*k*SA Multi-beam Optical Sensor (MOS)

Product Description and Technical Specifications

The *k*SA *Multi-beam Optical Sensor* (MOS) is an extremely sensitive laser based system for *in situ*, real-time monitoring of thin film strain. The strain measurement is performed by monitoring the substrate curvature with an array of parallel laser beams and a CCD area detector. Since the technique is optically based, it is compatible with CVD, sputtering, and MBE environments provided that optical access is available to the substrate. The system is ideally suited for real-time feedback to process control systems in the production or research environment.

- The MOS system is extremely robust – simultaneous detection of the laser spot array makes the measurement virtually immune to vibration.

- Flexible design allows mounting in either a single port (normal incidence) or 2-port configuration.

- Integrated Windows XP software provides real-time analysis and display of film strain, substrate curvature, stress-thickness product, or mean differential spot spacing.

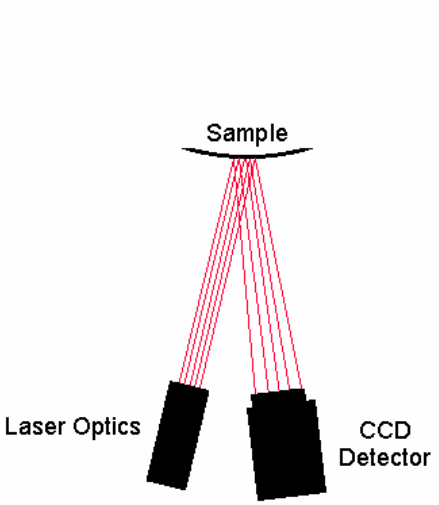
- Measurement can be performed with substrate rotation using fully supported external triggering functions.

- Optimized optics and detection system combined with proven fitting algorithms result in typical radius of curvature detection of 4 to 10 kilometers depending on system geometry.

- 2-dimensional laser array can provide surface curvature and strain topography mapping.

- Can be used for real-time reflectivity measurement and accurate film thickness determination.

Schematic illustration of the MOS system.



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STANDARD HARDWARE

High Sensitivity 8-bit Detector

High resolution, high sensitivity, anti-blooming, monochrome CCD detector and power control board.

Specifications:

CCD format:	*3-phase interline transfer CCD, removable IR cut filter, selectable electronic shutter, AGC (On/Off), Gamma(On/Off), on-chip integration capability*
Well depth:	*100,000 e-*
Pixel resolution:	*768(H) x 480(V), 11µm x 13µm pixel size*
Sensing area:	*2/3" format (8.8mm x 6.6mm)*
Spectral range:	*400-1100 nm (w/ IR filter out)*
S/N:	*56 dB*
Sensitivity:	*400 lux, f4, under 3200K lighting*
Exposure time:	*Variable from 1/10,000 to 1/30 sec (dip switch selectable)*
Triggering:	*Selectable field-on-demand triggering for synchronization with substrate rotation*
Output format:	*RS-170*
Lens mount:	*C-type*
Power:	*12V DC (internal from computer) or external 120/240V 210mA current consumption*
Camera Dimensions:	*86mm x 52 mm x 39mm*

Optional high-resolution detectors are available at additional cost (see optional hardware.)

Integrated Laser and Optics System

The MOS system utilizes a pair of etalons to generate a 2-D array of parallel laser beams from a single beam laser source. All optics are rigidly mounted to reduce vibrational noise. The laser system is stabilized and temperature controlled to maximize lifetime.

Diode Laser Module and Custom Optics

Specifications:

Fiber coupled, Peltier cooled laser diode package with integrated current controller and temperature controller.

Laser Wavelength:	*658nm nominal (other wavelengths available upon request.)*
Laser Output Power:	*>13 mW, measured directly at laser output. Note: All high-power beams are confined within the MOS housing even when the cover is removed for alignment. The cover is not interlocked. Direct access to the main beam is necessary during alignment. The total output power in the sample compartment is typically less than 50 microwatts.*
Beam Geometry:	*Circular Gaussian output with integrated long focal length lens cell*
Operation Mode:	*Constant current output*
Stability:	*≤ 0.2%*

High Performance Diode Laser Controller

Linear, low-noise diode laser controller operates in constant current mode with output power stability ≤ 0.2% typical (24 hours). Output power is current limited with slow start circuitry for extended diode laser life. Output power is computer controlled from threshold power to full rated output. Temperature control is factory set for 13°C and has an absolute stability of <0.2°C.

Automated Mirror Tracking with Servo Control

One application of the MOS system is monitoring curvature/stress during high temperature annealing. The thermal expansion inherent in most heater stages causes significant angular displacement of the heater stage and sample. The effect of the displacement is that the reflected beam array slowly drifts off the CCD during the temperature ramp. Compensation for this drift is made using servo-motor control of an optical flat mirror to provide fully automated tracking capability through the MOS software.

DELL Pentium Computer System

The MOS system is supplied with a fully configured DELL computer system. The current specifications are listed below.

Computer (optional)

- *Dell Precision 390 ConvertibleMiniTower*
- *PC Processor E6400 (2.13GHz, 1066, 2MB)*
- *1GB, 533MHz, DDR2 NECC SDRAM Memory, 2X512MB*
- *Dell UltraSharp 1907FP Flat Panel with Height Adjustable Stand,19.0 Inch VIS*
- *128MB PCIe x16 nVidia,Quadro NVS 285, dual VGA, Graphics Card*
- *160GB SATA 3.0Gb/s Hard Drive with NCQ and 8MB DataBurst Cache*
- *WINDOWS XP PRO Operating System*
- *48X/32X/48X CD-RW*
- *Built-in 1394-a Firewire Capability*

Computer Control Boards

The MOS system uses several control boards to interface from a host computer to the system. The standard system requires 3 available PCI slots and 2 additional (ISA or PCI) slots for detector power and servo motor interfacing.

Scientific Grade Analog Frame Digitization Board:

Programmable resolution scientific grade framegrabber utilizes digital clock sync technology to provide less than ±5ns jitter. Up to 30 Hz frame rate, no on-board memory (maps directly to host computer RAM or video RAM), runs on PCI bus as bus master. Programmable gain, offset, reference value, and video input. Utilizes speed of PCI bus to perform real-time display on computer monitor. Includes adapter cable for multiple video inputs, digital I/O, and external trigger capability.

Multifunction Digital and Analog I/O Board:

High-resolution 16-bit analog I/O board for control of laser output power and monitoring laser photodiode current. Additional analog input is provided and supported in software for reading instrumentation such as temperature controllers. A single programmable ±5V, 16-bit analog output is provided for equipment control. Requires 1 PCI slot.

Servo Control Board:

High-resolution 8-channel servo motor control board with 2 servo motor amplifiers to control an automated mirror stage. Requires 1 PCI slot for the board and 1 additional slot in the riser for cable interfacing.

OPTIONAL HARDWARE

12-bit High-resolution Detector/Digital Frame grabber (M-HRD/U)

The MOS system can be configured with 1300 x 1030 pixel, 12-bit, high-resolution detector. This detector offers a CCD sensor with nearly twice the spatial resolution of our standard 768x480 detector. The increased spatial resolution and bit depth can provide nearly twice the radius of curvature detection capability. In a well-controlled experimental setup, radius of curvature detection can approach 20km or greater. The ultimate resolution of the system is, of course, dependent on the particular configuration of the MOS system and to the customer's system.

Specifications:

CCD format:	*Progressive scan, interline transfer*
Peltier cooling:	*none*
Pixel resolution:	*1300(H) x 1030(V)*
Pixel size:	*6.7 um (H) x 6.7 um (V)*
Sensing area:	*2/3" format (8.8mm x 6.6mm)*
S/N:	*>56 dB*
Sensitivity:	*0.5 lux at f1.4, IR filter out*
Frame rate:	*12 frames/sec max*
Exposure time:	*83 usec to 83 msec.*
Output format:	*RS-422 12-bit digital*

High-resolution Programmable Shaft Encoder (M-HRSE)

The 12-bit absolute encoder with built-in programmable logic controller provides a complete solution for timing data acquisition with substrate rotation. The encoder provides up to 8 independent TTL level outputs. Programming is performed easily with a supplied Windows NT/2000/XP application and RS-232 interface. Custom mounting brackets are typically required for individual needs and can be manufactured at additional cost.

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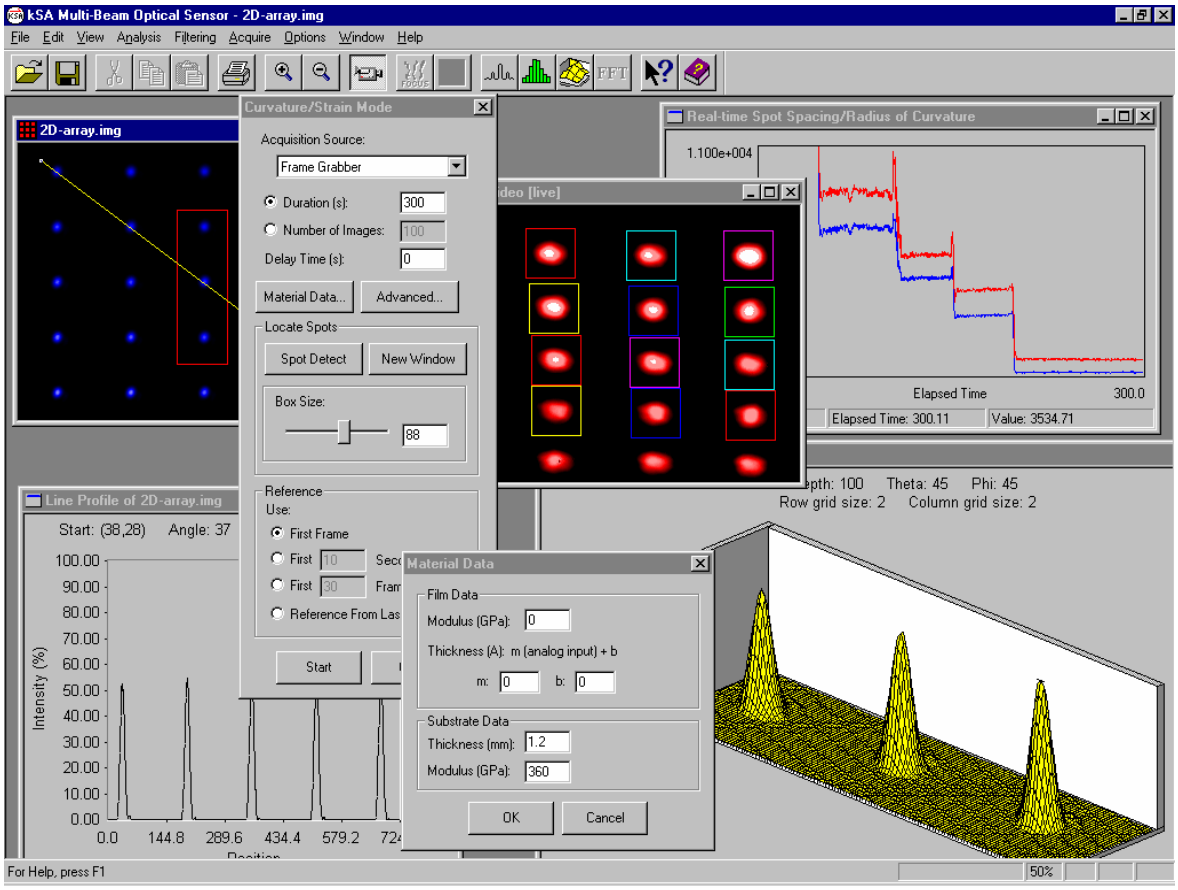
MOS INTEGRATED SOFTWARE DESCRIPTION (VERSION 4.0)



Summary of capabilities:

- Complete data acquisition and analysis control.
- Automatic laser spot detection.
- Automatic laser power control to ensure no saturation of detector as surface reflectivity changes.
- Real-time plotting of intensity, differential spot spacing, stress-thickness product, strain, and radius of curvature.
- Data acquisition modes:

1) **Focus mode:** for facilitating laser alignment and optics focusing by simultaneously monitoring the image and a line profile of the laser spot array.

2) **Curvature/Strain Mode**: An arbitrary number of laser spots, user configured, are tracked simultaneously, yielding time-resolved radius of curvature measurements, mean differential spot spacing, stress, and simultaneous intensity oscillation (determines film thickness). The mean differential spot spacing is used to calculate time resolved strain or stress thickness product using material parameters and growth rate.

- Film thickness can be read directly from thickness monitors using configurable 16-bit analog inputs. Alternatively, user can input deposition rate. Software support for direct measurements of film thickness using oscillations in the reflected laser intensity is under development.

- 16-bit analog output, software configurable for use as real-time feedback to deposition equipment. For example, film stress/strain can be can figured and output as an error signal to control deposition rate, chamber pressure or substrate temperature, etc.

- For time-resolved acquisition modes, a delay time between image acquisitions, accurate to 1 msec, may be selected.

- External triggering can be used to time data acquisition with external events or substrate rotation.

- Analysis Capabilities:

    1) **Line profile** for accurate determination of beam profiles.

    2) **Radius of curvature and strain analysis.** User input of physical geometry and substrate parameters yields calculation of radius of curvature, stress-thickness product, or relative stress as a function of time, temperature, or other user configurable input. Alternatively, simple centroid position and spot separation distance may be plotted.

- User-friendly Windows-standard environment with extensive error checking and file handling. Data storage in ASCII and binary file formats facilitate alternative data analysis by user. Direct printing of images or graphics using currently loaded Windows printer drivers. Cut-and-paste directly to clipboard, or into other applications such as MS Word.

- High-quality 2D and 3D graphics for data display. Numerous image and graphics editing capabilities, including false coloring using pre-loaded or user-defined color palettes, and label editing. Transport of graphics directly to Windows clipboard or exported to Windows Metafile or Tiff format.

OPTIONAL SOFTWARE

Growth Rate Monitor Option for the kSA MOS Software:

- Real-time update of current n, k, and deposition rate values and standard deviation of these values.
- Ability to generate a thin-film deposition recipe, so multiple layers can be properly fit in real-time. Each layer in the recipe will have a user-estimated n, k, and G value. Each layer can be triggered via an external trigger signal or can be time-based.
- Optional ability to output deposition rate, thickness, n, and k to analog output channels for input into process control system.
- External triggering can be used to time data acquisition with external events or substrate rotation if required.
- User-friendly Windows XP-standard environment with extensive error checking and file handling. Data storage in ASCII and binary file formats facilitate alternative data analysis by user. Direct printing of graphics using currently loaded Windows printer drivers. Cut-and-paste directly to clipboard, or into other applications such as MS Word. Transport of graphics directly to Windows clipboard or exported to Windows Metafile or Tiff format.
- Reflected intensity oscillation data recorded during growth can provide accurate film thickness and optical constant determination.