*k*SA 400 Analytical RHEED System - Product Specifications

RHEED (Reflection High-Energy Electron Diffraction) is a popular thin-film diagnostic technique, offering a wealth of valuable information. The kSA 400 system puts the power of RHEED at your fingertips. Combining a high-resolution, high-sensitivity imager and optimized optics with sophisticated, RHEED-specific acquisition and analysis software, the kSA 400 is your window to analytical RHEED. Designed for convenience, the kSA 400 gives you quantitative results out-of-the-box. All hardware interfacing is taken care of, and acquisition and analysis is visually driven, resulting in simple, straightforward user operation. Extensive input from our world-wide customer base has made our kSA 400 the industry's most powerful analytical RHEED system - the benchmark, against which all other systems are measured.

The goal of the kSA 400 system, now in its 4th generation, is to seamlessly provide you with the most information from your RHEED pattern. Whether you are analyzing a static diffraction pattern, or acquiring data during high-speed substrate rotation, results are immediately at your fingertips. The kSA 400 has been developed for both static as well as real-time acquisition and analysis. Determination of lattice spacing, strain evolution, growth rate, thickness, coherence lengths, and reconstruction evolution are just a mouse click away. The system is flexible, allowing you to analyze virtually any image feature you desire, or optionally, program your own custom analysis routines. The system is now offered with 2 different hardware configurations: 10 or 12-bit, depending on resolutions and dynamic range needs.

The kSA 400 system integrates easily with Staib, R-DEC, and Vieetech electron guns. With optional gun control software the kSA 400 provides the ability to store gun control settings and immediately ramp to them, fine-tune settings while simultaneously viewing the diffraction pattern, and acquire RHEED rocking curves, all with the click of a mouse. Exploit the power of RHEED with the kSA 400!

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1) HARDWARE

All kSA 400 systems are supplied as a turn key unit, ready to run out-of-the-box. The kSA 400 system can be supplied with either a 10-bit or 12-bit detector. The 10-bit detector yields 1024 intensity levels and utilizes Firewire technology for data transfer, while the 12-bit detector yields 4095 intensity levels and uses a dedicated Ethernet-based digital framegrabber. Specifications are listed below.

• Detector* - 10-bit Option

Progressive scan, interline-transfer, 30 fps (10-bit mode), 60fps (8-bit mode), IEEE-1394 CCD camera with Firewire adapter card.

Specifications:

Model:	*K 30FW*
CCD format:	*1/3" Hyper HAD progressive scan interline-transfer CCD*
Pixel resolution:	*640 (H) x 480 (V), 7.4 µm x 7.4 µm*
Sensing area:	*1/3" format*
Spectral range:	*280-1000 nm*
S/N:	*≥ 56 dB or better*
Sensitivity:	*1 lux at F1.4*
Exposure time:	*1usec – 65 sec.*
Output format:	*8-bit, 60 fps, or 10-bit, 30 fps, via IEEE 1394 interface*
Lens mount:	*C-type*
CCD Dimensions:	*64 (W) x 64 (H) x 60 (D) mm*
Power:	*8 – 30VDC from IEEE-1394 Control Board*
Interface:	*3-port IEEE-1394 400 Mbps Host PCI adapter*
Cabling:	*10 meter standard Firewire cable*

• Detector – 12-bit Option

Progressive scan, interline-transfer, 50 fps, 12-bit digital CCD camera with dedicated Ethernet-based digital framegrabber.

Specifications:

Model:	*K200D*
CCD format:	*1/2" Hyper HAD progressive scan interline-transfer CCD*
Pixel resolution:	*640 (H) x 480 (V), 9.9µm x 9.9 µm*
Sensing area:	*1/2" format*
Spectral range:	*280-1000 nm*
S/N:	*≥ 65 dB*
Sensitivity:	*1 lux at F1.4*
Exposure time:	*1ms – 10min. Controlled via TTL-level input*
Output format:	*12-bit, 50 fps, high speed data link connections*
Lens mount:	*C-type*
Power:	*12V DC (internal from frame grabber)*
CCD Dimensions:	*1.5in x 1.5inx 2.5in*
Interface:	*Programmable resolution, 40 MHz digital framegrabber handles up to 32k x 32k images, up to 32 bits/pixel. 2 MB image FIFO memory, 132 MB/s burst speeds. Programmable input trigger, output strobes, 4 general purpose I/O (TTL) lines, three general purpose RS422 outputs. Short-card PCI format, has on-board 12V (@ 800 mA) and 5V (@ 500 mA) outputs.*
Cabling:	*25' CAT5E Ethernet cable.*

* Optionally, *k*-Space also supplies 8-bit analog and other 10-bit/12-bit digital cameras. These cameras are fully supported and integrated into the kSA 400. Please contact us for details on other CCD cameras.

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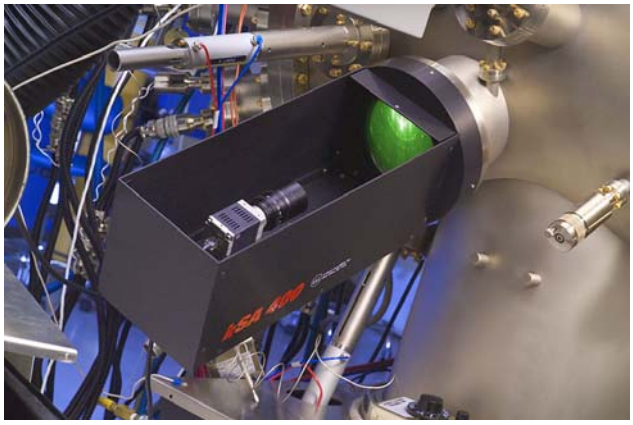
Optics

- 17mm f/0.95 C-mount lens (12-bit camera); 12mm f/1.4 C-mount lens (10-bit camera)
- Lens set for varying optical magnification without reducing light flux, allowing zoom for quantitative analysis and demagnification for entire screen imaging.
- Optical rail, rail carrier, post, and post holder for mounting detector and optics.

Viewport mount

Black anodized 6" or 8" o.d. RHEED/LEED flange mount, for mounting and concealing detector and optics. Features removable lid, notch for detector cable, and bottom plate slots for optical rail positioning. Standard 6" and 8" mounts; specific mounts for GENII and Riber systems available. Please specify viewport o.d. and chamber manufacturer.



Computer (optional)

- *Dell Precision Workstation 380 Desktop Computer*
- *3.4 GHz Processor with 2MB Cache, Pentium 4*
- *800 MHz Font Side Bus*
- *19" Flat Panel Monitor*
- *1GB, 400MHz, Double Data Rate SDRAM, ECC, 2 x 512 Memory*
- *128MB PCIe x 16 ATI FireGL V3100, Dual Monitor VGA or DVI*
- *80 GB, SATA, 7200 RPM Hard Drive*
- *48X CD-RW*
- *Built-in 1394-a Firewire Capability*
- *MS Windows XP Professional Operating System*

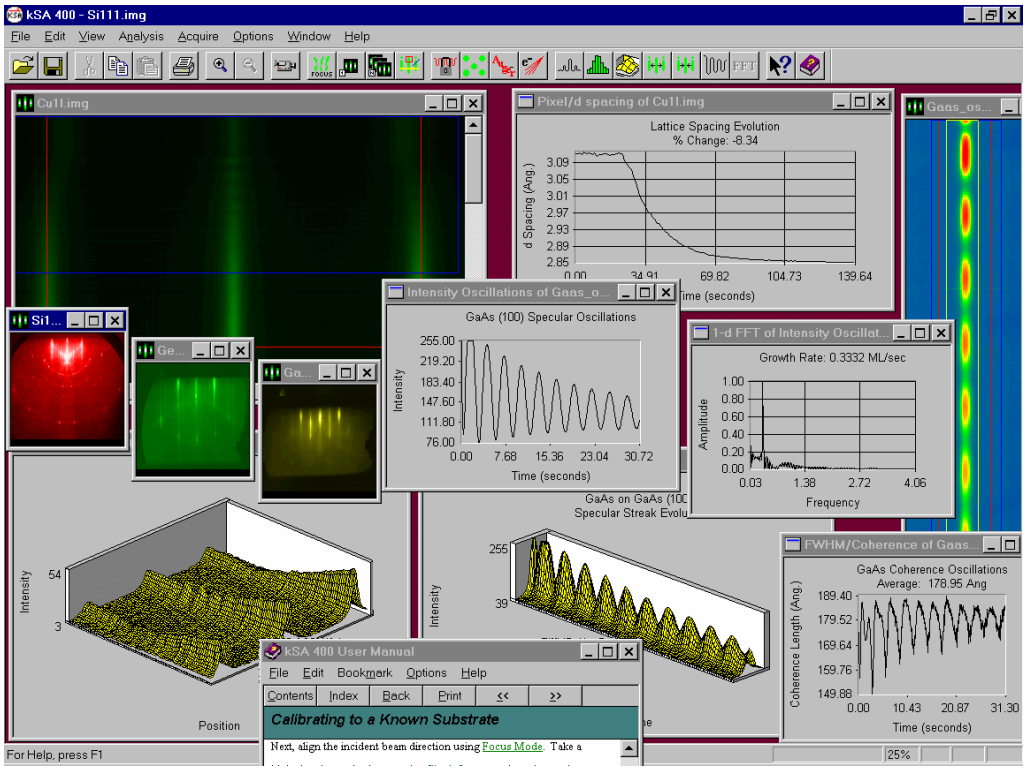
2) SOFTWARE (V4.60 CD)

- **Complete acquisition and analysis control.**

- **Computer-controlled, user-selectable CCD exposure control, to be applied to any data acquisition mode.**

- **Both static and time-resolved data acquisition and analysis.**

- **Data acquisition modes:**



  1) **Single Image Mode**: Acquires single images for quantitative static analysis and archiving.

  2) **Multiple Image Mode**: Acquires a user-selected number of diffraction images sequentially for quantitative analysis and archiving. Images may be acquired in real-time to system RAM (up to the limit of physical memory) or may be stored directly to hard disk.

  3) **Focus Mode**: Displays real-time line profiles, surface plots, and contour plots on user-defined regions of the diffraction pattern, allowing for easy focusing and alignment without having to save data.

  4) **Scan Mode**: An arbitrary number of lines and windows of the incoming diffraction pattern are monitored simultaneously, yielding time-resolved, simultaneous intensity oscillation (growth rate determination), lattice spacing, and coherence length determination. The lines can be of any length and orientation (within the bounds of the image), and the windows can be rectangles of any size.

  5) **Movie Mode:** Acquire complete image movies, with the capability to playback, analyze, and run Scan Mode on the movie. With acquired movies, the movie effectively becomes a built-in video cassette recorder and acts as a second acquisition source (in addition to the camera.).

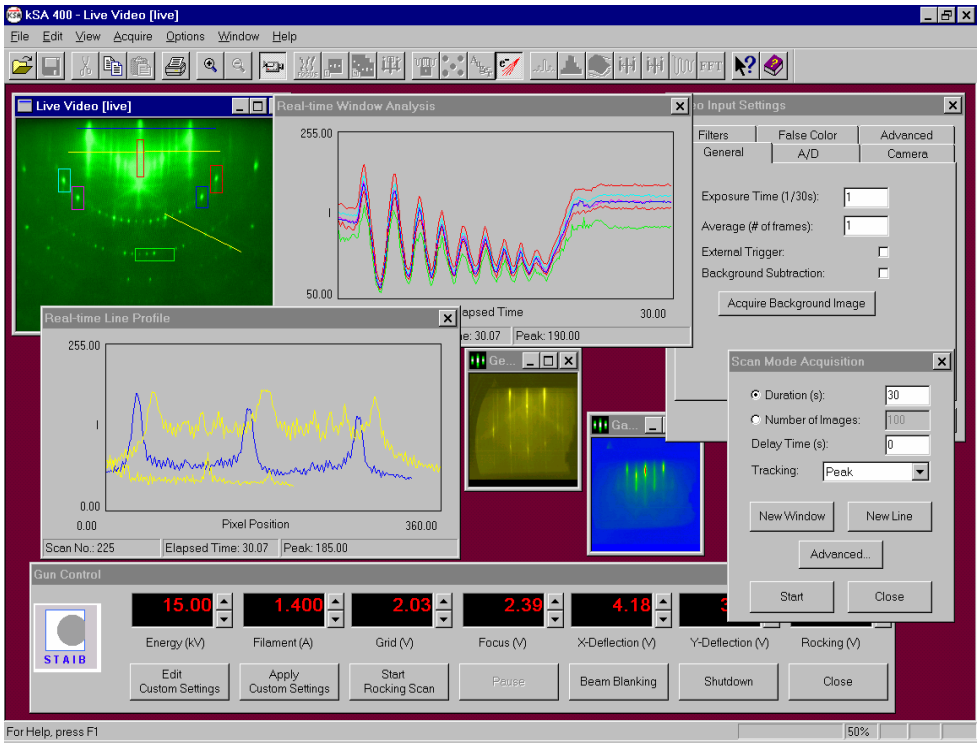
  6) **Interactive Accumulation Mode.** Allows continuous display of a real-time summed image, i.e. "interactive accumulation" mode. Useful for monitoring build-up of system noise, or monitoring pattern shifts with a single image.

- All windows may be set for tracking or no tracking. If tracking is set, the window repositions its center on the brightest portion of the diffraction streak/spot. The tracking may be performed on the centroid position of the window as well. The position of the peak intensity/centroid intensity is recorded for each incoming image during data acquisition.

- All acquisition modes allow the user to select the on-chip integration time and whether a background subtraction should be performed. This is useful, for example, if it is desired to remove the contribution of vacuum chamber light to the diffraction image. For time-resolved acquisition modes, a delay time between image acquisition, accurate to 0.01 sec, may be selected.

- **Analysis Capabilities:**

1) **Line profile fitting** for accurate determination of streak spacing/in-plane lattice spacing**.**
2) **FWHM / in-plane coherence length** determination.
3) **Time-resolved acquisition** (i.e. line scan and column scan modes,) for in-plane lattice spacing and coherence length is monitored during growth, annealing, etc., yielding what we term "strain profiles" and "domain profiles".

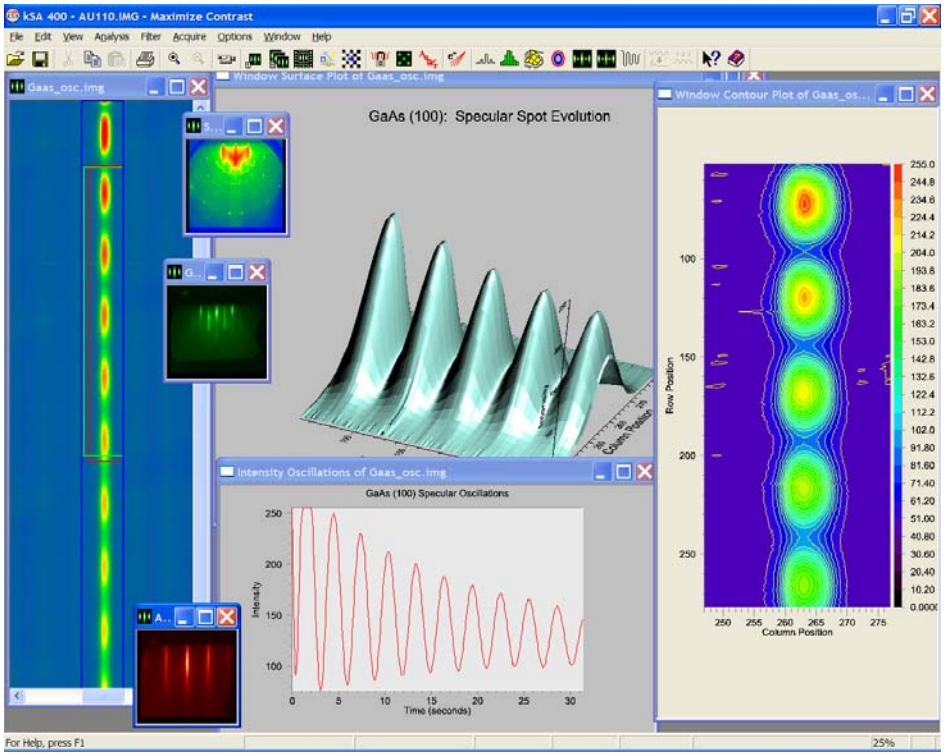


4) **Multiple RHEED oscillation monitoring:** The user may monitor an unlimited number of diffraction features, thereby determining the phase difference between oscillations of different diffraction order. Of course, rate/thickness determination is easily determined since the elapsed time during growth is accurately monitored (to within 0.01 sec accuracy.)
5) **In-plane spacing, coherence length, and intensity oscillations** are all monitored simultaneously during growth, so all three properties are determined.
6) **Growth Rate Determination.** Three different techniques may be used to analyze the RHEED intensity oscillations. Specifically, Fast-Fourier Transform (FFT) analysis, derivative analysis, and damped sine wave fitting analysis can all be used and compared for accurate growth rate and thickness analysis.

7) **3D image plotting** for both static diffraction images and evolving line scan, column scan, or dual scan images which shows evolution of growth in 3D.

- Focus mode for facilitating gun alignment and optics focusing by simultaneously monitoring the incoming diffraction image and a selected line profile of the diffraction pattern.

- 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.



- Image file conversion to Windows™ Metafile, .bmp, or .tif graphics file formats. This is useful for reading images into standard drawing/desktop publishing software, or to standard Postscript for direct hardcopy output of diffraction images.

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

- External trigger capability for triggering and synchronizing data acquisition at the occurrence of specific events, (e.g. at specific rotation angles during substrate rotation.)

- 12-bit analog input capability for simultaneously reading analog input channel during RHEED acquisition. (Requires separate purchase of analog input board).

Minimum System Requirements:

Processor:	Pentium IV
Speed:	1.5 GHz
Memory:	512 Mbytes
Video:	1024 x 768, 16-bit depth
Hard Disk:	40 Gbytes
Bus:	1 PCI expansion slot and 1 available L-Bracket position
OS:	Windows™ 2000 or Windows™ XP ONLY

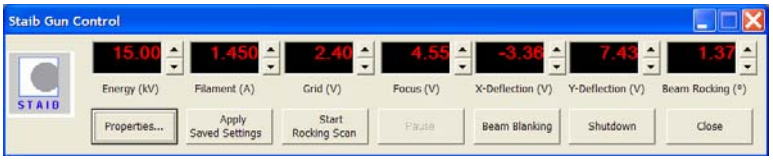
Optional Plug-In Modules (Quoted separately)

- **LEED I/V**: Up to 8 different windows of the incoming diffraction pattern may be simultaneously monitored and analyzed, while computer control of a 12-bit DAC controls the beam energy of an external LEED gun. Hence, I/V curves are effortlessly mapped out. Kinematic scattering calculation tracking or peak intensity tracking may be selected.

- **Phase-Locked Epitaxy (PLE):** PLE and timed shutter control via a parallel I/O board and integrated software. Up to 8 different processes with any combination of up to 8 different shutters may be cycled up to 1000 times, monitoring either the RHEED oscillations or absolute growth time for precise growth control. Delay time, recovery time, CCD integration time, and intensity tracking may be selected for each process. Enhanced programmability to the PLE process table allows for user-generated "recipes" for deposition. Acquired RHEED data is stored in extended memory for the entire run and may be stored to hard disk for post-analysis at the end of the run. Shutter open/close control is maintained via TTL-level voltage output of a 24-channel parallel I/O board in the back plane of the host computer.

- **Auger/X-Ray Photoemission Spectroscopy, AES/XPS (optional):** AES/XPS data acquisition via 12-bit DAC and ADC boards with accompanying control software. User-configurable output voltage (typically 0-10V) for external power supply control, and 12-bit ADC for signal digitization. User-selectable energy step size, number of samples per energy, scan rate, and number of scans. Data displayed during acquisition and stored to ASCII file upon data completion. Data acquisition may be externally triggered.

- **Electron Gun Control/Rocking Curve Scans (optional):** Complete control of Staib RHEED guns via an 8-channel, 16-bit DAC board and integrated software. Provides on-screen control and readout of beam energy, filament current, grid voltage, (x,y) deflection, and focus. Control is also provided for beam blanking (on/off) and beam rocking for guns with these capabilities. An integrated data acquisition mode is provided to acquire and display automated rocking curve scans. Requires one available full length PCI or ISA slot. All cables are included.

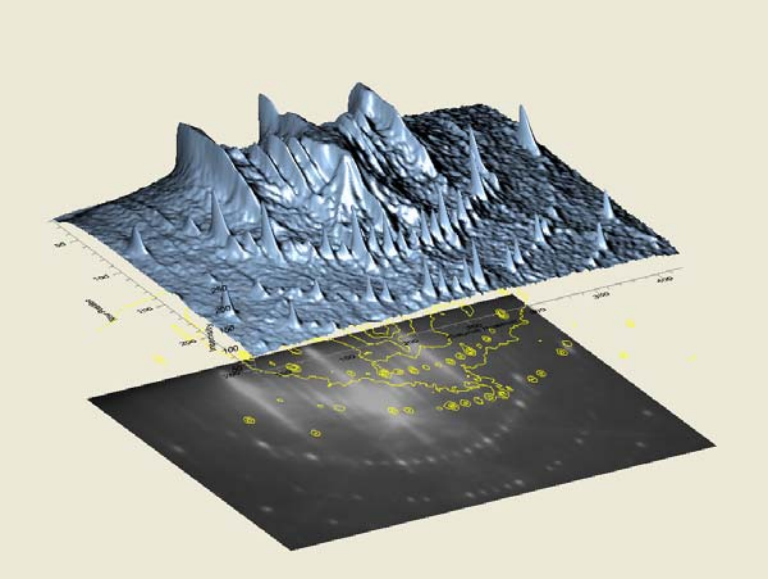


3) SOFTWARE ENHANCEMENTS

- **Version 3.7 Enhancements:**

1) **Digital Movies.** Complete digital movie capability. Movies can be recorded directly to hard disk or other storage media. Stored movies can be played back and analyzed using all *k*SA acquisition and analysis tools. Scan Mode can be run on movie files, selecting the movie file as the acquisition source vs. selecting the camera as the acquisition source. VCR-style control allows easy, instant navigation through movie files.

2) **Enhanced Real-Time Charts.** Real-Time Charts (RTCs) can now be opened, closed, smoothed, resized, and rescaled during acquisition. Any window analysis parameter can be plotted, either on the x-axis or the y-axis.



3) **New Image Processing.** An all-new image processing/filtering system can filter live video, single images, Scan Mode images, or movies. Filters include 2D FFT, 2-image manipulation (subtraction, addition, etc.,) edge detection, median filtering, band pass filtering, and contrast maximization.

4) **Better Growth Rate Determination.** We've added a discrete Fourier Transform (DFT) for 1D data sets that more accurately calculates growth rate by not forcing the data set to be a power of 2 in length. Additionally, we've added a peak (or valley, or both) counting algorithm that counts extremas and calculates growth rate by averaging extrema positions and time intervals.

5) **Multi-Threaded Video.** Multi-threaded video now allows the on-screen video to be displayed with interactive camera integration, frame summation, and filtering in real-time or near real-time, while the user performs other *k*SA 400 operations.

6) **Digital and Color Camera support.** The *k*SA 400 4.02 software offers complete support for digital, high-resolution, and high bit-depth cameras, as well as support for composite color cameras.

7) **Finite Width Lines in Scan Mode.** Acquired line width may be set to any measurement, vs. being restricted to a width of 1 when generating the Scan Mode image. The result is better statistical analysis (e.g. of lattice spacing) as you sample more of the diffraction pattern and average the statistical analysis calculation from as many lines as you choose.

8) **Increased Display Speed.** Image display routines have been rewritten in in-line assembly, resulting in very fast display times. This improvement becomes evident when working with the higher bit-depth digital cameras offered by *k*-Space.

9) **Analog and Digital I/O support.** Complete analog and digital I/O support for most data acquisition boards from Measurement Computing and Keithley-Metrabyte. Simultaneously monitor voltages from external sources (such as temperature probes) during image acquisition, or map image acquisition parameters (such as growth rate or lattice spacing) to analog or digital output channels.

10) **Image and Movie Compression.** The addition of lossless image and movie compression allows for on-the-fly or post acquisition compression. This applies to compression of images and movies taken with previous versions of the *k*SA 400 software. The "Zlib" routine used by *k*-Space typically compresses RHEED images and movies by a factor of 2 or greater.

11) **Miscellaneous Additions.** *k*SA 400 Version 3.7 software features many other new features, such as pixel mapping to real-life units, real-time image zoom-in (to 300%) and zoom-out (to 25%), interactive image accumulation up to 78-bit deep image support, standard deviation analysis, and global image time stamping.

- **Version 3.85 Enhancements:**

1) **Multiple Data Sets.** Multiple data sets may now be generated from a single acquisition. The *k*SA 400 may be programmed to separate the data based on multiple gun settings and can automatically change these settings continuously during deposition so you acquire two data sets, one for each gun setting. This is sold as an option.

2) **Programmable PLE.** We've added additional programmability to the PLE process table, so you can generate your own recipes for deposition.

3) **Analog and Digital I/O.** Allows for mapping of any parameter (e.g. intensity, lattice spacing, elapsed time, etc.) to any available analog or digital channel (based on the types of data acquisition boards present in your computer.) Real-time read and store incoming data on any available analog or digital channel.

- **Version 4.0 Enhancements:**

1) **Software Trigger Capability.** You can now monitor changes in incoming video, and start the acquisition based on these changes. For example, you can monitor a region for the appearance of a reconstruction feature, and the software will not begin acquisition until this feature is detected.

2) **Start/Stop Trigger.** An external signal input may now be used to begin and end the acquisition. This is separate from the standard "external trigger" capability, which uses a trigger signal to grab each frame of the data acquisition.

3) **Additional Analog/Digital Board Support.** Data Translation's DT334 board and multiple PCI-based boards from Measurement Computing are now supported.

4) **Better Graphing Capability.** New graphing capability includes interactive 3D rotation and perspective, the ability to plot individual data point markers with varying symbols, a new contour plot capability, and a data editor that allows direct editing of data associated with a graph.

5) **AVI Movie Extraction.** Any *k*SA 400 movie may now be exported to AVI movie format (.avi), allowing for easy viewing in common movie players.

6) **More Image Filters.** New image processing filters, including a floating point divide filter and an improved threshold filter.

7) **More Gun Control Settings.** Save up to 100 predefined gun control settings that can be set by a click of the mouse.

8) **More Efficient Long Scan Runs.** In the past, long acquisitions (a few hours or more) would take up to several minutes to allocate memory before the scan started: no longer. Now, at most a few seconds to allocate memory and then you're ready to begin acquiring.

- **Version 4.25 Enhancements:**

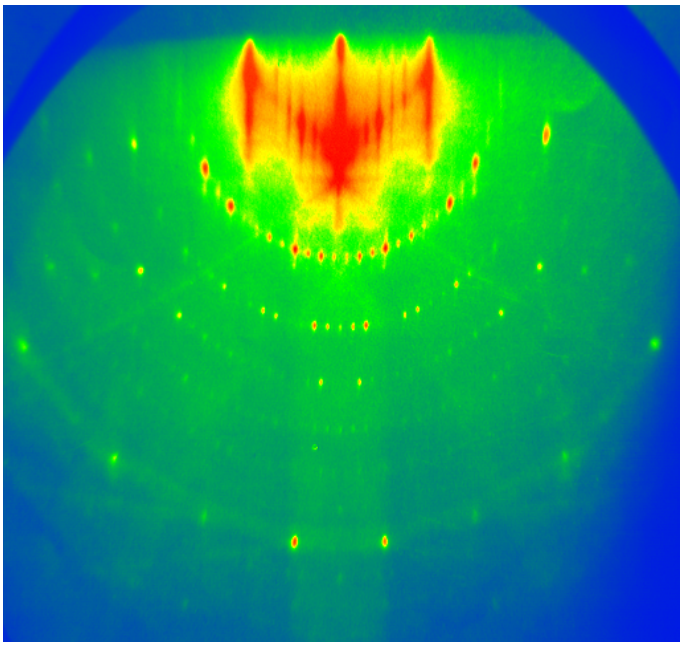
1) **Data Processing and Fitting Filters.** Now, in addition to image processing filters, a host of data processing and fitting filters are available. These filters can be applied to any 2D data, e.g. linescans, lattice spacing, intensity profiles, etc. Filters include bandpass, derivative, polynomial fit, Gaussian fit, cubic spline fit, and digital filter fit.

2) **Powerful IDL™ Graphics.** The IDL graphics and data processing language, developed by Research Systems, Inc. (www.rsiinc.com), has been incorporated into the kSA 400, yielding extraordinary graphing and visualization power. 3D rendering, triple region plots, multiple data set display, interactive mouse rotation, and full plot customization are just a few of the new data visualization features.

3) **Programmability.** You can now write your own image process filters, data processing filters, analysis routines, and real-time charts in the kSA 400. Using IDL™ (the Interactive Data Language), C-like procedures may be written using a standard text editor. These procedures are then compiled at launch of the kSA 400 system, and the successfully compiled procedures become part of the kSA 400 application.

4) **Additional Import/Export Capability.** All kSA 400 images may be exported to .tif, .gif, .bmp, and .png files. kSA 400 charts may be exported to .tif, .wmf, .bmp, .eps, .png, and .txt files.

5) **Spreadsheet/Excel™ Capability.** Any kSA 400 chart may now be displayed in Excel spreadsheet form, and may also be exported to .xls (Excel) file format.



6) **Networking Capability.** For sites desiring multiple users for data analysis and archiving, a network-capable software license is now possible, allowing multiple users to perform all kSA 400 functions, with the exception of data acquisition from a live video source.

7) **Firewire and USB Camera Support.** The kSA 400 now supports acquisition from IEEE-1394 (Firewire) and USB cameras.

8) **Real-Time/Near Real-Time Surface, Contour, and Histogram Charts.** Now you can display real-time (or near real-time, depending on your cpu speed and size of region of interest) surface, contour, and histogram charts as live video streams in, all while still acquiring data (Scan Mode) or simply displaying the incoming data (Focus Mode).

- **Version 4.30 Enhancements:**

1) **Double Precision Data Storage.** All calculated parameters are now stored with double precision instead of single precision float for utmost accuracy. All generated data files (with the exception of image files) store values as double precision float as well.

2) **Easy Chart Rescaling.** Simple x and y-range rescaling using mouse positioning over the chart. Does away with the need to manually set x-range and y-range with numerical values. Note the rescaling automatically applies to any derived charts, i.e. a derived chart is automatically updated based on the new data set in the rescaled chart.

3) **Movie Filters.** Now you can trim your movies by cutting frames at the beginning or end, and skipping N frames throughout the movie to generate new, smaller movies.

4) **More Image Processing Filters.** We've added more image processing filters, including "Spot Finder", which allows you to locate and mark spots in images.

5) **Three Different Fitting Techniques for Growth Rate.** We've added more growth rate fitting techniques. We now offer growth rate FFT, growth rate extrema counter and growth rate damped sine fit.

6) **User-Defined Current Limit for Gun Control Option.** Per our customers' requests, you can now set your own maximum allowable filament current. This value overrides the default gun maximum current, although the user's inputted value can never exceed the manufacturer's specified maximum value

- **Version 4.40 Enhancements:**

1) **Manual Tracking.** Allows user to manually move tracking boxes in the event that the spots move out of range, for example due to a phase transition.

2) **Storing Regions on an Image.** Associate a box with a certain spot on a RHEED pattern.

3) **Color Map.** Stores data in the same color as the box associated to the region the data came from.

- **Version 4.60 Enhancements:**

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4) **Real-Time Growth Rate.** Allows user to manually move tracking boxes in the event that the spots move out of range, for example due to a phase transition. A chart is displayed that shows the growth rate in real-time, while taking data. Previously growth rate could only be determined after the data run was finished, post acquisition

5) **Real-Time Scan Mode Image Display.** Allows user to see the lines in a Scan Mode image as it is being generated during acquisition as opposed to after the acquisition is complete.

6) **Region Color and Windows displayed and Stored in Data Files.** In Scan Mode when storing an image the selected regions (windows and lines) and their associated colors are saved and displayed in the data file. This makes it easy to go back and see where data was taken from in the image.

7) **Increased Data Point Limit.** Previous version of the kSA 400 could acquire a maximum of 30,000 data points in Scan Mode. Now the kSA 400 can acquire up to 1 billion data points to allow for taking a lot of data over a long period of time.

8) **Multiple Live Video Inputs to PXR Frame Grabber.** kSA 400 now accommodates inputs for up to four separate cameras using a PXR analog frame grabber.

9) **New Data Acquisition Support, Including USB-based analog I/O**. USB data I/O modules, for example analog in and analog out, are now supported. USB data modules plug into the USB port, no PCI slot needed.

10) **More Firewire Camera Support.** kSA 400 now supports a variety of firewire cameras with simple cabling and inexpensive firewire boards.

11) **More Efficient Memory Management.** kSA 400 is now more efficient with clearing memory that is no longer being used allowing users to run the software for long periods of time without running our of memory.

4) kSA 400 TYPICAL DATA RESOLUTION CAPABILITIES

Note: the following were determined using a P43 phosphor screen and a VG™ LEG110 RHEED gun operating at 14keV, with a main beam spot size on the phosphor of 0.86 mrad and a camera length of 12".

- 50 image acquisitions and data extractions per second maximum time resolution (model K200D camera). Camera shutter speed down to 100 usec.
- Time-resolved in-plane atomic spacing changes measurable to less than 0.06%.
- Time-resolved in-plane coherence length accuracy to within 10 Å (assuming the resolving power is not being approached).
- RHEED oscillations detectable when amplitude variation is at least 2% of the signal.