

**Operations Manual**  
for the  
**FILMETRICS F60**  
Thin-Film Mapper

Revision 7.17.6.0  
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# Welcome

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## What is the F60-t used for?

The F60 is a family of thin-film mapping tools that offer the user a low cost and easy to use platform for stand-alone thin-film thickness and  $n$  and  $k$  measurement for a range of applications. Thin-film thickness and  $n$  and  $k$  are mapped quickly and easily with the F60 advanced spectral reflectance system. The motorized R- $\Theta$  stage moves automatically to the selected measurement points and provides thickness measurements in seconds. The F60 can be used for high throughput measurements for process development and production monitoring.

**Warning:** Accurate measurements require suitable recipe settings and a valid baseline. Improper system setup or an aged lamp may also lead to errors. It is the user's responsibility to ensure that this instrument is being used properly for its intended purpose. Please contact Filmetrics support for assistance with any questions.

## Safety, Maintenance, and Care



This symbol indicates information or instructions that must be read and carefully followed to prevent hazards, injury to the operator, or damage to the instrument.



This symbol indicates a potential shock hazard. Areas marked with this symbol should be serviced by a trained service technician.



This symbol indicates that the product conforms to the WEEE (Waste in Electrical and Electronic Equipment) Directive 2002/96/EC.



This symbol indicates that the product meets the applicable EU safety, health and environmental protection directive requirements.



This label indicates the Model Number and Serial Number of the instrument. This information may be necessary when contacting Filmetrics for assistance.



**Disclaimer:** Use of this instrument in a manner inconsistent with the information and directions included in this manual may impair the protections designed into the product resulting in danger to the operator or damage to the instrument



**Installation Location:** When deciding on a location for the instrument, ensure that the instrument is installed in a well-ventilated location. Enclosing the unit, or blocking the vent holes, may impair the performance of the instrument or damage the internal components.

**Cleaning:** The need for periodic cleaning of the system is based on the cleanliness of the environment in which the system is installed. Only the external surfaces are to be cleaned. Cleaning and maintenance of all internal components is to be performed by a trained service technician. Do not use aerosol, or spray, cleaners as they may contaminate the sensitive optical surfaces on the instrument.



Before performing any service on the instrument ensure that the main power is disconnected.

Cleanroom, or low lint, wipes should be used to wipe down the system. A mixture of Isopropyl Alcohol (IPA) and De-ionized Water (DI H<sub>2</sub>O) at 70% DI H<sub>2</sub>O: 30% IPA is to be used for cleaning. Undiluted IPA may be used, if the 70:30 DI and IPA mixture is not available, but extra care must be taken. Avoid using stronger solvents, such as acetone, as these may compromise the surface finish.

Avoid excessive pressure on any surface when cleaning. Excessive force may bend a component, which would damage the system, or cause the system to be out of alignment.

Start with the top of the system and work down. Use slow motions, in a straight line, from the back to the front of the surface being cleaned. Change the cleaning wipe periodically to avoid re-depositing material back onto the surface being cleaned. Allow all cleaned surfaces to dry completely before restoring power to the system.

CE Mandated Warnings
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Please read the following instructions carefully to prevent potential shock or fire hazards. This manual should be retained for future use



Bitte lesen Sie die nachstehende Anleitung sorgfältig durch, um Stromschlag und Feuergefahr zu vermeiden. Diese Betriebsanleitung soll für späteren Gebrauch sorgfältig aufbewahrt werden.



Pregiamo di leggere accuratamente, le sequenti Istruzioni, per evitare Prossimi Incendi e Correnti.



Shock Hazard - Do Not Enter  
Achtung Hochspannung - Nicht Berühren  
Attenzione Corrent-Forte - Prego non toccare



The power cord should be removed after use.  
Das Stromkabel soll nach Gebrauch aus dem Gerät herausgezogen werden.  
La Corrente viene.



Never expose the unit to water or liquids. Avoid direct sun.  
Bringe das Gerät nicht mit Wasser oder anderen Flüssigkeiten in Berührung. Vermeide direkte Sonneneinstrahlung.  
Evitare contatto con acqua oppure liquidi Infiammabili al Macchinaggio. Anche entrate di Sole.



Do not insert any objects into the unit.  
Keinen Gegenstand in das Gerät einbringen. Do non inseriamo any obietta into gli unità.  
Non mettere ogetti dentro la Macchina.



Do not use near open flame or heat.  
Das Gerät nicht in der Nähe einer offenen Flamme oder Hitze benutzen.  
Non mettere la Macchina vicino a fuochi oppure Riscaldamenti.



The unit should never be enclosed or blocked.  
Das Gerät darf nicht eingeschlossen oder blockiert werden.  
La Macchina non chinderla per nessun motivo.



Connect unit only to a properly measured supply. Use only the which is provided with the unit.  
Schließen Sie das Gerät nur an eine ordnungsgemäss vermessene Stromversorgung an. Verwenden Sie  
nur ein , wie es auch mit dem Gerät ausgeliefert wird.  
Montare solo con misura normata. Adoperando solo così come e fornita la  
Macchina.

## Table of Contents

---

<b>1. Software Overview</b> .....	<b>8</b>
1.1 The Wafer Map Tab .....	9
1.2 The Measure Tab .....	11
1.3 Go To .....	13
1.4 The History Tab .....	14
1.5 The Edit Recipe Window .....	16
1.6 Menu Controls .....	18
1.7 Taking a Baseline .....	35
<b>2. Editing Film Recipes</b> .....	<b>37</b>
2.1 Adding, Changing, or Deleting a Structure .....	37
2.2 Map .....	47
2.3 Alarms .....	50
<b>3. Making Measurements</b> .....	<b>54</b>
3.1 Using the Autofocus Feature (if present) .....	54
3.2 Example A - Mapping Thickness Only .....	56
3.3 Example B - Mapping Thickness and Optical Constants .....	59
3.4 Measurement Assumptions .....	63
3.5 Hints for Improved Accuracy .....	64
3.6 Troubleshooting .....	66
<b>4. Understanding and Evaluating Measurement Results</b> .....	<b>77</b>
4.1 Display of Measured Data .....	77
4.2 Goodness of Fit .....	77
<b>5. Advanced Features</b> .....	<b>78</b>
5.1 Creating New Map Patterns .....	78
5.2 Editing Map Files Using Excel .....	80
5.3 Creating and Editing n and k Files .....	84
<b>6. Theory of Operation</b> .....	<b>86</b>
6.1 Measurement Theory .....	86
6.2 Thickness Measurement Details .....	87
6.3 The Baseline Measurement .....	87
<b>7. Appendices</b> .....	<b>89</b>
7.1 Performance Specifications .....	89
7.2 Application Note - Si3N4 .....	91

# 1. Software Overview

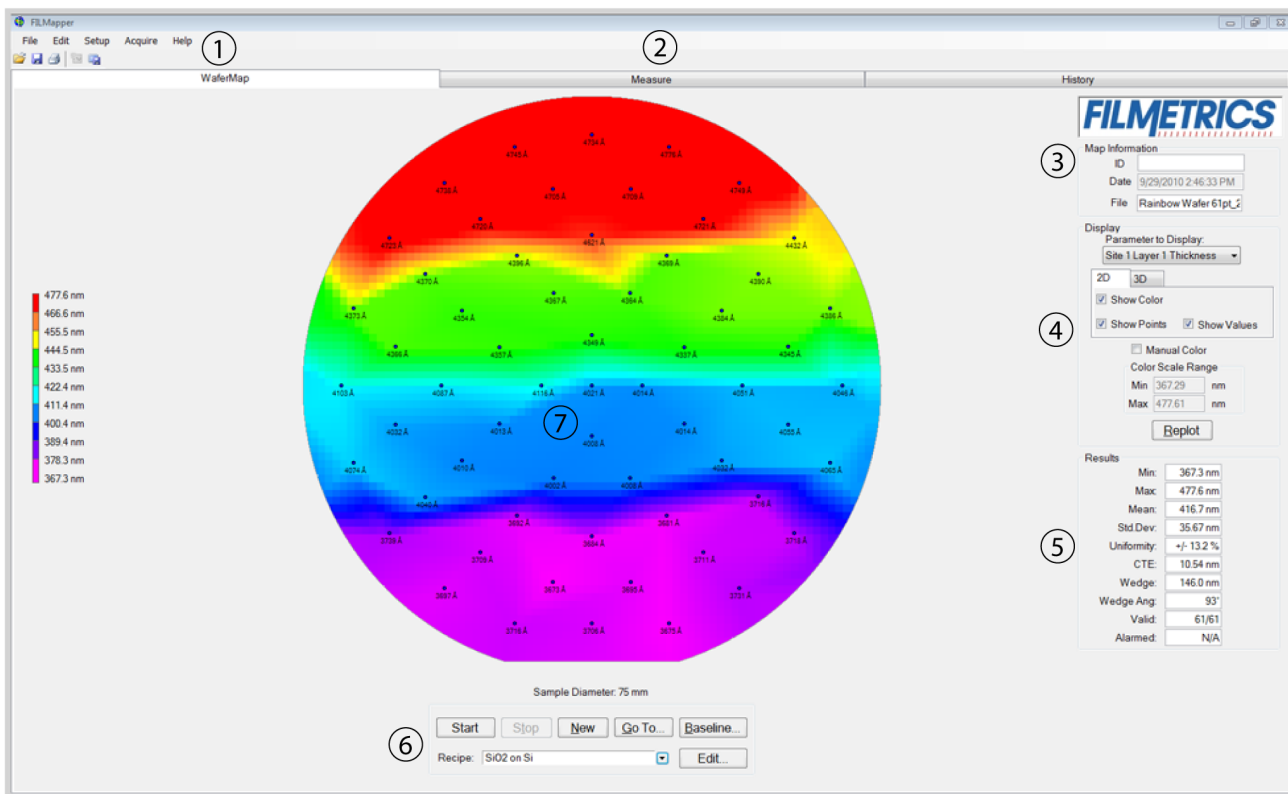
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The way that light reflects off a thin film is determined by the characteristics of the film, such as its thickness, optical constants, and roughness. The F60 is able to determine thin-film characteristics by first carefully measuring the amount of light reflected from the thin film over a range of wavelengths (i.e., by measuring the reflectance spectrum). It then analyzes this data by comparing it to a series of calculated reflectance spectra. Most of the features of the FILMapper software that runs the F60 can be divided into reflectance acquisition and reflectance analysis functions. The following pages outline the main features of the FILMapper software.

The [Wafer Map Tab](#) is used to initiate mapping and to display measurement results. The map configuration and the film properties to be mapped are specified in the [Edit Recipe > Wafer Map](#) dialog box.



## 1.1 The Wafer Map Tab



1. Standard Windows menus, including; [File](#), [Edit](#), [Setup](#), [Acquire](#), and [Help](#).
2. These tabs are used to select between the Wafer Map, [Measure](#), and [History](#) windows.
3. Information about the Operator can be entered here for tracking purposes. Sample information is automatically determined when the wafer map is saved.
4. This section is used to determine how the map is displayed. The **Replot** button must be clicked to enact any changes selected.
  - i. **Parameters to Display:** Allows the user to select which parameter (thickness, index, roughness, etc.) to display on the map.
  - ii. **2D/3D:** Allows the user to select between two dimensional and three dimensional maps.
  - iii. **Show Color:** Enables or disables the color bar on the left hand side of the map.
  - iv. **Show Points:** Enables or disables displaying the measured points on the map.
  - v. **Show Values:** Enables or disables displaying the
  - vi. **Manual Color:** Allows the user to input a manually selected color scale.
5. Statistical analysis for the set of measurements taken.
  - i. **Minimum** parameter value recorded for selected wafer, xmin.
  - ii. **Maximum** parameter value recorded for selected wafer, xmax.
  - iii. **Mean** (average) parameter value of all measurement locations, .

iv. **Std.Dev.** (Standard Deviation), or  $1\sigma$ , is calculated using the following equation: 
$$= \sqrt{\frac{\sum(x - \bar{x})^2}{n - 1}}$$

where  $\bar{x}$  is the mean and  $n$  is the number of measurements.

v. **Uniformity** as a percentage. The equation used in the uniformity calculation is determined under [Setup > Options > Map](#).

vi. **CTE** is the center to edge thickness variation calculated using a least squares linear fit of the average thickness of 10 radial regions. If the CTE is positive ( $> 0$ ), then the thickness is greater around the wafer edge. If the CTE is negative ( $< 0$ ), then the thickness is greater near the center of the wafer.

vii. The **Wedge** value is the product of the slope at the angle specified by the **Wedge Angle** and the sample diameter (for rectangular samples the length of the longest edge is used in place of diameter).

viii. The direction of maximum positive slope (increasing measured values) is given by the **Wedge Angle** where  $x=1, y=0$  is  $0^\circ$  (3 o'clock) and  $x=0, y=1$  is  $90^\circ$  (12 o'clock).

ix. **Valid** indicates how many locations have valid results out of the total number of measurement locations.

6. These options control the wafer map process.

i. **Start** or Restart the mapping cycle.

ii. **Stop** the mapping cycle.

iii. **New** clears the measurement results and displays the points to be measured as determined by the settings in [Edit Recipe > Wafer Map](#) tab.

iv. [Go To](#) to a specified location on the wafer.

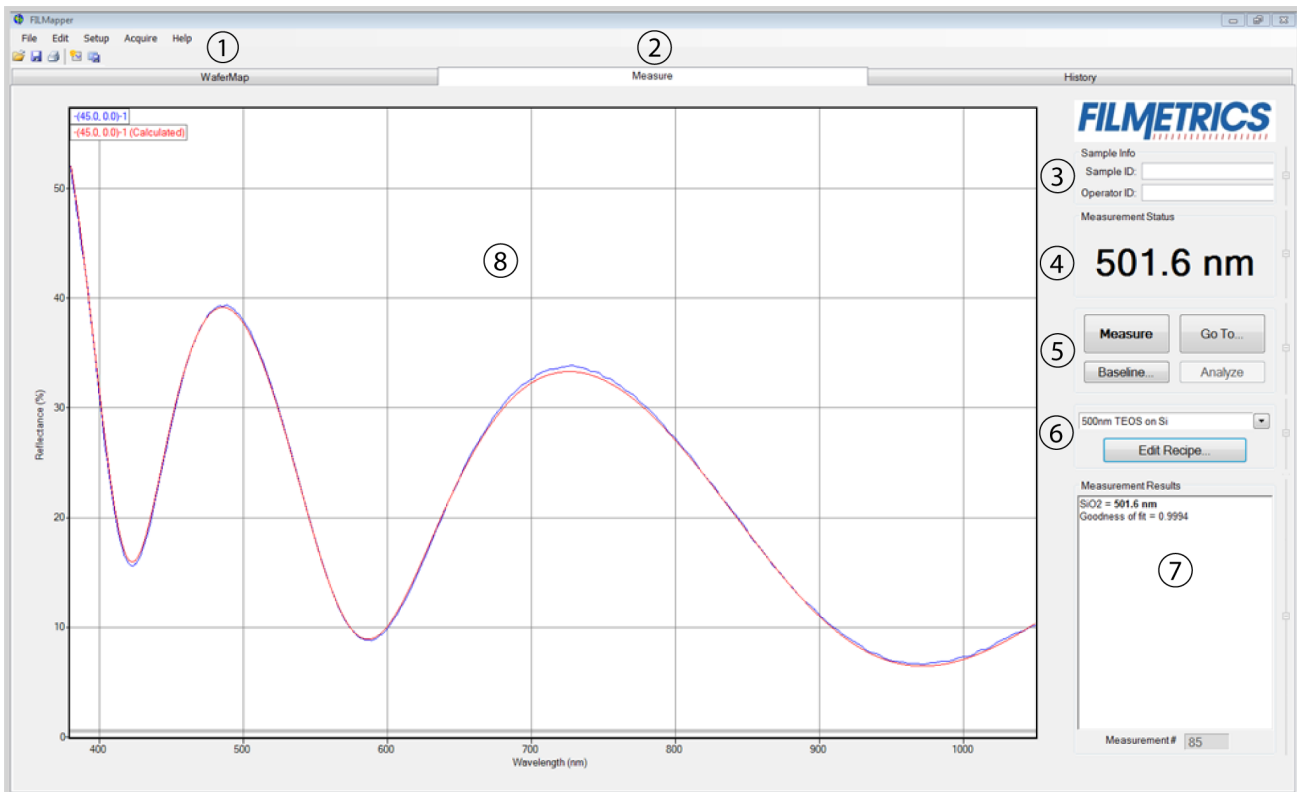
v. [Baseline](#) begins the baselining sequence.

vi. Used to select saved recipes.

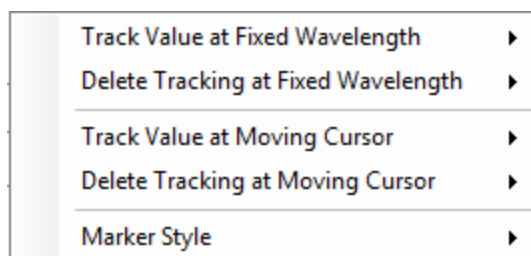
vii. Opens the [Edit Recipe](#) window.

7. Graphical display of the wafer with points of measurement as well as a color scale for thickness summary. The top of the image is the edge closest to the stage mirrors.

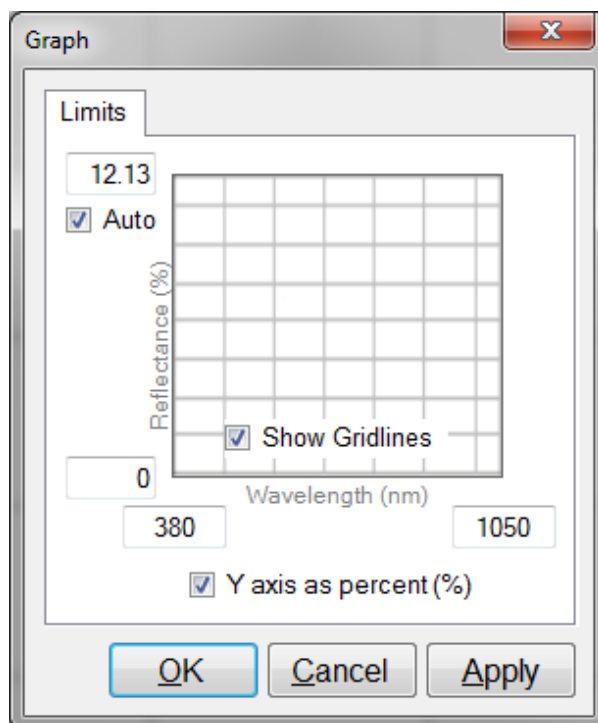
## 1.2 The Measure Tab



1. Standard Windows menus, including; [File](#), [Edit](#), [Setup](#), [Acquire](#), and [Help](#).
2. These tabs are used to select between the [Wafer Map](#), [Measure](#), and [History](#) windows.
3. Information about the **Operator** and **Sample** can be entered here for tracking purposes.
4. Displays the thickness of the film being solved for, as well as whether a sample is good or bad based on the settings selected in the [Alarms](#) tab.
5. **Measure** a sample, [Baseline](#) the system, or **Analyze** an already opened spectrum. If the **Measure** button is grayed out, the system will require a baseline before further measurements may be taken.
6. Select saved recipes from the drop-down list, or open the [Edit Recipe](#) dialog box.
7. Details about the calculated thickness, as well as any additional parameters that were solved for, including **Roughness**,  $n$  and  $k$ , and **Nonuniformity**, and the [Goodness of Fit \(GOF\)](#) are displayed here.
8. Graphical display for spectra. A click of the right mouse button while the cursor is within the graphical display opens the menu below for easy reading of cursor values in the **Measure Tab**. Use the keyboard up/down and right/left arrows to move the marker to a desired location.



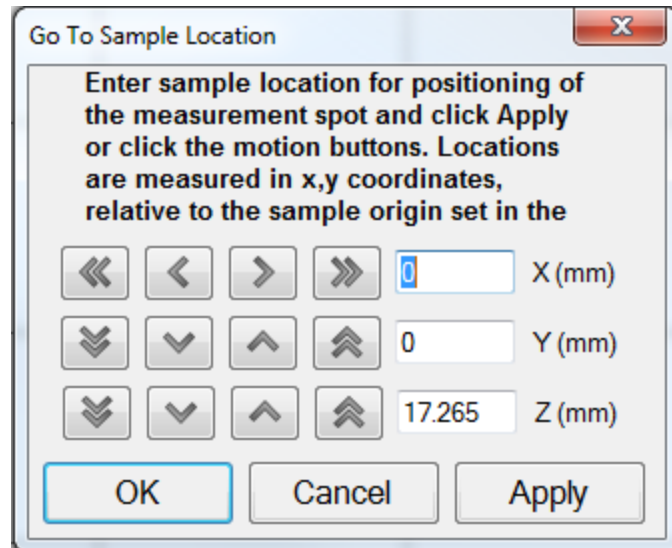
The graph limits can be changed by double-clicking on the graph display. The text boxes along the bottom of the graph control the wavelength range, in nanometers, displayed on the screen. The two on the left represent the Reflectance (%) range, with the max being set in the upper box and the min being set in the lower. The boxes on the right are for Transmittance (%). Check the **Auto** checkbox to activate y-axis autoscaling. The lower value is always 0 for autoscaling; the maximum y-axis upper limit is 5000. The axes can be set to display in percent or as a decimal value (100% = 1).



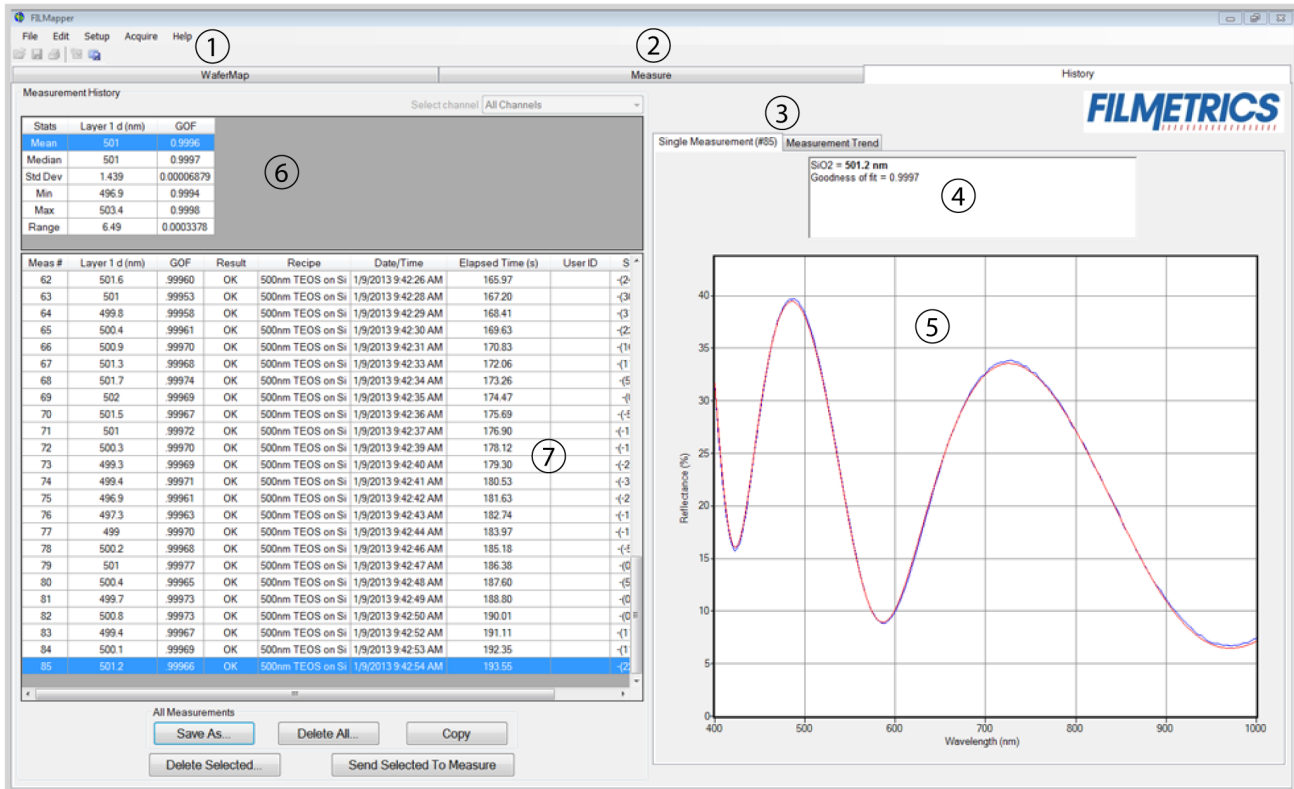
**Graph Options** can be accessed and edited by double-clicking on the main graph window.

## 1.3 Go To

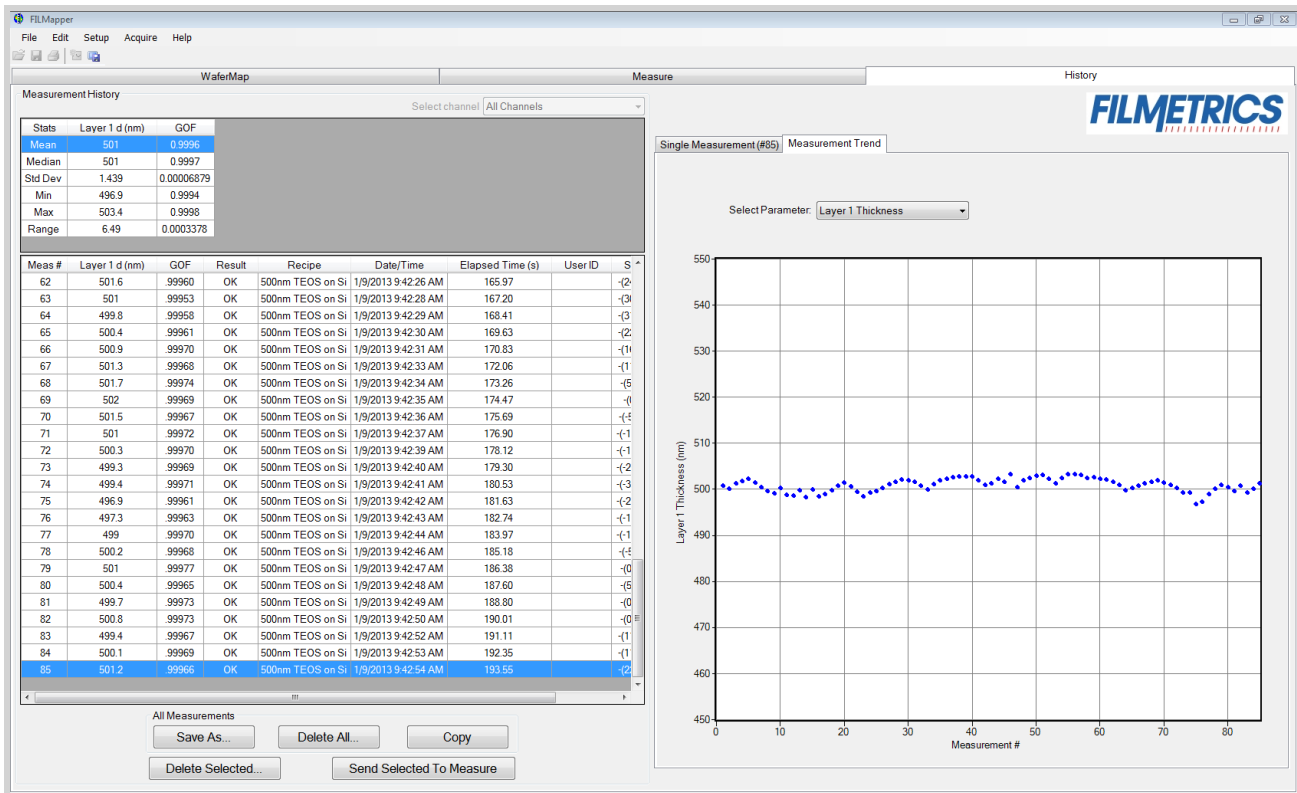
The **Go To** function allows the user to manually locate the system in the x, y, and, with capable systems, the z direction. Measurements may be entered as discrete coordinates, or by clicking on the arrow keys to move the stage accordingly. When using the arrow controls, the inner buttons allow a slower movement speed, while the outer buttons are for faster motion.



## 1.4 The History Tab



1. Standard Windows menus, including; [File](#), [Edit](#), [Setup](#), [Acquire](#), and [Help](#).
2. These tabs are used to select between the and **History** windows.
3. Used to alternate between the **Single Measurement** and **Measurement Trend** tab. Selecting the **Measurement Trend** tab will allow the user to see a plot of the measurement results versus measurement number. A drop-down list allows the user to select between which parameter is graphed.

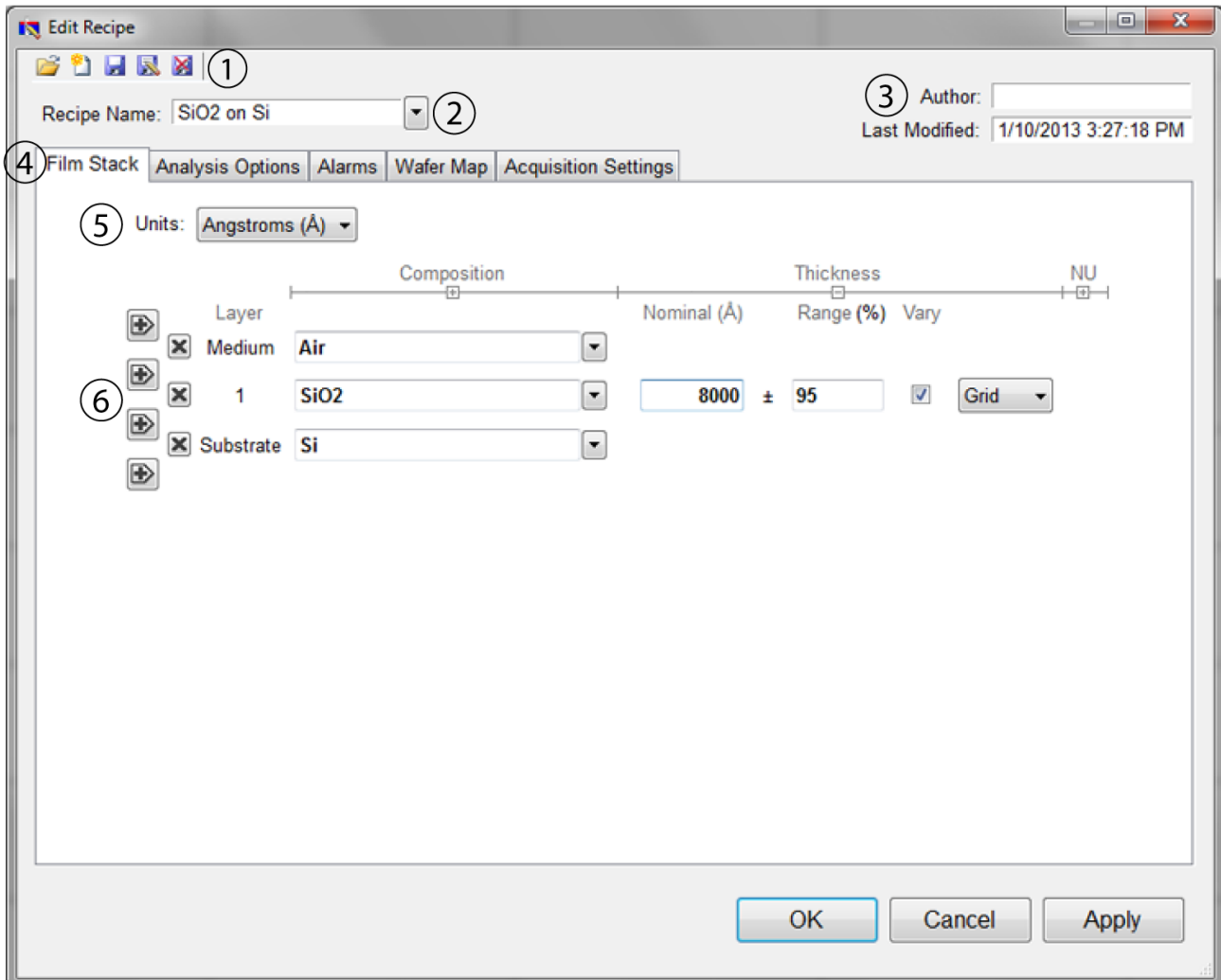


When the **Measurement Trend** tab is selected in the **History** window, the right side of the screens graphs the results.

4. Shows the measurement results for the selected spectrum (must be in **Single Measurement** mode).
5. Displays the selected spectrum (in **Single Measurement** mode).
6. Displays statistics for all measurements included in the history file.
7. This list contains all spectra currently included in the history file. Left clicking on a column header will re-sort the data in ascending or descending order based on the selected column. Right clicking anywhere in this box will allow the user to open the **Edit Columns** control panel.

## 1.5 The Edit Recipe Window

The **Edit Recipe** window is used to define the film stack and to set analysis and acquisition parameters.



1. These buttons allow you to, in order from left to right:
  - i. Open a saved recipe.
  - ii. Start a new recipe.
  - iii. Save the current settings.
  - iv. Save the current settings as a new recipe
  - v. Delete the current recipe.
2. Opens a drop-down list for quick access to saved recipes.
3. **Author**, as defined by user login name and recipe modification date is indicated here.
4. Allows the user to select between the **Film Stack**, [Analysis Options](#), [Alarms](#), [Wafer Map](#), and tabs.



5. The desired thickness units are chosen here. The choices include angstroms ( $\text{\AA}$ ,  $10^{-10}$  m), nanometers (nm,  $10^{-9}$  m), kilo-angstroms ( $k\text{\AA}$ ,  $10^{-7}$  m), microns ( $\mu\text{m}$ ,  $10^{-6}$  m), microinches, mils, millimeters (mm,  $10^{-3}$  m), and [Custom Units](#).

6. This is where the materials and parameters to be solved are defined.

## 1.6 Menu Controls

This section describes the various functions available through the standard Windows File Menus.

### [File Menu](#)

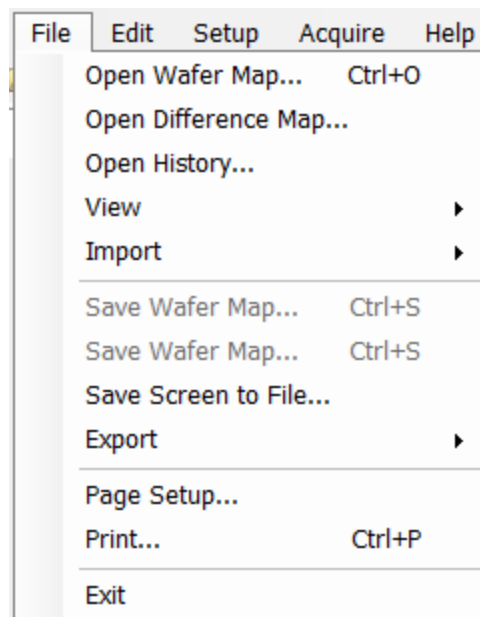
### [Edit Menu](#)

### [Setup Menu](#)

### [Acquire Menu](#)

### [Help Menu](#)

#### 1.6.1 File Menu



#### **Open Spectrum... (Measure Tab only)**

This command is used to open stored reflectance spectra, which are then displayed and can be analyzed for film properties.

#### **Open History...**

Previously saved **History** data containing measurements and statistics can be loaded with this command.

#### **Import: Recipe...**

To import recipes that were previously exported, or created with an older version of FILMapper, use this command.

**Import: Material...**

Custom materials, either created by the user or provided by Filmetrics, can be imported using this command.

**Import: License...**

When the user purchases an upgrade for the system, Filmetrics will send a license file to the user. The license must be imported into the software before upgrades are effective.

**Save Measured Spectrum... (Measure Tab only)**

This command is used to save spectra for export or later analysis. All data is saved along with the corresponding wavelength data in comma-delimited format. Files can be saved in four different formats:

\*.fmspe: This file can only be opened in FILMapper 5.0 or greater and is the preferred way to save spectra. Additional information from data acquisition is stored in this file.

\*.spe: This file can be opened in all versions of FILMapper.

\*.csv: This is a comma-delimited file that can be opened directly in Excel.

\*.txt: This is a tab-delimited file, and can be opened with a text editor.

**Save Screen to File... (Measure Tab only)**

This command takes a screenshot of the FILMapper window.

**Export: Recipe...**

Recipes can be exported for use on other computers running FILMapper. The exported file will also automatically include any material files required by the recipe. To duplicate an analysis, all that is needed is the exported recipe and the spectrum being analyzed.

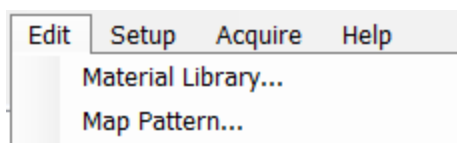
**Export: Recipe for FILMapper 4...**

This command will convert a recipe for use with FILMapper 4. This will not include material files or recipe features only available in FILMapper 7.

**Export: SystemInfo File...**

For certain upgrade purchases that can be done through software, the user will be required to send the SystemInfo file to Filmetrics, which can be exported using this command.

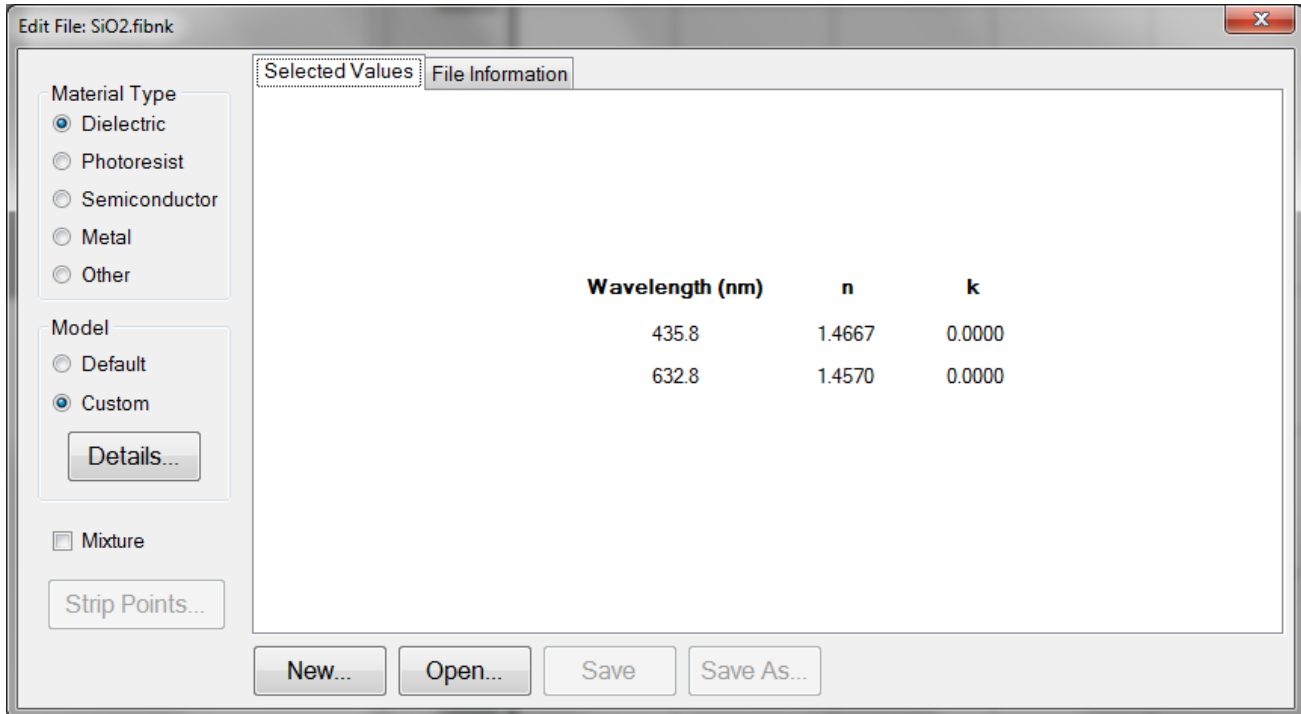
## 1.6.2 Edit Menu



This menu allows access to the [Material Library](#), as well as the [Map Pattern](#) editor.

## Material Library

The material library is used to display information about existing materials as well as create new ones. Material files shipped with FILMapper have the file extension “.fibnk” and will only display limited information. User created material files, “.fitnk”, can be plotted on a graph or viewed in table form.



A new material may be entered into the material library manually if refractive index ( $n$ ) and extinction coefficient ( $k$ ) are known as a function of wavelength for the new material.

To create a new material file:

1. Select **Edit > Material Library...** menu item. The **Edit Material** dialog box will appear.
2. Click **New...** to create a new material.
3. Select the type of material you are ready to create (Dielectric, Photoresist, Semiconductor, Metal, or Other).
4. Optimize the functionality of the file by entering index values over the entire wavelength range of the system. The wavelength unit is nanometers. Enter index information every 20 to 50 nm, depending on the complexity of the data. In areas where  $n$  or  $k$  is quickly changing, more densely spaced points should be entered.

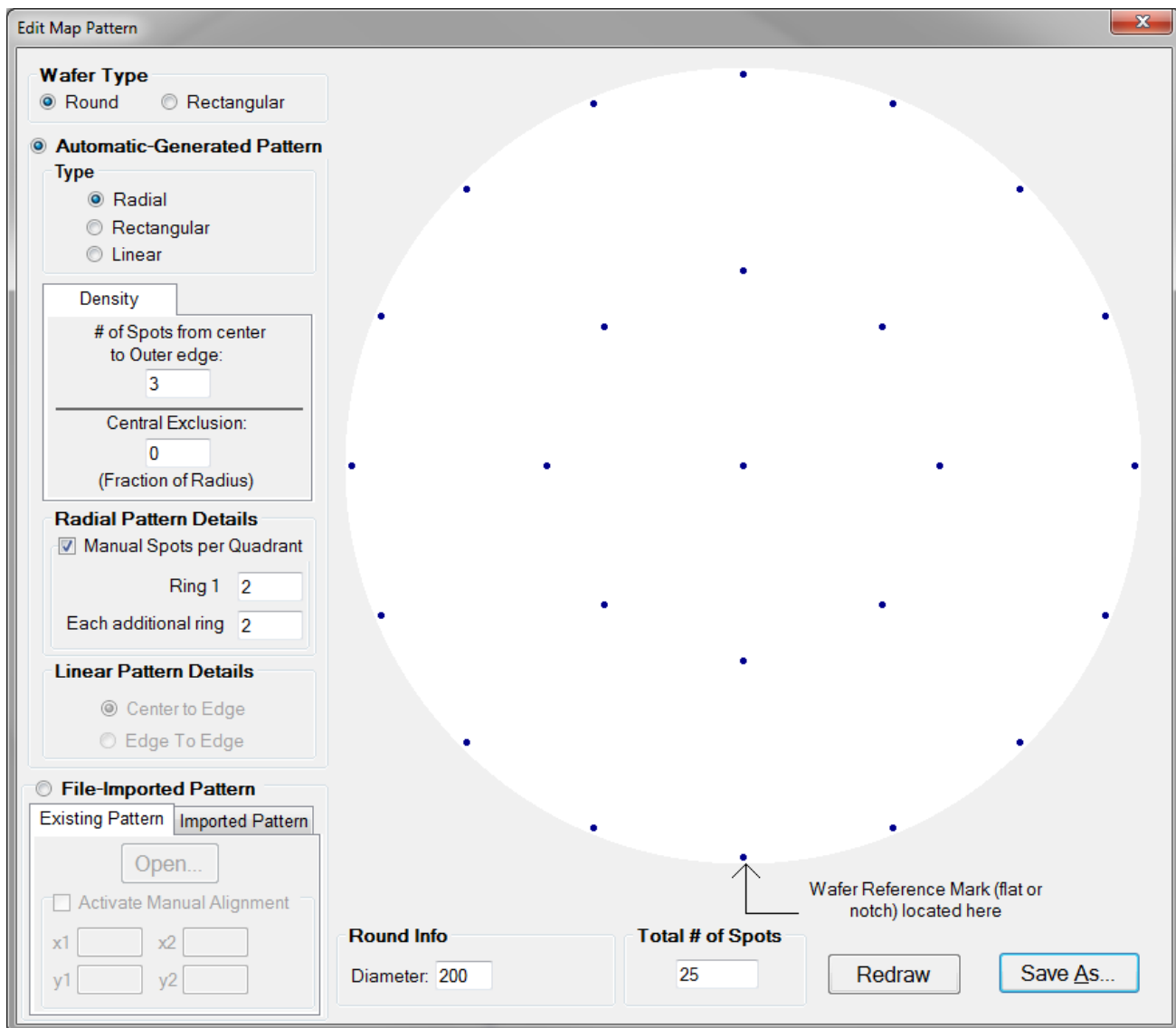
5. Alternatively, select the **Model > Custom** radio button and click the **Details** button. A **Custom Model Information** dialog box will appear. Select the appropriate model. Enter in the known coefficients and click **OK**. Cauchy coefficients are displayed in microns. If they are entered in Å, FILMapper will automatically detect this and convert them to microns.

6. Click the save button to save the material. You will be asked for a file name, and you may select one of two file types:

\*.fitnk: Creates a unified file with both  $n$  and  $k$  information. Compatible with FILMapper 6 and beyond.

\*.nnn: Creates a \*.nnn file and, if there is  $k$  in the material, a \*.kkk file to contain material data. For files with both  $n$  and  $k$ , the two files must have the same filename, for example xmaterial.nnn and xmaterial.kkk, in order for FILMapper to properly identify them. Compatible with all versions of FILMapper.

## Map Pattern...(Wafer Map tab only)



The **Edit Map Pattern** dialog allows the user to specify the measurement pattern on the wafer. Patterns can be generated automatically through the dialog, or pre-existing patterns can be opened or imported for review.

When generating patterns automatically, the user must first determine if the wafer shape is round or rectangular under the **Wafer Type** option. The pattern type specifies the pattern geometry within the wafer shape. With **Round** selected, the user can enter the expected wafer diameter into the **Round Info** text box at the bottom of the dialog window. If **Rectangular** is selected, the **Rectangle Info** will allow the input of both height and width data of the sample. All measurements are assumed to be in millimeters. FILMapper is able to automatically scale the wafer map to match other wafer sizes if a different wafer size is input during recipe creation in the [Edit Recipe > Wafer Map](#) dialog.

The pattern density and central exclusion features specify the exact distribution of the measurement points on the wafer. A greater density leads to an increased number of measurement spots, and can only be increased in whole numbers. **Central Exclusion** can be used when the user doesn't want a point in the exact center of the wafer. The exclusion must be  $<1$  in order to function properly. The **Radial Pattern Details** options are only enabled when the type is set to **Radial**. Enabling the Manual Spots per Quadrant option will allow the user to modify the number of measurement spots even further by increasing the number of spots per each concentric ring.

Rectangular patterns allow the user to modify spot density, or with the addition **Fixed** option allows the user to manually enter the number of spots per each row and column.

Linear patterns by default are set to measure from **Center to Edge**, but can be set to **Edge to Edge** using the **Linear Pattern Details** options.

An updated version of the map pattern can be displayed by clicking **Redraw** after changing any of the above values. **Save as** will save the new map pattern in the FILMapper\Patterns\Custom folder under a user determined name.

If the x-y coordinates for a specific pattern are known, the FILMapper software can recognize a text file of these coordinates. See [Editing Map Files Using Excel](#) for more details on creating custom maps.

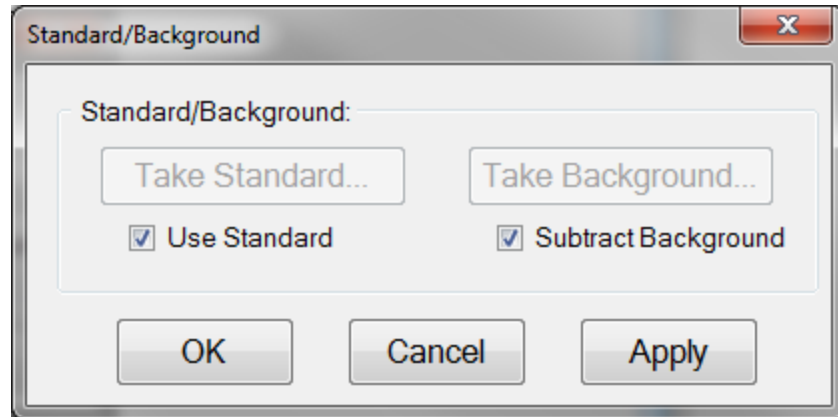
All custom patterns must be saved in FILMapper\Patterns\Custom folder. To select the new pattern in the **Edit Recipe>Wafer Map** tab, select the **Custom Coordinate System** and the name of the pattern from the drop-down box.

### 1.6.3 Setup Menu

This menu contains the settings for manually obtaining the [Standard/Background](#) information, [Display](#) options and the [Raw Signal](#) dialog. This is also where user access can be set through the [Access Control](#) option, as well as modifying some system [Options](#).

### Standard/Background

This control is used when manually taking and enabling/disabling the **Reflectance Standard** and **Background** compensation.

**Take Standard**

This button allows the reflectance standard portion of the baseline measurement to be taken without having to re-take the background measurement.

**Take Background**

This button allows the background portion of the baseline measurement to be taken without having to re-take the reference measurement.

**Use Standard**

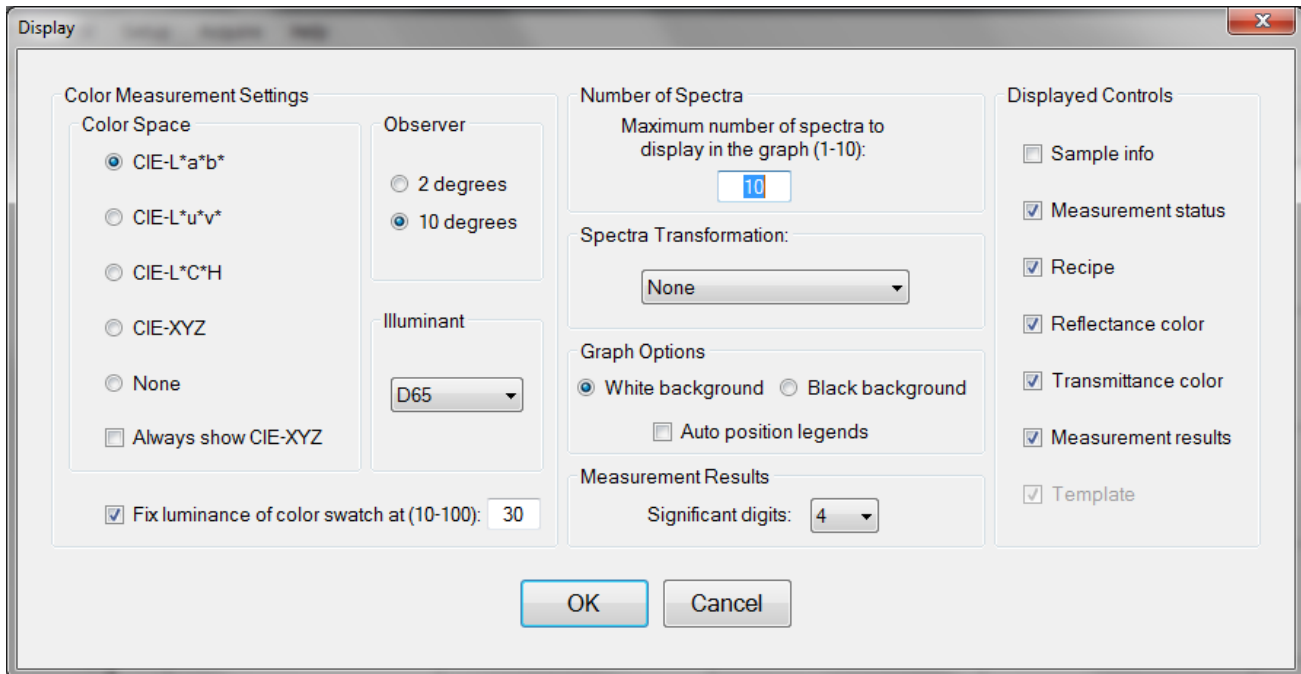
This checkbox allows the reflectance standard portion of the baseline correction to be enabled or disabled. This box is only available if a baseline has already been completed.

**Subtract Background**

This checkbox allows the background subtraction portion of the baseline correction to be enabled or disabled. This box is only available if a baseline has already been completed.

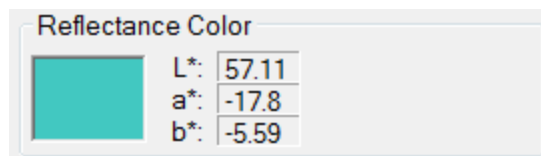


## Display



### Color Measurement Settings: Color Space

The color of a spectrum can be displayed and quantified on the main screen if a color space coordinate system is selected.



When a **Color Space** is selected, the color of the spectrum and the coordinates appear on the **Measure Tab**.

### Color Measurement Settings: Observer

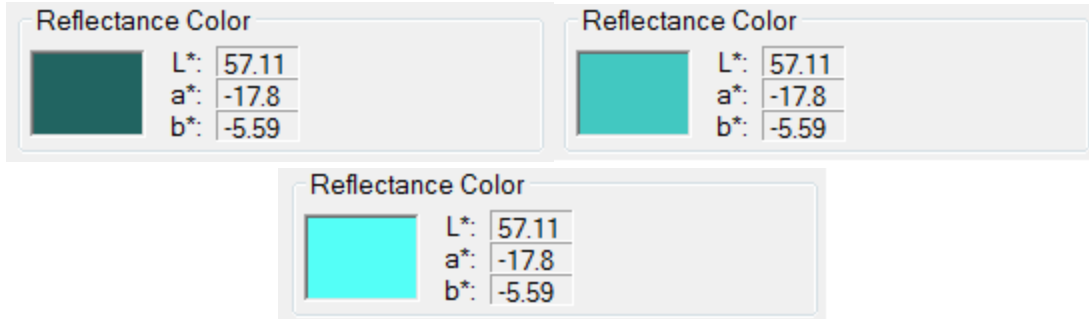
When a specific color space is chosen for display, this option allows the user to choose between the CIE 1931 2 degree observer and the CIE 1964 10 degree observer. Note that this variable is associated with the CIE eye-response convention (see, for example, [http://en.wikipedia.org/wiki/CIE\\_1931\\_color\\_space](http://en.wikipedia.org/wiki/CIE_1931_color_space)) and is unrelated to the illumination or collection angle of the measurement.

### Color Measurement Settings: Illuminant

This setting refers to the [standard illuminant](#) being used by the software to help determine the results of the color analysis.

### Color Measurement Settings: Fixed Luminance

The user can fix the luminance of the displayed color. Since antireflective coatings, for example, are inherently transmitting, the spectra have very little luminance and the coating color may appear black on the screen. Adjusting the luminance does not affect the color space coordinate results.



Spectrum colors of the same spectrum with fixed luminance of 10%, 40%, and 70%, respectively.

### Number of Spectra

This sets the maximum number of spectra (up to 10) displayed simultaneously on the main FILMapper screen. If the maximum number of spectra is reduced to fewer than the number already on the screen, the most recently selected spectra will remain.

### Spectra Transformation

For spectra with both reflectance and transmittance information present, you can have the software display them as separate spectra (none), added together (sum), or the absorbance (1-R-T).

### Graph Options

The background of the graph can be set to white or black using this option, as well as allowing the software to auto-position the legend box to avoid or minimize overlap with the displayed spectra.

### Measurement Results: Significant Digits

The user can select the number of significant figures, from 1 to 7, that the results are displayed in. For example, with the units set to Angstroms and 4 significant digits, The software would report a thickness of 7213 Å. If significant digits is switched to 3, it will instead display the thickness as 7210 Å.

### Displayed Controls

These checkboxes are used to determine which controls are shown on the right hand side of the FILMapper window.

### Access Control

FILMapper incorporates password protection to limit access to the measurement software and settings. When the software is initially installed, access control is turned off. The software will automatically boot up with Engineer level access that enables access to all features of the program except turning on and off access control and adding and deleting users.

The image shows a dialog box titled "Access Control". It contains the following elements:

- Access Level:** A dropdown menu currently showing "Engineer".
- User ID:** An empty text input field.
- Password:** An empty text input field.
- Activate Access Control:** A checkbox that is currently unchecked.
- Buttons:** "Log In" and "OK" buttons located at the bottom right of the dialog.

Turning on access control requires Supervisor level access. The software is delivered with one user, a supervisor, in the list of authorized users as shown below:

**UserID:** filmsuper

**Password:** filmetricsfff

To turn on access control, log in as filmsuper using the password shown above. The **Activate Access Control** checkbox should be selected, enabling access control functions. User ID and Password are case-sensitive.

To add an operator level user, select operator from the **Access Level** list box, type a user name and type an initial password for that user. Then click the **Add User** button. To add an engineer or a supervisor user follow the same procedure, but pick the appropriate access level from the list box before pressing the **Add User** button.

To delete a user, enter the **UserID** and press the **Delete User** button.

Operator and Engineer level users can change their passwords when they are logged in by entering their password into the password box and pressing the change button. Supervisor-level users can change their password or the password of any other user by selecting the appropriate access level, entering the appropriate **UserID** and the new password and pressing **Add User**. If the program finds that a user already exists, it will delete the old entry for that user and create a new entry.

We recommend that you create a new supervisor level user and delete the filmsuper user for maximum security. If all supervisor level users forget their passwords, it will be necessary to re-install the software and add all the users again.

## Raw Signal

### Raw Signal

The **Raw Signal** dialog box allows the user to plot the raw (no baseline corrections applied) spectrometer signal on the main graph. This is useful when setting integration times manually.

### Integration

The user can set the integration time and the number of integration cycles for the spectrometer. Increasing cycles can be used to help smooth the data being returned to FILMapper. Clicking **Update Recipe** transfers the listed integration time and cycles to the current recipe.

### Signal Corrections.

**Spectrum Preprocessing** allows the user to apply a smoothing function to the displayed spectra. See [here](#) for more details.

### Start/Stop

This button starts/stops the acquisition of the spectrometer signal.

### Graph Limits

This allows the user to either manually set or autoscale the graph limits. Click **Apply** after any changes to display them on the main FILMapper window.

## Options

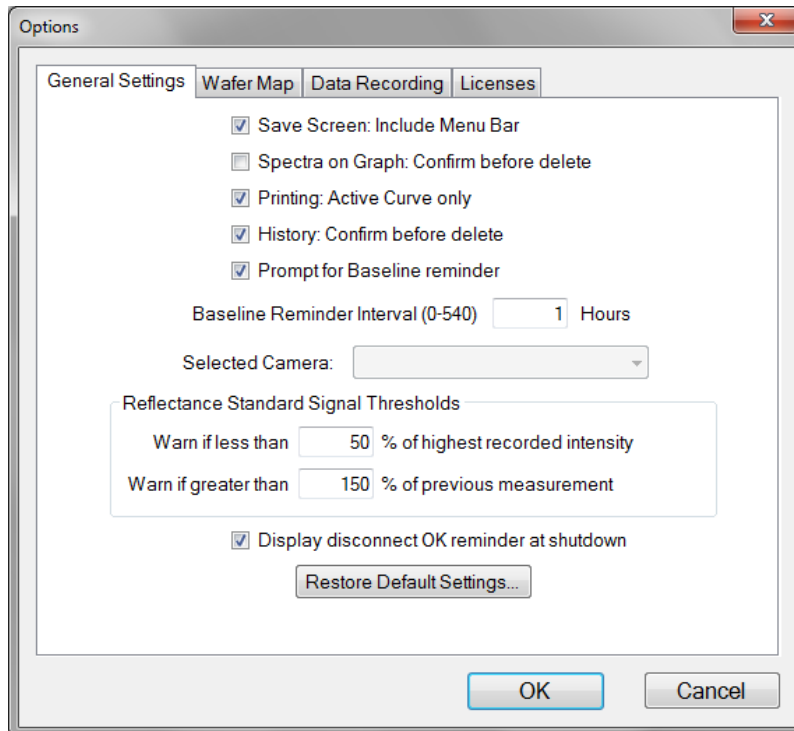
The **Options** menu allows the user to enable, disable, or modify several different settings within FILMapper.

### [General Settings](#)

### [Wafer Map](#)

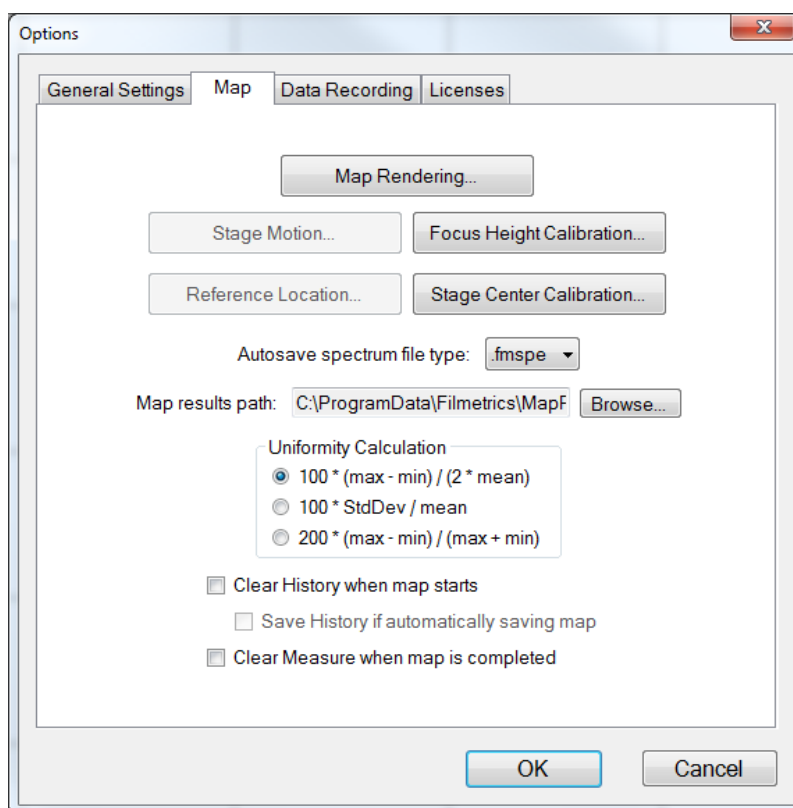
### [Data Recording](#)

## General Settings



The **General Settings** tab is used to enable, disable, and modify various options in the software. **Baseline Reminder** allows the user to set an interval at which the system will alert them to re-baseline the system. It is set at one hour by default. The **Selected Camera** pull down menu allows the user to enable the **Sample Cam** on equipped systems, or choose between different cameras if there is more than one connected to the computer. The **Reference Signal Thresholds** options are used by the software during the process. If, during the **Acquire Reference** step of the **Baseline**, the intensity of the reflectance standard goes above or below the percentages listed an error message will appear.

## Map



The **Map** tab allows the user to select the various options related to mapping process. **Map Rendering** allows the user to choose between either a full **Color** map, or a **Luminance** map which varies from white to dark blue. Users can also set whether or not to display invalid points, whether to use a linear interpolation between points, and what size font the results display as on the map.

**Stage Motion** allows the user to enable high speed motion controls, for faster mapping when the vacuum is in use. **Reference Location** allows the user to choose where on the sample to take the reference measurement. The default setting is automatic, and will take the reference measurement at (0,0) or a custom location can be defined. These options are not available for the StageBase-XY8-Auto-38 mm.

**Focus Height Calibration** can be used to manually re-home the z-motion of the system, and also to set an offset for focus height.

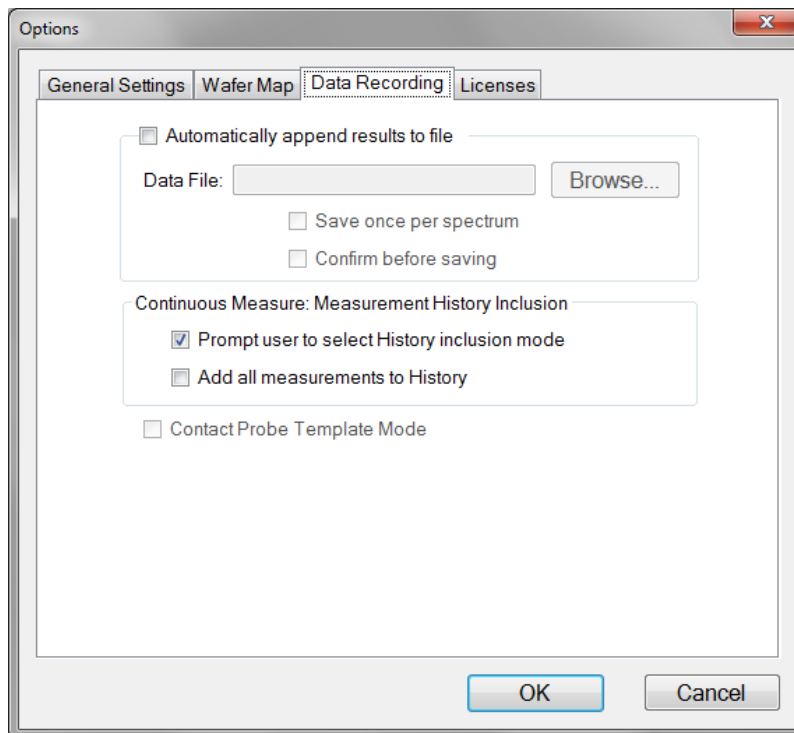
**Stage Center Calibration** is used to ensure that the sample is fully centered on the stage, and is most important when working with patterned samples. Instructions on how to use the function are included in the software.

When **Automatic Data Saving** is enabled under the **Edit Recipe > Wafer Map** tab, the options here are used to determine in what format the spectra are saved, and where on the computer they are saved.

**Uniformity Calculation** allows the user to determine the equation used to calculate the uniformity result in the wafer map.

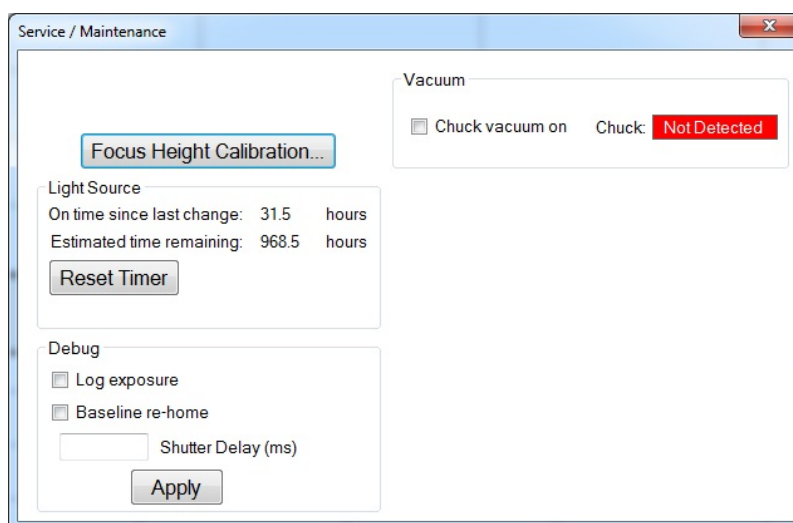
The final three options allow the user to automatically clear the history whenever a new map is started, and if that option is enabled to automatically save the history file created with each map. The user may also tell the system to automatically clear any spectra from the [Measure](#) tab when maps are completed.

## Data Recording



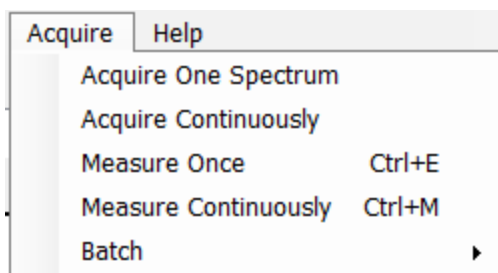
The **Data Recording** tab allows for automatic saving of all spectra and results to a central file. The user can also select between having the software provide a prompt for which data to include in the history file when using **Acquire > Continuous Measure** or to record all measurements to the **History** tab.

## Service/Maintenance



The **Service/Maintenance** dialog is used to enable and disable the vacuum, as well perform some basic service functions. No adjustments should be made to these settings without the supervision of a trained Filmetrics engineer.

### 1.6.4 Acquire Menu



#### **Acquire > Acquire One Spectrum**

This function collects a single spectrum and displays it on the screen. No analysis is performed until the recipe is changed or the **Analyze** button is clicked.

#### **Acquire > Acquire Continuously**

This feature collects real-time data from the spectrometer. It is useful when searching for a specific location to measure (for example, locating a more uniform area of the sample, or one that exhibits interference fringes). Stop continuous data acquisition by selecting **Acquire Continuously** again.

#### **Acquire > Measure Once**

This feature collects a spectrum, analyzes it and displays it on the screen. This is the same as pressing the **Measure** Button.

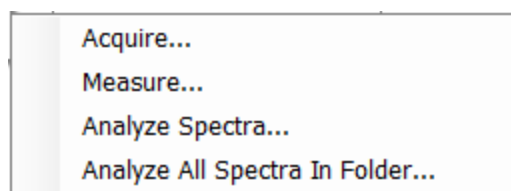


### Acquire > Measure Continuously

This feature collects real-time spectrum data and analyzes it – similar to repeatedly pressing the **Measure** button. A measurement interval time can be set in the recipe using the [Advanced](#) options underneath the tab. Stop continuous data acquisition by selecting **Measure Continuously** again, or by pressing Ctrl+M.

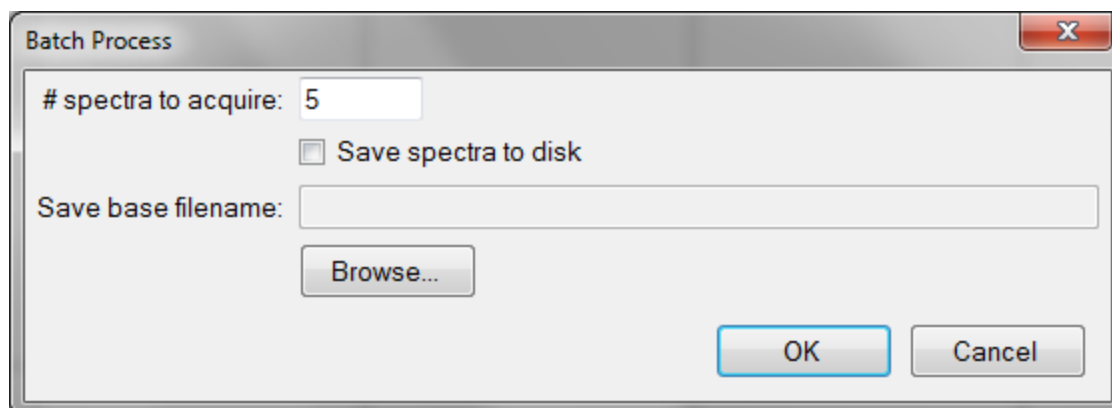
### Batch Acquire

The Batch functions allow you to act on groups of spectra, rather than each individual spectrum



### Acquire > Batch > Acquire

This option allows you to acquire a pre-selected number of spectra. You can also choose to save the batched spectra as they are acquired.



### Acquire > Batch > Measure

This option allows you to acquire and analyze a pre-selected number of spectra. You can also choose to save the batched spectra as they are acquired.

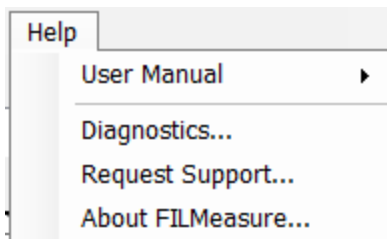
### Acquire > Batch > Analyze Spectra

This option allows the user to select multiple spectra for analysis by the current recipe. If there are more spectra to be analyzed than the software is set to [Display](#), the analyzed spectra can easily be retrieved from the tab.

### Acquire > Batch > Analyze All Spectra in Folder

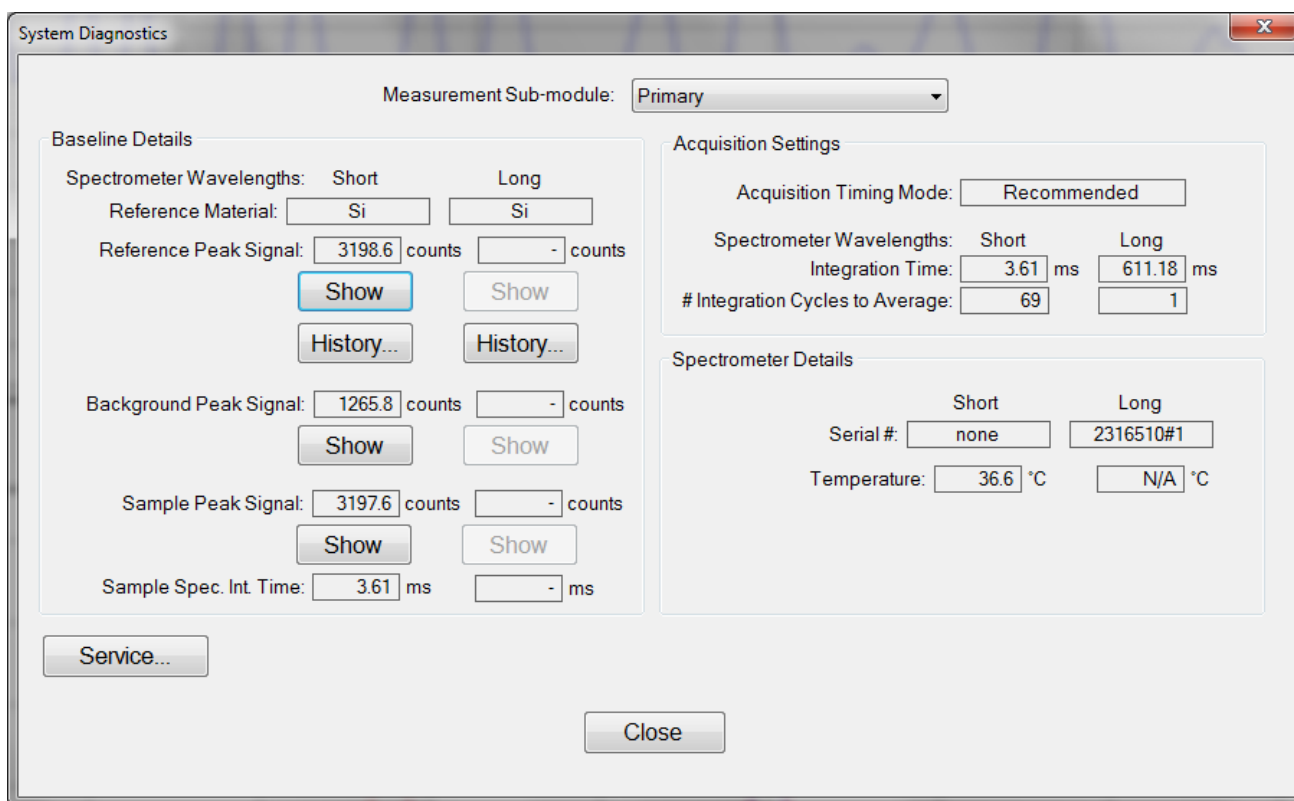
This option will analyze every spectrum in a folder with the currently selected recipe. If there are more spectra to be analyzed than the software is set to [Display](#), the analyzed spectra can easily be retrieved from the tab.

## 1.6.5 Help Menu



### Diagnostics

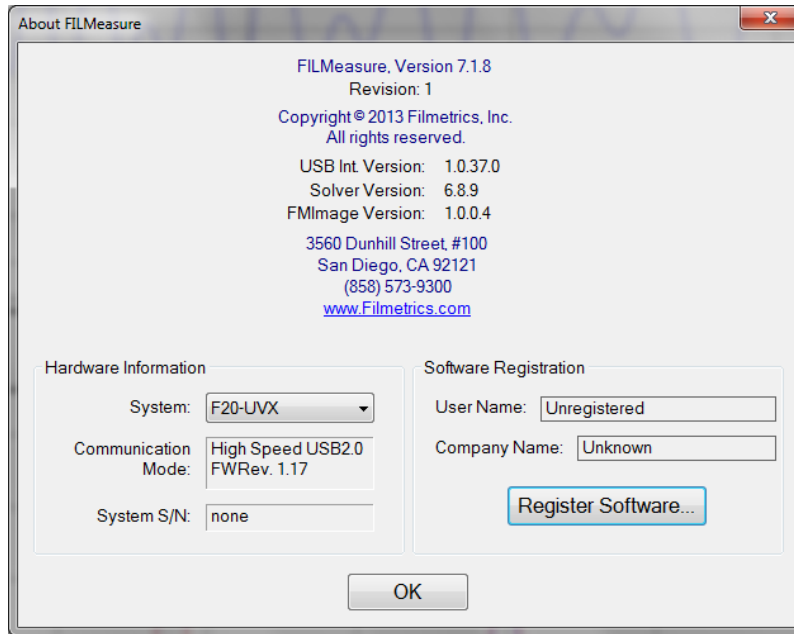
The diagnostics window gives information regarding the data taken during the baseline. Reference and background counts are shown (this is useful to see how much signal the system is getting; good signals typically are between 2500-3500 counts).



**Help > Diagnostics** shows the user information regarding the data taken during the baseline routine.

### Help > About FILMapper

Information about the hardware and software versions and the system serial number can be found here. Please have this information available when calling Filmetrics for technical assistance.



Help>About FILMapper... window

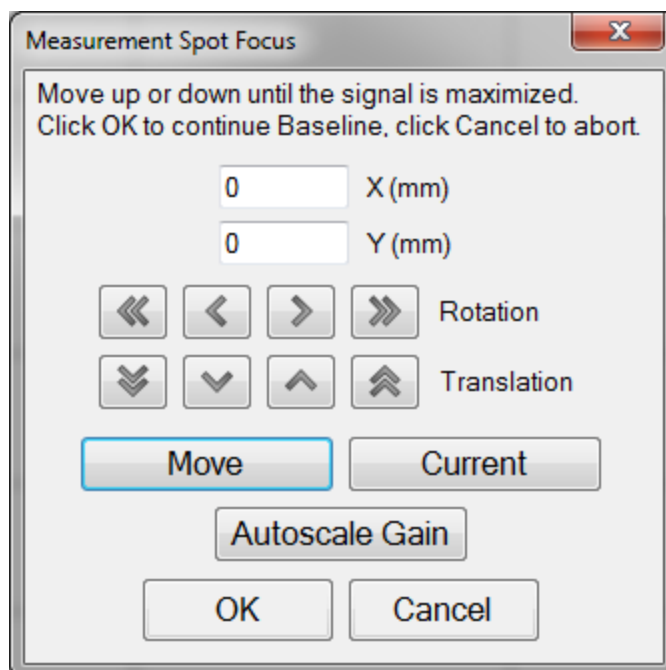
## 1.7 Taking a Baseline

The baseline measurement allows the FILMapper software to take into account the response inherent to the reflectance measurement hardware. It does this by first measuring a supplied sample, then a reflectance standard, and finally taking a “dark” reading. The light source should be allowed to stabilize at least ten minutes before the baseline is taken. When measuring films less than 1000 Å thick, the baseline should be periodically re-taken every 20-30 minutes. For thicker films, a new baseline can be taken less often.

Baseline measurements may be started two ways:

1. Select the **Baseline** button in the [Wafer Map](#) or [Measure Tab](#), which will guide the user through the baseline procedure, or
2. Select [Setup>Standard/Background...](#) from the menu bar in the **Measure Tab** for manual access to the baseline functions.

The first step of the baseline measurement is to take a spectrum from your sample. This done by placing the sample on the stage, and if necessary moving the stage over the sample using the [Go To](#) function. With the sample in place under the light path, you can then press the **Take Sample Reflectance** button. For systems with no z-motion, the software will automatically move to the next step of the baseline. Systems with manual z-motion will instead prompt the user with the **Measurement Spot Focus** dialog pictured below. This dialog allows the user to move the stage and automatically adjust the gain to best analyze the raw signal data. Once the system has been focused you can continue by pressing the OK button. Systems with automated z-motion will focus automatically.



The second step is to measure a reflectance standard. For systems with no z-motion, use a reflectance standard that is closest in height to your sample. This is to account for the fixed focus point, which you can read more about here. Click on **Take Reflectance Standard** to continue the baseline. For systems with manual z-motion, the software will prompt you to refocus the system similar to the last step. Replace your sample with the reflectance standard that most closely matches the overall reflectance of your sample, and then refocus the system. Also as before, automated z-motion systems will automatically refocus to the reflectance standard height. The reflectance standard that is used should be selected from the **Reference Material**: list. For reference materials not in the list, reflectance versus wavelength values may be entered into a comma-delimited text file with the extension “.rrr” (stored in the Material subfolder).

The background scan will be taken automatically. Most stages have a built-in tilted mirror or other reflector that is used to re-direct the incident light away from the collection optics.

When thin films (< 2000 Å, approximately) or  $n$  and  $k$  are being measured, a full wafer reference map will be required, and automatically measured. To determine if full wafer reference data is required, FILMapper checks the active **Recipe** settings. The pattern defined in that recipe will be used for the full wafer reference. If the map pattern, edge exclusion, or wafer diameter is changed, a new full wafer reference will be initiated. The full wafer reference map can be enabled or disabled underneath the [Edit Recipe>Wafer Map](#) tab.

After acquiring a baseline, the instrument is ready to begin making measurements. To verify that the system is working properly, you may select **Acquire>Single Acquire** from the **Measure Tab** menu bar, with the reflectance standard in place. You should see the reflectance spectrum of the reflectance standard.

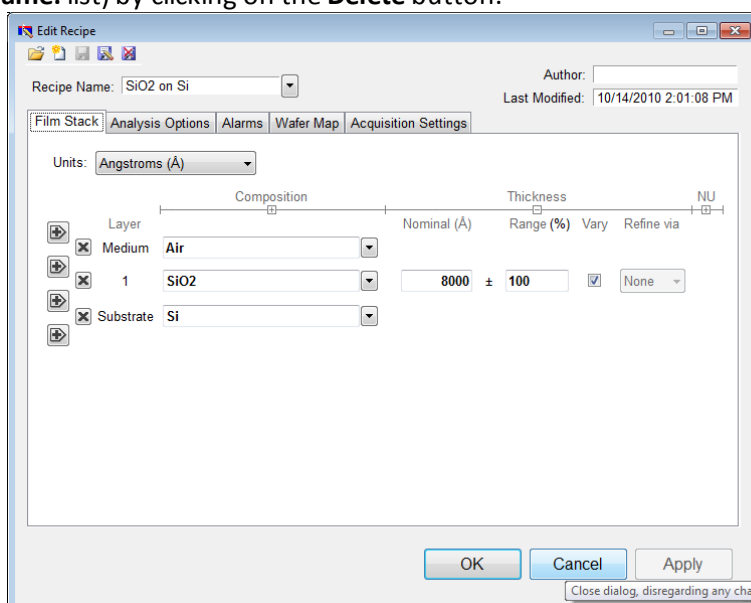
## 2. Editing Film Recipes

The description of the nominal film structure, as well as the measurement parameters, is specified in the [Edit Recipe](#) dialog box. Hundreds of different film structures and their measurement specifications may be saved.

The **Edit Recipe** dialog box is accessed with the **Edit Recipe...** button on the [Measure Tab](#), or the **Edit...** button on the [Wafer Map Tab](#). The **Edit Recipe** dialog box lists an initial guess at the specifications of the film structure to be measured. These specifications include the number of films in the structure, the layer order of the films in the structure, the specifications of individual films (thickness and index), and the film parameters to be measured.

### 2.1 Adding, Changing, or Deleting a Structure

When the [Edit Recipe](#) dialog box is opened, it shows the stored specifications of the structure selected from the **Recipe Name:** list, along with any changes made since the recipe was loaded. Changes to the structure selected can be permanently stored by making the desired changes and then clicking on **Save**. Changes can also be stored as a new recipe by clicking on **Save As**. A structure may be deleted (removed from the **Recipe Name:** list) by clicking on the **Delete** button.



The **Film Stack** tab is used to define the film structure and desired measurement units, as well as the starting guesses and constraints for thickness,  $n$ , and  $k$ . This is also where you determine any [Nonuniformity](#) that may be present in the sample. The [+ ] and [- ] above **Composition**, **Thickness** and **Nonuniformity** can be used to expand or hide solving options.

#### 2.1.1 Setting Up a Film Stack

When measuring a layer, the parameters (thickness,  $n$ , and  $k$ ) of the known films (including the incident medium and substrate) must be entered into the proper fields in the [Edit Recipe](#) dialog box, as well as initial guesses for the values to be measured. The refractive index ( $n$ ) and extinction coefficient ( $k$ ) values for common materials can be selected from the drop-down menus on the right-hand side of the listed materials, or by left-clicking on the material and using the [Search](#) function. Note that if a generic index is selected, the software will instead prompt for a new index value.

If a material is being measured is not present in the material library there are three possible approaches to complete the recipe:

- a) Choose a material in the library that is similar.
- b) If the material is transparent (an insulator), select “**Enter Refractive Index Value**” from the material list and enter a value for the refractive index ( $n$  will automatically be varied by FILMapper to account for dispersion effects, with the entered value being  $n$  at 632.8 nm).
- c) Create a new material file using the [Edit > Material Library...](#) dialog box. Enter the refractive index values for  $n$  and  $k$  as a function of wavelength and save the files so that they may be selected as in the recipe. See [Creating and Editing  \$n\$  and  \$k\$  Files](#) for more information.

## 2.1.2 Choosing the Films to be Measured

To measure a film's thickness, mark the check box on the right-hand side of the **Thickness** field under the **Film Stack** tab in the [Edit Recipe](#) dialog box. When no boxes are checked, the theoretical spectrum for the specified layer stack and thicknesses entered in the recipe will be displayed.

As with most measurements, the uncertainty of the measured data increases as the number of simultaneously measured values increases. Thus it is best to provide as much information about the film structure as possible.

## 2.1.3 Constraints

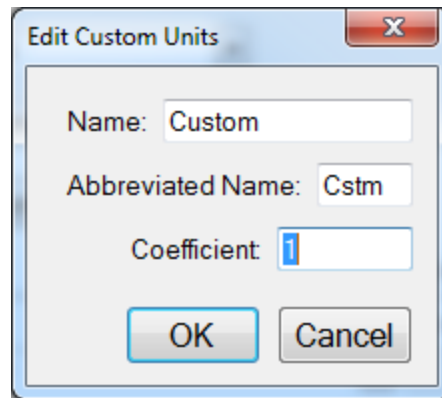
By setting constraints, the user can limit the possible values of the measured film properties. The constraints are set in conjunction with the values entered in the **Range** dialog box for **Thickness**. For example, if the initial guess of the measured thickness of a film is 100 nm and the thickness constraint is set at 50%, FILMapper will only consider possible thicknesses in the range 50 nm to 150 nm. The constraints for  $n$  and  $k$  are set using the  $n$  and  $k$  dialog boxes under **Composition**. These boxes are only visible when the **Thickness** or **Composition** options are expanded.

You can select between constraining by a percent of the thickness guess, or by absolute thickness units by clicking on the % or measurement unit above the constraints dialog box. Constraining the measurement range can speed up analysis and can also help exclude non-physical solutions.

## 2.1.4 Units

The **Units** drop down menu allows the user to easily switch between their desired measurement unit, ranging from angstroms up to inches. The software will automatically convert between units when a different unit is selected (e.g. 1 micron will be converted to 1000 nm).

The **Custom Unit** function allows you to create your own custom unit for measurements if the metric you'd like isn't already available in the drop-down list.



The **Edit Custom Units** dialog box.

To determine the correct coefficient to use, you must first know the relationship between your unit and nanometers. For example, if your units are  $\text{mg}/\text{ft}^2$  and it's been determined that  $1 \text{ mg}/\text{ft}^2$  works out to a film thickness of  $150 \text{ nm}$ , then you would calculate your coefficient as follows, where  $X$  is the coefficient.

$$1 \frac{\text{mg}}{\text{ft}^2} * X \frac{\text{nm}}{\frac{\text{mg}}{\text{ft}^2}} = 150 \text{ nm}$$

$$X_{\text{nm}} = \frac{150 \text{ nm}}{1 \text{ nm}}$$

$$X = 150$$

Custom units can be saved as part of the **Recipe** file, and only one custom unit can be saved per recipe.

### 2.1.5 Composition

When measuring the  $n$  and  $k$  of a film, the general dependence of these values upon wavelength must be specified. This dependence is determined by the type of material to be measured. For example, insulators, semiconductors, and metals all have a unique type of  $n$  and  $k$  wavelength dependence.

Dozens of models for these different dependencies have been proposed and used over the years. FILMapper uses a few of the most versatile and accepted models. For insulators the Cauchy model is used, for semiconductors either the Amorphous or Bridge-Lorentzian model, and for metals the Drude model.

There are also a number of special-purpose models for specific applications. These models, and starting coefficients values, are selected automatically when a material is chosen from the **Material** lists in the [Edit Recipe](#) dialog box. Other models may also be specified by selecting them from the **nk Model** drop-down menu under the **Composition** tab which is accessed by right clicking on the **Meas** checkbox when solving for optical constants is enabled.

### 2.1.6 Grid Search for Thickness

There are a number of methods that FILMapper can use to determine thickness. Each is a different trade-off between speed, accuracy, and robustness (i.e., the ability to find the best solution among many that are nearly as good). Because thickness can vary over many orders of magnitude and many near-solutions may exist, it is often best to use a very robust method to get close to the best solution, and then let a more accurate method take over.

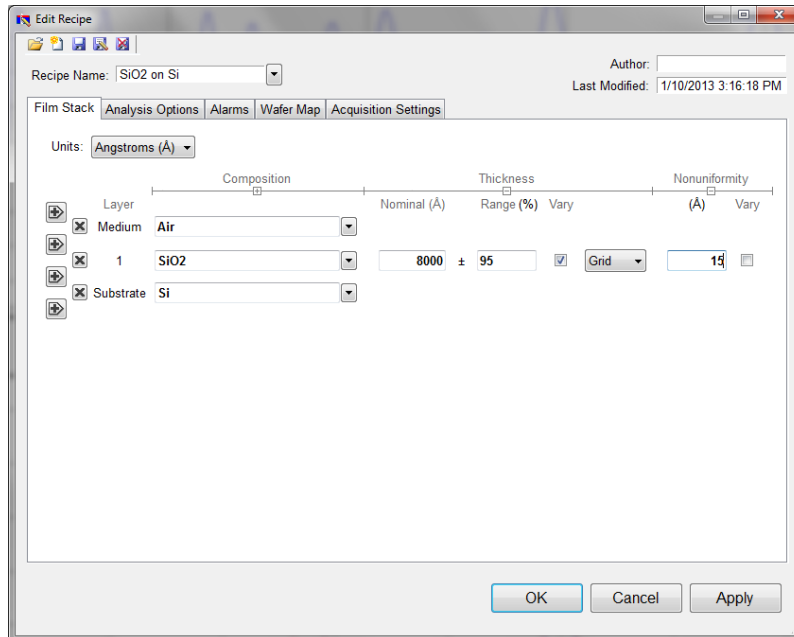
One very robust method is the **Grid** method, which can be activated by selecting the **Grid** option in the **Refine via** drop-down menu. The **Grid** method searches the entire allowed thickness range (as defined by the initial guess and the constraints) to find the best initial thickness. However, on some very complex multilayer spectra, it is possible for the Grid method to give the wrong answer. In such cases it is best to use the [Fourier Transform\(FFT\)](#) method to determine initial thicknesses, or to provide them manually.

### 2.1.7 Fourier Search for Thickness

The **FFT** option in the **Refine via** drop-down list is an alternative option to let FILMapper choose an initial thickness for analysis. The Fourier Transform method analyzes the oscillations present in the spectrum and determines the film thicknesses based on the periodicity of those oscillations. It is generally somewhat less robust than the [Grid](#) method, but is better at finding the correct thickness in cases where the shape of the initial theoretical spectrum is different than the measured data (i.e., the reflectance spectrum is non-ideal in some way) or occasionally in cases where there is more than one film thickness is being measured.



## 2.1.8 Nonuniformity

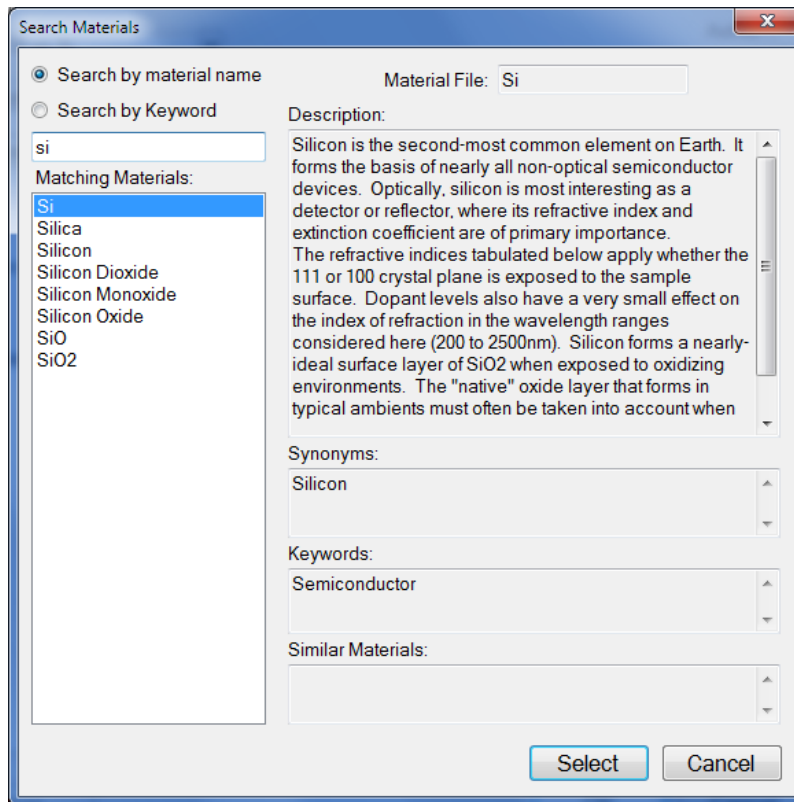


The **Edit Recipe** > **Film Stack** tab with the **Nonuniformity** option expanded.

Selecting this option enables modeling of thickness nonuniformity within the measurement spot. An initial guess for **Nonuniformity** must first be made, and then solving can be enabled or disabled by toggling the **Vary** box. If solving is not enabled, the software will assume the value provided for nonuniformity.

*Note: Solving for nonuniformity can greatly increase solving time.*

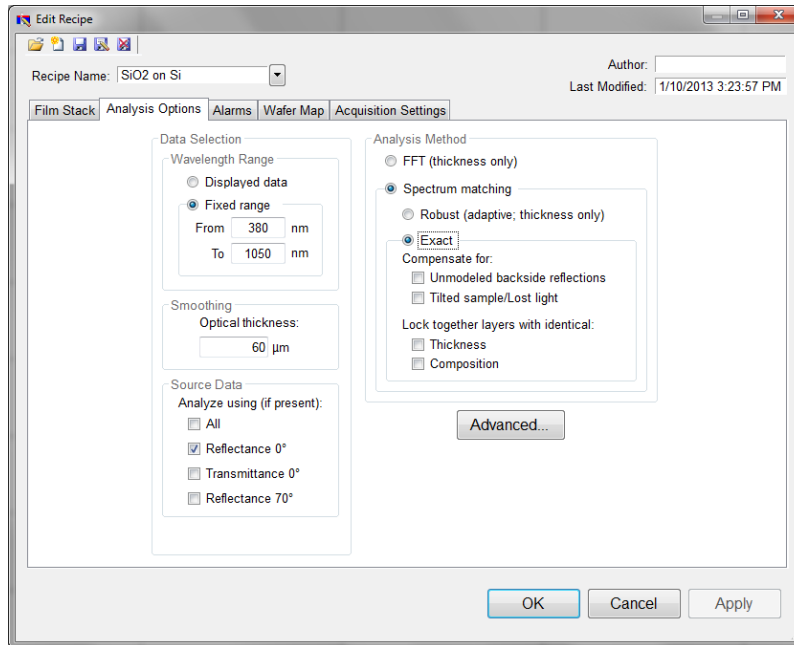
## 2.1.9 Search



The **Search Materials** dialog box is accessible by left-clicking on a material name in the [Edit Recipe > Film Stack](#) tab, or by selecting **Search...** from the material selection drop-down list.

*Note: When clicking on a generic index file, the software will instead provide you with a dialog to enter a new index value.*

This feature allows the user to search for materials by using either the material name, or a keyword for a certain class of materials. The search function will also show a brief **Description** of the material selected, as well as any **Synonyms** or **Keywords** related to the material file. When files have a **Synonym**, that means they are referencing the same material file under different names. For example, if Silicon is selected the file that will be shown in the **Film Stack** is Si, not Silicon, as that is the file both names are referencing. The **Similar Materials** box will list any materials that may have similar optical properties. Correct setting of the following options will help ensure accurate measurements. Many of the options are set automatically when film information is supplied in the [Edit Recipe](#) dialog box, and all of them can be saved so that subsequent measurements can be made as quickly and easily as possible. If [Robust \(Adaptive; Thickness Only\)](#) or [FFT \(Thickness Only\)](#) is checked



## 2.1.10 Data Selection

### Wavelength Range

This sets the wavelength range that is to be analyzed. It may be set as either the entire range displayed on the graph or a fixed range as defined by the user. Wavelength range may also be changed by clicking and dragging the ends of the gray bar near the bottom of the graph area in the main FILMapper window. Moving the bar will cause the software to reanalyze the data in the newly selected wavelength range.

### Smoothing

This function performs wavelength-dependent boxcar averaging on the measured spectra. This can improve signal-to-noise levels and can filter out oscillations that correspond to optical thicknesses (defined as thickness \* refractive index) equal or greater than the specified value. This value should be lowered to increase smoothing, and raised to decrease smoothing. To eliminate smoothing, enter a very high value (1000  $\mu\text{m}$ , for example).

### Source Data

If more than one data set is present, this option tells the software whether to analyze the 0 degree reflectance data, 0 degree transmittance data, 70 degree reflectance data, or some combination of the three.

*Note: While every Filmetrics system is capable of opening and analyzing spectra with 70 degree reflectance data, only the [F10-RTA](#) is capable of collecting this data.*

## 2.1.11 Enable FFT (Thickness Only)

The **FFT (thickness only)** solver is one of three analysis methods available in the FILMapper software.

This solver is best suited for films greater than 250 nm thick, as well as multi-layered films. It is also an effective option when the index of refraction of the film isn't well known. While this feature is selected there will be fewer options under the [Analysis Options](#) tab. You cannot solve for index, roughness, or nonuniformity with the **FFT (thickness only)** solver enabled. More information on the solver can be found [here](#).

### 2.1.12 Enable Robust (Adaptive; Thickness Only)

The **Robust (adaptive; thickness only)** solver is the second of three analysis methods available within FILMapper. It is best suited for measuring the thickness of single-layer films greater than 150 nm thick.

This method can oftentimes successfully measure films when the data is affected by non-ideal properties, such as thickness nonuniformity, grading, and birefringence. Much like the **FFT (thickness only)** solver, enabling **Robust (adaptive; thickness only)** will limit the options available in the [Analysis Options](#) tab. You also cannot solve for roughness, nonuniformity or index with the **Robust (adaptive; thickness only)** solver enabled.

### 2.1.13 Exact Spectrum Matching

The **Exact Spectrum Matching** is the third of three analysis methods available in FILMapper. This solver can be used to measure thickness, thickness nonuniformity, and roughness of single and multilayer films, and can additionally solve for index.

#### Unmodeled Backside Reflections

When measuring films on transparent substrates, reflectance off of the backside of the substrate may occur. Selecting **Compensate for: Unmodeled backside reflections** allows the software to shift the intensity of the calculated reflectance curve to account for the additional light. This feature should not be used when measuring very thin films (< 100 nm).

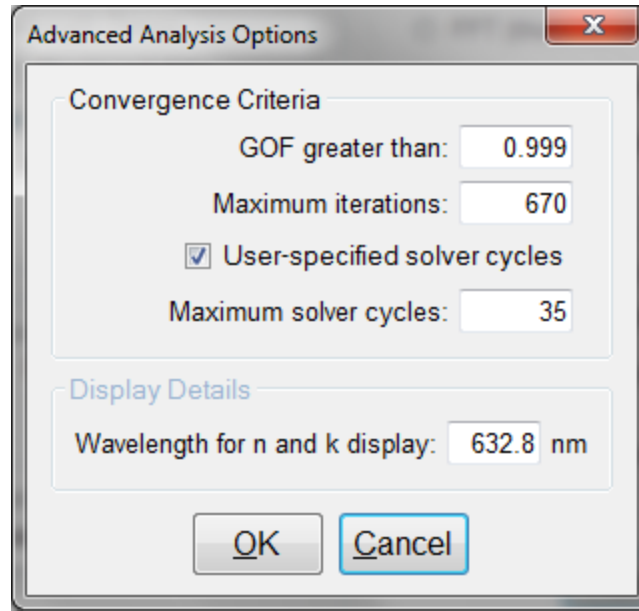
#### Tilted Sample/Lost Light

Samples with non-coplanar surfaces scatter some of the light away from the collection optics. This option automatically compensates for the light lost due to nonplanarity.

#### Lock Identical Layers

Samples comprised of repeating layers can be more accurately measured by activating this option. By activating these options, all properties of any layers that initially have the same material or thickness are locked together.

### 2.1.14 Analysis Options: Advanced



Advanced Analysis Options for Spectrum Matching.

### Convergence Criteria

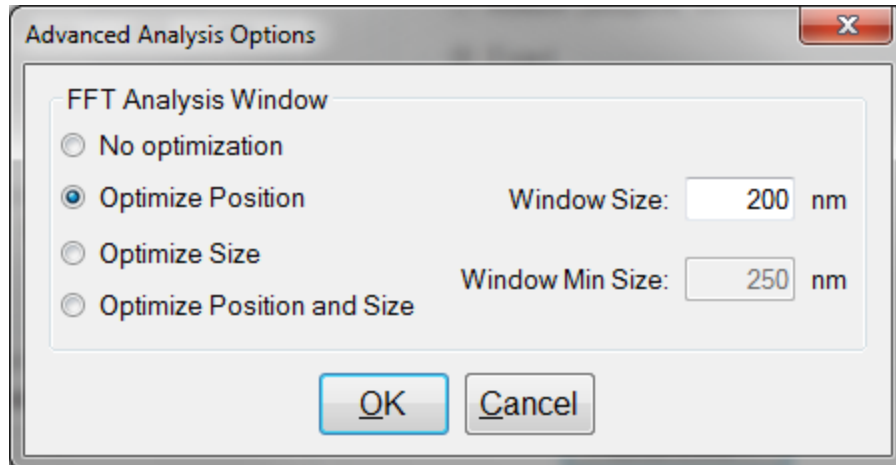
This sets the minimum **GOF** between the measured and calculated spectra that is attained before the measurement routines consider the solution final. In most cases a value of 0.999 is sufficient. For cases where the desired **GOF** is not attainable, the value in the **Maximum Iterations** field limits the number of iterations performed by the analysis routine.

### Solver Cycles

This option will enable multiple solver cycles, with the number of cycles being defined by the number entered in the text box. When using this option, the software will run through the model for a solution once, and then try again starting from the solution previously found. This can help find the best solution amongst a number of near-best solutions, which can be the case when solving for a large number of parameters (several thicknesses and/or refractive index). A greater number of cycles will lead to a longer solving time.

### Display Details

This feature controls the wavelength at which  $n$  and  $k$  are displayed in the **Measurement Details** portion of the main screen. These values are only displayed if solving for  $n$  or  $k$  is selected in the **Film Stack** tab.



Advanced Analysis Options for FFT Analysis.

### FFT Analysis Window

When the FFT solver is selected, the advanced options give you access to various settings to help optimize analysis performance. When **Optimize Position** is selected, the solver will check for the best possible GOF value in different areas across the spectrum in a wavelength range defined by the entered window size. For example, if a window size of 200 nm is selected, the solver will look at six different 200 nm sections of the spectrum, and then select the range that provides the best GOF.

If **Optimize Size** is selected, the solver will instead begin with a minimum window size as defined by the user. It will then start at the center of the analysis range, and then extend equally in both directions six times to find the best GOF. When **Optimize Position and Size** is selected, the software does both functions, resulting in measuring thirty-one different combinations of location and analysis range.

## 2.2 Map

The screenshot shows the 'Edit Recipe' dialog box with the 'Wafer Map' tab selected. The 'Recipe Name' is 'Si Thickness Standard' and the 'Author' is 'AH'. The 'Last Modified' date is '12/9/2015 8:08:20 PM'. The 'Wafer Map' tab is active, showing the following settings:

- Measurement Configuration:**
  - Wafer Diameter: 100mm (3.9")
  - Coordinate system: Polar
  - Number of Points: 1
  - Edge exclusion: 0 mm
  - AutoFocus in center only
- Automatic Data Saving:**
  - Save map to disk
  - Save spectra
  - Export to custom format
- Pattern Avoidance:**
  - Pattern Avoidance
  - Spot Size: 0.5 mm
  - Pattern Size: 0.05 mm
  - Rectangular
  - Radial
  - Spacing: 1 degrees
- Invalid Meas. Retry:**
  - Invalid Meas. Retry
- Additional Parameters To Be Mapped:**
  - Fabry-Perot dip
  - Reflectivity band center
  - Average reflectance ratio
    - Starting wavelength: 0 nm
    - Ending wavelength: 0 nm
    - Reference wavelength: 0 nm
  - GOF ( solve for Goodness Of Fit)
  - Focus Height
- Full Wafer Reference Mode:**
  - Automatic
  - Off
  - On

Buttons at the bottom: OK, Cancel, Apply.

This wafer map tab allows the user to specify various settings in relation to how the map is generated. This includes the size and type of wafer to be analyzed, the configuration of the measurement spots, which parameters should be mapped, where **AutoFocus** functionality should be used if available, as well as data saving protocols. It also allows the user to define settings for pattern avoidance and accounting for invalid measurement spots. This is also where the preferences for the full wafer reference are set.

### 2.2.1 Measurement Configuration

**Wafer Diameter:** Diameter of wafer to be measured – choose from list. When using rectangular patterns, this option will switch to **Width** and **Height**, with text boxes to enter the appropriate values.

**Coordinate System:** Polar, Rectangular, Linear, or Custom.

**Number of Points or Custom Name:** Choose from the list the number of points to be measured or select the name of the custom pattern file.

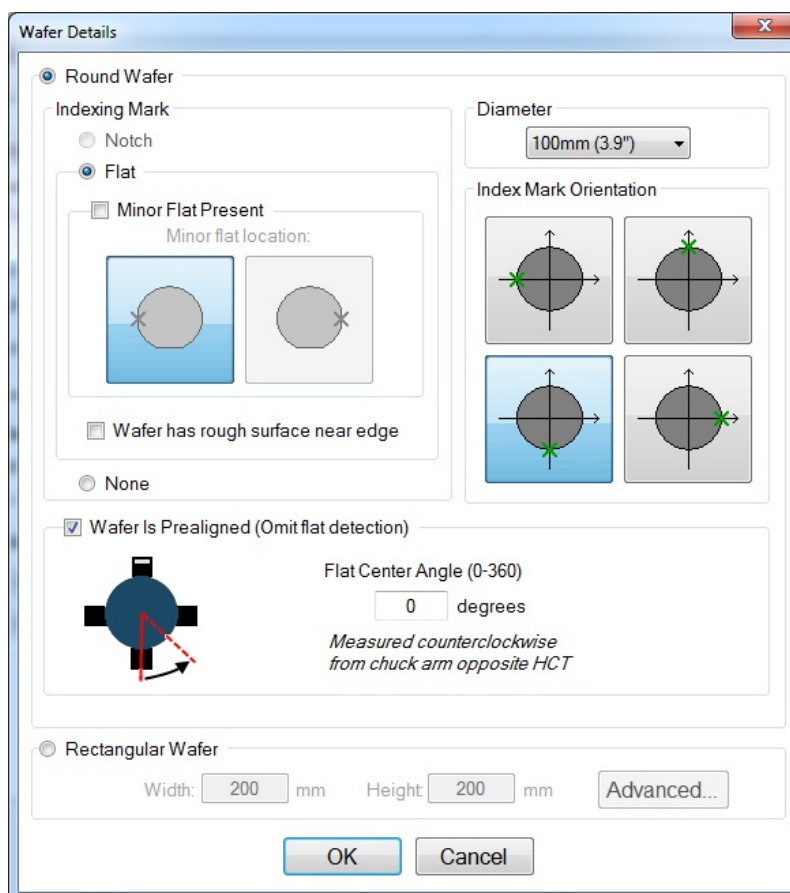
**Edge Exclusion:** Distance from outermost points to the edge of the wafer.

**Wafer Details:** Opens the [Edit Wafer Details](#) dialog box, which is used to determine the location of the index mark on the wafer.

**Advanced Settings:** When using a rectangular map, the advanced rectangular map settings option is enabled for use. This menu allows the user to define the sample origin point in one of five locations; top-left, top-right, center, bottom-left, or bottom-right. **Automatic Alignment** can be used to help find the edges of the sample.

## Edit Wafer Details

The Edit Wafer Details window is accessible underneath the [Edit Recipe > Wafer Map](#) tab. It allows the user to configure the recipe for the type of substrate being measured, round or rectangular.





For round wafers, the **Indexing Mark** (either notch or flat), wafer **Diameter**, and **Index Mark Orientation** are specified. The **Diameter** is selected from the pull-down menu, and the **Indexing Mark** is selected by clicking on the **Flat** or **Notch** option. The system will limit the available indexing options based on the wafer diameter selected. For wafer with minor flats (150mm and smaller), the **Minor Flat Present** check box should only be selected if one is present.

The example shown above indicates a 200mm wafer (**Diameter**) with a notch (**Indexing Mark**) located in the 6:00 o'clock position (**Index Mark Orientation**)

The **Wafer has rough surface near edge** check box is only for wafer with coatings or features that have very low reflectivity at, or near, the edge of the wafer. This features calls a flat finding routine that is more robust, but is much slower, than the standard flat finding routine and should only be used when necessary.

The **Prealigner** option is only available if the option has been included with the system in question. When the **Use Prealigner** box is selected in the recipe **Wafer Details** window, the wafer will be moved from the cassette to the prealigner for centering and orienting the wafer so that its center is in a predefined position and its mark (flat or notch) is at a predefined angle (direction), and then to the wafer chuck. The system then skips the wafer chuck based centering and orienting and proceeds with the measurement. For patterned wafers, it should be confirmed that the system can reliably find the Deskew marks and subsequent measurement locations. If not, changes to the recipe, such as the Deskew and Registration Mark search area box size, or robot station information, may need to be made.

*Note: The **Use Prealigner** option will only be available for wafer sizes that are compatible with the type of prealigner that has been ordered. The option will be grayed out for incompatible wafer types.*

### 2.2.2 Automatic Data Saving

If a filename is entered in the upper right corner of the **Wafer Map View>Map Information** field, then a new folder with that name will appear in the FILMapper\Map Results folder. If no name is specified, all saved data will appear in the Map Results folder.

**Save Results to Disk:** Automatically saves the map after completion of measurement. This comma delimited text file contains measurement coordinates and results.

**Save Spectra:** Saves the spectrum acquired at each point as a separate file. Each file is saved in measurement order, "0" being the first measurement. File extension is .fmspe by default, but can be set underneath the [Setup>Options>Wafer Map](#) tab. Each spectrum may be opened in the [Measure Tab](#).

### 2.2.3 Pattern Avoidance

The pattern avoidance feature enables the system to target areas on a patterned wafer that do not scatter light (i.e. avoid trench areas). If a measurement shows low reflectance, the stage will move to a nearby location where a pad is expected (as defined by the settings described below). This feature should not be selected when measuring blanket wafers.

**Spot Size:** The size of the measured spot.

**Pattern Size:** The size of the features to be avoided.

**Rectangular, Radial:** The pattern layout geometry.

**Spacing:** The center-to-center separation of elements making up the pattern.

## 2.2.4 Invalid Measurement Retry

Activating this feature allows the software to try up to 4 additional measurement locations, within the **Spot Size** specified from the designated location until a valid measurement is made. “**Invalid**” measurements are defined in the **Constraints** tab. This function is especially helpful when measuring non-uniform samples.

## 2.2.5 Additional Parameters To Be Mapped

**Average Reflectance Ratio:** This maps the average reflectance ratio, which is defined as the average reflectance between the **Starting Wavelength** and the **Ending Wavelength**, divided by the reflectance at the specified **Reference Wavelength**. The [Goodness Of Fit](#) can also be included as a parameter to be mapped. For systems with automated z-motion, the focus height can be tracked as well.

## 2.2.6 GOF (Solve for Goodness of Fit)

Enabling this feature saves [GOF](#) results with the map. To see the GOF map, use the drop down above the Manual Color Range box under the [Wafer Map Tab](#).

## 2.2.7 Full Wafer Reference Mode

This option allows you to choose whether or not to enable Full Wafer Reference Mode, or to let the software decide based on the parameters set to be solved for. A full wafer reference is suggested when mapping for optical constants, or very thin films (< 50nm).

## 2.3 Alarms

Minimum Valid GOF: 0

Activate alarms

Thickness Limits (Å)

Layer	Nominal	Min	Max
Medium			
1	6000	5800	6200
Substrate			

OK Cancel Apply

## Minimum Valid GOF

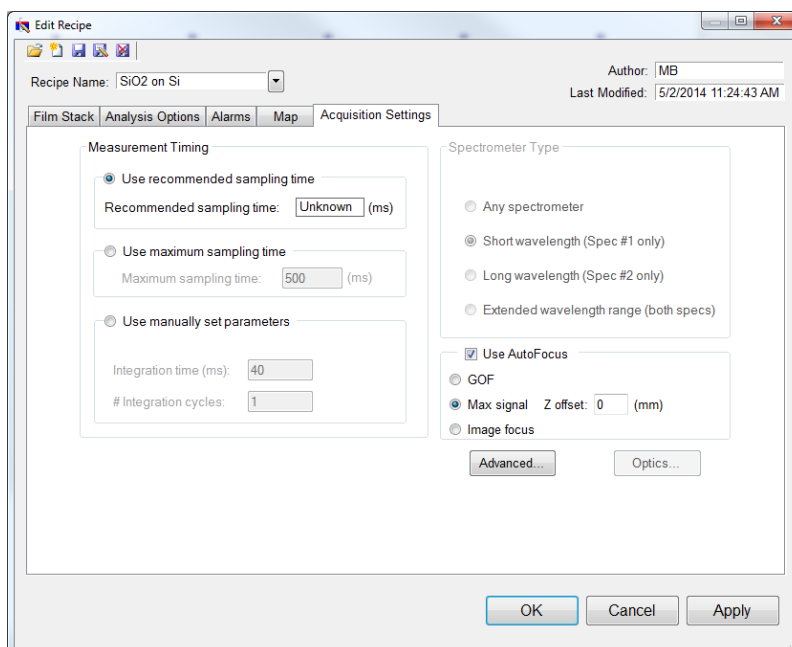
Constraining the **Minimum Valid GOF** will exclude measurements where the calculated **GOF** does not reach the specified limit. A warning or “**Invalid**” result will appear if the GOF constraint is not met. Specify 0 to have all solutions reported.

## Activate Alarms

When **Activate Alarms** is selected, an alarm will trigger if the measured thickness of the sample is outside the specified **Thickness Limits**. Measurements that fall within the thickness limits will be indicated by a green box surrounding the measurement result in the **Measurement Status** window under the . A measurement that falls outside of the selected limits will instead show a red box surrounding the measurement result.

## Thickness Limits

Setting the minimum and maximum allowable thickness limits will trigger an alarm if the measured thickness is outside the limits when **Activate Alarms** is selected.



This menu lets the user control [Measurement Timing](#), [Spectrometer Type](#) (on EXR and UVX systems), [AutoFocus](#) settings, and [Advanced Acquisition Settings](#).

### 2.3.1 Measurement Timing

### Use Recommended Sampling Time

Selecting this option uses the sampling time that has been automatically calculated by the software during the baseline procedure. The displayed value is the total sampling time and not necessarily the integration time. To see the integration time and number of integration cycles go to the [Help > Diagnostics](#) menu.

### Use Maximum Sampling Time

Users can set a maximum sampling time by selecting this option. By increasing sampling time the user may see a decrease in signal noise, but at the trade-off of a longer acquisition time. Integration time and cycles will still be determined by the FILMeasure software.

### Use Manually Set Parameters

Users can set both the integration time per acquisition cycle and the number of integration cycles over which to average. When using this option, the total sampling time is equal to the integration time multiplied by the number of integration cycles.

To set the integration time manually, set the sample on the stage and select [Setup>Raw Signal...](#) If the proper integration time is unknown, an initial value of 40ms is a good starting guess. The vertical scale of the spectrum extends from zero to 4000. Thus, a good working level is when the peak height of the sample being measured, or the reflectance standard, whichever is greater, is 3000-3500 counts. If the maximum signal is too low, increase the integration time. Too large an integration time will result in excessive dark current, so it is sometimes necessary to accept a smaller signal level to limit the dark current.

#### Notes:

1. *If the reference measurement saturates, the software will display a detector saturation error. Analyzing a saturated spectrum will result in spurious final measurements. Take a new baseline with a lowered integration time.*
2. *If the integration time is changed, it will be necessary to perform the baseline procedure, or re-acquire the reflectance standard and background scans.*

## 2.3.2 Spectrometer Type

EXR and UVX systems have two spectrometers (VIS-NIR and UV/VIS-NIR respectively). Here the user can choose to use only one or both spectrometers.

## 2.3.3 AutoFocus

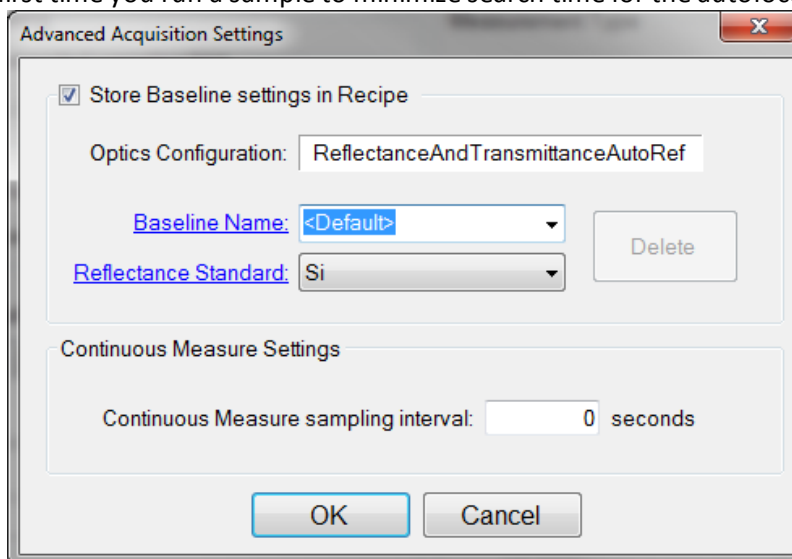
For systems with automated z-motion, FILMapper is capable of autofocusing on the sample and reflectance standard when making measurements. There are three different options available to users:

**GOF:** This autofocus function is intended to optimize focus based on the best goodness of fit measured off the sample. It is important to make sure that the recipe selected accurately matches the intended application to minimize measurement time.

**Max Signal:** This autofocus technique works by maximizing the raw signal returned from the spectrometer to determine best focus. It is the fastest of the three options.

**Image Focus:** Only for systems with the integrated camera, this technique focuses based on the image from the SampleCam.

Regardless of technique used, it is suggested to first use the manual focus controls to bring the system to a rough focus the first time you run a sample to minimize search time for the autofocus function.



#### Store Baseline settings in Recipe

This option allows the user to save the selected **Optics Configuration**, **Baseline Name**, and **Reflectance Standard** used with each individual recipe.

#### Continuous Measure Settings

This option allows the user to set an interval, in seconds, between measurements when using the **Measure > Continuous Measure** command from the [Acquire Menu](#). By default this is set to 0.

## 3. Making Measurements

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Focusing on systems with the automated z-motion controller is very similar to that of the fiber with lens assembly or microscope based systems, only with the controls for height adjustment included in the software.

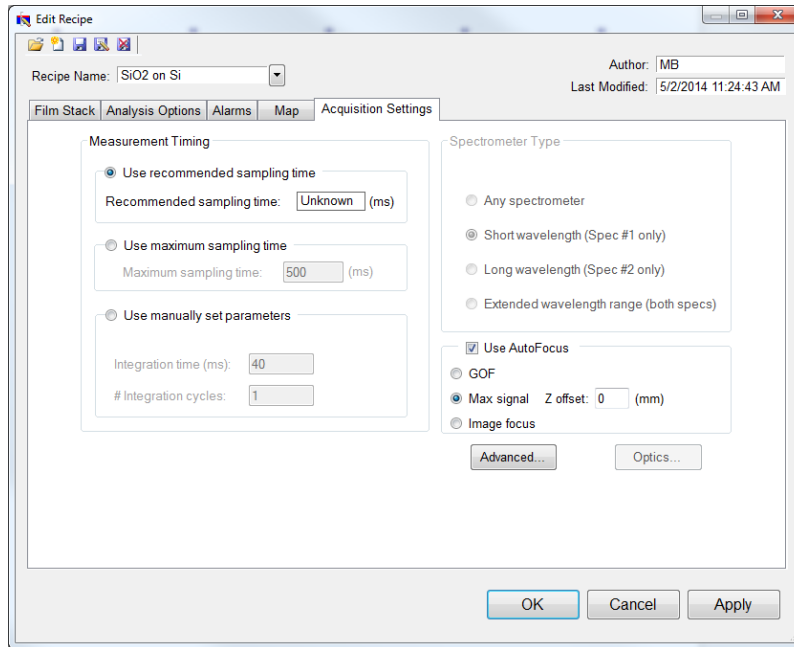
1. Turn on the light source for the system.
2. Start FILMapper.
3. Go to the [Setup>Raw Signal...](#) dialog box, set the integration time for 20 milliseconds, and click **Apply**.
4. Place a reflective sample, such as a silicon or BK7 reflectance standard on the sample stage. You will now see the raw signal from the image sensor. If the signal exceeds 4000 counts, reduce the integration time .
5. Adjust the focus to maximize the measured signal using the focus controls in the software.
6. If micropositioners are present on the optical assembly, F3-XXT systems for example, they may be adjusted at this time . Alternate making adjustments between the two knobs until signal is maximized. As the system is very sensitive to the tip/tilt adjustments being made with the micropositioners, it is important that adjustments are made slowly and in small increments.
7. Close the **Setup>Raw Signal...** dialog box. Focusing is now complete.

You will be prompted to focus the system during the [Baseline](#) during both the sample and reference steps. For the most accurate results, it is important to refocus to your sample after the **Baseline**.

### 3.1 Using the Autofocus Feature (if present)

This section will cover the additional options made available to user for F60's with the optional **Autofocus** upgrade.

To use the autofocus feature, the user must first enable the function in the recipe underneath the [Acquisition Settings](#) tab, and then pick between one of the three autofocus routines.

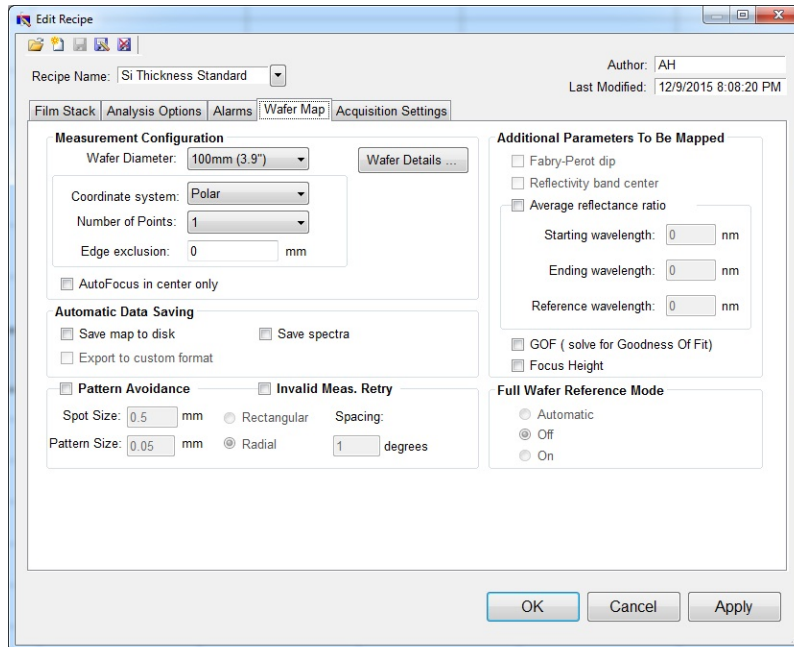


**GOF:** This routine searches for optimal focus by measuring the sample against the current recipe, and then selecting the focus height that provides the highest GOF value. When using this feature it is important to make sure that the recipe selected matches the sample to be measured.

**Max Signal:** This routine searches for optimal focus by looking for the highest raw signal reflectance from the sample. For transparent samples, it is suggested that the user enter a sample thickness or Z offset to help insure the focus routine focuses to the top surface.

**Image Focus:** This routine is only available on systems that also have the integrated SampleCam. This routine searches for optimal focus using the camera image provided from the sample cam.

Once an autofocus routine has been selected, you will also be able to add **Focus Height** as a variable that can be displayed on your measurement maps by clicking on the box underneath the **Additional Parameters To Be Mapped** section of the [Wafer Map](#) tab in the recipe.



## 3.2 Example A - Mapping Thickness Only

### Measuring the Thickness of SiO<sub>2</sub> on Silicon

For this example we will demonstrate only the measurement of SiO<sub>2</sub> on silicon, but this type of measurement has an extremely broad range of applications, including photoresists, hardcoats and polysilicon, to name just a few.

[Continue to Step 1...](#)

### Example A - Preparing the Film Stack

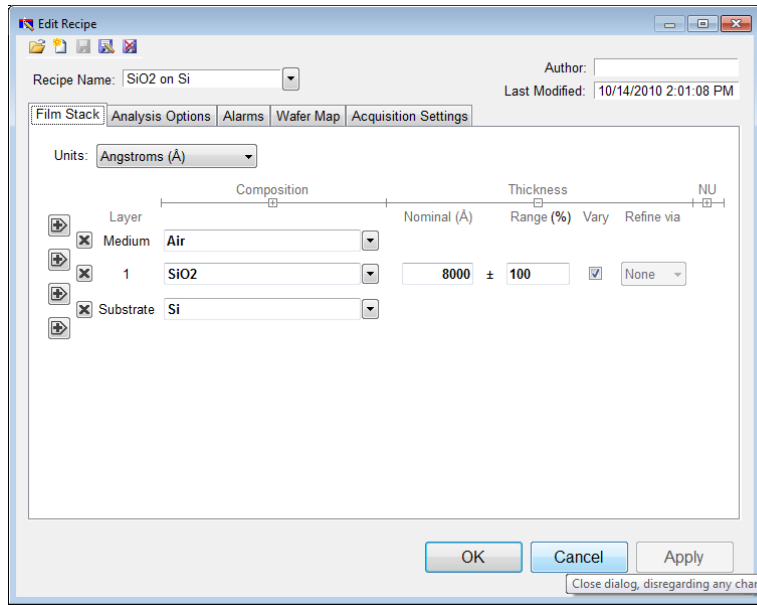
#### Step 1: Select the film stack

Select the film stack to be measured, in this case “SiO<sub>2</sub> on Si”, from the **Recipe**: list box on the main screen. If the film stack to be measured does not exist, continue on to step 2 to define a recipe (see [Editing Film Recipes](#)). If the recipe does exist, continue to step 4.

#### Step 2: Edit the film stack

To edit the stack, click the [Edit Recipe](#) button to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected. Also enter your best guess for the thickness of the film to be measured, and check that only the SiO<sub>2</sub> layer thickness is being measured.





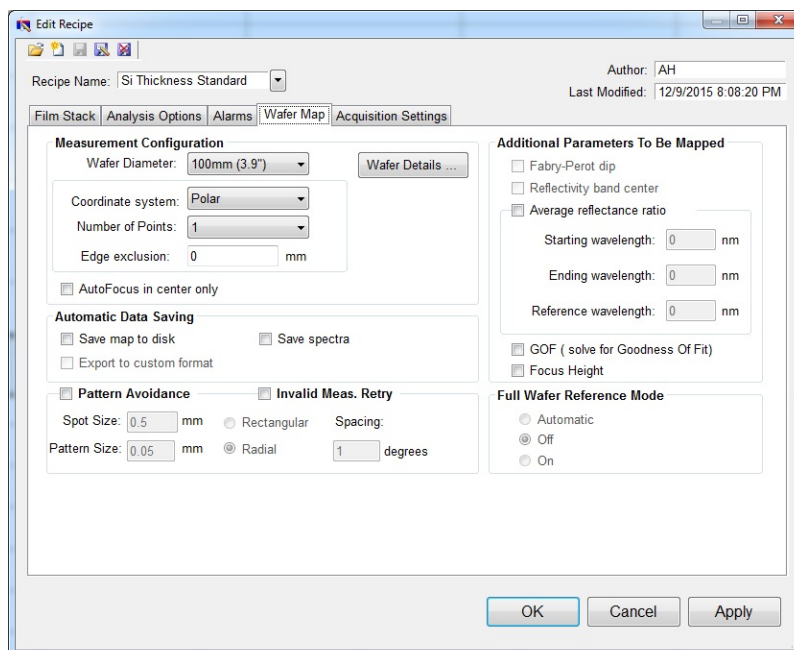
Example **Edit Recipe>Film Stack** window for measuring SiO2 on Si

### [Continue to Step 3](#)

## Example A - Preparing the Map and Baseline

### Step 3: Edit the mapping routine

Edit the [Edit Recipe>Wafer Map](#) tab for the desired set of measurement spots on the wafer. Use the [Wafer Details](#) button to set the notch location on the wafer.



Example **Edit Recipe>Wafer Map Tab** for specifying mapping parameters.

#### Step 4: Take a Baseline Measurement

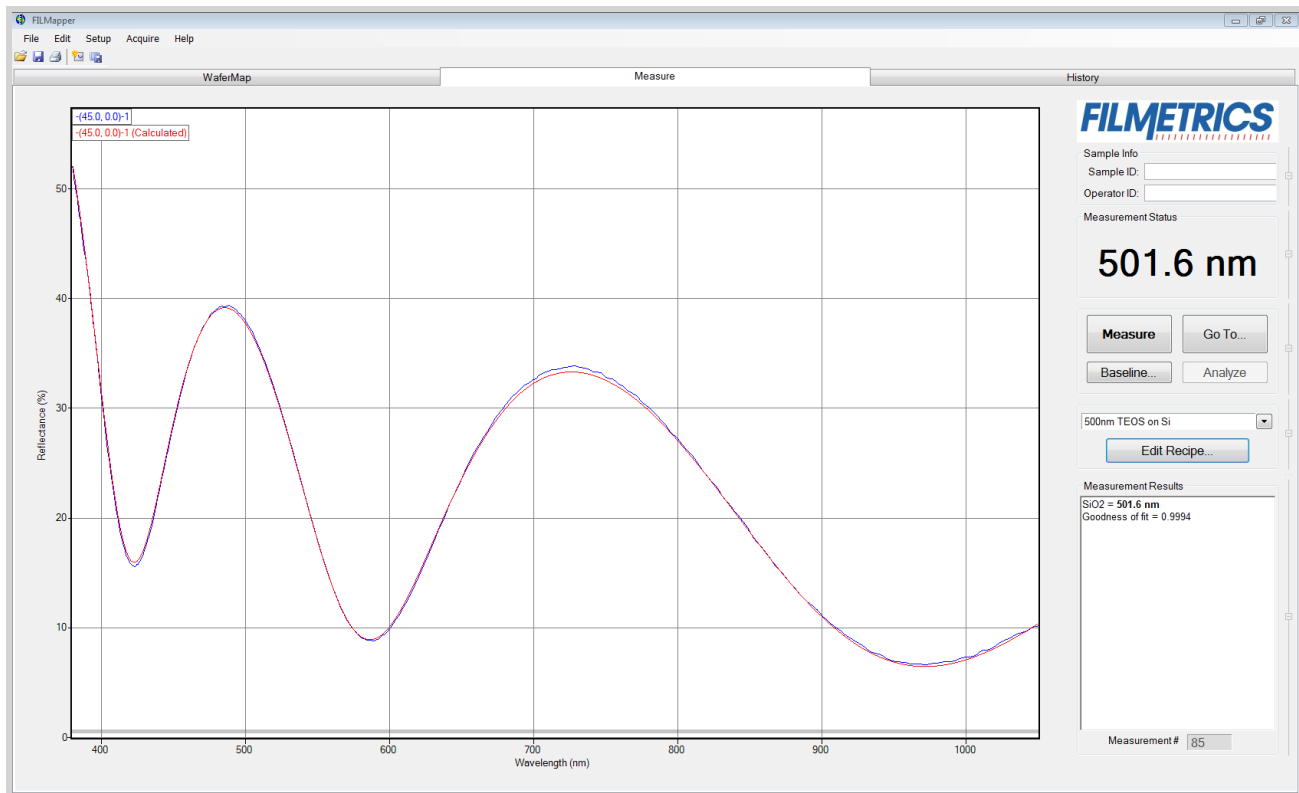
Take a baseline measurement by first clicking on the **Baseline** button. A dialog box will appear to step you through the process. In the **Acquire Reference** dialog box, make certain to select the reference material that will be used ("Si" in this case). Then put the reference sample on the measurement stage and click **OK**. The dark measurement will automatically be made after this reference measurement.

#### [Continue to Step 5](#)

### Example A - Making the Measurements and Map

#### Step 5: Make the Measurement at a Single Spot ( only necessary on the first of a set of wafers )

Place your sample on the stage. After choosing an appropriate spot on the wafer using the [Go To...](#) button, return to the [Measure Tab](#) and make the thickness measurement by clicking on the **Measure** button. FILMapper will then acquire the reflectance spectrum and calculate the corresponding thickness. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.) In most cases they will not overlap, but will be separated in amplitude.

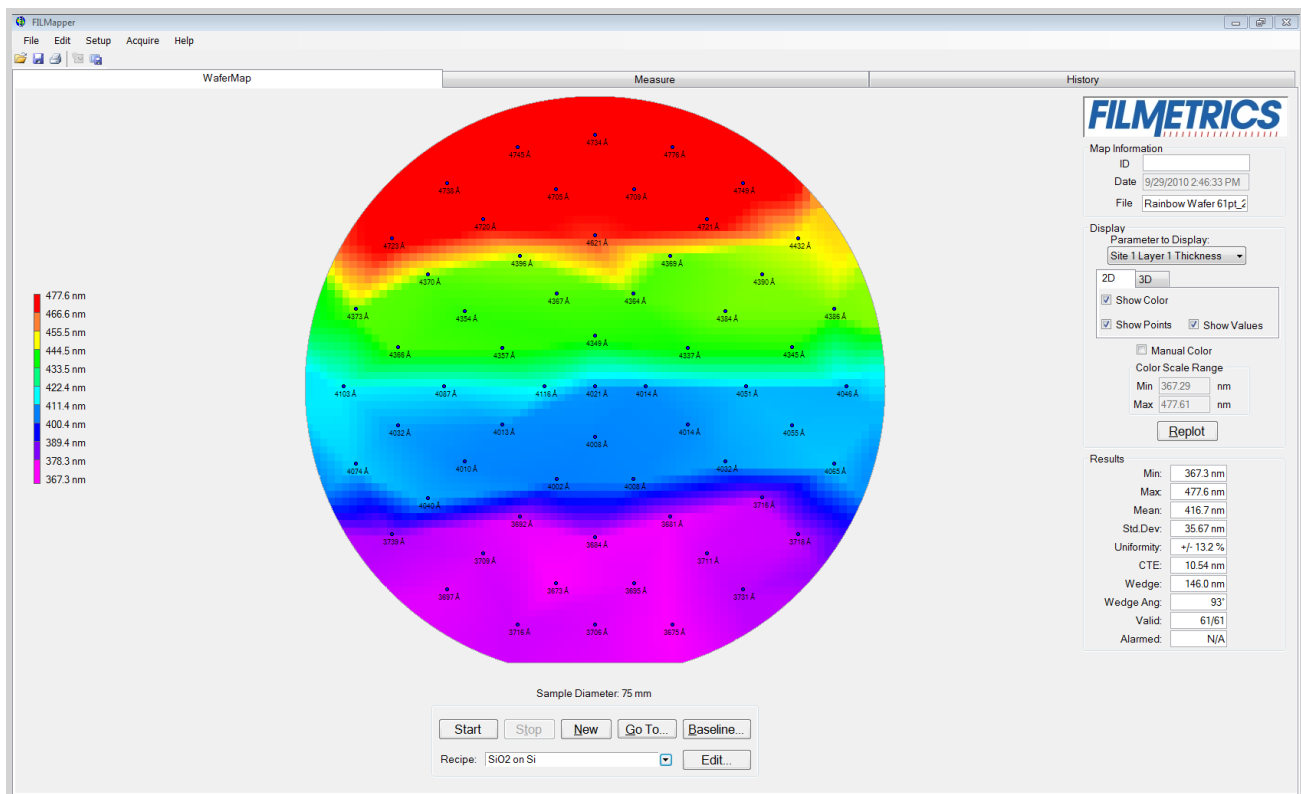


Measured and calculated reflectance spectra when measuring the thickness of SiO<sub>2</sub> on silicon.

If the calculated (red) and measured (blue) minima and maxima do not coincide, then the measurement was not successful. There are several possible causes of an unsuccessful measurement. The most common for this type of measurement are described in the [Troubleshooting](#) section.

### Step 6: Map the Wafer

Having received an encouraging answer for the thickness at the specified spot, run the wafer mapping routine by clicking on the **Map** button. The program will revert to the [Wafer Map Tab](#) and will begin to display the thicknesses on the wafer as the measurements are being made. After the mapping is complete, a thickness color map will be generated and statistical analysis for the current set of measurements will be presented.



Color wafer map of SiO<sub>2</sub> on silicon.

To switch the color map display between multicolor and a single-color shading, go to the **Setup>Wafer Map Coloring...** menu item.

## 3.3 Example B - Mapping Thickness and Optical Constants

### Measuring the Thickness of Si<sub>3</sub>N<sub>4</sub> on Silicon

For this example we will demonstrate mapping thickness and optical constants ( $n$  and  $k$ ) of Si<sub>3</sub>N<sub>4</sub> on silicon.

Continue to Step 1...

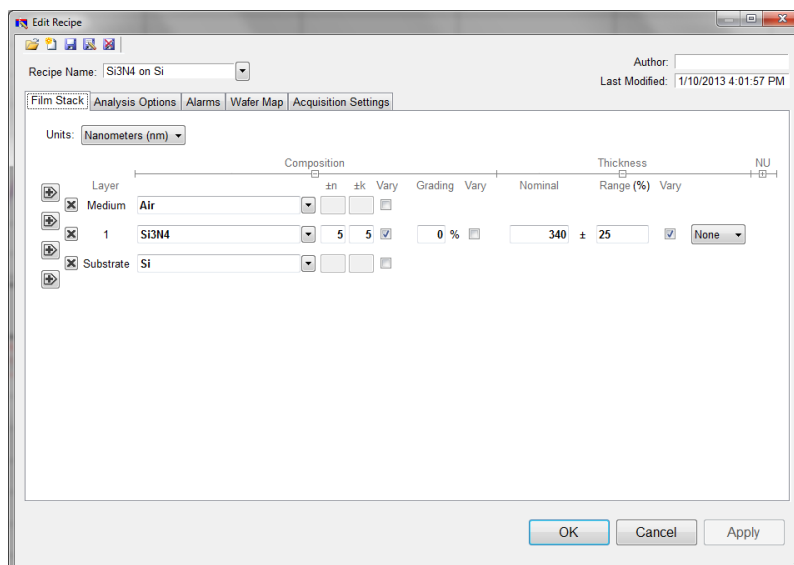
## Example B - Preparing the Film Stack

### Step 1: Select the film structure

Select the film stack to be measured, in this case “Si3N4 on Si”, from the **Recipe:** list box on the main screen. If the film stack to be measured does not exist, continue on to step 2 to define a recipe (see [Editing Film Recipes](#)). If the recipe does exist, continue to step 4.

### Step 2: Edit the film structure

To edit the stack, click the [Edit Recipe](#) button to open the dialog box. Check to see that the film sequence matches that of the actual sample. If not, different films can be selected. Also enter your best guess for the thickness of the film to be measured, and check that the Si3N4 layer thickness ( $d$ ),  $n$ , and  $k$  are being measured.



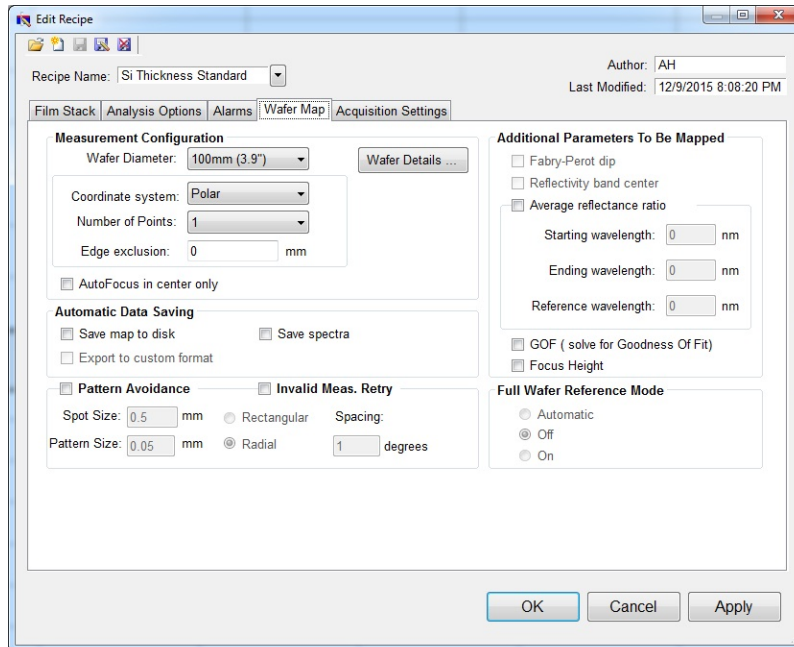
Example **Edit Recipe>Film Stack** window for measuring thickness,  $n$ , and  $k$  of Si3N4 on Si.

Continue to Step 3...

## Example B - Preparing the Map and Baseline

### Step 3: Edit the mapping routine

Edit the [Edit Recipe>Wafer Map](#) tab for the desired set of measurement spots on the wafer. Use the [Wafer Details](#) button to set the notch location on the wafer.



Example **Edit Recipe>Wafer Map Tab** for specifying mapping parameters.

#### Step 4: Take a Baseline Measurement

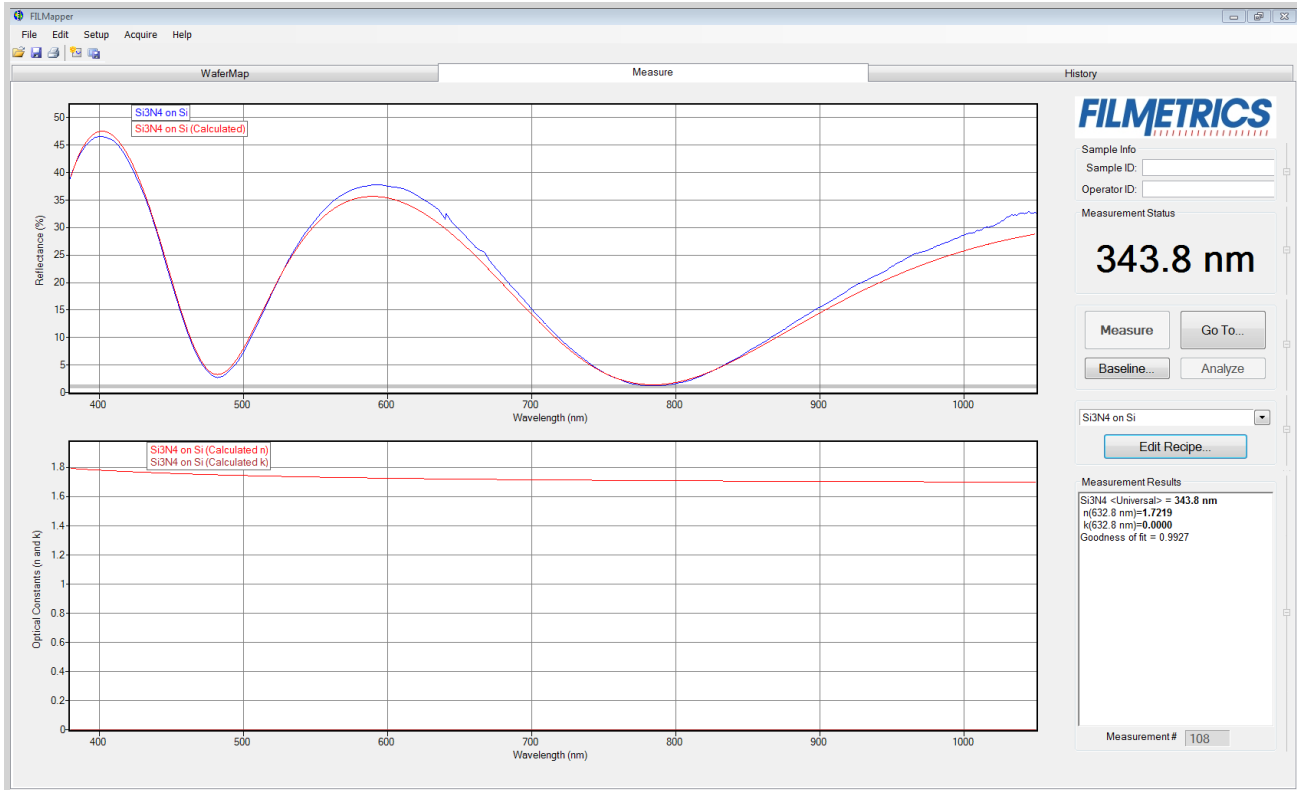
Take a baseline measurement by first clicking on the **Baseline** button. A dialog box will appear to step you through the process. In the **Acquire Reference** dialog box, make certain to select the reference material that will be used ("Si" in this case). Then put the reflectance standard on the measurement stage and click **OK**. The dark measurement will automatically be made after this reference measurement. A full wafer reference measurement will be made (i.e. each point of the pattern specified in the active recipe will be measured).

Continue to Step 5...

### Example B - Making the Measurement and Map

#### Step 5: Make the Measurement at a Single Spot ( only necessary on the first of a set of wafers )

Place your sample on the stage. After choosing an appropriate spot on the wafer using the **Go To...** button, return to the **Measure Tab** and make the thickness measurement by clicking on the **Measure** button. FILMapper will then acquire the reflectance spectrum and calculate the corresponding thickness and optical constants. If the measurement was successful, the minima and the maxima of the calculated reflectance (the red line on the graph) will coincide in wavelength with the minima and the maxima of the measured reflectance (the blue line on the graph.)

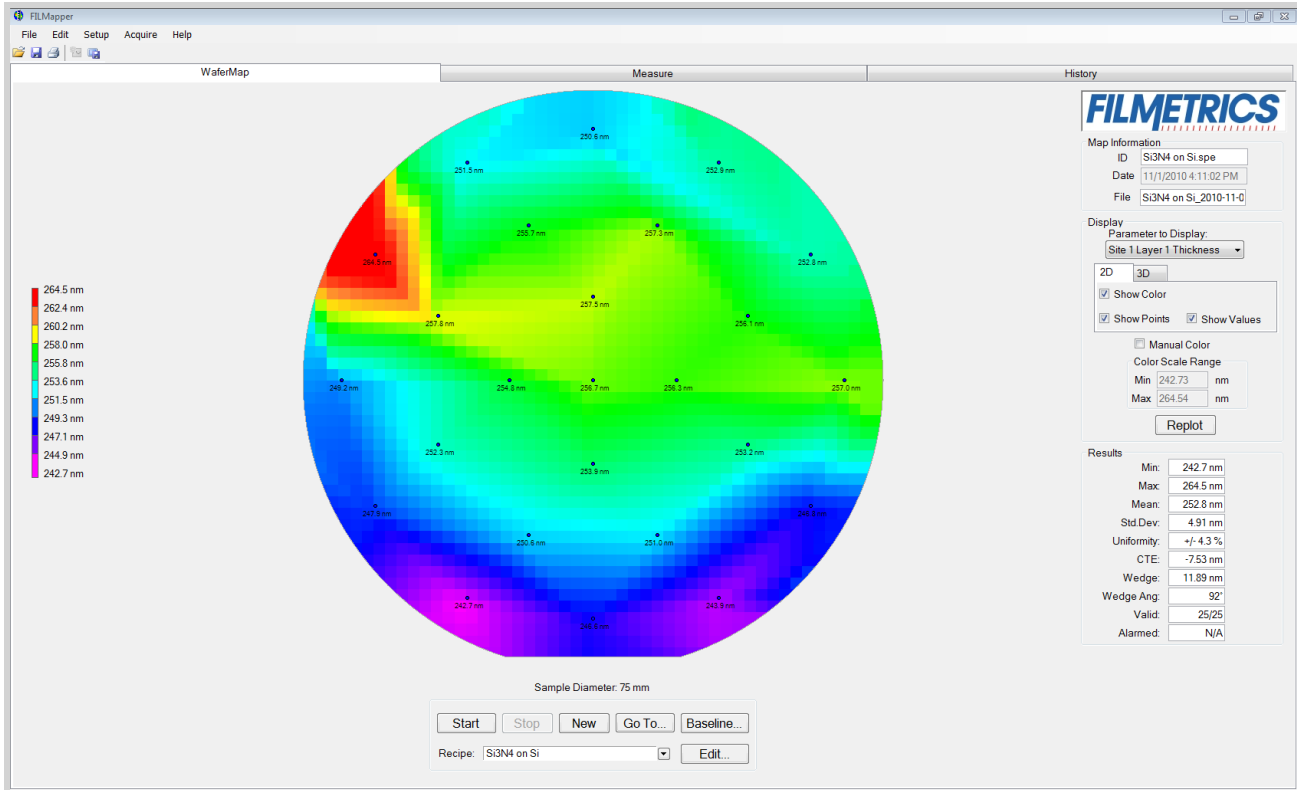


Measured and calculated reflectance spectra when measuring the thickness,  $n$ , and  $k$  of Si<sub>3</sub>N<sub>4</sub> on silicon.

If the calculated (red) and measured (blue) spectra do not fall on top of each other, the resulting thickness,  $n$ , and  $k$  values are incorrect. If the mismatch between measured data and calculation is only slight, the results reported will only be off by a small amount. If the measured and calculated spectra match, but the results are implausible, there may be a problem with the sample positioning and light collection. Causes and corrective actions to improve the measurement are listed in [Case #5](#) and [Case #6](#) in the [Troubleshooting](#) section.

### Step 6: Map the Wafer

Having received an encouraging answer at the specified spot, run the wafer mapping routine by clicking on the **Map** button. The program will revert to the [Wafer Map Tab](#) and will begin to display the thicknesses on the wafer as the measurements are being made. After the mapping is complete, a thickness color map will be generated and statistical analysis for the current set of measurements will be presented. To view other parameters on the color map, select the parameters (i.e. refractive index) from the **Display:** drop-down box.



Map of the refractive index of Si<sub>3</sub>N<sub>4</sub> on silicon.

### 3.4 Measurement Assumptions

The following assumptions must be valid if accurate measurements are to be made.

1. Every film present in the structure is specified in the **Edit Recipe** dialog box. This includes every film present in the sample including so-called adhesion films, oxide films (unless they are less than 20 Å thick), and films on the bottom surface of the substrate if the substrate is transparent.
2. If the film is , it has been accounted for in the recipe.
3. The light source has been allowed to warm up for at least 5 minutes if measuring thickness of films greater than 250nm, or 15 minutes if measuring thickness of films less than 250nm, refractive index, or reflectance.

In addition, the following assumptions are made if optical constants and/or very thin films (<500 Å) are to be measured:

4. If any grading is present (i.e. the refractive index and extinction coefficient are constant as a function of depth and constant over the entire spot being measured), it has been accounted for in the recipe.
5. The sample is flat. (The vacuum chuck may help in this case when samples are warped.)

6. No changes to the measurement system (such as fibers being moved) or light source have occurred since the acquisition of the most recent baseline.

7. No significant changes in room temperature (> 5 degrees F) have occurred since acquisition of the most recent baseline.

If any of the above assumptions are not true, it may still be possible to make a measurement, but accuracy may be degraded.

## 3.5 Hints for Improved Accuracy

This section contains various tips to help improve accuracy in your measurements.

### [Roughness.](#)

#### [Restricting the wavelength range of the analyzed reflection spectra.](#)

#### [Measuring thickness when the approximate thickness is not well known.](#)

### 3.5.1 Roughness

Slight amounts of surface or interface roughness that may be present can decrease the **GOF** value of a measurement. Entering a value or solving for roughness can partially account for this roughness so that a better **GOF** may be achieved. Generally, roughness is only present when the sample surface looks hazy at the measurement spot. The fact that haze can be seen means that there is scattered light. (A perfectly smooth surface will scatter no light, and thus the measured spot will not be visible.) Usually roughness less than 2.5 nm will not be visible, while roughness greater than about 25 nm will be extremely hazy.

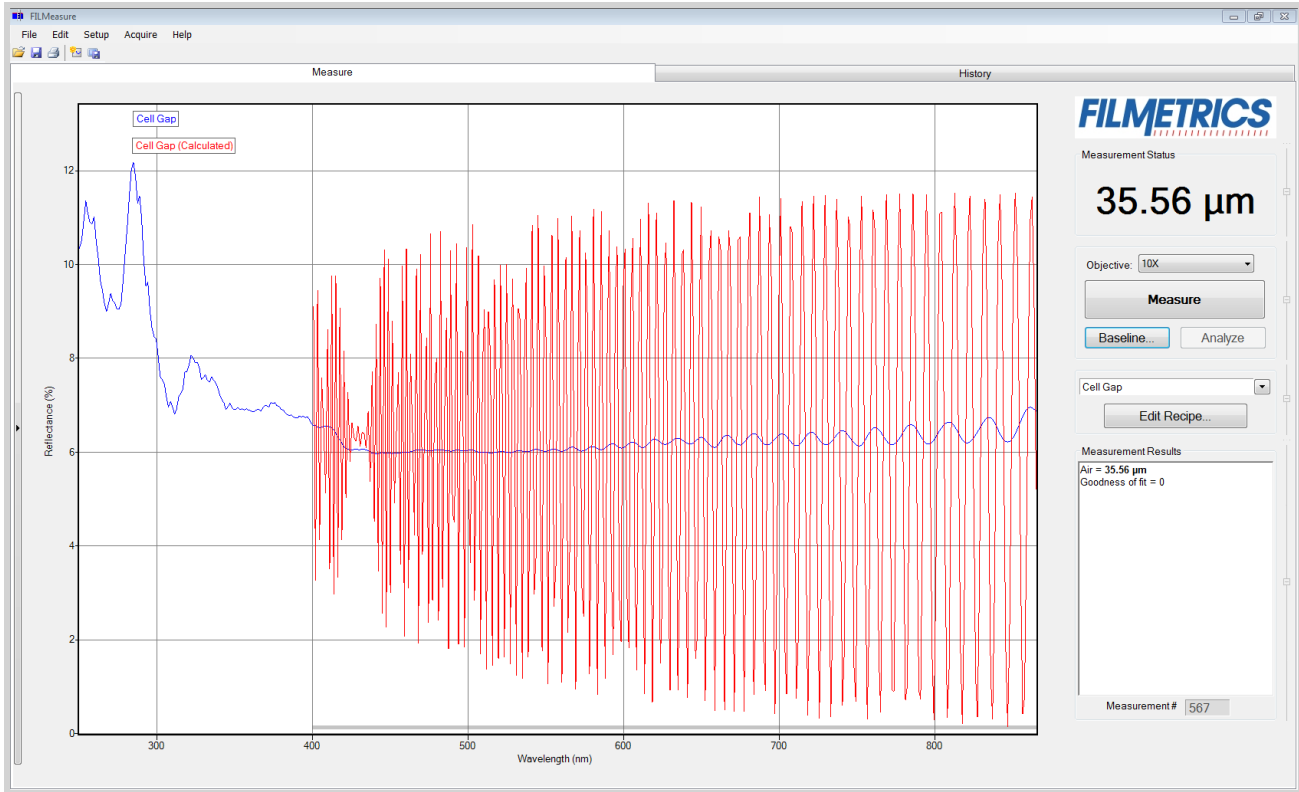
FILMapper assumes a Gaussian distribution of the surface height irregularities about the mean and it assumes that the roughness is small compared to the wavelength. FILMapper reports the rms roughness value.

### 3.5.2 Restricting the wavelength range of the analyzed reflectance spectrum

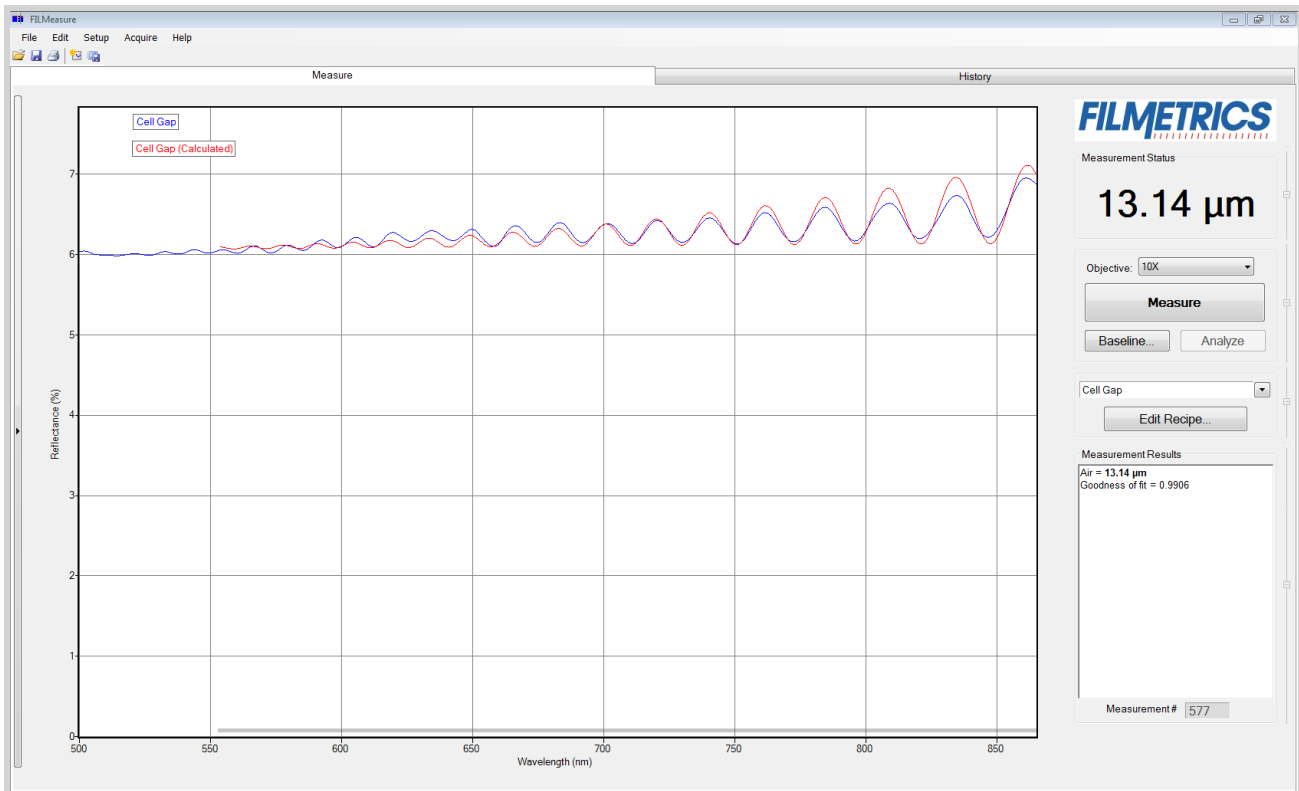
Occasionally spectra from measured films are adversely affected by factors such as absorbing dyes, birefringence, or nonuniformity – all of which are difficult to model properly. It is often still possible to make accurate thickness measurements of these films by analyzing only unaffected portions of the spectra. The portion of the spectrum that is used to calculate film properties is determined in the recipe underneath the [Analysis Options](#) tab.

You can also adjust the wavelength analysis range in the main FILMapper window using the gray bar at the bottom of the graph. Click and drag either end of the bar to a new position on the x-axis to adjust the analysis range.





Example of a non-ideal film (spectrum with no oscillations at lower wavelengths) that requires reduced wavelength range for accurate measurement.



Example of a reduced wavelength range for measuring thickness of non-ideal films.

### 3.5.3 Measuring thickness when the approximate thickness is not well known

Unless otherwise specified, FILMapper will determine a film's thickness by finding the best answer within about 1000 Å of the initial (user supplied) value. If the approximate thickness of the film is not known to better than about 1000 Å, then the [Grid](#) method or the [Fourier Transform](#) method of determining approximate thickness may be applied. See [Editing Film Structures](#) for more details.

## 3.6 Troubleshooting

For error messages or hardware problems encountered with your Filmetrics instrument, please use the chart below to best diagnose your problem. For help with modeling, see [Troubleshooting - Thickness Modeling](#).

### Question 1: Are you able to start FILMapper without an error message?

No: Continue to [Question 2](#).

Yes: Continue to [Question 1-1](#).

#### Question 1-1: What sort of problem are you seeing?

1: The lamp doesn't turn on or the fan isn't working properly. See the [Non-Operating Box, Lamp, or Fan Troubleshooting Guide](#).

2: I get an error message when I click on something. Continue to [Question 1-1-2](#).

3: Measurement results are wrong or unstable, after they had been good. See the [Measurement Results are Incorrect or Unstable Troubleshooting Guide](#).

4: Measurement and/or baseline takes longer than it used to. See the [Slow Operation Troubleshooting Guide](#).

#### Question 1-1-2: If you're still seeing an error after you've power cycled and installed new software, then select the description which most closely describes your error.

1: The error occurs during the baseline. See the [Error Message During Baseline Troubleshooting Guide](#).

2: Some other error. See the [Error Messages -Miscellaneous Troubleshooting Guide](#).

### Question 2: Are you able to launch FILMapper but it shows an error?

Yes: Continue to [Question 2-1](#).

No: Then you need to install the software that come with your new system, or you can request new software. See the [Software Reinstallation Guide](#).

#### Question 2-1: Does the error message start with "No Filmetrics instruments detected...."?

Yes: See the [Non-Operating Box, Lamp, or Fan Guide](#).

### 3.6.1 Power Cycling

Over the years we've found that about a third of support issues can be resolved by simply power cycling the Filmetrics system and computer. Follow the simple steps below to power cycle your instrument. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

**Step 1:** Shut down FILMapper (it's OK in the rare case that you can't).

**Step 2:** Unplug all electrical connectors from the back of your Filmetrics box.

**Step 3:** Restart your computer, giving it time to load all drivers.

**Step 4:** Reconnect the electrical connections to your Filmetrics box. (Make sure that the power cord is getting power, and that any switch near the power connector is turned on.)

**Step 5:** Restart FILMapper

### 3.6.2 Software Reinstallation Guide

Follow the steps below to reinstall FILMapper. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section. *Warning: Upgrading software versions may result in slightly different (<1%) measurement results due to continual improvement of our solving algorithms and material files.*

**Step 1:** Shut down FILMapper (it's OK in the rare case that you can't).

**Step 2:** Unplug all electrical connectors from the back of your Filmetrics system.

**Step 3:** Are you installing this software on a computer which already has FILMapper installed?

**Yes:** Go to Step 4.

**Yes:** Jump to [Step 6](#).

**Step 4:** Make a backup copy of your recipe and material files:

**FILMapper versions 5 and up:**

**On Windows XP:** Backup the directory `C:\Documents and Settings\All Users\Application Data\Filmetrics`

*Note: The application Data folder may be hidden by default.*

**On Windows 7/8/Vista:** Backup the directory `C:\Program Data\Filmetrics\`

*Note: The Program Data folder may be hidden by default.*

**Step 5:** Uninstall the current version of software:

**On windows XP:** Click Start > Control Panel > Add or Remove Programs > FILMapper > Uninstall

**On Windows 7/Vista:** Click the Start orb > Control Panel > Programs and Features > FILMapper > Uninstall

**On Windows 8:** Control Panel > More settings > Programs and Features > FILMapper > Uninstall

**Step 6:** Run the software installer and follow installer instructions.

*Note: you will need administrative privileges to install the software.*

**Step 7:** Reconnect your Filmetrics system.

*Note for Windows XP: The "New Hardware Found" wizard may appear if your instrument has a USB connection. You **must** click "Next and complete the driver installation process. This dialog box may appear multiple times depending on the system configuration.*

*Note for Windows 7/8/Vista: An Information balloon may appear over the taskbar while drivers are being installed. Please wait until the balloon indicates the drivers have been installed before starting FILMapper.*

**Step 8:** Run the software to verify the installation was successful.

### 3.6.3 Non-Operating Box, Lamp, Or Fan

Follow the steps below to troubleshoot symptoms of a non-operating spectrometer, light source, or fan. These are usually caused by having too much or not enough light. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

**Step 1:** Does the green LED on the right side of the front panel illuminate?

**Yes:** Jump to [Step 3](#).

**No:** Go to Step 2.

**Step 2:** Is the power cord fully inserted into the back of the unit and a powered wall outlet? If your unit has a rear power switch, is it on?

**Yes:** Go to Step 3

**No:** Plug into a powered outlet or switch on the unit

**Step 3:** Does the LED light on the light source switch illuminate when switched on?

**Yes:** go to Step 4

**No:** Possible faulty switch or faulty indicator lamp, contact [Filmetrics](#).

**Step 4:** Is the cooling fan spinning? Determine this by listening to the cooling fan which is located directly below the light source. (You'll need to get close to hear the fans on systems built after 2010.) For F50 systems the chassis cooling fan is louder than the light source cooling fan. You'll need to get close to the light source to hear the light source cooling fan.

**Yes:** Go to Step 5.

**No:** The cooling fan needs replacement, contact [Filmetrics](#). *Note: a bad cooling fan can draw enough power to prevent the light source and box from operating properly.*

**Step 5:** Does the light source illuminate?

**Yes:** Go to Step 6

**Step 6:** The following steps are to troubleshoot a box that is not being detected by the FILMetrics software. This could be a software driver or (rarely) a hardware problem. To see what hardware your computer is detecting, look in the windows device manager. (instructions on how to access the Device Manager are included at the end of this document.)

In the Device Manager, which device do you see?

**"Filmetrics Measurement Instrument" or similar:** In this case the system should be operation correctly. If not, please contact [Filmetrics](#).

**"Unknown Device" or similar:** The hardware appears to be operating properly, but the drivers for the hardware are not installed. If you have already power cycled and installed the most current Filmetrics software, please contact [Filmetrics](#) for further assistance.

**Neither of the above:** The hardware is not working properly. Go to Step 7

**Step 7:** Try a new USB cable and plug it into a different USB port. Does this fix the problem?

**Yes:** Either the USB cable or port was bad.

**No:** The USB controller inside the FILMetrics box may be bad. Please contact [Filmetrics](#).

#### Accessing Device Manager in Windows 7:

1. Click on the Start Orb.
2. In the Star Search box type: device manager. Press enter.
3. Select Device manager from the list.
4. You should see a Filmetrics Measurement Instrument tab. Expand the tab and the appropriate driver should be listed for the Filmetrics instrument.

#### Accessing Device Manager in Windows XP:

1. Click Start.
2. Click on Control Panel
3. In the Control Panel double-click the Systems icon.
4. In the Systems Properties window click on the Hardware tab.
5. In the Hardware tab click the Device Manager button.
6. You should see a Filmetrics Measurement Instrument tab. Expand the tab and the appropriate driver should be listed for the Filmetrics instrument.

### 3.6.4 Error Message during Baseline

Follow the steps below to troubleshoot error messages encountered while taking a baseline. These are usually caused by having too much or not enough light. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

**Step 1:** Which error message are you seeing while taking a baseline?

**Received light signal is too bright:** If you are manually setting the integration time (see ) then you need to reduce the integration time. Otherwise you can reduce the light source intensity by using a flattening or neutral density filter. Optical filters can be purchased on our website, [www.filmetrics.com](http://www.filmetrics.com).

**Baseline Failure. Reference and background spectra are almost the same:** This error is often caused by using the reference sample during the background step or vice versa, and is easily corrected by taking retaking the baseline while providing the proper material for the proper step. If this is not the case, go to Step 2.

**Spectrometer peak intensity is x% of previous reference intensity:** This error is often caused by using the incorrect reference sample and is easily corrected. Jump to [Step 5](#).

**Step 2:** Does the light source illuminate?

**Yes:** Go to Step 3.

**No:** Check the [Non-Operating Box, Lamp, Or Fan Troubleshooting Guide](#).

**Step 3:** Check to see if there is a broken or misconnected fiber. With the light source on, confirm that the illumination fiber is screwed into the light source securely, and that plenty of light is exiting the fiber at the far end near where the sample is placed. The light can be seen by placing paper (e.g., business card) near the sample location (do not look directly into the fiber if you are using a UV source). If plenty of light is seen, next check the return fiber by removing it from the spectrometer input and connecting it to the light source (removing the other fiber first). You should see light at the far end as before, but it may be 3-4 times smaller and dimmer. Did you see light at the sample end using both fibers in the light source?

**Yes:** The fiber appears to be good. Replace the fibers securely in their original positions (there will be a white band on the light source fiber if the two ends are different) and go to Step 4.

**No:** The fiber optic may be broken. Replacements can be purchased on our website, [www.filmetrics.com](http://www.filmetrics.com)

**Step 4:** Does your system have multiple spectrometers (i.e. EXR or UVX)

**Yes:** Check the **Acquisition Settings** tab under **Edit Recipe** to make sure that your fiber optic configuration matches the enabled spectrometers. Do this by making sure that each enabled spectrometer has a fiber attached to it (or disable a spectrometer that is not being used).

**No:** If you are still experience problems, please contact us using the [Contact Information](#) section.

**Step 5:** Was the correct reference selected from the drop-down list?

**Yes:** Go to Step 6.

**No:** Re-baseline using the correct reference.

**Step 6:** Has the light source lamp recently been changed?

**Yes:** This error is an expected response, no further action required

**No:** Go to Step 7.

**Step 7:** Has the optical configuration been altered (i.e. switching from standard spot size to small spot optics or a contact probe)?

**Yes:** This error is an expected response, no further action required

**No:** If you are still experiencing problems, please contact us using the [Contact Information](#) section.

### 3.6.5 Measurement Results are Incorrect or Unstable.

Follow the steps below to troubleshoot when measurement results are incorrect or unstable after the results had been good for some time. Additional help troubleshooting general measurement issues may be found in the [Troubleshooting: Thickness Modeling](#) section. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

**Step 1:** First confirm that you have selected the correct recipe for the sample that you are measuring (i.e., the same recipe that previously was giving good measurements). *Note that this troubleshooting guide does not cover instances where recipe parameters have been changed.*

**Step 2:** Confirm that the light source is turned on Place a piece of paper at the sample measurement location and confirm that you can see a light beam. Can the light beam be seen?

**Yes:** Jump to [Step 4](#)

**No:** Go to Step 3

**Step 3:** Is there light coming out of the light source? (If you are checking a UV light source, put on the goggles that were supplied with the light source before checking.)

**Yes:** It appears the fiber may be broken. Replacements can be purchased on our website [www.filmetrics.com](http://www.filmetrics.com)

**Step 4:** Perform a new baseline, paying particular attention to make sure that you are using the proper reference and that it is clean with the correct side up.

**Step 5:** Put a sample that is known to be good on the stage and perform a measurement. If the measurement is still not correct, go to Step 6.

**Step 6:** Your lamp may be weak and needs to be replaced. .

If you are still experiencing problems with an unstable or incorrect measurement after the preceding steps, please contact us using the methods described in the [Contact Information](#) section.

### 3.6.6 Slow Operation Troubleshooting Guide

Follow the simple steps below to troubleshoot slow system operation. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

**Step 1:** When did you experience the slow operation?

**During a baseline:** Go to Step 2.

**When I click Measure:** Jump to [Step 7](#).

**Step 2:** Slow baselines are generally caused by a low light level, which can have several causes. Does the light source illuminate (be sure it is switched on, and that the shutter is open on UV systems)

**Yes:** Go to Step 3.

**No:** Check the [Non-Operating Box, Light, or Fan Troubleshooting Guide](#).

**Step 3:** Check to see if there is a broken or misconnected fiber. With the light source on, confirm that the illumination fiber is screwed into the light source securely, and that plenty of light is exiting the fiber at the far end near where the sample is placed. The light can be seen by placing paper (e.g., business card) near the sample location (do not look directly into the fiber if you are using a UV source). If plenty of light is seen, next check the return fiber by removing it from the spectrometer input and connecting it to the light source (removing the other fiber first). You should see light at the far end as before, but it may be 3-4 times smaller and dimmer. Did you see light at the sample end using both fibers in the light source?

**Yes:** The fiber appears to be good. Replace the fibers securely into their original positions on the spectrometer box and light source (there will be a white band on the light source fiber if the two ends are different) and go to Step 4.

**No:** The fiber optic may be broken. Replacements can be purchased on our website, [www.filmetrics.com](http://www.filmetrics.com)

**Step 4:** Does your system have multiple spectrometers (i.e. EXR or UVX)

**Yes:** Check the Acquisition Settings tab under Edit Recipe to make sure that your fiber optic configuration matches the enabled spectrometers. Do this by making sure that each enabled spectrometer has a fiber attached to it (or disable a spectrometer that is not being used).

**No:** Go to Step 5.

**Step 5:** It may be that your lamp is old and needs to be replaced. .

**Step 7:** Unless the slow operation during measurement is a new problem, please confirm that your computer meets the minimum system requirements as listed in the [system specifications](#). If it doesn't, please upgrade your computer. Otherwise, go to Step 8.

**Step 8:** A measurement that takes a long time generally means that there is a large amount of processing required to find a solution, which is usually caused by a non-optimal recipe setting. Please first confirm that you have selected the correct recipe for the film stack you are measuring. Otherwise, go to Step 9.

**Step 9:** Open the recipe and make sure that you are not solving for too many parameters. Solving for one or two thicknesses or a thickness and index should only take a second or two, but in some circumstances the solving time can be increased 5-10x for each additional parameter. Solving for nonuniformity (or adding it to increase accuracy of other parameters) can be especially time consuming.

**Step 10:** If you are solving for more than one thick layer (i.e., >10 um), you can speed up the solving process by reducing the thickness constraint range (which can be safely reduced even more by using an accurate nominal thickness guess)

If you are still experiencing problems with a slow measurement after the preceding steps, please contact us using the methods described in the [Contact Information](#) section.

### 3.6.7 Error Messages - Miscellaneous Troubleshooting Guide

This guide provides extended information on error messages a user may encounter on rare occasion while using our software. Further assistance may be received by contacting us using the methods described in the [Contact Information](#) section.

#### **Error during spectrum analysis/ unable to analyze spectrum.**

This error is generally caused by a problem with the recipe constraints. Try adjusting the solver wavelength range, thickness constraint range, or starting thickness value. Also make certain that the starting thickness values have been entered using the correct units of measure specified for the recipe.



**Spectrum saturated.**

This error indicates that the sample measured is more reflective than the spectrometer was expecting. Reflectance data may not be accurate as a result. Take a new baseline to fix this problem.

### 3.6.8 Troubleshooting: Measurement Results

In all cases it has been assumed that the user has read the [Measurement Assumptions](#) section, and that each criterion has been met.

[Case #1: No oscillations, or portions of oscillations, are present in the measured reflectance spectrum.](#)

[Case #2: The measured reflectance spectrum has periodic oscillations across the entire screen, but its minima and maxima do not match up with the calculated reflectance.](#)

[Case #3: Two or more different, but nearly the same, thickness readings are obtainable from the same measurement location.](#)

[Case #4: Poor matches between the measured and calculated reflectance spectra when measuring thickness and optical constants.](#)

[Case #5: Several different answers, or one unreasonable answer, are found when measuring thickness and optical constants, even though a good match is found between the measured and calculated reflectance spectra.](#)

#### **Case 1: No oscillations, or portions of oscillations, are present in the measured reflectance spectrum.**

There can be several possible causes in this case;

1. The film may just be very thin ( $<200 \text{ \AA}$ ), thus presenting no discernible oscillations or only one identifiable minima or maxima. The solver will not be able to accurately analyze films without at least one discernible full oscillation, in general meaning a film less than 0.2 microns thick.
2. If the film is very rough, non-uniform in thickness over the measurement area, or has a graded interface it may not support coherent optical interference and thus it may not be able to be measured. Try moving to a different measurement spot for a better signal.

#### **Case 2: The measured reflectance spectrum has periodic oscillations across the entire screen, but its minima and maxima do not match up with the calculated reflectance.**

The most common cause is that the initial thickness guess was considerably different than the actual film thickness, and due to the constraints on possible thicknesses, FILMapper was unable to find the correct answer.

To better understand this, it helps to know that the number of oscillations on the screen is proportional to the film thickness. For example, if the measured spectrum has roughly twice the number of the oscillations that the calculated spectrum has, then the measured film is roughly twice the thickness of the calculated thickness. Using this information, the initial thickness guess and the thickness constraints can be set more appropriately in the [Edit Recipe](#) dialog box.

### **Case 3: Two or more different, but nearly the same, thickness readings are obtainable from the same measurement location.**

When this occurs usually the measured and calculated spectra match somewhat, but not very well across the entire spectra (i.e., the measured and calculated spectra match exactly only over a small wavelength range and then gradually walk off one another outside this wavelength range). When thickness is the only value being measured, this is normally caused by the refractive index of the measured layer not matching that used by FILMapper, especially when the film is greater than one micron thick. Unless more accurate index values can be obtained, the best way to solve this problem is to restrict the wavelength range used in the analysis.

### **Case 4: Poor matches between the measured and calculated reflectance spectra when measuring thickness and optical constants.**

There can be many causes of this problem, including those listed in [Case #1](#) and [Case #2](#) above. Most commonly when a poor fit between the spectra occurs, it is because:

- 1) The components of the film structure are not all included in the [Edit Recipe > Film Stack](#) dialog box. Adjust the recipe accordingly and reanalyze the spectrum.
- 2) Very inaccurate initial guesses for the film thickness(es) have been listed. Try a new nominal starting guess, or expand the thickness constraint range.
- 3) The optical constants listed in the **Edit Recipe > Film Stack** dialog box are far from the actual optical constants in the material. Try selecting a different but similar material file if one is present, for example switching from Acrylic to Acrylic - 2.
- 4) The film being measured has properties that are not taken into account by FILMapper. Examples of these properties are graded interfaces and non-uniform films. You can enable solving for these conditions in the recipe.

*Note: Enabling Nonuniformity solving will increase solving time.*

**Case 5: Several different answers, or one unreasonable answer, are found when measuring thickness and optical constants, even though a good match is found between the measured and calculated reflectance spectra.**

This normally occurs when a large number of properties are being measured on a very thin film. In general, the thinner a film is the less unique information that can be obtained from it. To understand this, see [Theory of Operation](#). To solve the problem, you can either:

- A. Decrease the number of variables solved for.
- B. Increase the amount of data provided to the solver (analyzing reflectance and transmittance at the same time, or using the multi-spectral solver).
- C. Enable multiple **Solver Cycles** under the [Edit Recipe > Analysis Options > Advanced](#) dialog.

## 4. Understanding and Evaluating Measurement Results

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This section covers information on the [Display of Measured Spectra](#) and a more in depth look at the [Goodness Of Fit](#) value.

### 4.1 Display of Measured Data

Once film stack and measurement information have been entered and a baseline has been taken, measurements may be made by clicking on the **Measure** button. After measurement, the measured and calculated reflectance spectra are displayed on the graph, and the thicknesses of the films are listed in the results box. If any of the thickness values were measured, they are displayed in bold numbers.

The quality and accuracy of the result is determined by how well the measured spectrum matches with the calculated spectrum. In general, thickness information is determined by the number of oscillations, and index information is determined by the amplitude of the oscillations. In the case of the [Robust \(adaptive; thickness only\)](#) solver and [Exact Spectrum Matching](#) solver, a good result is one where the minima and maxima of the measured and calculated spectrum align. For the solver, this is when the measured intensity peaks overlap. See the [Goodness of Fit](#) and [Troubleshooting - Thickness Modeling](#) sections for more information.

### 4.2 Goodness of Fit

The accuracy of a calculation fit, and thus the reliability of the measurement, can be judged by the match between the measured and calculated spectra, which is quantified by the GOF value. GOF is a number between 0 and 1.

A perfect match between measured and theoretical spectra will result in a GOF of 1. To ensure accurate results the user may set a minimum acceptable GOF value by entering a number between 0 and 1 into **GOF Error** on the [Alarms Tab](#) in the [Edit Recipe](#) dialog box. A warning message will be displayed after each measurement where the GOF falls below the user-specified **GOF Error**. If the GOF is less than 1 there are several possible causes:

- b) **Incorrect Structure Definition** – If the refractive index of one or more layers in the structure is different from what is described in the recipe, then there will be some mismatch between the blue curve and the red curve.
- c) **Graded Interfaces** – The amplitude of the peaks in the spectrum depends on both the size of the change in refractive index at each interface in the layer structure and the sharpness of the interface. For example, in many hardcoat samples there is some degree of layer intermixing at the interface, leading to a weaker than expected reflectance at that interface. In severe cases the peaks may disappear entirely.

## 5. Advanced Features

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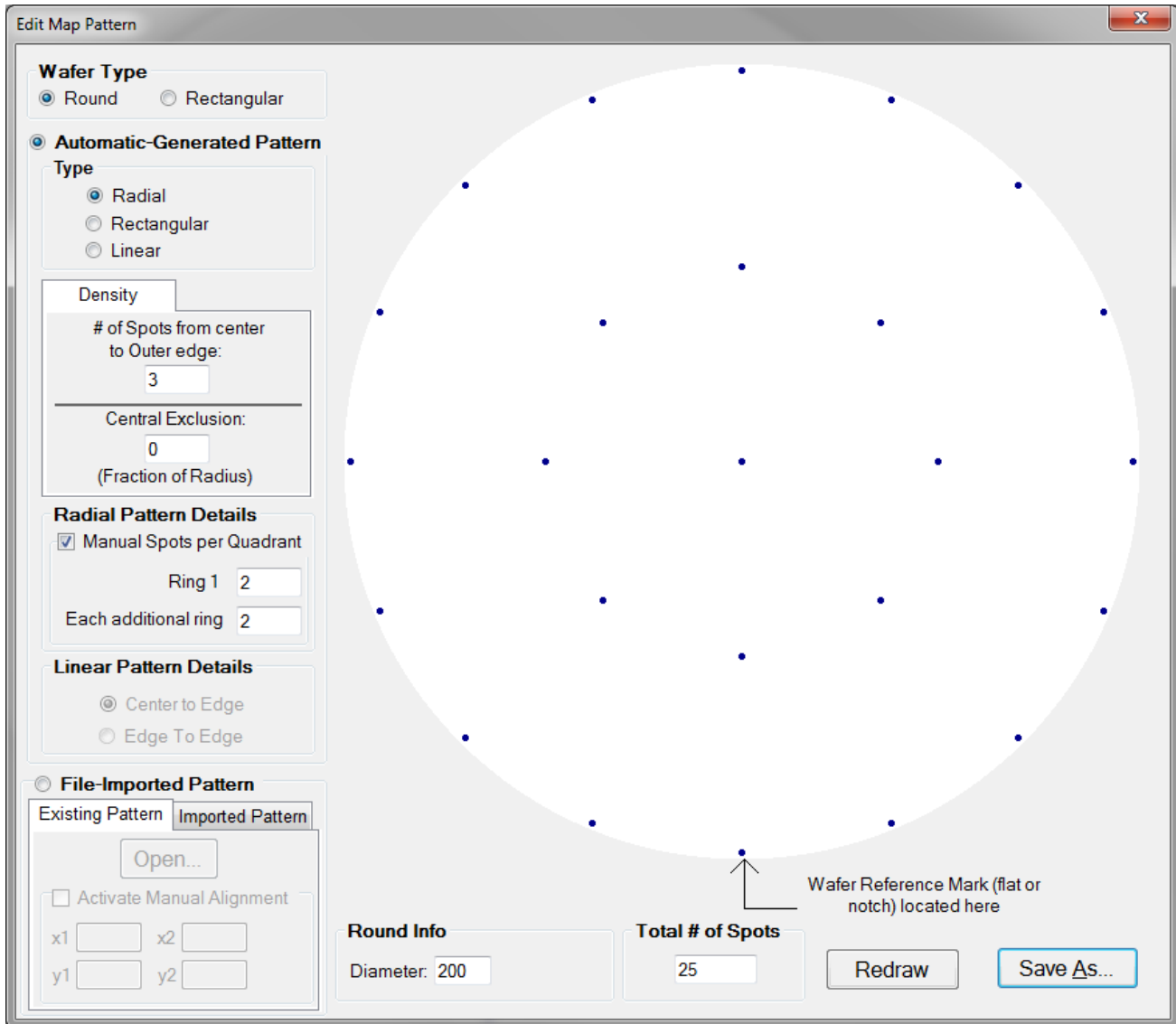
This section describes several advanced features available within FILMapper. This includes the creation of new map files, editing those files within Windows Excel, and how to create and edit  $n$  and  $k$  files.

[Editing Map Files Using Excel](#)

[Creating and Editing  \$n\$  and  \$k\$  Files](#)

### 5.1 Creating New Map Patterns

The **Edit Map Pattern** tool is best used for simpler maps on blanket wafers. For more complex maps, see the Recipe Tab. To create a new wafer map pattern, go to the and select [Edit > Map Pattern...](#) Once selected, a new window appears which allows parameters to be adjusted to create a custom wafer map.



1. Select the shape of the wafer to be either **Round** or **Square**.
2. Select how the measurement points are distributed on the sample. The alignment can be **Radial (Polar)**, **Rectangular**, or **Linear**.
3. Control the measurement point density. The **# of Spots from Center to Outer Edge** specifies how many points are placed in a line between center and edge. The **Central Exclusion** specifies how much of the center (if any) should be excluded from measurement.
4. Select how many spots are in each quarter section of the ring (when the **Radial** pattern type is selected). When **Manual Spots per Quadrant** is not selected, **Ring 1** is automatically set to 1, and **Each additional ring** is automatically set to 2.
5. Select whether the measurement points should span the **Center to Edge**, or the **Edge to Edge** (only available when the Linear pattern type is selected).

6. Use **Redraw** to refresh the wafer map based on the current settings to make sure the map is correct.

7. **Save** the wafer map to a file, for subsequent use in a **Recipe**.

The user can also open an **Existing Pattern** for editing, or **Import** one that has been [created using Excel](#).

## 5.2 Editing Map Files Using Excel

Map files can be edited further using Microsoft Excel in order to create more complex patterns. The \*.pat file created by FILMapper can be imported into Excel for editing and saved as a comma-delimited file. The newly edited file can then be opened using FILMapper to create more intricate map patterns. The example below shows how to create an “X” pattern starting with the default pattern.

### Example: Creating an “X” map pattern starting with the default map pattern

#### Step 1: Create a new map file

In the map window, go to [Edit > Map Pattern...](#) Using a **Round** wafer type and a **Radial** pattern type, select 3 for # **Spots from center to Outer Edge**. Select **Manual Spots per Quadrant** and use 2 for **Ring 1** and **Each additional ring**.

Save this default map pattern as **Custom**.

#### Step 2: Import the map pattern into Excel

Using Excel, open the file **Custom.pat**. This file can be found in **C:\Program Files\FILMapper\Patterns\Custom\**. (Note: If the file does not appear, in the **Open** dialog box, choose **All Files (\*.\*)** under File Type.)

You will be prompted to import this file; when prompted select **Delimited** and click **Next**. When prompted, only select **Comma** for the **Delimiters**.

#### Step 3: Edit map pattern in Excel

Starting in the fourth row, the values are stored as x-y coordinate values, as a fraction of the radius of the wafer. When generating new maps, values can be entered as either a fraction of the radius of the wafer or a discrete number as long as all values are to the same scale. To create the “X” pattern, delete the highlighted rows shown in Figure 4.1, so that there are no empty rows between values. Also delete the first two rows by selecting rows 1 and 2 and selecting **Delete** from the **Edit** menu.



	A	B	C	D	E
1	Version	1			
2	GUID	9edf4a33d97a4c2183ce5f2dfd471ca8			
3	25				
4	0	0			
5	0.5	0			
6	0.353553	0.353553			
7	3.06E-17	0.5			
8	-0.35355	0.353553			
9	-0.5	6.12E-17			
10	-0.35355	-0.35355			
11	-9.18E-17	-0.5			
12	0.353553	-0.35355			
13	1	0			
14	0.92388	0.382683			
15	0.707107	0.707107			
16	0.382683	0.92388			
17	6.12E-17	1			
18	-0.38268	0.92388			
19	-0.70711	0.707107			
20	-0.92388	0.382683			
21	-1	1.22E-16			
22	-0.92388	-0.38268			
23	-0.70711	-0.70711			
24	-0.38268	-0.92388			
25	-1.84E-16	-1			
26	0.382683	-0.92388			
27	0.707107	-0.70711			
28	0.92388	-0.38268			

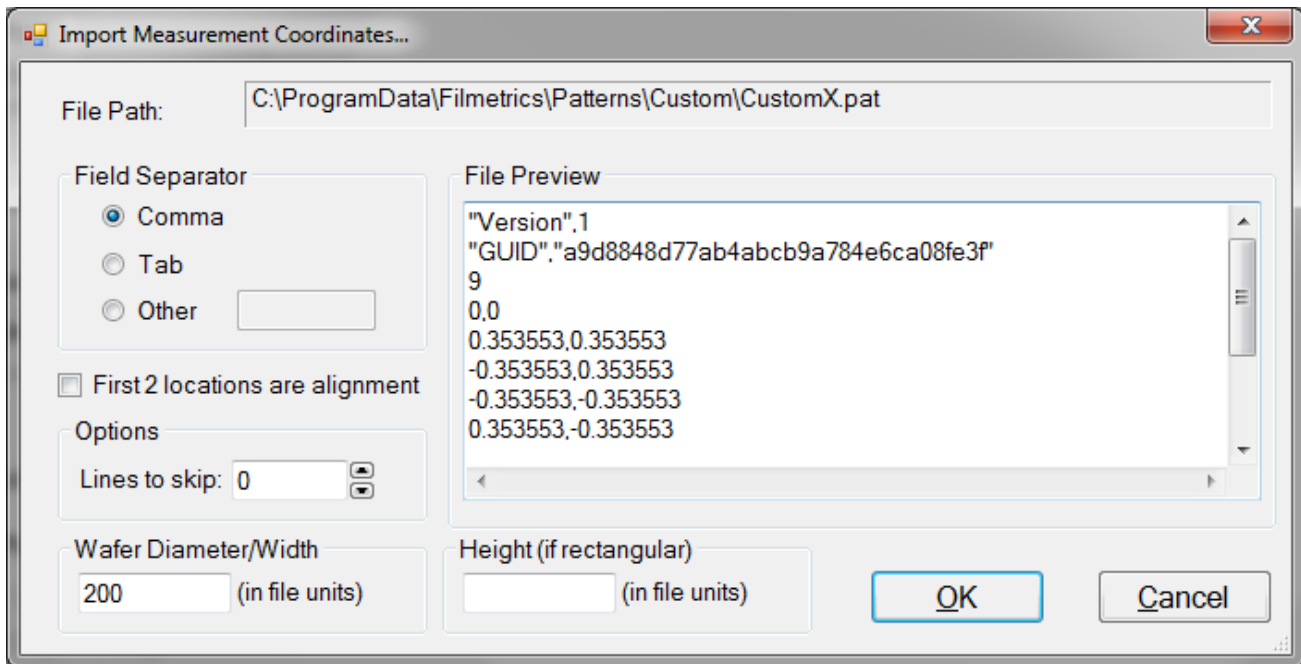
Delete the highlighted cells to leave the desired coordinates.

#### Step 4: Save map pattern

After the modifications have been made, select **File>Save**. Check to make sure that the **File Name** box is "**CustomEdit.pat**" (note that quotation marks must be used to enclose the filename in Excel to force the extension to **.pat**) and that the **File Type** is **CSV (Comma delimited) (\*.csv)**. Then click **Save**.

#### Step 5: Import the Map Pattern

In FILMapper, click on the **Edit** menu and select **Map Pattern....** Enable the radio button for **File-Imported Pattern**, and then switch to the **Imported Pattern** tab and click **Open....** The following dialog will open.



Increase the **Options > Line to skip** value until the first value visible in the list is the first coordinate in the series. The **Wafer Diameter/Width** and **Height** must also be set here according to the values you used for the coordinate scale you used. If you used fractional values, set the Wafer Diameter/Width, and Height for rectangular samples, to 2 (-1 to 1). If you used whole values, simply enter the dimensions of your sample. Click **OK** when finished.

#### Step 6: Save the Pattern File

The new pattern file should now be displayed in the **Edit Map Pattern** Window. Confirm it matches the expected pattern, and then save the new pattern using the **Save As** button.

Note: If the wafer map does not show up as described, open the file **C:\Program Files\FILMapper\Patterns\custom\Custom.pat** using a text editor, such as Microsoft Notepad. Check to see that the first row does not contain a comma. If it does, delete the comma and save the file.

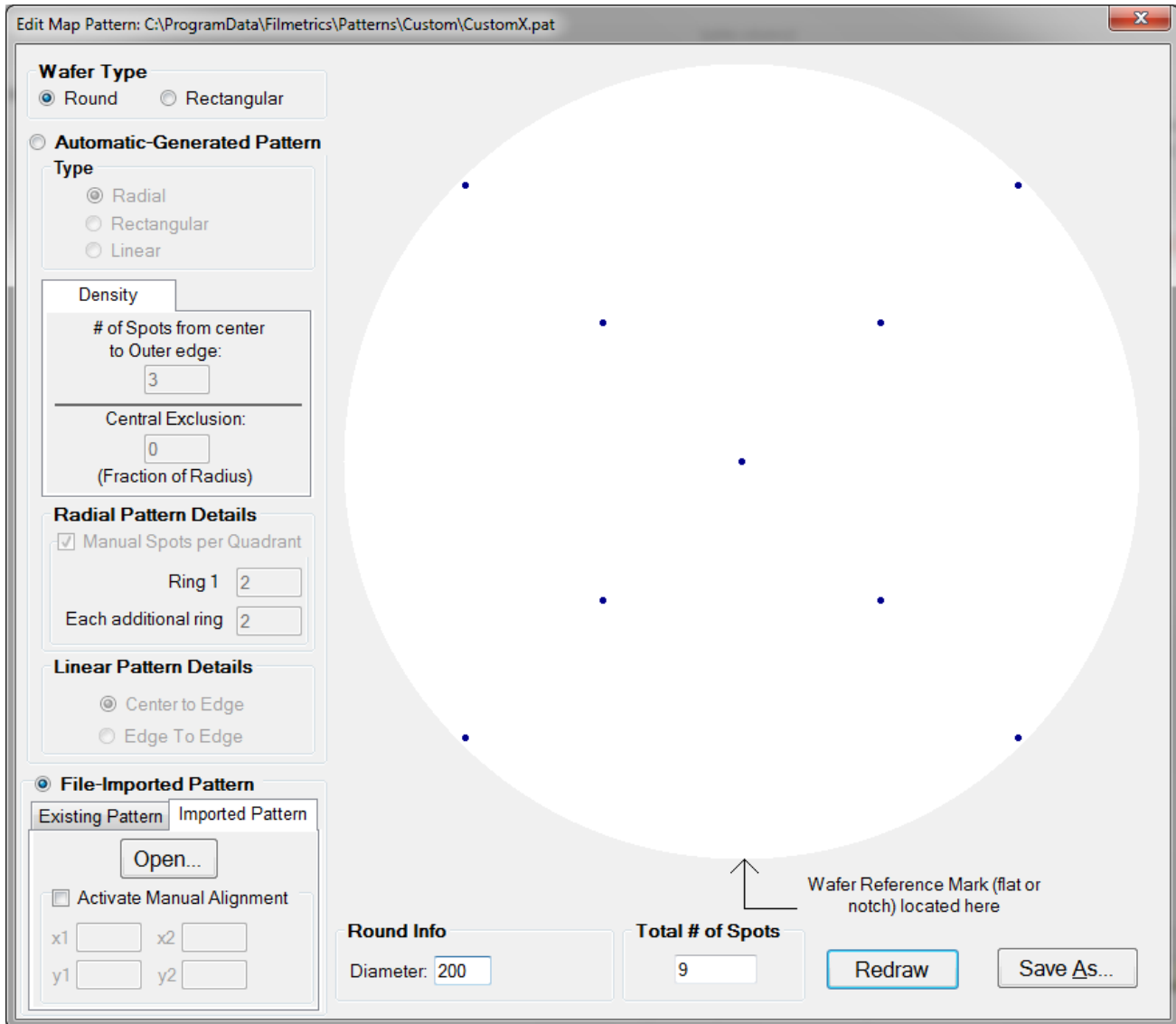


Figure: "X" pattern created using Excel.

### Step 7: Load map pattern in FILMapper

In FILMapper, click the **Edit...** button next to the **Recipe** pull-down menu if you are in the Wafer Map Tab, or **Edit Recipe** if you are in the Measure Tab. Click the **Wafer Map** tab and select **Custom** for the **Coordinate System**. Under **Custom Name**, all the names of custom map files will be listed. Here, select **Custom Edit**, and then click **OK**. In the Wafer Map Tab, you should now see the "X" pattern you created. FILMapper is capable of automatically resizing the map pattern after it has originally been created, so there is no need to create multiple versions of the same file. Simply adjust the wafer size underneath the **Wafer Map** tab.

## 5.3 Creating and Editing $n$ and $k$ Files

### Creating new $n$ and $k$ files

New  $n$  and  $k$  files can be created by going to [Edit > Material Library...](#) Clicking the **New** button will allow the user to define a new material file. Once clicked, while the **Default Model** is selected, the user can manually enter wavelength versus  $n$  or wavelength versus  $k$  values. It is also possible to copy and paste values into the columns if the data is available.

The user can also select **Custom Model**. While this is selected, clicking on the **Model...** button allows the user to create  $n$  and  $k$  files using predefined mathematical models.

Once completed, clicking **Save As...** will save the new file as a custom material for later use.

### Editing $n$ and $k$ files

Existing material files can be edited by going to [Edit > Material Library...](#) There, the user can load a material file by clicking **Open**. Values can then be changed manually. Clicking **Save** will save over the original file for later use. Use **Save As** to save the edited file under a new name.

### Converting Microsoft Excel files into FILMapper $n$ and $k$ files

For wavelength versus  $n$  or wavelength versus  $k$  data saved in Excel (\*.xls) format, the data can be directly saved as material files that can be read by FILMapper.

### For .nnn and .kkk files.

For both  $n$  and  $k$  files, the data should follow the format shown below, where the wavelength values, in units of nanometers, are in the first column, and the  $n$  or  $k$  values are in the second. Note that the version number (cell B1) refers to version of the file. For this cell, you can use 1. The material number (cell B2) refers to what material category the file corresponds to. The material categories (and their corresponding numbers) are: Metal (1), Semiconductor (2), Dielectric (3), Other (4), and Photoresist (6). By putting the correct value for the material number, the file will automatically be sorted into the correct category when selecting the material in the window.

To save the file created by Microsoft Excel, go to **File>Save As...** For **Save as Type:** choose **CSV (Comma delimited) (\*.csv)**. For  $n$  files, save the file as "**FILENAME.nnn**", and for  $k$  files, save the file as "**FILENAME.kkk**" (FILENAME represents the name you wish to call the file; note that quotation marks must be used to enclose the filename in Excel to force the extension to **.nnn** or **.kkk**). The file can then be saved to the desktop, and [Imported](#) using the **File > Import > Material File** option

	A	B
1	Version	1
2	Material	3
3	206.6	1.543
4	226.7	1.5228
5	248.3	1.5084
6	265.2	1.5
7	280.3	1.494
8	302.2	1.4872
9	330.3	1.4805
10	361.1	1.4751

### For .fitnk files.

The data should follow the format of shown below, where the wavelength values, in units of nanometers, are in the first column, index of refraction ( $n$ ) in the second, and extinction coefficient ( $k$ ) if present, in the third.

The first few columns of the file should be identical to the figure below the only exception being cell B3 which should contain a number describing the material category. The material categories (and their corresponding numbers) are: Metal (1), Semiconductor (2), Dielectric (3), Other (4), and Photoresist (6).

To save the file created by Microsoft Excel, go to **File > Save As...** For **Save as Type:** choose **CSV (Comma delimited) (\*.csv)**. Save the file as "FILENAME.fitnk" (FILENAME represents the name you wish to call the file; note that quotation marks must be used to enclose the filename in Excel to force the extension to .fitnk). The file can then be saved to the desktop, and [Imported](#) using the **File > Import > Material File** option

	A	B	C
1	Version	1	
2	Compat. Version	1	
3	Material	3	
4	File Information		
5	Wavelength (nm)	n	k
6	206.6	1.543	0
7	226.7	1.5228	0
8	248.3	1.5084	0
9	265.2	1.5	0
10	280.3	1.494	0
11	302.2	1.4872	0
12	330.3	1.4805	0
13	361.1	1.4751	0

## 6. Theory of Operation

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This section describes how the instruments work and includes the theory the measurements are based on, specifics about the hardware, and more detail about the baseline measurement.

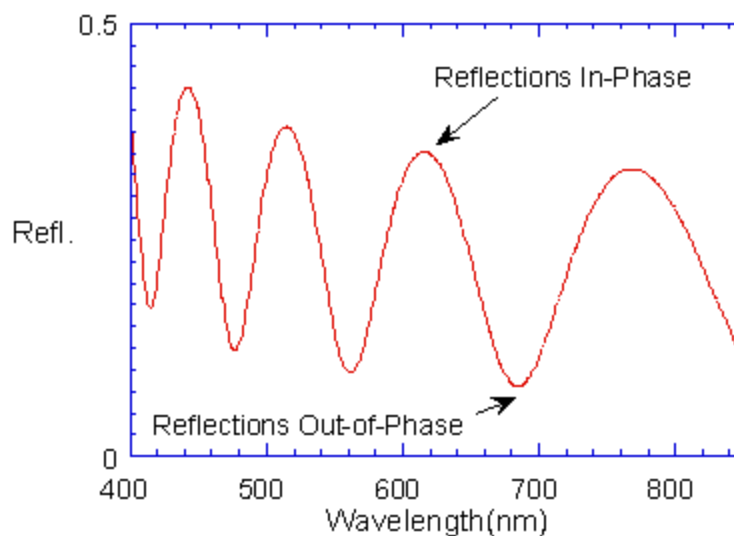
### [Measurement Theory](#)

#### [Thickness Measurement Details](#)

#### [The Baseline Measurement](#)

### 6.1 Measurement Theory

Our instruments measure thin-film characteristics by either reflecting light from, or transmitting light through the sample, and then analyzing this light over a range of wavelengths. Because of its wave-like properties, light reflected from the top and bottom interfaces of a thin film can be in-phase so that reflections add, or out-of-phase so that reflections subtract. Whether the reflections are in- or out-of-phase (or somewhere in between) depends on the wavelength of the light, as well as the thickness and properties of the film (e.g., reflections are in-phase when  $\lambda = (2*n*d)/i$ , where  $\lambda$  is the wavelength,  $n$  is the refractive index,  $d$  is the film thickness, and  $i$  is an integer). The result is characteristic intensity oscillations in the reflectance spectrum (see Figure below). In general, the thicker the film, the more oscillations there are in a given wavelength range.



Example of reflectance spectrum with oscillations.

The amplitude of the oscillations is determined by the refractive index and extinction coefficient of the films and substrate. Therefore, by analyzing the period and amplitude of these oscillations, our instruments can determine thickness of multiple thin films.

## 6.2 Thickness Measurement Details

Optical thin-film thickness measurements require the successful completion of two tasks: acquisition and then analysis of an accurate reflectance spectrum. To determine film thickness, FILMapper calculates a reflectance spectrum that matches as closely as possible the measured spectrum. FILMapper begins with an initial guess for what the reflectance spectrum should look like theoretically, based on the user's input of a film structure for the sample. Then FILMapper varies the parameters it is solving for until the calculated reflectance spectrum matches the measured data. Mathematically, this procedure is complicated by the fact that as the thickness of the films in the calculation is varied there can be many near matches. Therefore, an approach that simply homes in on a solution by finding successively better approximations will not work unless the starting guess for optical thickness is within approximately 1000 Å if the actual thickness.

FILMapper avoids homing in on a false solution by searching the entire acceptable thickness range to determine the thickness that gives the best possible match between the measured and calculated spectra. The thickness range searched is determined by the initial guess for thickness together with the thickness constraint. Since the time to find a solution is proportional to the range of thicknesses being searched it is beneficial to provide an initial guess close to the thickness of the films to be measured.

## 6.3 The Baseline Measurement

The baseline measurement allows the FILMapper software to take into account the response inherent to the reflectance measurement hardware. It does this by measuring a reflectance standard and by taking a "dark" reading. In any optical system there are many components whose characteristics vary with wavelength (e.g., the output of the light source and the sensitivity of the spectrometer). However, when reflectance measurements are made, only variations in reflectance vs. wavelength due to the sample under test are of interest. Therefore, FILMapper must perform a calibration to determine the spectral response of the system. This is done by making a measurement of a reflectance standard that has known reflectance characteristics. Note that it is not necessary for the reflectance standard to be the same as the substrate upon which films to be measured reside. The only purpose served by the reflectance standard is to permit calibration of the optical system. For example, it is possible to use a Si wafer as the reflectance standard and then measure films on GaAs, InP, glass, plastic, etc.

After the reference measurement is made a dark reading is taken. A non-zero dark level is due to current leakage inherent to photodiodes, which causes each photodiode in the array to slowly charge up even when no light enters the spectrometer. Thus, in order to make an accurate measurement of the light entering the spectrometer, it is necessary to subtract this "dark" current contribution. This is the purpose of the background reading, which measures the magnitude of the dark current for a given integration time. When a "dark" measurement is made, a spectrum is measured that represents the signal generated by the spectrometer when a sample of zero reflectance is measured. To simulate a sample with zero reflectance during a "dark" measurement, a specularly reflecting sample can be held at an angle with the light source turned on, or in the case of the UV light source, the shutter may simply be closed.

## How to Contact Us

We welcome suggestions from our users on ways to improve our software and hardware. Please send us any suggestions you may have for improvements in the help file or new features you would like to see in the software.

We may be reached by phone at +1-858-573-9300, by fax at +1-858-573-9400, by the Contact Us Now form on [our website](#), or by e-mail at [support@filmetrics.com](mailto:support@filmetrics.com).



## 7. Appendices

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This section contains information on various topics as listed below:

[Performance Specifications](#)

[Application Note: Silicon Nitride](#)

[Software License Agreement](#)

### 7.1 Performance Specifications

	F60-t-UV	F60-t-UVX	F60-t	F60-t-EXR	F60-t-NIR	F60-t-XT	F60-t-XXT
Wavelength Range:	190-1100 nm	190-1700 nm	380-1050 nm	380-1700 nm	950-1700 nm	1440-1690 nm	1520-1580 nm
Thickness Measurement Range*:	5 nm-40 $\mu$ m	5 nm-250 $\mu$ m	20 nm-700 $\mu$ m	20 nm-250 $\mu$ m	100 nm-250 $\mu$ m	0.2 $\mu$ m-450 $\mu$ m	10 $\mu$ m-1 mm
Thickness Req'd to Measure $n$ and $k$ *:	50 nm and up		100 nm and up		500 nm and up	-	-
Accuracy*:	The greater of 0.4% or 1 nm		The greater of 0.4% or 2 nm		The greater of 0.4% or 3 nm	The greater of 0.4% or 5 nm	
Precision <sup>1</sup> :	0.1 nm				0.2 nm	1 nm	
Stability <sup>2</sup> :	0.07 nm				0.12 nm	1 nm	
Spot Size:	Standard 1.5mm, Optional down to 20 $\mu$ m					600 $\mu$ m	25 $\mu$ m
Light Source:	Deuterium & Tungsten-Halogen		Tungsten-Halogen				1550nm SLED

#### Wafer Handling:

2", 3", 100 mm, 150 mm, 200 mm, 300mm

#### Power Requirements:

100-240 VAC, 50-60 Hz, Vacuum

#### Dimensions(cm):

Measurement Station: 44LW x 35W x 38H.

Controller: 56L x 48W x 14H.

**Weight:**

Measurement Station: 23 kg (51 lbs)

Controller: 18 kg (39 lbs)

\* Material dependent.

<sup>1</sup>  $1\sigma$  of 100 measurements of 500 nm SiO<sub>2</sub>-on-Si. Average of  $1\sigma$  over 20 successive days.

<sup>2</sup>  $2\sigma$  of daily average of 100 measurements of 500 nm SiO<sub>2</sub>-on-Si over 20 successive days.

Specifications subject to change without notice.

## 7.2 Application Note - Si<sub>3</sub>N<sub>4</sub>

### Theoretical Underpinnings

The refractive index of a single layer film is related primarily to the depth of the minima found in the measured reflectance. The reflectance at the interference fringe minima of a film deposited onto Si is zero when the refractive index is near 1.97. The reflectance at the fringe minima for a film with a refractive index of 2.00 is the same as that for a film with a refractive index of 1.94. Therefore, it can be difficult to unambiguously determine the refractive index from a reflectance measurement. However, for most films the user knows that the refractive index is either always greater than or always less than 1.97 so there is no uncertainty. Silicon nitride is one of the few rare films whose refractive index spans this critical range. Fortunately, there is a solution for silicon nitride that allows us to determine which of the two possible refractive index values is correct. This is done by measuring both  $n$  and  $k$  for silicon nitride and by realizing that silicon nitride with a refractive index larger than 1.97 has measurable absorption (non-zero  $k$ ) at wavelengths less than 420 nm. Thus, to get good results for  $n$  the widest possible wavelength range should be used (especially going down to short wavelengths) and the user should simultaneously measure both  $n$  and  $k$ .

[Continue to Discussion of  \$n\$  and  \$k\$  Measurement.](#)

### Discussion of Si<sub>3</sub>N<sub>4</sub> $n$ and $k$ Measurement

Silicon nitride is a dielectric material commonly used in semiconductor fabrication processes. The refractive index of stoichiometric Silicon Nitride is 2.05 at 633 nm. However, in practice the refractive index of deposited films can vary from 1.7 or less (films containing excess hydrogen or oxygen) to as high as 2.5 or more (Si rich films). The measurement of  $n$  and  $k$  is complicated by the fact that this refractive index range (1.7 to 2.5) spans a critical range for films deposited on Si substrates. In order to get an unambiguous result for measurement of  $n$ , the structure description should be set by choosing “Si<sub>3</sub>N<sub>4</sub> (Si Rich)” as the material for the silicon nitride layer. To confirm that the proper model is chosen, go to the options tab and note that the model displayed is “Si<sub>3</sub>N<sub>4</sub>”. If the Si<sub>3</sub>N<sub>4</sub> model is not displayed in the [nk Model](#) list and Si<sub>3</sub>N<sub>4</sub> is not in the list of models, then newer software is required. It is important that both  $n$  and  $k$  be measured simultaneously (put a check mark for  $n$  and for  $k$  in the [Edit Recipe>Film Stack](#) dialog box). When using the Si<sub>3</sub>N<sub>4</sub> model the constraints for  $n$  and  $k$  should be set to large values (at least 5). If the film is very thin (less than 50 nm), it may be necessary to set the material to “Si<sub>3</sub>N<sub>4</sub>” or “Si<sub>3</sub>N<sub>4</sub>-thin”, instead of “Si<sub>3</sub>N<sub>4</sub> (Si Rich)”, to get reproducible results, but this should only be used as a last resort.

[Continue to Step by Step Instructions for measuring Si<sub>3</sub>N<sub>4</sub>.](#)

### Step-by-step instructions for measuring silicon nitride on Si

1. Start FILMapper and click the [Edit Recipe](#) button.
2. Set the material for the **Medium** to “Air”.

3. Set the material for **Layer 1** to “Si<sub>3</sub>N<sub>4</sub> (Si Rich)”.
4. Enter a guess for the layer thickness of the silicon nitride into the thickness box for **Layer 1**.
5. Put check marks in the d, n, and k check boxes for **Layer 1**.
6. Set the constraint for d to 75%.
7. Set the constraint for n to 5 and the constraint for k to 5.
8. Set the material for the **Substrate** to “Si”.
9. Select **Grid** from thickness solver options pull down menu under **Thickness**.
10. Go to the [Analysis Options](#) tab.
11. Make sure there is no check mark for **Compensate for: > Unmodelled Back-side reflections**.
12. Under [Advanced Analysis Options](#), set the number of **Iterations** to “600” and set **GOF greater than** to “0.999”.
13. Under [Data Selection](#) select **Fixed Range** and enter “From: 200” and “To: 1100”.
14. Click **Save As** and give the recipe a name.
15. Follow the instructions in Example B for measuring thickness and optical constants.

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