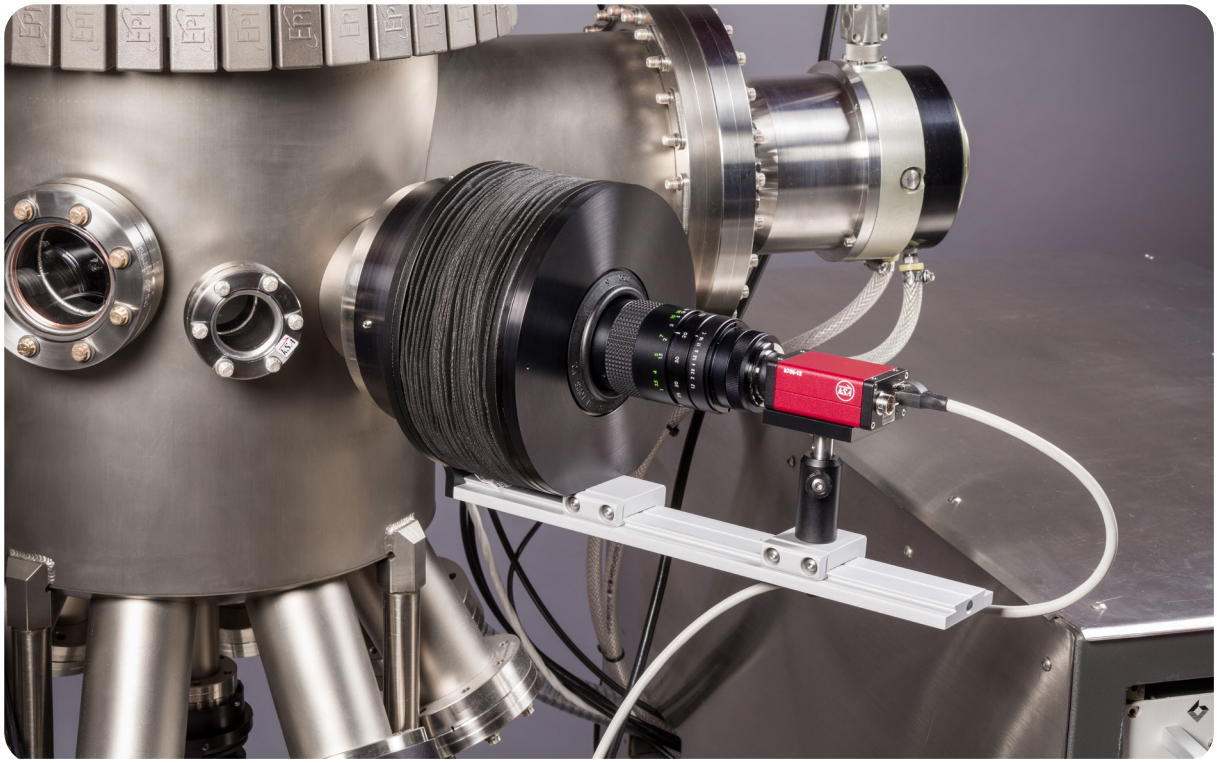
kSA 400 Analytical RHEED System
Product Specifications



The kSA 400 is the industry's most powerful analytical Reflection High-Energy Electron Diffraction (RHEED) analysis system available, providing the most information from RHEED patterns. This advanced surface science tool combines a high-resolution, high-sensitivity camera and optimized optics with sophisticated data acquisition and analysis software designed specifically for RHEED. Extensive input from k-Space's worldwide customer base has made this system both powerful and user friendly. Real-time results are available for both static patterns and during deposition and annealing. The system offers seamless integration with Staib and R-DEC electron guns. The kSA 400 is used to evaluate:

- Growth rate
- Lattice spacing
- Strain evolution
- Coherence length and surface evolution
- Reconstruction evolution
- Surface structure

Exploit the Power of RHEED with the kSA 400!

System Overview

Every kSA 400 system comes with all of the software and hardware needed for full RHEED acquisition and analysis. Select the options from the standard package, and expand the capabilities from the list of optional plug-ins and add-ons. Each subsystem is detailed in the following sections.

Components and Options

STANDARD PACKAGE	
Component / Description	**Option / Part Number**
Detector	k700-12: all around camera
	k2750-14: high resolution & sensitivity
Flange Mount (Please specify the value of X based on the flange outer diameter. See page 4 for more information.)	k4AFM-X: Standard
	k4OFM-X: Open with soft cover
	k4RAFM-X: Right angle right
	k4RRAFM-X: Right angle left
Data Acquisition and Analysis Software	kSA 400
	kSA 400 Lite
OPTIONAL ADD-ONS	
Computer	kCPU-DT: kSA Desktop
	kNB-LLT: Laptop
	kNB-LLT: Laptop Computer
	kCPU-A4U: kSA 4U Rack Mount
	kCPU-DELL: Dell Desktop
Software	k4MDS: Multiple Data Set Acquisition
	k4AOS: Analysis only software
Trigger / Home Pulse Signal Conditioner	k4SIGC
Rotation Monitoring and Triggering	kSA-RMT
Optically Based Rotational Triggering	kSA-TRG
Data Acquisition Trigger Cable	k700-T: 30’ cable for k700-12
	k2750-T: 30’ cable for k2750-14
OPTIONAL PLUG-INS	
LEED I/V	k4LIV
Phase Locked Epitaxy	k4PLE
Auger / X-Ray Photo-Emission Spectroscopy (XPS)	k4AXR
Electron Gun Control / Beam Rocking	k4EGC (Staib)
	k4EGC-R (R-DEC)
Digital I/O for k4MDS and kSA-RMT interfacing	k4DIGIO

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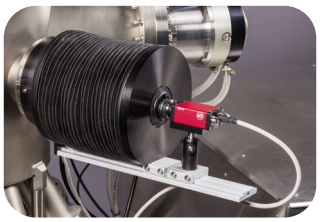
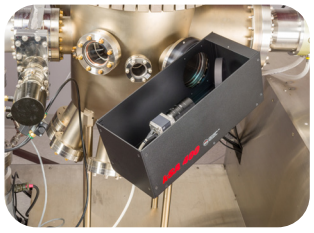
Hardware Specifications

Detectors

		
MODEL	k700-12	k2750-14
kSA 400 PURPOSE	Good All Around Camera	High Resolution and High Sensitivity
CCD FORMAT AND TYPE	1/2” Sony ICX414 Progressive Scan	1” Sony ICX694 Progressive Scan
RESOLUTION (pixels)	656 x 492	2752 x 2206
PIXEL SIZE (µm x µm)	9.9	4.54
DYNAMIC RANGE (dB)	62	64
TOTAL QUANTUM EFFICIENCY (% at 530 nm)	33	65
EXPOSURE TIME (msec)	0.026 - 60,000	0.041 - 38,000
FRAME RATE (frames per sec)	88	15
BIT DEPTH (bits)	12	14
LENS MOUNT	C-type	C-type
DIMENSIONS (L x W x H, mm)	86.4 x 44 x 29	86.4 x 44 x 29
POWER (V DC)	12 (Power over Ethernet)	12 (Power over Ethernet)
INTERFACE	GigE	GigE
INTERFACE BOARD	PCIe-GIE72, PCIe x4 slot (PCIe slot upon request)	PCIe-GIE72, PCIe x4 slot (PCIe slot upon request)
CABLING	30’ CAT6 DBL S (double shielded)	30’ CAT6 DBL S (double shielded)
TRIGGERING	External trigger via TTL level input pulse (requires optional k700-T cable)	External trigger via TTL level input pulse (Requires optional k2750-T cable)

Flange Mounts

k-Space offers three different flange mounts to accommodate most chamber configurations. All options limit stray light on the RHEED screen, for optimum image contrast. All mounts have adjustable rails to ensure proper location of the camera and lens. Customized flange mounts and optics are available upon request.

			
MODEL (X = FLANGE SIZE)	Standard k4AFM-X	Open with Soft Cover k4OFM-X	Right Angle k4RRAFM-X (Left, as shown) k4RAFM-X (Right)
CONFLAT FLANGE SIZES	4.5”, 6”, 8”	4.5”, 6”, 8”	4.5”, 6”, 8”
SPACE REQUIREMENTS* (W x H x L)	7.8” x 8.5” x 13.2” - 14.6”	3.0” x 4.5” x 14.1”	6.2” x 6.7” x 16.2”
BENEFITS	Easy access to camera & RHEED screen via magnetically coupled sleeve Completely light tight	Used when rigid mounting cannot be accommodated Easy cover removal / replacement	Enables mounting with limited access to the viewport

*NOTES: A range is included for the standard mount length, as space requirements are dependent on lens and camera selection. The open mount space requirements do not include the soft cover. Dimensions for all mounts do not include flange adapter ring. Dimensions are included here for guidance only. Please allow at least 1” additional length for cable bend radius. If your application has specific space constraints, please contact k-Space for drawings.

Optics

k-Space ensures the proper selection of optics and lens spacers based on the selected flange mount, camera, and RHEED screen position. Standard optics include:

- Lens
- Optical rail
- Rail carrier
- Post
- Post holder for mounting detector and optics

For high pressure RHEED applications, or systems with non-zero flange mount-to-RHEED screen distances, customers must specify the distance between the RHEED screen and the view port, along with any other important focal distances and imaging areas. This will help to ensure that the optics are optimized for the specified application.

Computer Requirements

k-Space highly recommends purchasing a custom computer specifically designed by k-Space for optimum data throughput, fast processing and optimum expandability, and to ensure your system is ready to use right out of the box. Please refer to the kSA computer product specification for details. If another computer is used it must meet the following minimum specifications:

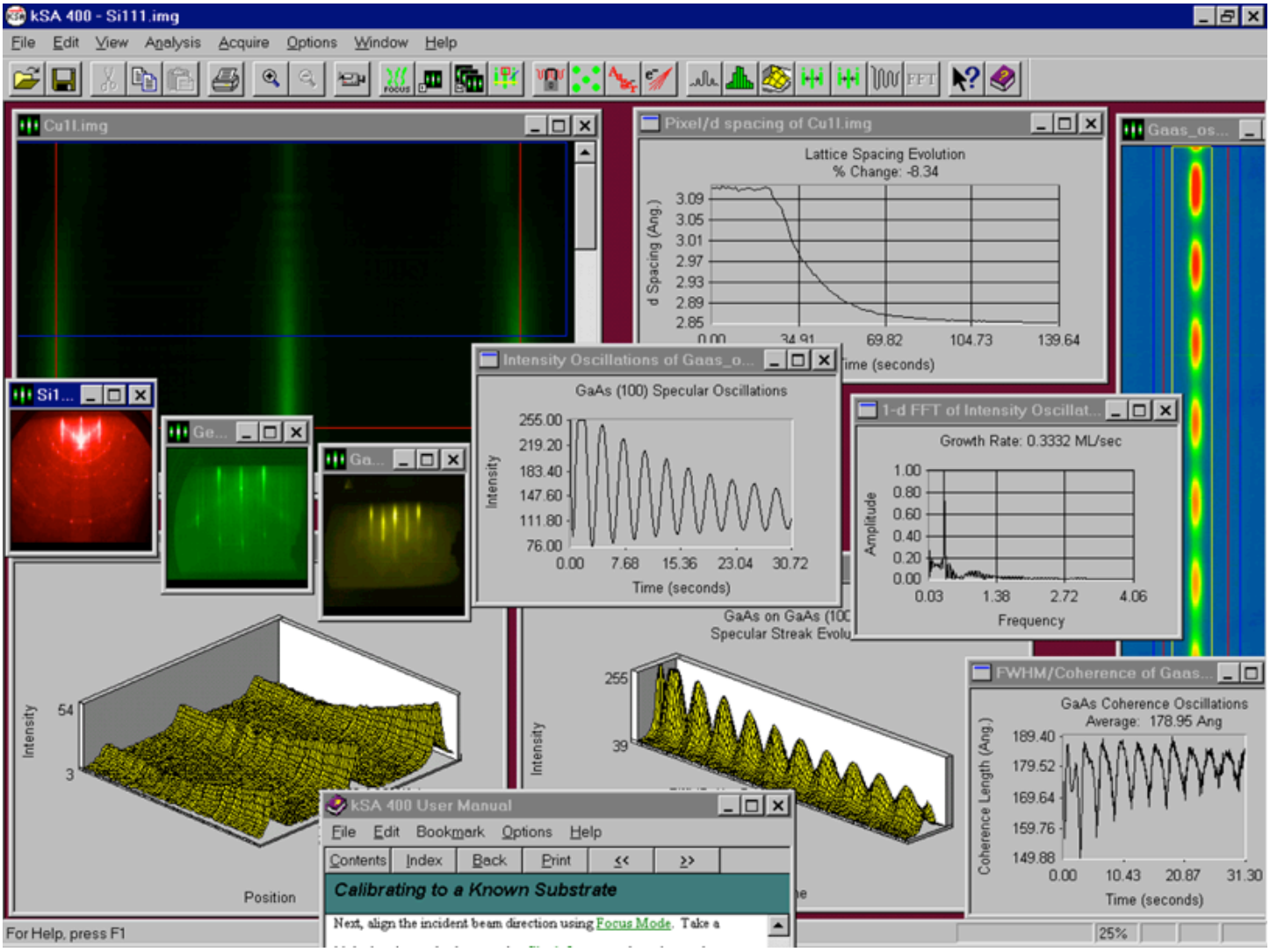
l-*Processor:* Dual Core or higher, minimum I5
m-*Memory:* Minimum 8 GB for kSA 400 Lite; 16 GB for kSA 400
n-*Video:* 1 GB DVI or HDMI video card
o-*Hard Disk:* Minimum 500 GB
p-*OS:* Windows™ 10
q-*Minimum Backplane Slots:* 1 available PCIe x4 slot for camera interface board
r-*Plug-In Options:* For users purchasing any of the Plug-In options (LEED I/V, PLE, Auger/XPS, or Electron Gun Control), additional data acquisition boards and PCI slots will be required. Please refer to the appropriate Plug-In Section in these specifications for further details.
s-*Power Supply:* Because the standard kSA 400 draws its power from the computer, we recommend 365-450W for the computer power supply.

Functional Specifications

Time resolved in plane atomic spacing changes	0.06% change detectable
Time resolved in plane coherence length accuracy	± 10 Å
RHEED oscillation detection level	Amplitude variation > 2% of signal

Software

The kSA 400 is the most powerful analytical RHEED software available. k-Space offers three RHEED software packages for a full range of RHEED acquisition and analysis. All are user-friendly, and built in the Windows 10 standard environment, with extensive error-checking and file handling. The tables on the following pages highlight the capabilities of each package.



RHEED Acquisition and Analysis Software Suite

kSA 400

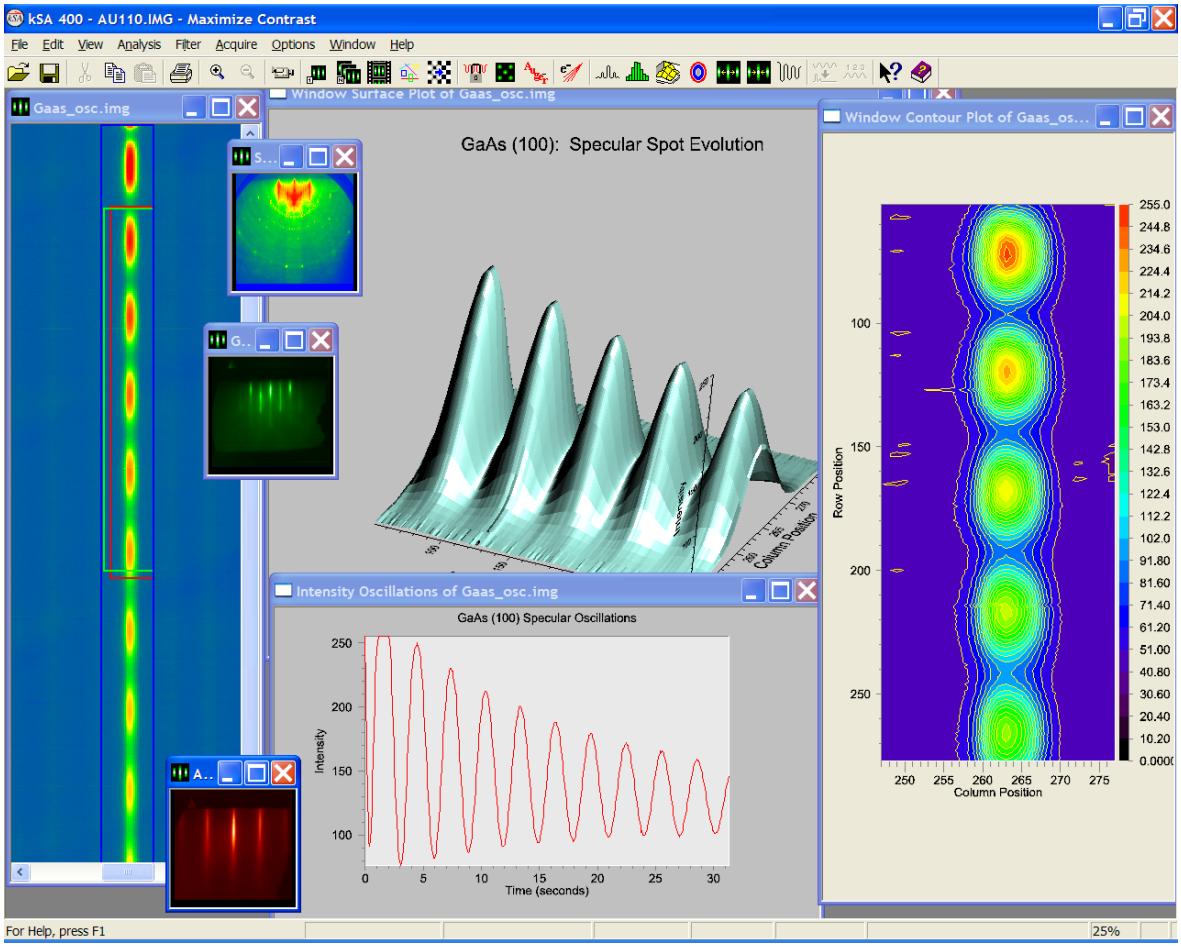
The kSA 400 is the most advanced, full feature RHEED Data Acquisition and Analysis package available. With a long list of capabilities, the kSA 400 offers the most insight from RHEED patterns. One complimentary kSA 400 AOS license is included with the standard kSA 400.

kSA 400 Lite

A RHEED acquisition and analysis package for those requiring only basic image capture and data analysis. The Lite package can be upgraded to the full featured version of kSA 400 at any time.

kSA 400 AOS

An analysis only version designed for users who want to perform post-acquisition display, processing, and analysis away from the laboratory. The analysis software license is available to users that currently own a full kSA 400 system.



Acquisition Modes

CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
ACQUISITION			
Camera Control			
Full exposure control	✓	✓	
Soft or hard external triggering	✓	✓	
Gain control	✓	✓	
Programmable 8-bit or 10-bit data output	✓	✓	
Programmable binning for up to 50 fps output	✓	✓	
Data Acquisition Modes			
Single Image Mode: Acquire single images for quantitative static analysis and archiving.	✓	✓	
Multiple Image Mode: Acquire a user selected number of diffraction images sequentially for quantitative analysis and archiving. Acquire in real-time to system RAM up to the limit of physical memory, or store to hard disk.	✓		
Focus Mode: Display real-time line profiles, surface plots, and contour plots on user-defined regions of the diffraction pattern, enabling focusing and alignment without saving.	✓		
Scan Mode: Simultaneously monitor an arbitrary number of lines and windows of the incoming diffraction pattern, 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 or ellipses of any size.	✓		
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 acts as an acquisition source for later analysis.	✓		
Interactive Accumulation Mode: Continuous display of a real-time summed image. Useful for monitoring build-up of system noise, or monitoring pattern shifts with a single image.	✓		
Growth Rate Mode: Acquire intensity data from an unlimited number of user defined windows, which can be rectangles or ellipses.	✓	limited to 1 window	

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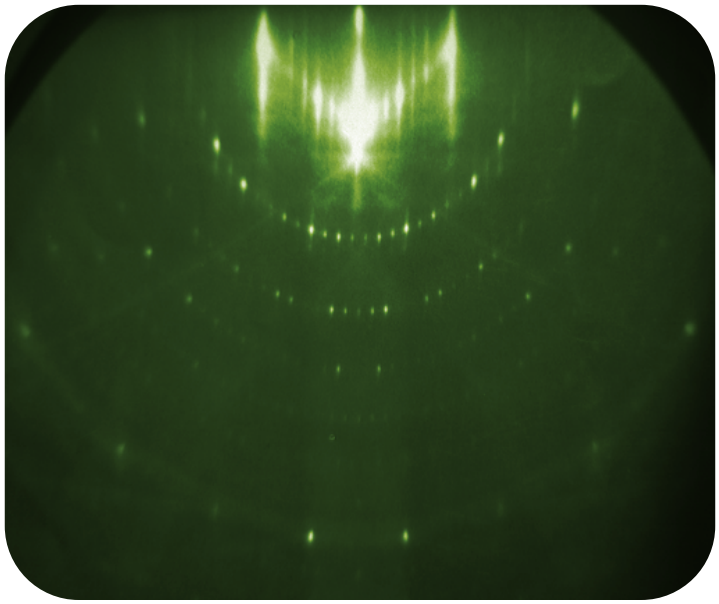
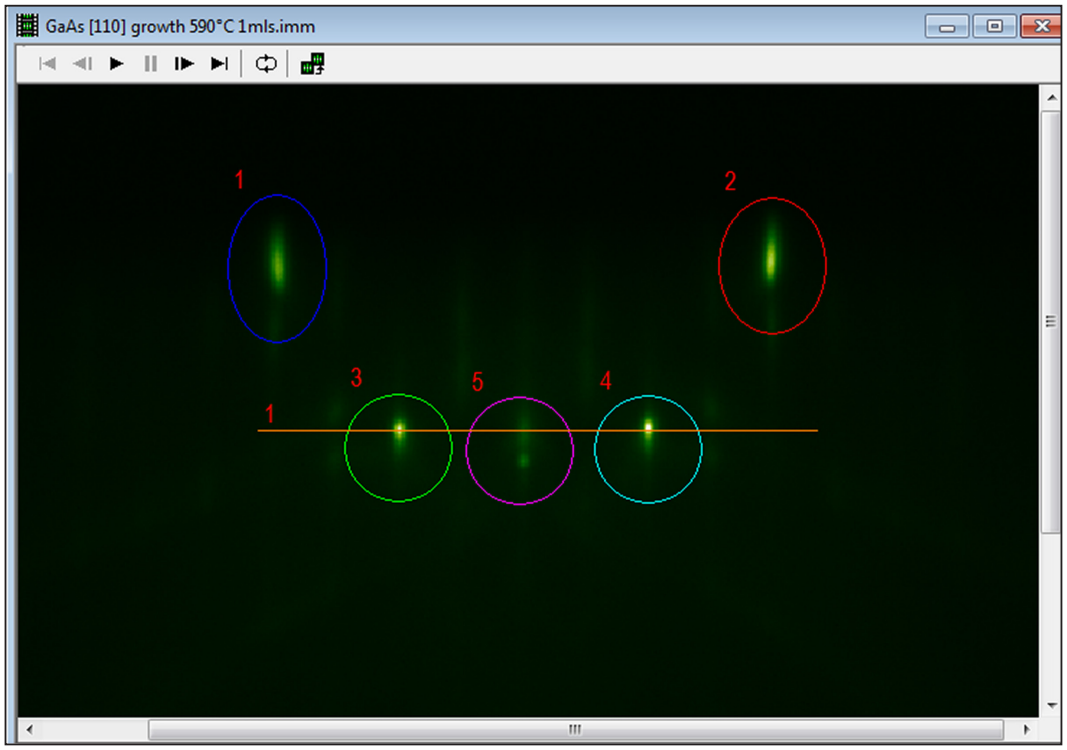
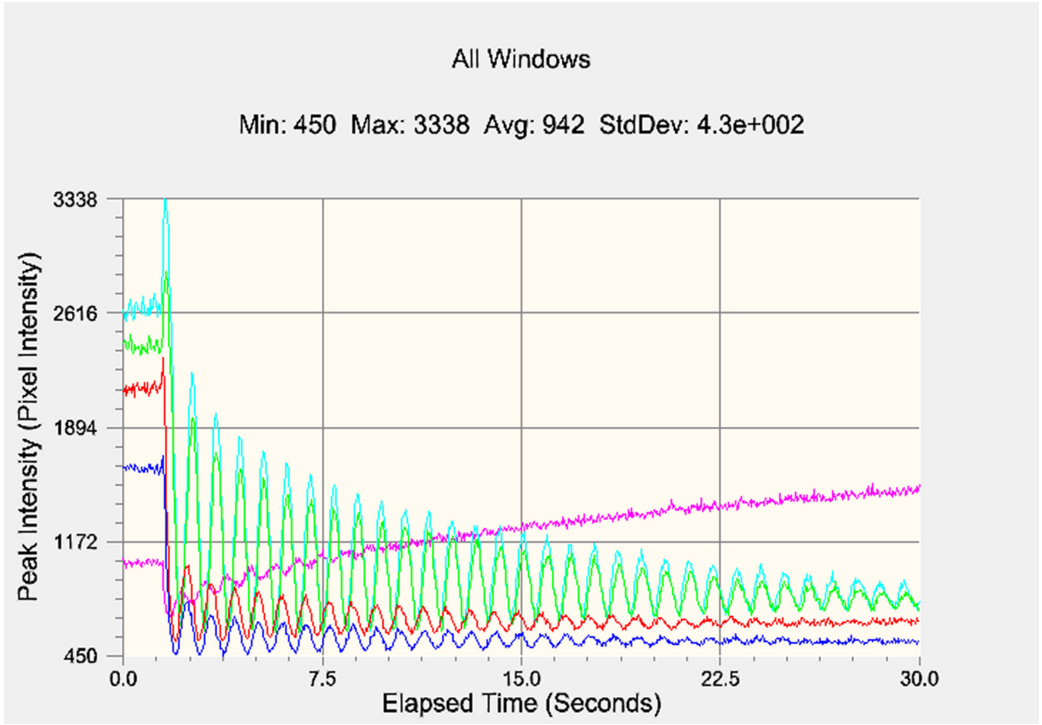
CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
Acquisition Capabilities			
Tracking: Repositions window center on the brightest portion of the diffraction streak/ spot, or on the centroid position. The position of the peak intensity/centroid intensity is recorded for each incoming image during data acquisition.	✓	✓	
Manual Tracking: Manually move tracking boxes in the event that the spots move out of range, for example due to a phase transition.	✓	✓	
Multi-Threaded Video: Display the on-screen video with interactive camera integration, frame summation, and filtering in real-time or near real-time, while performing other kSA 400 operations.	✓	✓	
Real-Time Zoom: Live video zoom from 25% to 300%.	✓	✓	
External Trigger: Trigger and synchronize data acquisition at the occurrence of specific events, (e.g. at specific rotation angles during substrate rotation.)	✓	✓	
Start / Stop Trigger: Begin and end data acquisition from an external signal input. This is separate from the standard external trigger capability, which uses a trigger signal to grab each frame of the data acquisition.	✓	✓	
Real-Time False Color Palettes: Choose from over 100 colors to apply to the real-time image.	✓	✓	
Enhanced Real-Time Charts: Open, close, smooth, resize or rescale real-time charts during acquisition. Any window analysis parameter can be plotted on the x or y axis.	✓	✓	
Plug-In and Add-On Support: Support for Multiple Data Sets and all Plug-Ins.	✓		



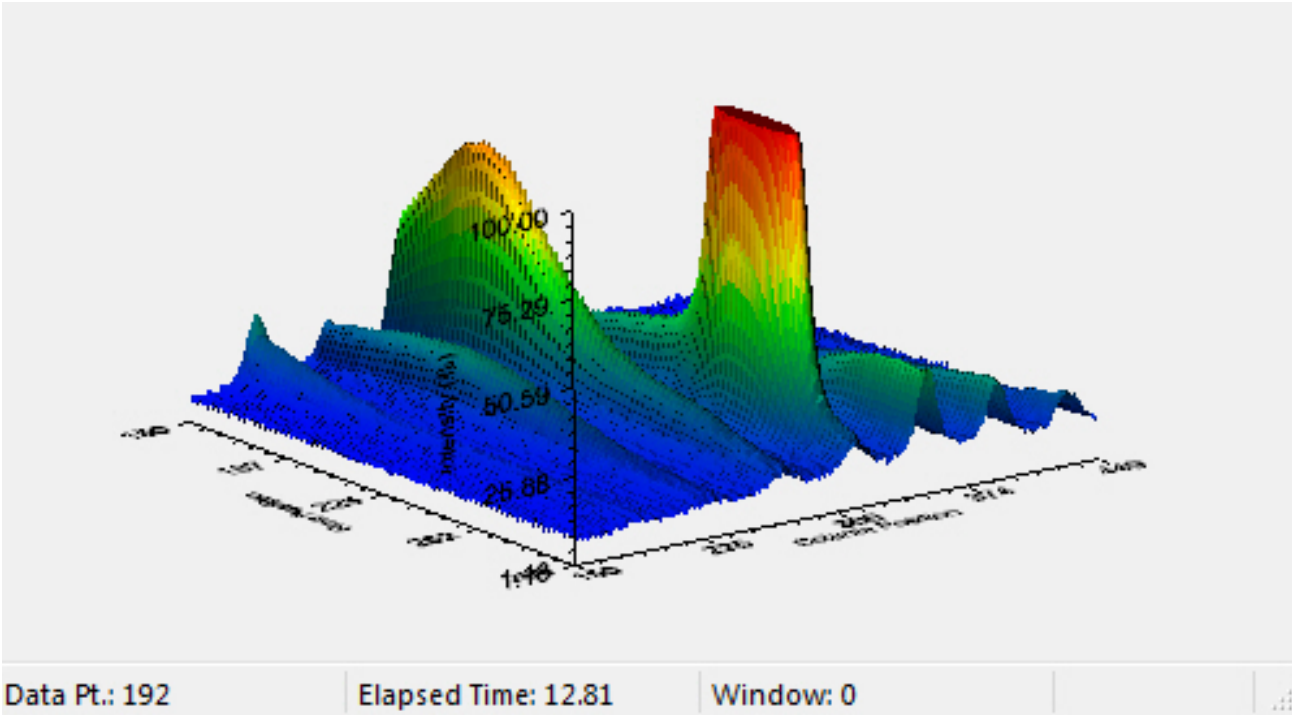
Sample Image from RHEED Image Library



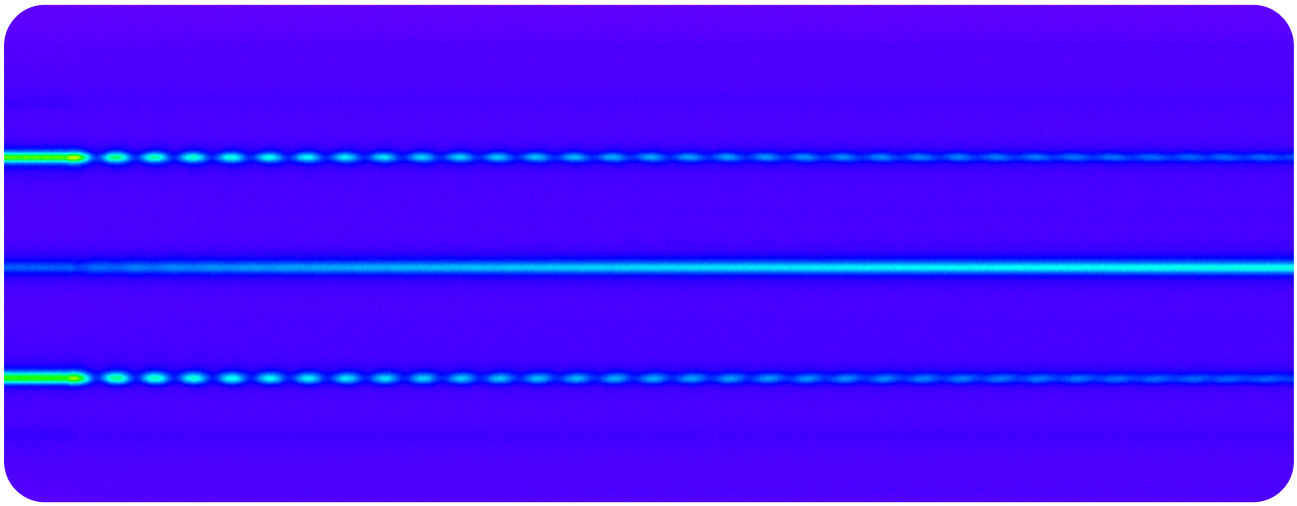


Window Analysis and Charts in Real-Time

CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
Acquisition Capabilities			
Real-Time Exposure Control & Background Subtraction: Select the camera integration time and turn background subtraction on or off. 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 acquisitions, accurate to 0.01 sec, may be selected.	✓	✓	
Real-Time Near Real-Time Surface, Contour and Histogram Charts: Display real-time (or near real-time, depending on CPU speed and size of region of interest) surface, contour, and histogram charts as live video streams in, while acquiring data (scan mode) or displaying data (focus mode).	✓		
Real-Time Growth Rate Determination: Determine real-time growth rate using damped sine wave fitting analysis during acquisition. Compare this with growth rate and thickness analysis using Discrete-Fourier Transform (DFT) analysis and derivative analysis.	✓	✓	
Real-Time Lattice Spacing: Display the surface lattice spacing, or with an uncalibrated RHEED pattern, display the raw pixel spacing, during data acquisition.	✓		
Real-Time FWHM / Coherence Length: Display the evolution of the diffraction streak FWHM/coherence length during data acquisition.	✓		
Easy Chart Rescaling: Position the mouse on the chart for simple x and y rescaling, which automatically applies to any derived charts.	✓		
ANALYSIS			
Image Analysis Capabilities			
Line Profile Analysis: Analyze line profiles at any angle, length or width.	✓	✓	✓
Statistical Analysis: Full statistical analysis of user-definable windows of any size and location on the image source.	✓	✓	✓
Surface Plots	✓		✓
Contour Plots	✓		✓
Triple Region Plot: Overlay surface, contour and image plots.	✓		✓



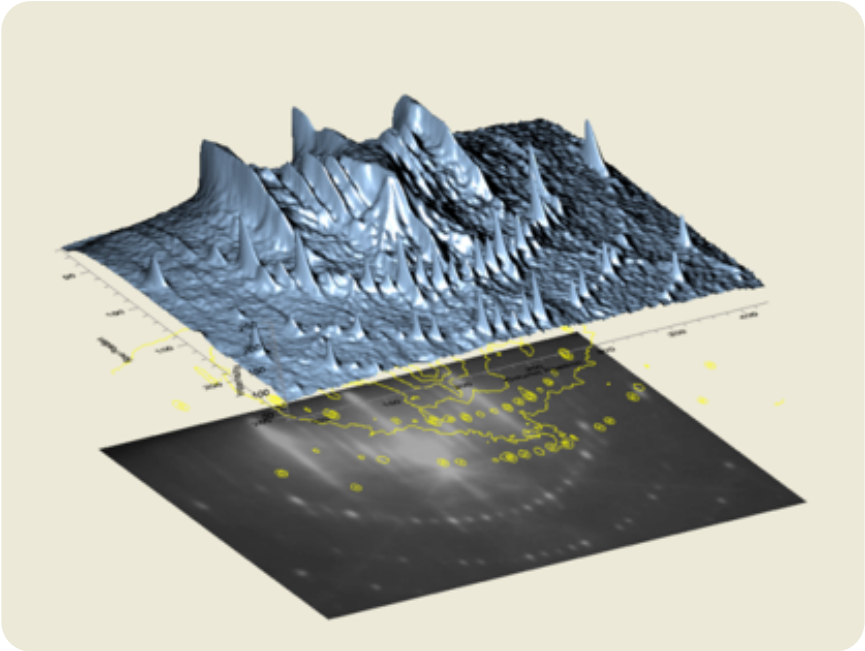
Surface Plot



Scan Mode Image

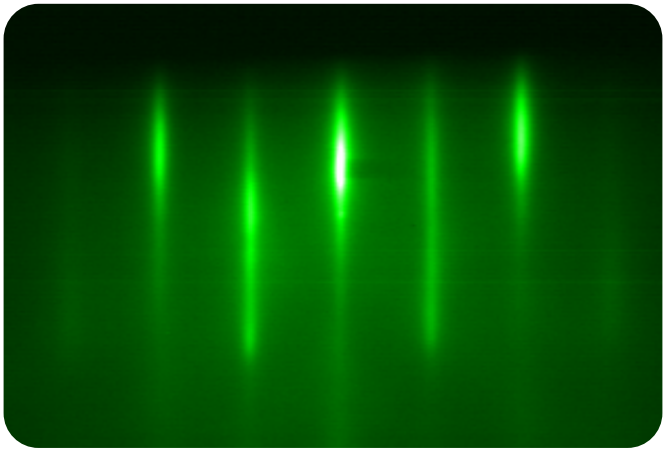
CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
ANALYSIS			
Data Analysis Capabilities			
Data Calculations: Data calculated from each window includes: peak intensity, minimum intensity, summed intensity, average intensity, centroid intensity, elapsed time, data point, peak row, peak column, centroid row, centroid column, standard deviation of intensity.	✓	✓	✓
3 Growth Rate Analysis Methods: Determine growth rate during or after acquisition, using damped sine wave fitting analysis. Compare this with growth rate and thickness analysis using Discrete-Fourier Transform (DFT) analysis and derivative analysis. Output includes growth rate, total thickness, and error in rate determination. All three methods allow for user configurable fitting parameters.	✓	✓	✓
Line Profile Fitting: Accurate determination of streak spacing/in-plane lattice spacing.	✓		✓
FWHM / In-Plane Coherence: Determine FWHM / in-plane coherence length with accuracy.	✓		✓
Time-Resolved Analysis: Monitor in-plane lattice spacing and coherence length to determine strain profiles and domain profiles.	✓		✓
Multiple RHEED Oscillation Monitoring: Monitor an unlimited number of diffraction features to determine growth rate from each as well as phase differences between the oscillations.	✓		✓
In-Plane Spacing, Coherence Length and Intensity Oscillations: Determine all three properties through simultaneous monitoring during growth and conduct post-growth analysis from .kdt data files.	✓		✓
Image Processing Filters: Filter live video, single images, scan mode images, or movies, including 2D FFT, 2-image manipulation (subtraction, addition, etc.,) edge detection, median filtering, band pass filtering, contrast maximization and much more.	✓		✓
Data Processing Filters: Apply data processing and fitting filters to any 2D data, such as linescans, lattice spacing, intensity profiles, etc. Filters include bandpass, derivative, polynomial fit, Gaussian fit, cubic spline fit, Savitzky - Golay digital filter, and much more.	✓		✓

CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
Data Analysis Capabilities			
Advanced Plotting Capabilities: Plot static diffraction images and evolving line scan, column scan, or dual scan images to view evolution of growth in 3D. Interactive 3D graphing enables rotation and perspective, the ability to plot individual data point markers with varying symbols, contour plotting, and a data editor that allows direct editing of data associated with a graph. Data visualization features include 3D rendering, triple region plots, multiple data set display, interactive mouse rotation, and full plot customization. Edit colors and transport graphics directly to Windows™ clipboard, exported to Windows™ Metafile, or .tif format.	✓		✓
EXPORT			
Compress and Convert Image Files: Compress images on-the-fly or post acquisition including files taken with previous versions of the kSA 400 software. The "Zlib" routine is lossless, and typically compresses RHEED images by a factor of 2 or more. Convert to .wmf, .bmp, .eps, .tif, .gif, or .png graphics file formats.	✓	✓	✓
Compress and Convert Movie Files: Compress movies on-the-fly or post acquisition including files taken with previous versions of the kSA 400 software. The "Zlib" routine is lossless, and typically compresses RHEED images by a factor of 2 or more. Convert any kSA .imm movie file to AVI movie format (.avi).	✓		✓
Export Data Sets: Display and export charts in Excel (.xls) spreadsheet form.	✓	✓	✓
Custom Export: Define which parameters to export and save in a template file.	✓	✓	✓



Powerful Plotting Tools

CAPABILITY	kSA 400	kSA 400 Lite	kSA 400 AOS
DATA STORAGE AND COMMUNICATIONS			
Analog and Digital I/O Support: Complete analog and digital I/O support for most data acquisition boards from Measurement Computing Data Translation and National Instruments. 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. Support for PCI and USB-based data acquisition boards.	✓	✓	✓
TCP / IP Support: The kSA 400 supports full TCP / IP communication. Transfer data and control acquisition via the kSA TCP/IP interface.	✓	✓	✓
Networking Capability: Network capable software license for multiple users for data analysis and archiving, with the exception of data acquisition from a live video source.	✓		✓
Log Files: A continuously updated log file records all events, including acquisition times, error messages, processing messages, hardware communication, etc. The log file can be viewed to determine actions and to troubleshoot.	✓	✓	✓
Preferences and Configuration Files: Save all user interface and processing settings to a unique file for multiple users and/or disaster recovery.	✓		✓
User Programmable: Write image processing filters, data processing filters, analysis routines, and real-time charts using IDL™ (the Interactive Data Language). Edit these C-like procedures with a standard text editor, which are compiled at launch of the system. Successfully compiled procedures become part of the kSA 400 application.	✓		✓
Double Precision Data Storage: Store all calculated parameters 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.	✓	✓	✓
RHEED Image Library: Compare important RHEED information with real-world examples of RHEED images and movies supplied by other kSA 400 users.	✓		



Sample Image from RHEED Image Library

Plug-Ins and Add-Ons

The following plug-ins and add-ons expand the capabilities of the kSA 400 system.

Phase Locked Epitaxy and Timed Shutter Control (K4PLE): With an 8-bit DAC 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. Requires one available full length PCI slot.

Electron Gun Control / Beam Rocking (K4EGC or K4EGC-R): Complete control of Staib or R-DEC electron guns with 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. Requires one available full length PCI slot.

Rotation Monitoring and Triggering (kSA RMAT): A 12-bit absolute encoder with built-in programmable logic controller. Trigger accuracy to 0.088 degrees (4096 positions in 360 degrees). Up to 4 independent TTL level outputs, accessible through the supplied encoder cable.

Optically-Based Rotational Triggering (kSA-TRG): Module provides ability to synchronize data acquisition with sample rotation. Includes optical sensor with mounting holes, and cable. Custom mounting brackets quoted separately.

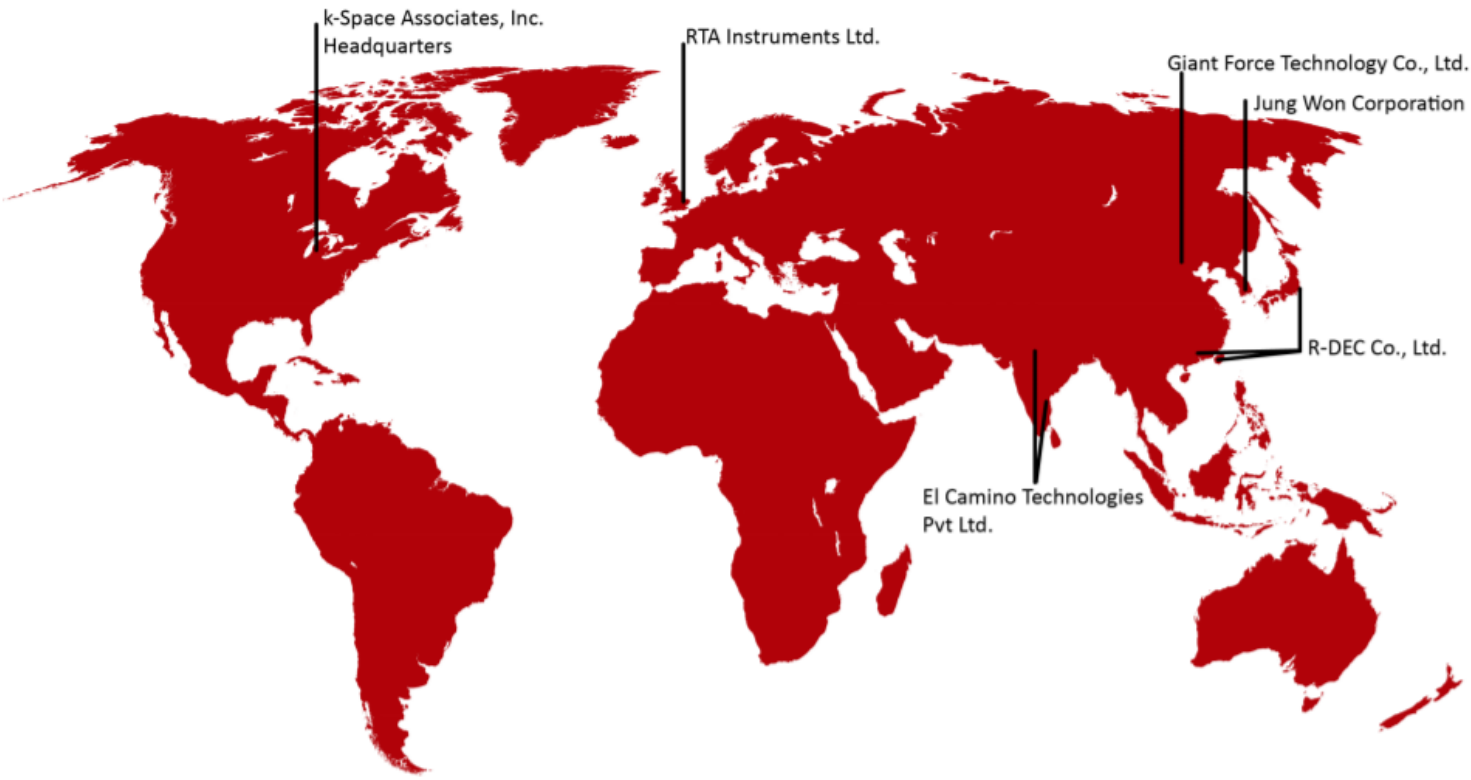
Multiple Data Sets (K4MDS): Generate multiple data sets from a single acquisition by programming the system to separate the data based on multiple gun settings, rotation angles, or other user defined setting. Separating data sets enhances the user's ability to analyze data quickly and efficiently.

Computer (kCPU-DT, kCPU-A4U, kCPU-DELL): High performance computer to meet the processing requirements of the kSA 400 software and analysis tools. Systems purchased with a computer are fully tested and ready for analysis.

LEED I/V (K4LIV): Simultaneously monitor and analyze up to 8 different windows of the incoming diffraction pattern while a 12-bit DAC controls the beam energy of an external LEED gun. Map out I/V curves and select kinematic scattering calculation tracking or peak intensity tracking. Requires one available full length PCI slot.

Auger / X-Ray Photo-emission Spectroscopy (AES / XPS) (K4AXR): AES/XPS data acquisition via 12-bit DAC and ADC boards with accompanying control software. User-configurable output voltage, energy step size, number of samples per energy, scan rate, and number of scans. Requires one available full length PCI slot.

Trigger / Home Pulse Signal Conditioner for kSA 400 Control Computer (k4SIGC): Signal Conditioner accepts 2 V to 25 V rising/falling edge pulse, with a pulse width greater than 100 µs via a BNC connector and converts this into a TTL signal suitable for integration with kSA 400 hardware and software.



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