e.g.,

$$f(x) = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4$$

Rectangle

This is a plot property. The rectangle plot property is only available for 3-D plotting and specifies the exact location and size of the rectangle of data that is used for plotting.



Columns (vertical) are numbered from left to right.

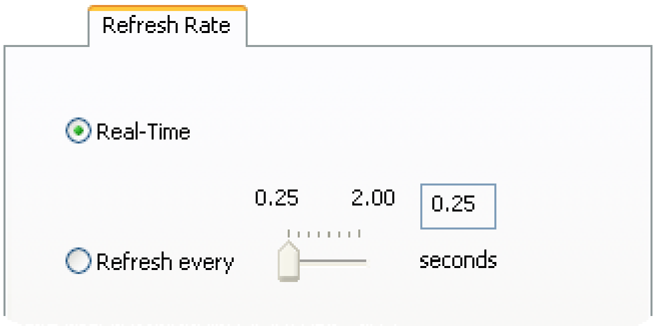
The ***Width*** is the number of columns wide the rectangle is.

Rows (horizontal) are numbered from top to bottom.

The ***Height*** is the number of rows high the rectangle is.

Refresh Rate

This is a plot property used to specify how fast the data is updated in some real-time charts.



Choose either

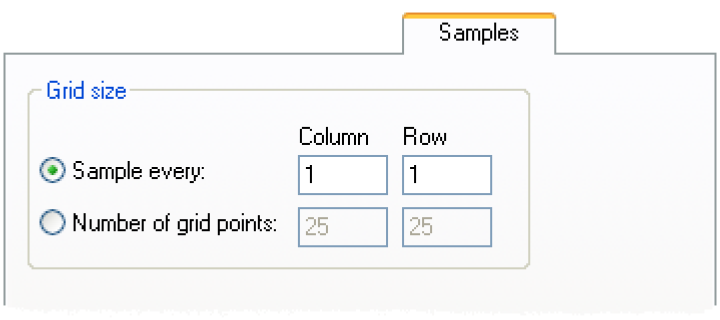
Real-Time – for updating the chart as fast as the computer is able

or

Refresh every – to update the chart in intervals starting as low as 0.25 seconds and going up to 2.00 seconds (in intervals of 0.25 seconds)

Samples

This is a plot property used to specify how many data points are used to generate a 3-D plot (Surface Plot, Contour Plot, and Triple Region Plot.)



Choose either

Sample every – choose the number of samples based on the numbers of rows and columns (up to the size of the rectangle of data being plotted. For example, if a rectangle is 25 rows by 25 columns, then *Sample every* 1 row and 1 column will give a total of 625 (= 25 * 25) data points.

or

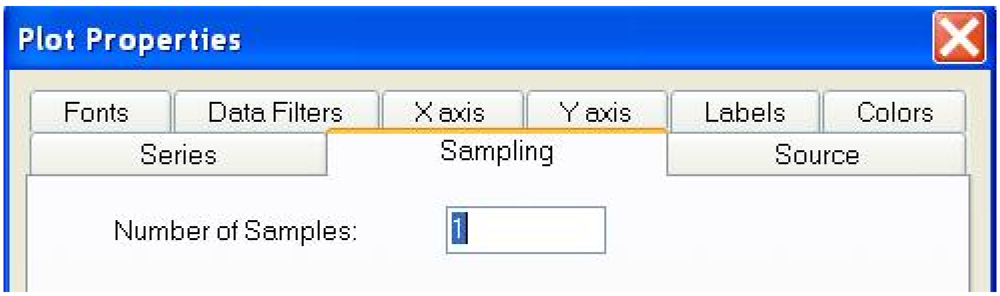
Number of grid points – to choose the total number of data points sampled in the rectangle. For example, setting these values 25 by 25 will give 625 (= 25 * 25) total data points, no matter how big the rectangle is. However, if the rectangle is smaller than 25 by 25 (or if, say, there are fewer than 25 rows (or columns)), then the software is only able to gather a data point for each row (or column). Please see the technical note below.

Technical Note:

The software does not interpolate data between rows or columns. That is, grid size cannot be smaller than image resolution. *Sample every* gives the highest resolution plot at 1 column, 1 row. Even though *Number of grid points* can be set to as high as 1000 by 1000 – thereby dividing data of a small rectangle into decimal values of rows and columns – the resolution does not improve beyond 1 column, 1 row.

Sampling

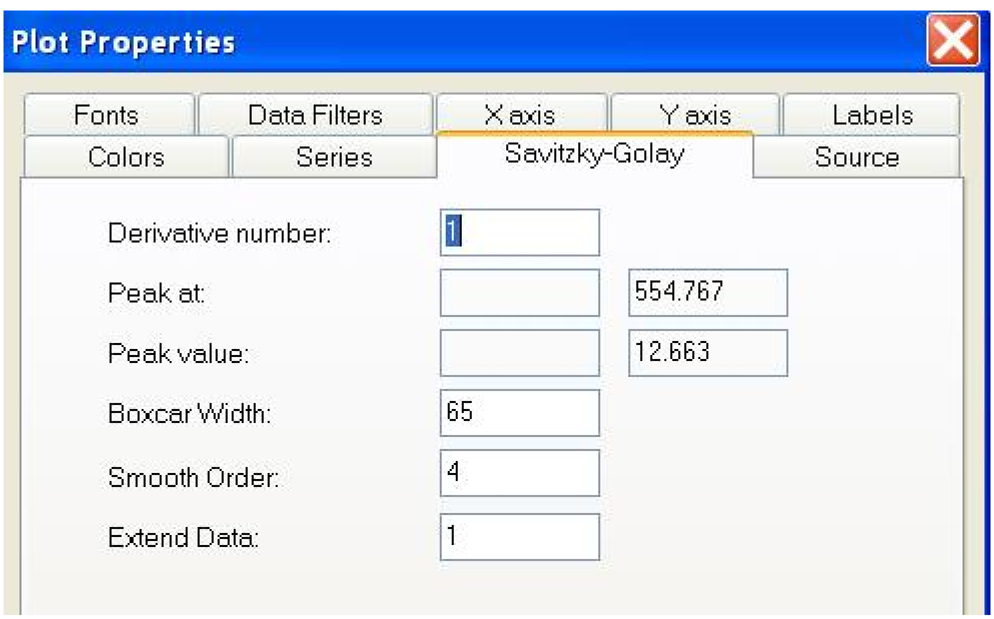
This is a plot property for the Sampling analysis plot.



Specify the number of samples to use.

Savitzky-Golay

This is a plot property used to specify the parameters of the Savitzky-Golay smoothing function which applies a Savitzky-Golay digital smoothing polynomial (DISPO) filter to the current plot.



Specify:

Derivative number - A non-zero number results in calculation of the derivative of the specified order. The highest order allowed is equal to the order of the smoothing polynomial used. For example, use of a fourth order smoothing polynomial allows up to the fourth derivative to be calculated. Enter a value of zero for smoothing only.

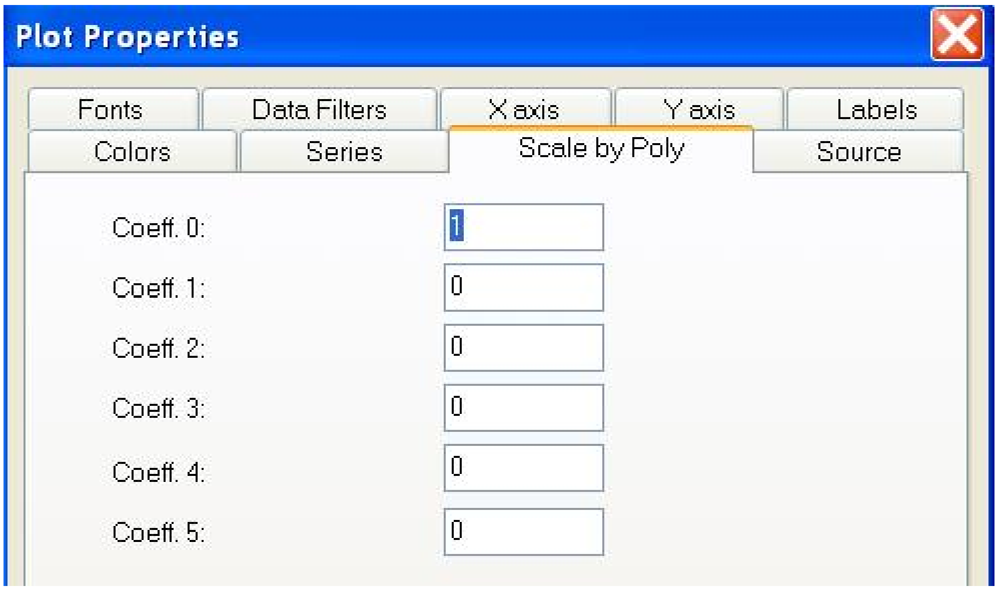
Boxcar Width - Specifies the number of data points used in smoothing each data point (must be odd). For example, a setting of N results in smoothing each data point with the (N-1)/2 neighboring data points on either side.

Smooth Order - Specifies the order of the smoothing polynomial (typically 4th order). A value of zero gives moving average, a.k.a. "boxcar" smoothing.

Extend Data - A value of 1 allows the data range to be extended to accommodate the smoothing width. This is done by repeating the data points at the ends of the range as needed. A value of 0 will disable this, preventing the data points near the ends of the range from being smoothed.

Scale by Poly

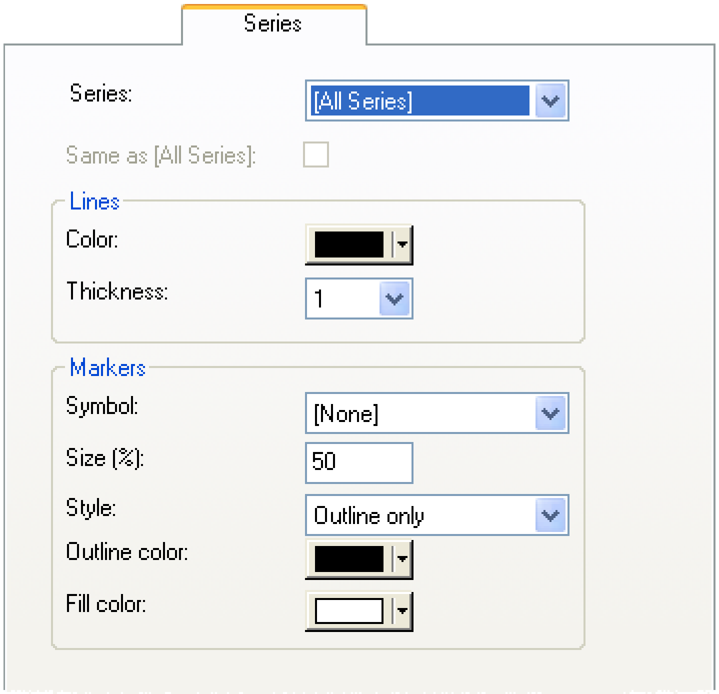
This is a plot property used to specify the coefficients for the Scale by Ploy analysis plot.



Up to six coefficients can be entered which will be used by the generic scale by polynomial algorithm.

Series

This is a plot property available for 2-D line plots (e.g., Line Profile, FFT). If an image has more than one series (or set) of data, use this tab to distinguish the data plots from one another by using colors or markers.



Specify:

Series – to choose different *Lines* and *Marker* options for up to 100 different series on the same plot.

Choose:

[All Series] – to select default *Lines* and *Marker* options.

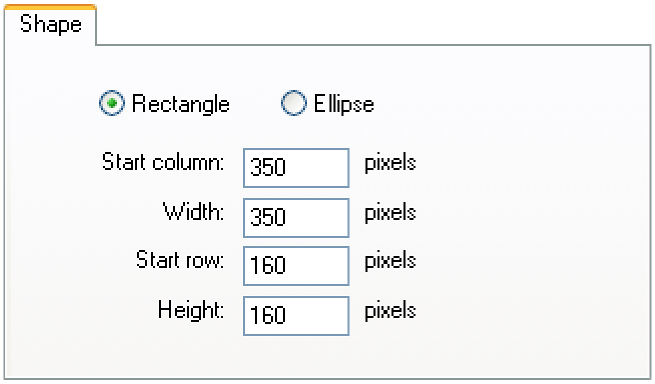
Series 1 (up to ***Series 100***) – to select *Lines* and *Marker* options for a particular series.

With *Series 1* selected, click ***Same as [All Series]*** to choose the default *Lines* and *Markers* for that series.

Then choose *Line* color and thickness, and the symbol, size, style, and colors of the *Markers* for each data point.

Shape

This is a plot property. But it also appears as a pop-up window when a rectangle or ellipse is double-clicked in an analysis tool (like Histogram and Statistics) for changing the shape's properties.



Columns (vertical) are numbered from left to right.

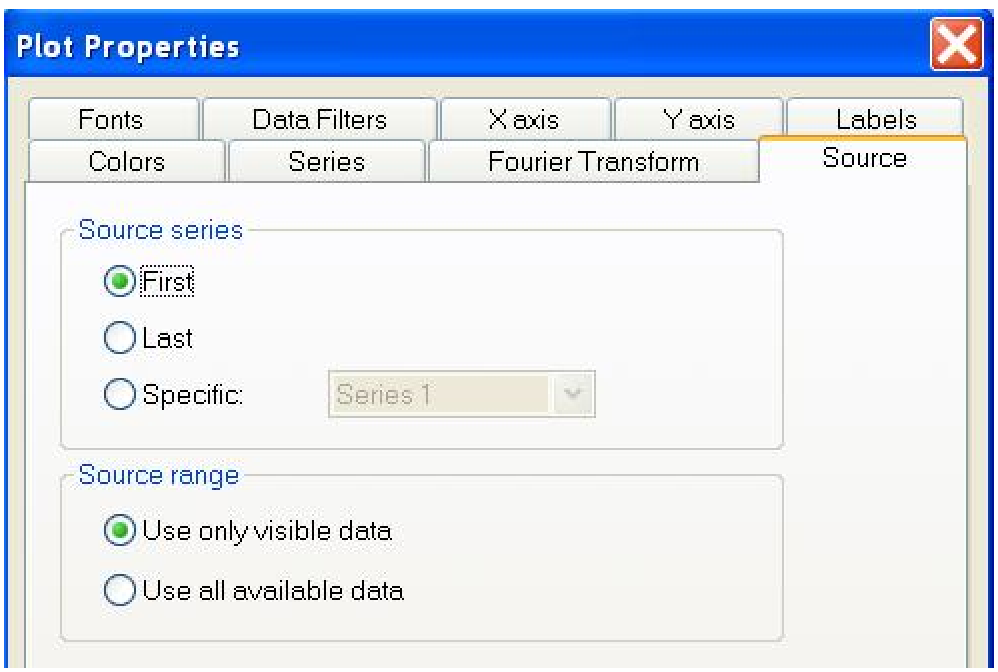
The ***Width*** is the number of columns wide the rectangle or ellipse is.

Rows (horizontal) are numbered from top to bottom.

The ***Height*** is the number of rows high the rectangle or ellipse is.

Source

This is a plot property that is used to specify what series is analyzed/plotted by the 2-D analysis tools.



When the original data has multiple series, then specify:

First – to gather data for analysis from the first series in the original data

or

Last – to gather data for analysis from the last series in the original data

or

Specific – to gather data for analysis from a user-specified series in the original data. Use the drop-down box to specify which series.

For ***Source range***, specify:

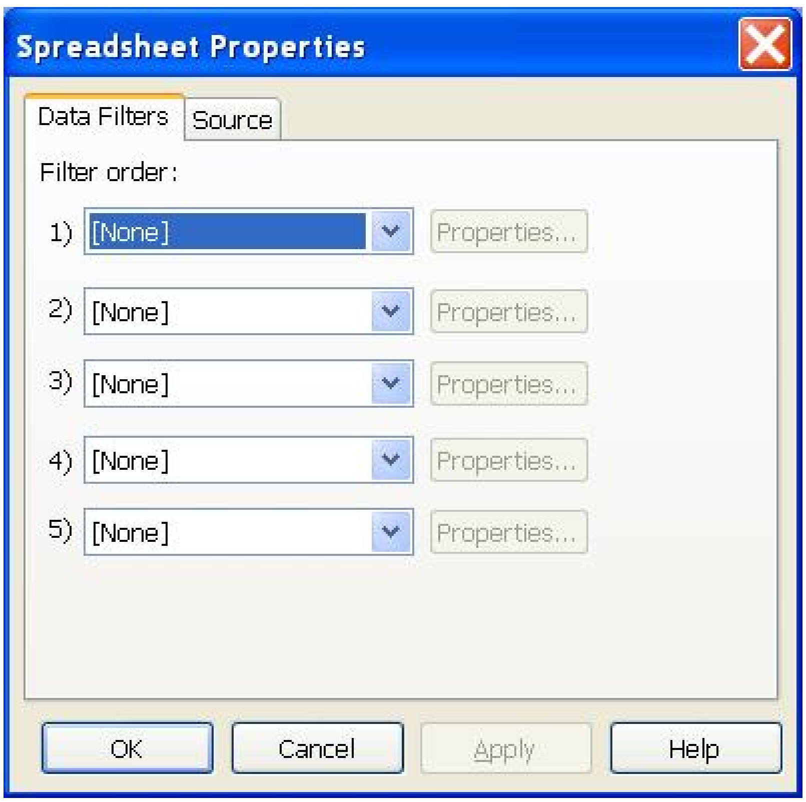
Use only visible data – for analyzing only the data visible in the original plot. This is useful when a user has set a domain/range to limit the original data (using, for example, *Set X-Min* by right clicking the original plot).

or

Use all available data – for analyzing all data from the original plot, even if some of it is no longer visible because the user has set a domain/range to limit the original data (using, for example, *Set X-Min* by right clicking the original plot).

Spreadsheet Properties

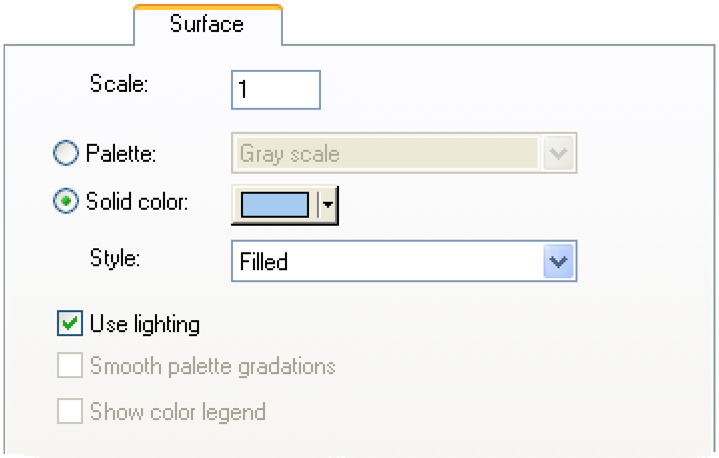
The Spreadsheet Properties dialog box is opened by right clicking the Spreadsheet and selecting Properties.



Up to five Filters can be selected to be applied to the spreadsheet data, changing the data itself.

Surface

This is a plot property used to zoom in or colorize a 3-D plot (Surface Plot, Contour Plot, and Triple Region Plot). This is necessary because magnification is not available for 3-D plots.



Scale may be set to integer and non-integer values, for precise scaling of the data plot both up and down.

Choose either:

Palette – for the same palette options available in the Image Properties.

Then check ***Smooth palette gradations*** and/or ***Show color legend.***

or

Solid color – for a solid color value of the 3-D surface of the plot.

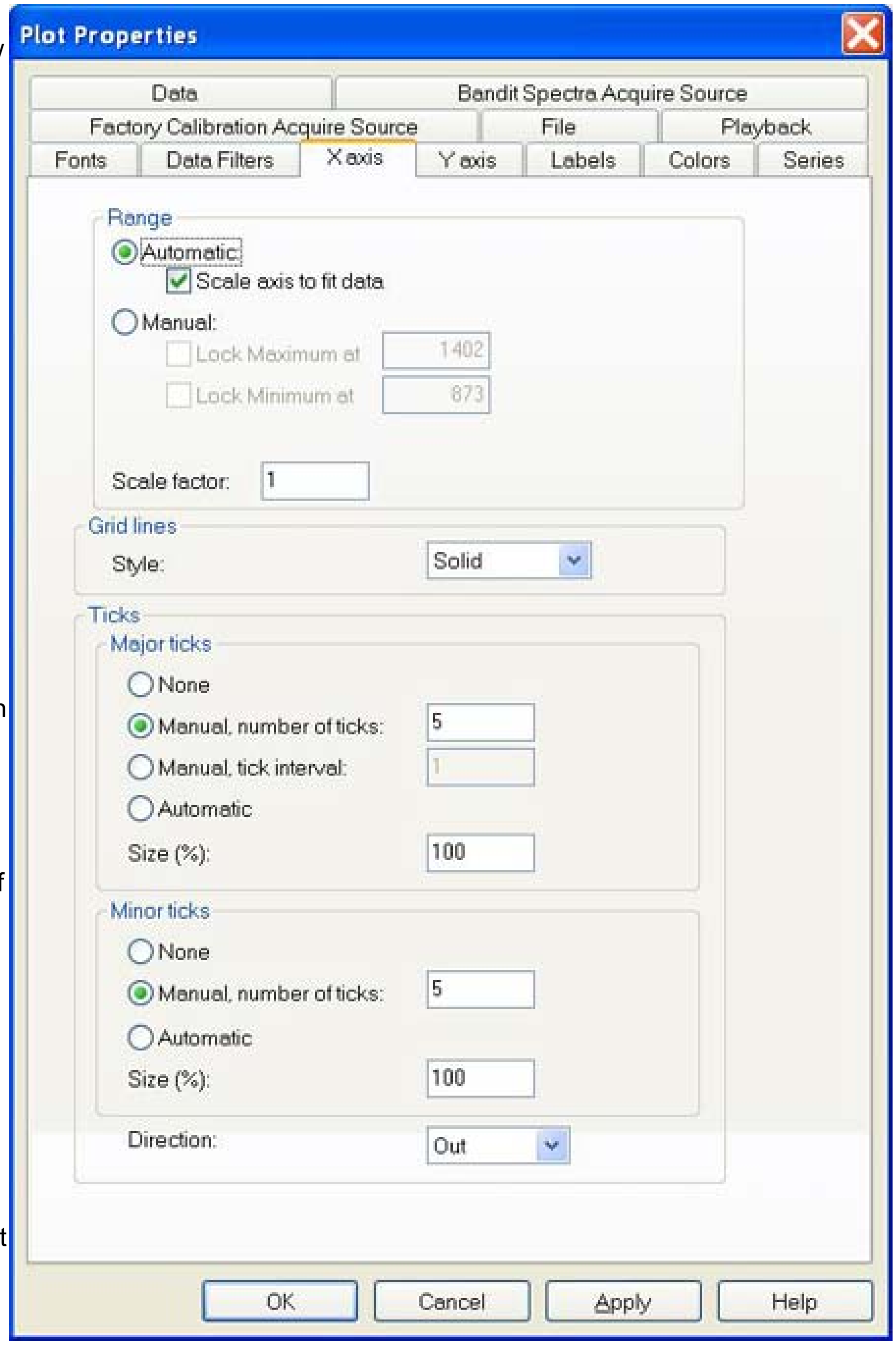
Check ***Use lighting*** to vary intensities of the color in order to indicate ripples or patterns in the surface.

Style - use the drop down arrow to select from a number of different display styles

X/Y/Z Axis

This is a plot property used for specifying plotting options for the axes.

Specify:



Range – for the high and low values plotted and whether the user chooses it or it is done automatically.

Choose:

> ***Automatic*** - then select ***Scale axis to fit data*** and the software will utilize all the available plot space for displaying the data.
>
> or
>
> ***Manual*** - and set ***Lock Maximum*** and ***Lock Minimum*** at the points required.

Choose a ***Scale factor*** (integers 1 to 100) to zoom in by this multiplication factor. This will reduce the amount of data that is viewable.

Grid lines - specifies the style (dashed, dotted, etc.) of grid lines that extend the length of the *Major ticks*. Note that 3-D plots do not have grid lines available.

Ticks - specify the size and number of major and minor ticks, and then select what ***Direction*** (***In*** for tick marks inside the plot – where they may intersect the data, ***Out*** for tick marks outside the plot – away from the data).

General Note:

The Range may also be set by right-clicking the desired boundary and selecting *Set X-Min*, *Set X-Max*, *Set Y-Min*, or *Set Y-Max*.

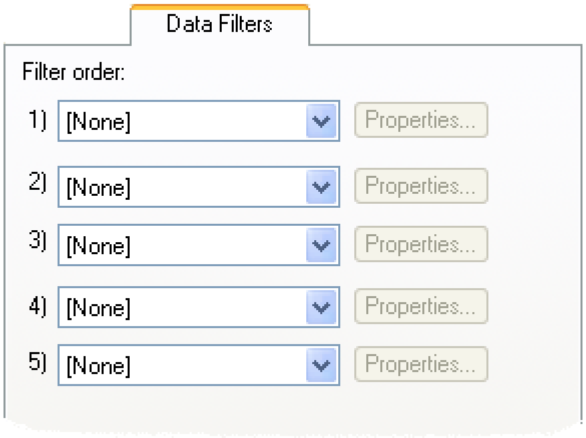
Filters

Data filters

Data Filters

Data filters are for plots. Applying a data filter to a plot changes the plot itself.

Find the Data Filters tab by right-clicking the plot and selecting Properties.



For ***2-D plots***, choose:

- Boxcar Smooth
- Constant Scale
- Derivative
- Digital Filter Fit
- Exponential Fit
- Gauss Fit
- Linear Scale
- Normalizer
- Polynomial Fit
- Reverse
- Savitzky-Golay
- Scale by Poly
- Spike Remover

For ***3-D plots***, choose:

- Scale
- Smooth

kSA systems also allow for user-created IDL filters.

General Note:

Some of the same tools are available under the ***Analysis*** menu option with a plot window selected. Using those tools creates a new plot. That makes it different from the Data Filters, which change the plot itself.

Boxcar Smooth

This is a 2-D data filter. It smoothes a 2D line plot with a boxcar average of the specified width. Use this filter to reduce the amount of noise in the plot.

Specify the ***Width*** of the side of the smoothing window using odd values between 3 and 101. For the filter to be meaningful, ensure that the specified width is smaller than either dimension of the plot.

For example, *width* 3 specifies a 3 by 3 smoothing window with 9 total elements. The smoothed element will be in the middle of that box.

Technical Note:

Specifically, the function employed is this:

$$R_i = \begin{cases} \frac{1}{w}\sum_{j=0}^{w-1} A_{i+j-w/2}, & i = w/2, \ldots, N-w \\ A_i, & otherwise \end{cases}$$

where

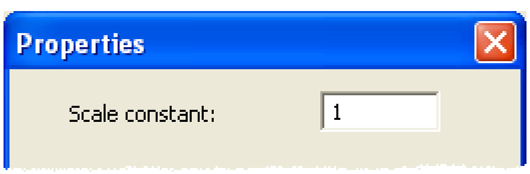
R = result

A = array (of any dimension)

w = width (user-specified)

Constant Scale

This is a 2-D data filter. It is similar to the Linear Scale and Scale by Poly filters.

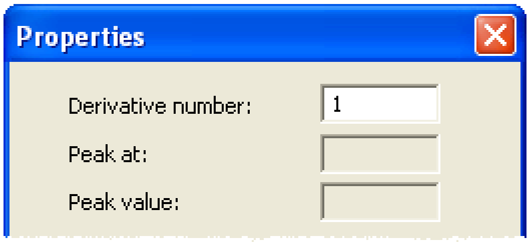


Specify ***Scale constant*** for the multiplier of all dependent values. For example, if peak intensity is 50%, average intensity is 35%, and *scale constant* is 2, then applying this filter means the peak intensity is 100% and the average intensity is 70%.

Note: negative and decimal values are allowed.

Derivative

This is a 2-D data filter that plots a derivative of a plot. Because the tool uses data points rather than a function, this tool actually calculates ***Δy/ Δx*** *(Delta Y* divided by *Delta X*) and connects resultant data points with a straight line – for the first derivative. It does likewise for other orders.



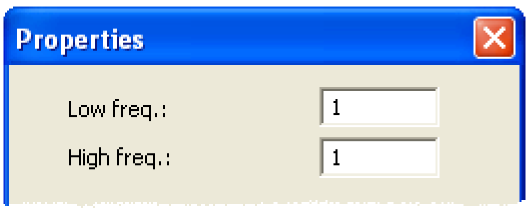
Specify:

Derivative number – for which derivative to take, up to the fifth (5) derivative

Peak at and ***Peak value*** are not alterable, and do not show any data for this data filter. To view these, apply the Derivative analysis tool and then look at the Derivative plot property.

Digital Filter Fit

This is a 2-D data filter used to construct highpass, lowpass, bandpass, and bandstop filters.



Specify:

Low freq. – the lower frequency of the filter as a fraction of the Nyquist frequency

High freq. – the upper frequency of the filter as a fraction of the Nyquist frequency

The following conditions are necessary for various types of filters:

No Filtering: ***Low*** = 0 and ***High*** = 1

Low Pass: ***Low*** = 0 and 0 < ***High*** < 1

High Pass: 0 < ***Low*** < 1 and ***High*** = 1

Band Pass: 0 < ***Low*** < ***High*** < 1

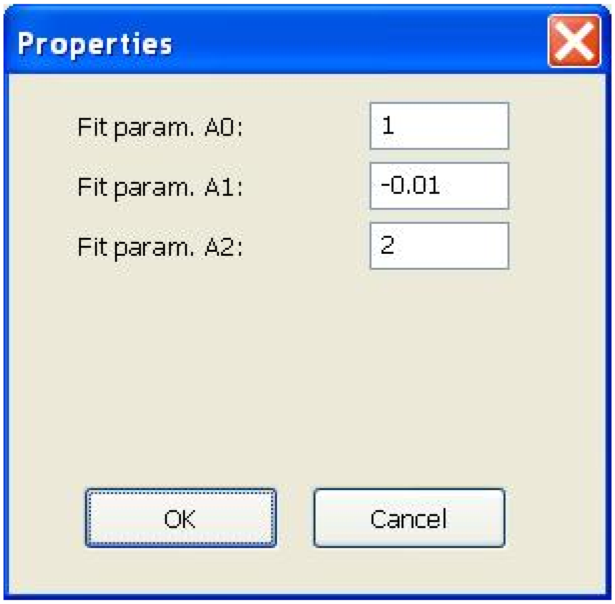
Band Stop: 0 < ***High*** < ***Low*** < 1

Exponential Fit

This is a 2-D data filter that replaces the plotted data with a generic exponential fit using an algorithm that attempts to fit an exponential curve of the form:

$$f(\lambda) = a_0 e^{a_1 \lambda} + a_2$$

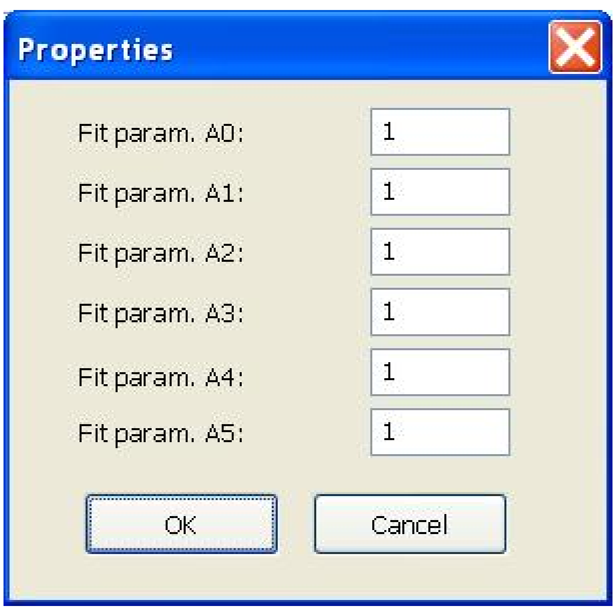
to a spectrum.



Specify initial guesses for the Fit Parameters A0, A1, A2

Gauss Fit

This is a 2-D data filter that computes a non-linear least-squares fit to a function f(x) with six parameters and replaces the original data with the fitted equation.



f(x) is a linear combination of a Gaussian and a quadratic:

$$f(x) = A_0 e^{\frac{-z^2}{2}} + A_3 + A_4 x + A_5 x^2$$

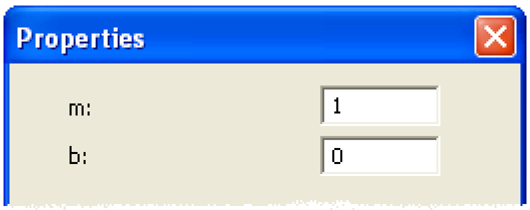
where

$$z = \frac{x - A_1}{A_2}.$$

Note: to view the Gauss fit together with the original data, use the Gauss Fit analysis tool (under the Analysis menu).

Linear Scale

This is a 2-D data filter. It is similar to the Constant Scale filter, but with the additional function of being able to add a constant to every dependent value (see *b* below). To scale for higher powers of x, use the Scale by Poly.



Specify:

m – for the multiplier of all dependent values. For example, if peak intensity is 50%, average intensity is 35%, and m = 2, then applying this filter means the peak intensity is 100% and the average intensity is 70%.

b – for adding a constant to all dependent values. For example, if peak intensity is 50%, minimum intensity is 2%, and b = 1, then applying is filter means the peak intensity is 51% and the minimum intensity is 3%.

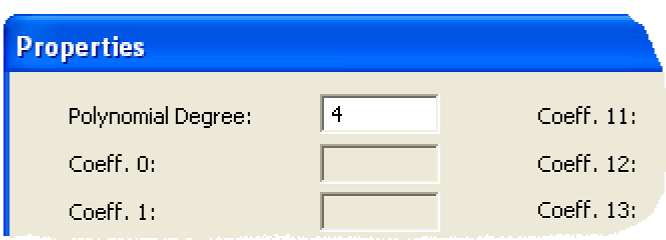
Note: negative and decimal values are allowed.

Normalizer

This is a 2-D data filter that takes the plot's peak value and calculates the scale factor required to bring the peak to the maximum intensity value. It then multiplies that scale factor times every data point.

Polynomial Fit

This is a 2-D data filter that replaces the plotted data with a fitted polynomial.



Specify the ***Polynomial Degree*** to choose the highest degree term. For example, if *Polynomial Degree* is set to 4, then the software will fit the data to a fourth degree function, e.g.,

$$f(x) = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4$$

The software provides the value of the *Coefficients* only when applying the Polynomial Fit analysis tool, which plots the polynomial fit on top of the original data.

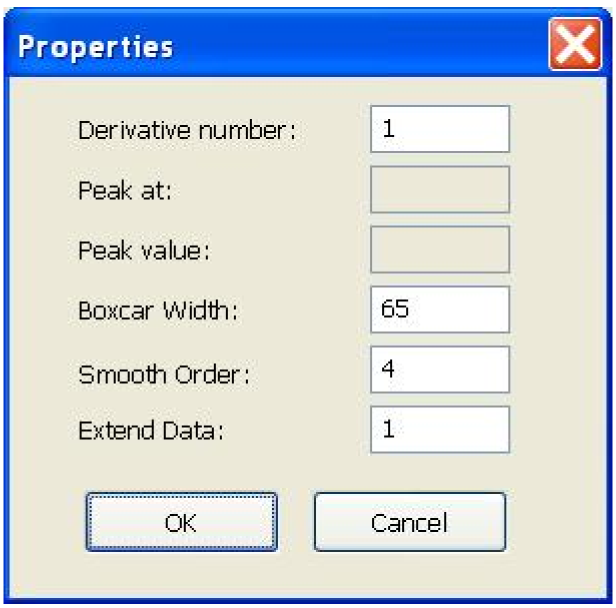
Reverse

This is a 2-D data filter. It swaps the data from the beginning and the end, which in effect flips the plot over a vertical line. For example, if the first data point has a value of 3 and the last one has a value of 7, then applying this filter yields a plot with the first data point with a value of 7 and the last data point with a value of 3.

Savitzky-Golay

This is a 2-D data filter that removes high frequency noise from data, while preserving the original shape and features of the signal, and is well adapted for data smoothing.

It performs a local polynomial regression of specified order on a specified number of adjacent points in order to determine the smoothed value at each point. An advantage of this technique is that derivatives may be trivially calculated from the smoothing polynomial.



Specify:

Derivative number - A non-zero number results in calculation of the derivative of the specified order. The highest order allowed is equal to the order of the smoothing polynomial used. For example, use of a fourth order smoothing polynomial allows up to the fourth derivative to be calculated. Enter a value of zero for smoothing only.

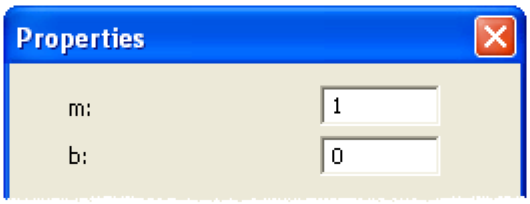
Boxcar width - Specifies the number of data points used in smoothing each data point (must be odd). For example, a setting of N results in smoothing each data point with the (N-1)/2 neighboring data points on either side.

Smooth Order - Specifies the order of the smoothing polynomial (typically 4th order). A value of zero gives moving average, a.k.a. “boxcar” smoothing.

Extend data - A value of 1 allows the data range to be extended to accommodate the smoothing width. This is done by repeating the data points at the ends of the range as needed. A value of 0 will disable this, preventing the data points near the ends of the range from being smoothed.

Scale

This is a 3-D data filter. It is similar to the Linear Scale filter, but for 3-D plots. This is useful for zooming in on a 3-D plot, particularly because the Zoom buttons are not enabled for a 3-D plot.



Specify:

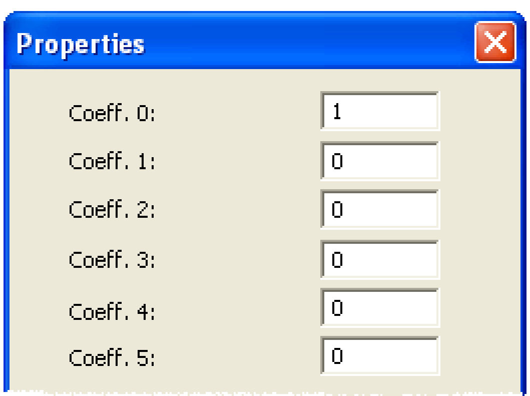
m – for the multiplier of all dependent values. For example, if peak intensity is 50%, average intensity is 35%, and m = 2, then applying this filter means the peak intensity is 100% and the average intensity is 70%.

b – for adding a constant to all dependent values. For example, if peak intensity is 50%, minimum intensity is 2%, and b = 1, then applying is filter means the peak intensity is 51% and the minimum intensity is 3%.

Scale by Poly

This is a 2-D data filter. It is used to scale the data by a polynomial (up to fifth degree).

$$f(x) = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + c_4 x^4 + c_5 x^5$$



Specify:

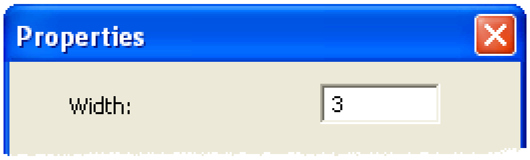
Coeff. 0 – to set the constant coefficient: for example, inputting 10 will increase the intensity of all values by 10 counts.

Coeff. 1 – to set the scaling coefficient: for example, if the value of the peak intensity is 50%, the minimum intensity is 2%, then setting *Coeff. 0* to 2 means applying this filter will result in a peak intensity of 100% and a minimum intensity of 4%.

Coeff. 2 (and others) – to set the coefficient(s) of the power terms

Smooth

This is a 3-D data filter. It smoothes a 3-D surface plot with a boxcar average. Use this filter to reduce the amount of noise in the plot.



Specify the ***Width*** of the side of the smoothing window using odd values between 3 and 101. For the filter to be meaningful, ensure that the specified width is smaller than either dimension of the plot.

For example, *width* 3 specifies a 3 by 3 smoothing window with 9 total elements. The smoothed element will be in the middle of that box.

Technical Note:

Specifically, the function employed is this:

$$R_i = \begin{cases} \frac{1}{w} \sum_{j=0}^{w-1} A_{i+j-w/2}, & i = w/2, \ldots, N-w \\ A_i, & otherwise \end{cases}$$

where

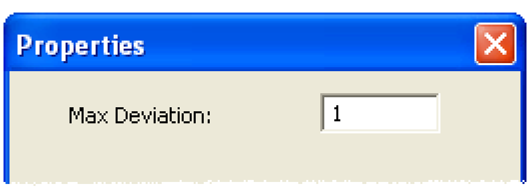
R = result

A = array (of any dimension)

w = width (user-specified)

Spike Remover

This is a 2-D data filter. It is used to flatten widely-varying dependent values (vertical axis, Y-values).



Specify ***Max Deviation*** to the maximum difference between sequential Y-values. This filter is not recursive and proceeds from left to right. That means when the algorithm identifies a deviation between two points greater than the *Max Deviation*, it makes Y-values of both points equal to that of the point on the left. It then proceeds to the next Y-value to the right, comparing it to the point immediately to its left. If that Y-value difference is also larger than the *Max Deviation*, then it too will be set to the Y-value of the left point.

Consequently, this filter often yields flattened portions of curved plots.

image filters

Image Filters

Applying an image filter creates a new image that has been filtered: the original remains unaltered.

The only images available in BandiT are pyrometric scan mode images generated for computing growth rate (set in the Pyrometric Oscillations Advanced Acquisition Option). Thus, there is no reason to filter these images from a computation standpoint. For improving data visualization, the user may wish to use palettes, which provide different color options without changing the data. Such colorized Images can be exported for use in reports, but may need to be filtered for better printing, etc. So it is for reporting purposes that the image filtering capability is available in BandiT.

With an image window selected, select the Filter menu.

To create a filtered image or movie, select:

-
- 2D FFT
- Bayer Grayscale to Color
- Binning
- Black Offset Correction
- Brightness Adjust
- Crop
- Edge Detection
- Edge Detection (Roberts)
- Edge Detection (Sobel)
- Field Doubling
- Flip Horizontal / Vertical
- Gamma
- Histogram Equalization
- Invert
- Log Scaling
- Maximize Contrast
- Median Filter
- Neutral Density
- Reverse 2x1 Binning
- Rotate

- Scale to New Size
- Smooth
- Spot Finder
- Threshold
- Unsharp Masking

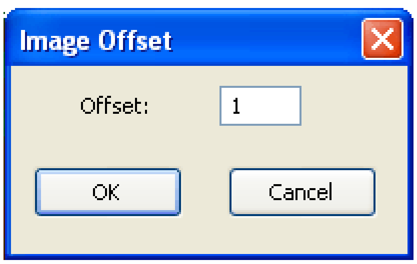
To create a new image by combining two sources in various ways, select:

- Add
- And
- Average
- Divide
- Exclusive-Or
- Or
- Subtract

kSA systems also allow for user-created IDL filters.

Black Offset Correction

This is an image filter that subtracts off an intensity value from the image and then re-scales the image intensity from 0 to 100%. It is useful for subtracting off noise from an phosphor screen image.



Specify:

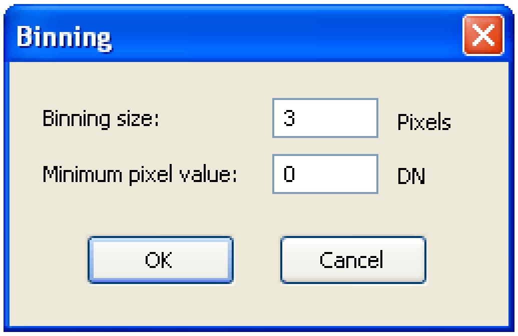
Offset – type in a value from 0 to 4095 to subtract off that value from all pixel values. Resultant values below zero are zeroed.

Binning

This is an image filter used for reducing noise. It does not alter acquisition, only the image already taken. *Binning* combines the readings from a block of pixels to increase the signal to noise ratio. Of course, this reduces the size of the image, meaning lower resolution.

As an example, suppose the binning size is set at 2 pixels. That means that a 2x2 block (containing 4 pixels) will be reduced to a single pixel.

The algorithm first "bins" starting in the upper left corner of the image. Then it selects the next block for binning to the immediate right of the first block (not overlapped). After coming to the end of a row, the algorithm starts with the next row that has not yet been part of a bin.



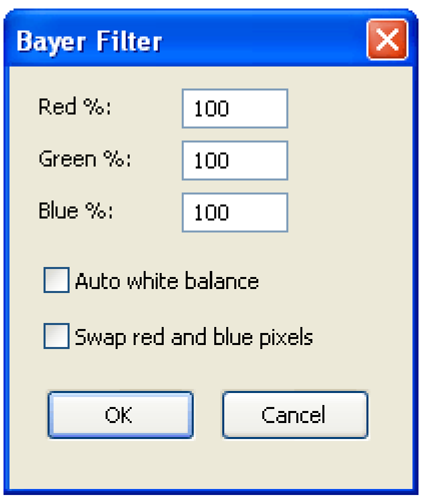
Specify:

Binning size – the size of the bin that will be used. A binning size of 2 will reduce the size of the image by 2^2; a binning size of 3 will reduce the size of the image by 3^2, and so on.

Minimum pixel value – set the value below which pixel values are not added to the bin. 2^{12}= 4096 values are available, with 0 excluding nothing and 4095 excluding all pixel values.

Bayer Grayscale to Color

This is an image filter that is useful for cameras that use the Bayer filter for capturing color information. These tend to be less expensive cameras because they need only one sensor to acquire data. Data for these cameras is acquired in a grayscale format and then can be converted to RGB color using this filter.



Specify ***Red %***, ***Green %*** , ***Blue %*** – to adjust the values of each color. This percentage is multiplied by 255 and the result is then rounded to an integer. Color values are between 0 and 255, so any percentage yielding a value greater than 255 will be set at 255.

Check:

Auto white balance – to rescale based on summed values. Checking this option and clicking *OK* takes the total green value, divides it by the total red value, multiples the result by 2, and then normalizes the red value to the green value. Then it does the same thing for blue values with respect to the green value. Finally, the algorithm un-checks the ***Auto white balance*** checkbox and resets the preferences of red/green/blue scale to the calculated values.

The filtered image that appears upon clicking the OK button has not yet had the ***Auto white balance*** feature applied. Click the original image again and re-open the filter. The ***Auto white balance*** checkbox will be un-checked and the red/green/blue % fields will be updated. Simply click *OK* to see the changes take effect.

Swap red and blue pixels – to swap all the red pixels values with the blue pixel values. Sometimes, the Bayer filter consistently creates colors that are different from what they should be. Swapping these two pixel values usually corrects this problem.

And

This is an image filter that uses two sources and the logical AND operator to create a new image. The filter works by applying the AND operator to the two sources bit-wise.

For example, suppose two images were each composed of one pixel of 2 bit depth. Thus, the entire image is made up of an array 2^2 = 4 numbers in length. Further suppose that the first image (or pixel, in this example) is the array 1, 1, 0, 0 and that the second has the array 1, 0, 1, 0. Using the AND operator leads to the result 1, 0, 0, 0 because

1 AND 1 = 1

1 AND 0 = 0

0 AND 1 = 0

0 AND 0 = 0.

Add

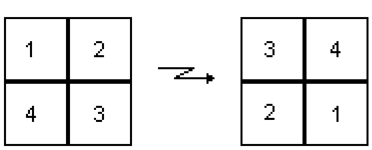
This is an image filter that uses two sources and adds their pixel intensities together to create one new image.

2-D FFT

This is an image filter that performs two 1-dimensional FFT transforms, first replacing each row with its row transform and then replacing each column with its column transform.

The algorithm first pads both the length and width of the image dimension with zeros until they are of a size that is a power of 2. Because the values in the rows and columns of the image are intensities, the imaginary component of the complex array (input into to the Fast Fourier Transform algorithm) is taken to be zero.

2-D Fourier transforms simply involve a number of 1-D transforms, and as aforementioned, this one replaces first the rows with their transforms and then the columns with their transforms. But in order to place the origin of the frequency spectrum at the center of the image, the image is quartered and quadrants are swapped: 1 with 3, and 2 with 4, as shown in the diagram below.



Technical Note:

In the discussion above, it is assumed that the user is familiar with 1-D FFT. For more information on that topic, please see the 1-D FFT topic.

Average

This is an image filter that uses two sources and averages (means) their pixel intensities to create one new image.

Black Offset Correction - No Scale

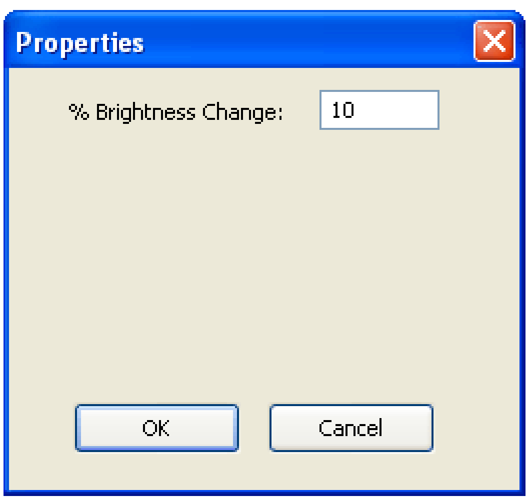
This is an image filter that subtracts off an intensity value from the image, but does not re-scale the image intensity. It is useful for subtracting off noise from an phosphor screen image.

Specify:

> ***Offset*** – type in a value from 0 to 4095 to subtract off that value from all pixel values. Resultant values below zero are zeroed.

Brightness Adjust

This is an image filter that adjusts the brightness of both monochromatic and color images. Color images not already in HSB (Hue, Saturation, Brightness) format are first converted and then converted back after brightness is adjusted using the algorithm described below.

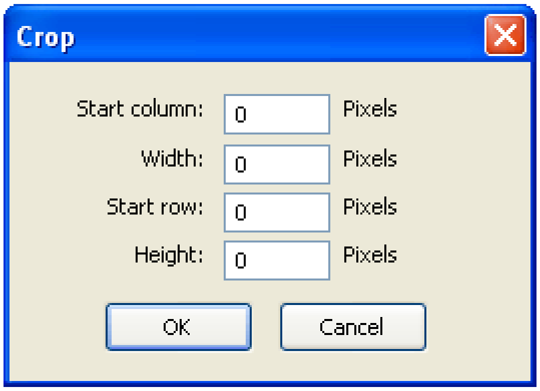


Specify ***% Brightness Change*** between -100 and 1000. The number is then divided by 100 and the result added to 1. That number is then used to scale the brightness values.

> For example, suppose the *% Brightness Change* is -10. Then the scale factor will be 1-10/100 = 0.9

Crop

This is an image filter that allows the user to keep only a certain part of the image and throw the rest away. This is particularly useful when the image is much larger than what the user needs. It also reduces file size.



Specify:

Start column – for where cropping begins, along with *Start row*. The 0 column is the left of the image.

Width – for how wide (horizontal) the smaller cropped image will be, starting from the *Start column* and moving left.

Start row – for where cropping begins, along with *Start column*. The 0 row is the top of the image.

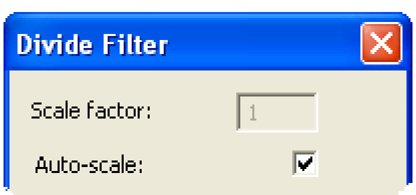
Height – for how tall (vertical) the smaller cropped image will be, starting from the *Start column* and moving down.

Divide

This is an image filter that uses two sources that must be of the same size.

Order is important: the first image is divided by the second, with each pixel intensity value in the first image divided by the corresponding pixel intensity value in the second image.

After clicking the *OK* button in the *two sources* dialog, the following dialog appears:



Select ***Auto-scale*** and the resultant image's pixel values will be scaled by multiplication up to the maximum intensity value, which depends on the bit depth.

For example, suppose the highest intensity value in an 8-bit resultant image is 25 and the lowest intensity value in the resultant image is 2. Then the Auto-scale function will multiply the highest intensity value, 25, by a factor of 10.2, making the new highest intensity value 255. All the other pixel intensity values will be multiplied by the same factor, making the lowest intensity value, for example, 20.4, which will be rounded down to 20

Un-checking this option means setting the ***Scale factor***, which is the multiplication value used for scaling the resultant pixel values. A value of 1 leaves the resultant image unchanged. Any value that results in a pixel intensity value too high or too low (beyond the limits (0 to 255 for 8-bit images)) will be set to the highest- or lowest-possible scale factor.

Edge Detection

This is one of three edge detection image filters. This one uses the simple homogeneity function on a 3x3 matrix of pixels in order to transform the image. The function subtracts each of the eight surrounding pixels from the middle pixel, notes the largest difference, and then uses the absolute value of that largest difference as the value of that middle pixel in the new image.

For example, in the 3x3 matrix of pixel values below, 11 is center value and |11-16| = 5 is the maximum difference. So 5 will be the value of the center pixel in the filtered image.

11 13 15

16 11 11

16 12 11

There are an infinite number of edge orientations, widths, and shapes. Some edge detection algorithms work well for one image and poorly for others, so it may take experimentation to determine the best technique. See also Edge Detection (Roberts) and Edge Detection (Sobel).

Edge Detection (Roberts)

This is one of three edge detection image filters. This one uses the Roberts edge enhancement operator for images, as outlined below.

If

$$(j,k)$$

is the coordinate of each pixel

$$I_{jk}$$

in the original image, and

$$R_{jk}$$

is the Roberts-transformed pixel, then

$$R_{jk} = \left|I_{jk} - I_{j+1,k+1}\right| + \left|I_{j,k+1} - I_{j+1,k}\right|.$$

There are an infinite number of edge orientations, widths, and shapes. Some edge detection algorithms work well for one image and poorly for others, so it may take experimentation to determine the best technique. See also Edge Detection and Edge Detection (Sobel).

Edge Detection (Sobel)

This is one of three edge detection image filters. This one uses the Sobel edge enhancement operator for images, as outlined below.

If

$$(j,k)$$

is the coordinate of each pixel

$$I_{jk}$$

in the original image, and

$$S_{jk}$$

is the Sobel-transformed pixel, then

$$S_{jk} = |S_X| + |S_Y|$$

where

$$S_X = I_{j+1,k+1} + 2 \cdot I_{j+1,k} + I_{j+1,k-1} - \left(I_{j-1,k+1} + 2 \cdot I_{j-1,k} + I_{j-1,k-1}\right)$$

$$S_Y = I_{j-1,k-1} + 2 \cdot I_{j,k-1} + I_{j+1,k-1} - \left(I_{j-1,k+1} + 2 \cdot I_{j,k} + 1 + I_{j+1,k+1}\right).$$

There are an infinite number of edge orientations, widths, and shapes. Some edge detection algorithms work well for one image and poorly for others, so it may take experimentation to determine the best technique. See also Edge Detection and Edge Detection (Roberts).

Exclusive-Or

This is an image filter that uses two sources and logical XOR operator to create a new image. The filter works by applying the XOR operator to the two sources bit-wise.

For example, suppose two images were each composed of one pixel of 2 bit depth. Thus, the entire image is made up of an array 2^2 = 4 numbers in length. Further suppose that the first image (or pixel, in this example) is the array 1, 1, 0, 0 and that the second has the array 1, 0, 1, 0. Using the XOR operator leads to the result 0, 1, 1, 0 because

1 XOR 1 = 0

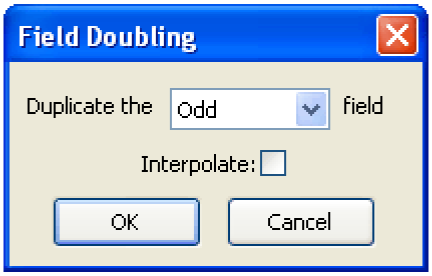
1 XOR 0 = 1

0 XOR 1 = 1

0 XOR 0 = 0.

Field Doubling

This is an image filter that doubles either the odd or even field (rows) in an image. It is useful for images that have been captured with an interlacing camera. BandiT Scan Mode Images do not need this filter because of how they are created.



Specify

Odd or ***Even*** – for which field gets row-by-row doubling and which field gets eliminated from the image

or

check ***Interpolate*** for software interpolation of the missing field.

Flip Horizontal/Vertical

These are two image filters that are used to flip images.

Choose:

Flip Horizontal – the resultant image has the same rows top-to-bottom (i.e., is flipped about a vertical axis)

Flip Vertical – the resultant image has the opposite rows top-to-bottom (i.e., is flipped about a horizontal axis)

Gamma

This is an image filter that is used to control the overall brightness of an image. Images not properly gamma corrected can look either bleached out or too dark, often with an unnatural gradient between light and dark. For a color image, gamma correction also changes the ratios between red, green and blue.

Brightness:

For brightness, most computer monitors take pixel intensity and raise it to the power of approximately 2.5 (depends on system and monitor). That is, if *x* is the pixel intensity, then computer monitors display about

$$x^{2.5}$$

So, because the range of pixel intensity is between 0 and 1, raising it to the power of 2.5 decreases the display intensity. Setting a gamma correction of 2.5 raises the display intensity to (1/2.5). That is,

$$\left(x^{2.5}\right)^{\frac{1}{2.5}} = x,$$

so the image displayed looks like the image taken by the camera.

Color:

The same thing that happens in brightness happens in color intensity. That is, for each color, computer monitors display about

$$x^{2.5}$$

of the original color.

For example, assume a Red/Green/Blue (RGB) color space with values between 0 and 255 for each color. Suppose a color is 80 Red, 20 Green and 20 blue, or having a ratio of 4:1:1. The image will appear with a ratio of approximately

$$4^{2.5}:1^{2.5}:1^{2.5} = 32:1:1$$

so the color will appear much more red than it actually is. Set the gamma factor to about 2.5 to correct for the display, which will apply a power of (1/2.5) to the display image.

Histogram Equalization

This is an image filter that adjusts the color table. First, the software obtains a pixel-distribution histogram. Then, it takes the cumulative integral and scales it, applying it to the current color table.

HSB Adjustment

This is an image filter for images captured with a color camera that divides the image into Hue, Saturation, and Brightness.

IDL Filters

The kSA software supports Interactive Data Language™ (IDL) filters, enabling users to program their own IDL filters (*.pro files). These then become available in the View menu when saved in this folder:

…\kSA\kSA BandiT\PROGRAM\idlprocs

Learn more about IDL at the RSI's Web site:

www.rsinc.com/idl/

Invert

This is an image filter that inverts the palette of the image.

For colored images, this results in an opposite color change—blue for orange, violet for yellow, etc.

For monochromatic images, this filter inverts the grey scale—black for white, etc.

For falsely-colored images (created with the palette), this filter inverts the palette—for example, if choosing IDL-13 palette (black and rainbow) in the original image, the brightest portion of the image is red, meaning that the *Invert* filtered image displays red for the darkest part of the image.

.

Log Scaling

This is an image filter that scales image intensity pixel-by-pixel using the following equation:

$$N = \frac{m}{\log(m)} \cdot \log(I)$$

where

m = maximum intensity value in the whole image

I = original pixel intensity

N = new pixel intensity

Maximize Contrast

This is an image filter that applies the following equation pixel by pixel to maximize the difference between high and low intensity of the whole image:

$$N = \frac{(I - \min)}{(\min - \max)} \cdot \max$$

where

min = minimum pixel intensity

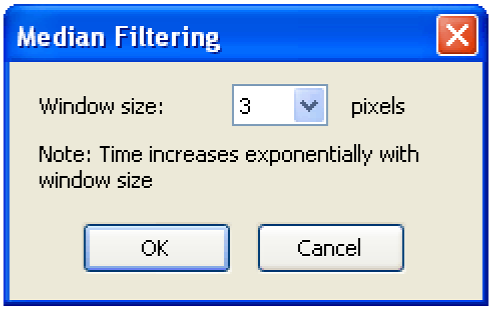
max = maximum pixel intensity

I = original pixel intensity

N = new pixel intensity

Median Filter

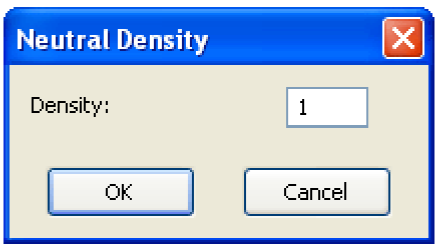
This is an image filter used for removing "salt and pepper noise," or isolated high or low values. The median filter replaces each point with the median of the values in the two-dimensional window of the specified width. It is similar to smoothing with a boxcar filter, but does not blur edges larger than the window.



Choose 3, 5, 7, or 9 for the window width and height from which the median value is taken. Even numbers are not available because the median of an even number of elements is the average of the two middle numbers.

Neutral Density

This is an image filter that divides the intensity by a scale factor.



Specify ***Density***, which is then input into the following formula:

$$N = \frac{I}{10^{Density}}$$

where

I = original pixel intensity

N = new pixel intensity

Or

This is an image filter that uses two sources and logical OR operator to create a new image. The filter works by applying the OR operator to the two sources bit-wise.

For example, suppose two images were each composed of one pixel of 2 bit depth. Thus, the entire image is made up of an array 2^2 = 4 numbers in length. Further suppose that the first image (or pixel, in this example) is the array 1, 1, 0, 0 and that the second has the array 1, 0, 1, 0. Using the OR operator leads to the result 1, 1, 1, 0 because

1 OR 1 = 1

1 OR 0 = 1

0 OR 1 = 1

0 OR 0 = 0.

Reverse 2x1 Binning

This is an image filter that reverses a common 2x1 binning option available on some cameras. That binning is done to speed up acquisition at the expense of resolution and image size.

This filter takes two adjacent rows and averages them to make a third row in between them. The resulting image is twice as tall.

Technical Note:

The assumption that the filter gives an accurate reversal of the camera binning is based on a linear response of the detector between intensity signals.

RSB Adjustment

This is an image filter for adjusting images captured with a color camera that divides the image into Red, Green, and Blue.

RGB to Grayscale

This is an image filter for converting images captured with a color camera that divides the image into Red, Green, and Blue to a grayscale.

Rotate

This is an image filter that refers to four rotate options. Three of them:

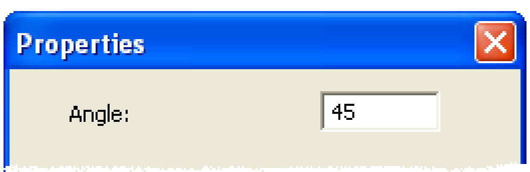
Rotate 180 Degrees

Rotate 90 Degrees Left

Rotate 90 Degrees Right

are common choices that can all be done by the fourth:

Rotate Any Angle



Angles are in degrees, so choose a number (including decimal values) between -360 and 360.

Choose positive values to rotate the image counterclockwise (left).

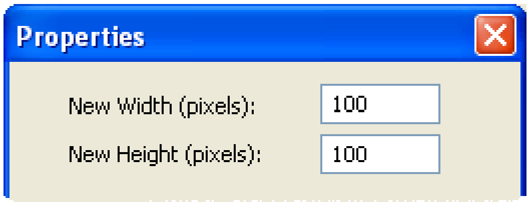
Negative values rotate the image clockwise (right).

Technical Note:

There are two different functions called for rotate. Using *Rotate Any Angle* is less efficient when rotating in increments of 90 degrees than the other rotate functions, which rotate only in increments of 90 degrees.

Scale to New Size

This is an image filter that uses nearest-neighbor sampling to scale the image to a user-specified size. The filter will stretch or compress an image along both axes to match the new dimensions. It does not retain proportions. It is a very fast filter, but can result in jagged edges and loss of apparent resolution, even when scaling down.



Specify ***New Width (pixels)*** and ***New Height (pixels)*** to set the size of the scaled image.

Smooth

This is an image filter that applies the Boxcar smooth algorithm to arrays of the pixel intensities.

Specify the ***Width*** of the side of the smoothing window using odd values between 3 and 101. For the filter to be meaningful, ensure that the specified width is smaller than either dimension of the image.

For example, *width* 3 specifies a 3 by 3 smoothing window with 9 total elements. The smoothed element will be in the middle of that box.

Technical Note:

Specifically, the function employed is this:

$$R_i = \begin{cases} \frac{1}{w}\sum_{j=0}^{w-1} A_{i+j-w/2}, & i = w/2, \ldots, N-w \\ A_i, & otherwise \end{cases}$$

where

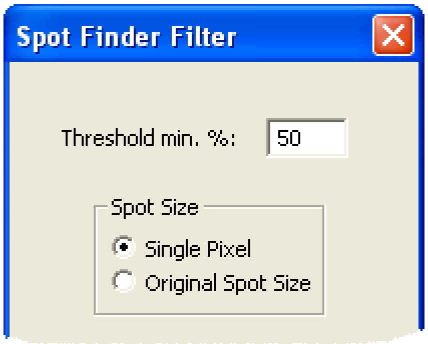
R = result

A = array (of any dimension)

w = width (user-specified)

Spot Finder

This is an image filter used to find spots on an image that meet or exceed a minimum intensity.



Specify ***Threshold min. %*** – for the intensity percentage needed for an area of the image to be considered a spot

Choose ***Spot Size*** of:

Single Pixel – for placing a single pixel at the centroid of the spot

Original Spot Size – for placing a circle of the original spot size at the centroid of the spot

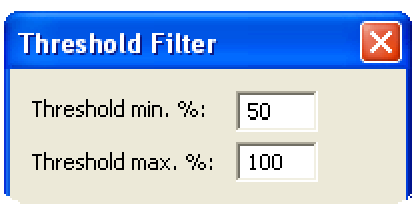
Note that saturated images and/or images with a lot of pixel intensities at 100% may make this filter behave in unpredictable ways.

Subtract

This is an image filter that uses two sources and subtracts one's intensity values from the other. Order is important: the second one is subtracted from the first, with any negative values zeroed out (black).

Threshold

This is an image filter that can bring up the low intensities and reduce maximum intensities.



Specify:

Threshold min. % – to set the value to which all pixel intensities lower than the threshold will be set.

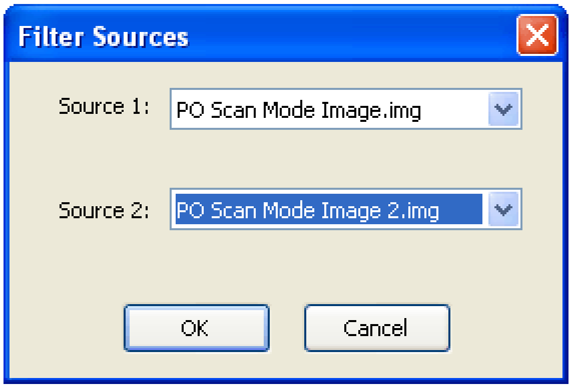
For example, with a setting of 50%, all pixel intensities below 50% will be brought up to 50%. Setting this parameter to 0% means no pixel intensities are increased.

Threshold max. % – to set the value to which all pixel intensities higher than the threshold will be set.

For example, with a setting of 100%, no pixel intensity values are lowered. A setting of 90% will reduce only those pixel intensities above 90% to 90%.

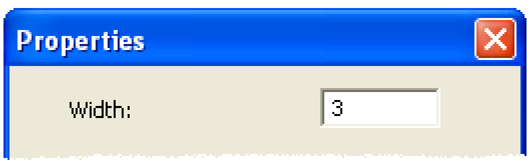
Two Sources

These filters use images, combining them in various ways to create a new image. Select any open image document for either source.



Unsharp Masking

This is an image filter that first subtracts a smoothed image from the original image and then scales the result.



Specify the Width of the side of the smoothing window using odd values between 3 and 101. For the filter to be meaningful, ensure that the specified width is smaller than either dimension of the image.

> For example, *width* 3 specifies a 3 by 3 smoothing window with 9 total elements. The smoothed element will be in the middle of that box.

Then the smoothed image will be subtracted from the original image.

Finally, a scale is applied to the result:

$$N = (I - \min) \cdot \frac{\max}{\max - \min}$$

where

> *min* = minimum intensity
>
> *max* = maximum intensity
>
> *I* = original pixel value (of result of original image minus smoothed image)
>
> *N* = new pixel value

Technical Note:

For color images, the filter first converts any other color formats to Hue-Saturation-Brightness (HSB) first (more at HSB Adjustment). Then applies the filter to the brightness values, and converts the resultant image back to the original color table (e.g. RGB).

Save export

File Formats

k-Space has created the following proprietary formats:

- img (kSA Images)
- kdt (kSA Data Files)
- bsrf (kSA BandiT Spectra Reference File)
- mrk (kSA BandiT Multi-wafer Marker File)
- rcp (kSA BandiT recipe files)
- dls (kSA Platen Custom Scan)

Except for reference files, kSA proprietary file types contain a variable-length header that contains all the pertinent information on how the data was acquired as well as any user-entered comments (use the Comments property for images and the File plot property otherwise). After that header, the data is stored in binary format. For this reason, direct reads of kSA proprietary files into external applications is difficult, which is why there are several exporting options. Reference files may be viewed using a text editor, but will only be useful within the kSA application.

What follows below is a general description of each file type. If needing the exact file format for an external read into another application, please contact us.

- ***img—Scan Mode Image***

Image files in BandiT are created using the Pyrometric Oscillations Advanced Acquisition Option and are a visual record of the Spectra versus Wavelength plot (seen in the Real-time BandiT Spectra chart during acquisition). Taking a horizontal Line Profile of the Scan Mode Image yields the same Spectra versus Wavelength plot, the data of which is also recorded in the *.kdt file.

There are two exporting options. The first is simply to click the Copy button (Control+C) and paste the image into another program. The second—which ensures no loss of resolution—is to select the image and use File/Export from the menu, saving the exported file as a *.tiff.

- ***kdt—Data Files***

Apply the Spreadsheet analysis tool to any *.kdt plot to see the two-column data from the plot itself, with the left column the dependent (horizontal axis) values and the right column the independent (vertical axis) values. Right-clicking the plot and selecting the data tab shows that there are many other values to plot, revealing that *.kdt files have an enormous amount of data in them.

Depending on acquisition, that data can come in two types, each with its own plot property: BandiT Computed Data and BandiT Spectral Data.

BandiT Computed Data—users choosing to use the option ***Minimal data output (default)*** in the BandiT I/O Settings Advanced Acquisition Option have acquired *BandiT Computed Data*. It is a "narrow-column" data, meaning that for each data point there are ***single*** values in each column (*a* time, *a* temperature, *a* wavelength, etc.).

BandiT Spectral Data—users choosing instead the option to ***Store raw and fully processed spectra*** have acquired both the *BandiT Computed Data* and the *BandiT Spectral Data*. *BandiT Spectral Data* is a "wide-column" data, meaning that for each data point there are multiple values that require multiple columns in order to contain all of it (a *spectra*). The program automatically uses this data to compute the *BandiT Computed Data*.

If storing raw and fully processed spectra, then the user has the option of switching between the two types plotted by clicking the Data and Spectra tabs at the bottom of the plot. The kdt toolbar gives the user control over the replay of the acquisition. Of course, if no such toolbar is available, then only the BandiT Computed Data was acquired.

Note that due to their size, exporting data (especially ***BandiT Spectral Data***) may take several minutes. Modern computers can handle most (if not all) user needs, but because it is possible to ***Store incrementally*** (set in the BandiT I/O Settings Advanced Acquisition Option), files can be so large that they cannot be re-opened unless more RAM is available.

- ***bsrf—Spectra Reference File***

These files are like *BandiT Spectra Data* *.kdt files, but contain only one spectra. The *.kdt toolbar capabilities are limited. There are two options for viewing the spectra data:

Data tab – click the ***Data*** tab at the bottom of the plot to see a spreadsheet view of the data (number of wavelengths and intensity) in one row.

Spreadsheet – apply the analysis tool (under the Analysis menu) to see a spreadsheet view of the data (wavelength and corresponding intensity) in two column format.

- ***mrk—Multi-wafer BandiT Marker File***

These files contain all the marker positions specified in the Real-time Bandit Temperature (Full Rotation), including the marker position found when calibrating the homepulse. They are saved and loaded by right-clicking that chart, and may be viewed outside the BandiT application by using a common text editor.

- ***rcp—BandiT Recipe file***

These files contain information specified in the Spectra Processing Advanced Acquisition Option dialog. They are saved and loaded via that dialog, and may be viewed outside the BandiT application by using a common text editor.

- ***dls—Platen Custom Scan file***

These files contain information specified in the Custom Platen Scan dialog. They are saved and loaded via that dialog, and may be viewed outside the BandiT application by using a common text editor.

Saving

It is recommended that all data is ***Saved*** in the kSA file formats. In this form it can be reopened in the BandiT software and all analysis tools can be used. Data can be saved automatically by the BandiT software depending on the options chosen in the Document Generation tab of the Advanced Acquisition Options.

If you want to use the data in some other application then you can additionally ***Export*** your data in a number of formats - see Exporting.

kSA systems save generated data/image files in k-Space's proprietary file formats:

- img (kSA Images)
- kdt (kSA Data Files)
- bsrf (kSA BandiT Spectra Reference File)
- mrk (kSA BandiT Multi-wafer Marker File)
- rcp (kSA BandiT recipe files)

Re-open any of these file types in kSA applications and employ all the analysis tools and any other functionality as if the data/image had just been acquired. Of course, this also means that these file types cannot be opened by off-the-shelf software applications.

For this reason, kSA applications can export to a variety of file types.

General Note:

Log files are saved as Text Documents (*.txt)

Exporting

(See also Saving.)

kSA systems can export files to a variety of file formats for use in other applications. The format available depends on the file:

- bmp (Windows Bitmap)
- txt (Text Documents) – plot data vs. all data for some plots
- eps (Encapsulated Postscript File) #
- png (PNG Image) #
- tif (Tiff Image) #
- wmf (Windows Metafile) #
- xls (Excel File) – plot data vs. all data for some plots #

Those marked with the # cannot be re-opened in kSA applications. However, even those that have been exported and can be re-opened in kSA applications will not have the same functionality as those saved in kSA's proprietary formats. It is for that reason that, when possible, it is better to save files rather than export them.

Glossary

Average Intensity

Mean intensity of the area specified by the user

Average (# of frames)

Number of frames of input gathered and averaged together to make a single datum/image

Bit depth

Number of bits used to store information about each pixel in an image. The higher the depth, the better the resolution and the larger the file size.

*kdt file

A proprietary file type. They contain temperature and/or full optical spectra data. These files can only be read correctly by the kSA software. Data contained within and displayed from *.kdt files may be exported to various common file formats, including *.bmp, *.wmf, and ASCII *.txt files. Learn more in the help topic "File Formats"

Bandpass

Type of digital filter that transmits a particular band of frequencies, but lowers the transmission rate of that values above and below that band

Bandstop

Type of digital filter that suppresses a given range of frequencies, transmitting only those above and below that band

Highpass

Type of digital filter with one transmission band that extends from a lower-bound freqency (other than 0) to frequency approaching infinity

Lowpass

Also known as a spatial averager, this digital filter is a method of convolution that reduces random noise by replacing the value of each pixel with the average of that pixel and its neighbors (or of its neighbors alone)

kSA BandiT Install Guide

k-Space Associates, Inc., © 2004-2007. This document is provided in hard copy form with kSA BandiT systems. It is also available in *.pdf format at www.k-space.com.

kSA Multi-Wafer BandiT

This new product from k-Space Associates gathers the kSA BandiT data from multiple wafers as they spin around on a platen, displaying and saving each wafer's data in a different file. Please contact us if you have a single-wafer system and would like to learn more about kSA's Multi-Wafer BandiT.

Normalized Intensity

Intensity values linearly scaled to be between 0 and 1.

Nyquist Frequency

1/(2T), where T is the time between data samples. This frequency comes from the Nyquist criterion, which postulates that the pickup sampling frequency must be at least twice the rate that brightness changes for any detail to be resolved.

Acquire in Progress

Is 1 (if in progress) or 0 (if not)

Adjusted Elapsed Time

Time spent in acquisition. This will only differ (be smaller) than Elapsed Time if pausing during acquisition.

Band Edge Wavelength

The wavelength calculated from the linear fit crossing the horizontal axis that, in turn, is used to calculate the BandiT temperature

Band Gap Linear Fit X/Y Pos

If X, then it is an array containing the two X-values (independent values, horizontal axis) of the linear fit. If Y, then it is an array containing the two Y-values (dependent values, vertical axis) of the linear fit. Plotting the Y versus X values gives a graph with the linear fit.

BandiT Background Width

Number of wavelengths per spectra in the BandiT Dark Background, which itself is a spectra that must be acquired before the software allows for temperature acquisition. See the BandiT Dark Background acquisition mode (Help topic) for more information.

BandiT Fit Spectra

A fitted spectra value used internally by the program for computing BandiT temperature

BandiT Fit Spectra Width

Number of data points in the BandiT Fit Spectra

BandiT Normalized Spectra

A normalized (0 to 1) plot of BandiT Spectra, which is a plot of detected intensity versus wavelength

BandiT Spectra

A plot of detected intensity versus wavelength. From this data, the software calculates temperature.

BandiT Spectra Wavelength

The lowest wavelength detected

BandiT Temperature

Computed temperature using the proprietary algorithm developed by k-Space Associates

Confidence

A measure of how well the fitting equation matches the data. Usually, a confidence value greater than or equal to 85% is adequate for most users.

Data Point

The sequential number assigned to acquired data

Data Set

When BandiT supports multiple wafers, this will be the number of wafers. The spectrometer will separate data from each wafer into separate data sets.

Elapsed Time

How much time has passed since starting acquisition

Number of Linear Fits

The number of data points (x,y) used to plot the linear fit. Usually, this number is 2.

Number of Wavelengths

The number of wavelengths in the BandiT Spectra.

Peak Spectra Intensity

Maxiumum value of the Spectra source (specified in the BandiT Temperature Acquisition dialog)

Pyrometry Value

The temperature calculated via pyrometry when using BandiT in transmission mode and measuring black-body radiation as the signal source

Samples per Data Point

Number of measurements taken for each data point

Spectrometer Integration Time

Amount of time that the spectrometer collects signal before digitizing and reading out the signal

TC Temperature

(T)hermo(C)ouple Temperature as measured by the thermocouple inside the chamber. Usually, thermocouples are not used unless making calibration files.

Pop-Ups and Jumps

When a word is green, clicking on it will provide either a pop-up window (such as this one) or a jump to another topic in the Help file. To undo a jump, simply use the "Back" command at the top of the Help file window.

USB Security Key

A (U)niversal (S)erial (B)us device that comes with the software and must be plugged in to a computer before it can run any kSA software. Because the key is programmable, some software capabilities may be hidden/disabled depending on the system purchased.

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