kSA ACE - Atomic Control for Epitaxy

Atomic Flux Control

Accurate and high resolution flux and growth rate monitoring

kSA ACE is a highly sensitive instrument that measures the *in situ* flux rate of atomic species using the principle of atomic absorption spectroscopy. The kSA ACE system uses conventional hollow cathode lamps (HCLs) to generate the atomic emission for the elements of interest. A high-sensitivity, UV-optimized solid-state spectrometer is utilized to monitor the absorption, along with a second spectrometer to monitor signal drift from the HCLs. Since the technique is inherently material-specific, the signal does not respond to other species or radiation in the chamber. kSA ACE can measure each material of interest independently with high accuracy, providing precise material-specific flux control in multi-source evaporation or co-sputtering processes. With its high sensitivity and long-term repeatability under continuous operation, kSA ACE has applications in the fabrication of III-V and II-VI compounds, semiconductor devices, thin film sensors, solar cells, optical coatings, x-ray optics, flat panel displays, and more.

Real-Time System Capabilities
Real-time flux density measurement
Real-time growth rate measurement
Real-time composition control

Processes
Molecular Beam Epitaxy
Evaporation: Knudsen (effusion) cells, e-beam sources, ion-beam assisted, induction source, resistive heated source
Sputtering: RF/DC magnetron, ion-beam, reactive
Pulsed laser deposition
Plasma etch processes

Material Examples [1]
Ag, Al, Au, Ba, Bi, Ca, Cd, Co, Cr, Ca, Cu, Dy, Fe, Ga, Ge, Hf, In, La, Mg, Mn, Mo, Ni, Pb, Si, Sn, Sr, Ta, Ti, W, Y, Zn, Zr

[1] The sensitivity of the ACE system depends on the material as well as the absorption path. The system cannot detect molecular species such as molecules from a compound sputtering target, or molecular species such as As_2, Se_2, etc., from evaporation sources. Some materials are not available in hollow cathode lamps.

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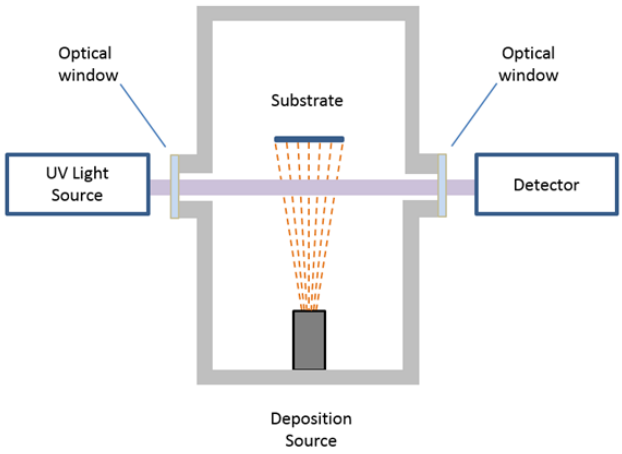
Technology Overview

The kSA ACE instrument combines the UV atomic emission lines of up to three hollow cathode lamps (HCLs) into a colinear beam. The beam is split into a reference channel and a signal channel. High-sensitivity, high-spatial-resolution spectrometers are used to monitor the reference channel and signal channel—for up to three selected elements. The reference channel provides continuous correction for HCL intensity fluctuation. The signal beam is fiber coupled to lens cells on the process chamber and then passes through the flux of the deposition sources, resulting in attenuation of the atomic lines specific to the resonant absorption of the atom species. The attenuation is proportional to the atomic density within the volume of the signal channel beam. The system also includes a Xe flash lamp, colinear with the HCL beam path, to correct for viewport coating. The entire optical subsystem is temperature stabilized, including HCLs, beam collimation optics, and spectrometers, to ensure long-term stability and accuracy.



Model	Description
ACE-FM-SP	• Provides real-time monitoring of atomic fluxes via Atomic Absorption Spectroscopy of specified elements, up to three per system. Measures real-time growth rate and flux density. Single pass beam optics. • Provides analog voltage outputs proportional to absorption or rate and TCP/IP for process control. • Includes kSA ACE 4U and 1U hardware/electronics rack, fibers, detector and source optical heads, mounting hardware, cabling and kSA ACE software. • Note: kSA ACE requires one USB computer connection. Optional computer quoted separately.
ACE-FM-DP	• Provides real-time monitoring of atomic fluxes via Atomic Absorption Spectroscopy of specified elements, up to three per system. Measures real-time growth rate and flux density. Dual pass beam optics. • Provides analog voltage outputs proportional to absorption or rate and TCP/IP for process control. • Includes kSA ACE 4U and 1U hardware/electronics rack, fibers, detector and source optical heads, mounting hardware, cabling and kSA ACE software. • Note: kSA ACE requires one USB computer connection. Optional computer quoted separately.

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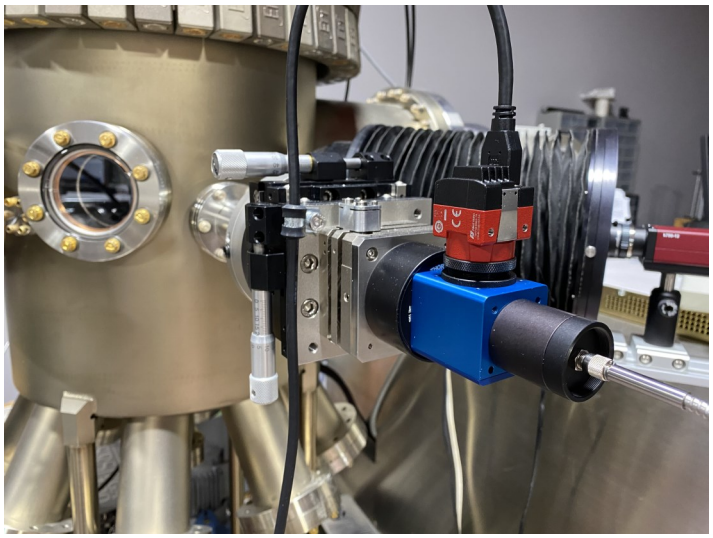
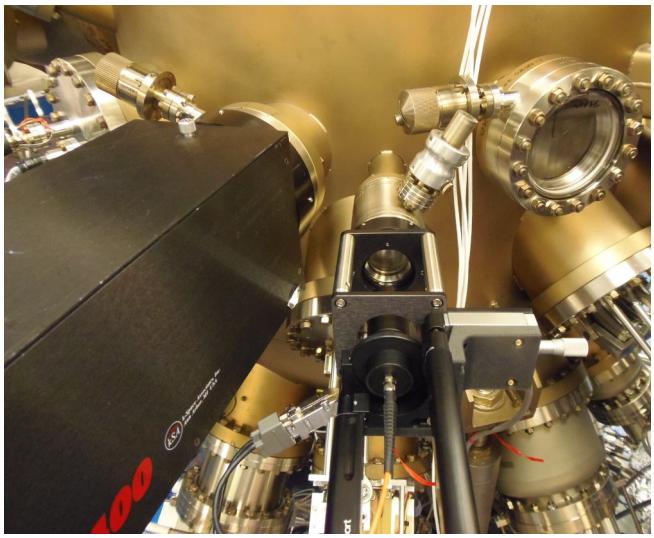


kSA ACE detector with beam monitoring camera for ease of alignment and real-time characterization of beam profile.



kSA ACE motorized auto-alignment correcting light source optics head.

Specifications

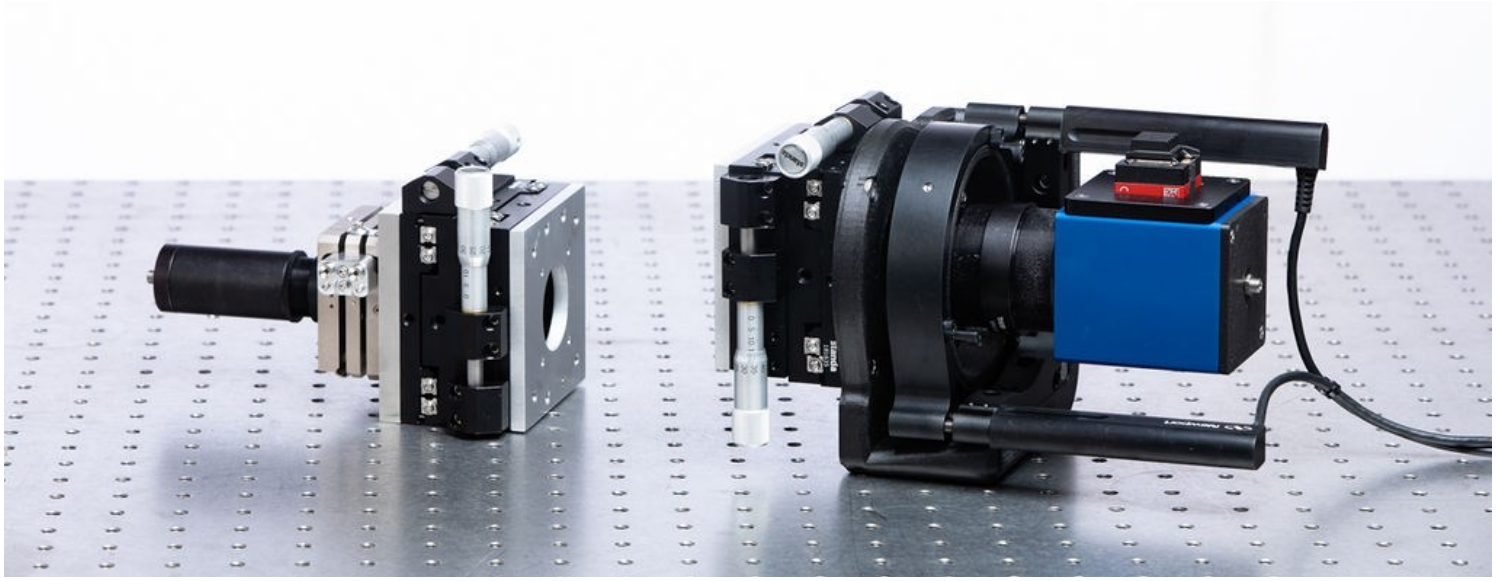
Operating Pressure Range	Typical physical vapor deposition conditions for MBE, e-beam, PLD, and sputtering processes.
Stability	Better than 0.1% over a 2 hr deposition. System is re-zeroed every time the growth is interrupted/source shutter is closed.
Source Flux Control	TCP/IP or analog output. Typical update rate: 0.5—1.0 Hz.
# of Sources Operational at One Time:	1-3
Sources Available[1]	Ag, Al, Au, Ba, Bi, Ca, Cd, Co, Cr, Ca, Cu, Dy, Fe, Ga, Ge, Hf, In, La, Mg, Mn, Mo, Ni, Pb, Si, Sn, Sr, Ta, Ti, W, Y, Zn, Zr
Communications and I/O Interface	USB, Analog, TCP/IP

[1]The sensitivity of the ACE system depends on the material as well as the absorption path. The system cannot detect molecular species such as molecules from a compound sputtering target, or molecular species such as As2, Se2, etc., from evaporation sources. Some materials are not available in hollow cathode lamps.

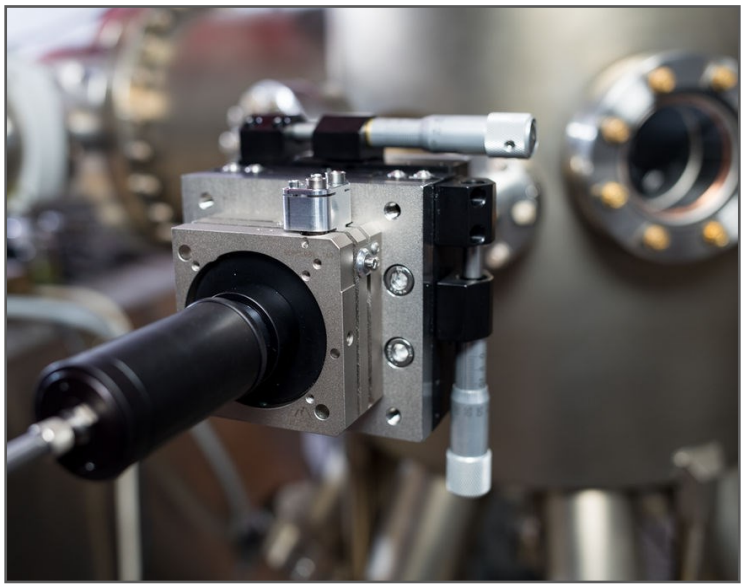
Options

Model	Description
ACE-BD	• Beam drift control for real-time alignment of the beam. Only applicable to single pass systems.
kCPU-DT	• kSA Mid Tower-Style Integrated Controller. High-performance control platform optimized for real-time process monitoring. Includes Monitor, keyboard, and mouse.

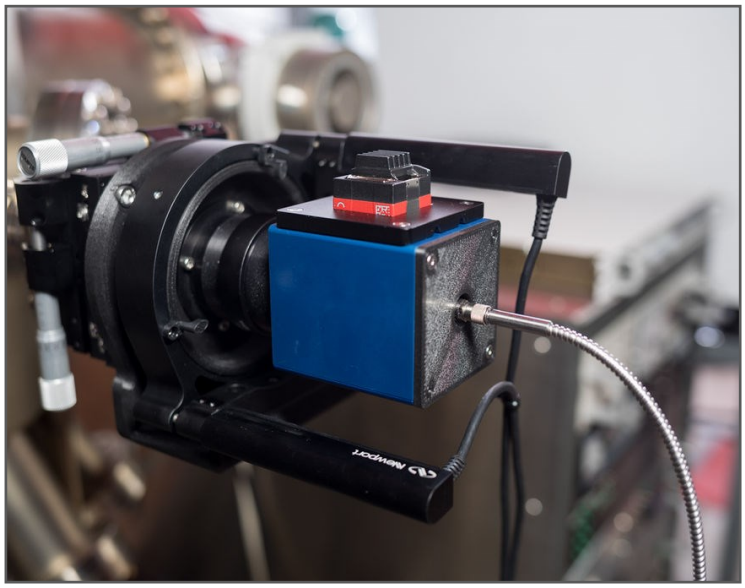
Optics Heads



The emission optics head (light source, left) and the detector optics head install on viewports directly opposite of each other on the chamber. See additional optical access information under *Additional Requirements* section.



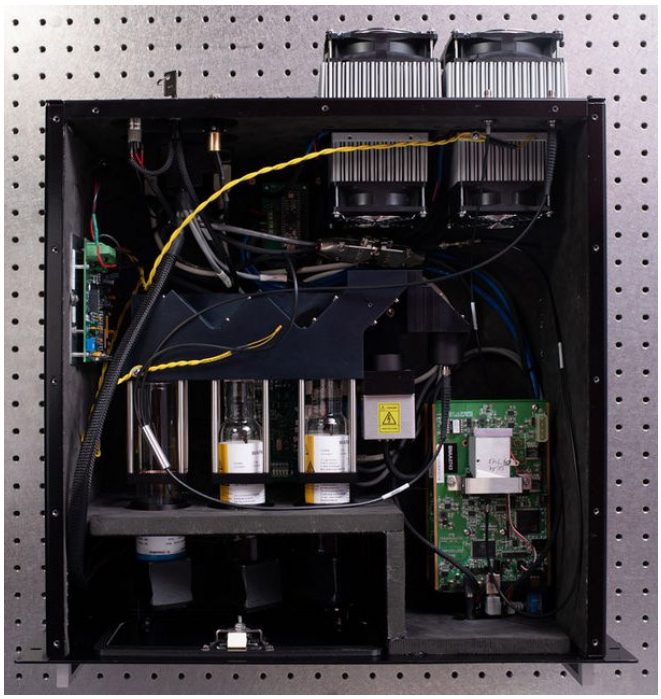
Emission Optics Head (Light Source)



Detector Optics Head with Auto Alignment Motors

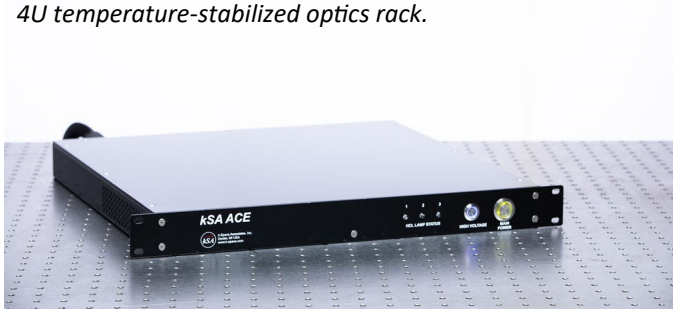
This detector head with camera allows for real-time adjustment of the beam position to account for any mechanical drift. This is typically needed on large, production-level chambers where the thermo-mechanical drift is prevalent.

19” Racks



Interior of temperature stabilized optics rack showing three HCL bulbs.

4U temperature-stabilized optics rack.



1U power rack

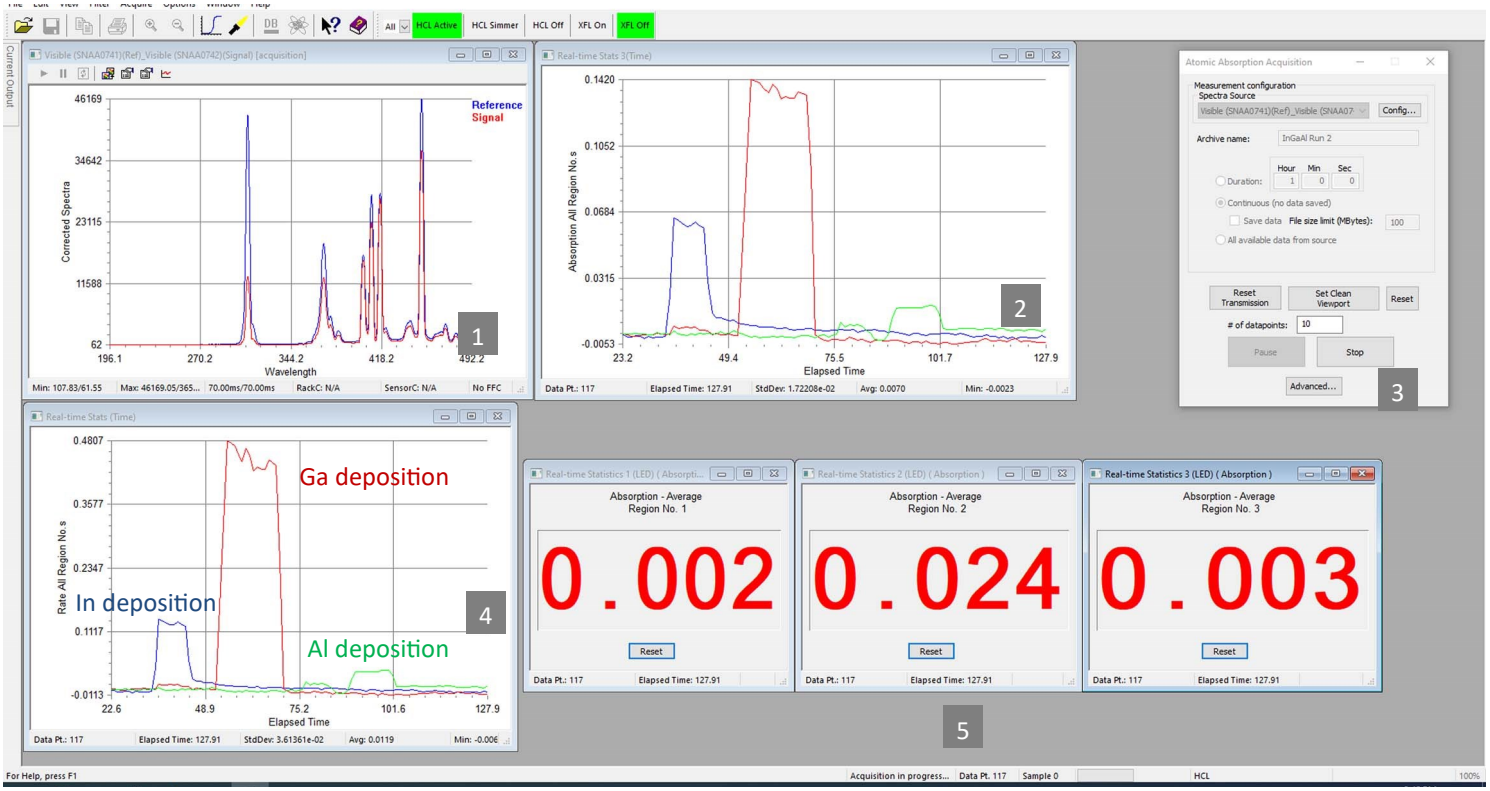
Additional System Information

Choose the elements that you want to measure.

A computer is required to control the kSA ACE. Purchase the computer through k-Space (recommended) or supply your own.

kSA ACE Software

The kSA ACE software is built on the well-known k-Space software platform and offers a user-friendly interface with flexibility and customizability. The screenshot below shows source cell transmission as a function of time, live absorption spectra, HCL and reference signal levels, and HCL lamp current.



1	Corrected Spectra. The reference is blue and the signal is red.
2	Live Absorption of each material. Blue is In, red is Ga, and green is Al.
3	Measurement configuration dialog.
4	Live Deposition Rate of each material. Blue is In, red is Ga, and green is Al.
5	Absorption Average of each material.

Additional Requirements

Optical Access

Two diametrically opposed UV quartz viewports (2.75” or greater) that are positioned just in front of the substrate (on the deposition side) when in the deposition position. k-Space can supply the UV viewports if needed. Note that depending on the materials being deposited, the viewports may need to be heated or shuttered to minimize viewport coating.

Computer Requirements

k-Space highly recommends purchasing a kCPU-DT computer from k-Space, listed in the options, for optimum use with kSA ACE data acquisition and analysis software. Computers purchased from k-Space have all software, drivers, suggested settings, and required files pre-installed for fast and easy system set-up. Please refer to the kSA Computer Product Specifications for details. If another computer is used it must meet the following minimum specifications:

Operating System: Windows 10
Processor: Dual Core Processor (I5 or better)
RAM: Minimum 8 GB
Hard Drive: Minimum 250 GB
Video: 1024 x 768, 16-bit depth or better
Interface: USB 2.0 port or higher

Facilities Specifications

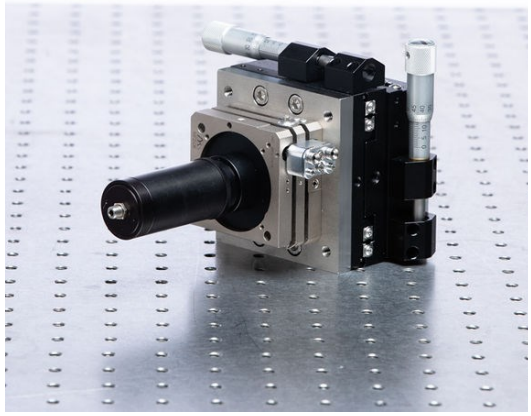
120VAC with 10A max or 230VAC with 5A max, 50/60Hz compatible.

Installation and Training

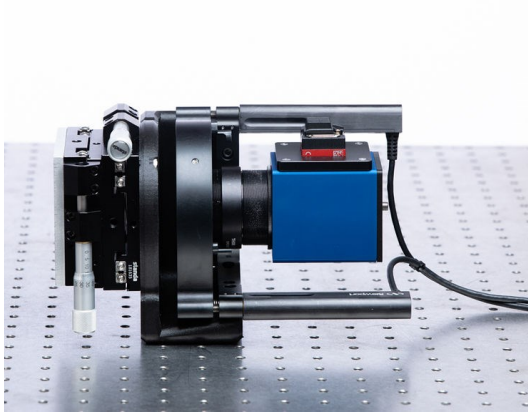
A minimum of 2-3 days of on-site customer installation and training are required with system purchase.

Warranty

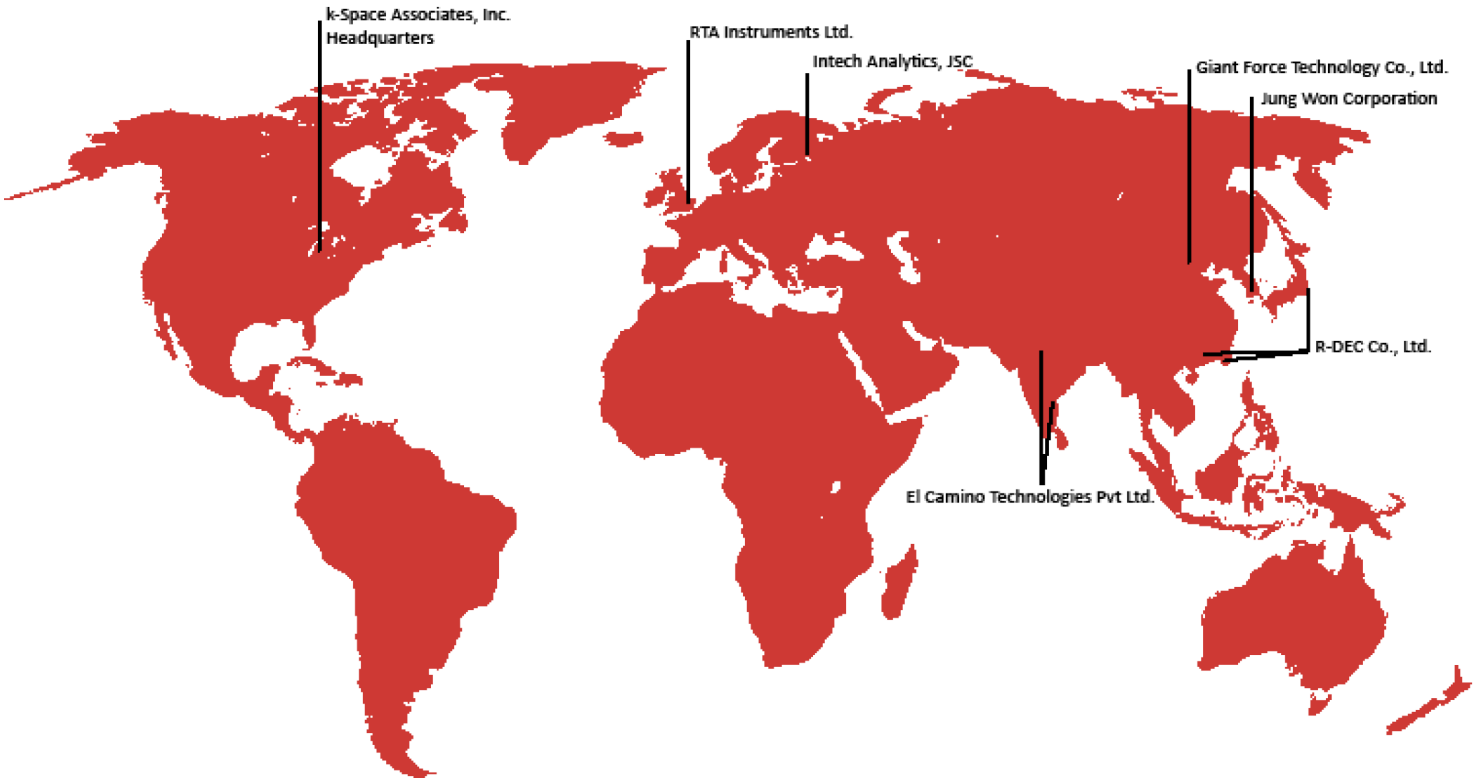
All kSA systems and integrated components are warranted against defective materials and workmanship for a period of ONE YEAR from the date of delivery to the original purchaser.



Emission optics head (light source)



Detector optics head



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