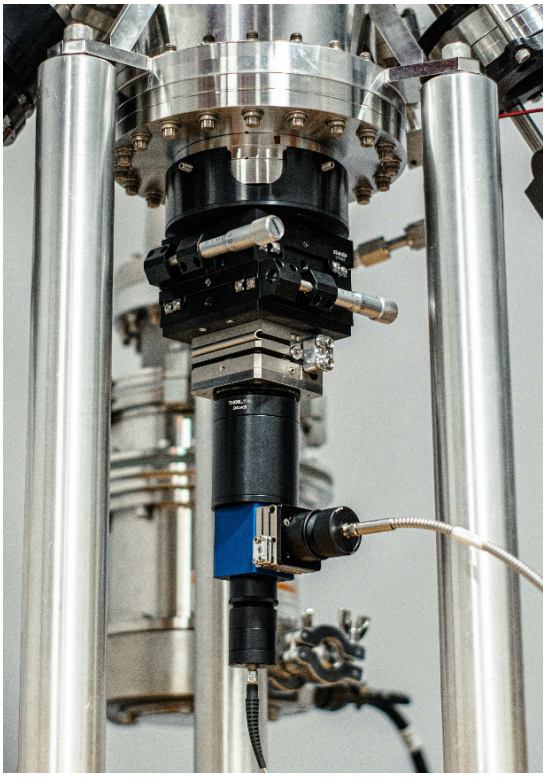
kSA SpectR

User Manual



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Contents

Document Revision History

Release date	*Changes*
8/28/2023	Initial release

Safety and Precautions

To keep the kSA SpectR system operational and to keep those who use it from harm, please heed the cautions and warnings noted below.

Symbols and Labels

When you see the symbols or labels below, be sure to read them carefully to determine the potential safety issue.

Note
This list includes the potential cautions and/or warnings for multiple k-Space products. Some of these may not apply to your installation or testing environment.

Sign	*Potential Safety Concern*
WARNING 	Indicates the possibility of: ▪ Minor injury ▪ Damage to the system or its accessories ▪ Problems relating to the quality of the process
DANGER 	Indicates the possibility of: ▪ Very serious injury ▪ Fatality ▪ Considerable damage to property
EYE PROTECTION 	Indicates that you should wear protective laser goggles/glasses.
LASER RADIATION 	Indicates that there is potential for laser exposure.

Sign	*Potential Safety Concern*
HEAVY OBJECT 	Indicates that the object is heavy and possibly awkward for one person to lift without assistance. Multiple people should assist in the lifting of this object.
BURN HAZARD 	Indicates that hot surfaces pose a risk for burns when a compartment is opened.

Cautions and Warnings

It is important that you take the following precautions when working with these components of your kSA SpectR system.

Sign	*Precautions*
ALIGNMENT 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 system is a Class IIIA laser. (Only Class I lasers present no concern for eye injuries.) ▪ **Always** set the laser interlock to **OFF** when the laser is not in use.
DIODE LASER 	When the system is not in use for extended periods of time, shut down the laser. Laser diodes have a finite lifetime, and proper care will ensure that it lasts as long as possible.
DIODE LASER CONFIGURATION 	The diode laser controller supplied with your complete system has been pre-configured with the correct operating parameters for that particular laser, and they will protect that laser from damage. Do not change these operating parameters. Refer to the diode controller configuration sheet supplied with the system for the correct settings.
DIODE LASER POWER AND CONTROL 	**Never** disconnect or connect the laser diode control cable while the controller is powered up—this will destroy the laser. Diode lasers are extremely electrostatically sensitive and are not protected against static discharge when disconnected from the controller unless specific precautions are taken to short the laser power leads. Fiber-coupled laser packages have a shorting switch to protect the laser when it's not connected to the controller. Be sure to use this switch when disconnecting the cables.
ELECTRONIC BOARDS 	Whenever handling any electronic boards, ensure that you are properly grounded and that you do not touch the contact pads along the bottom of the board.
FIBER OPTIC CABLES 	▪ Optical fibers are fragile. Do not kink or allow them to be snagged on sharp edges. ▪ Do not bend the cables to a radius of < 13 cm. ▪ Do not sharply bend or kink armored fiber optic cables.

Sign	*Precautions*
I/O INTERFACE 	Before making connections, refer to the Rack Mount Controller Installation information for a complete functional description of each pin in the BNC and DB-15 I/O connectors on the rack controller.
INTERNATIONAL INSTALLATIONS 	Outside of North America, please be sure to check that the power setting on the back of the computer matches the supplied power in your region.
LAMP 	▪ **Never** stare into the lamp output. The lamp output contains focused infrared radiation, and long-term exposure to the lamp output can cause serious damage to your eyes. ▪ 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 the bulb.
OPTICS 	▪ Do **not** allow debris to fall into the optical port on detector heads. ▪ Do **not** open optical head cases in dirty environments. ▪ Do **not** touch internal optical surfaces inside the optical head.
POWER 	▪ Use a surge protector for all AC power cable connections. ▪ Connect all cables before plugging in the system. Ensure that the unit is plugged in to 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**. ▪ **Always** unplug the rack controller when replacing or servicing the lamp.
SERVICE 	Do **not** service the unit beyond the procedures described in this document. None of the parts in the rack controller should be serviced by the user; contact kSA to service those.
SMA CONNECTOR ENDS 	Do **not** allow SMA connector ends of optical cables to touch dirt or grease.
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 around the lamp housing air intake fan or the exhaust vents.
WATER AND MOISTURE 	Do **not** use the system near water or in any area where excessive moisture or condensation may come in contact with system components.

1 kSA SpectR Overview

The kSA SpectR system is an non-contact, non-invasive, optically based, real-time metrology instrument. This powerful in situ tool monitors and controls film deposition processes. The primary function of the kSA SpectR is to monitor the spectral reflectivity of a film stack during deposition.

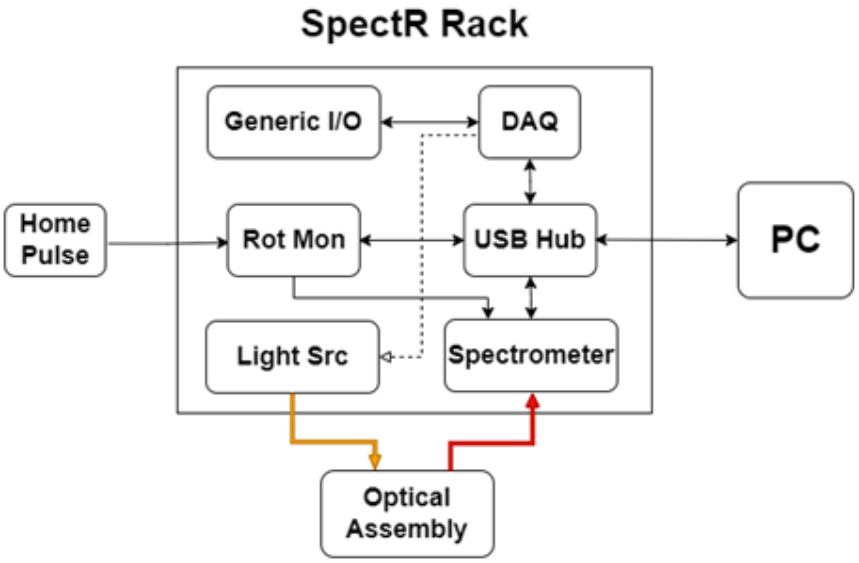
The kSA SpectR system consists of one or more spectrometers, a broadband light source with an integrated shutter, and the associated electronics, all contained in a 3U rack. k-Space can configure your kSA SpectR with a spectrometer that covers the visible wavelength range, the near infrared (NIR) range, or both ranges (if you choose a dual-spectrometer system).

The integrated shutter allows the system to remove any stray light that would otherwise compromise the reflectivity measurement. This is especially important with NIR units, and/or with units intended for use during high-temperature growth. In both cases, blackbody radiation can introduce a significant background signal. The light source and spectrometer are fiber-coupled to the optical assembly, which is mounted on the deposition chamber, as described in the Optical Assembly section.

The system contains a data acquisition (DAQ) board that controls the light source/shutter and provides user-assignable digital and analog I/O. In addition, the system contains a microprocessor-based rotation monitor that synchronizes the operation of the light source's integrated shutter with the reflectivity measurement. This can also be used to sync the reflectivity measurement with the substrate rotation using a home pulse provided by the deposition chamber. This can be beneficial if the substrate suffers from wobble, which can lead to significant variations in the measured reflectivity during rotation. By synchronizing with the rotation, you can set up the measurements to occur only at a point where the optics are perfectly normal to the sample, ensuring the most accurate reflectivity value possible.

The front panel of the kSA SpectR rack (shown below) includes the main power switch and controls for the laser, light source, and shutter.

The following block diagram depicts the components in the kSA SpectR rack and the flow of data and information.



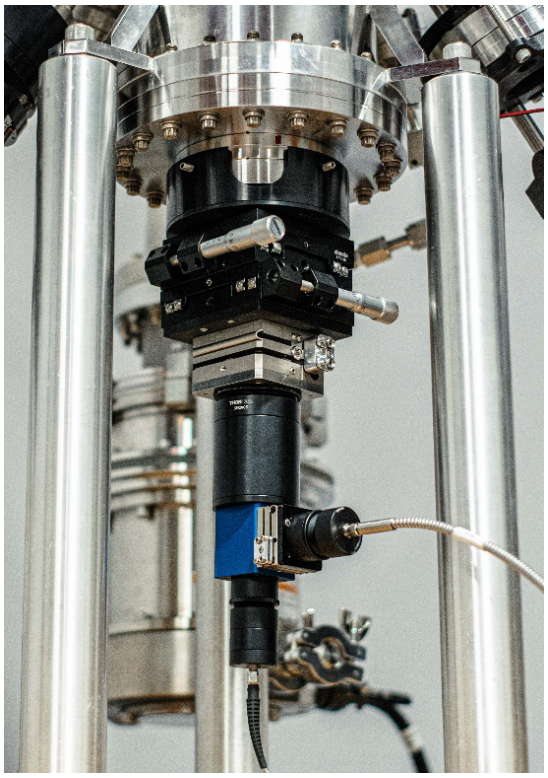
The kSA SpectR uses the following equation to calculate the absolute reflectivity.

$$R_{abs}(\lambda) = \frac{I_{open}(\lambda) - I_{closed}(\lambda)}{I_{ref}(\lambda)} R_{ref}(\lambda)$$

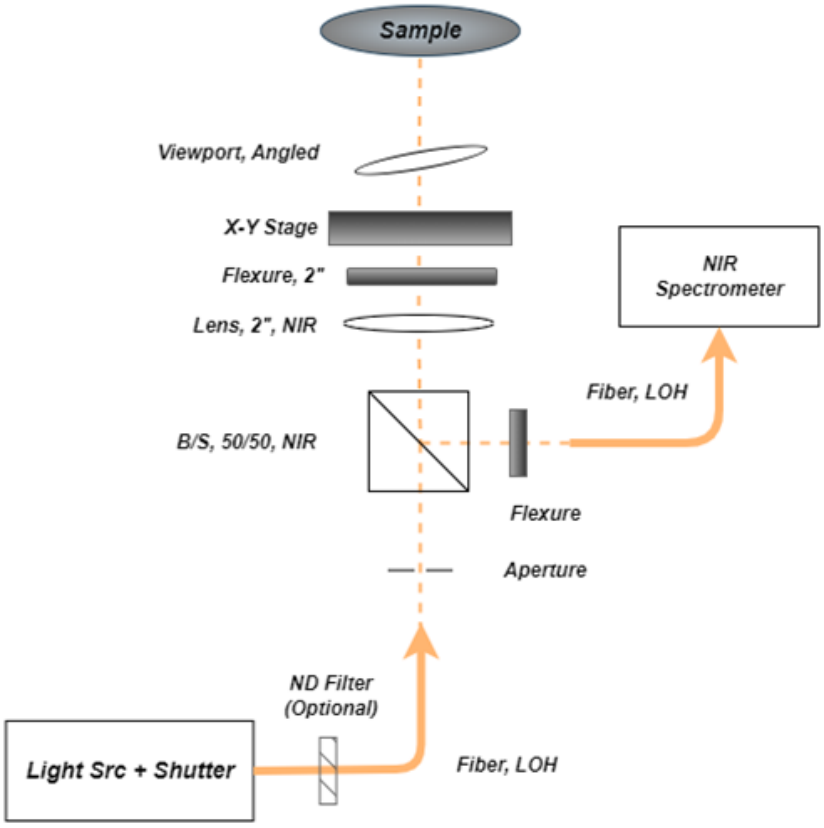
Variable	*Description*
$R_{abs}(\lambda)$	Spectral reflectivity of the sample in an absolute sense
$R_{ref}(\lambda)$	Corresponding quantity for the reference sample used to calibrate the system
$I_{open}\lambda)$	Raw spectral intensity measured with the shutter open
$I_{closed}(\lambda)$	Raw spectral intensity measured with the shutter closed
$I_{ref}(\lambda)$	Raw spectral intensity measured using the reference sample

1.1 Optical Assembly

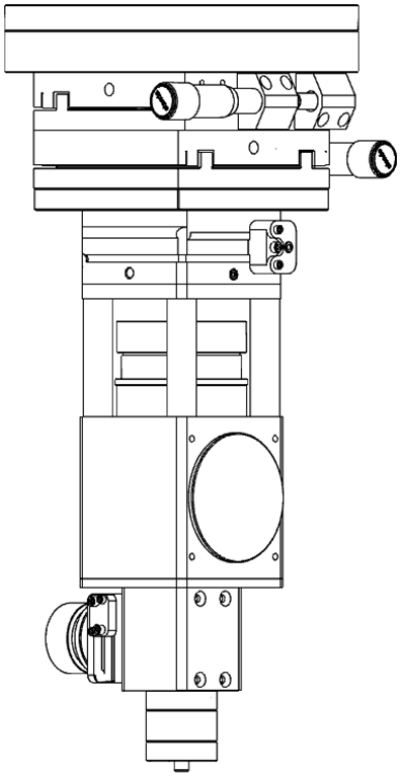
The image below depicts a typical kSA SpectR single-port, NIR optical assembly mounted on a 4.5” CF viewport. Note that both the broadband light source and the NIR spectrometer are fiber-coupled. Also note that this system incorporates an x-y translation stage for precise alignment to a specific location on the sample.



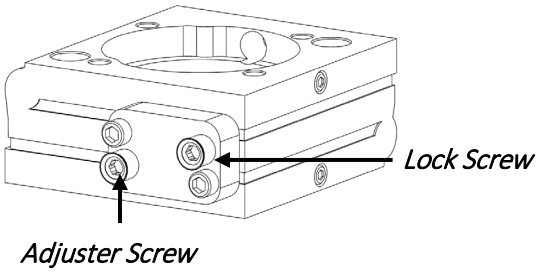
The schematic below provides a schematic of the kSA SpectR NIR optical assembly.



The kSA SpectR NIR optical assembly shown below includes two flexures that allow you to adjust the position and tilt of the assembly.



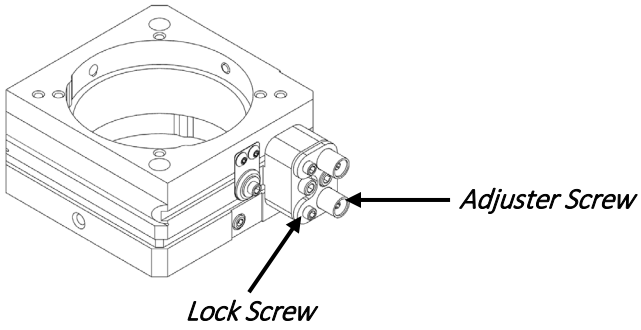
- A 1” flexure allows for precise alignment of the spectrometer’s fiber feed relative to the light source. This has a pair of adjustment screws and corresponding locking screws (the locking screws have the shorter heads). These screws require a 5/64” (2 mm) hex key. Note that k-Space engineers configure these during instrument commissioning, and they should **not** need to be adjusted under normal circumstances.



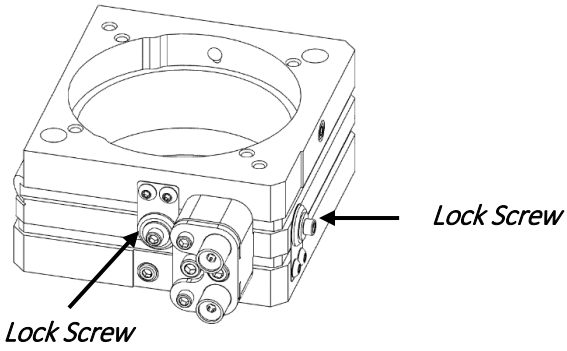
The chamber mounting hardware provides several degrees of freedom to enable precise adjustment of the optics relative to the sample.

- A 2” flexure allows for adjustment of the overall tip and tilt of the assembly. Like the 1” flexure, this has a pair of adjustment screws and corresponding locking screws The adjustment and locking screws require a 5/64” (2 mm) hex key. The flexures provide up to 6° of angular motion for each axis.

> **Important!**
>
> ***This adjustment is critical to ensure that the optics assembly is precisely normal to the sample.***
> *See How to Align the Optical Assembly for details on the alignment procedure.*

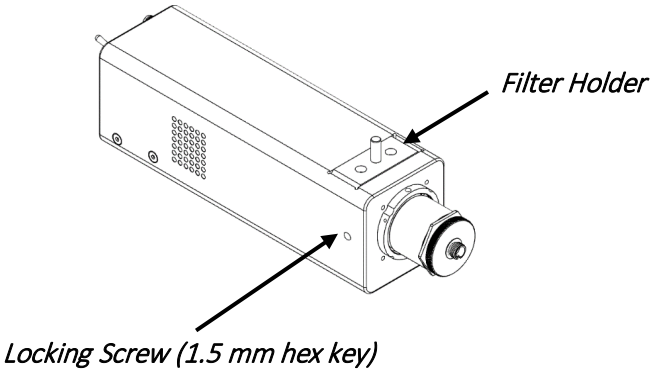


In addition to the locking screws on the adjuster, the system uses a pair of foil locks to secure the 2” flexure position so that it does not drift over time after alignment.



1.1.1 Light source neutral density filter option

When working with highly reflective samples, such as distributed Bragg reflectors (DBRs), it is sometimes necessary to reduce the output of the light source to prevent saturation of the spectrometer. This is typically required for visible spectrometers only, as they are inherently much more sensitive than NIR units. For that reason, the internal light source in the kSA SpectR rack has a built-in holder for 1” filters. If necessary, k-Space will provide an appropriate neutral density (ND) filter. You can lock the filter holder in place using a 1.5 mm hex key to tighten the set screw.



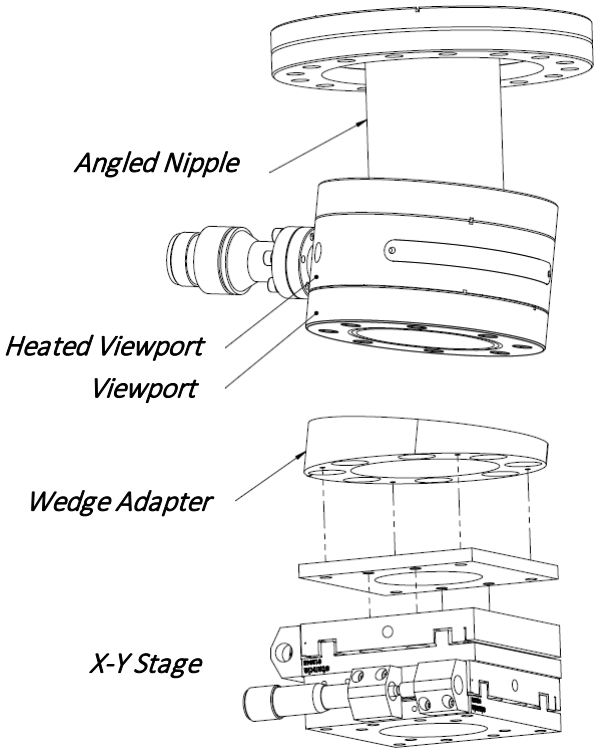
1.1.2 Translation stage option

k-Space offers an optional precision x-y stage that provides translation for the optical assembly. This allows you to precisely position the measurement spot at a specific location on the sample.

1.1.3 Angled nipple option

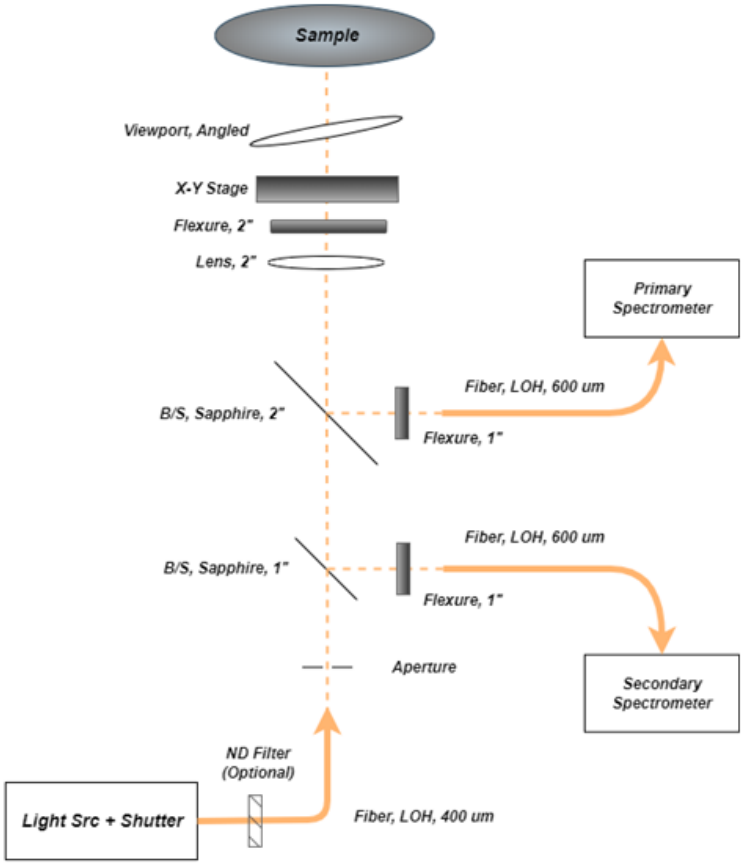
Because the kSA SpectR is intended to measure the absolute spectral reflectivity of a sample, for single-port (i.e., normal incidence) systems, it is critical that it does not detect any light reflected off the deposition chamber's viewport, as this could compromise the reflectivity measurement. To address this, the kSA SpectR uses an angled viewport, which directs the reflection of the incident light at an angle so that the detector cannot see it.

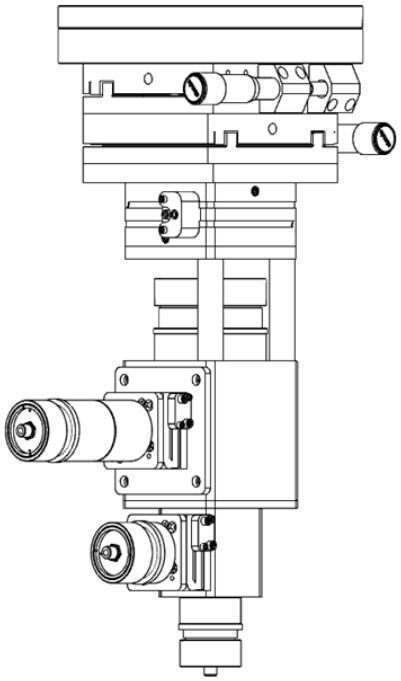
For systems with a heated viewport, the alternative solution is to use the angled nipple/wedge adapter solution depicted below. The angled nipple places the heated viewport at the desired angle, and the wedge adapter allows the optical assembly to remain at normal incidence to the sample. Because of the angles involved, it results in a somewhat reduced clear aperture.



1.1.4 Dual-range spectrometer option

If you need a broader spectral range than a single spectrometer can provide, k-Space offers dual-range spectrometer systems. The example system below uses sapphire beam splitters to preserve spectral neutrality so that either feed can use a visible or NIR spectrometer.


Sample
Viewport, Angled
X-Y Stage
Flexure, 2"
Lens, 2"
Primary Spectrometer
B/S, Sapphire, 2"
Fiber, LOH, 600 um
Flexure, 1"
B/S, Sapphire, 1"
Fiber, LOH, 600 um
Flexure, 1"
Aperture
Secondary Spectrometer
ND Filter (Optional)
Light Src + Shutter
Fiber, LOH, 400 um



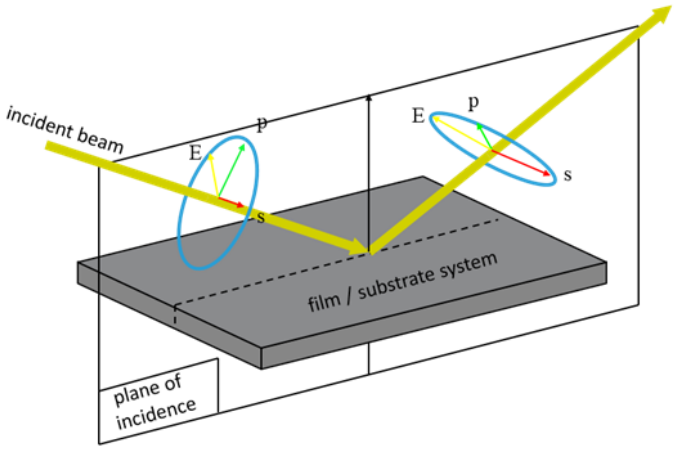
1.1.5 Two port option

k-Space can configure the optics in a two-port arrangement, in which the light source and detector are specularly opposed at an off-normal incidence angle. For these systems, polarization effects must be considered to obtain accurate reflectivity results. There are two possible polarization states.

- *p* (i.e., TM): The polarization vector is parallel to the plane of incidence and reflection.
- *s* (i.e., TE): The polarization vector is perpendicular to the plane of incidence and reflection (from the German term *senkrecht*).

> ***Note***
>
> *For single-port (normal incidence) systems, there is no distinction between the two states, so the polarization state selection is immaterial.*

The image below illustrates the definition of the *s* and *p* polarization states.



1.2 Broadband Light Source

The kSA SpectR software application allows you to control the broadband light source remotely through the software. To enable this feature, follow the steps below.

1. In the Single-wafer Spectral Reflectivity Acquisition window, click the **Advanced** button to open the Advanced Acquisition Options dialog.
2. Click the Reflectivity Shutter and Light Configuration tab.
3. Check the **Enable light control** box, and then select the digital output channel used to control this feature.
4. Click **OK** to save this setting. The **Light Source Control** button on the toolbar should now be enabled. When you click that button, the kSA SpectR application will toggle the light source on/off.

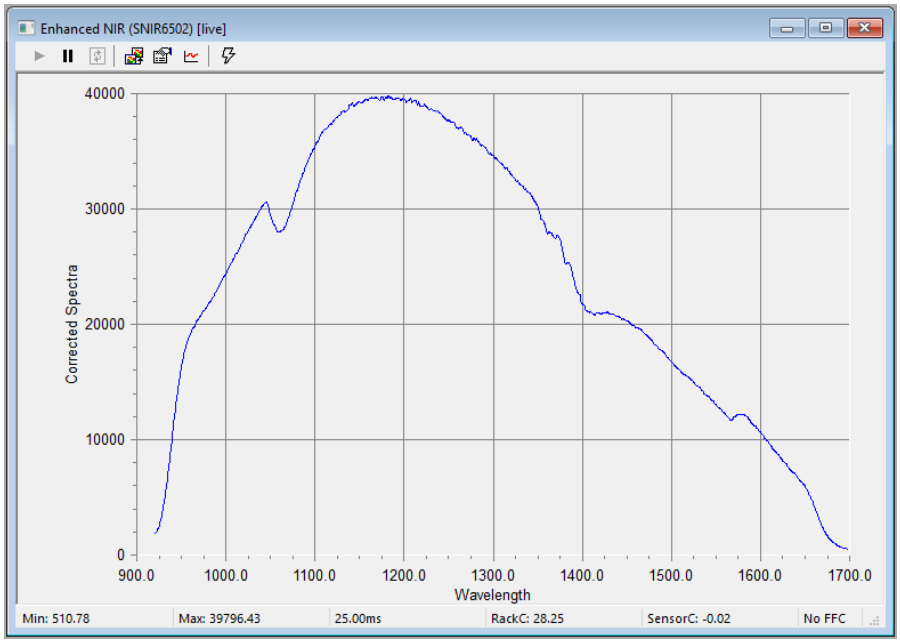
1.3 Spectrometer

The kSA SpectR is based on one or more sensitive solid-state spectrometers. Depending on the purpose, k-Space offers NIR units with a wavelength range of approximately 900-1700 nm and visible units with a range of approximately 350-1100 nm. The kSA SpectR software application enables you to view the data in a Live Spectrometer window as they are being acquired.

➢ To open a Live Spectrometer window, select the desired spectrometer from the **View** menu or click the **Live Spectrometer** button on the toolbar.

The screenshot below shows a typical live spectrometer window in the kSA SpectR application. The status bar along the bottom of the window displays the minimum and maximum spectral intensity, the integration time, the electronics (i.e., rack) temperature, the sensor temperature, and the flat field correction (FFC) status. The FFC is a correction curve that serves to flatten the spectrometer's inherent wavelength-dependent response.

> ***Note***
>
> *Do **not** use the FFC in the kSA SpectR application, as the reference spectrum fulfills its function.*



To enable/disable the spectrometer's external trigger, click the **External Trigger** button on the toolbar along the top of the Live Spectrometer window.

To adjust the settings for the spectrometer, right-click the Live Spectrometer window and select **Properties** to open the Spectrometer Properties dialog. This dialog includes several tabbed pages, each with different parameters and options that apply to the selected spectrometer.

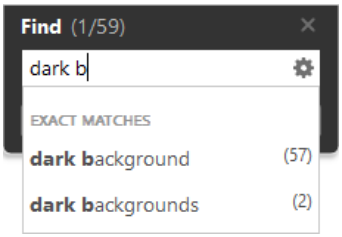
1.4 k-Space's Customer Focus

k-Space has always made customer needs a primary focus. As technology evolves, k-Space continues to update and enhance all of our products with new features and improved software. Many of the enhancements and features we have implemented are a direct result of suggestions from our customers. We highly encourage customer feedback and suggestions for any of our products. We listen to our customers and constantly look for ways to ensure that our instruments provide expert metrology solutions and simplify their work.

k-Space takes pride in giving our customers excellent technical support — the engineers who design and build the tools and software routinely respond directly to customers with personalized solutions. Please contact us with any suggestions, comments, or questions.

1.5 Finding Information in This User Guide

- The How-To Guides chapter includes a collection of the most commonly used kSA SpectR procedures to make it easy for you to find important processes.
- Throughout this manual, there are numerous instances of blue, underlined text that link to related information elsewhere in the manual. Click these links to jump to the related content, and then press **ALT+** ◀ on your keyboard to return to the previous location.
- To search for content within this user manual, press **CTRL+F** or click the button on the Acrobat Reader toolbar. When the Find dialog opens in the upper-right corner of the window, enter a search term, and then press the **ENTER** key on your keyboard to initiate the search. As you enter the search term, Acrobat Reader lists potential matches, so if your term is on the list, you can select it from that list.



2 Exploring the kSA SpectR Software Application

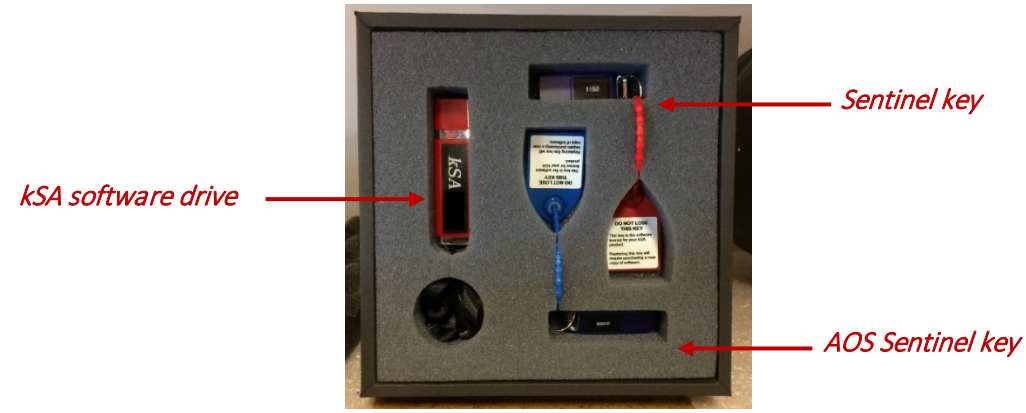
The kSA SpectR uses proprietary software to collect, analyze, and store data. k-Space uses a common software user interface (UI) for many of its core products. With the consistent look and feel across products, customers with multiple k-Space products are already accustomed to the interface and can start using the software right away. For those who are not familiar with k-Space software, this chapter describes various features of the UI.

2.1 Sentinel Key

All kSA SpectR systems require a dedicated Sentinel key to access the software. The Sentinel key is a USB firmware adapter that contains your kSA SpectR software license. It provides access to all data acquisition and analysis features included with your license, activates any purchased plug-in options, and protects the kSA SpectR software from illegal distribution.

Your kSA SpectR system includes a custom-fitted box (similar to the one in the following image) that contains your Sentinel keys and software (on a USB drive).

- The Sentinel key with a red tag provides access to all data acquisition and analysis features included with your software license.
- The Sentinel key with a blue tag provides access to the analysis-only software (AOS) features. The AOS version of the application includes all of the analysis capabilities but none of the acquisition capabilities.
- The kSA software drive (red or black USB drive) contains the software installation files, registration file, and other important files.

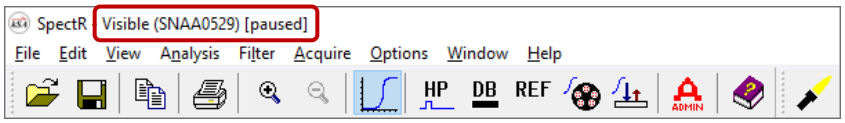


To run the kSA SpectR application, insert the Sentinel key into an available USB port on the kSA SpectR computer.

2.2 Software User Interface

To open the kSA SpectR application, double-click the kSA SpectR icon on your Windows desktop, or select **SpectR > SpectR** from the Windows Start menu.

Like other Windows applications, the kSA SpectR application uses menus and toolbars to provide access to various windows, dialogs, and commands. The menus, commands, and toolbar buttons that are available at any given time depend on the active window in the application. The title bar at the top of the kSA SpectR application displays the name of the active window.



2.2.1 Menus and Menu Commands

The following menus are available in the kSA software UI.

Menu	*Available Actions*
File	Open, close, save, export, and print data; exit the kSA application.
Edit	Undo the last action, copy the contents of the active window, and access the applicable Properties dialog.
View	Open a Live Spectrometer window; zoom in/out in the active window. If a data acquisition window is open, it also includes available real-time charts.
Analysis	*(Available only when the active window is a data file)* Select available post-acquisition analysis plots. These are generally not used for the kSA SpectR.
Acquire	Select available data acquisition modes.

Menu	*Available Actions*
Options	Specify options for the kSA system and activity and data logging; save or recall all software settings.
Window	Arrange the open plot windows; quickly switch between open windows.
Help	View version and copyright information for the kSA software; view contact information for k-Space Associates, Inc.

2.2.2 Main Toolbar

The buttons on the main toolbar of kSA applications give you quick access to many of the options that are available on the various menus. The toolbar buttons are grouped together based on function.

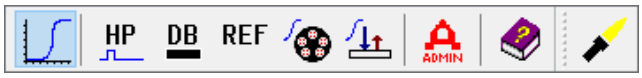
Standard toolbar

These buttons have the same functionality as in other Windows applications.

Toolbar Button	*Description*
Open file 	Opens a dialog for you to browse to and select a data file to open.
Save file 	Saves the data in the active window to a file.
Copy content 	Copies the selected data to the Windows clipboard, making it available to paste into documents in other applications.
Print file 	Prints the data in the active window.
Zoom in/out 	Zooms in and out in the active window.

kSA SpectR toolbar

These buttons provide access to hardware features that are controlled through the software.



Toolbar Button	*Description*
Live Spectrometer 	Opens a Live Spectrometer window, where you can view data in real-time as they are being acquired.

Toolbar Button	*Description*
Home Pulse Positioning 	*(N/A for the kSA SpectR)*
Dark Background 	Opens the Dark Background Acquisition window to acquire background data in the absence of light. The application then subtracts that data from the live spectra to reduce noise.
Reference 	Opens the Reference Acquisition window to acquire reference data, based on a specified number of samples, to normalize the acquired spectrum.
Single-wafer Spectral Reflectivity 	Opens the Single-wafer Spectral Reflectivity Acquisition window to measure reflectivity, film thickness / growth rate, and optical constants (*n*, *k*).
Software User Mode 	Opens the Select User Mode dialog, where you can select the user mode level for the kSA SpectR application.
User Manual 	Opens a PDF of this user manual.
Light Source Control 	Toggles the light source off and on.

2.2.3 Plot Window Toolbars

The Live Spectrometer window and many **.kdt** plot windows include their own toolbars along the top of the plot window.

Live Spectrometer toolbar

The Live Spectrometer toolbar is available within Live Spectrometer windows. These buttons control the spectrometer as it acquires data.

Toolbar Button	*Description*
Resume 	Resumes a live display of the spectrometer output that has been paused.
Pause 	Pauses the live display of the spectrometer output.
Refresh 	Updates the display in the Live Spectrometer window to show the current data.

Toolbar Button	Description
Snapshot 	Captures a screenshot of the current spectrum and saves it to a file.
Properties 	Opens the Spectrometer Properties dialog, where you can change parameters for the selected spectrometer.
Plot Properties 	Opens the Plot Properties dialog, where you can change parameters for the Live Video window display.

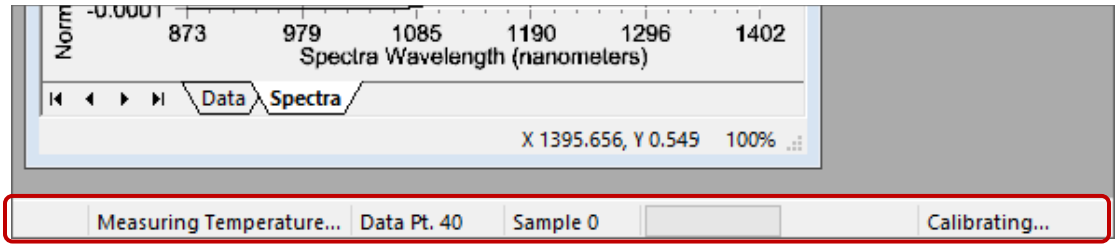
kdt toolbar

The kdt toolbar is available within kdt plot windows that display spectral data. These buttons control the playback of the plotted data.

Toolbar Button	Description
Rewind ⏮	Returns to the first frame of the data file.
Reverse ◀❙	Moves back one frame at a time.
Play ▶	Plays the data in the file.
Pause ❚❚	Pauses the display of data in the file.
Advance ❙▶	Advances one frame at a time.
Go to end ▶❙	Advances to the last frame of the data file.
Loop ⟲	Automatically replays the data from the beginning after it reaches the last frame.
Snapshot 	Captures a screen shot of the current frame of the **.kdt** data file and displays the snapshot in a new data window.

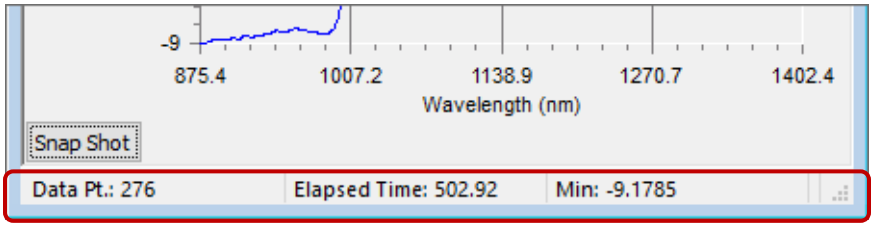
2.2.4 Status Bars

The kSA SpectR application includes a status bar along the bottom of the main application window to display information about the current data acquisition or analysis.



In addition, the Live Spectrometer window includes a status bar that provides up-to-date information about the selected spectrometer throughout the acquisition. This information includes the minimum and maximum spectra intensity values; spectrometer integration time; rack, sensor, and optic temperatures; and flat field correction status.

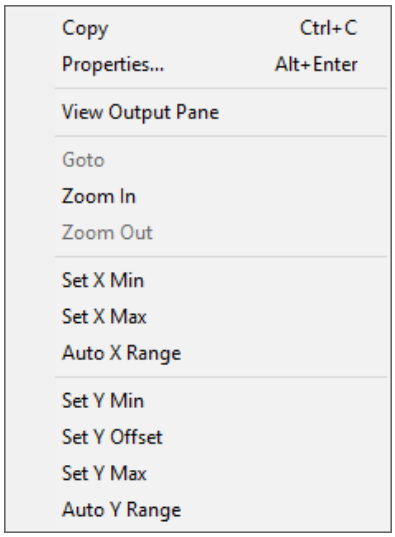
Many of the real-time charts also include a status bar along the bottom of the plot window to display relevant information about the acquired data.



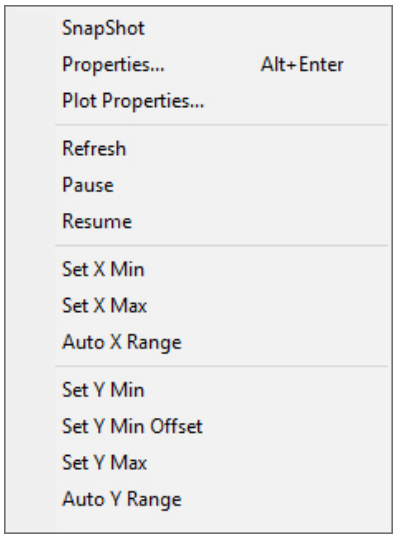
2.2.5 Right-click context menus

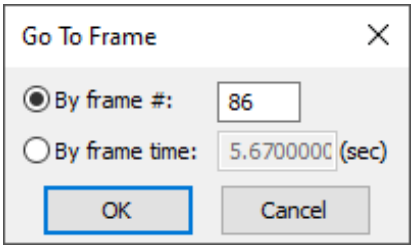
When you right-click the a Live Spectrometer window or a data plot window, the application displays a context menu that includes commands for manipulating the display in the window. The commands at the top of the Live Spectrometer right-click menu are the same as the commands on the Live Spectrometer toolbar.

Data or Analysis plot window



Live Spectrometer window



Menu Command	*Description*
Copy	Copies the plotted data to the Windows clipboard, making it available to paste into documents in other applications.
Properties	Opens the Spectrometer Properties dialog, where you can change parameters for the selected spectrometer.
View Output Pane	Toggles a data pane below the plot to display the output.
Goto	Opens the Go To Frame dialog, where you can specify the exact frame to jump to — the exact frame number or the frame at a specific elapsed time. 
Zoom In/Zoom Out	Zooms in on/out of the plotted data.
Set X Min/Max **Set Y Min/Max**	Sets the minimum/maximum value for the X/Y axis to the X/Y value of the current cursor position. In other words, when you right-click a position on the plot and select **Set X Min**, that cursor position becomes the lowest X value on the plot. The application removes all data left of that position and spreads the remaining data to fill the plot window.
Auto X/Y Range	Resets the minimum and maximum X/Y values to the default values.
Set Y Min Offset	Sets the minimum Y value as an offset from the maximum Y value, rather than using an absolute value.

3 How-To Guides

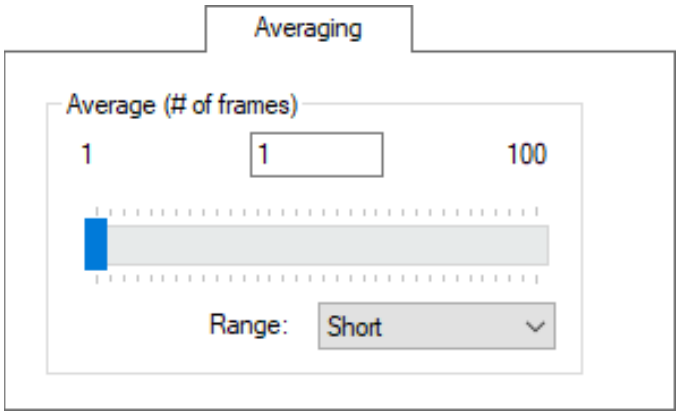
This chapter provides step-by-step instructions for some of the most commonly used features and applications of the kSA SpectR system.

- Aligning the optical assembly
- Acquiring a dark background
- Acquiring a reference spectrum
- Acquiring spectral reflectivity data
- Performing a reflectivity fit
- Setting the spectra phase delay
- Calibrating the spectrometer

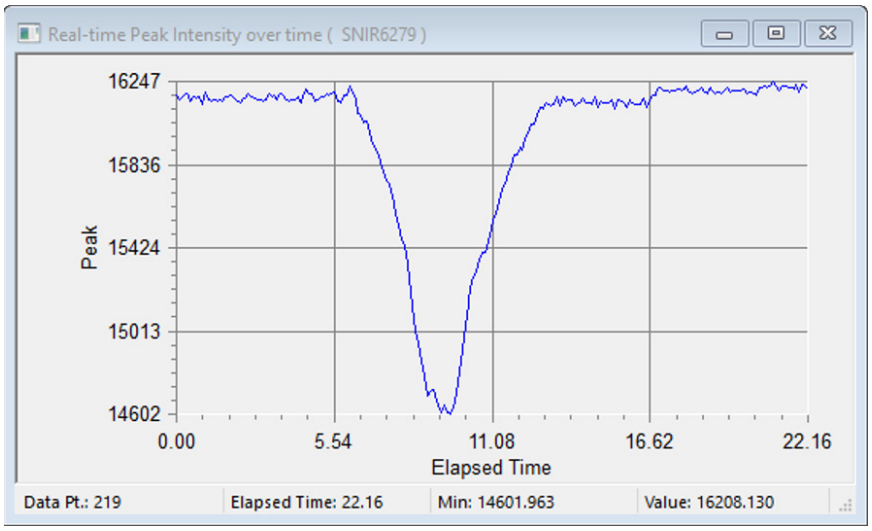
3.1 How to Align the Optical Assembly

This alignment procedure is best done with a stationary (i.e., non-rotating) wafer.

1. Open a Live Spectrometer window by selecting the applicable spectrometer from the **View** menu or by clicking the  button on the toolbar.
2. Right-click the Live Spectrometer window, select **Properties**, and click the Spectrometer tab.
3. Use the slider to set the desired integration time, and verify that the **External trigger** checkbox is cleared to ensure that the spectrometer is in free-running mode.
4. Click the Averaging tab and ensure that the averaging is set to **1**.



5. Select **Acquire > Peak Intensity Alignment Acquisition**.
6. In the Peak Intensity Alignment Acquisition window, select the desired spectrometer from the **Peak intensity** drop-down list.
7. Click the **Advanced** button, and then click the Delay tab.
8. Select **Between data points** from the drop-down list in the **Delay type** field, and then choose the **No delay** option below that.
9. Choose the amount of data to save — **Continuous (no data saved)** to view the data without saving them, or **Duration** to acquire data for a specific length of time.
10. Select **View > Real-time Peak Intensity over time** to view that real-time chart (RTC) during acquisition. Note that if your system has multiple spectrometers, the application will open a separate chart for each one.



11. Click **Start** when you are ready to start the acquisition. Observe the RTC and adjust the optics such that the intensity is maximized (see Optical Assembly for details).

> ***Notes***
>
> - *After you complete the alignment, you may need to adjust the **Processing intensity floor** setting on the Spectrometer Configuration > Spectral Reflectivity Configuration tab to account for any resulting changes in intensity.*
> - *For best results, you should acquire a new reference spectrum any time you adjust the optics or load a new sample.*

3.2 How to Acquire a Dark Background

In many cases, the spectra acquired during data acquisition contain stray signals (aka, noise) that distort the actual spectra of the sample. To account for this noise, the kSA SpectR includes the Dark Background Acquisition mode, which acquires data in the absence of light to represent the spectral noise. The application then subtracts the noise from the live spectra during data acquisition, resulting in clean spectra that are free of noise.

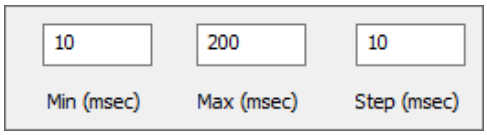
> **Important!**
>
> *You will need to acquire a dark background the first time you run the kSA SpectR and on a regular basis — e.g., before each temperature acquisition, once a week, once a day, etc.*

3.2.1 Specifying integration times

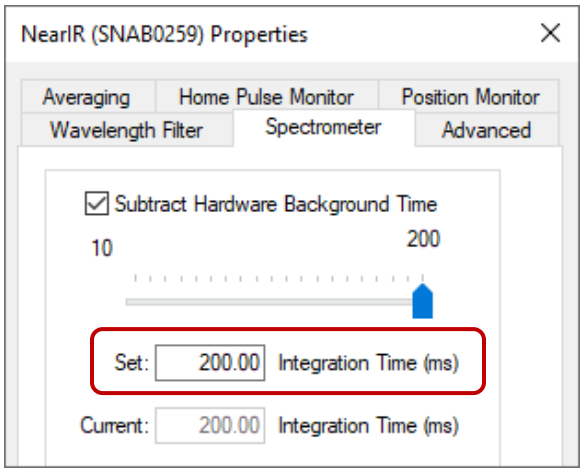
A spectrometer's integration time is the length of time the detector collects a signal before it digitizes and sends the signal to the application for processing. The integration time plays an important role in reducing noise in the incoming spectrometer signals.

To remove background noise from a live spectra, you must acquire the live spectra at an integration time for which you have a corresponding dark background spectrum. To ensure this, you can acquire dark background data for a range of integration times. That range should include the integration times that you will use for data acquisition.

To define the range, use the **Min**, **Max**, and **Step** fields in the Dark Background Acquisition window. For example, if you acquire a dark background using the values shown in the image below, the application will acquire background data at the **10**, **20**, **30**, **…**, **190**, **200 ms** integration times only and then save the data in a dark background **.kdt** file.



To remove background noise from the live spectra during data acquisition, check the **Subtract Hardware Background Time** box on the Spectrometer Properties > Spectrometer tab, and then in the **Set Integration Time** field, specify the integration time to use during data acquisition. The value in this field must be one of the times included in the dark background data. Using the example above, the spectrometer integration time of 200 ms is valid, as background data were acquired at that integration time.



The status bar in the Live Spectrometer window displays the spectrometer integration time.

3.2.2 Acquiring dark background spectra

Important!

*You must eliminate all light from the chamber when you acquire a dark background. The best way to ensure this is by removing the fiber from the spectrometer's input SMA fitting (labeled **SPECTROMETER**) on the back of the electronics rack and tightly covering the input with the black plastic cap provided.*

Follow these steps to acquire dark background data.

1. Allow the electronics rack sufficient time to reach thermal equilibrium before acquiring a dark background. The noise is caused by thermally generated charge carriers in the spectrometer's sensor material and is thus strongly temperature dependent.
2. Select the applicable spectrometer from the **View** menu or click the  button on the toolbar to open a Live Spectrometer window. Dark background data are spectrometer-specific, so you must acquire the dark background using the same spectrometer you will use for data acquisition.
3. Note the sensor temperature, and verify that the electronics rack has had sufficient time to reach thermal equilibrium.
4. Right-click the Live Spectrometer window, select **Properties**, click the Spectrometer tab, and verify that the **External trigger** box is cleared to ensure that the spectrometer is in free-running mode.
5. Select **Acquire > Dark Background** or click the  button on the toolbar to open the Dark Background Acquisition window, and select the applicable spectrometer in the **Spectra Source** field.
6. Verify that the **Samples per datapoint**, and **Min / Max / Step** settings are correct.
7. Click the **Start** button to begin the acquisition. After the acquisition is complete, the application will automatically apply the new dark background to subsequent acquired spectra.

8. Verify that the desired range of integration times is available by right-clicking the Live Spectrometer window, selecting the **Properties** dialog, and clicking the Spectrometer tab. The spectrometer should be in the 0 ± 100 counts range at every available integration time.
9. Reconnect the fiber to the spectrometer input on the back of the electronics rack.

> ***Note***
>
> *If the system has multiple spectrometers, repeat this procedure for each one.*

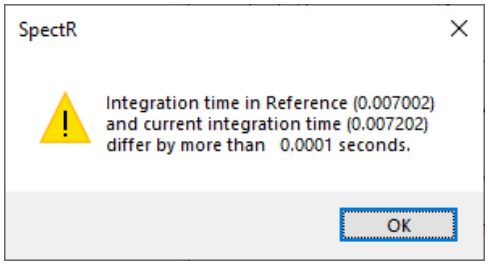
3.3 How to Acquire a Reference Spectrum

The kSA SpectR uses reference data (spectrum of the lamp intensity) to normalize the spectra acquired during data acquisition. This provides a flatter baseline and results in a more accurate extrema wavelength determination. The application saves the reference data in a reference **.bsrf** file.

> ***Important!***
>
> *It is critical that you take the reference at the same lamp power that you will use during data acquisition, as the shape of the lamp's output spectrum is strongly power-dependent.*

Follow the procedure below to obtain a reference spectrum.

1. Select the applicable spectrometer from the **View** menu or click the  button on the toolbar.
2. Right-click the Live Spectrometer window, select **Properties**, and click the Spectrometer tab.
3. Use the slider to set the desired integration time (in ms), and verify that the **External trigger** checkbox is cleared to ensure that the spectrometer is in free-running mode.

> ***Note***
>
> *The integration time for the reference spectrum must be the same as the integration time you will use during spectral reflectivity data acquisition.*
>
> 
>

4. Select **Acquire > Reference (Single Wafer)** to open the Reference (Single Wafer) Acquisition window.

5. Select the desired spectrometer from the **Spectra source** drop-down list.
6. Enter the desired name for the data file in the **Archive Name** field, and specify the number of **Samples** to collect.
7. In the **Processing intensity floor** field, enter the minimum value of the peak intensity that a spectrum must possess to be considered valid.
8. Check the **Auto-select reference** checkbox to use the new reference after it is acquired.
9. Click **Start** when you are ready to begin the acquisition.

3.4 How to Acquire Spectral Reflectivity Data

Follow the procedure below to acquire spectral reflectivity data.

1. Select the applicable spectrometer from the **View** menu or click the  button on the toolbar to open the **Live Spectrometer** window.
2. Right-click on the **Live Spectrometer** window, select **Properties**, and click the Spectrometer tab.
3. Use the slider to set the desired integration time. The selected integration time must match the integration time used to acquire the reference spectrum.
4. If you are using the light source's integrated shutter, confirm that one of the following conditions is met to prevent the shutter from attempting to open and close too quickly.
   - The spectrometers are externally triggered.
   - The acquisition delay time is at least 2.0 seconds.
   - The spectrometer integration time is at least 2.0 seconds.
5. Select **Acquire > Single-wafer Spectral Reflectivity** or click the  button on the toolbar to open the Single-wafer Spectral Reflectivity Acquisition window.
6. Select the applicable spectrometer from the **Spectral Reflectivity** drop-down list.
7. Click the **Config** button to open the Spectrometer Configuration Options dialog and specify settings on each applicable tabbed page, and then click **OK** to apply the settings.
8. If your kSA SpectR has multiple spectrometers, repeat **steps 1-6** for each additional spectrometer.
9. In the **Run name** field, enter the name of the file in which the save the acquired data.
10. Choose the amount of data to save — **Continuous (no data saved)** to view the data without saving, or **Duration** to acquire the data for a specific length of time.
11. Click **Start** to begin the acquisition.
12. Select the desired RTCs from the **View** menu. The following RTCs are available for Single-wafer Spectral Reflectivity acquisitions.
    - Overall Reflectivity
    - Real-time Stats/Real-time Stats 2
    - Spectra/Spectra 1/Spectra 2
    - Real-time Fabry-Perot

3.5 How to Perform a Reflectivity Fit

The kSA SpectR uses a sophisticated Virtual Interface algorithm that was originally developed at Sandia National Laboratories to determine the growth rate, layer thickness, and optical constants (*n, k*) from the measured reflectivity of a multi-layer structure in real-time. This algorithm utilizes non-linear least-squares fitting to extract the optical constants and growth rates of the various layers without requiring any a priori knowledge of their values. The application achieves this by automatically calculating the necessary initial estimates for the fitting routine from the extrema and inflection points in the measured reflectivity, which it obtains using digital filtering techniques.

3.5.1 Technical details

To accomplish an accurate fitting, the following requirements must be met.

- Accurate absolute reflectivity values: To ensure this, use a bare sample of known reflectivity to perform a calibration before starting the deposition. If any errors arise from mis-calibration or absorption from coated viewports, the system can use an adjustable scaling factor *s* to address them. This scaling factor relates the measured reflectivity values to the fitted reflectivity as follows:

  $$\boldsymbol{R_{meas} = s \cdot R_{fit}}$$

  If the optical constants of the film are known with confidence, their values can be fixed. This mode requires only a relative (rather than absolute) reflectivity measurement. However, the accuracy of the results depends on the accuracy of the supplied optical constants. In this case, the best-fit value of the scaling factor *s* is a calculated value. The *s* value can indicate the accuracy of the supplied optical constants.

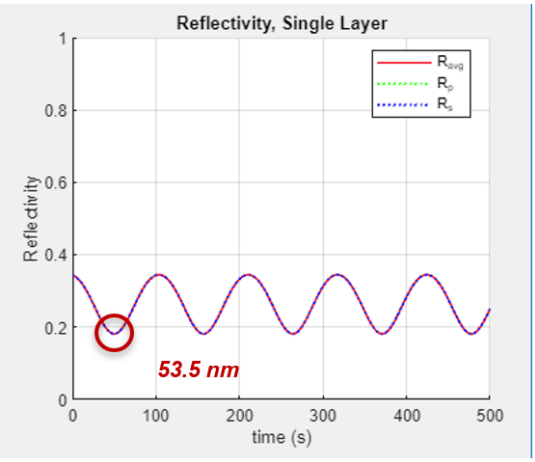
  During film growth, the reflectivity at a given wavelength (λ) oscillates with a period equal to $\frac{\lambda}{2nG}$, where *G* is the growth rate. Since the product *nG* is fixed by the oscillation period, any error in *G* results in an equal but opposite error in *n*. (*G* and *s* are strongly correlated; a change in *s* is accompanied by roughly the same percentage change in *G*, but in the opposite direction.) This highlights the need to determine absolute reflectivity to obtain accurate growth rates.
- A minimum of one extremum and one inflection point: (i.e., a quarter of an oscillation period). A conservative rule of thumb is that the minimum measurable thickness is approximately $\frac{\lambda}{4n}$. To obtain the best fit, the sampling rate should be large enough relative to the growth rate to give at least 15-20 data points per oscillation period.
- Acceptable film roughness: If the film is too rough, this can lead to significant damping of the reflectivity. Accurate values for the extinction coefficient *k* require several oscillations to determine the absorption-induced damping. The greater the damping, the greater the number of oscillation periods required.
- Wavelength: The choice of wavelength typically represents a trade-off between using a shorter wavelength, which gives a shorter oscillation period (and hence a lower minimum thickness) and a longer wavelength, which has lower absorption for typical materials (and hence a greater maximum thickness). As a rule of thumb, it is best to use the lowest possible wavelength that does not produce heavily damped oscillations. In addition, the

light must be monochromatic, with bandwidth $\Delta\lambda$ roughly 10 nm or less. This is dictated by the requirement that the coherence length $\frac{\lambda^2}{\Delta\lambda}$ be much larger than the optical thickness of the film, i.e., $\Delta\lambda \ll \frac{\lambda^2}{nd}$.

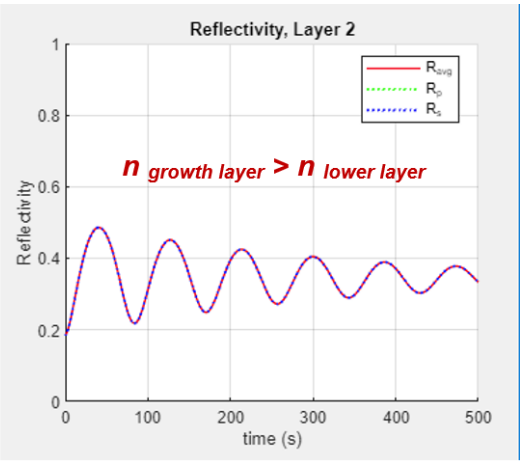
- **Polarization:** If you perform the reflectivity measurement at a non-normal incidence angle, you must distinguish the two polarizations of reflected light. The reflectivity of *p*-polarized light becomes very sensitive to the incidence angle near Brewster's angle. Therefore, k-Space does not recommend that you use this polarization unless the incidence angle is known precisely and is not subject to drift during deposition (such as due to rotation-induced substrate wobble).

For best results, analyze films with high-amplitude oscillations of two to three periods. To obtain such oscillations, deposit materials with large differences in refractive indices. You should also choose the film thickness such that the new layer starts when the reflectivity of the underlying structure differs as much as possible from the bulk reflectivity of the new film material.

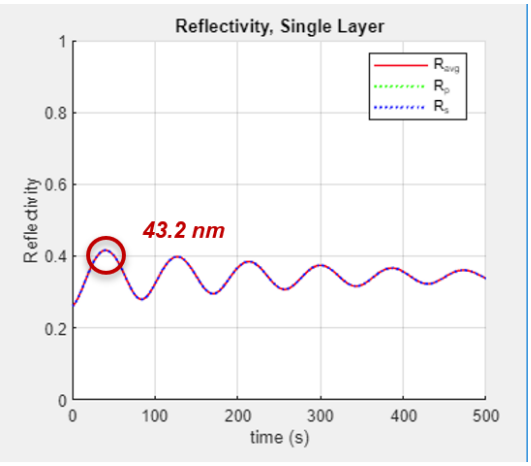
For example, if the index of the growth layer is greater than that of the underlying layer, the oscillations will be maximized if the underlying layer thickness is such that its reflectivity is at a minimum. If, on the other hand, the index of the growth layer is less than that of the underlying layer, the oscillations will be maximized if the underlying layer thickness is such that its reflectivity is at a maximum. The images below illustrate these two cases. Typically, the calibration process is designed to take full advantage of these effects, but for in situ control, it must deal with the interference patterns that result from the desired device structure.



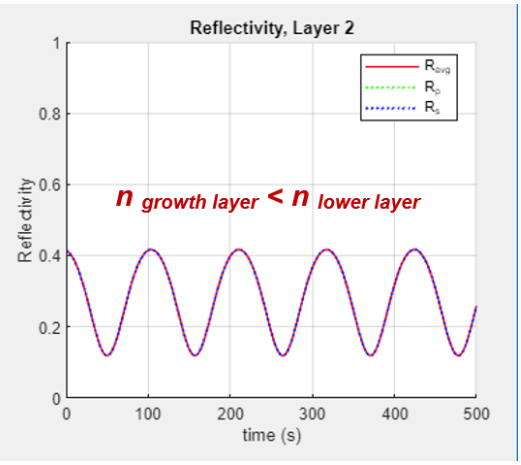
660 nm reflectivity of AlAs film on GaAs substrate



660 nm reflectivity of GaAs film on 53.5 nm AlAs film on GaAs substrate



660 nm reflectivity of GaAs film on AlAs substrate.



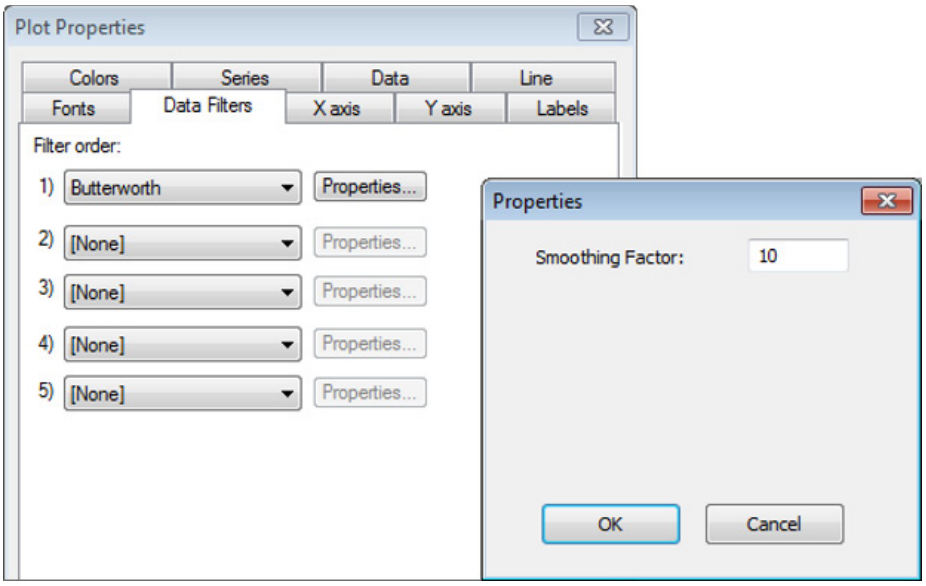
660 nm reflectivity of AlAs film on 43.2 nm GaAs film on AlAs substrate.

The algorithm also provides estimates of the standard error for each fitted parameter. It is important to examine these error estimates before using the results for process control. The standard error estimates for each parameter represent 1-σ values, under the tacit assumption that the reflectivity values are perfectly accurate. In practice, this is difficult to achieve in the presence of wobbling substrates, light source instability, and drifts in the electronics. With care, it is possible to control these effects to better than one percent.

3.5.2 Performing a reflectivity fit

Follow the procedure below to perform a reflectivity fit.

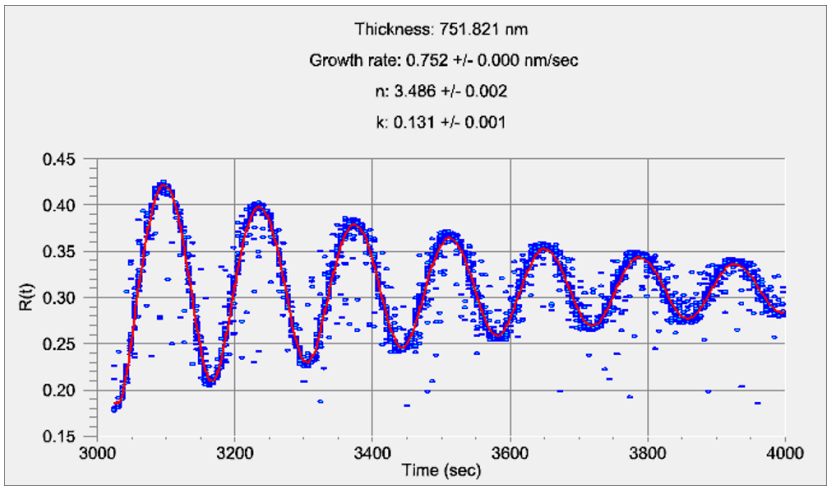
1. Open the desired montage plot (**.img**) file and select **Analysis > Vertical Line Profile** to create a Vertical Line Profile.
2. Select the line in the image window and drag it to the desired wavelength (as indicated at the top of the Vertical Line Profile window).
3. *(Optional)* Define the time range for which to display the data.
   a. In the Vertical Line Profile window, place the cursor at the desired minimum X value.
   b. Right-click that location and select **Set X Min**. The plot removes all data to the left of that point and shifts the plotted data such that that point is the minimum X value.
   c. Place the cursor at the desired maximum X value, right-click, and select **Set X Max**. The application removes all data to the right of that point and shifts the plotted data to fill the plot window.
4. *(Optional)* Smooth the data by applying up to five data filters. For example, to apply a 4th order Butterworth low-pass filter, follow these steps.
   a. Right-click the chart, select **Properties**, and click the **Data Filters** tab.
   b. In the first drop-down list, select **Butterworth** and then click the **Properties** button.
   c. In the Properties dialog, enter the desired **Smoothing Factor**, which is the ratio of the filter's time constant to the data sampling interval. Note that this introduces a lag that is proportional to the smoothing factor. The default value is 1 (no smoothing).



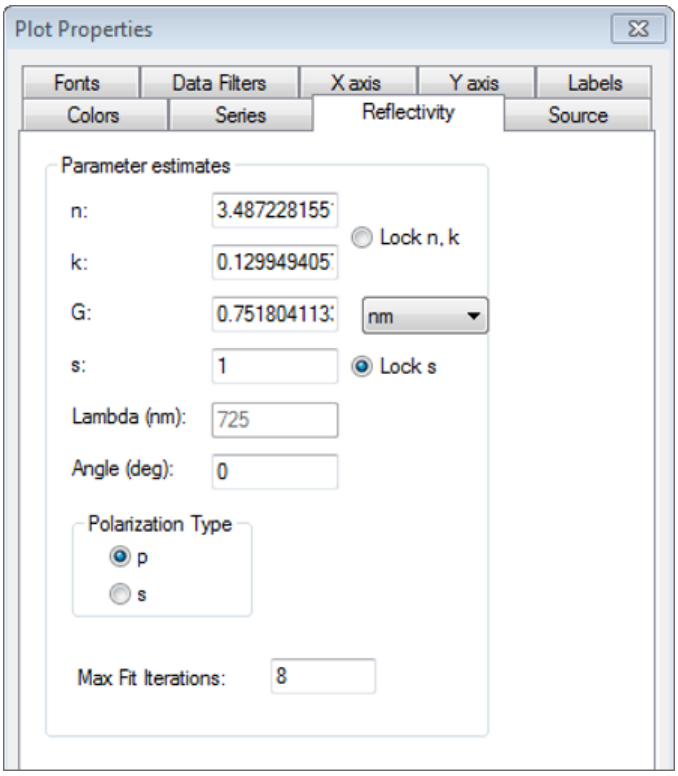
d. To add other filters, select them in the subsequent rows.

e. Click **OK** to apply the selected filters.

5. Select **Analysis > Reflectivity Fit** to open a chart that displays the fitted film thickness, growth rate, and optical properties.



To configure the fit, right-click the plot window, select **Properties**, click the **Reflectivity** tab, and specify the reflectivity parameters. As with any fitting algorithm, the better the estimate of the fitting parameters, the faster the convergence. In the Virtual Interface algorithm, either *n* and *k,* or *s* must be locked, allowing the unlocked parameters to be calculated. Note that when the fit converges, the ***n***, ***k***, and ***G*** fields contain the fitted values, which are also displayed on the chart.

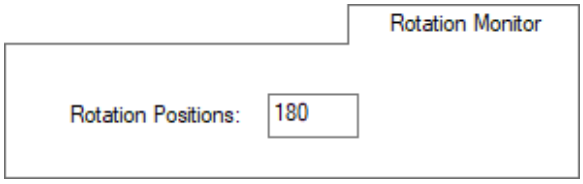


Field Name	*Description*
n	Index of refraction of the deposited material. If unknown, enter **1** (i.e., vacuum).
k	Extinction coefficient (i.e., imaginary part of the complex index of refraction) of the deposited material. If unknown, enter **0** (i.e., no absorption).
G	Estimated growth rate (in nm or µm) per unit time. If unknown, enter **0**.
s	Reflectivity scale factor for the fit, intended to account for such things as absorption from a coated viewport or reflectivity calibration errors. This parameter relates the measured reflectivity values to the absolute reflectivity via $\boldsymbol{R_{meas} = s \cdot R_{fit}}$. You can adjust this, unless $\boldsymbol{n}$ and $\boldsymbol{k}$ are locked at specific values, in which case the best-fit value of $\boldsymbol{s}$ is a calculated value.
Lambda	The application automatically enters the wavelength value of the vertical line profile, but you can enter a different value.
Angle	Angle of incidence of the incoming light source beam, with respect to the normal to the surface.
Polarization Type	Choose the applicable polarization type, as described in the two-port option section.
Max Fit Iterations	Maximum number of attempts to fit the data. If, for some reason, the fit fails to converge, try increasing this number.

3.6 How to Set the Spectra Phase Delay

Follow the procedure below to set the phase delay.

1. Select the applicable spectrometer from the **View** menu or click the  button on the toolbar to open the Live Spectrometer window.
2. Right-click the Live Spectrometer window and select **Properties**.
3. On the Spectrometer tab, use the slider to set the desired integration time, and verify that the **External trigger** box is checked.
4. Click the Rotation Monitor tab, and enter the desired number of rotation positions.



The application evenly divides each rotation period into this number of positions.

> ***Note***
>
> *The total acquisition time (spectrometer integration time multiplied by number of positions, plus processing time) must be less than the rotation period.*
>
> *For example, for a rotation rate of 30 RPM, the rotation period is 2 sec. If the integration time is 20 ms, the maximum number of rotation positions per cycle is 100 (2 sec/20 ms). If you reduce this by 10% to allow for processing time, etc., the result is 90 rotation positions. If this number is too large, the measurements will fall out of synchronization.*

5. Open the Spectra Phase Delay Selection Acquisition window, and then select the desired spectrometer in the **Acquire source** field.
6. Verify that the platter is rotating and check the value in the **Rotation Positions** field.
7. Open the Real-time Phase Delay Section RTC.
8. Click **Start** when you are ready to begin the acquisition.

   When acquisition starts, the rotation monitor will attempt to lock on to the RPM of the rotating platen. After several rotations, the RPM estimate will lock, and the plotted line will begin to re-trace itself. The highest value on the **Phase Delay** axis should be the value of the largest rotation position (i.e., total number - 1). For example, if you use the default value of 250 rotation positions, the display should read 249. If not, decrease the number of rotation positions and/or the integration time.
9. Allow the acquisition to run for several rotations to ensure that the system is working properly, then click the **Stop** button. The RTC places a marker at the location that represents the current phase delay. You can move the marker by clicking the triangle at the top and dragging it to the desired position.

   This defines the phase delay value that the application will use going forward. To save this value, click the **Set Phase Delay** button or close the Spectra Phase Delay Selection Acquisition window.

3.7 How to Calibrate the Spectrometer

k-Space calibrated the kSA SpectR spectrometer prior to shipment. However, during shipment, the spectrometer was subject to mechanical and thermal shock that may have led to a small spectral shift — on the order of 0.5 to 1 nm. To determine if a post-shipment correction is needed, perform a Mercury-Argon (Hg-Ar) line source calibration. If a correction is needed, this procedure determines the magnitude of that correction.

> ***Note***
>
> *For maintenance purposes, you should perform a new Hg-Ar calibration and acquire a new dark background every 6 months. You must also acquire a new reference after a Hg-Ar calibration to correct for any shift in the spectra.*

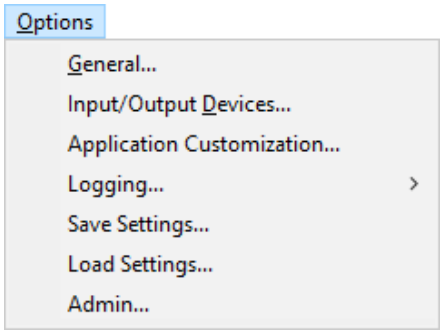
1. Install the kSA lens tube spacer between the fiber and spectrometer input to reduce the intensity of the HgAr source.
2. Select **Acquire > Spectrometer Calibration**.
3. In the Spectrometer Calibration Acquisition window, click the **Advanced** button.
4. In the Advanced Acquisition Options dialog, click the Advanced Settings tab, and check the **Hg 546.1nm** and **Hg 763.5nm** boxes in the **Select Spectral Lines** section, and click **OK**.
5. Wait at least **15 mins** for the spectrometer to reach operating temperature.
6. Choose the **Calibrate for** option, and then enter **30** in the **Sec** field.
7. Right-click the Live Spectrometer window and select **Properties**.
8. On the Spectrometer tab, adjust the integration time to ensure that the spectrometer is not saturated (typically between **20** and **40 msec**).
9. If the magnitude of the indicated shift in wavelength is **≥ 0.2 nm**, accept the new calibration when prompted. The application will save the settings in the spectrometer **.stp** file and reinitialize the spectrometer.

   > ***Note***
   >
   > *Be sure that the shift to does not exceed **± 1.5nm**. The wavelength of the Hg 546 line may end up high and the 763.5nm line low. It is not possible to match both.*
   >
   > *If the shift exceeds ± 1.5nm, contact k-Space for assistance.*

10. Click the **Snapshot**  button on the Live Spectrometer toolbar to capture a snapshot of the spectrum, and save it as a **.kdt** file (for example, SNAA0758 HgAr.kdt). Re-run the calibration in **Continuous** mode to verify that the calibration correction is within the acceptable limits.
11. Acquire a post-calibration dark background, and save the dark background **.kdt** file.
12. Reconnect the spectrometer fiber optics cable to its original port.
13. Remove the HgAr cable and store it in a protected location.

4 Configuring the kSA SpectR Software

The kSA SpectR software includes numerous options that allow you to customize the operation and various aspects of the application. You can access these options through the commands on the **Options** menu. The settings you choose for these options apply to all users for all acquisition modes and analysis tools.



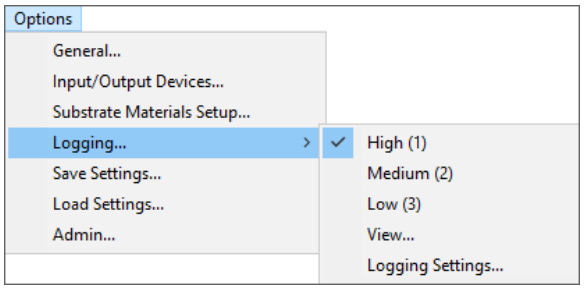
4.1 General and Input/Output Device Options

The Options menu provides access to the General Options dialog and the Input/Output Device Options dialog. These dialogs include multiple tabbed pages that contain options for controlling the general operation and functionality of the kSA SpectR system and options for configuring the analog and digital input and output boards, respectively.

For a detailed description of each option and setting, refer to Appendix A: General Software Options and Appendix B: Input and Output Device Options.

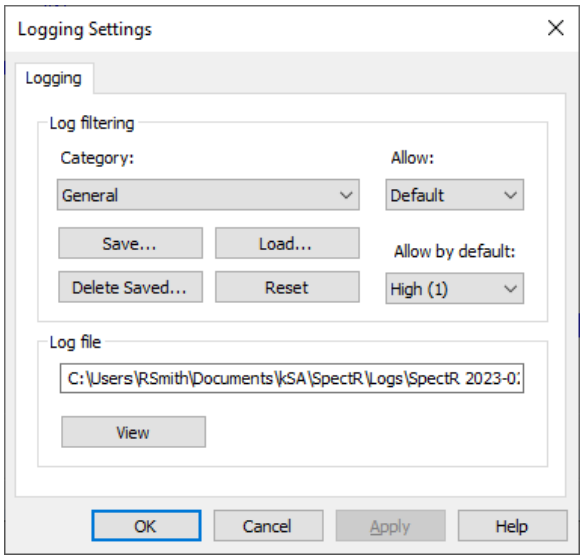
4.2 Data and Activity Logging

The kSA SpectR software records details on errors and certain activities that occur while the application is running. Each time an error or a selected activity occurs, the application records relevant information (error, activity, date and time, etc.) in the log file and saves the file in the folder specified in the **Logs** field on the General Options > Directories tab. The log file is in standard text **.txt** format, so you can view it using any text editing application.



➢ Select **Options > Logging** to access the following commands.

- **High/Medium/Low:** Applies the selected logging level.
- **View.** Opens the current log file in Microsoft Notepad.
- **Logging Settings.** Opens the Logging Settings dialog, where you can specify options for the data and activity log files. The fields in this dialog correspond to the fields on the General Options > Logging tab.



4.3 Saved Software Settings

You can save all current kSA SpectR application settings in a kSA personality (.ksaxml) file. These files contain settings for all the windows and dialogs in the kSA SpectR software (i.e., any kSA SpectR setting that you can update in the computer registry).

When you load a personality file, the application will apply those settings whenever you open the kSA SpectR application, ensuring consistent settings and consistent results.

Follow these steps to save your kSA SpectR software settings.

1. Verify that all custom settings are exactly the way you want them, and that all windows, dialogs, and plot windows that you want to display are open in the main window.
2. If an acquisition window is open, close it; this will also close all open real-time charts.

3. Select **Options > Save Settings**.
4. In the Browse for personality file dialog, navigate to the applicable folder location, and enter a descriptive file name for the settings file.
5. Click the **Save** button.

The application saves all kSA SpectR settings, including your custom settings. The process may take several seconds to complete.

> ***Note***
>
> *You can check the **Save settings at program exit** box on the General Options > General tab to automatically load the current settings each time you open the kSA SpectR application.*

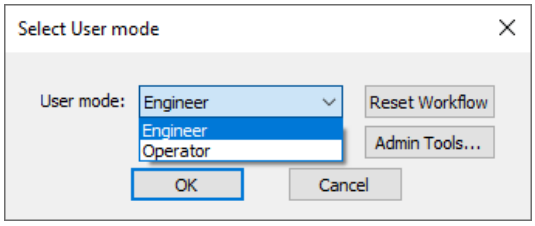
After you create one or more personality files, you can load the settings contained in those files, as follows.

1. Select **Options > Load Settings**.
2. The application displays a prompt asking you to confirm that you want to load archived preferences. If you click **Yes**, the application will overwrite the current settings with those from the saved personality file.
3. In the Browse for personality file dialog, navigate to and select the applicable personality file, and click the **Open** button.
4. When prompted to reinitialize all boards, click **Yes** to apply your custom settings immediately.

4.4 Software User Mode

The kSA SpectR application can be run in two different modes — Engineer or Operator. This may be useful in cases where you want to restrict certain users from accessing the configuration options and advanced acquisition options areas of the application.

➢ To select the user mode, select **Options > Admin** or click the ADMIN button on the toolbar. Select the desired mode from the **User mode** drop-down list, and then click **OK**.



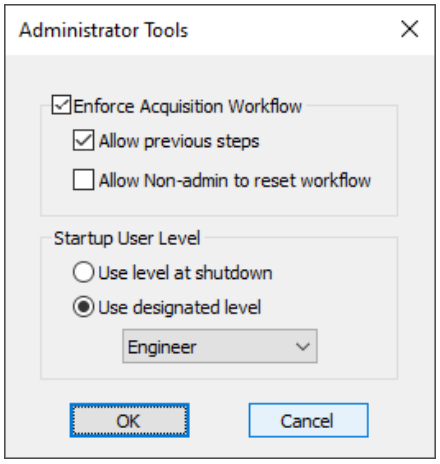
- The **Engineer** mode provides full access to every window, dialog, and command in the kSA SpectR application, and the Select User mode dialog includes the **Reset Workflow** (to start the pre-defined workflow from the beginning) and **Admin Tools** (to open the Administrator Tools dialog) buttons.

- The **Operator** mode has access to only certain acquisition modes and read-only access to options dialogs.

4.4.1 Administrator Tools

Use this dialog to specify workflow options and the default user level. This dialog is available only when the kSA SpectR software is in **Engineer** mode.

➢ To access the Administrator Tools dialog, click the **Admin Tools** button in the Select User Mode dialog.



Field Name	*Description*
Enforce Acquisition Workflow	Forces the user to work through the procedures in a pre-defined workflow. ▪ **Allow previous steps:** Keeps the previous steps in the workflow enabled so that you can go back to them. ▪ **Allow Non-admin to reset workflow:** Enables the **Reset Workflow** button (in the Select User Mode dialog) for all user modes.
Startup User Level	User mode in which to open the kSA SpectR application every time. ▪ **Use level at shutdown:** Opens in the user mode that was in use the last time the system shut down. ▪ **Use designated level:** Opens in the user mode selected here.

5 Common Tasks in the kSA SpectR Software

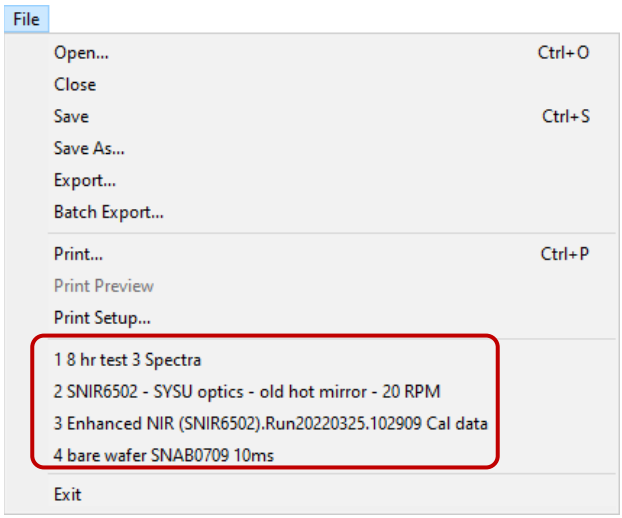
As with any software application, there are certain tasks that you will perform frequently in the kSA SpectR software. This chapter describes some of the most common tasks. The commands for these tasks are available on the **File**, **Edit**, and **Window** menus.

5.1 Opening Data Files

When you acquire data with the kSA SpectR, you can save them in proprietary k-Space file formats. You can use these files for data analysis, and in some cases, you can select a data file instead of a spectrometer as the data source in the active data acquisition window.

You can open a kSA SpectR data file using any of the following methods.

- Browse to the applicable file using any of the following commands.
  - Click the **Open** button on the toolbar.
  - Select **File > Open**.
  - Press **CTRL+O** on your keyboard.
- Select a recently saved file from the Most Recently Used (MRU) list on the **File** menu. The MRU list includes up to the last 10 saved data files opened in the kSA SpectR application. The files are listed in the order they were opened, with the most recent file at the top.



5.1.1 kSA SpectR file formats

The kSA SpectR application saves data in several different proprietary file formats. Because external applications cannot read data from kSA proprietary files, the kSA SpectR software provides several options for exporting the data to other more common formats.

Filename Extension	*Data Type*	*File Contents*
bsrf	Reference	Reference spectrum acquired through a reference acquisition to normalize the acquired spectra. During data acquisition, the application uses this spectrum to normalize the spectra as they are acquired.
exprt	Custom export	Settings for a custom data export.
img	Scan Mode image	Scan Mode image data generated during data acquisition.
kdt	Acquired data	Data acquired via the various data acquisition modes. The specific contents of the **.kdt** file depends on the acquisition mode used to acquire the data. In many cases, you can select a **.kdt** file as the spectra source in the data acquisition window, and acquire data from the file as if it were a live spectrometer.
ksaxml	Saved settings	All current software settings for the kSA SpectR application.
log	Data and activity logs	Record of activity that occurs as you use your kSA SpectR system for data and activity logging purposes.
stp	Spectrometer source	Parameters for the kSA SpectR spectrometers, including the wavelength range of the spectrometer and any correction shift determined by a Hg-Ar line source calibration.

5.2 Saving and Exporting kSA SpectR Data

After you acquire data or complete an analysis, you can save the data for future reference. When you save data, the application retains the original data, which include details that are specific to the kSA SpectR application and that only k-Space software can read.

The kSA SpectR software includes options for exporting the data to other formats to enable you to view the information in other applications, such as Microsoft Word or Excel or other graphics applications. When you export data, the application retains the original data in the selected format, but it does **not** export the data that are specific to the kSA SpectR.

5.2.1 Saving kSA SpectR data

k-Space recommends that you save all acquired data in the proprietary kSA file formats. These files contain data that are specific to the kSA SpectR and allow you to use the built-in data analysis tools on those data.

Use any of the following methods to save the data in the active window.

- Click the **Save** button on the toolbar.
- Select **File > Save**.
- Press **CTRL+S** on your keyboard.
- Select **File > Save As** to specify a name for the file.
- Set up the application to save data automatically by enabling the **Store Incrementally** and/or **Auto-save documents** options on the Advanced Acquisition Options > Document Generation tab.

5.2.2 Exporting kSA SpectR data

There may be times when you need to view kSA SpectR data in non-kSA applications. Because the k-Space proprietary format is not compatible with third-party applications, the kSA SpectR application allows you to export data to other formats. The exported data will **not** include the same details as those saved in proprietary k-Space format.

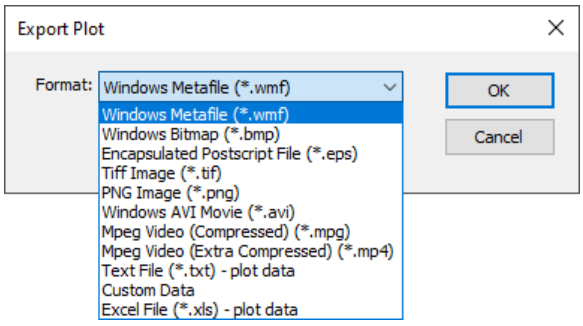
The kSA SpectR application offers three options for exporting data — standard export, custom export, and batch export.

Standard export

Follow these steps to export data contained in the active window.

1. Select the window that contains the data to export.
2. Select **File > Export** to open the Export Plot or Export Image dialog.

   The data formats available for export depend on the type of data you are exporting. For example, the following options are available for exporting acquired spectral data.

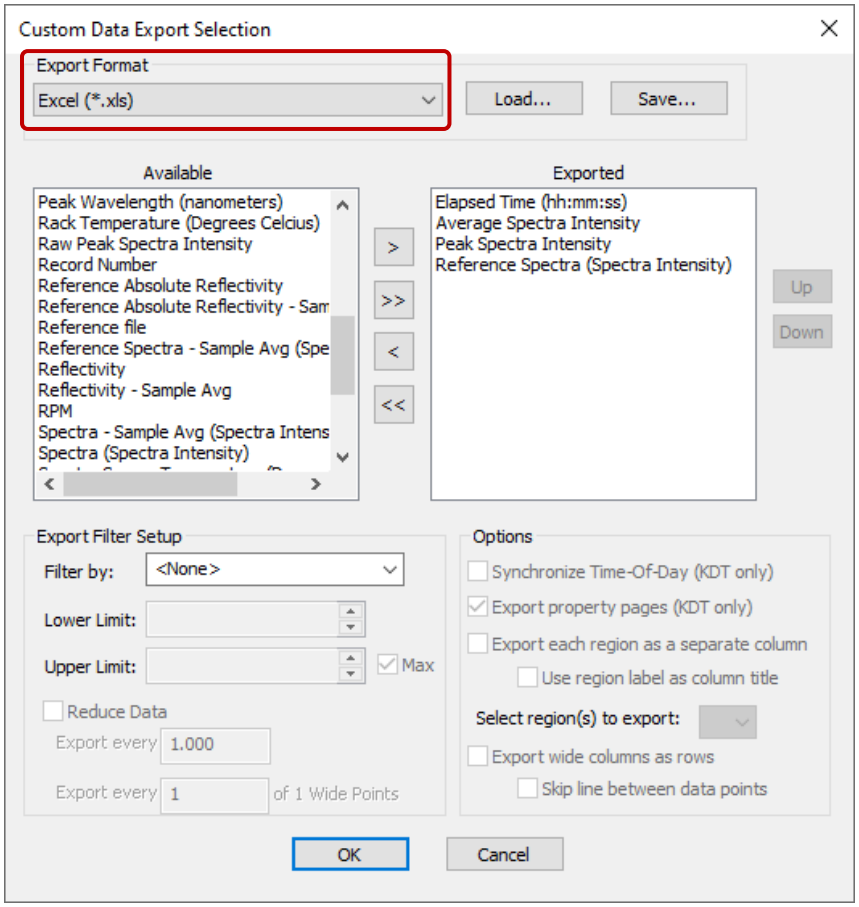


3. Select the format for the exported data, and then click **OK**.
4. In the Save Copy As dialog that opens, select the appropriate folder location for the export file, enter a descriptive file name, and click **Save**.

Custom data export

For most kSA SpectR data types, you can select specific data to include in the export file and specify options for the data, and then you can save these settings as a custom export recipe (**.exprt**) file.

1. Select the window that contains the data to export, and then select **File > Export**.
2. In the Export Plot dialog, select **Custom Data** from the drop-down list, and click **OK**.
3. In the Custom Data Export Selection dialog, select the desired export file type from the drop-down list in the **Export Format** section, and then specify the remaining parameters as applicable.



Field Name	*Description*
Export Format	Format for the exported data. To load settings from a saved export recipe file, click the **Load** button. To save the current settings to an export recipe file, click the **Save** button.
Available / Exported	Use the **Select** [>], **Select all** [>>], **Remove** [<], and **Remove all** [<<] buttons to move the data types to export between the **Available** and **Exported** panes. The data are stored in the order listed in the **Exported** pane. To change the order, highlight the data types in the **Exported** pane and click the **Up** or **Down** button to move them to the preferred positions.
Export Filter Setup	You can exclude certain data from the export file by selecting a filter (data points or elapsed time) and specifying the range of data to exclude. To export all applicable data, select **<None>**. To further reduce the amount of exported data, check the **Reduce Data** box and specify the number of data points to skip.

Field Name	*Description*
Options	▪ **Synchronize Time-Of-Day:** Uses the time stamp from the original **.kdt** file. To use the time that the export file was created, clear this box. ▪ **Export property pages:** Exports **all** data available in all tabs in the Plot Properties dialog (many of these parameters are not listed in the **Available** pane). ▪ **Export each region as a separate column:** *(N/A for the kSA SpectR)* ▪ **Select region(s) to export:** *(N/A for the kSA SpectR)* ▪ **Export wide columns as rows:** Exports each element in the array as a separate row, instead of exporting each as a column. This makes the output file long instead of wide. Check the **Skip line between data points** to add a blank line between each data point to break up the data in the export file.

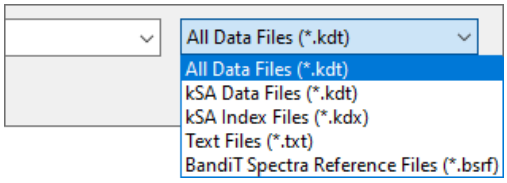
4. After you have selected the data to export and specified the application options, click **OK**.
5. In the Save As dialog that opens, select the appropriate folder location for the export file, enter a descriptive name for the file, and click **Save**.

> ***Tip: Automatically export custom data***
>
> *You can set up the kSA SpectR to automatically export data using a custom export recipe at the end of every acquisition by checking the **Auto Export data** box on the Advanced Acquisition Options > Document Generation tab, choosing the **Custom using** option, and selecting the preferred custom export recipe file.*

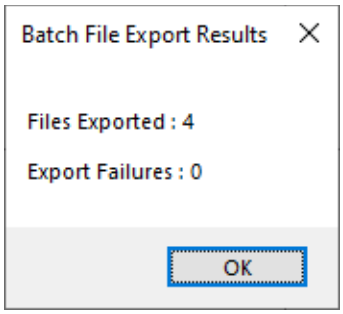
Batch export

The kSA SpectR software enables you to export data from multiple files into a single export file. Note that all files included in the batch must be of the same file type.

1. Select **File > Batch Export**.
2. In the Open dialog, select the files to include in the export file, and then click the **Open** button.

> ***Note***
>
> *By default, the Open dialog lists all available **.kdt** files. You can select a different proprietary k-Space file format from the drop-down list in the lower-right corner of the Open dialog.*
>
> 
>

3. In the Custom Data Export Selection dialog, specify the export options.
4. Click **OK** to begin the export. When the export is complete, the application displays the export results.



5.3 Printing Plots and Data

Use any of the following methods to print data from the active window.

- Click the **Print** button on the toolbar.
- Select **File > Print**.
- Press **CTRL+P** on your keyboard.

The application opens the standard Windows Print dialog, where you can select options for your specific printer and specify the pages and number of copies to print.

To select the orientation and paper size for the printed file, select **File > Print Setup**.

5.4 Copying and Pasting Images and Data

You can use any of the following methods to copy data from the active window to the Windows clipboard. You can then paste the clipboard contents into other applications, such as Microsoft Word or Excel or Paint.

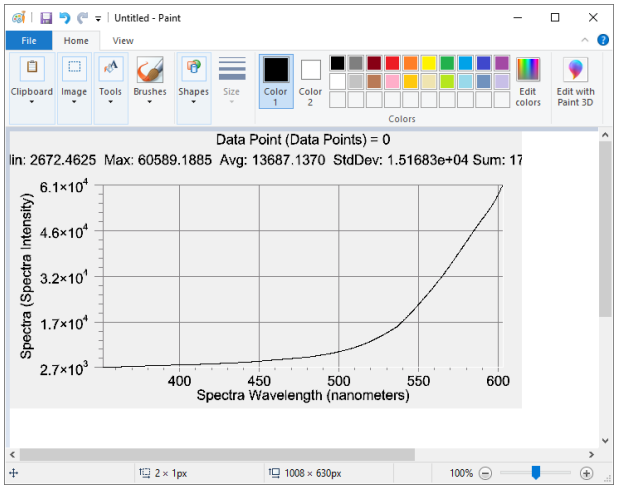
- Click the **Copy** button on the toolbar.
- Select **Edit > Copy**.
- Press **CTRL+C** on your keyboard.
- Right-click the active window and select **Copy**.

5.4.1 Pasting Windows clipboard contents

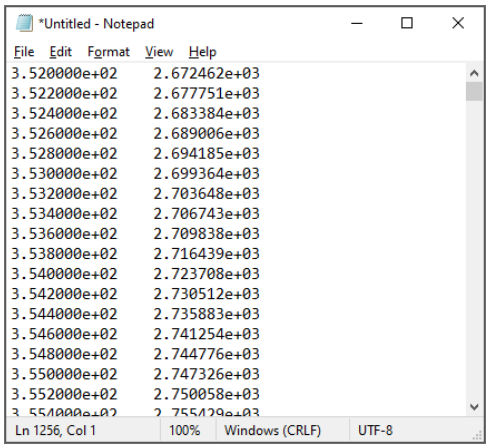
When you copy data from a Scan Mode image (**.img**) window, the copied content will always be pasted as an image, regardless of the application into which you're pasting the content.

When you copy data from a kdt plot window, you have the option to paste the data as an image or as formatted numerical data in certain applications.

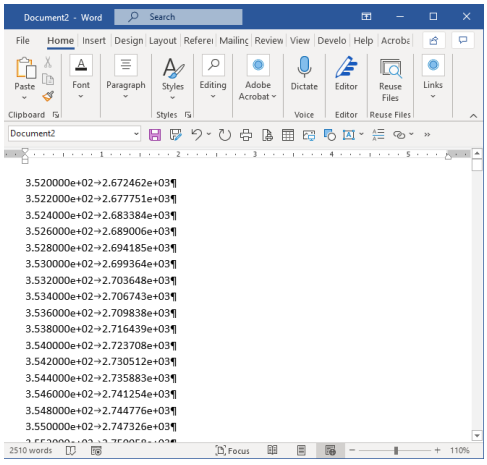
- **Graphics applications**: (e.g., Microsoft Paint) The content will always be pasted as an image.

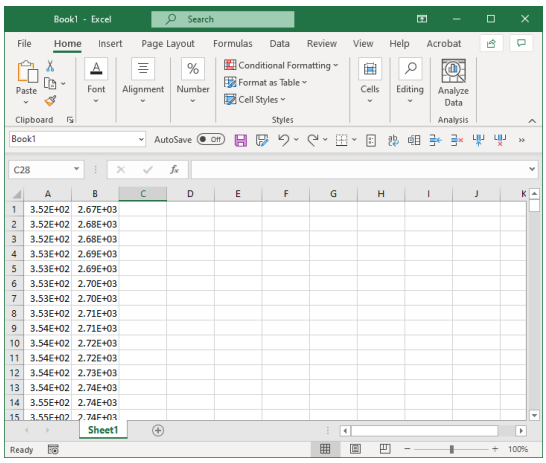


- **Simple text editor:** (e.g., Microsoft Notepad) The content will always be pasted as formatted numerical data.

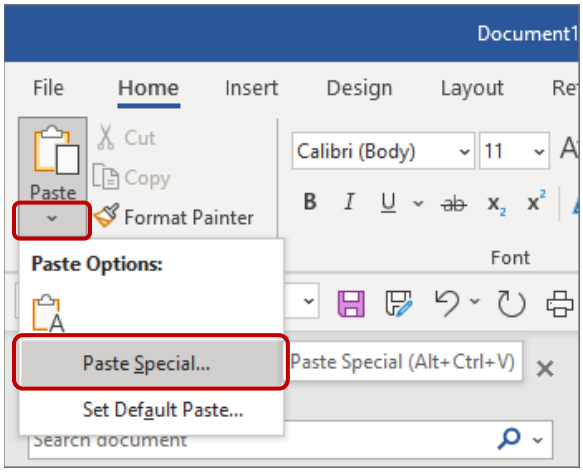


- **Word processors or spreadsheets:** (e.g., Microsoft Word or Excel) By default (when you press **CTRL+V**), the contents will be pasted as formatted numerical data.

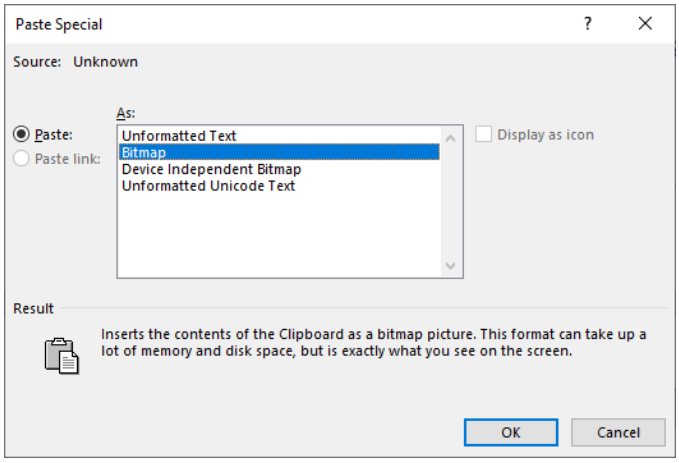




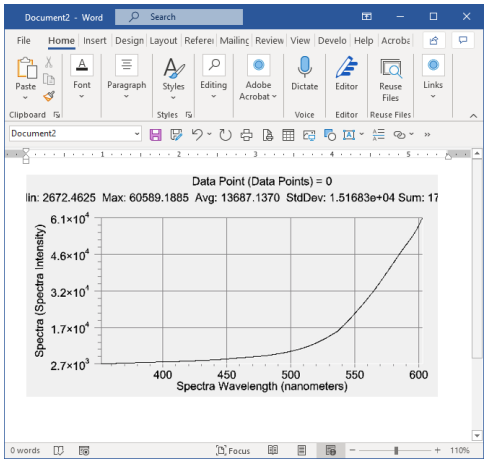
To paste the clipboard contents as an image, click the arrow on the **Paste** button on the **Home** ribbon, and then select the **Paste Special** option.

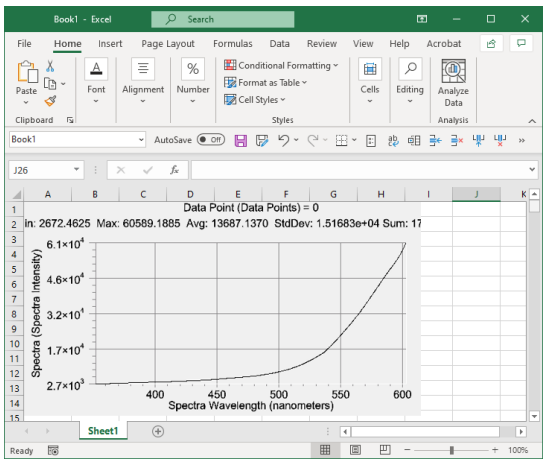


In the Paste Special dialog, select **Bitmap**, and then click **OK**.



The contents will be pasted into the application as an image.





5.5 Setting Data Display Properties

Each open data or analysis window in the kSA SpectR application has an associated Properties dialog that contains options for customizing the data displayed in the plot window.

➢ Use any of the following methods to open the Properties dialog for the active window.

- Select **Edit > Properties**.
- Right-click the window and select **Properties**.
- For the Live Spectrometer window, click the  button on the Live Spectrometer toolbar.
- For real-time chart windows, double-click inside the window.

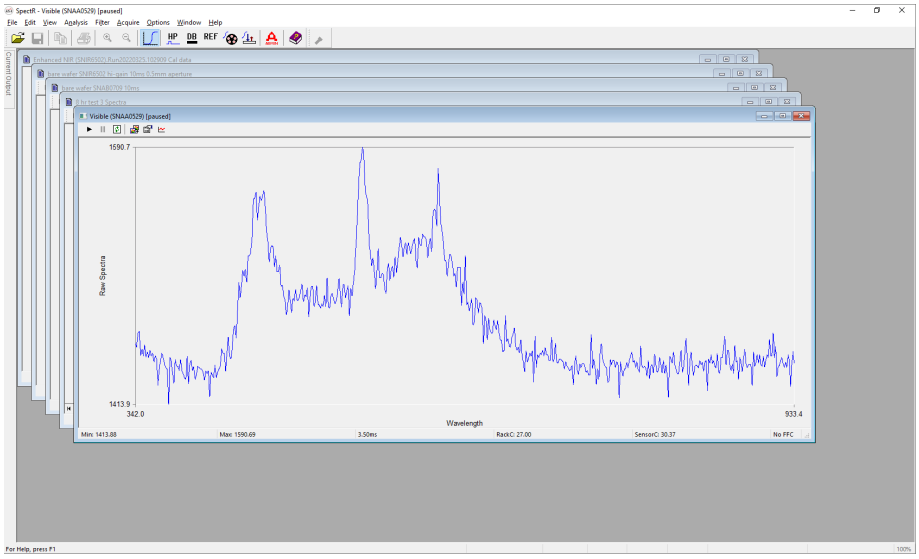
The Properties dialog that opens depends on the active window.

- **Live Spectrometer window:** The Spectrometer Properties dialog includes options that affect the way the spectrometer acquires data.
- **Scan Mode image window:** The Image properties dialog includes comments and details on the settings used to acquire the image.
- **kdt plot window:** The Plot Properties dialog includes options that affect the way the data are plotted, without affecting the original acquired data.

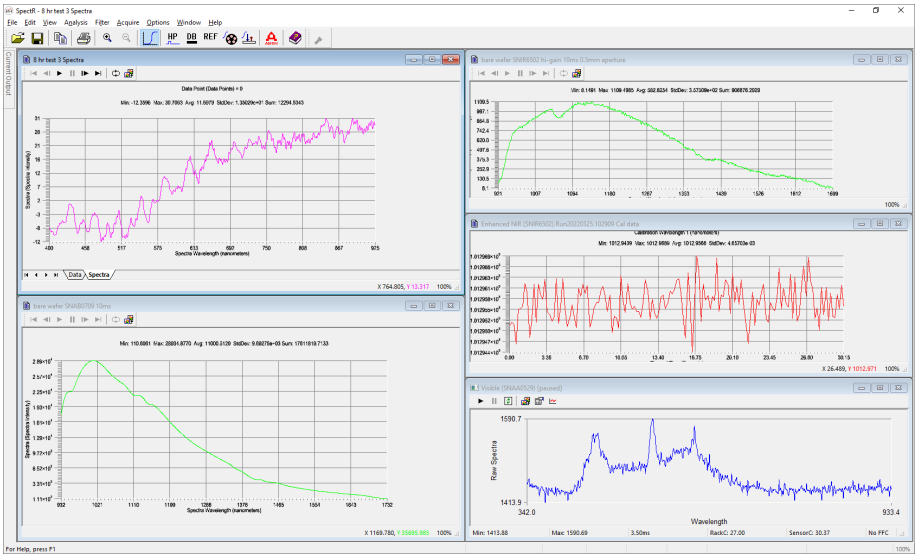
5.6 Arranging Open Data and Plot Windows

The **Window** menu includes the following commands for switching between open windows and choosing how those windows are arranged in the main window.

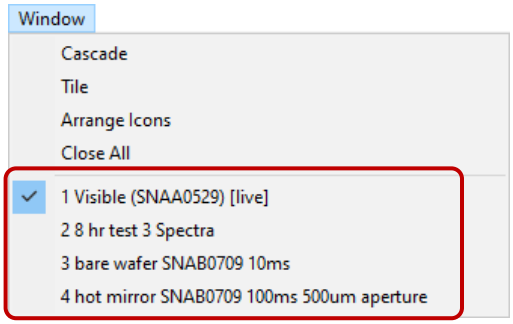
- **Cascade:** Displays all open windows, one on top of the other, such that the title bar for each window is visible. To quickly switch between windows, click the title bar for the window you want to view.



- **Tile:** Resizes all open windows so that they fit in the main window without overlapping.



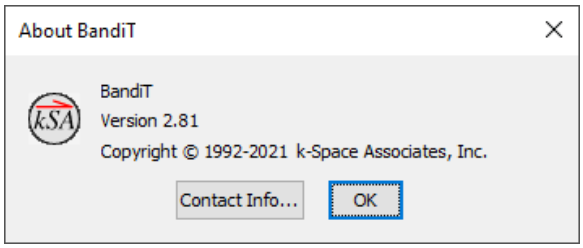
- **Close all:** closes all open windows at the same time, so you do not need to close them individually.
- **<window name>:** The Window menu includes a list of all open windows and denotes the active window with a checkmark to the left of the window name. To quickly switch between windows, select the preferred window from the menu.



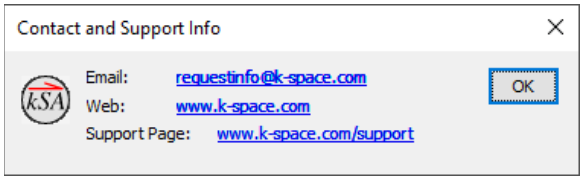
5.7 Getting Help

Use the commands on the **Help** menu to access information about your kSA SpectR software.

- **User manual:** Opens a searchable PDF of this ***kSA SpectR User Manual***. See Finding Information in This User Manual for information on searching for specific content.
- **About:** Displays the kSA SpectR software version information and provides access to k-Space contact information.



- **Contact and Support Info:** Provides links to contact information for k-Space.



6 Data Acquisition Modes in the kSA SpectR Software

The kSA SpectR system includes several data acquisition modes that enable you to capture very extensive and wide-ranging data. You can view and analyze these data using the various kSA SpectR real-time and post-acquisition analysis tools.

During data acquisition, the application captures and stores data in **.kdt** data files using a proprietary k-Space data format.

The following data acquisition modes are available for kSA SpectR systems. Note that not all modes are applicable to every system.

6.1 Common Acquisition Parameters

Most kSA SpectR acquisition modes include the following fields and buttons.

- **Data source:** Source of the acquired data. This could be a spectrometer or, in some cases, a spectral **.kdt** file. If you select a spectral **.kdt** file, the application will acquire data from the file as if it were a live feed.

  The name of the data source field depends on the acquisition window. For example, in the Dark Background Acquisition window, it is named **Spectra source**; in the Single-wafer Spectra Reflectivity window, it is named **Spectral Reflectivity**; etc.
- **Acquired data file name:** Name of the file to save the acquired data in. The name of the acquired data file field (**Run name** or **Archive name**) depends on the acquisition window.

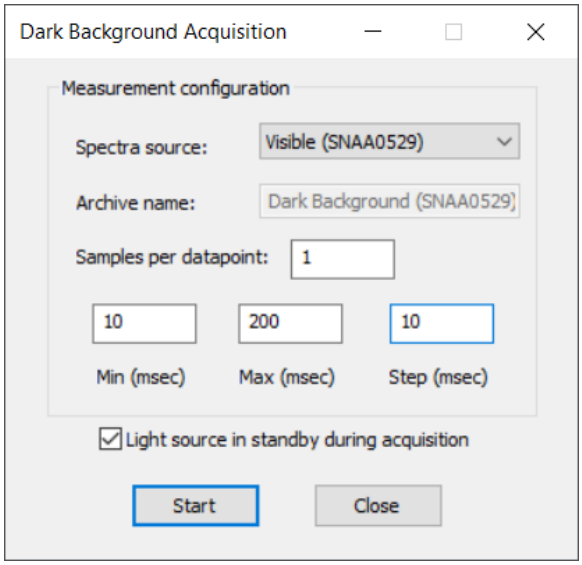
  This field may be grayed out and unavailable, depending on the selection in the **File name format** field on the Advanced Acquisition Options > Document Generation tab.
  - If you selected **Manual run name**, the **Archive name** field will be available, and you must enter a name for the data file.
  - If you selected **Auto-incrementing run name**, **Date/time-based run name**, or **Base Name Only**, the field will be grayed out, with the default file name already entered.
- **Advanced button:** Opens the Advanced Acquisition Options dialog, where you can choose options for the current acquisition.
- **Start/Close buttons:** The **Start** button initiates data acquisition. During acquisition, the labels for the **Start** and **Close** buttons change to **Pause** and **Stop**, respectively.

  The **Close** button closes the acquisition window and any open real-time analysis windows.

6.2 Dark Background Acquisition

The **Dark Background Acquisition mode** obtains spectral data in the absence of light. These spectra represent the inherent background noise that is present even in the absence of an external signal. The application automatically subtracts the background spectra from the measured spectra to provide the cleanest spectra for analysis.

➢ To access the Dark Background Acquisition window, select **Acquire > Dark Background** or click the **Dark Background** DB button on the toolbar.



Field Name	*Description*
Spectra source	Select the applicable spectrometer as the data source. Dark background data are spectrometer-specific, so you must select the spectrometer you will use for data acquisition.
Archive Name	Name of acquired data file.
Samples per datapoint	Number of samples to take for each data point. Sampling serves to reduce random noise by averaging multiple spectra together.
Min / Max / Step	These fields define the range of integration times (**Min/Max**) for which to acquire dark background data and the increment (**Step**) by which to increase each successive integration time. See Specifying integration times for important information.
Light Source in standby during acquisition	Puts the light source is in standby mode, to eliminate as much light as possible in the chamber.

6.3 Flat Field Correction Acquisition

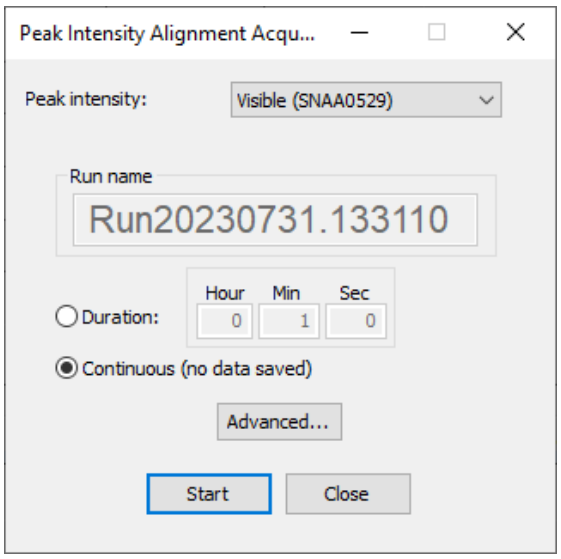
The **Flat Field Correction Acquisition** mode can be used to acquire a correction curve that serves to "flatten" the spectrometer's inherent wavelength-dependent response. If needed,

k-Space performs this procedure prior to shipping the system and, under normal circumstances, you should not need to repeat it.

6.4 Peak Intensity Alignment Acquisition

Use the **Peak Intensity Alignment Acquisition mode** to facilitate alignment of the optical assemblies. When this mode is active, the **Real-time Peak Intensity Over Time** RTC is available. You can maximize the reflected intensity by observing the peak intensity vs. time on the RTC to ensure that the source and detector optics are precisely normal to the sample (for single-port systems) or specularly opposed with respect to the sample (for two-port systems).

➢ To access the Peak Intensity Alignment Acquisition window, select **Acquire > Peak Intensity Alignment Acquisition**.

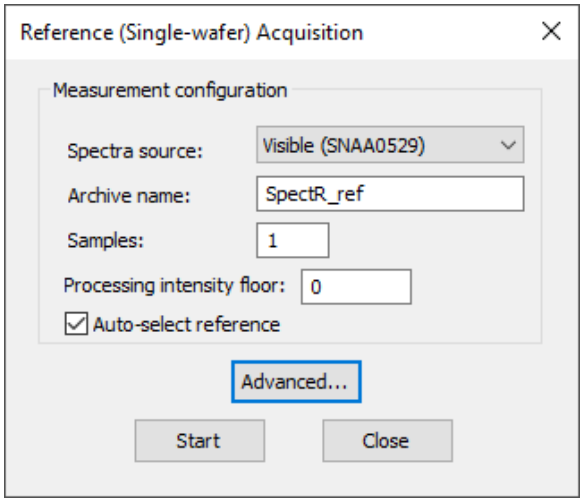


Field Name	*Description*
Peak Intensity	Select the applicable spectrometer as the data source.
Run name	Name of the acquired data file.
Amount of data to acquire	Choose the amount of data to acquire. ▪ **Duration:** Acquires data for the exact length of time specified in the **Hour**, **Min**, and **Sec** fields. ***Note:*** *You can enter up to 4 digits for both seconds and minutes and up to 3 digits for hours. The application will convert to the appropriate number of hours/minutes/seconds, if needed.* *For example, if you enter **9999** seconds, the application will convert the duration to **2 hr, 46 min, and 39 sec**.* ▪ **Continuous (no data saved):** Acquires data continuously, until you click the **Stop** button. You can monitor and analyze the data as it's acquired, but the application does not save the data.
Advanced	Opens the Advanced Acquisition Options dialog.

6.5 Reference (Single-wafer) Acquisition

The **Reference (Single-wafer) Acquisition mode** captures reference spectra while the platen is stationary. The application uses reference spectra to normalize the measured spectral reflectivity to that of a bare substrate, typically obtained just prior to growth.

➢ Select **Acquire > Reference (Single Wafer)**.

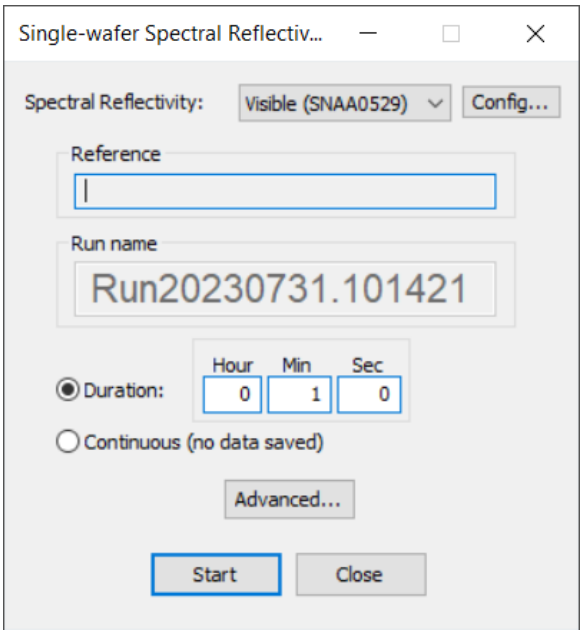


Field Name	*Description*
Spectra source	Select the applicable data source.
Archive name	Name of the acquired data file.
Samples	Number of samples to acquire. It is helpful to acquire multiple samples to reduce random noise.
Processing intensity floor	Minimum peak intensity value that a spectrum must possess to be considered valid. The application will ignore any spectra with peak intensities below this value.
Auto-select reference	Automatically selects the new reference when the acquisition is complete.
Advanced	Opens the Advanced Acquisition Options dialog.

6.6 Single-wafer Spectral Reflectivity Acquisition

The **Single-wafer Spectral Reflectivity Acquisition mode** measures reflectivity, film thickness / growth rate, and optical constants (*n*, *k*) simultaneously. The application saves a **.kdt** file containing the Fabry-Perot Dip spectra (both raw and normalized) when you use this mode to acquire data. You can also use this mode to create montage plots in the form of scan-mode images (**.img**).

➢ Select **Acquire > Single-wafer Spectral Reflectivity** or click the  button on the toolbar.

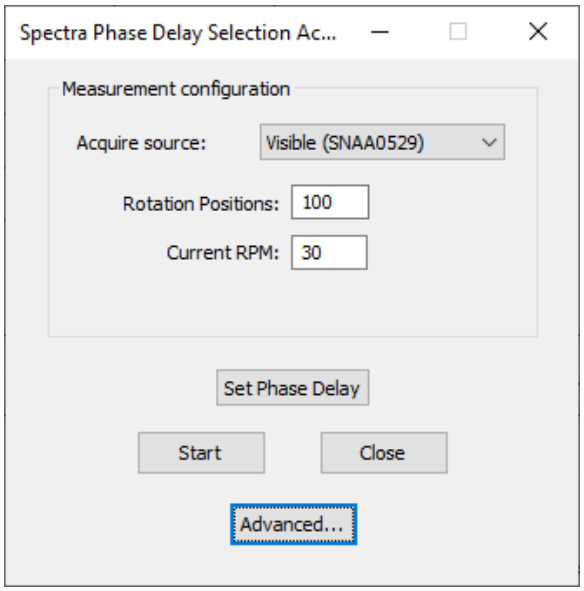


Field Name	*Description*
Spectral Reflectivity	Select the applicable data source.
Reference	Name of the file that contains the reference spectrum to use.
Run name	Name of the acquired data file.
Amount of data to acquire	Choose the amount of data to acquire. ▪ **Duration:** Acquires data for the length of time specified in the **Hour**, **Min**, and **Sec** fields. ▪ **Continuous (no data saved):** Acquires data continuously, until you click the **Stop** button. You can monitor and analyze the data as it's acquired, but the application does not save the data.
Advanced	Opens the Advanced Acquisition Options dialog.

6.7 Spectra Phase Delay Selection Acquisition

The **Spectra Phase Delay Selection Acquisition mode** sets the rotational position at which to acquire data. The application uses the phase delay to ensure that data acquisition occurs when the sample is in that position. After the system receives a Home pulse, the application delays the triggering the spectrometer by the selected amount.

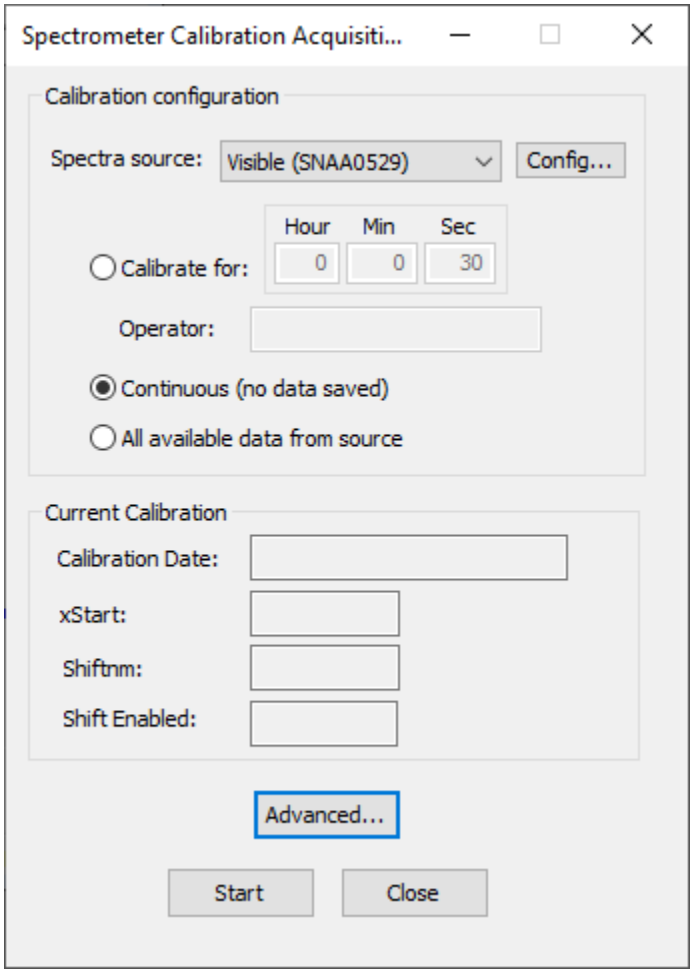
➢ Select **Acquire > Spectra Phase Delay Selection**.



Field Name	*Description*
Acquire source	Select the applicable data source.
Rotation Positions	Number of rotation positions to track.
Current RPM	Number of revolutions that the sample makes every minute on the rotation stage, if known.
Set Phase Delay	Sets the position marker at the current position. After that point, the system will be triggered to take a snapshot of data only when the stage rotation reaches this position.
Advanced	Opens the Advanced Acquisition Options dialog.

6.8 Spectrometer Calibration Acquisition

The **Spectrometer Calibration Acquisition mode** verifies that the spectrometer is properly calibrated by comparing acquired spectra against known spectral lines from a special Hg/Ar lamp. k-Space performs this calibration during instrument commissioning, but there may be times when you may need to calibrate the spectrometer.



Field Name	*Description*
Spectra Source	Select the spectrometer to calibrate as the data source.
Calibrate for/ Continuous/ All available data from source	Amount of data to acquire for the calibration. ▪ **Calibrate for:** Runs the calibration for the exact length of time specified here. You must also enter the name or ID of the operator who is performing the calibration in the **Operator** field. ▪ **Continuous:** Runs the calibration continuously, until you click the **Stop** button. The application does **not** save the acquired data. ▪ **All available data from source:** Uses all data from a saved **.kdt** file.
Current Calibration	The application enters this information from the current calibration. ▪ **Calibration Date:** Today's date. ▪ **xStart:** Starting wavelength in nm. ▪ **Shiftnm:** Overall wavelength shift (in nm) to apply, relative to the original factory settings. ▪ **Shift Enabled:** Shift status — **1** (shift is enabled) or **0** (shift is disabled).
Advanced	Opens the Advanced Acquisition Options dialog.

7 Data Analysis

In addition to the numerous data acquisition capabilities available for the kSA SpectR system, the kSA SpectR application also includes many powerful analysis tools. For example, the Real-time Charts and Montage plots are particularly useful.

7.1 Real-time Charts

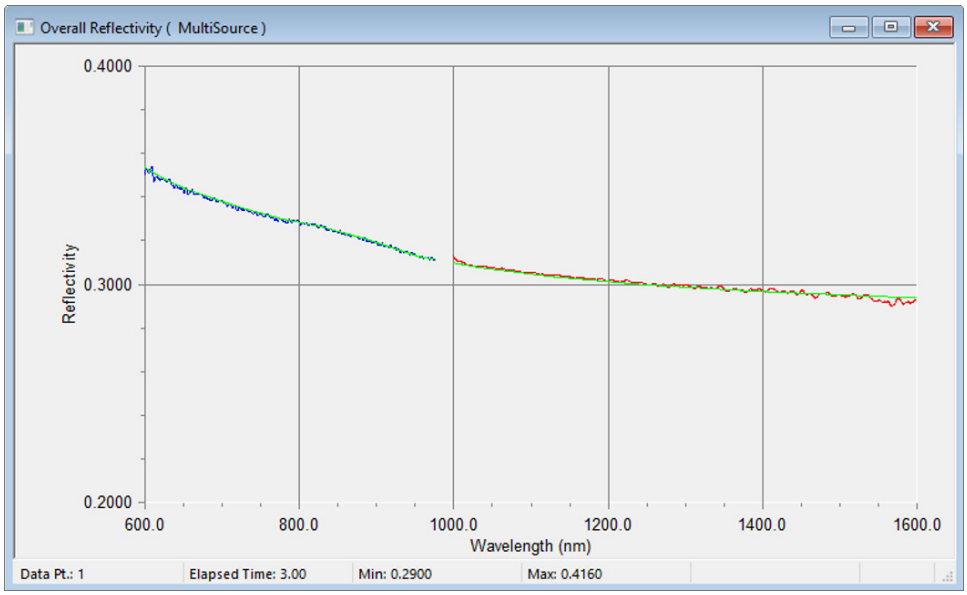
The kSA SpectR application includes numerous real-time charts (RTCs) that allow you to view raw and processed data in real-time. These charts provide valuable data and information that you can analyze as they are being acquired. You can open multiple RTCs for each acquisition, enabling you to monitor several aspects of the acquisition simultaneously.

➢ To view one or more RTCs, open a data acquisition window, and then select the desired RTCs from the **View** menu. The RTCs that are available for selection depend on the selected data acquisition window.

> *Notes*
>
> - *Each RTC has an associated Plot Properties dialog that is comprised of several tabbed pages with options and settings that control how the data are displayed in the plot window.*
> - *For most RTCs, you can select the parameter to plot from the drop-down list on the Plot Properties > Data tab.*
> - *Several RTCs include a **Snap Shot** button. During acquisition (or after acquisition is complete), you can click that button to capture data at the current point. The application automatically saves the data in a file of the appropriate type (based on the acquisition mode).*

7.1.1 Overall Reflectivity

RTC, which displays the live reflectivity measurements and the reflectivity of the reference used to calibrate the system (green trace).

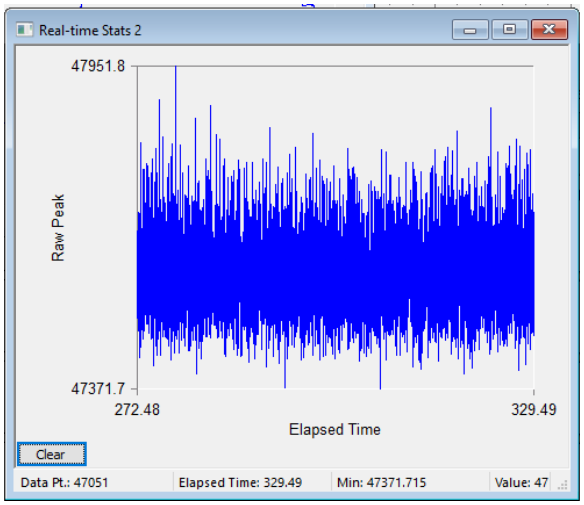


This MultiSource chart can display data from multiple spectrometers simultaneously. For example, the plot above shows the reflectivity of GaAs measured using a dual-spectrometer system. The blue trace represents the output from a visible spectrometer; the red trace represents the output from a NIR spectrometer.

The **Export** button at the lower left can be used to automatically save the data to the **Output** directory in the form of a txt file in (see the **SpectR Software Installation Guide** for details regarding setting the various file directory locations).

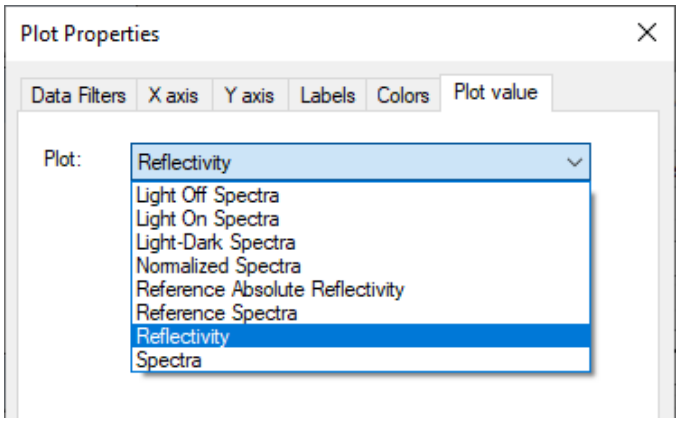
7.1.2 Real-time Stats

RTCs allow you to view raw and processed scalar data as a function of elapsed time during acquisition. The **Clear** button at the lower left can be used to clear the displayed data and reset the minimum value of the time scale.



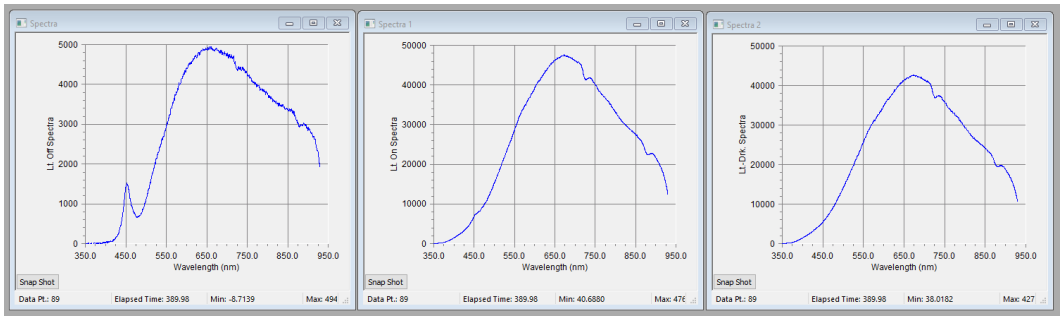
7.1.3 Spectra RTCs

allow you to customize the display by choosing from the following dropdown list on the **Plot value** tab.



Item	*Description*
Light Off Spectra	Raw spectra acquired with the light source's shutter closed (if in use).
Light On Spectra	Raw spectra acquired with the light source's shutter open (if in use).
Light - Dark Spectra	The difference between the shutter open and shutter closed raw spectra (if in use).
Normalized Spectra	Raw spectra divided by the reference spectrum.
Reference Absolute Reflectivity	Absolute reflectivity of the reference used to calibrate the system (static). See Reference Acquisition for more details.
Reference Spectra	The raw reference spectrum (static).
Reflectivity	The calculated absolute reflectivity spectra.
Spectra	The current spectrum (same as the **Real-time Spectra** RTC).

The configuration of the three Spectra RTCs shown below (**Light Off Spectra**, **Light On Spectra**, and **Light - Dark Spectra**) is particularly useful when using the light source's shutter, as it illustrates its effectiveness at removing stray light which might otherwise compromise the reflectivity measurement.



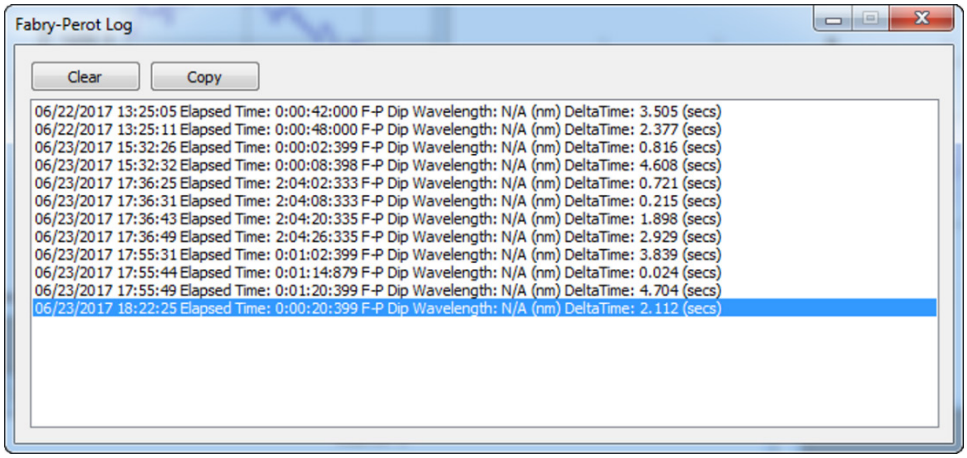
The **Snap Shot** button at the lower left can be used to open a new window containing spectra data that can be saved as a **.kdt** file, or exported in a variety of different formats

7.1.4 Real-time Fabry-Perot

RTC can be used to display the results of the Fabry-Perot Dip and/or Passband Edge detection feature. While the acquisition is running, click the **F-P Dip** button at the lower left to trigger the measurement(s).

This feature uses the settings on the Extrema Finder tab of the Spectrometer Configuration Options dialog. If the application finds an extremum that is not a valley, or if it finds multiple extrema, the system generates an error condition. Every time the application initiates a measurement, it creates an entry in the Fabry-Perot Log, which you can access from the **View** menu. The log entries include the time of day, time elapsed since the start of the data acquisition, time elapsed since the measurement was requested, and the measurement results.

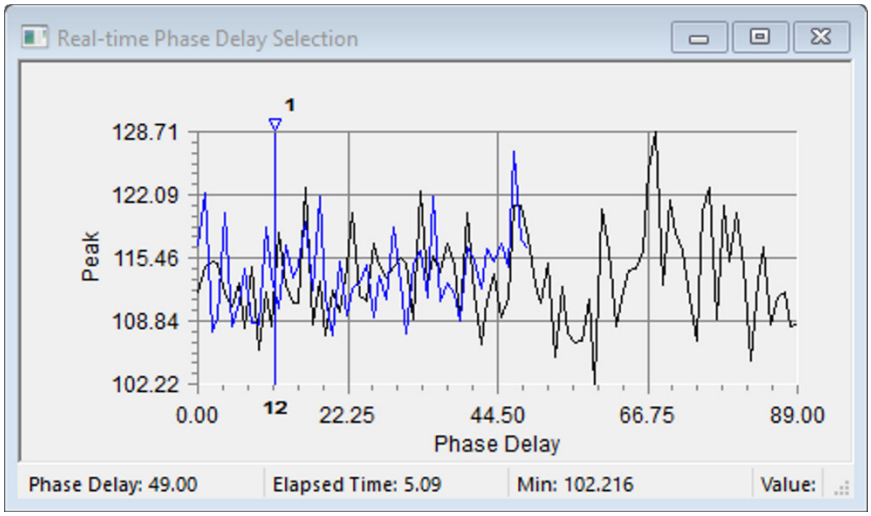
In addition, the application saves the spectra (both raw and normalized) in a **.kdt** file. Note that you can also initiate the measurement via a digital input signal by checking the **Find spectral extrema when triggered** box on the Spectral Reflectivity Configuration tab of the Spectrometer Configuration Options dialog.



7.1.5 Real-time Phase Delay Selection

This RTC allows you to select the sample position on a rotating platen that will trigger data acquisition. The application places a marker on the plot to indicate the trigger position. Move the marker to the appropriate position by clicking the triangle at the top of the marker line and dragging it to the desired position.

to open that RTC. To select the value to plot in the RTC, right-click the chart, select **Properties**, click the **Plot Value** tab, and then select the desired value from the **Plot** drop-down list. The application plots the selected parameter as a function of the rotation position.

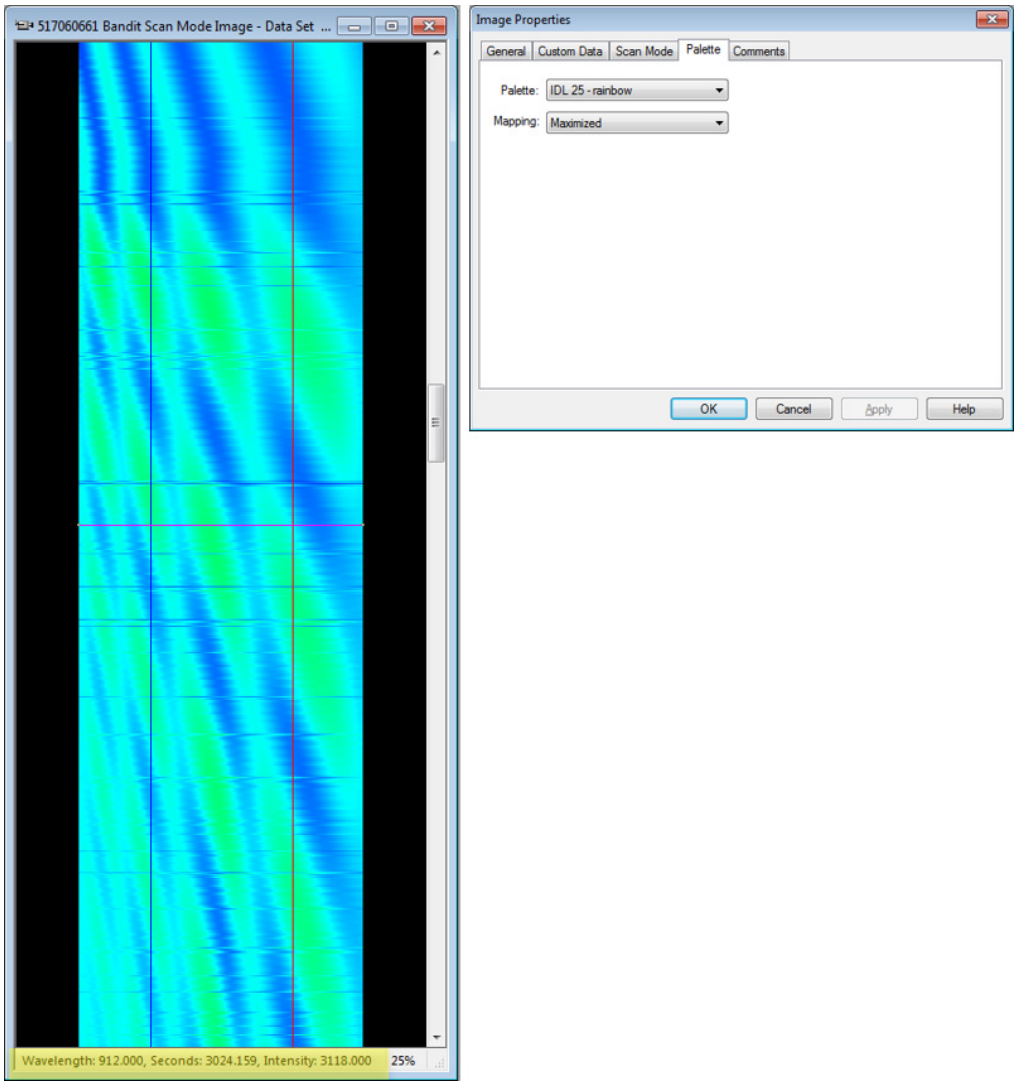


7.2 Montage (Scan Mode Image) Plots

The kSA SpectR application enables you to view the measured reflectivity simultaneously as a function of both time and wavelength, in the form of a scan mode image (a.k.a. montage plot). If operating in multi-wafer mode, you can acquire a separate montage plot for each satellite.

To view a montage plot, open the desired scan mode image (**.img**) file. You can change the colors to distinguish the changes better by right clicking the image window, selecting **Properties**, clicking the **Palette** tab, and selecting the desired color palette from the **Palette** drop-down list.

You can enhance the details in the image by re-mapping the palette to maximize the contrast. To do this, select **Maximized** from the drop-down list in the **Mapping** field. Note that as you move the cursor around the image, the application continuously updates the cursor position and intensity value in the status bar at bottom of the image window.



7.2.1 Analyzing a montage plot

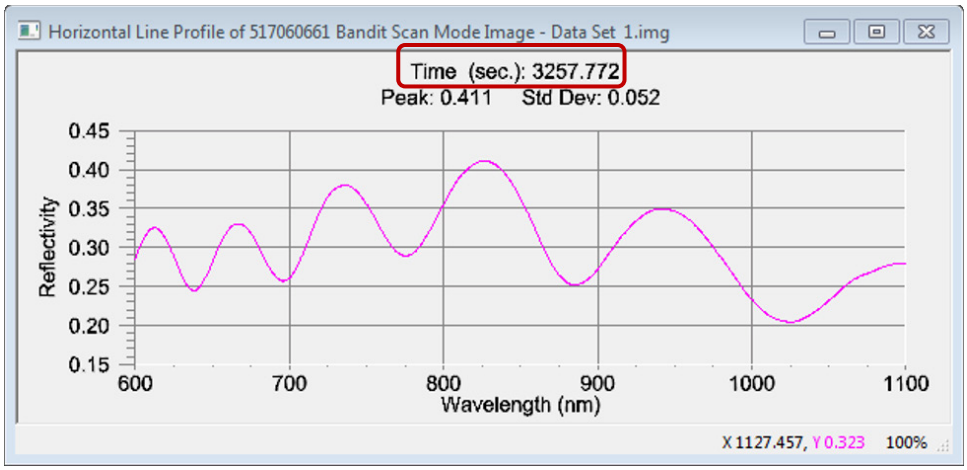
The kSA SpectR application includes several post-acquisition analysis tools you can use to analyze scan mode images.

You can create the horizontal or vertical line profile plots from a montage plot by selecting the desired line profile from the **Analysis** menu.

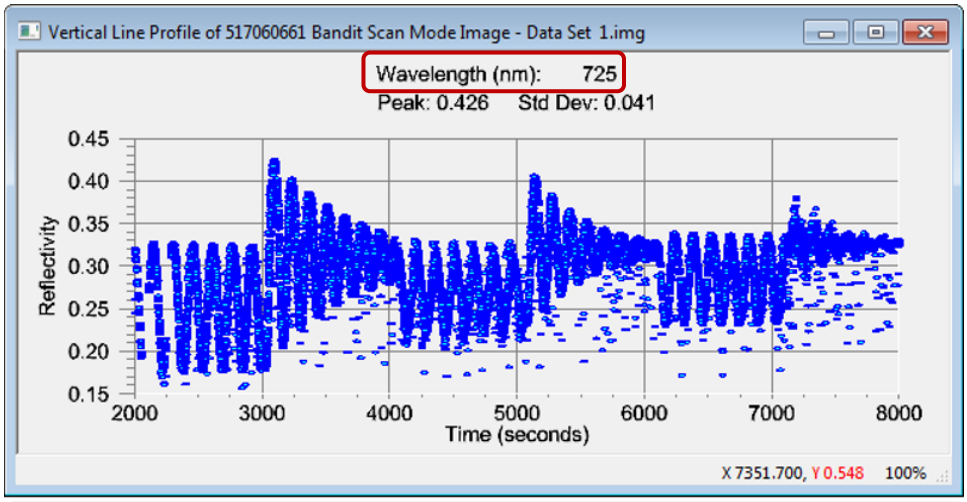
When you select a line profile, the application places a line on the line profile window and analyzes the data beneath the line. To move the line, click it and drag it to the desired location, or use the up and down arrow keys on the keyboard to move it.

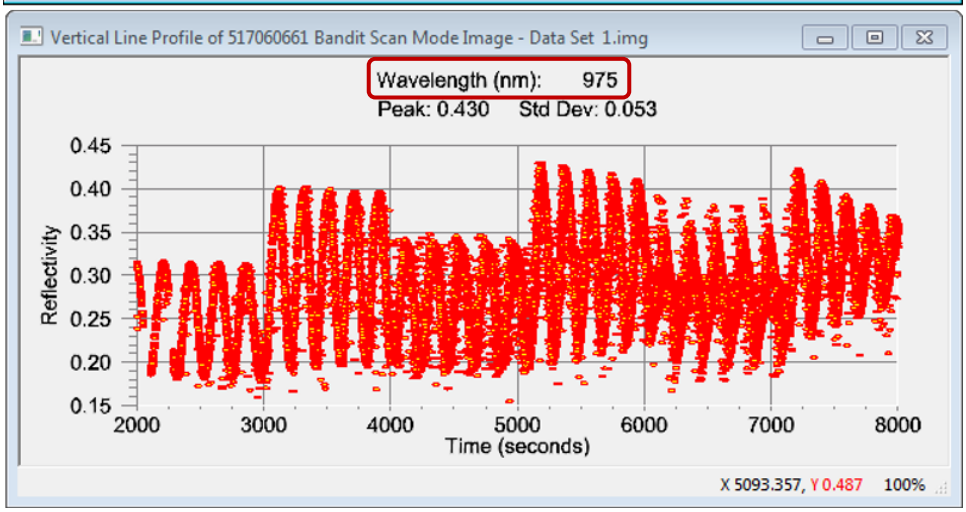
Note that you can display multiple line profiles simultaneously.

- **Horizontal Line Profile:** The application places a horizontal line on the image and plots the data beneath the line in a separate Horizontal Line Profile plot window, as shown in the following image. At the top of the plot window, the application displays the time for the current position of the line. To display data for a particular time, move the line on the image until the plot shows the desired time.



- **Vertical Line Profile:** The application places a vertical line on the image and plots the data beneath the line in a separate Vertical Line Profile plot window, as shown below. At the top of the plot window, the application displays the wavelength for the current position of the line. To display data for a particular wavelength, move the line on the image until the plot shows the desired wavelength. You can perform a reflectivity fit on this data.





8 k-Space Service and Support

k-Space stands behind all metrology systems and software that we provide to our customers. If you find that you need support or service on any k-Space products, several options are available.

8.1 Contacting Us

k-Space provides technical support by telephone, fax, or email during normal business hours (Monday through Friday, between 8:30 a.m. and 5:30 p.m. ET) at no charge during the warranty period. On-call after-hours technical support via phone or email is also available and may incur an hourly charge.

Telephone: (734) 426-7977
Fax: (734) 426-7955
Email (general inquiries): requestinfo@k-space.com
Email (technical support): support@k-space.com
Website: k-space.com

8.2 Onsite Service

k-Space offers onsite technical support and servicing. All onsite work will be performed by a qualified k-Space field-service engineer (FSE). The rates may require a minimum charge, downtime fees, and travel costs. For information and quotes for onsite service, please contact k-Space.

8.3 Factory Service

k-Space charges for the following non-warranty services that are performed at the k-Space facilities.

- Processing and diagnostics
- In-house labor
- Replacement parts (based upon standard k-Space pricing)
- Shipping via UPS Ground service, unless otherwise specified

8.4 Warranty

All k-Space systems and components are warranted against defective materials and workmanship for a period of one (1) year from the date of delivery (including any consignment parts). All field services are subject to the labor costs as outlined in the Onsite Service section.

k-Space will not charge labor or parts fees for service performed on warranty parts at the k-Space facility. k-Space customers may purchase an optional two-year warranty at the time of their initial order, for an additional percentage of the new unit purchase cost.

All k-Space software improvements and upgrades made during the warranty period, deemed applicable by k-Space, are included. Furthermore, all software issues identified (and deemed applicable by k-Space) during the warranty period will be fixed by k-Space at no cost to the customer. Extended warranty options are also available for purchase after system installation and before warranty expiration.

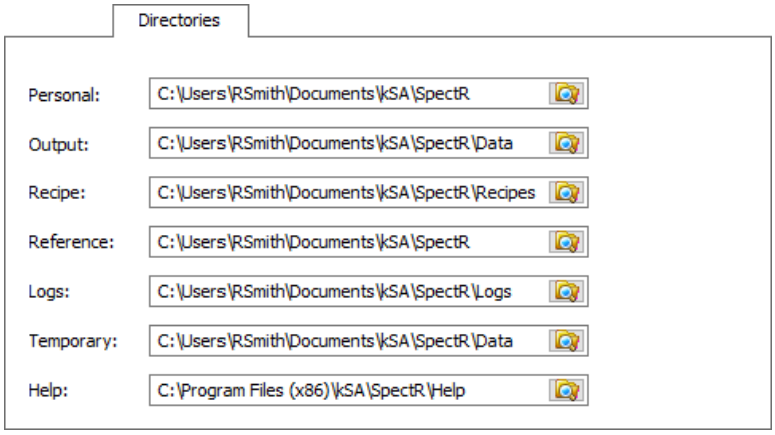
Appendix A: General Software Options

The General Options dialog includes several tabbed pages with settings that control the general operation and functionality of the kSA SpectR software and system. These settings apply to users and data acquisitions. Only the tabs that are most relevant to the kSA SpectR are discussed below. For information on any tabs or settings not mentioned here, please contact k-Space.

➢ To access the General Options dialog, select **Options > General**.

Directories tab

Use the **General Options > Directories** tab to specify the default folder location for the different types of data.

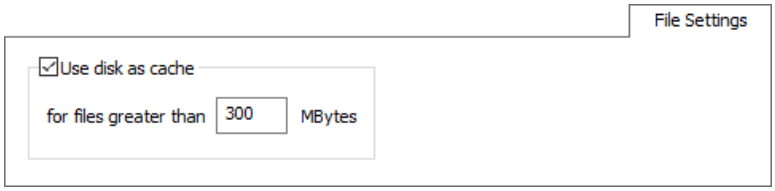


Field Name	*Description*
Personal	Location to save all user-specific files.
Output	Location to save all acquired data (**.kdt**) files (including data files that are saved automatically).
Recipe	Location to look for recipe (**.rcp**) files that contain the kSA SpectR system preferences.
Reference	Location to save the kSA SpectR reference (**.ref**) files.
Logs	Location to save all logging (**.log**) files.
Temporary	Location to save temporary data files.
Help	Location of the PDF of this user manual.

File Settings tab

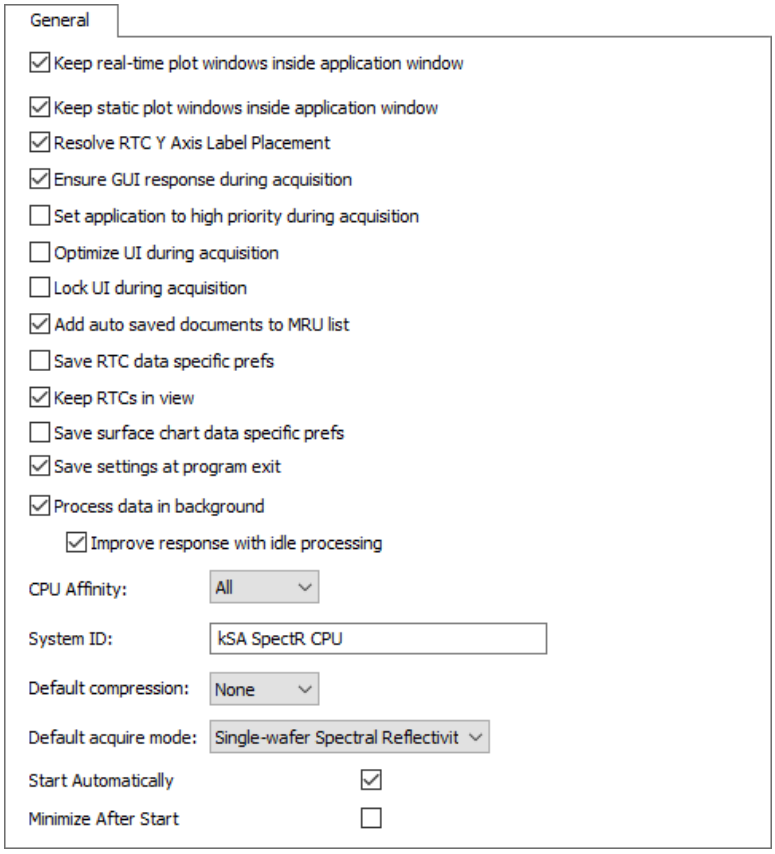
Use the **General Options > File Settings** tab to enable the disk cache feature. When enabled, the application will write data to the disk cache before writing to the disk during data acquisition.

Check the **Use disk as cache** box to enable the disk cache, and then specify the file size above which to cache the data. When a file reaches this file size during data acquisition, the application will write the data to the cache.



General tab

Use the **General Options > General** tab to set options that control the user interface (UI) and the operation and behavior of the software during data acquisition. In the descriptions below, references to "user activity" represents such activities as moving the mouse, moving a data or plot window, refreshing the screen, or clicking buttons in the application.

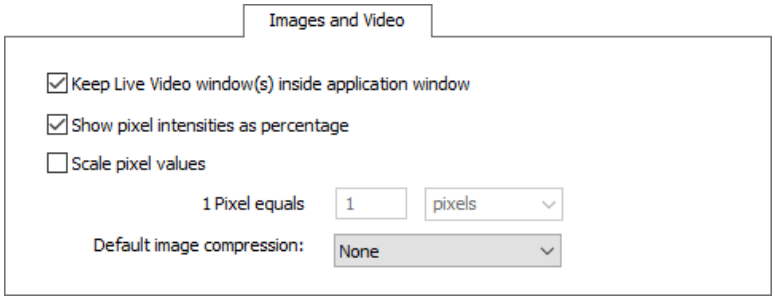


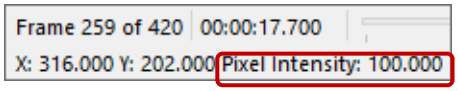
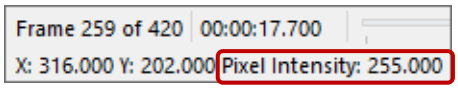
Field Name	*Description*
Keep real-time plot windows inside application window	Prevents any open real-time plot windows from being moved outside the main kSA SpectR application window.
Keep static plot windows inside application window	Prevents any open analysis plot windows from being moved outside the main application window.
Resolve RTC Y Axis Label Placement	Centers Y-axis labels on plots. This is checked by default, and in general, you should not change it.
Ensure GUI response during acquisition	Enables the software to immediately respond to user activity during data acquisition. Unless you need absolute timing precision, this box should be checked. To ensure maximum data throughput during acquisition, clear this box.
Set application to high priority during acquisition	Gives the kSA SpectR software the highest priority, in terms of processing resources, if other applications are running on the kSA SpectR computer during data acquisition. This ensures that only real-time events are executed before the kSA SpectR task. Generally, you do not need to check this box.
Optimize UI during acquisition	Gives user activity lower priority during data acquisition. This will lead to fewer data interruptions, as these activities can reduce performance during acquisition.
Lock UI during acquisition	Ignores any user activity during data acquisition.
Add auto saved documents to MRU list	If you check this box **and** the **Auto-save documents** box on the Advanced Acquisition Options > Document Generation tab , the application includes the auto-saved documents to the MRU list.
Save RTC data specific prefs	If you change the X and/or Y ranges for a real-time chart (using the **Set X Max/Min** or **Set Y Max/Min** commands on the right-click menu in the RTC window), they will default back to the original values when you close the chart window. Check this box to keep those settings the next time the RTC is opened for any applicable data acquisition mode.
Keep RTCs in view	If you resize the main application window, some of the open RTCs might move outside the window frame. Check this box to automatically move RTCs to the center of the main application window any time it is resized.
Save surface chart data specific prefs	Synchronizes the look and feel (colors, etc.) of 3-D analysis plots for images.
Save settings at program exit	Saves the current kSA SpectR settings when you exit the application. You can save these settings manually by choosing **Options > Save Settings**.

Field Name	*Description*
Process data in background	Processes data in the background when processor power is available. This helps to reduce the amount of processor power required to run the data acquisition. **k-Space recommends that you always check this box.** If this box is cleared, the acquisition could potentially be interrupted. You cannot change this setting when a data acquisition window is open. If the box is grayed out, close the current acquisition window. Check the **Improve response with idle processing** box to improve overall system responsiveness.
CPU Affinity	CPU used for processing.
System ID	This field defaults to the computer name, but you can change it if needed.
Default compression	Select **None** for no compression or **ZLib** to compress the data using the zlib lossless data format. Note that compression uses system resources that may affect performance during data acquisition.
Default acquire mode	Automatically opens a data acquisition window and any previously opened RTCs when you open the application. Select the preferred data acquisition mode and then check either or both of the following. ▪ **Start Automatically:** Starts data acquisition using the default acquisition mode as soon as the software opens. ▪ **Minimize After Start:** Reduces the acquisition window size to display as a banner when the software opens.  When the acquisition window is minimized, you can click the  button to restore the window to full size or the  button to close it. ***Note:*** *This option applies to the automatic acquisition at startup only. The application will not automatically minimize the acquisition window for subsequent acquisitions.*

Images and Video tab

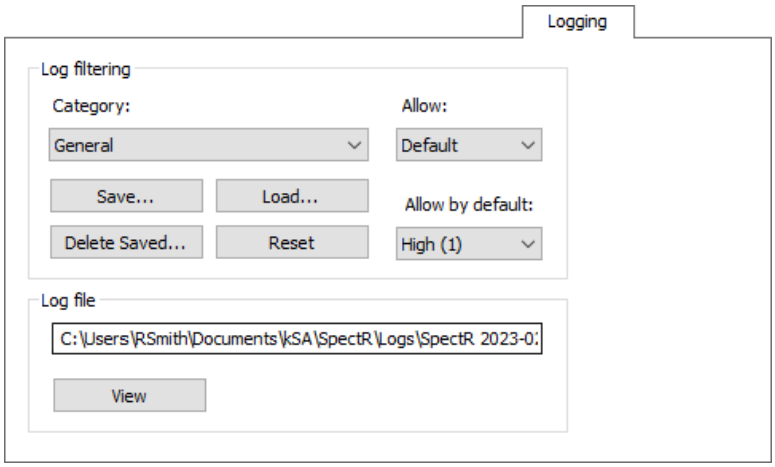
Use the **General Options > Images and Video** tab to specify options for kSA SpectR image and video files.

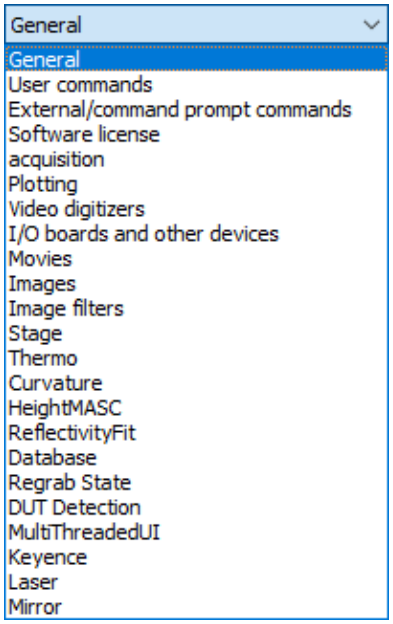


Field Name	*Description*
Keep Live Video window(s) inside application window	Prevents the Live Video window from being moved outside the main kSA SpectR application window.
Show pixel intensities as percentage	The application displays the intensity for the current position of the cursor in the status bar at the bottom of the image or video window. Check this box to display the intensity as a percentage of the maximum possible intensity.  If you clear this box, the application will display intensity as the value of the raw signal count. 
Scale pixel values	Scales the acquired data to use a length unit of measure (inches, cm, etc.) instead of pixels. Enter the pixel value by which to scale the data in the **1 Pixel equals** field, and then select the unit of measure for the pixel equivalent.
Default image compression	To use image compression, select **ZLib**, which is a lossless data format that can be used across platforms. To disable image compression, select **None**.

Logging tab

Use the **General Options > Logging** tab to configure data and activity logging, as described in the Data and Activity Logging section. When logging is enabled, the application records details for all activity that occurs while the application is running. Logs are useful, both for recording software activity and for capturing the causes of errors, if any occur.



Field Name	*Description*
Category	Select each applicable category, in turn, to specify logging settings for that category. You can specify different settings for each category. 
Allow/Allow by default	Level of logging to allow for the selected category. ▪ **None:** Does not log any data or activity . ▪ **All:** Logs all system information. ▪ **High:** Logs high-level details, such as start/stop times, data acquisitions, system information, and program errors. ▪ **Medium:** Logs the same details as **High**, plus any application warnings. ▪ **Low:** Logs the same details as **Medium**, plus any applicable notes. ▪ **Default:** *(for **Allow** field only)* Uses the logging level selected in the **Allow by default** field.
Save	Saves the current settings for the selected category.
Load	Loads the settings from a saved logging preferences (**.log**) file.
Delete Saved	Deletes all saved logging preferences files.
Reset	Resets all logging levels for all categories to **Medium**.
Log File	Displays the name and complete path for the current log file.
View	Opens the current log text file in Microsoft Notepad, where you can view the logged information.

Appendix B: Input/Output Device Options

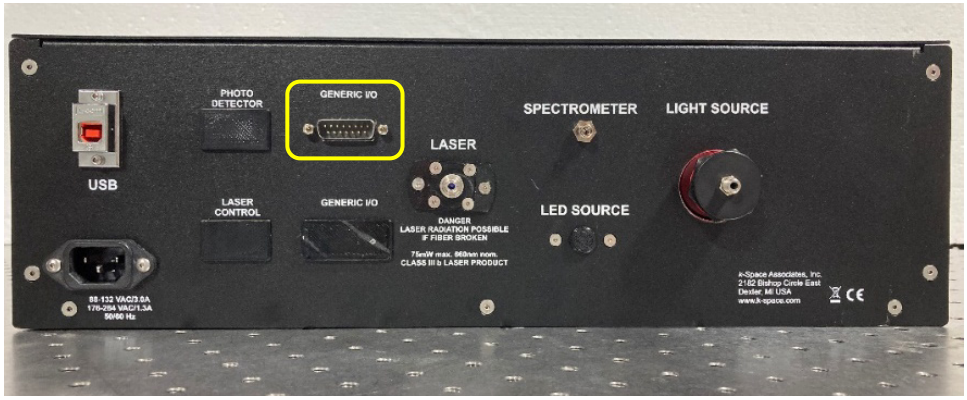
The kSA SpectR system includes a number of analog and digital input and output boards that provide specific functionality, such as analog and digital input/output, counter/timer functions, etc. These capabilities are enabled by your Sentinel key.

The Input/Output Device Options dialog includes several tabbed pages for configuring the analog and digital boards installed in your kSA SpectR system. Only the tabs that are most relevant to the kSA SpectR are discussed below. For information on any tabs or settings not mentioned here, please contact k-Space.

➢ To access the Input/Output Device Options dialog, select **Options > Input/Output Devices**.

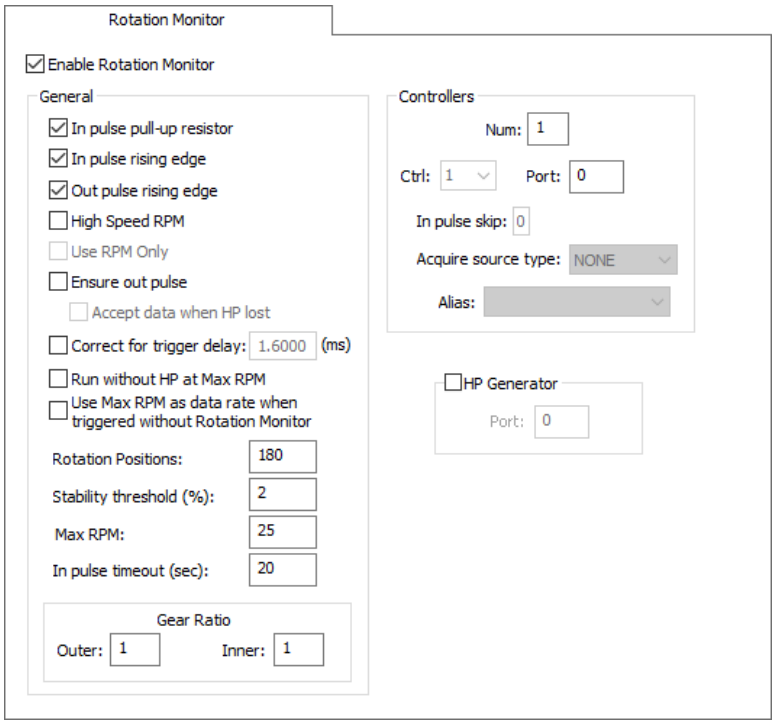
The kSA SpectR system includes user-assignable analog and digital I/O, accessible using the **Generic I/O** 15 pin "D" connector on the back of the rack. You can select the board models and corresponding options in the **Input/Output Device Options** dialog.

Note
*See section 3 of the **kSA SpectR Software Installation Guide** for more details.*

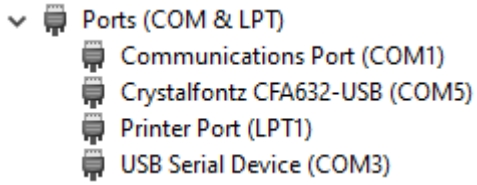


Rotation Monitor tab

The kSA SpectR system allows data acquisition to be synchronized with the rotation of the samples using a home pulse provided by the reactor. Use the **Input/Output Device Options > Rotation Monitor** tab to configure settings for that board.

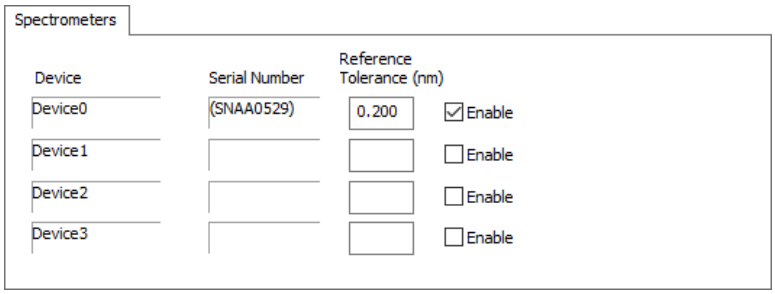


Field Name	*Description*
Enable Rotation Monitor	Enables the system to synchronize data acquisition with the rotation of the samples using a reactor home pulse.
In pulse rising edge	Check this box if the input pulse is active high (i.e., rising edge). If the input pulse is active low (i.e., falling edge), clear this box.
Out pulse rising edge	Check this box if the output pulse is active high (i.e., rising edge). If the output pulse is active low (i.e., falling edge), clear this box.
Rotation Positions	Number of rotation positions (maximum of 250). The application divides each rotation period evenly into this number of positions. Note that the total acquisition time (i.e., spectrometer integration time multiplied by number of positions, plus processing time) must be less than the rotation period.
Stability threshold	Maximum variation allowed in the rotation rate (default is 2%). If the acquisition exceeds this value, an error condition occurs, and the system pauses data acquisition until the rotation rate becomes sufficiently stable again.
Max RPM	Maximum rotation rate anticipated for the run. The application uses this value, in combination with the **Duration** setting in the acquisition window, to determine the total number of rotations to measure. The acquisition will run until this estimated number of rotations has been observed, or until the specified amount of time has elapsed, whichever comes first. So, to prevent the acquisition from timing out early, set the **Max RPM** value to the maximum rotation rate anticipated during the run. If in doubt, choose a large number.
In pulse timeout	Maximum time to allow between the input pulses before an error condition occurs and the data acquisition is halted.

Field Name	*Description*
Gear Ratio	If your system does not have a rotation ratio that is 1:1, use these fields to specify the ratio between the outer gear (the one that measures the rotation rate) and the inner gear (the one tied to the sample rotation).
Port	Number of the port that corresponds to the rotation controller. This is listed in the Windows Device Manager as **USB Serial Device (COM x)**, where **x** represents the port number. 

Spectrometers tab

The kSA SpectR system supports the use of multiple spectrometers. Use the **Input/Output Device Options > Spectrometers** tab to enable the applicable spectrometers.



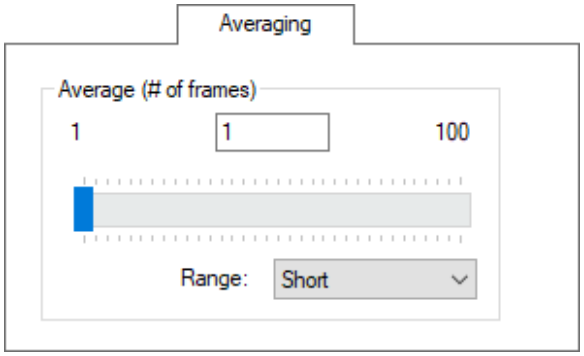
Field Name	*Description*
Device	The application assigns an ID number to each available spectrometer and displays that ID in this column.
Serial Number	The application also reads the manufacturer's serial number for the spectrometer and displays that information in this column.
Reference Tolerance	This tolerance value dictates how closely the wavelength range of a reference spectrum must match the current spectrometer range (default is 0.2 nm). For example, if a spectrometer is re-calibrated and the wavelength shifts by more than this amount, you cannot use previously acquired references.
Enable	You must check this box for the spectrometers that you will use. The application lists all enabled spectrometers on the **View** menu.

Appendix C: Spectrometer Properties

To adjust the settings for the spectrometer, right-click the Live Spectrometer window and select **Properties** to open the Spectrometer Properties dialog. This dialog includes several tabbed pages, each with different parameters and options that apply to the selected spectrometer. Only the tabs that are most relevant to the kSA SpectR are discussed below. For information on any tabs or settings not mentioned here, please contact k-Space.

Averaging tab

Use the **Spectrometer Properties > Averaging** tab to specify the number of frames from multiple spectra to average together before performing any analysis to reduce the effects of random noise. Note that this is different from **sampling**, in which the analysis is performed on each of the spectra separately, and then the results are averaged together.

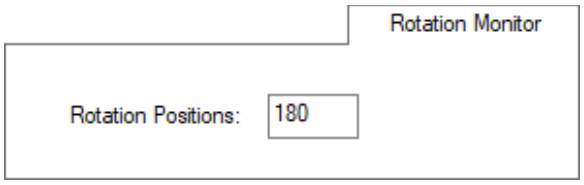


In the **Range** field, select the applicable range to set the scale for the **Average** slider, and then use the slider to specify the number of frames to average together to generate a spectrum.

- **Short:** 1 – 100
- **Medium:** 1 – 1,000
- **Long:** 1 – 20,000

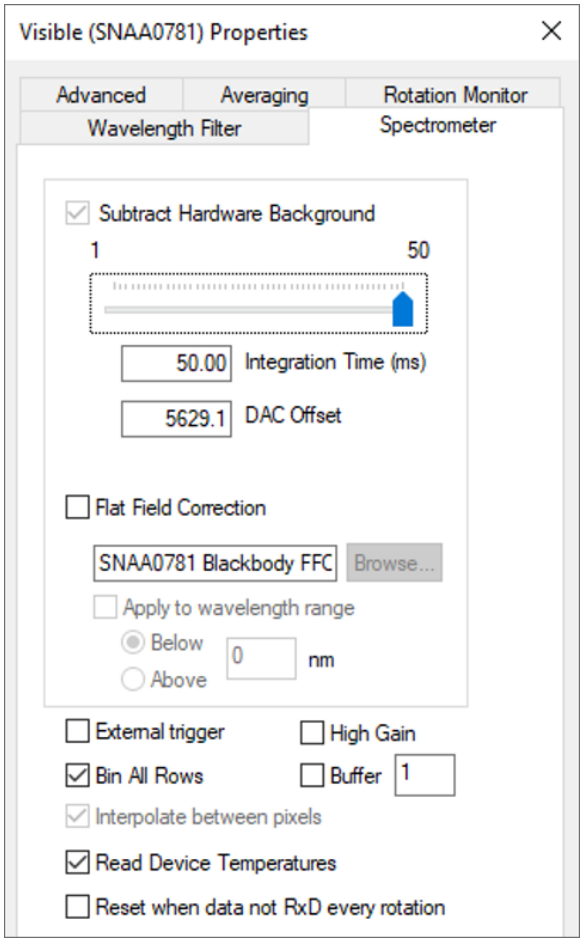
Rotation Monitor tab

Use the **Spectrometer Properties > Rotation Monitor** tab to specify the number of rotation positions to track across the rotating platen to monitor rotation. This determines the resolution of the rotation monitor; i.e., for 100 positions, there is a position every 3.6 degrees on the platen.



Spectrometer tab

Use the **Spectrometer Properties > Spectrometer** tab to specify data acquisition options for the selected spectrometer.



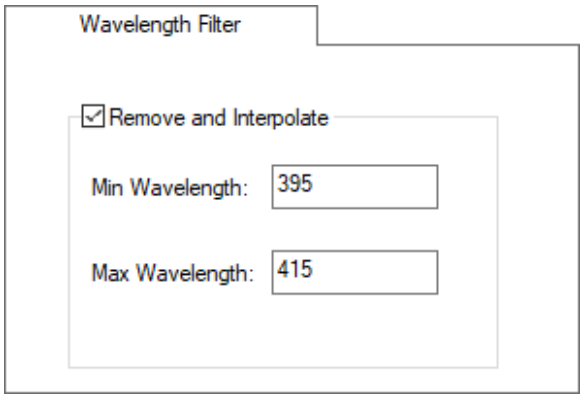
Field Name	*Description*
Subtract Hardware Background	If a dark background file is available for the selected spectrometer, this box will automatically be checked. Dark background data are spectra that represent the inherent background noise due to thermally generated charge carriers. To provide the cleanest spectra for analysis, the application subtracts these spectra from the measured spectra, leaving only the noise-free spectra.
Integration Time	Length of time for the spectrometer to collect a signal before it digitizes and reads the signal. Use the integration time to decrease (low values) or increase (high values) the intensity.

Field Name	*Description*
Flat Field Correction	This checkbox should be cleared, as the kSA SpectR does not use FFC.
External trigger	Acquires data only when the spectrometer trigger input line senses a signal (depends on the current acquisition mode).
High Gain	Places the spectrometer in high-gain mode, in which the gain is increased 20x. This facilitates the detection of weaker signals. However, it also results in higher noise, so the signal-to-noise (S/N) ratio can be compromised. It is generally only recommended for spectrometer's containing a cooled sensor, as this serves to significantly reduce the noise.
Bin All Rows	Combines the corresponding pixels in the individual columns in a 2-dimensional sensor array, effectively creating a single row of pixels. This feature only applies to visible spectrometers and should always be enabled when using such spectrometers.
Read Device Temperatures	Reads the real-time temperature of the rack (i.e., internal PCB) and sensor and displays these values in the status bar of the Live Spectrometer window.

Wavelength Filter tab

Use the **Spectrometer Properties > Wavelength Filter** tab to filter out a portion of the spectrum. This can be beneficial for systems that incorporate a laser for curvature, and/or reflectivity measurements. To enable the filter, check the **Remove and Interpolate** box, and then specify the range of wavelengths to remove.

In the example shown below, to avoid the intense reflections from a 405 nm laser, the application removes wavelengths between 395 and 415 nm and replaces them with interpolated data.



Appendix D: Spectrometer Configuration Options

In the Single-wafer Spectral Reflectivity Acquisition window, the **Spectral Reflectivity** field includes an associated Configuration Options dialog, where you can specify options for the selected spectral reflectivity source. The dialog contains numerous options for configuring the source for the current data acquisition. Be sure to verify and adjust these options before you start the data acquisition.

Only the tabs that are most relevant to the kSA SpectR are discussed below. For information on any tabs or settings not mentioned here, please contact k-Space.

- To access the Spectrometer Configuration Options dialog, click the **Config** button in the Single-wafer Spectral Reflectivity Acquisition window.

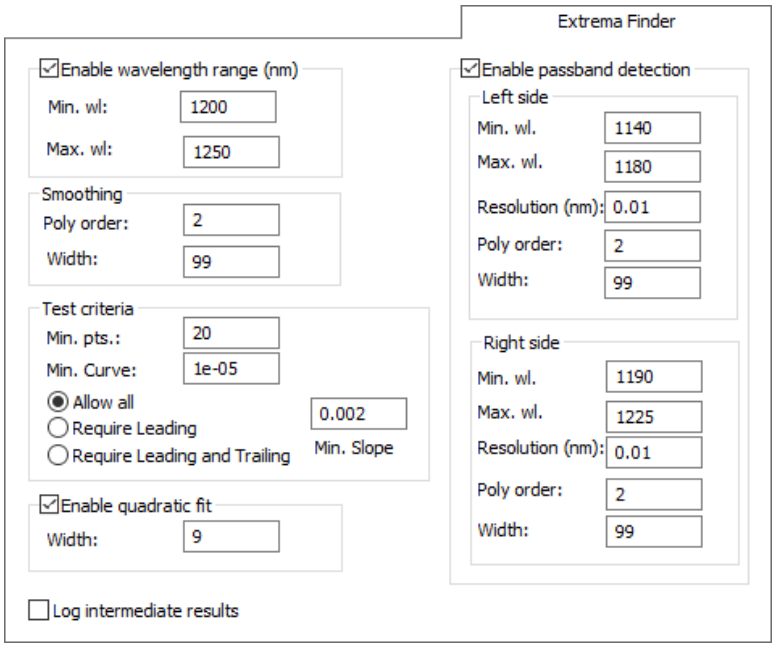
Extrema Finder tab

Use the **Spectrometer Configuration > Extrema Finder** tab to configure the settings used to find the extrema and/or passband edges in the **Real-time Fabry-Perot chart.** (See How to Acquire Spectral Reflectivity Data for more details.)

This can be accomplished by applying a low-pass digital smoothing filter using the Savitzky-Golay moving window least-squares polynomial fitting method. This can smooth noisy data without loss of resolution, provided that the filter width is not too much wider than the FWHM of the features in the data. Because the data are fitted using polynomials, it is trivial to calculate the derivatives (up to the order of the smoothing polynomial).

This feature can find extrema (such as the Fabry-Perot Dip) by finding the zeroes in the first derivative. To be considered valid, extrema candidates must fall within the specified wavelength range, and meet the minimum curvature and minimum slope criteria specified on this tab.

This feature can also find the passband edges by finding the peaks in the first derivative (i.e., inflection points). To increase the precision of the results, the data are interpolated to the desired wavelength resolution. Note that there are independent settings for finding the left and right passband edges.



Field Name	*Description*
Enable wavelength range	Rejects any extrema candidates outside the range defined by the **Min. wl** and **Max. wl** fields.
Smoothing	Uses a local least-squares polynomial to approximate the data within a moving window. ▪ **Poly order:** Order of the polynomial for the filter. ▪ **Width:** Total width of the smoothing window (must be an odd value).

Test criteria	▪ **Min. pts:** Minimum number of consecutive rising or falling points that must precede the candidate in question.
	▪ **Min. Curve:** Minimum absolute value required for the candidate's curvature (i.e., second derivative).
	▪ Choose the candidates to allow.
	  ▪ **Allow all:** Allows all candidates, regardless of the number of points or slope value.
	  ▪ **Require leading / Require leading and traling:** Requires at least the number of points specified in the **Min pts** field with a slope for which the absolute value meets or exceeds the **Min. Slope**.

Enable quadratic fit	Performs a least-squares quadratic fit in the vicinity of an extremum to refine its wavelength value. The value in the **Width** field defines the range of data points to fit on either side of the extremum.
Enable passband detection	Enables the finding of the passband edges. **Note that there are independent settings for the left and right edges.**
Min. wl.	Minimum wavelength for an inflection point candidate.
Max. wl.	Maximum wavelength for an inflection point candidate.
Resolution (nm)	Wavelength resolution to be used for interpolating the data.
Poly order	Order of the polynomial for the smoothing filter.
Width	Total width of the smoothing window (must be an odd value).

Field Name	*Description*
Log intermediate results	Generates a log file containing diagnostic information.

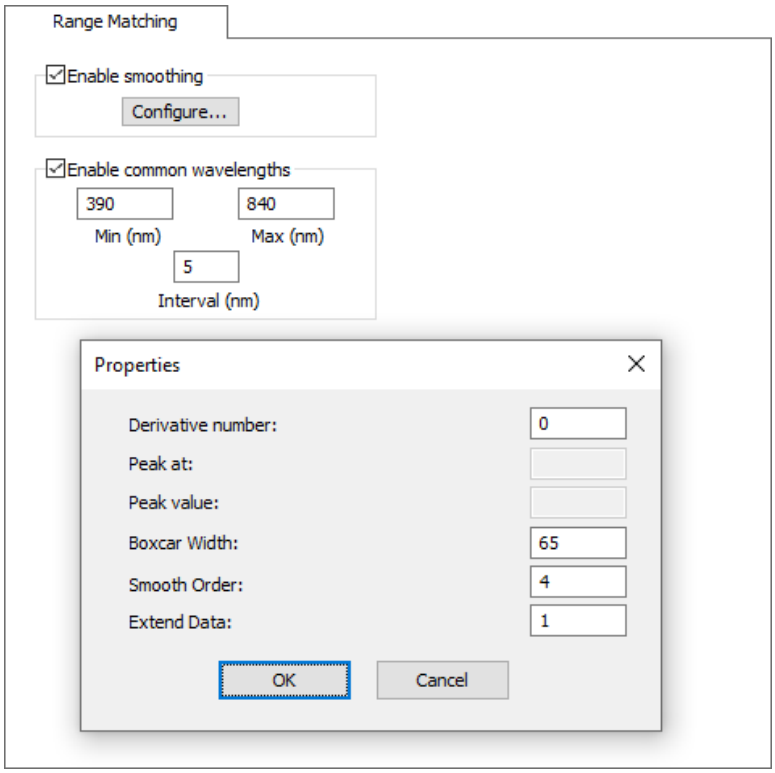
Range Matching tab

Use the**Spectrometer Configuration > Range Matching** tab to enable smoothing, and to interpolate the spectra to a common set of wavelength values.

The **Enable smoothing** option applies a low-pass digital smoothing filter using the Savitzky-Golay moving window least-squares polynomial fitting method. This can smooth noisy data without loss of resolution, provided that the filter width is not too much wider than the FWHM of the features in the data.

The **Enable common wavelengths** option interpolates the spectra to a common set of wavelength values defined by the **Min**, **Max**, and **Interval** values. This allows the data to be properly scaled using an **Absolute reflectivity file** specified in the Reference tab.

Note
*The **Enable common wavelengths** options must be enabled to obtain a valid reflectivity value.*



Field Name	*Description*

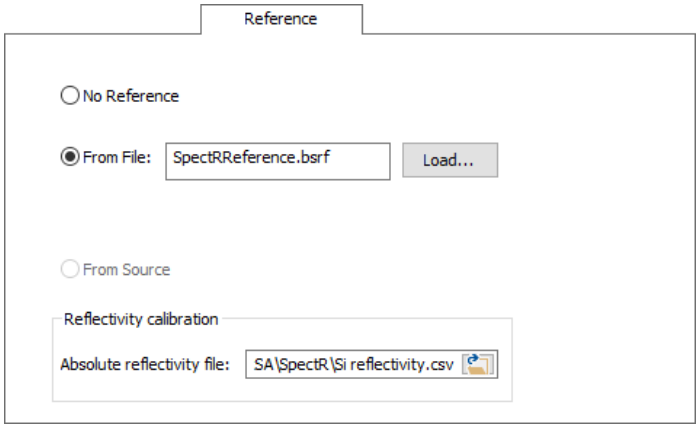
Enable smoothing	Applies a low-pass digital smoothing filter to the spectra before analysis, and then click the **Configure** button to specify the following parameters.
	▪ **Derivative number:** Derivative number (**0** for smoothing only).
	▪ **Boxcar Width:** Total width of the smoothing window (must be an odd number of data points).
	▪ **Smooth Order:** Order of the least-squares polynomial used to approximate the data within the moving window.Typical values are 2 or 4.
	▪ **Extend Data:** Choose the applicable option for extending data beyond the ends of the spectrum.
	  ▪ **0:** Excludes data points near the ends of the spectrum from smoothing, as there is an insufficient number of neighboring points to fill the window.
	  ▪ **1:** Repeats the data at the ends of the spectrum as needed so that the smoothing window can be applied across the entire spectrum.
	Typically, option 1 is chosen.

Enable common wavelengths	Check this box to interpolate the spectra to a common set of wavelength values defined by the **Min, Max**, and **Interval** fields.

Reference tab

Use the **Spectrometer Configuration > Reference** tab to choose data to use as a reference spectrum to normalize the measured spectral reflectivity to that of a bare substrate.

> ***Note***
>
> *If you checked the **Auto-select reference** box in the Reference (Single Wafer) Acquisition window when the reference data were acquired, that reference file should already be loaded.*



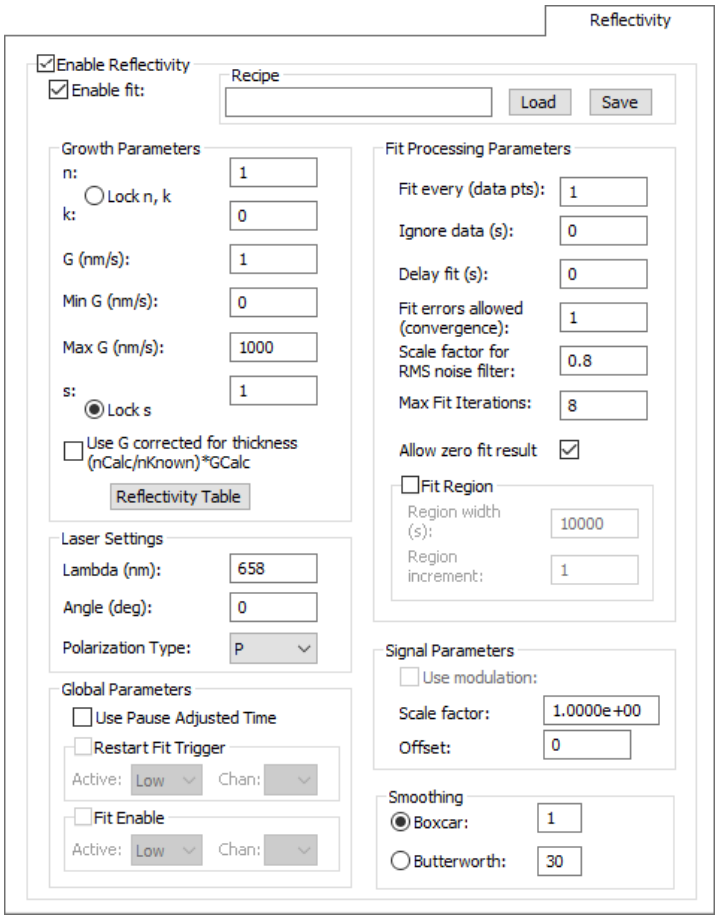
Field Name	*Description*
Reference	Choose the desired reference option. ▪ **No Reference:** The application will not normalize the spectral data. ▪ **From File:** The application uses the data contained in the selected **.bsrf** reference file. ▪ **From Source:** This option is not available.

Field Name	*Description*
Reflectivity calibration	In the **Absolute reflectivity file** field, select a calibration file that corresponds to the selected reference spectrum. This **.csv** file should represent the absolute reflectivity (0-1) of the substrate. The application uses the data to convert the measured reflectivity of the reference to an absolute scale. The wavelength range must encompass the spectrometer range. If you checked the **Enable common wavelengths** box on the Range Matching tab, the application will interpolate data to a common set of wavelength values, so the range and spacing need not match exactly.

Reflectivity tab

Use the **Spectrometer Configuration > Reflectivity** tab to enable the reflectivity calculation and fitting and to specify growth and fitting parameters.

During film growth, the reflectivity at a given wavelength λ oscillates with a period equal to $\lambda/2nG$, where G is the growth rate. The kSA SpectR system can exploit this to determine the growth rate, layer thickness, and optical constants (n, k) from the measured reflectivity of a multi-layer structure in real-time using a sophisticated Virtual Interface algorithm originally developed at Sandia National Laboratories, as described in the How to Perform a Reflectivity Fit section.



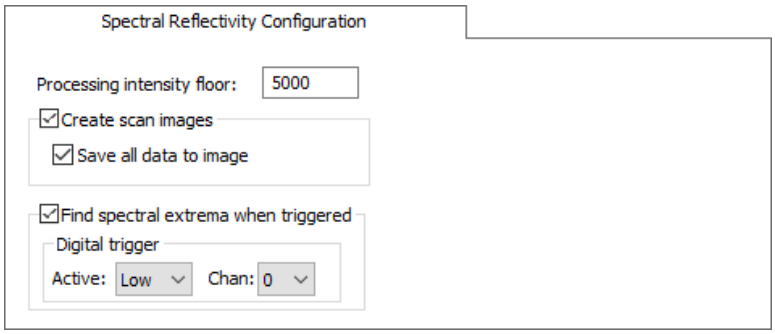
Field Name	*Description*
Enable Reflectivity	Enables the reflectivity algorithm and uses the parameters below.
Enable fit	Enables data fitting during acquisition.
Recipe	Displays the name of the selected reflectivity recipe (**.rrp**) file. ▪ **Load:** Loads and applies settings from a saved recipe file. ▪ **Save:** Saves the current settings in a recipe file.
Growth Parameters	Estimates for the applicable growth parameters. As with any fitting algorithm, the better the estimate of the fitting parameters, the faster the convergence. ***Note:*** *You must choose either the* ***Lock n, k*** *option or the* ***Lock s*** *option.* ▪ **n:** Index of refraction of the deposited material. If this value is unknown, enter **1** (i.e., vacuum) ▪ **k:** Extinction coefficient (i.e., imaginary part of the complex index of refraction) of the deposited material. If unknown, enter **0** (i.e., no absorption). ▪ **G:** Estimated growth rate (in nm/s). If unknown, enter **0**. ▪ **Min/Max G:** Range of valid growth rate values. ▪ **s:** Reflectivity scale factor for the fit, intended to account for such things as absorption from a coated viewport or reflectivity calibration errors. This parameter relates the measured reflectivity values to the absolute reflectivity via $\boldsymbol{R_{meas} = s \cdot R_{fit}}$. You can adjust this, unless *n* and *k* are locked at specific values, in which case the best-fit value of *s* is calculated. ▪ **Reflectivity Table:** Opens the Reflectivity Properties dialog, where you can view **n** and **k** values for selected materials. Click the **Reflectivity Table** button again to close the dialog.

Laser Settings	▪ **Lambda:** light source's wavelength value.
	▪ **Angle:** Angle of incidence of the incoming light source beam, with respect to the normal to the surface.
	▪ **Polarization:** Choose the applicable polarization type.
	  ▪ ***p:*** The polarization vector is parallel to the plane of incidence and reflection.
	  ▪ ***s:*** The polarization vector is perpendicular to the plane of incidence and reflection (from the German *senkrecht*).
	Note: *In the case of normal incidence (i.e., 0°), the choice of polarization is immaterial, as there is no distinction between the two polarization types.*

Field Name	*Description*
Fit Processing Parameters	These parameters regulate the fit updates and allow the fit region to move along with the data (i.e., at any particular time, the fit can include all acquired data, or a limited range of data points). ▪ **Fit every:** Data point interval at which to perform a reflectivity fit. Fitting uses a significant amount of computer resources and can slow the acquisition, especially for large data sets. (**10** is a typical value.) ▪ **Ignore data:** Length of time to wait before starting to fit data acquired from that point on. This helps with deposition processes with too little data at the beginning to provide a good fit. ▪ **Delay fit:** Length of time to wait before starting to fit all the acquired data, including those acquired during the delay. ▪ **Fit Errors Allowed:** Number of consecutive fitting errors allowed before the application stops fitting data. ***Example:*** *If you allow 1 fit error and the algorithm detects an error, it assumes good fit values and continues fitting based on the last good fit. If an error occurs when fitting the next set of data points, it sets the fit to 0 and stops fitting.* ▪ **Scale factor for RMS noise filter:** The cutoff for a low-pass RMS noise filter (default **0.8**). A lower cutoff value rejects more data, whereas a higher value allows noisier data to be included in the fit ▪ **Max Fit Iterations:** Maximum number of attempts to fit the data. ▪ **Allow zero fit result:** Accepts fit values of 0 (no fit). ▪ **Fit Region:** Allows the system to fit to the latest subset of the total data. This is recommended if the deposition rate will vary because the fit normally takes into account all of the data, and changes in deposition rates will result in a failure to fit those changes correctly. ▪ **Region width:** Total number of seconds of data that will be put into the fitting algorithm. ▪ **Region increment:** Rate at which the window of data slides along with the data. I.e., for an increment of 10, the application will drop 10 data points after the **Region width** has passed.
Signal Parameters	▪ **Use Modulation:** *(N/A for the kSA SpectR)* ▪ **Scale factor:** The application calculates and enters this value through a Reflectivity Calibration acquisition. It is the ratio of the reflectivity to the raw signal. ▪ **Offset:** Intensity value (positive value) to subtract from the signal to account for ambient light.
Smoothing	Smoothing method and smoothing factor to use.

Spectral Reflectivity Configuration tab

Use the **Spectrometer Configuration > Spectral Reflectivity Configuration** tab to specify the minimum value of the peak intensity that a spectrum must possess to be considered valid, to enable the application to create scan images from the acquired data, and to enable a digital input signal to trigger a Fabry-Perot extrema measurement.



Field Name	*Description*
Processing intensity floor	The minimum value of the peak intensity that a spectrum must possess to be considered valid. The application ignores spectra with peak intensities below this value.
Create scan images	Check this box to create montage plots. If using multi-wafer mode, it will create a separate plot for each active satellite. Check the **Save all data to image** box to save all the valid spectra from each rotation. If this box is cleared, the application will save only the first valid spectrum from each rotation.
Find spectral extrema when triggered	Check this box to use a digital input signal on the selected I/O channel to trigger the Fabry-Perot extrema measurement. Select the type of input pulse that will trigger the measurement — active high (i.e., rising edge) or active low (i.e., falling edge).

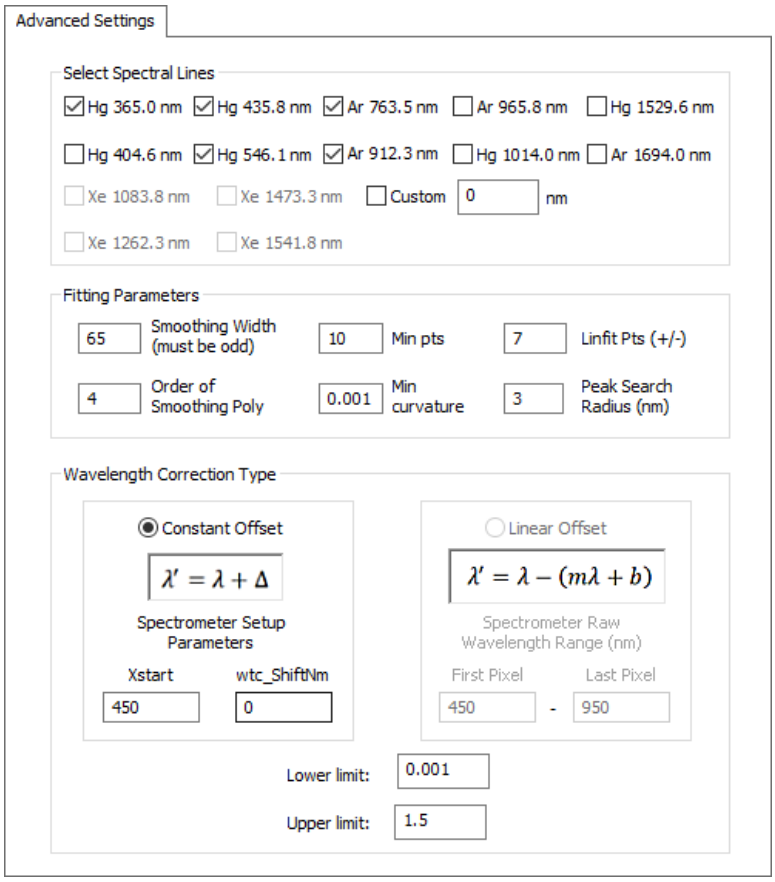
Appendix E: Advanced Acquisition Options

Each acquisition mode includes an associated Advanced Acquisition Options dialog, where you can specify parameters for that acquisition mode. The Advanced Acquisition Options dialog contains several tabbed pages with various options. The tabs that are available depend on the selected acquisition mode. Only the tabs that are most relevant to the kSA SpectR are discussed below. For information on any tabs or settings not mentioned here, please contact k-Space.

- To access the Advanced Acquisition Options dialog, click the **Advanced** button in the selected data acquisition window.

Advanced Settings tab

Use the **Advanced Acquisition Options > Advanced Settings** tab to specify parameters for determining the center wavelength of the selected spectral lines and calculating a spectrometer offset based on the published wavelength values.



Field Name	*Description*
Select Spectral Lines	Check the box for one or more spectral lines to use to determine the spectrometer offset.
Fitting Parameters	▪ **Smoothing Width**: Total number of points to use for the digital boxcar smoothing filter. ▪ **Order of Smoothing Poly**: Smoothing polynomial order (**0** for boxcar). ▪ **Min pts:** Minimum number of consecutive data points required for slopes of the same sign (increasing or decreasing) to be considered a valid peak. This will reject any spurious noise spikes. ▪ **Min curvature:** Minimum curvature (i.e., second derivative value) required to be considered a valid peak. This will reject small peaks. ▪ **Linfit Pts:** Number of points to use in the linear fit. For example, if you enter **7**, the application fits the 7 neighboring data points on either side of the data point closest to the zero crossing in the 1st derivative. ▪ **Peak Search Radius:** Radius of the peak search window. For example, if you enter **3**, the application will reject any peaks that are more than 3nm from the target wavelength.

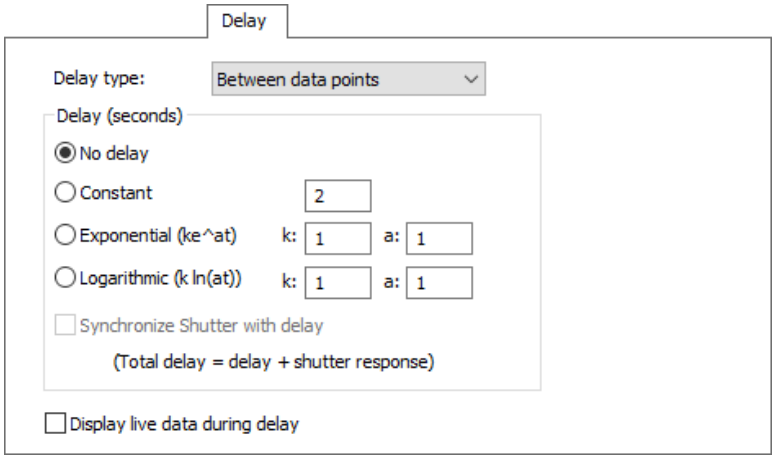
Wavelength Correction Type	▪ **Constant Offset:** Uses the **Spectrometer Setup Parameters** to correct the wavelength by a constant amount. These parameters are specific to the selected spectrometer.
	  ▪ **Xstart:** Starting wavelength in nm.
	  ▪ **wtc_ShiftNm:** Overall wavelength shift (in nm) to apply, relative to original factory settings.
	▪ **Linear Offset:** This option is not currently available for the kSA SpectR.

Field Name	Description
Lower/Upper limit	Range of wavelength shifts (in nm) to allow.

Delay tab

Use the **Advanced Acquisition Options > Delay** tab to add a delay between data points to limit the file size or to provide a constant time interval, even if the spectrometer integration time can vary.

There are three different types of delays available, and each type is independent of the others, so be sure to set up all three, if desired.

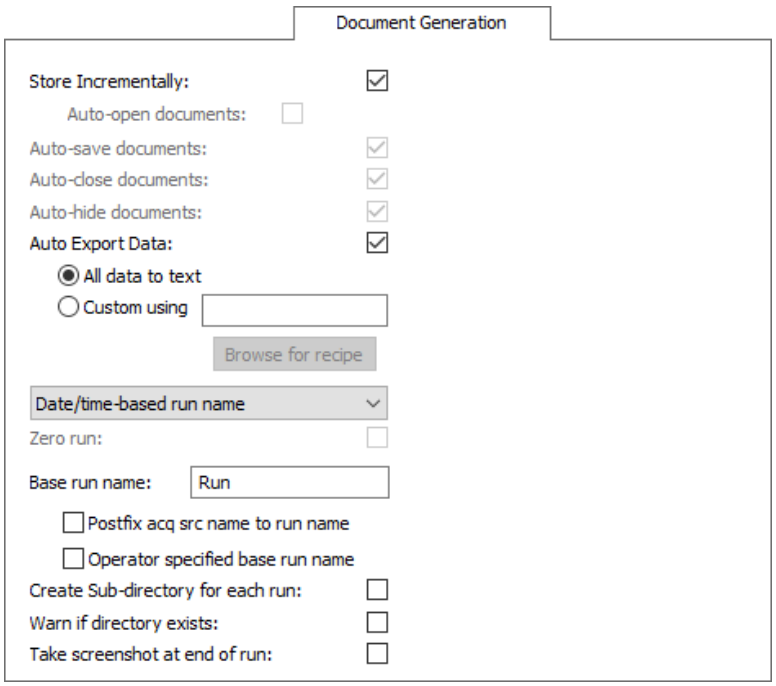


Field Name	Description
Delay type	Select each delay type, in turn, and then specify options for the selected delay type. ▪ **Between data points:** Delays acquisition between each data point acquired. ▪ **Before first data point:** Delays acquisition before the first data point is acquired. ▪ **Between samples:** Delays acquisition between each sample of acquired data. (Specify the number of samples per data point on the General tab of the Advanced Acquisition Options dialog.)

Field Name	*Description*
Delay	Choose the applicable delay option for the selected delay type. ▪ **No delay:** Prevents any delay for the selected delay type during acquisition. To have no delays of any kind during the acquisition, select **No delay** for all 3 delay types. ▪ **Constant:** Uses the specified delay for all delays of this type. This is similar to skipping frames, but it is more exact because frame skipping depends on computer speed,which changes from computer to computer and can change during acquisition. ▪ **Exponential:** Samples the data in time intervals that follow the dependent value of an exponential curve — slowly at first and then faster and faster — using the constants you enter for **k** and **a**. This is helpful for processes in which the most important part happens at the end of the process. Note that the **a** parameter must be a positive number. ▪ **Logarithmic:** Samples the data in time intervals that follow the dependent value of a logarithmic curve — quickly at first and then slower and slower — using the constants you enter for **k** and **a**. This is helpful for processes in which the most important part happens at the beginning of the process. ▪ **Synchronize Shutter with delay:** Synchronizes the shutter motion with the delay. The total delay is the length of delay specified above plus the shutter response time. You must set the shutter control and response time on the Chamber Control tab of the Input/Output Device Options dialog. *Example: if the delay type is **Between data points**, the kSA SpectR will open/close the shutter for each data point. The delay is needed because the mechanical shutters take time to open (typically about 2s), and the shutter must be fully open for the kSA SpectR to capture the data.*
Display live data during delay	Keeps the image in the video window live. If you clear the box, the last sample remains in the Live window until the next sample is acquired.

Document Generation tab

Use the **Advanced Acquisition Options > Document Generation** tab to define how the application names and saves documents generated during data acquisition.

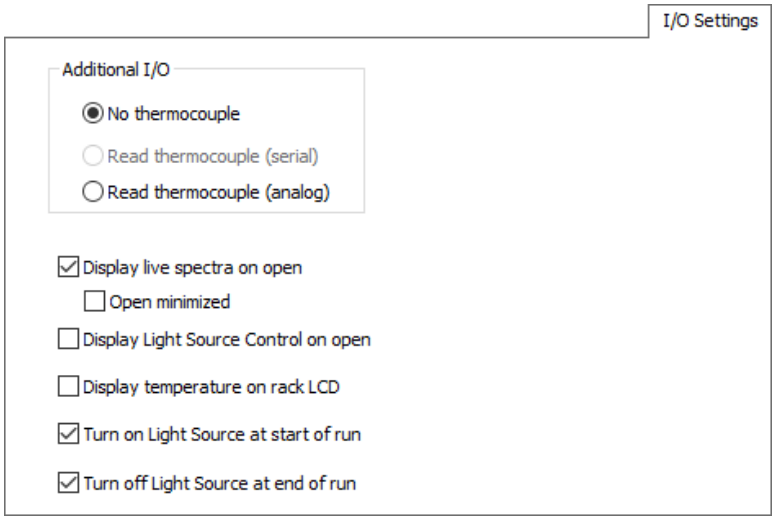


Field Name	*Description*
Store Incrementally	Saves data in small groups instead of waiting until the system RAM is full. k-Space recommends that you enable this feature for longer data acquisitions (longer than 5 minutes). When you check this box, the application automatically checks and disables the **Auto-open documents**, **Auto-save documents**, **Auto-close documents**, and **Auto-hide documents** boxes.
Auto-save documents	Automatically saves acquired data to both RAM and disk.
Auto-close documents	*(Available only when the **Auto-save documents** checkbox is checked)* Automatically closes the acquired data file as soon as data acquisition is complete.
Auto-hide documents	*(Available only when the **Auto-close documents** checkbox is checked)* Briefly flashes the data on the screen while it is being saved. This mostly serves as a visual aid to remind you that the document has been saved and closed.
Auto-export data	Saves all acquired data to both a **.kdt** file and to one of the following. ▪ **All data to text:** Exports all acquired data to ASCII **.txt** files. ▪ **Custom using:** Exports only the data specified in the selected custom export recipe file (**.exprt**). Click the **Browse for recipe** button to select the applicable export recipe file. ***Note:*** *Enabling this option may result in very large files that take considerable time to save. In general, it is a good idea to store data in the native **.kdt** format and then, if needed, export the data after acquisition.*

Field Name	*Description*
File name format	*(This is the unlabeled drop-down list below the **Auto Export** fields.)* Select the format to use when naming the data acquisition files. ▪ **Manual run name:** Requires you to enter a file name for each data acquisition. ▪ **Auto-incrementing run name:** Uses the name in the **Base run name** field, appends a number to the end of the base name, and increments it by 1 (up to 9999) for each new acquisition. *Example: For a base run name of **Run**, the first acquired file will be **Run0001**, the second will be **Run0002**, the third will be **Run0003**, etc.* ▪ To start the count at **0000**, check the **Zero run** box. ▪ **Date/time-based run name:** Uses the name specified in the **Base run name** field and appends the computer's date/time stamp to the end of the file name for each new acquisition. *Example: For a base run name of **Run** and a file generated at **1:59:40 p.m.** on **June 19, 2021**, the file name will be **Run20210619.135940**, where **20210619** represents the date in **YYYYMMDD** format and **135940** represents the time in **HHMMSS**.* ▪ **Base Name Only:** Uses the name specified in the **Base run name** field for every new acquisition. The software will prompt you to confirm that you want to replace it after each acquisition.

I/O Settings tab

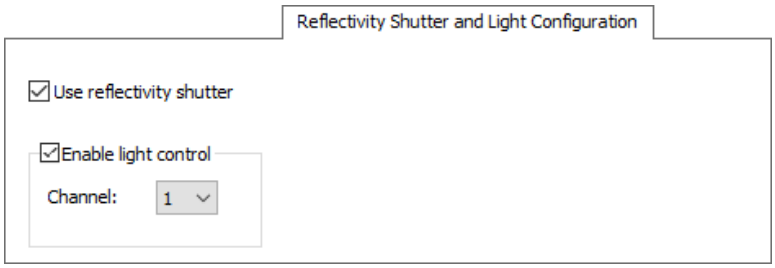
Use the **Advanced Acquisition Options > I/O Settings** tab to select various input and output options.



Field Name	*Description*
Additional I/O	Choose the applicable option for handling thermocouple data. ▪ **No thermocouple:** Ignores and discards thermocouple data without saving them. ▪ **Read thermocouple (serial):** Reads the thermocouple value as a serial input. This setting depends on the port. For information on the data format, contact k-Space. ▪ **Read thermocouple (analog):** Reads the thermocouple value as an analog (i.e., voltage) input.
Display live spectra on open	Opens the Live Spectrometer window automatically each time you open an acquisition window. You can check the **Open Minimized** box to automatically minimize the spectra window when it opens, so that only the title bar is visible.  When the window is minimized, click the  button to expand it.
Display Light Source Control on Open	Opens the Light Source Control window automatically each time the application opens.
Display temperature on rack LCD	Simultaneously updates the data on the rack display and on the application interface on the computer.
Turn on Light Source at start of run	Automatically turns the broadband light source on when you click the **Start** button in the acquisition window.
Turn off Light Source at end of run	Automatically turns the broadband light source off when you click the **Stop** button in the acquisition window.

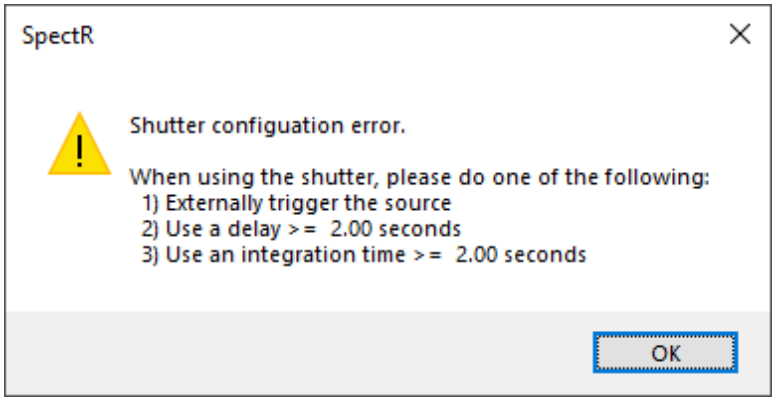
Reflectivity Shutter and Light Configuration tab

Use the **Advanced Acquisition Options > Reflectivity Shutter and Light Configuration** tab to enable the reflectivity shutter and light source control.



Field Name	*Description*
Use reflectivity shutter	Check this box to enable the broadband light source's integrated shutter. Note that the shutter is controlled by digital output channel 0 on the I/O board.
Enable light control	Check this box to control the broadband light source remotely with the  button on the toolbar. In the **Channel** field, select the digital output channel used to control this feature (Default is **3**)

> ***Note***
>
> *If using the light source's integrated **shutter**, one of the following 3 conditions must be met to prevent the shutter from attempting to open and close too quickly:*
>
> - *the spectrometers must be externally triggered*
> - *the acquisition delay time must be at least 2.0 seconds*
> - *the integration time of the spectrometer(s) must be at least 2.0 seconds*



Appendix F: Image and Plot Properties

Every image and data plot window includes in the kSA SpectR application has an associated Properties dialog that is comprised of several tabbed pages with options that affect the way the data are displayed.

For Scan mode image windows, you can view information about the image — image type, date it was acquired, exposure time, etc. — in the associated Image Properties dialog. You can also add comments about the image for future reference.

For **.kdt** data plot windows, you can select the data to display for the X and Y axes, change the colors, fonts, and labels for the plot window and plotted data, and apply filters to the data. You can also view the settings selected for reflectivity, reference file, extrema finder, and more in the associated Plot Properties dialog.

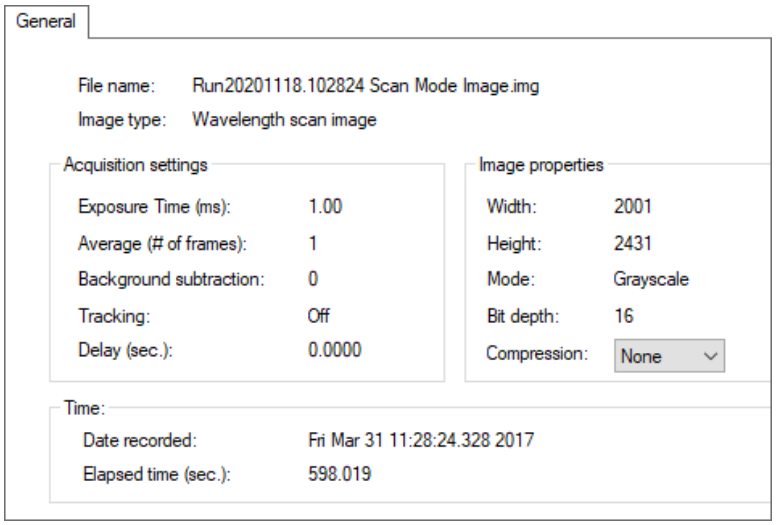
Image Properties

Most of the fields in this dialog are for informational purposes only, so they are grayed out and cannot be modified. However, you can add or update comments and apply a color palette to the display.

- To access the Image Properties dialog, right-click a Scan mode image window and select **Properties**.

General tab

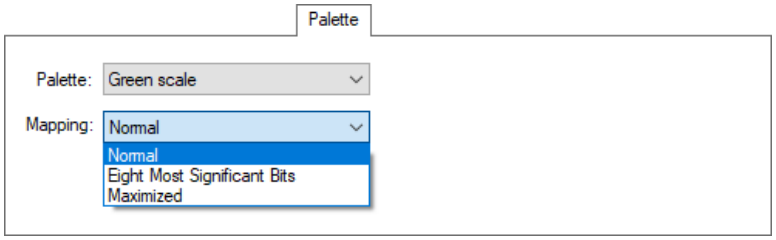
The **Image Properties > General** tab displays the settings that were used to capture the selected image and other general information. These fields are read-only and cannot be modified.



Field Name	*Description*
File name	Name of the selected image or movie file.
Image type	Image type (single image, movie frame, or line scan) for the selected image or movie.
Acquisition settings	Parameter settings that were in effect when the selected image or movie was acquired. ▪ **Exposure Time:** Length of exposure used. ▪ **Average:** Number of frames of data that were summed together for each data point. ▪ **Background Subtraction:** Background subtraction setting used. ▪ **Tracking:** Tracking type used during the acquisition to monitor areas with high intensity. ▪ **Delay:** Time delay that was used between data points.
Image properties	Dimensions, color mode (based on the method and camera that were used to generate the image), bit depth, and compression type. ***Note:*** *Bit depth usually depends on the physical characteristics of the camera. For example, with a bit depth of 8, the maximum number of grayscale intensities (black to white) or colors is 2^8 or 256.*
Time	Date and time the image or movie was captured and the length of time (including pauses) it took to record the image or movie.

Palette tab

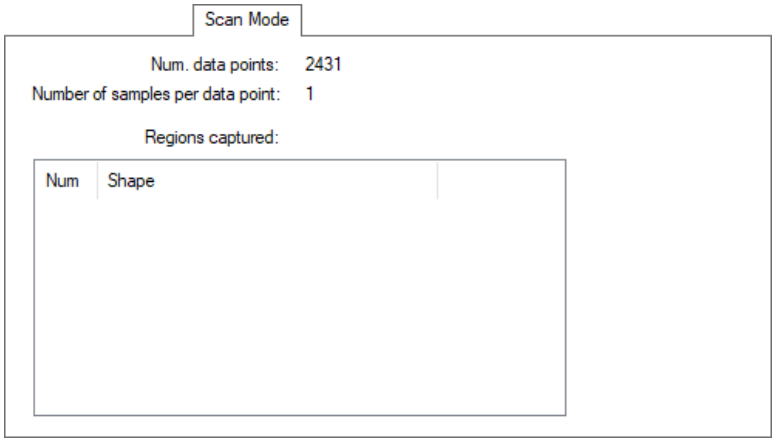
Use the **Image Properties > Palette tab** to colorize the selected image or movie. Note that this feature changes the way the image is **displayed** only; it does **not** alter the original image.



Field Name	*Description*
Palette	Select the preferred color scheme. There is an extensive list of palettes to choose from. Note that the **Green scale** palette most closely simulates the RHEED screen colors.
Mapping	Select the preferred level of data to map to the selected camera. ▪ **Normal:** Displays the data in its original format. ▪ **Eight Most Significant Bits:** Keeps only the most significant 8 bits that comprise the image. This reduces the number of shades to a value that is visible to the human eye. ▪ **Maximized:** Displays the data scaled over 8 bits, or 256 levels, so that the brightest part of the image is white, and the darkest part is black.

Scan Mode tab

The **Image Properties > Scan Mode** tab displays information about the selected Scan Mode image. These fields are read-only and cannot be modified.



Field Name	*Description*
Num data points	Number of data points collected.
Number of samples per data point	Number of measurements taken for each data point.
Regions captured	*(N/A for the kSA SpectR)*

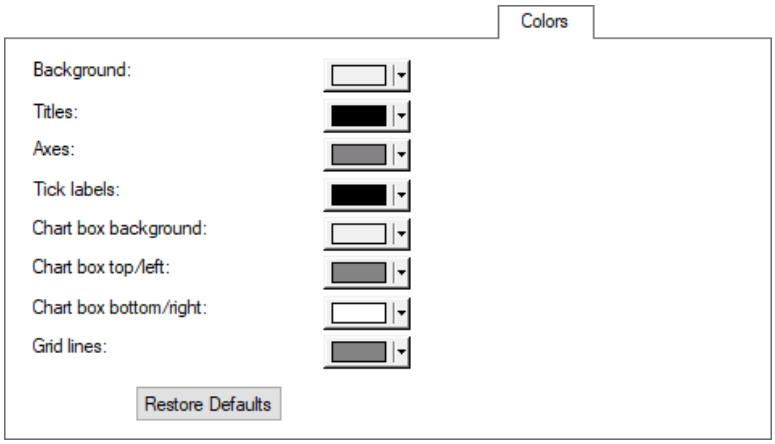
Plot Properties

The kSA SpectR application displays data for both RTCs and post-acquisition analysis plots in plot windows. Each plot window has an associated Plot Properties dialog, where you can modify the available parameters to change the way the data are displayed.

The Plot Properties dialog is also available for acquired data (**.kdt** and **.bsrf**) files.

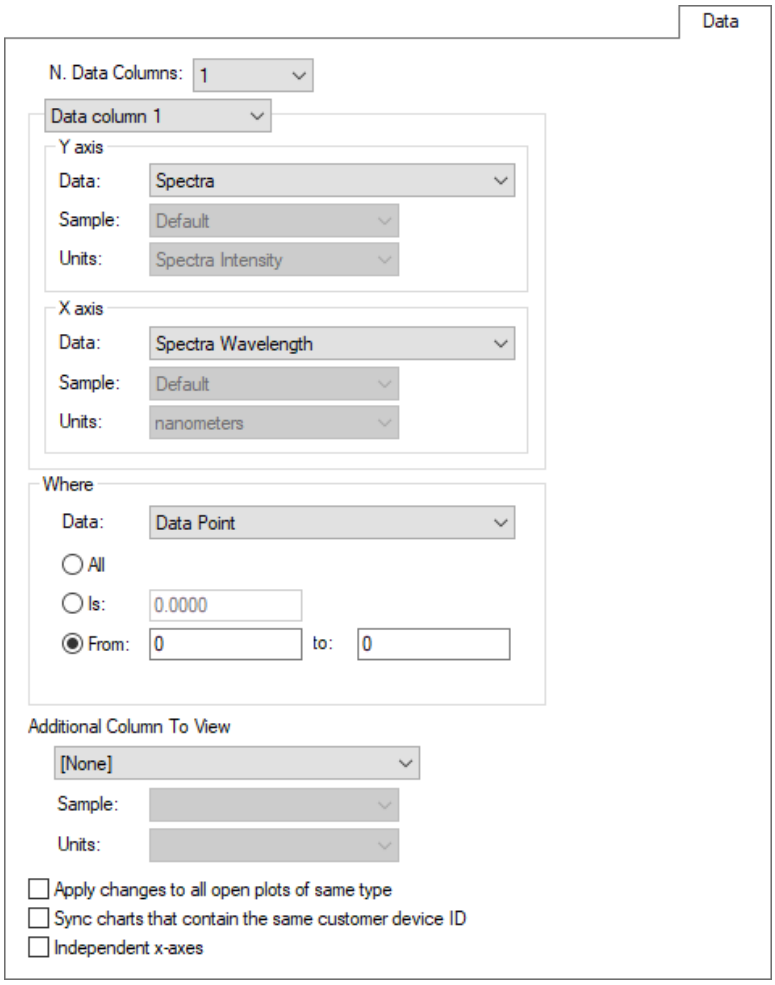
Colors tab

Use the **Plot Properties > Colors** tab to select colors for the various elements in the plot window. The elements available on this tab vary based on the selected plot type.



Data tab

Use the **Plot Properties > Data** tab to specify the number of columns to plot and to select the data to plot for those columns.

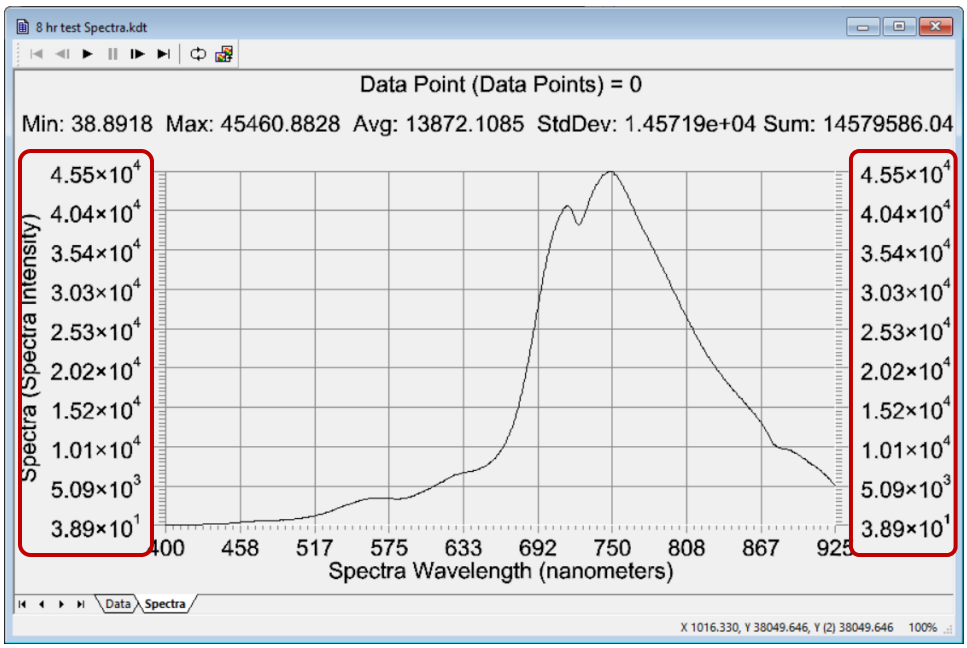


Field Name	*Description*
# of data columns / N Data Columns	Number of columns of data to plot. If you select **2** or more columns, you can specify display options for the Y axis.
Data Columns	The items in this drop-down list corresponds with the number selected in the **# of data columns/N Data Columns** field (i.e., if you select **3**, the drop-down list includes **Data column 1**, **Data column 2**, **Data column 3**). Select each data column, in turn, and then in the **Data** field for the **Y axis** and **X axis** sections, select the type of data to plot for that column.
Where	Filters the plotted data by the selected data type. ▪ **All:** Plots the entire range of data. If there is a large amount of data, it may take several minutes to generate the plot. ▪ **Is:** Plots a specific spectrum based on the data type selected. In the corresponding field, enter the data value to plot. ▪ **From:** Plots a specific range of data. In the corresponding fields, enter the lower and upper limit of the range to plot.
Additional Column to View	*(Optional)* Additional data type to display with the other title information along the top.

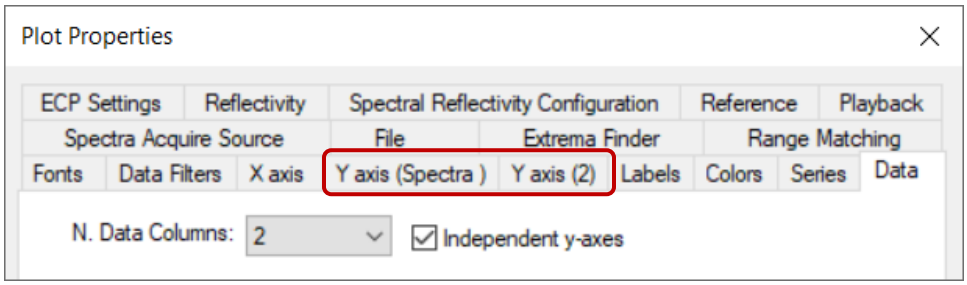
Field Name	*Description*
Apply changes to all open plots of same type	Applies any changes made on this tab to all open computed data plots.
Sync charts that contain the same customer device ID	Applies these settings to all plots generated for the current kSA SpectR system.
Independent x-axes	Uses different X axis data for each column. When this box is clear, the application plots the same X axis data against the different Y axes data.

Y axis display options

For some plots, when you select **2** columns in the **# of data columns** field on the Plot Properties > Data tab, the **Independent y-axes** box may be available, depending on the type of data. When you check this box, the application displays a separate Y axis for each column.



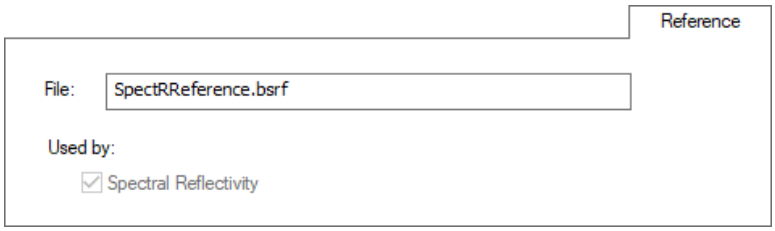
In addition, the Plot Properties dialog will include a Y axis tab for each column, so that you can define the range and tickmark properties for each. Note that you must close and then reopen the Plot Properties dialog before the additional Y axis tabs will be available.



Reference tab

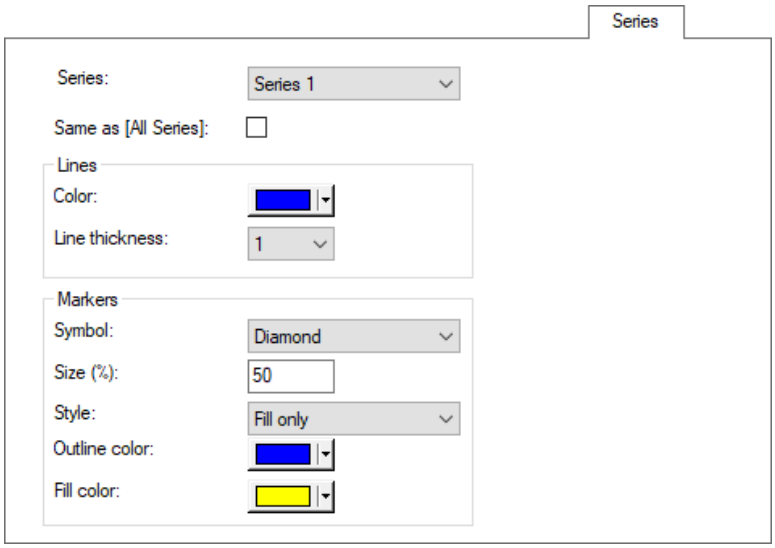
The fields on the **Plot Properties > Reference** tab are read-only and reflects the option selected on the Spectrometer Configuration > Reference tab when the data were acquired for this kdt plot window.

- If the **No Reference** option was selected, the **File** field displays **None**.
- If the **From File** option was selected, the **File** field displays the name of the reference (**.bsrf**) file that was used.



Series tab

Use the **Plot Properties > Series** tab for images, platen scans, and plots with more than one series (or set) of data, to define parameters that will distinguish the sets from one another.

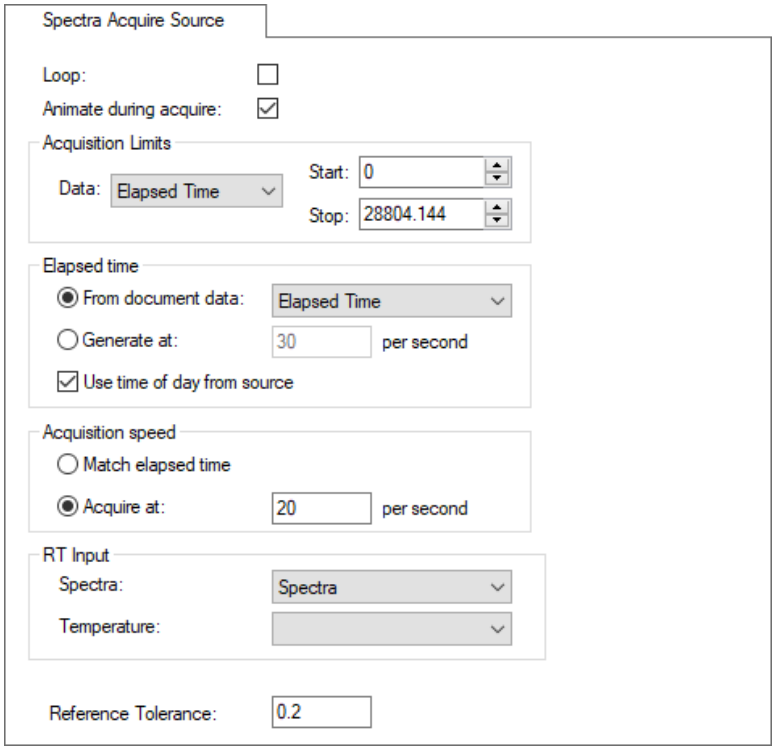


Field Name	*Description*
Series	Select each applicable series, in turn, to specify line and marker options for that series. You can specify options for up to 100 different series. To specify settings that will be used by multiple series, select **[All Series]**, and then specify the applicable settings. You can then apply these settings to a specific series by selecting that series in the **Series** field and checking the **Same as [All Series]** box. The application will disable all other fields for that series and apply the settings you selected for **[All Series]**.
Lines	Line color and thickness (in pixels) for the selected series.

Field Name	*Description*
Markers	Marker symbol to use for the selected series and attributes for the markers, including the size as a percentage of the original, the style (filled or outlined), and the colors for the fill and outline.

Spectra Acquire Source

Use the **Plot Properties > Spectra Acquire Source** tab to configure a **.kdt** data file to function as the data source, as if it were live spectrometer data.



Field Name	*Description*
Loop	Continues acquiring data from the beginning of the **.kdt** file when it reaches the end. This is different from the Loop button on the kdt toolbar, which loops through the playback only, not the acquisition.
Animate during acquire	This box is checked by default and cannot be changed. It enables you to view the data in the **.kdt** file as it is played during acquisition.
Acquisition Limits	Defines the parameters that start and stop acquisition, based on the selected data type. The application trims data outside these bounds, enabling you to begin and end acquisition at any point. ***Note:*** *The increment values for the **Start** and **Stop** fields are based on the values in the **.kdt** file.* ▪ *If you select **Data Points**, the values are sequential numbers.* ▪ *If you select **Elapsed Time**, the values are the recorded time values.*

Field Name	*Description*
Elapsed time	Choose the preferred option for compressing the spectra over time. ▪ **From document data:** Bases the elapsed time on the data selected here. Most kSA SpectR users select **Elapsed Time**, so that the elapsed times for the new **.kdt** acquisition and the source **.kdt** file match. ▪ **Generate at:** Divides the data in the **.kdt** by the number specified here, resulting in the acquired data covering the specified number of data points per second. *Example: If the .kdt file contains 8,000 data points that were generated over 9,999 seconds, and the Generate at value is 1000, the new .kdt file will contain all 8,000 data points, compressed to a total elapsed time of 8sec (8000/1000).*
Acquisition speed	Choose the preferred speed at which the spectra will be available for processing during a new acquisition. ▪ **Match elapsed time:** Makes the data available for processing at the same speed at which it was originally acquired. ▪ **Acquire at:** Makes the data available at the speed specified here.
RT Input	Use these fields to specify options for reprocessing data from a saved file as if it were real-time data. ▪ **Spectra:** Spectra source ▪ **Temperature:** *(N/A for the kSA SpectR)*
Reference Tolerance	Tolerance value that dictates how closely the wavelength range of a reference spectrum must match the current spectrometer range. For example, if a spectrometer is re-calibrated and the wavelength shifts by more than this amount, you cannot use previously acquired reference spectra.