

Operations Manual
for the
F54-XY-200
Thin-Film Mapper

Revision 9.4.4.2
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Welcome

What is the F54-XY-200 used for?

The Filmetrics F54-XY-200 is used to measure the thickness of dielectrics, semiconductors, and thin metal films. Measured films must be optically smooth and between 4 nm and 115 microns thick (depending upon F54-XY-200 model). Optical constants (n and k) can also be measured on a variety of dielectric films. Commonly measured films include semiconductor process films such as oxides, nitrides, resists, and polysilicon, optical coatings such as hardness and anti-reflection coatings, flat panel display films such as polyimides, resist, and cell gaps, and the various coatings used in CD and DVD manufacture. Films that can not be measured include very rough films and opaque dielectric films.

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 product's built-in protections resulting in danger to the operator or damage to the instrument.



Installation Location: Install the instrument 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: Periodically clean the system based on the cleanliness of the environment in which the system is installed. Only the external surfaces should 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.



Disconnect the main power before performing any service on the instrument.

Cleanroom or low lint wipes should be used to wipe down the system. A mixture of Isopropyl Alcohol (IPA) and De-ionized Water (DI H₂O) at 70% DI H₂O: 30% IPA should 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.

When cleaning, 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



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.



Preghiamo 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 Macchineggio. 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 with a reliable earth ground. 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

1. Software Overview	8
1.1 Menu Controls	9
1.2 The Wafer Map Tab	28
1.3 The Recipe Tab	32
1.4 The Measure Tab	41
1.5 The History Tab	43
1.6 The Edit Recipe Window	45
1. Calibrating The Camera	47
1.7 Set Spot Location	47
1.8 Magnification for Stage	48
1.9 Focus Edge Positions	48
2. Editing Film Recipes	53
2.1 Adding, Changing, or Deleting a Structure	53
2.2 Film Stack	54
2.3 Analysis Options	59
2.4 Alarms	64
2.5 Wafer Map	65
2.6 Acquisition Settings	67
3. Making Measurements	70
3.1 Taking a Baseline	70
3.2 Focusing a Microscope Image on a Perfectly Flat Surface	71
3.3 Measurement Assumptions	72
3.4 Hints for Improved Accuracy	72
3.5 Troubleshooting: Measurement Results	74
4. Understanding and Evaluating Measurement Results	77
4.1 Display of Measured Data	77
4.2 Fast Fourier Transform Mode (FFT Mode)	77
4.3 Goodness of Fit	79
5. Advanced Features	80
5.1 Creating New Map Patterns	80
5.2 Editing Map Files Using Excel	82
5.3 Creating and Editing n and k Files	86
6. Theory of Operation	88
6.1 Measurement Theory	88
6.2 Thickness Measurement Details	89
6.3 F54-XY-200 Hardware Operation	89
6.4 The Baseline Measurement	90
Performance Specifications	91
Light Bulb Replacement	93
End User Software License	94

1. Software Overview

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 F54-XY-200 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 F54-XY-200 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 Menu Controls

This section describes the various functions available through the standard menus.

[File Menu](#)

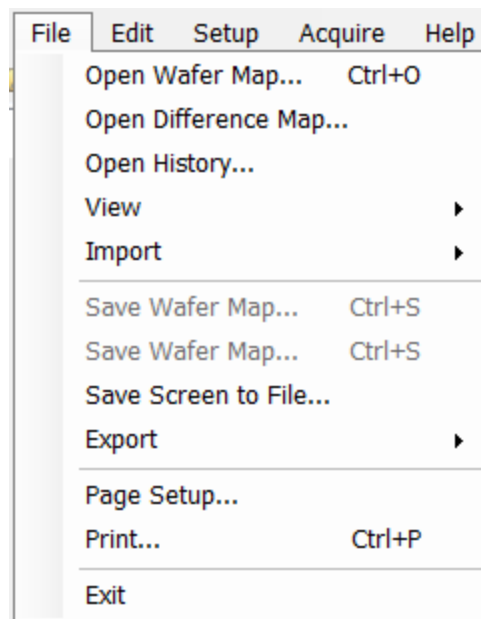
[Edit Menu](#)

[Setup Menu](#)

[Acquire Menu](#)

[Help Menu](#)

1.1.1 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...

Load previously saved [History](#) data containing measurements and statistics.

Open Wafer Map... (Wafer Map Tab only)

Open stored wafer maps, which are then displayed and can be analyzed for film thickness.

Open Difference Map... (Wafer Map Tab only)

Display thickness differences between two maps (Map2-Map1). Film structure and map pattern must be the same for both map recipes. Press the **Select Map** button to browse for the map files.

Import: Recipe...

Import recipes that were previously exported or created with an older version of FILMapper.

Import: Material...

Import materials not currently in the software either, created by the user or provided by Filmetrics.

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. Files can be saved in four different formats:

*.fmspe: This file can only be opened in FILMapper 6.0 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)

Take a screenshot of the FILMapper window.

Save Wafer Map... (Wafer Map Tab only)

Save measured wafer maps for export or later analysis. Files can be saved in two different formats:

*.fiwmc: This file can only be opened in FILMapper 7.10 or later, and is the preferred way to save maps. This file will contain all data captured in measurement process including individual spectra, results, images, and more.

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

Export: Recipe...

Recipes can be exported for use on other computers running FILMapper. The exported file automatically includes any material files required by the recipe. Duplicate an analysis on any other computer running FILMapper using the exported recipe and the spectrum being analyzed.

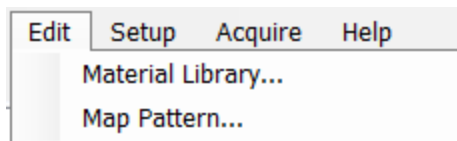
Export: Recipe for FILMapper 4...

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

Export: SystemInfo File...

For certain software upgrades the user is required to send the SystemInfo file to Filmetrics which can be exported using this command.

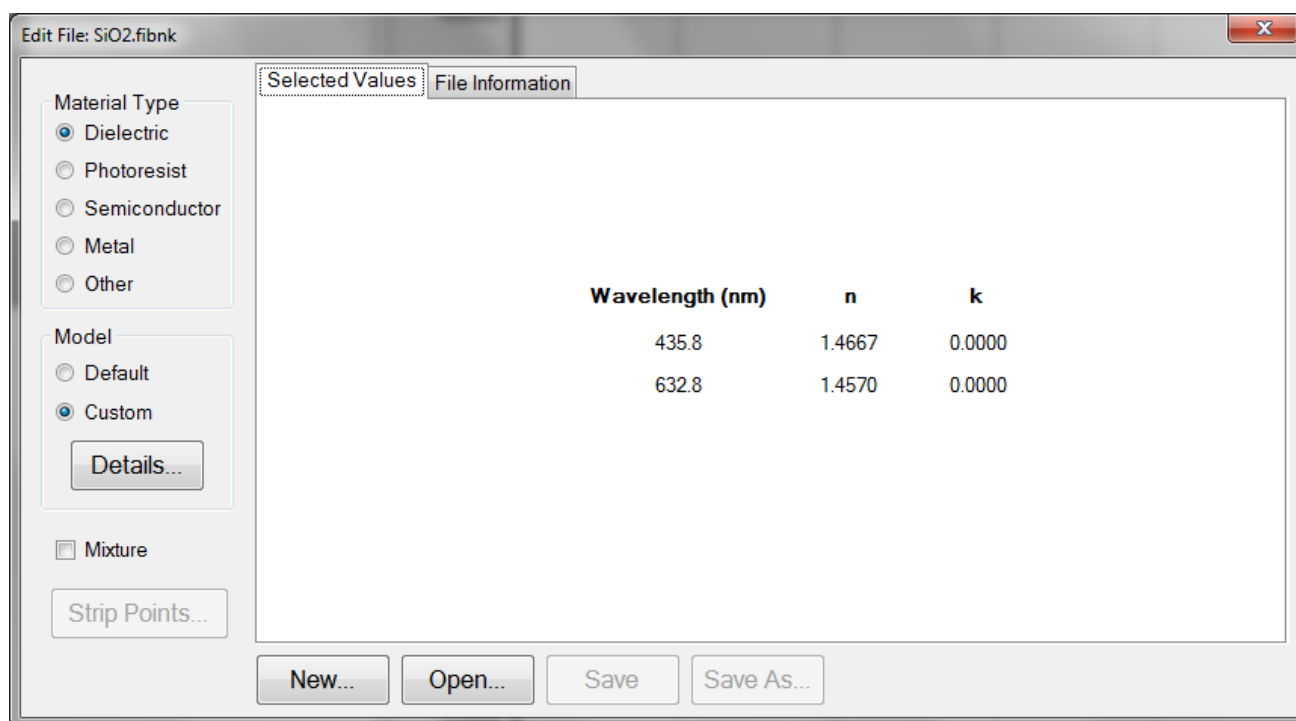
1.1.2 Edit Menu



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

Edit Map Pattern

Wafer Type
☒ Round ☐ Rectangular

Auto-Generated Pattern
Type
☒ Radial
☐ Rectangular
☐ Linear

Density
 # of Spots from center to Outer edge:
 3
 Central Exclusion:
 0
 (Fraction of Radius)

Radial Pattern Details
☒ Manual Spots per Quadrant
 Ring 1 2
 Each additional ring 2

Linear Pattern Details
☒ Center to Edge
☐ Edge To Edge

Existing Pattern
 Open...

Imported
 Open...

Rectangle Info
 Width: 200 Height: 200

Total # of Spots
 25

Wafer Reference Mark (flat or notch) located here

Redraw Save As...

The **Edit Map Pattern** dialog is used 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, 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. If **Round** is selected, 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** allows the input of both height and width data of the sample. All measurements are assumed to be in millimeters. FILMapper will 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 to set an exclusion zone in the center of the wafer where no points are placed. 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 for further modification of the number of measurement spots even further by increasing the number of spots per each concentric ring.

Rectangular patterns are used to modify spot density, and with the additional **Fixed** option allow the manual entry of 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.

Display an updated version of the map pattern 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, FILMapper software will recognize a text file of these coordinates. See [Editing Map Files Using Excel](#) for more details on creating custom maps.

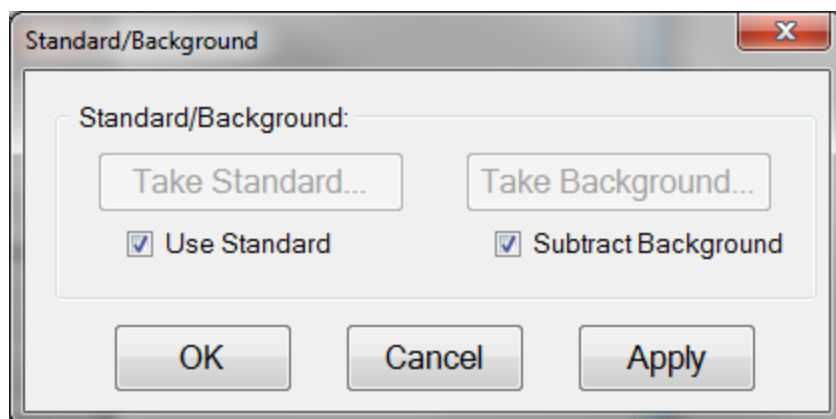
All custom patterns must be saved in FILMapper\Patterns\Custom folder. To select the new pattern in the **Edit Recipe > Wafer Map** tab, select the **Custom Coordinate System** and the name of the pattern from the drop-down box.

1.1.3 Setup Menu

This menu contains the settings for [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

Display

✕

Color Measurement Settings

Color Space

- ☒ CIE-L*a*b*
- ☐ CIE-L*u*v*
- ☐ CIE-L*C*h
- ☐ CIE-XYZ
- ☐ None
- ☐ Always show CIE-XYZ

Observer

- ☐ 2 degrees
- ☒ 10 degrees

Illuminant

D65

☒ Fix luminance of color swatch at (10-100): 70

☒ Restrict Wavelength

Lower limit: 360 nm Upper limit: 830 nm

Number of Spectra

Maximum number of spectra to display in the graph (1-10): 3

☐ Show Dual Spectrum Graphs

Spectra Transformation:

None

Graph Options

- ☒ White background ☐ Black background
- ☒ Auto position legends

Measurement Results

Significant digits: 4

Displayed Controls

- ☒ Sample info
- ☒ Measurement status
- ☒ Recipe
- ☐ Color
- ☒ Additional color
- ☒ Measurement results
- ☒ Template

OK Cancel

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.

You may also use the **Show Dual Spectrum Graphs** option to display two measurement graphs concurrently. The data will remain the same across both graphs (spectra and modeled fit), but you can set the graph options for both windows independently. This can be used to focus on a specific area of interest on a spectra while still seeing the effects on the dataset as a whole.

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

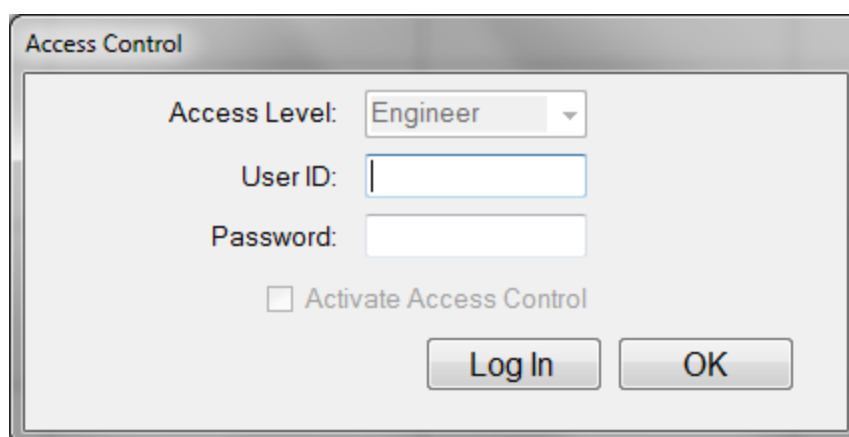
he user can select the number of significant figures, from 1 to 7, that the results are displayed in. For example, with the units set to *Angstroms* and 4 significant digits, The software would report a thickness of 7213 Å. If significant digits is switched to 3, it will instead display the thickness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

Displayed Controls

These checkboxes are used to determine which controls are shown on the right hand side of the FILMapper window. Some options may not be available based on current system configuration.

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 automatically starts 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:** A text input field.
- Password:** A text input field.
- Activate Access Control:** An unchecked checkbox.
- Log In** and **OK** buttons at the bottom right.

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. Select the **Activate Access Control** checkbox to enable 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 username and an initial password, and then click the **Add User** button. To add an engineer or a supervisor user, use the same procedure as above, then select the appropriate access level from the list box before clicking the **Add User** button.

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

Operator and Engineer level users passwords can be changed while logged in by entering the password into the password box and pressing the change button. Supervisor-level user passwords, or the password of any other user, can be changed by selecting the appropriate access level, entering the appropriate **UserID** and new password, then pressing **Add User**. If the software finds that a user already exists, the old entry for that user will be deleted and a new entry created.

We recommend creating a new supervisor level user, then deleting 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 **Apply** will show the changes in the main graph window. Clicking **Update Recipe** transfers the listed integration time and cycles to the current recipe.

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](#)

[Data Recording](#)

[Calibration](#)

General Settings

The **General Settings** tab is used to enable, disable, and modify various options in the software.

☒ **Save Screen: Include Menu Bar**

Hide or show the menu bar when using *Save Screen to File*.

☒ **Spectra on Graph: Confirm before delete**

Enable or disable whether the software displays a warning before clearing all spectra on the screen when the *Clear Graph* button is pressed.

☒ **Automatically increase max. number of Spectra on Graph**

Enable or disable automatically increasing the number of spectra displayed on the graph when opening multiple saved spectra.

☒ **Confirm before increasing**

You can also set whether to show a confirmation message before increasing the number of spectra.

☒ **Printing: Active Curve only**

Toggle whether the software prints out all currently loaded spectra, or only the active curve when using the *Print* feature.

☒ **History: Confirm before delete**

Enable or disable whether the warning dialog before you delete entries in the history file.

Edit Columns...

Open a dialog that allows you to control which columns are visible in the [History](#) tab.

☒ **Prompt for Baseline reminder**

Reminder Interval (0-540) hours

Enable or disable the baseline reminder feature, and if enabled to set the reminder interval.

Reflectance Standard Signal Thresholds

Warn if less than % of highest recorded intensity

Warn if greater than % of previous measurement

Set your *Reflectance Standard Signal Threshold* values. These determine at what percentage of the initial signal intensity the software will display a warning during the process. This feature is used to track lamp health, proper baseline procedure, and other parameters.

☐ **Uniform Spectrum Data Point Spacing**

☒ Standard Spacing ☐ Fine Spacing

Enable or disable the *Uniform Spectra Data Point Spacing* function. When enabled, saved spectra will have their values set to a multiple of 1, 2 or 5. *Standard Spacing* sets the spacing equal or greater than the smallest interval in the data, while *Fine Spacing* sets the spacing to shorter than the smallest interval.

☐ **Share Settings with all users**

For systems with multiple user accounts, enable or disable sharing settings across all users. A folder to store the settings file may be selected.

☐ **Share Settings with selected users**

For systems with multiple user accounts, enable or disable sharing settings across any users who have selected this option. A folder to store the settings file may be selected. This option is only available if *Share Settings with all users* isn't enabled.

This feature allows the user to select a different location for their *Recipes* folder, for example to a shared network drive. This can be useful for syncing recipes across multiple instruments in varying locations.

Custom Recipes Path:

Selecting **Reset** will instruct the software to look in the default location for the *Recipe* folder.

Custom Material Path:

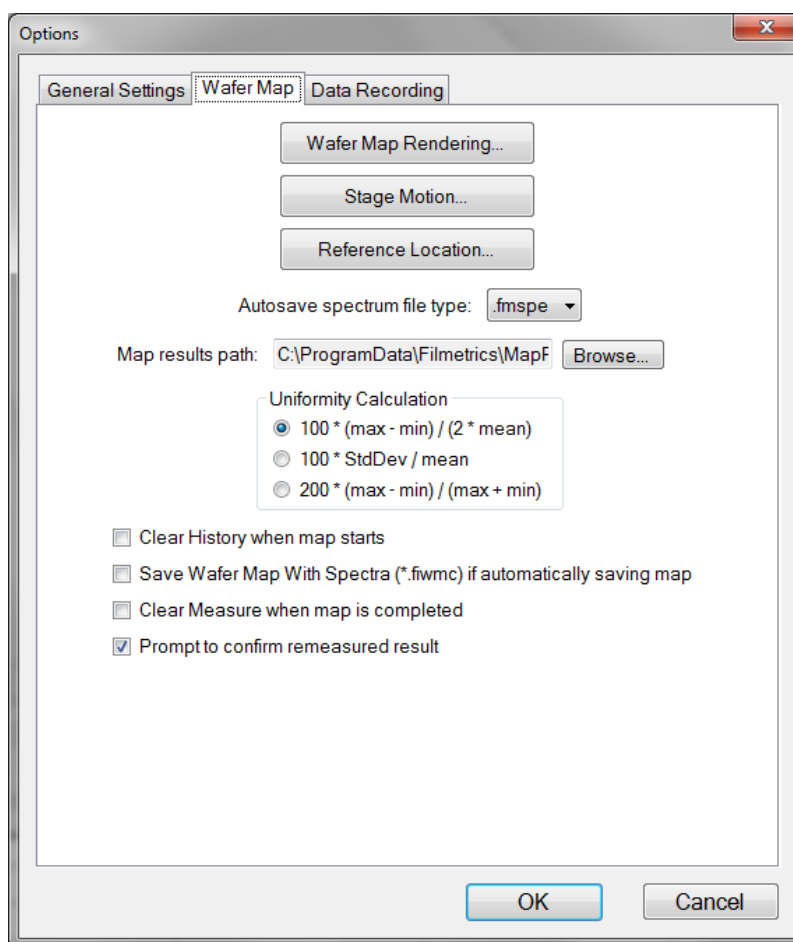
This feature is similar to the one above, only it allows you to choose a different location for your *Materials* folder.

☒ **Display disconnect OK reminder at shutdown**

Enable or disable whether the software prompts you when it is ok to disconnect the instrument at software shutdown.

Click to restore all settings to their default values.

Map



The **Map** tab allows the user to select the various options related to mapping process. **Wafer 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. You can also set the speed of the stage when the motion buttons are used.

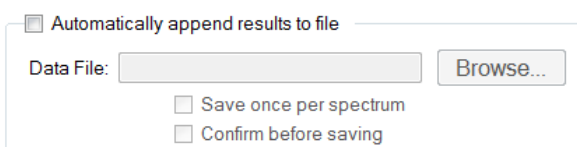
When [Automatic Data Saving](#) is enabled under the [Edit Recipe > Wafer Map](#) tab, the options here are used to determine in what format the spectra are saved, and where on the computer they are saved.

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

The final four options allow the user to automatically clear the history whenever a new map is started, and if the option is enabled in the [recipe](#) to save map files as the .fiwmc file type. The user may also tell the system to automatically clear any spectra from the [Measure](#) tab when maps are completed. Finally, the user may select whether to be prompted before reanalyzing data under the **Map** tab.

Data Recording

The **Data Recording** tab contains controls for the various methods by which FILMapper may automatically save collected data.



☐ Automatically append results to file

Data File:

☐ Save once per spectrum

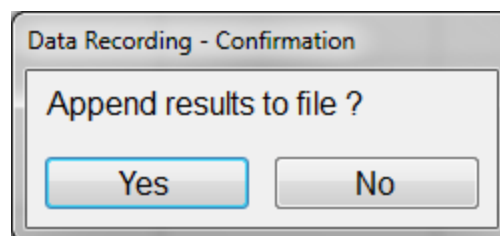
☐ Confirm before saving

Enabling *Automatically append results to file* will instruct the software to create an excel file at a specified location in which a running tally of measured results are kept.

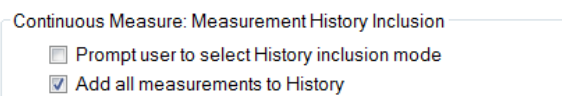
This feature is different from the [History](#) tab in that it only records results, not the spectra files as well. It does not however have an upper limit on the number of spectra that can be recorded.

Enabling *Save once per spectrum* will only append results when the **Measure** button is pressed or a saved spectra is opened in the software. Any changes in the recipe applied to existing spectra will not be recorded. When this feature is disabled, any time a spectra is analyzed the result is entered into the file.

When *Confirm before saving* is turned on, the software will provide a prompt before appending data to the excel file.



Continuous Measure: Measurement History Inclusion controls which spectra are included in the **History** tab when the [Acquire > Measure Continuously](#) feature is used.

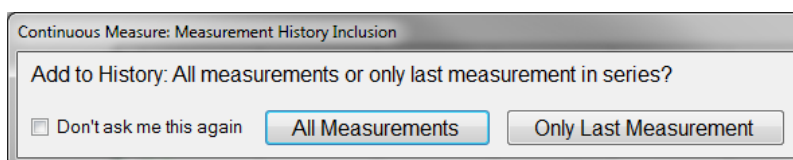


Continuous Measure: Measurement History Inclusion

☐ Prompt user to select History inclusion mode

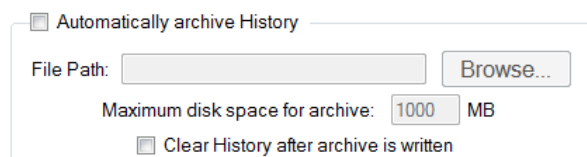
☒ Add all measurements to History

If the software is set to *Prompt user to select History inclusion mode*, a dialog will pop up prior to beginning the continuous measure asking the user whether to save all measurements while measuring continuously, or only the last measurement. The only last measurement feature can be useful on less ideal surfaces (rough, non-uniform, etc.) where the user may have to search around the sample surface for a spectrum capable of being analyzed.



Clicking **Don't ask me this again** will disable the prompt, and the user will have to navigate back to this menu to re-enable the feature.

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.



☐ Automatically archive History

File Path:

Maximum disk space for archive: MB

☐ Clear History after archive is written

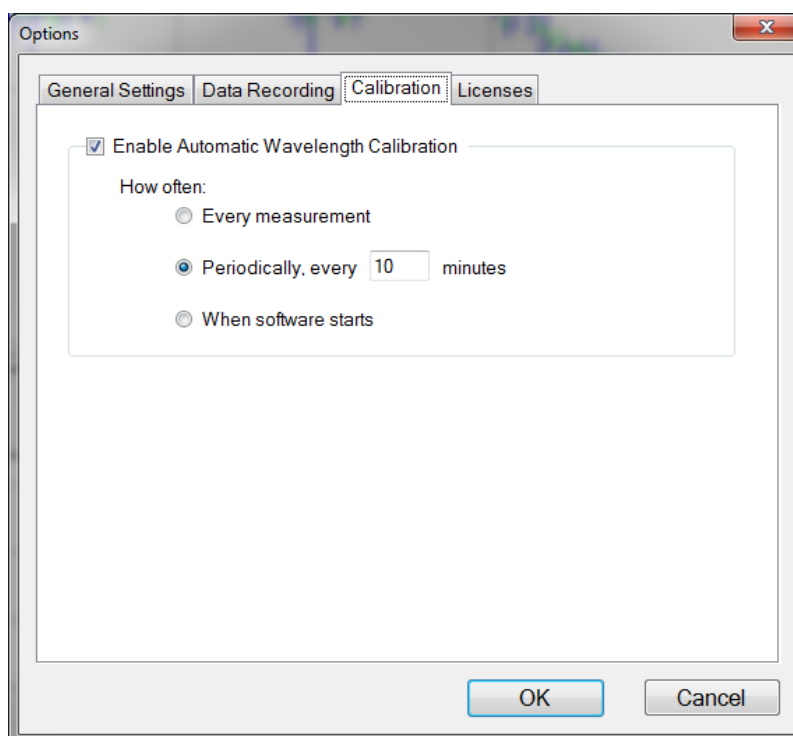
The *Automatically archive History* feature can be used to have the software save a copy of the history file whenever it hits 1000 measurements.

The history files are saved in the following format (YYYY-MM-DD-X) where YYYY is the year, MM is the month, DD is the day, and X is a serialized number based on how many history files have been saved on a given day.

A value can be entered in megabytes for the maximum disk space to be allocated for the saved archives. This will keep the software from using up all available hard disk space if the feature is enabled and then forgotten. Should the software hit the allocated max, it will delete the oldest files in the selected folder until enough space is available for the new history file.

Clicking **Clear History after archive is written** will instruct the software to automatically clear the history results after 1000 measurements have been reached, and then begin counting towards the next group. When it is disabled the history feature will work in the normal mode upon reaching 1000 measurements (newest measurement is added as Meas #1000, Meas #1 is deleted). It will write the next history file upon reaching 1000 measurements again, not each time the *Meas#* counter shows 1000.

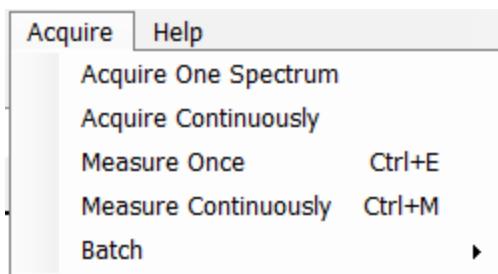
Calibration



The F54-XY-200 uses an integrated atomic-emission-line light source to update the wavelength calibration of the measurement system's spectrometer. By allowing a system to self-calibrate, automatic wavelength calibration provides significant compensation for calibration drift that could be caused by large temperature changes or by moderate mechanical shock.

The **Wavelength Calibration** tab allows to user to choose how often they would like the system to automatically calibrate the wavelength response of the system. Users can choose to calibrate with every measurement, periodically, or whenever the software boots up. This action is performed in the background and does not require any user input beyond setting the interval.

1.1.4 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

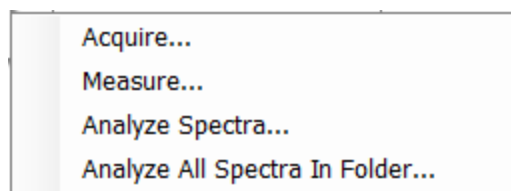
This feature collects a spectrum, analyzes it and displays it on the screen.

Acquire > Measure Continuously

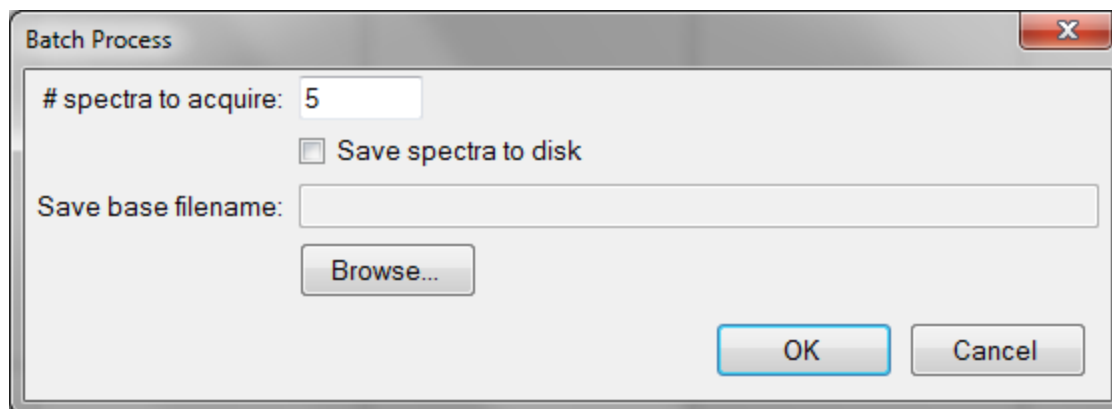
This feature collects real-time spectrum data and analyzes it. A measurement interval time can be set in the recipe using the [Advanced](#) options underneath the tab. Stop continuous data acquisition by selecting **Measure Continuously** again, or by pressing Ctrl+M.

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.

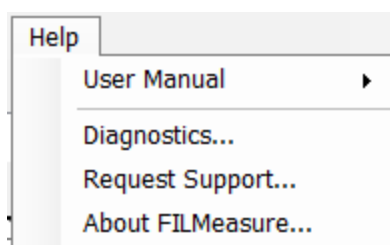
Acquire > Batch > Analyze Spectra

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

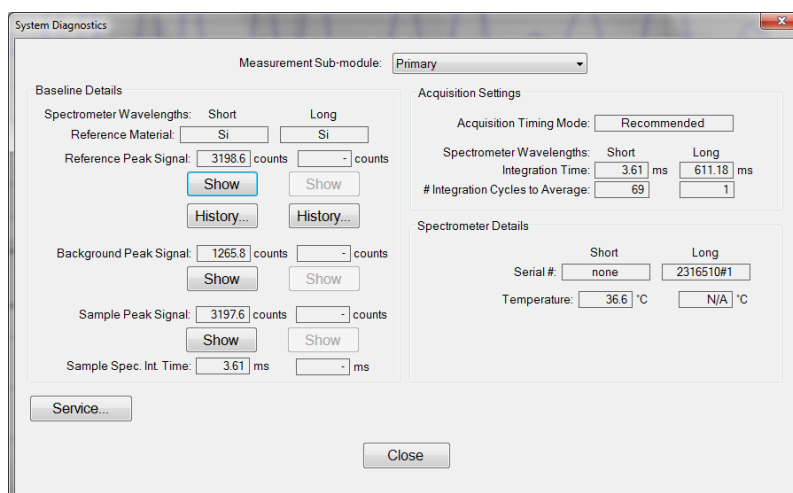
This option will analyze every spectrum in a folder with the currently selected recipe. If there are more spectra to be analyzed than the software is set to [Display](#), the analyzed spectra can easily be retrieved from the tab.

1.1.5 Help Menu



Diagnostics

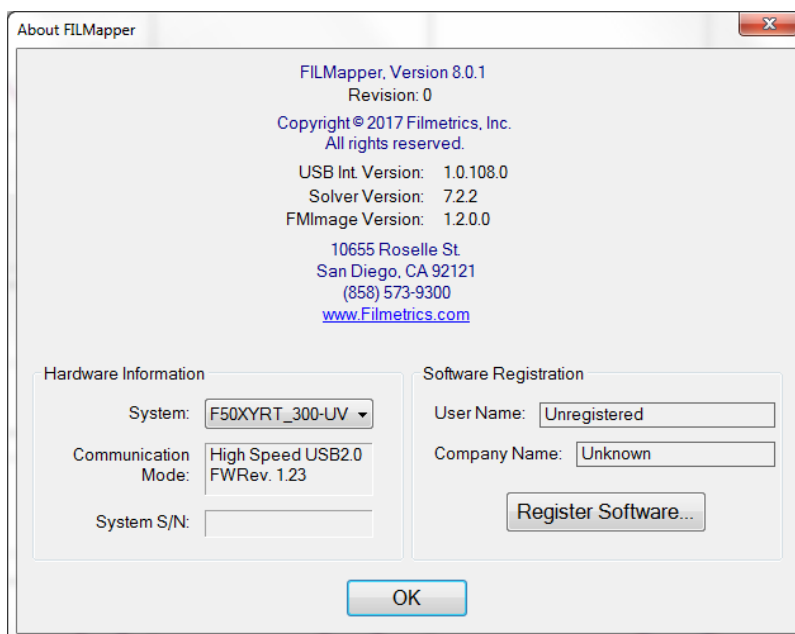
The diagnostics window gives information regarding the data taken during the baseline. Reference and background counts are shown (this is useful to see how much signal the system is getting; good reference signals typically are between 2500-3500 counts).



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

Help > About FILMapper

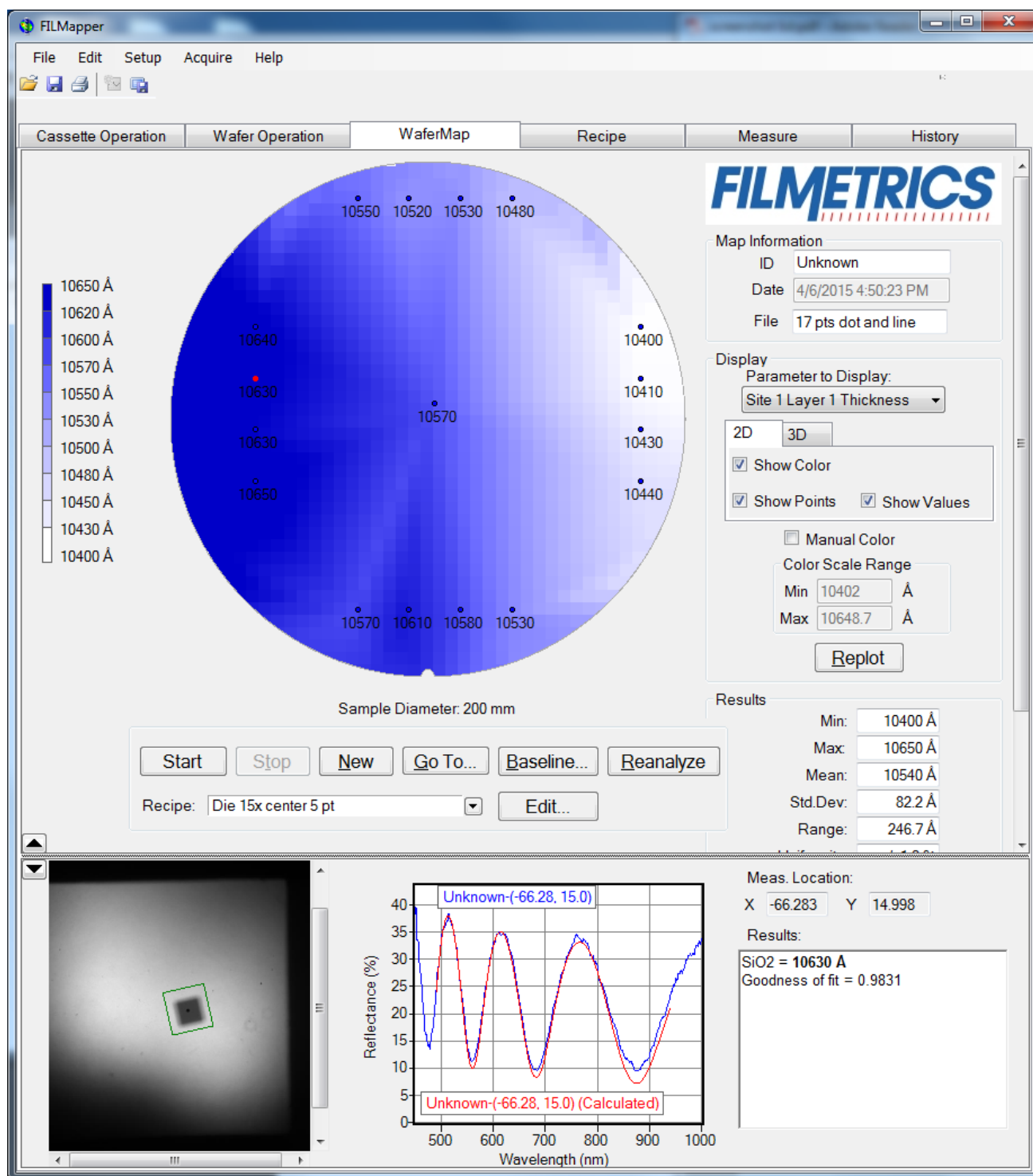
Information about the hardware and software versions and the system serial number can be found here. Please have this information available when calling Filmetrics for technical assistance.



Help>About FILMapper... window

1.2 The Wafer Map Tab

Clicking on the **Wafer Map** tab at the top of the screen will bring up the wafer map window. If wafers have been measured, the 2D/3D wafer thickness data will be displayed.



Below the wafer map are several controls for making a single wafer measurement.

Start: If a wafer is on the stage, this command button allows you to map the current wafer with the selected recipe. See Wafer Operation, for details on loading a wafer onto the stage for measurement. If a baseline has not yet been completed, the **Start** button will not be available.

Stop: Only available while a map is in progress, this command buttons allows you to pause the mapping process. While paused you may **Resume** the current map, start a **New** map, or **Go To** a specific point.

New: Clears any previous result, presenting you with a new wafer map.

Go To: Allows you to select a specific point on the map for measurement, as well as adjust the focus height. The **Fine Alignment** refers to the location of the micropositioner.

Baseline: Causes the system to take a fresh baseline.

Reanalyze: If the selected **Recipe** has been changed after a wafer map has been completed, the **Reanalyze** button can be used to have the software reanalyze the wafer using the new recipe.

Recipe: This dropdown list allows you to select between any previously generated recipe files.

Edit Recipe: Clicking on the **Edit Recipe** command button opens the [Film Stack](#) dialog box, where the user can determine the settings to be used to measure a given film. See [Editing Film Recipes](#) for further details.

1.2.1 Wafer Map Settings and Results

Map Information: Includes **Wafer ID**, **Date**, and **File** name.

If the map is acquired manually, as defined above, the ID information may be entered in these fields and saved using the **File > Save Wafer Map...**

If a map is acquired as part of a full cassette measurement procedure and then uploaded for viewing, the ID information is designated by the cassette slot number, or, if used, the bar coded identification tags.

Display:

Parameter to Display: This field specifies which value is to be mapped (thickness, index, etc.).

2D/3D: This function allows the user to switch between 2 dimensional and 3 dimensional mapping, as well as enabling or disabling the color scale, displayed measurement points, or displayed values.

Manual Color: The software automatically selects the minimum and maximum scale range values, unless this feature is selected and minimum and maximum values are entered manually.

Replot: Once any of the above settings have been changed, click this button to regenerate the results map with the new settings.

Results:

Minimum parameter value recorded for selected wafer, x_{\min} .

Maximum parameter value recorded for selected wafer, x_{\max} .

Mean (average) parameter value of all measurement locations, \bar{x} .

Std.Dev. (Standard Deviation), or 1σ , is calculated using the following equation:

$$= \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}} \quad \text{where } \bar{x} \text{ is the mean and } n \text{ is the number of measurements.}$$

Range is the difference in thickness between **Max** and **Min**.

Uniformity expressed in percentage per the equation selected under the [Setup > Options > Wafer Map](#) settings.

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.

Wedge and **Wedge Angle** are computed using a least-squares fit of a plane to the measured data.

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

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).

Valid indicates how many locations have valid results (GOF greater than the **GOF Error** threshold) out of the total number of measurement locations.

Alarmed indicates how many locations were outside of the thickness limits set under the [Alarms](#) tab in the recipe out of the total number of measurement locations.

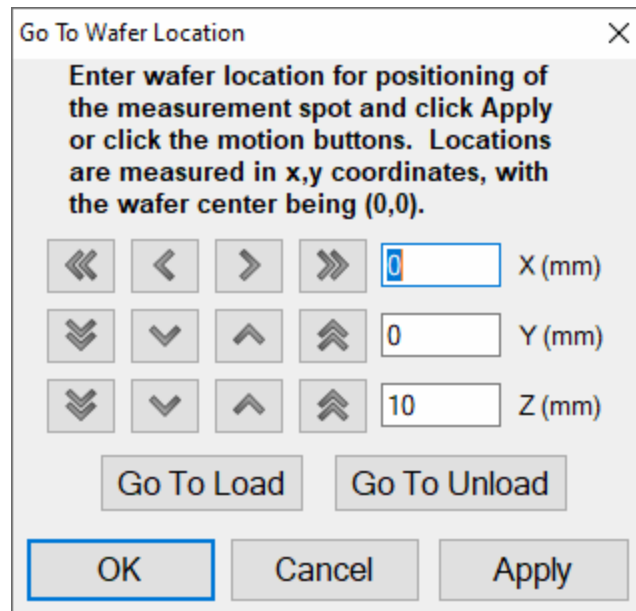
The command button pictured below can be found in the lower left corner of the **Wafer Map** tab. By clicking on this command button, you can toggle whether to display individual spectra in the **Wafer Map** tab.



When spectra are displayed, the image taken with that spectra will be displayed to the left of the measurement graph, with the measurement result and location being displayed to the right.

1.2.2 Go To

The **Go To** function allows the user to manually locate the system in the x, y directions, 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 single arrows allow a slower movement speed while the double arrows are for faster motion.



The dialog box is titled "Go To Wafer Location" and includes a close button (X) in the top right corner. The main text area contains the instruction: "Enter wafer location for positioning of the measurement spot and click Apply or click the motion buttons. Locations are measured in x,y coordinates, with the wafer center being (0,0)." Below this text are three rows of controls for X, Y, and Z coordinates. Each row consists of four arrow buttons (double arrows for fast movement, single arrows for slow movement) followed by a text input field. The X (mm) field contains "0", the Y (mm) field contains "0", and the Z (mm) field contains "10". Below these fields are two buttons: "Go To Load" and "Go To Unload". At the bottom of the dialog are three buttons: "OK", "Cancel", and "Apply".

Go To Wafer Location

Enter wafer location for positioning of the measurement spot and click Apply or click the motion buttons. Locations are measured in x,y coordinates, with the wafer center being (0,0).

« < > » X (mm)

⇓ ↓ ↑ ⇓ 0 Y (mm)

⇓ ↓ ↑ ⇓ 10 Z (mm)

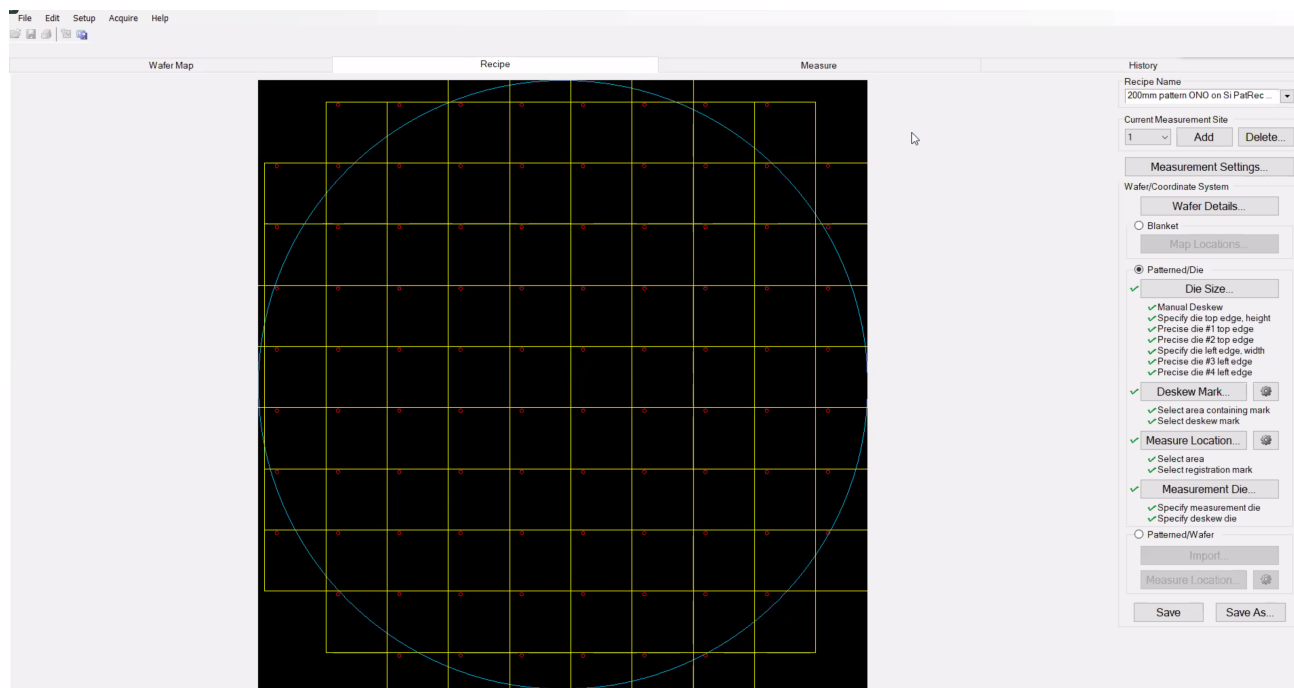
Go To Load Go To Unload

OK Cancel Apply

1.3 The Recipe Tab

Note: Requires UPG-F54-XY-PatternRecognition

FILMapper is pre-loaded with a [material library](#) and [recipes](#) for typical film stacks. Create a new recipe by editing from an existing recipe and saving it with a new recipe name. Clicking the **Recipe** tab at the top of the screen opens the **Recipe** window, as shown below. This window shows the controls on the right hand side and graphics area left side. When this window is first opened the graphics area is blank.



A summary of the important areas of the **Edit Recipe** window are provided below. These are covered in more detail in the following sections.

Recipe Name: This text box displays the recipe name. The user can select from a pull-down list of existing recipes in the recipe directory. All recipes are saved as *.fitrp files in the C:\ProgramData\Filmetrics\Recipes folder.

Current Measurement Site: The field allows the user to select the number of measurement sites within the die area.

Film Stack: Press this command button to display the [Edit Recipe](#) dialog. This dialog window allows the user to define the film stack on the wafer, define the analysis options, and set the measurement constraints.

Wafer/Coordinate System: This area encompasses the setup activities listed below.

Wafer Details: This command allows the user to select the wafer size and indexing option for the current recipe.

Blanket: This command is for blanket wafers or some test wafers that do not have repeat patterns within each die or that do not have uniform die size.

Map Locations: Press this button to define the measurement locations on the wafer based on pre-defined wafer coordinates. The user will have to check **Blanket** in order to enable this button.

Patterned/Die: This area is for setting up measurement locations based on known **Die** information.

Die Size: This command is to define the size of the die for patterned wafer measurement. Check **Patterned/Die** to enable this and the three following buttons.

Deskew Mark: This command is to define a deskew mark for pattern alignment for patterned wafer measurement.

Measure Location: This command is to specify measurement location within each die for patterned wafer measurement. A registration mark is selected within this step for reference to the measurement location in the die.

Measurement Die: This command is to select the die on the wafer for measurement.

Patterned/Wafer This area is for setting up measurement locations based on known x, y locations.

Import: This command is to import a text-file containing x and y coordinates of the measurement points.

Measure Location: This command is to specify measurement location within each die for patterned wafer measurement. A registration mark is selected within this step for reference to the measurement location in the die.

Save: This command allows the user to save the recipe with the existing recipe name in the Recipe Name field. Please make sure this is what is intended as this action will discard the original information stored with this recipe.

Save As: Press this command to save the current recipe with a new name in the recipe folder.

1.3.1 Measurement Site

This function is intended for multiple measurement sites within a die on patterned wafers. One example is for STI wafers where a single recipe can specify the measurement site for the trench oxide measurement and another site for the oxide/nitride/oxide film stack in the active area. Each measurement site has to be associated with its own film stack information and pattern/coordinate system.

1.3.2 Wafer/Coordinate System

There are three coordinate systems used for recipe setup and wafer measurement. They are **Blanket**, **Patterned/Die**, and **Patterned/Wafer**. All three coordinate systems place the wafer notch down at the bottom for wafer map display (6 o'clock position).

The **Blanket** coordinate system is for blanket wafers or patterned wafers that are not suitable for using pattern recognition to locate the measurement sites.

The **Patterned/Die** system is for patterned wafers with uniform die size and a repeating die pattern.

A faster way to set up a recipe for patterned wafers is to use the **Patterned/Wafer** coordinate system if the x-y coordinates of the measurement sites are known. This coordinate system allows the user to set up recipes quickly by importing coordinate files and then confirming measurement locations.

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.

*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.*

Blanket

If you check **Blanket** and then select **Map Locations**, the dialog window **Edit Map Locations** appears on the display, as shown below. When **Blanket** is selected, the functions for patterned wafer are disabled. You use this function to set up measurement locations for blanket wafers or wafers without repeat patterns in each die or with die of different sizes.

The parameters for the Blanket map are defined using the pull-down menus.

Coordinate System: This pull-down allows the user to select from **Polar**, **Square**, or **Custom** coordinate systems based on the type of substrate being measured.

Number of Points: When **Polar** or **Square** coordinate systems are selected, this pull-down menu allows the user to select the number of points for the wafer map. Based on the number of points, a pre-arranged wafer map will be used.

Custom Coordinates: When the **Custom** coordinate system option is selected, the **Number of Points** pull-down changes to **Custom Name** and the pull-down menu references the custom map patterns that are available (see below).

Edge Exclusion: Allows the user to specify the edge exclusion to be used on the software when determining the map pattern.

Measurement Spot Size: Allows the user to specify the effective spot size to be used by the software when solving for the film properties. The spot size selected should account for any features on the substrate or the roughness of the film stack.

When **Custom** map patterns are required, the map pattern must be created and saved in the appropriate location. See [Creating New Map Patterns](#) and [Editing Map Patterns Using Excel](#) for more details .

Patterned/Die

If you check **Patterned/Die**, the **Map Locations** function for blanket wafers is disabled. The four command buttons within this section are all enabled. The procedures listed below each command button are performed sequentially after the command button is clicked. Note that when the die size is changed the deskew marks, measurement locations, and the measurement die will have to be updated. **Measure Location** and **Measurement Die** can be performed individually without affecting the other functions.

1. [Die Size](#)
2. [Deskew Mark](#)
3. [Measure Location](#)
4. [Measurement Die](#)

Die Size

The **Die Size** function defines the die size and locations on the wafer. When this button is clicked the software opens a wizard to guide you through the each step of the process. As each step of the process is completed, the software will place a check mark next to that step on the bar to the right of the **Recipe** tab. Once the **Die Size** has been determined, you may move on to the [Deskew Mark](#) adjustment.

Deskew Mark

With the **Die Size** process completed, the next step is to set the **Deskew Mark** in the system.

Select Location for Deskew Mark

Wafer coordinates

X: 1.78 mm Y: -25.889 mm

Wafer coordinates

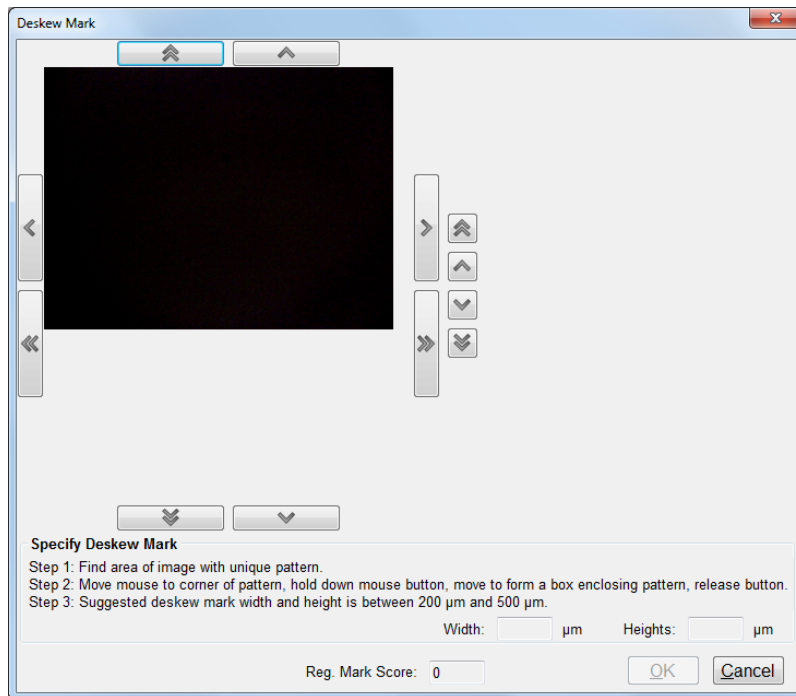
(-8.413315, -35.98656)

X: 10.193 mm Y: 10.098 mm

OK Cancel

Select location for Deskew Mark

Clicking on **Deskew Mark** will first bring up the above window. The upper section is used to determine, by mouse click or manually entered X,Y coordinates, where on the wafer the deskew mark is located. The lower section is used to determine the location of the deskew mark within the individual die select above. Click **OK** to continue to the next step.



Select area containing Deskew Mark

Follow the steps in the **Deskew Mark Wizard** to complete the **Deskew Mark** adjustment. It is suggested to select a deskew mark that is unique, high contrast, and preferably empty in the middle for the best results.

On the **Recipe** tab, next to the **Deskew Mark** button, is an additional button that allows brings up the **Advanced Pattern Recognition Details** window.

From this window the **Current Deskew Mark** can be deleted and the type of image to use for the deskew mark can be selected (GOF Image or Regular Image).

Measure Location

The Measure Location function allows you to determine exactly where on each die the measurement should be taken.

Select Location for Measurement Spot

Wafer coordinates

X: 2.8 mm Y: 39.281 mm

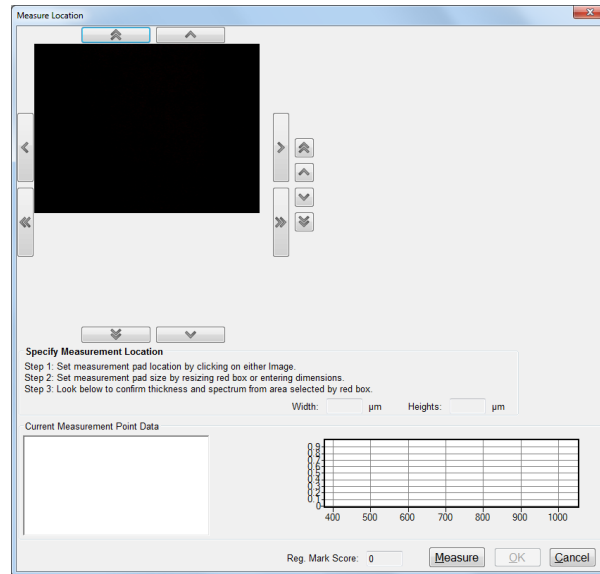
Wafer coordinates

X: 11.213 mm Y: 14.679 mm

(-8.413315, 24.60173)

OK Cancel

Similar to the Deskew Mark adjustment, the first step is to determine where on the wafer the system should look. The upper section is used to determine which die to use, while the lower section specifies where specifically on the die the system should look. Locations can be entered by mouse click, or by entering the x,y coordinates by hand. Click OK to move to the next step.

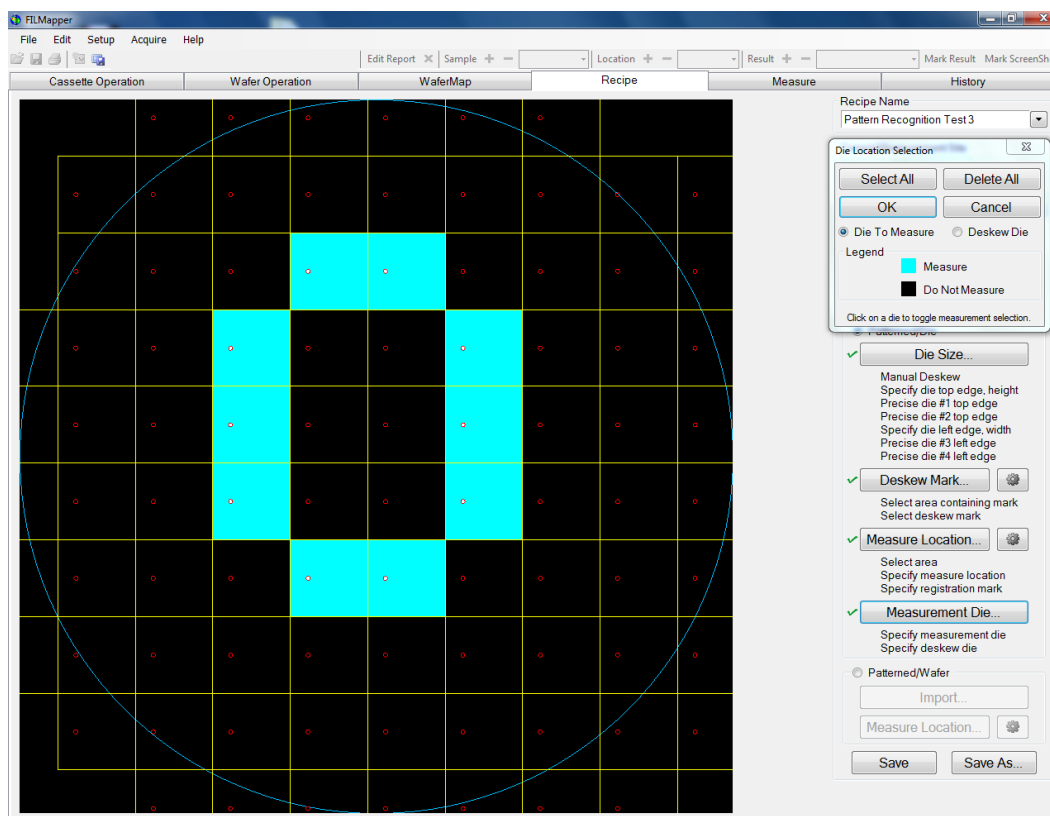


With the wafer coordinates determined, the system will next open the **Measure Location Wizard**. Follow the steps listed to complete the adjustment. The display will show the wafer image on the left and a measured spectrum with on the bottom.

- The number of oscillations on the screen is proportional to the film thickness. Using this information, the initial thickness guess and the measurement constraints can be set more appropriately in the [Edit Recipe](#) dialog.
- Restrict the wavelength range used in the analysis when only a portion of the measured spectrum displays oscillations. The portion of the reflectance spectrum that is used to calculate film thickness is defined in the [Edit Recipe > Analysis Options](#) tab setting.

Measurement Die

With the [Die Size](#), [Deskew Mark](#), and [Measurement Location](#) set, the last step is to determine exactly which die to use for measurement.



Example measurement die selection

Clicking on **Measurement Die** will open the **Die Location Selection** dialog window. While the radio button is set to **Die To Measure**, clicking on any die in the wafer drawing to the left will toggle the system between selecting to take a measurement from a given die. The **Select All** can be used to toggle on measurement of all dies, and the **Delete All** button is used to clear all previous selections at once.

Clicking on the **Deskew Die** radio button will allow the user to select between two different dies to use for the deskew adjustment. For best possible results, it is selected to pick two die that are far away from each other. Click **OK** to apply the changes.

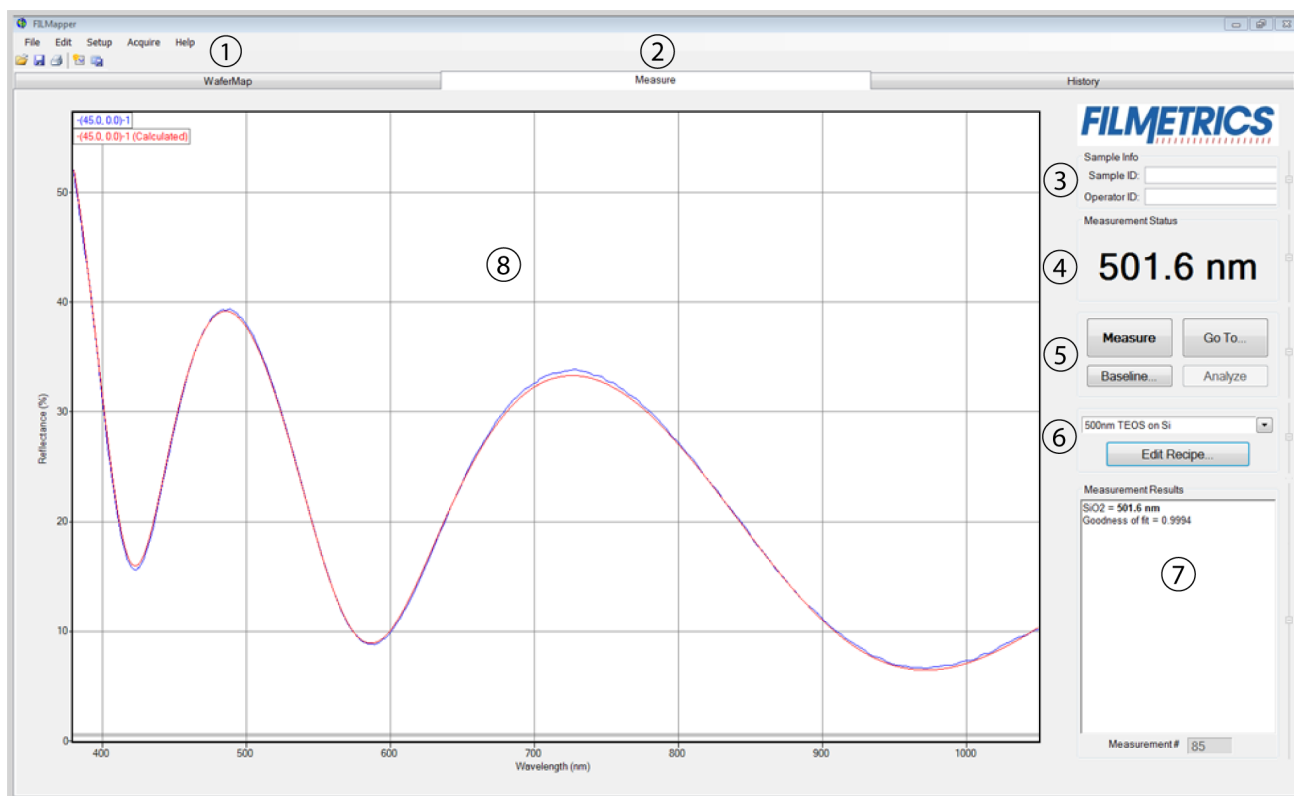
Patterned/Wafer

If x and y coordinates for all measurement spots are available the **Patterned/Wafer** coordinate system is a much quicker way to set up the recipe. First a text file has to be prepared from the x and y coordinates of the measurement locations. Then the file is imported to the system by selecting the Import command button.

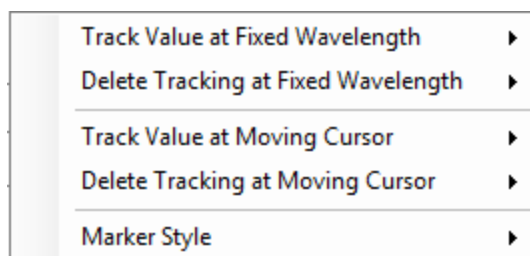
A window will come up allowing for navigation to the file containing the coordinate information. When the file is selected, the **Import Measurement Coordinates** window will come up. This allows for selection of the separator and for skipping lines if necessary. The coordinate information will be displayed in the **File Preview** field.

The last step is to select the measurement location by clicking the [Measure Location](#) command button

1.4 The Measure Tab



1. Standard Windows menus: [File](#), [Edit](#), [Setup](#), [Acquire](#), and [Help](#).
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.

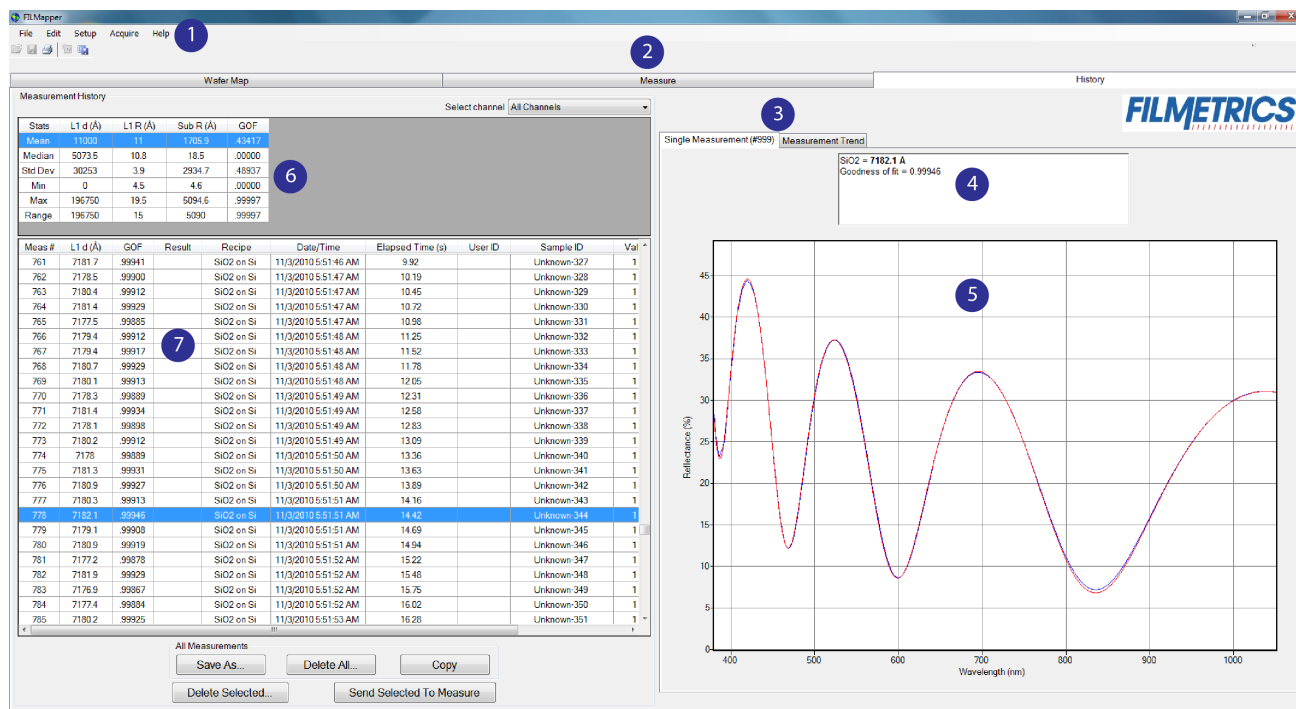


The graph limits can be changed by double-clicking on the graph display. The text boxes along the bottom of the graph control the wavelength range, in nanometers, displayed on the screen. For systems with multiple spectrometers, the software will automatically resize to match anytime the selected spectrometer is changed.

The two boxes 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).

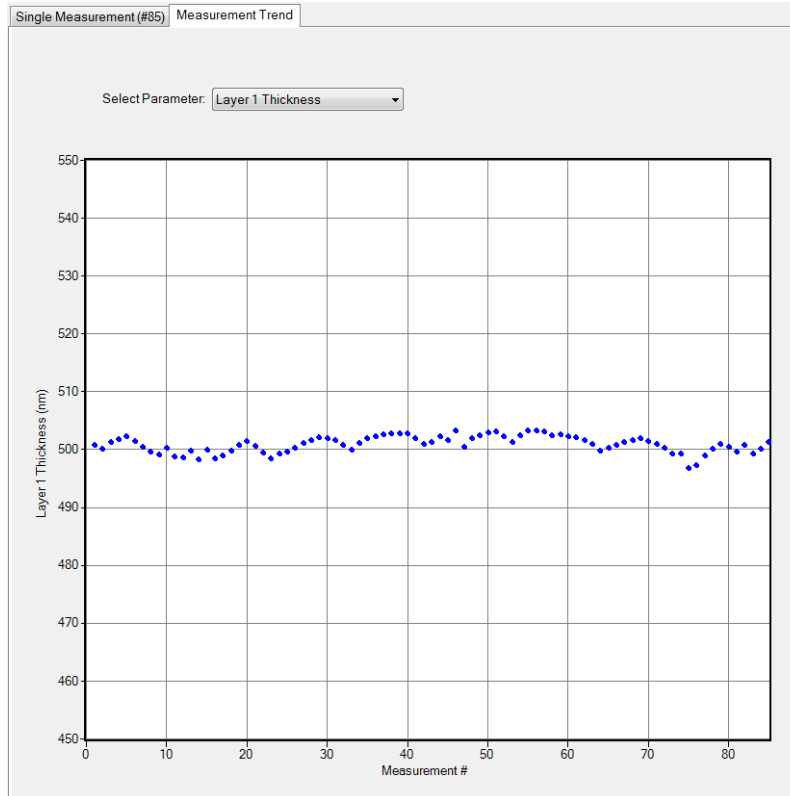
Graph Options can be accessed and edited by double-clicking on the main graph window.

1.5 The History Tab



1. Standard Windows menus, including; [File](#), [Edit](#), [Setup](#), [Acquire](#), and [Help](#).

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 displayed.

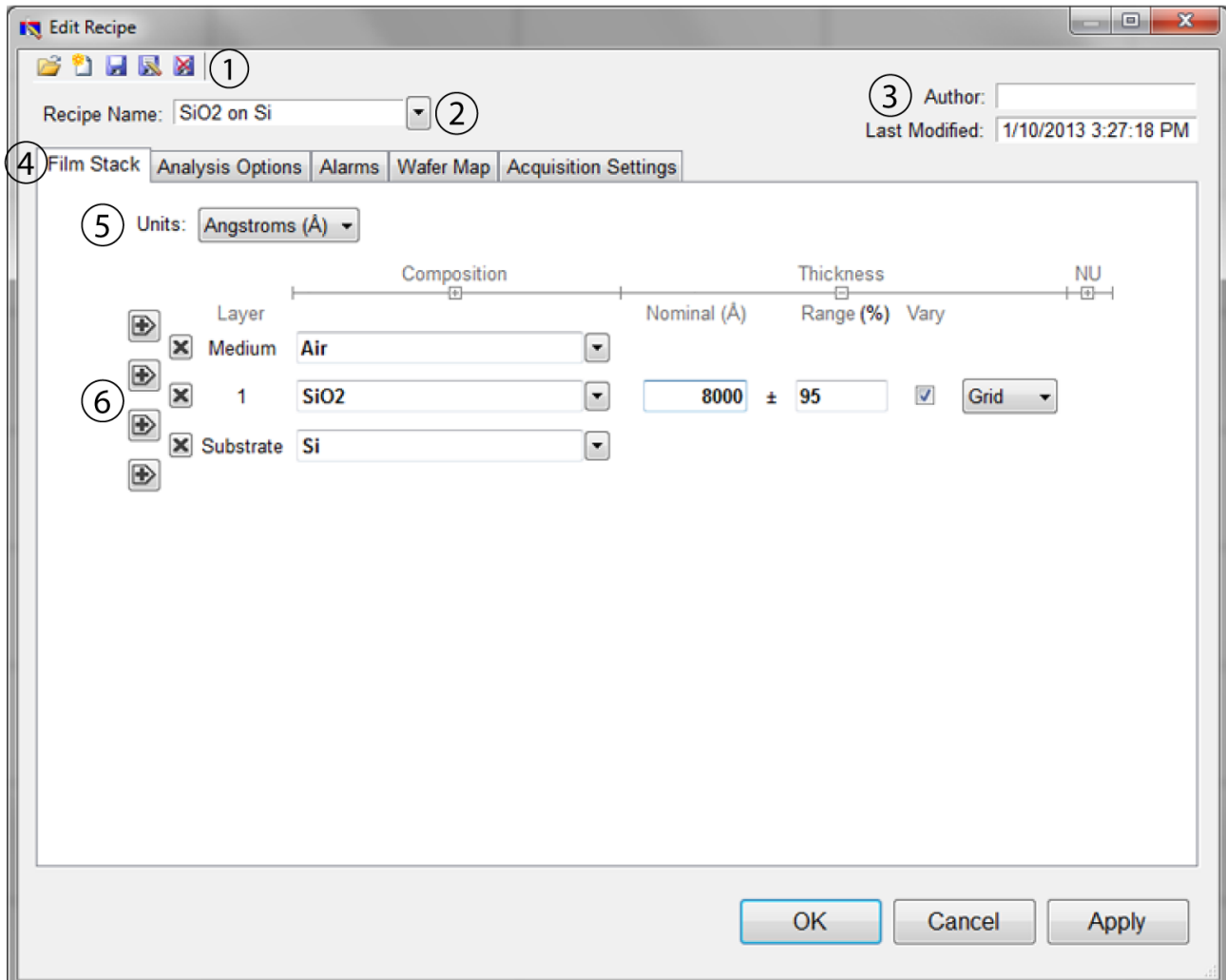


When the **Measurement Trend** tab is selected in the **History** window, the right side of the screens graphs the results.

4. Shows the measurement results for the selected spectrum (must be in **Single Measurement** mode).
5. Displays the selected spectrum in **Single Measurement** mode or the measurement trend plot in **Measurement Trend** mode.
6. Displays statistics for all measurements included in the history file. This data can be selected for copying and pasting outside of the software.
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.

1.6 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 (\AA , 10^{-10} m), nanometers (nm, 10^{-9} m), kilo-angstroms ($k\text{\AA}$, 10^{-7} m), microns (μm , 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. Calibrating The Camera

Many of the F54-XY-200's advanced features are dependent on the ability to finely locate the measurement spot in the camera image. This click-to-move functionality allows the end user to center the measurement position anywhere in the camera image simply by clicking on the point they wish to see. However before this functionality can be enabled, a number of calibrations need to be completed.

Camera calibrations:

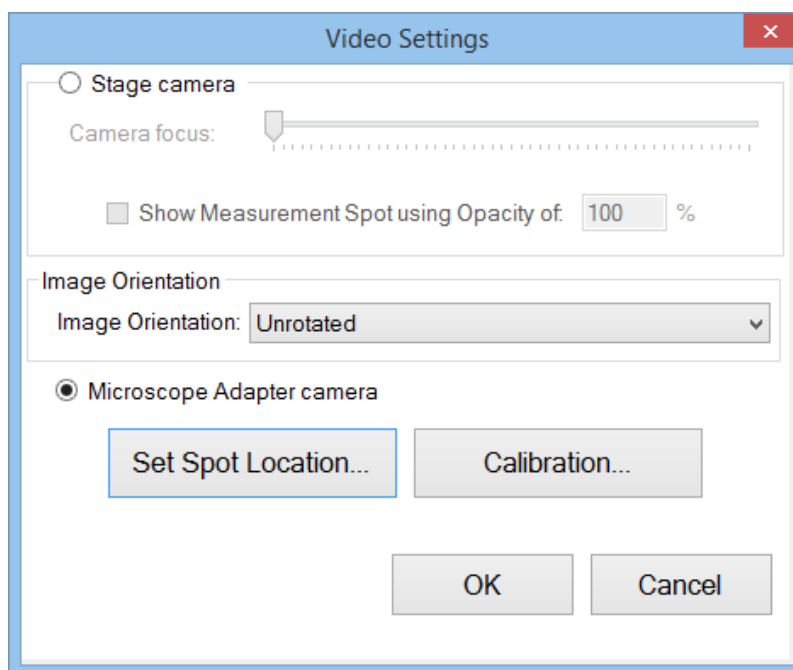
[Set Spot Location.](#)

[Magnification for the Stage.](#)

[Focus Edge Positions.](#)

1.7 Set Spot Location

This calibration is used to teach the software where the measurement spot is in the camera image, which is the first step in enabling click-to-move functionality. To begin this calibration go to the **Measure** tab, and then select the **Live Video** tab on the left hand side of the screen. If the camera has been hidden, it can be expanded by clicking the large vertical button to the left of the graph window. Click on the settings button to open the **Video Settings** dialog box.



Once the **Video Settings** dialog box has opened, click on **Set Spot Location...** to begin the calibration. FILMapper will automatically move the wafer chuck to the Homing and Calibration Target (HCT) to perform the calibration. Once it is complete press **OK** to apply the new calibration.

1.8 Magnification for Stage

This process is used to calibrate the range of motion displayed in the video image against the physical motion of the stage. This calibration is the second step in enabling the click-to-move functionality.

To access the stage magnification calibration, go to the **Measure** tab. Within the **Measure** tab select the settings button from above the video image. Depending on screen resolution the button will either read as **Settings...** or will instead look like the image below.



Inside the **Video Settings** dialog, select the **Camera Calibrations...** button to access the **Camera/Optics Calibration Dialog** box. Select **Calibrate** next to the **Magnification for stage:** option to begin the calibration process.

The first step of the calibration will be to locate an easily identifiable feature on the HCT that is nearby to the upper dashed line in image. Once a feature has been identified, press the **Next** button.

Using the mouse, place the cursor on the feature and then left click, taking care to note the precise location of the cursor on the feature. After the cursor has been placed, continue to the next step using the **Next** button.

For the third step, use the motion controls provided to move the wafer chuck until the feature is aligned with the lower dashed line. Use the slow motor control (single arrow) for this step to avoid losing track of your feature. Click **Next** to continue to the final step.

Using the mouse, place the cursor on the new location of the selected feature in the video image, taking care to try and place the cursor in the exact same spot on the feature as selected in step 2. Press **Finish** to complete the calibration.

With the stage magnification calibration complete, the user may now move on to the [micropositioner magnification calibration](#).

1.9 Focus Edge Positions

This calibration is used to identify the edges of the field stops in the image system, which are used when [focusing on unpatterned surfaces](#).

Before beginning the calibration, set the camera at the widest zoom setting by placing the indicator all the way to the left of the slider bar above the video image. The system will also have to be focused to either a loaded sample or the Homing and Calibration Target (HCT), so that the field stops are visible in the image.



To access this calibration, go to the **Measure** tab. Select the settings button from above the video image. Depending on screen resolution the button will either read as **Settings...** or will instead look like the image below.

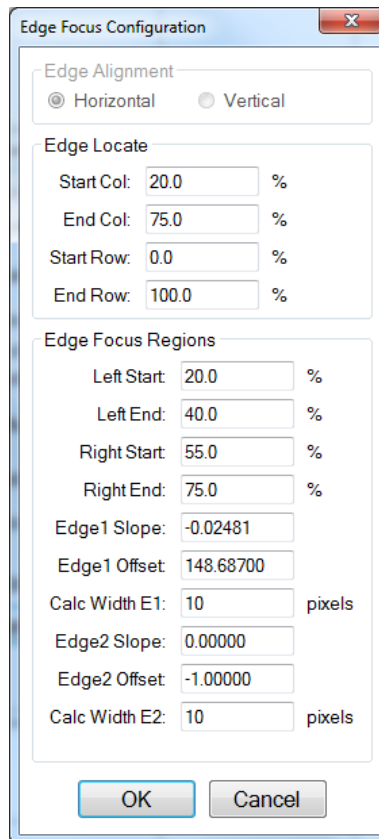


Inside the **Video Settings** dialog, select the **Camera Calibrations** button to access the **Camera/Optics Calibration** dialog box. You must establish the basic configuration parameters for the software to detect the field stop edges in the camera image. These options can be found by clicking on the [Configure Button](#) under the **Focus Edge Position:** section. Once the basic configurations have been entered, you can continue on to the [Focus Edge Locations](#) calibration by clicking the **Calibrate** command button.

1.9.1 Edge Focus Configuration

Before you can run the [Focus Edge Locations](#) calibration, you must first provide the software with some basic information about where in the image those field stop edges fall. These values are; **Start Column**, **End Column**, **Start Row**, **End Row**, **Left Start**, **Left End**, **Right Start**, and **Right End**.

Once these have been defined you can continue on to the **Focus Edge Locations** calibration. More information on what these values mean and how they should be set can be found below.



The image shows a software dialog box titled "Edge Focus Configuration". It contains three main sections: "Edge Alignment", "Edge Locate", and "Edge Focus Regions".

- Edge Alignment:** Has two radio buttons: "Horizontal" (which is selected) and "Vertical".
- Edge Locate:** Contains four input fields with percentage suffixes:
 - Start Col: 20.0 %
 - End Col: 75.0 %
 - Start Row: 0.0 %
 - End Row: 100.0 %
- Edge Focus Regions:** Contains several input fields:
 - Left Start: 20.0 %
 - Left End: 40.0 %
 - Right Start: 55.0 %
 - Right End: 75.0 %
 - Edge1 Slope: -0.02481
 - Edge1 Offset: 148.68700
 - Calc Width E1: 10 pixels
 - Edge2 Slope: 0.00000
 - Edge2 Offset: -1.00000
 - Calc Width E2: 10 pixels

At the bottom of the dialog are "OK" and "Cancel" buttons.

Edge Alignment determines whether you're looking at the configuration for the Horizontal or Vertical field stop edges.

Edge Locate: is used to indicate where in the image the field stop edges are. All locations are given by percentage distance across the frame. For column measurements, 0% is the far left edge of the camera image, and 100% is the far right edge of the camera image. For Row measurements, 0% is the bottom edge of the camera image, and 100% is the top of the camera image.

Start Col: indicates where in the camera image the left field stop edge is located. This will be indicated by a white dashed line in the **Focus Edge Locations** calibration.

End Col: indicates where in the camera image the right field stop edge is located. This will be indicated by a white dashed line in the **Focus Edge Locations** calibration.

Start Row: indicates where in the camera image upper field stop edge is located.

End Row: indicates where in the camera image the lower field stop edge is located.

Edge Focus Regions is used to define additional information to help the **Focus Edge Locations** calibration accurately determine the location of the field stop edges.

Left Start: should be placed as close to the left field stop edge while remaining in the illuminated area of the camera image. This will be indicated with a blue dashed line in the **Focus Edge Locations** calibration.

Left End: should be placed close to the center of the illuminated area of the camera image, but not overlapping with **Right Start**. This will be indicated with a blue dashed line in the **Focus Edge Locations** calibration.

Right Start: should be placed close to the center of the illuminated area of the camera image, but not overlapping with **Left End**. This will be indicated with a blue dashed line in the **Focus Edge Locations** calibration.

Right End: should be placed close to the right field stop edge while remaining in the illuminated area of the camera image. This will be indicated with a blue dashed line in the **Focus Edge Locations** calibration.

Edge 1 Slope refers to the slope of line in the image associated with the left or top field stop edge, depending on the selected **Edge Alignment**. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

Edge 1 Offset refers to the offset from the edge of the camera image associated with the left or top field stop edge, depending on the selected **Edge Alignment**. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

Calc Width E1 refers to width of the focused field stop edge in the image. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

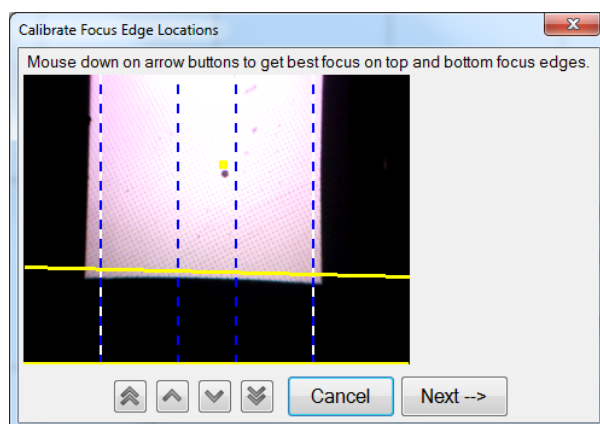
Edge 2 Slope refers to the slope of line in the image associated with the right or bottom field stop edge, depending on the selected **Edge Alignment**. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

Edge 2 Offset refers to the offset from the edge of the camera image associated with the right or bottom field stop edge, depending on the selected **Edge Alignment**. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

Calc Width E2 refers to width of the focused field stop edge in the image. This value will automatically be determined by the **Focus Edge Locations** calibration. A value may also be entered manually, though it is not suggested.

1.9.2 Focus Edge Locations

This calibration is used to determine the exact location of the field stop edges to aid the software when using the image based autofocus functionality. Before beginning this calibration, please insure that the basic parameters required have been entered under the [Focus Edge Configuration](#) dialog box. Once the basic configuration has been completed, click on the **Calibrate** button to begin.



1. Bring the camera image into focus using the arrow controls at the bottom of the dialog box. If the sample is not patterned, you can use the field stop edges to confirm focus.
2. Confirm that the vertical dashed lines all fall within the illuminated area. If they do not, adjust the values accordingly in the **Focus Edge Configuration** (white - **Start Col** and **End Col**, light blue - **Left Start** and **Right End**, dark blue - **Left End** and **Right Start**).
3. If a calibration has been completed previously, or values were entered manually for the slope, offset and line width, there will be two solid yellow lines indicating where the currently defined focus edges are.
4. Click **Next** to run the calibration. The software will attempt to locate the focus edge using the parameters provided, and the new edge locations will be highlighted with solid red lines. Click OK to complete the calibration. The newly calculated values for the slope, offset, and edge width will now be entered in the configuration dialog.

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.

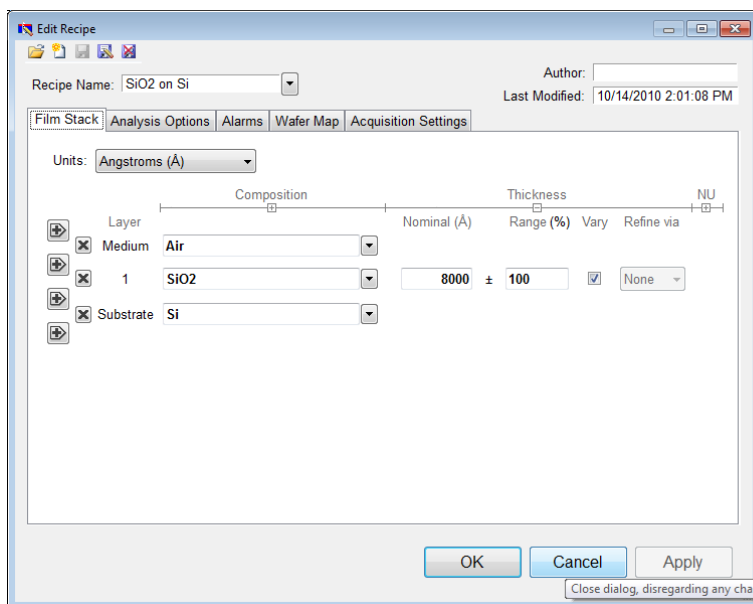
Recipes are used to configure the film stack, measurement map, and acquisition settings for the system. If varying samples or processes are being measured, multiple recipes can be saved to quickly switch settings as appropriate.

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 selected structure can be permanently stored by making the desired changes and clicking **Save**. Changes can also be stored as a new recipe by clicking **Save As**. A structure may be deleted (removed from the **Recipe Name:** list) by clicking the **Delete** button.

2.2 Film Stack



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 .

2.2.1 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.

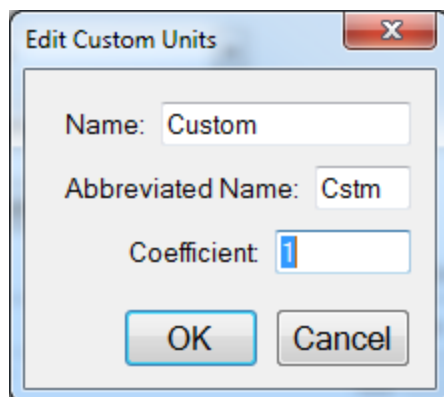
If a material is being measured is not present in the material library there are three possible approaches to complete the recipe:

- Choose a material in the library that is similar.
- 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).
- 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.

2.2.2 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 mg/ft² and it's been determined that 1 mg/ft² works out to a film thickness of 150 nm, then you would calculate your coefficient as follows, where X is the coefficient.

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

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

$$X = 150$$

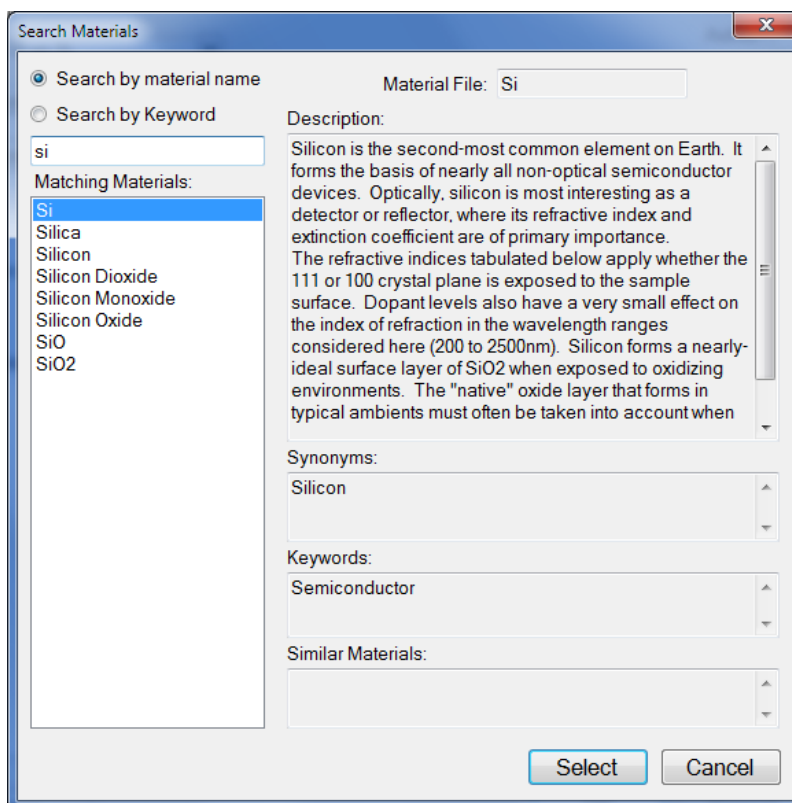
Custom units can be saved as part of the **Recipe** file, and only one custom unit can be saved per recipe.

2.2.3 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.

2.2.4 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.

2.2.5 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.

Measurement results that are equal or nearly equal to the min or max thickness limit will be marked as invalid, unless the minimum GOF limit is 0 (using the above example, a result of 50 nm would show as invalid). This feature is intended to make sure that the user is alerted to results that may not be accurate as the correct solution is not available in the currently provided range. To clear the invalid result, simply use a larger constraint or change the nominal thickness value.

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.

2.2.6 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.

2.2.7 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.

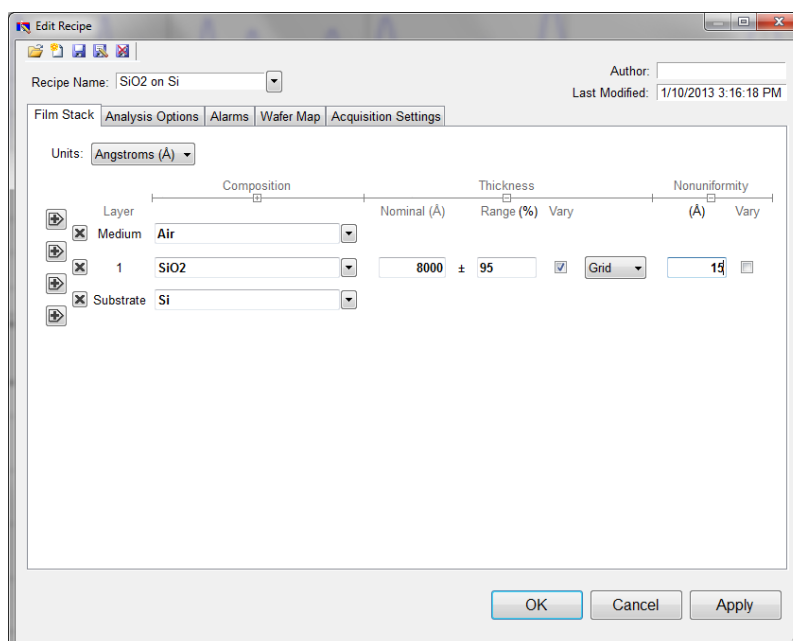
2.2.8 Composition

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.

2.2.9 Nonuniformity



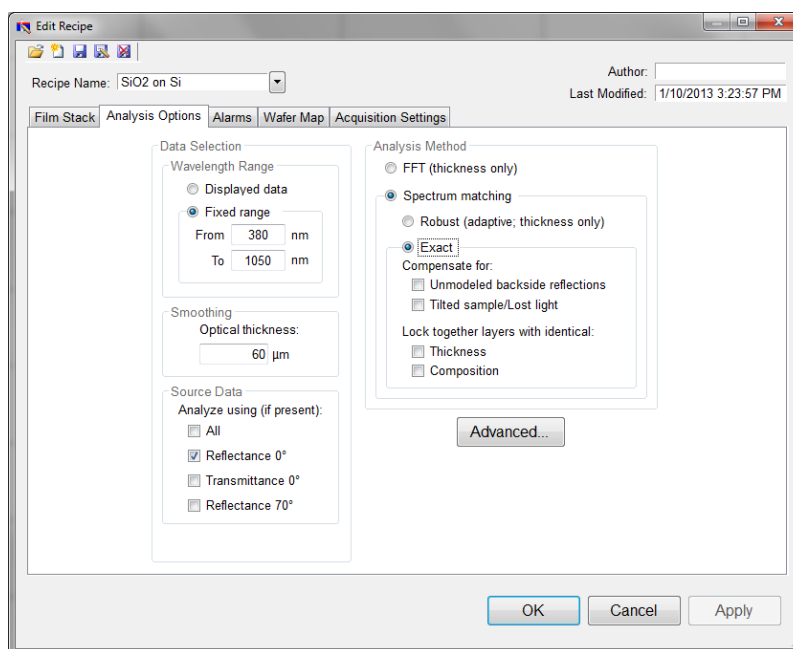
The **Edit Recipe** > **Film Stack** tab with the **Nonuniformity** option expanded.

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.

2.3 Analysis Options

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, only the [Data Selection](#) settings will be accessible.



2.3.1 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 μm, 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.

2.3.2 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](#).

2.3.3 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.

2.3.4 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).

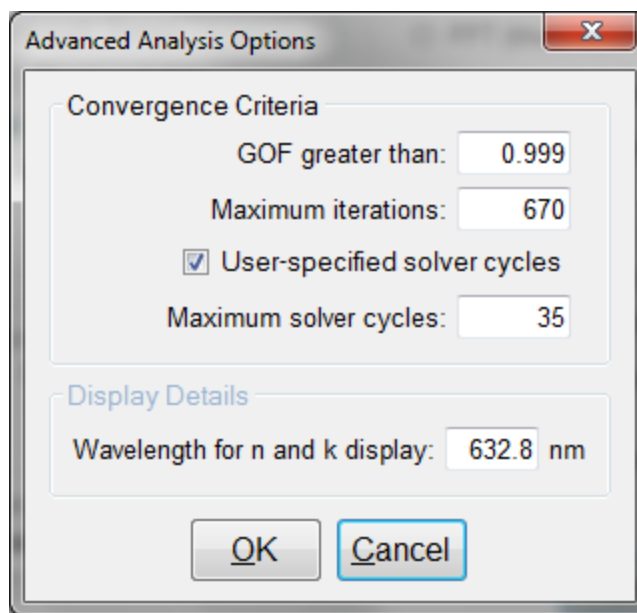
Tilted Sample/Lost Light

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.

2.3.5 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

FFT Analysis Window

☒ No optimization

☐ Optimize Position Window Size: 2000 nm

☐ Optimize Size Window Min Size: 2000 nm

☐ Optimize Position and Size

FFT Total Thickness

☐ Measure Total Thickness Min. Peak Height: 50 %

FFT Window Function: None

FFT Scaling Factor: 1

OK Cancel

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.

The **FFT Total Thickness** is used when only the total thickness of a multi-layer stack is of interest. In these cases the user would define a single layer recipe, and enable the total thickness option. The solver will then perform a special analysis and look for the peak that corresponds with the thickest measured value within the current parameters of the recipe, checked against a minimum peak height. This value is used to insure that only a true thickness peak, and not a side lobe of another peak is identified as the correct result.

The **FFT Window Function** allows you to select between four different window functions to apply to the FFT analysis. By default this feature will be disabled (*None*). Descriptions of different mathematical functions can be found [here](#)

The **FFT Scaling Factor** is used for non-ideal samples, where there maybe an alignment in the x-axis of the FFT plot, but not the y-axis. This may occur for many reasons such as a very rough, non-uniform, or in some other way non-ideal film. By adjusting the scaling factor, you can increase or decrease the amplitude of the modelled fit to improve your GOF values.

2.4 Alarms

Recipe Name: SiO2 on Si

Author:

Last Modified: 1/10/2013 3:23:11 PM

Film Stack | Analysis Options | **Alarms** | Wafer Map | Acquisition Settings

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 [Measure Tab](#). 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.

2.5 Wafer Map

The screenshot shows the 'Edit Recipe' dialog box with the 'Wafer Map' tab selected. The 'Recipe Name' is 'SiO2 on Si'. The 'Author' is 'Filmetrics, Inc.' and the 'Last Modified' date is '3/2/2017 1:48:57 PM'. The 'Wafer Map' tab contains several sections:

- Measurement Configuration:**
 - Wafer Diameter: 200mm (7.9")
 - Coordinate system: Custom
 - Custom Name: Custom1
 - Edge exclusion: 0 mm
- Indexing:**
 - Flat
 - Notch (selected)
 - None
 - Rectangle
 - Advanced...
- 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)
- Offset Map Origin:**
 - Relative to Start Location
 - Absolute
 - X: 0 mm Y: 0 mm
- Automatic Data Saving:**
 - Save map to disk
 - Export to custom format
 - Save spectra
- Pattern Avoidance:**
 - Spot Size: 0.5 mm
 - Pattern Size: 0.05 mm
 - Rectangular
 - Radial (selected)
 - Spacing: 1 degrees
- Invalid Meas. Retry:**
 - Invalid Meas. Retry

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.

2.5.1 Measurement Configuration

Wafer Diameter: Diameter of wafer to be measured – choose from the 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: 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.

2.5.2 Offset Map Origin

This feature is intended to allow the origin point location used for the measurement map to be specified. If no option is selected, the software defaults to centering all maps around the (0,0) measurement location. Once selected there are two options available:

1. **Relative to Start Location** - When the **Start** button is clicked, the software uses the current (x,y) position as the origin for the map. This position is not saved as part of the recipe.
2. **Absolute** - Set a specific (x,y) location as the origin of the map.

2.5.3 Automatic Data Saving

If a filename is entered in the upper right corner of the **Wafer Map View>Map Information** field, 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. Depending on the settings in [Setup>Options>Wafer Map](#), maps are saved as an .fimap or .fiwmc file.

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 .fmspe is saved by default, but can be set in **Setup > Options > Wafer Map**. Each spectrum may be opened in the [Measure Tab](#).

2.5.4 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.

2.5.5 Invalid Measurement Retry

Activating this feature allows the software to try up to four additional measurement locations, within the **Spot Size** specified if the first measurement turns up as invalid. Invalid measurements are defined by the minimum valid GOF in the **Alarms** tab. If a valid measurement is found, the result will be shown on the resulting map. If no valid measurement is found in any location, the spot will be marked invalid. This function is especially helpful when measuring non-uniform samples.

2.5.6 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.

2.5.7 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](#).

2.5.8 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).

2.6 Acquisition Settings

2.6.1 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 FILMapper 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*

2.6.2 AutoFocus

The F54-XY-200 can autofocus on sample and reflectance standards when making measurements. Three focusing options are available in the Acquisition Settings tab in the Recipe:

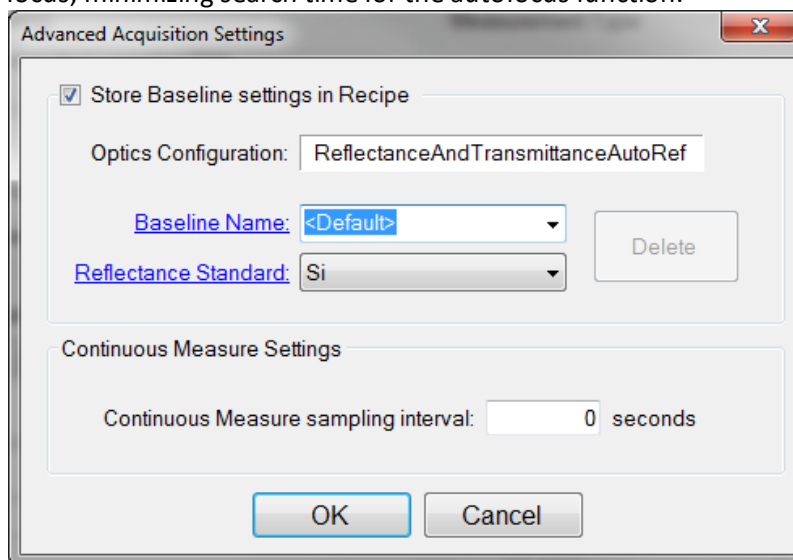
GOF: Optimizes focus based on the best goodness of fit measurement of the sample. The recipe selected should accurately match the intended application to minimize measurement time.

Max Signal: Maximizes the raw signal returned from the spectrometer to determine best focus. This option has additional controls to help optimize its use.

- **Smp Thickness:** Use with transparent substrates. Enter the substrate thickness to allow the software to correctly identify the top surface from the bottom surface when focusing.
- **Z Offset:** Accounts for differences between image focus and max signal focus by setting an offset during measurements so that saved camera images looks sharp.
- **Reflectance Objective:** Special controls for systems using reflective objectives.
- **Range:** Set how large of a range the autofocus routine should cover, depending on the currently selected objective. Selecting a smaller percentage can speed up acquisition, though runs the risk of not capturing the correct focus height.
- **Step Size:** Determine how far the z motor should move between steps when trying to focus on the surface. Smaller values may be more sensitive to changes but will slow down acquisition.

Image Focus: Uses the knife edges in the image field to focus to the sample surface. This is the recommended routine to use.

Regardless of technique used, manual focus controls are suggested during first sample run to bring the system to a rough focus, minimizing 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

3.1 Taking a Baseline

The Baseline

The baseline measurement allows the FILMapper software to account for the response inherent to the reflectance measurement hardware. It does this by first measuring the sample, then a reflectance standard, and finally by taking a “dark” reading.

In the F54-XY-200, this process is partially automated, requiring the user to load a sample, then hit the **Baseline** button on either the *Wafer Map*, *Recipe* (pattern recognition enabled systems only), or *Measure* tab. The light source should be allowed to stabilize at least ten minutes before the baseline is taken.

When thin films ($< 2000 \text{ \AA}$, 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 in the Edit Recipe > Wafer Map tab.

Taking a Baseline

Baseline measurements may be started two ways:

1. Click the **Baseline** button which will guide the user through the baseline procedure, or
2. Select *Setup > Standard/Background...* from the menu bar for manual access to the baseline functions.

The following instructions assume the user has selected either the *Use Recommended Sampling Time* or *Use Maximum Sampling Time* option under [Edit Recipe > Acquisition Settings > Measurement Timing](#). For the *Use Manual Integration Times* option, *Step 2* will be skipped.

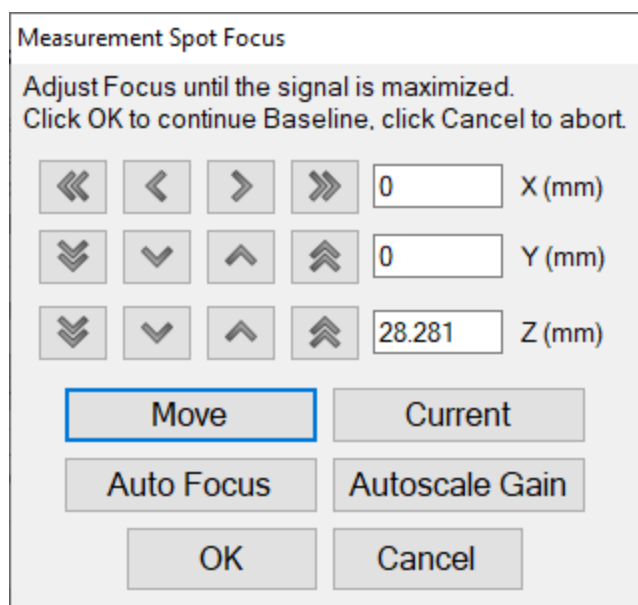
Step 1: Load the Sample

Begin the baseline measurement by loading the sample using the following instructions:

With the safety lid closed on the F54-XY-200, click [Go To](#), then **Go To Unload** to move the stage to the unload position. Open the safety lid then place the sample on the stage using the alignment pins to center the sample as necessary. When the sample is satisfactorily positioned on the stage, close the safety lid and click **Go To Load** to move the sample into position. Click **OK** to exit the dialog.

Step 2: Acquire a Sample Spectrum

This step determines the best combination of integration time and cycles for measuring the sample. First, click the **Baseline** button. In the dialog box, select **Acquire Sample Spectrum**. Upon selection, a control will open to move the stage in X, Y, and Z, and a continuously updating view of raw signal will be shown on the main graph in the *Measure* tab.



Move to the measurement location using the motion controls. Focus to the surface automatically by clicking **Auto Focus**, or manually using the z controls in the control panel.

For manual focus, if the raw signal curve is too low or too high to identify changes in signal, click **Autoscale Gain** to automatically adjust the integration time and better analyze the raw signal spectra. It may be necessary to click **Autoscale Gain** more than once as focus is adjusted. Once focused, click **OK** to continue.

Step 3: Take a Reflectance Spectrum

The last step is to take a spectrum of a reflectance standard. Select the reference material to use in the dropdown (typically Si) and click **Acquire Reference Spectrum**. The system will move to the selected standard and take a measurement, followed by a dark measurement completing the baseline. The system is now ready to take data.

3.2 Focusing a Microscope Image on a Perfectly Flat Surface

In many cases, samples will have visible features that allow users to focus the microscope image. However, for perfectly specular (mirror-like) samples like blanket wafers, focusing the microscope may be difficult. To assist with these cases the F64 takes advantage of the [Köhler illumination](#) technique, which can be helpful in obtaining a focused image despite a lack of visual reference points on the sample.

In a Köhler illuminated microscope there are three additional focal points in the light path. The F64 uses one of these points in particular, the field diaphragm or field stop, as a guide when focusing the system. These are visible as the black edges that surround the camera image.

In order to aid the image based autofocus routine, it will be necessary to calibrate the location of the field stop edges in the video image. This process should have been completed upon initial installation and setup of the system. However should that information have been lost or damaged, instructions on how to complete the calibration can be found [here](#).

3.3 Measurement Assumptions

The following assumptions must be valid if accurate measurements are to be made with the F54-XY-200

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 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.
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.

3.4 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.

3.4.1 Roughness

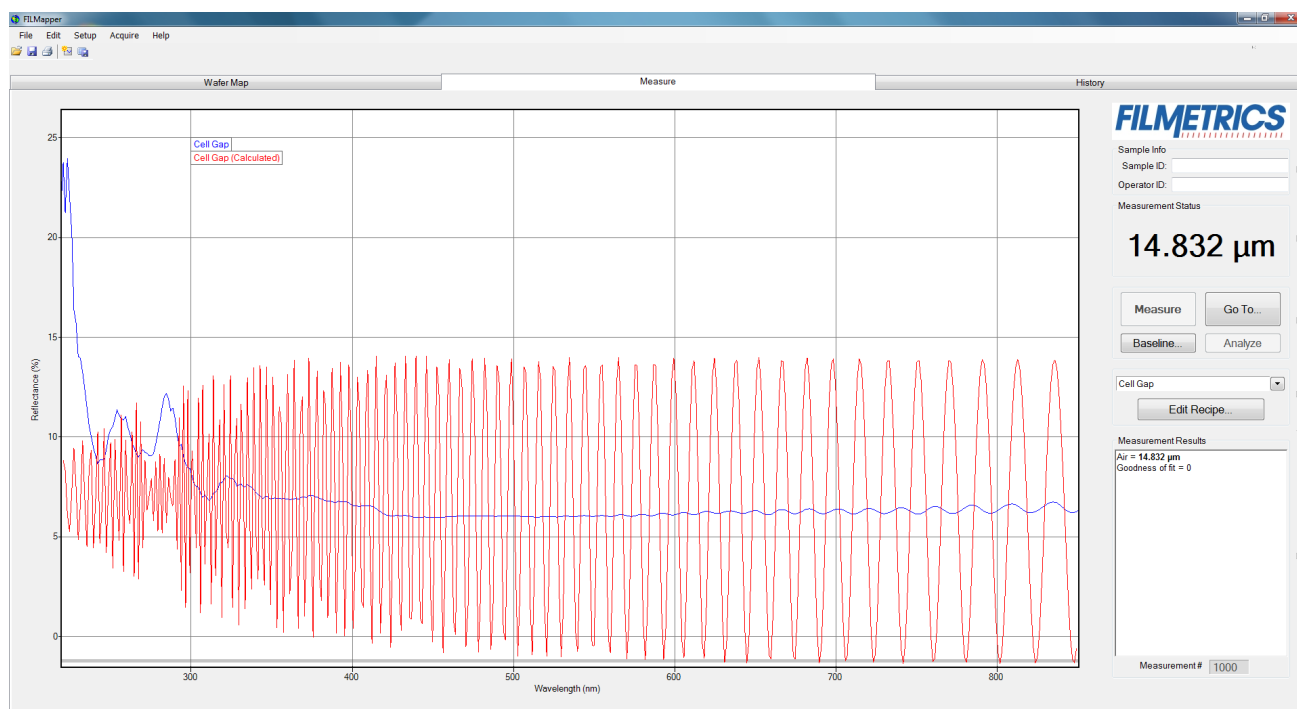
Slight amounts of surface or interface roughness that may be present can decrease the **GOF** value of a measurement. Entering a value or solving for roughness can partially account for this roughness so that a better **GOF** may be achieved. Generally, roughness is only present when the sample surface 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.

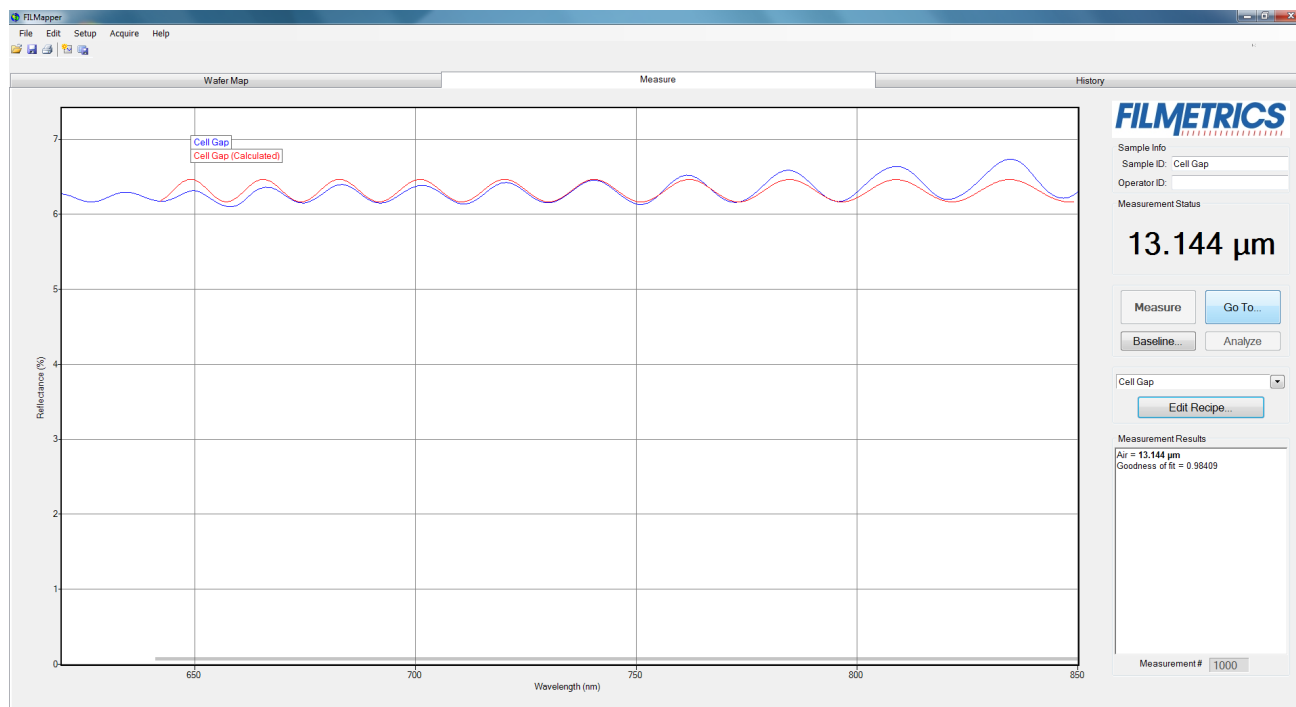
3.4.2 Restricting the wavelength range of the analyzed reflectance spectrum

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.

3.4.3 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.

3.5 Troubleshooting: Measurement Results

In all cases it has been assumed that the user has read the section, and that each criterion has been met.

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

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 FFT 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. Another possible cause is found in [Case #3](#) (incorrect dispersion).

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

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 [FFT \(thickness only\)](#) solver, this is when the measured intensity peaks overlap. See the [Goodness of Fit](#) and [Troubleshooting - Thickness Modeling](#) sections for more information.

4.2 Fast Fourier Transform Mode (FFT Mode)

The FFT mode tends to be more robust when measuring very thick films or thick multi-layer stacks, where the total thickness is greater than 5 microns.

The **Measure Tab** shows a split screen with the measured spectrum on the top graph and the FFT spectrum on the bottom graph.

In FFT mode, instead of matching the measured reflectance spectrum with a calculated reflectance spectrum, FILMapper identifies the peaks in the FFT Spectrum and uses them to compute the layer thicknesses. The number of possible FFT peaks is $n*(n+1)/2$ where n is the number of layers. Thus, for a two layer structure, we expect to see three peaks in the FFT spectrum.

The image above shows the screen just after measurement of a two layer stack using FFT mode. The upper graph shows a blue curve representing the reflectance spectrum of the sample. The lower graph shows a blue and red FFT spectrum. The blue FFT spectrum is computed from the measured reflectance. The red FFT spectrum is computed from the theoretical reflectance spectrum of a layer stack with the measured layer thicknesses. The small side lobes visible on either side of the two tall peaks are artifacts of the FFT process and can generally be ignored. The only time the side lobes will cause a problem is if a weak peak from a multi-layer sample is very close to a much stronger peak. If this case occurs FILMapper may lock onto one of the side lobes by mistake and it may not be possible to measure the layer thickness associated with the weak peak. Reducing the **Constraint** and/or increasing the guess for the thickness for the layer with the weak peak may be helpful in getting FILMapper to lock onto the weak peak. If the peak is too weak to reliably measure it is best to change the layer structure definition so that the layer corresponding to the weak peak is eliminated.

Along with the measured layer thicknesses, the **Results** text box displays important information about the measurement. This important information includes the [Goodness Of Fit \(GOF\)](#) and a description of which peaks were used to determine the measured layer thicknesses. In the figure above layer 1 thickness is determined based on the position of the peak located at 4.780 microns and layer 2 thickness is determined using the peak corresponding to layers 1+2 (7.011 microns). Notice that the thickness of layer 2 is not exactly equal to $7.011 - 4.780 = 2.231$ microns. FILMapper computes a thickness for layer 2 of 2.113 microns because it precisely accounts for the fact that layer 2 has a different refractive index than layer 1.

Discussion of GOF:

A perfect match between measured and theoretical FFT 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](#) settings in **Edit Recipe**. 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 as follows:

- a) **Nonuniformity** – Any variation of layer thickness within the measurement spot will result in a reduction in the FFT peak heights. In order to permit easy visual interpretation of the FFT results FILMapper always scales the amplitude of the red curve so that it matches the blue curve. However, if the scaling factor is not 1.0, FILMapper reports a reduced GOF even if the red curve appears to exactly match the blue curve on the screen.
- b) **Incorrect Structure Definition** – If the refractive index of one or more layers in the structure is different from what is described in the layer structure, then the FFT peak amplitudes in the blue curve will not match the peak heights in the red curve. The software will attempt to scale the red curve, but if there is more than one FFT peak present, the scaling will only result in one correct peak height. If you wish to view the impact of changing the refractive index of one or more layers, simply change the refractive index in the **Edit Recipe** dialog box and click **Analyze**. If there is only a single layer you will notice that the GOF will change, but the red curve should not change much. If there are multiple layers in the structure you will notice that the relative peak heights in the red curve will change when you click **Analyze**.

c) **Graded Interfaces** – The amplitude of the peaks in the FFT spectrum depends on both the difference in refractive index at each interface in the layer structure and the sharpness of the interface. In many common samples you will find that there is some degree of layer intermixing at the interface, leading to a weaker than expected reflectance at that interface. The FFT peak(s) associated with the intermixed interface will suffer a reduced amplitude and in severe cases the peaks may disappear entirely.

4.3 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 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:

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.

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

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

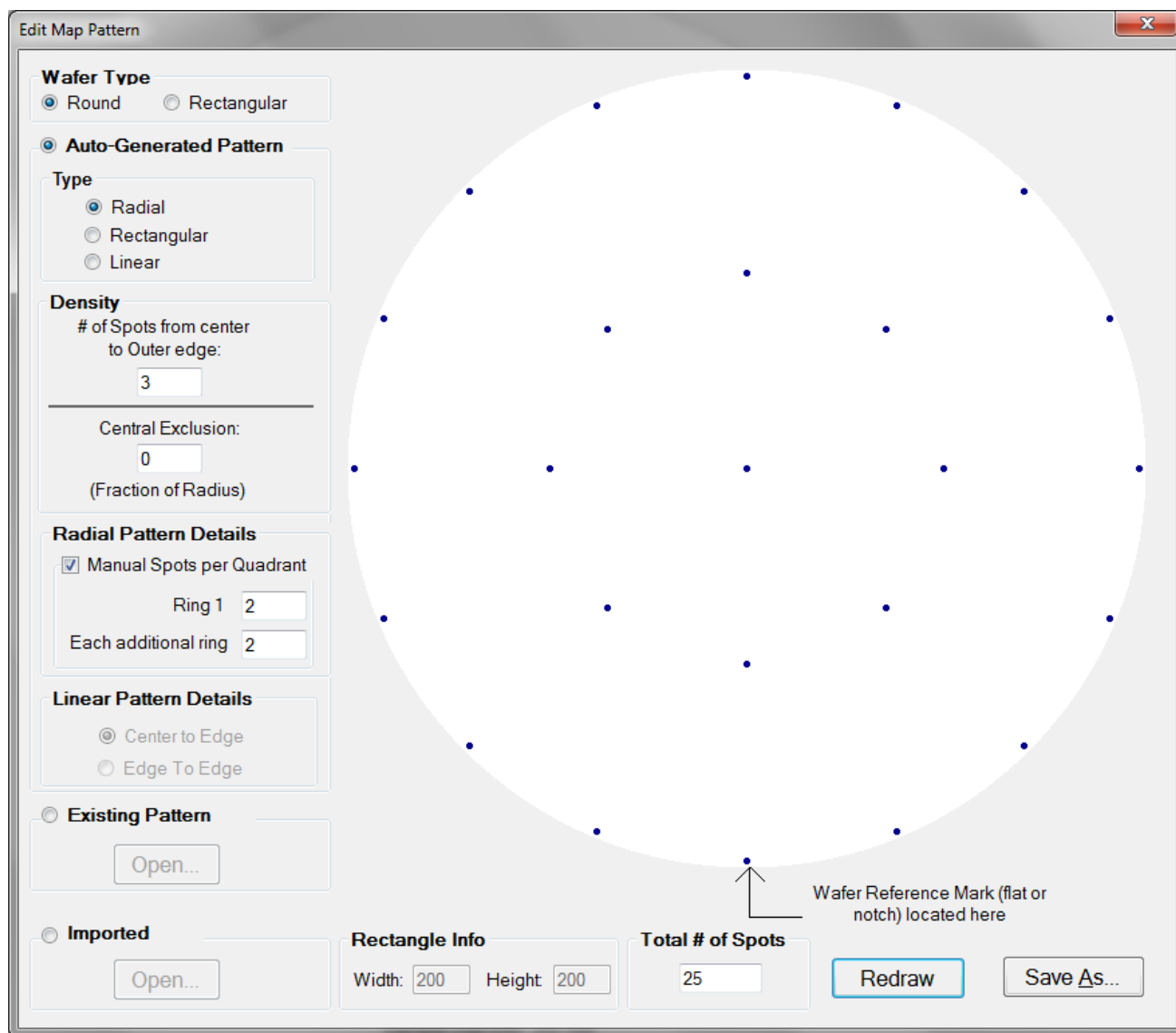
[Using the Map Pattern Generator](#)

[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 [Wafer Map Tab](#) 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 **Round** or **Square** wafer shape.
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 the center and the 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 verify the map is correct.
7. **Save** the wafer map to a file for subsequent use in a **Recipe**.

An **Existing Pattern** can also be opened for editing, or **Import** one that has been [created using Excel](#).

5.2 Editing Map Files Using Excel

Map files can be further edited 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 (.csv). The newly edited file can then be used in 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.)

When prompted to import this file, select **Delimited**, click **Next**, then select **Comma** for the **Delimiters**.

Step 3: Edit map pattern in Excel

Starting in the fourth row, 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 below so that there are no empty rows between values. 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			

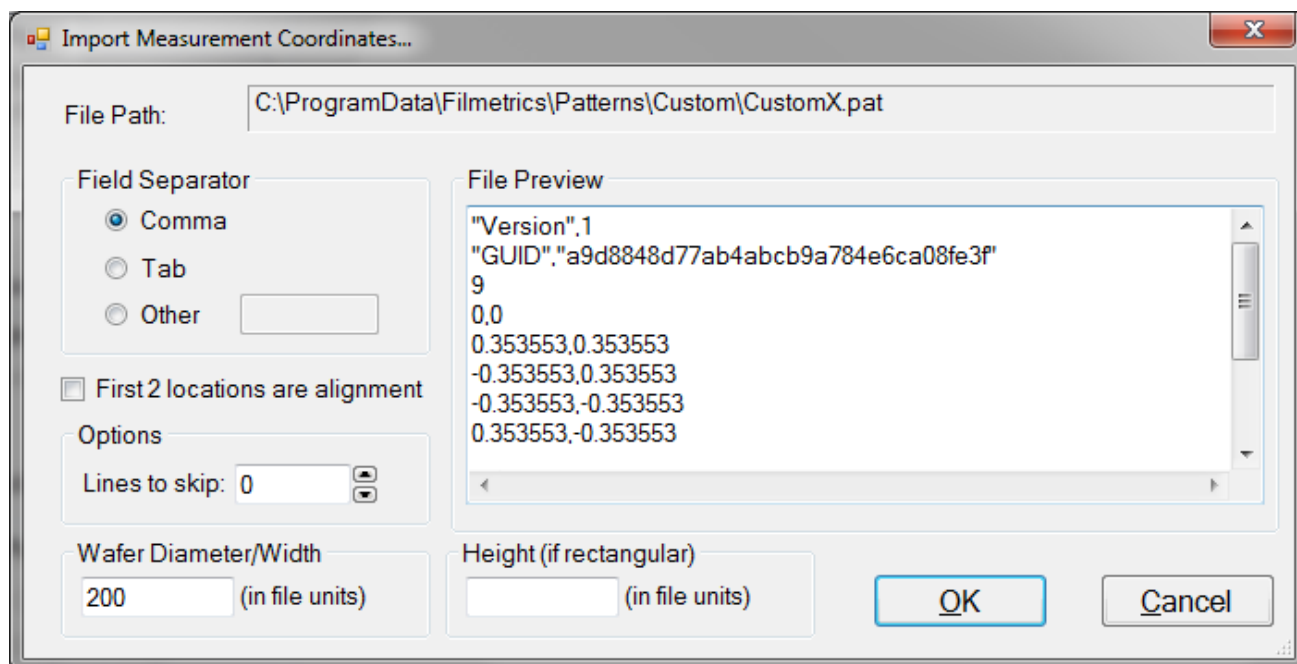
Delete the highlighted cells to leave the desired coordinates.

Step 4: Save map pattern

After the modifications have been made, select **File > Save**. Check that the **File Name** box is **"CustomEdit.pat"** (note: 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)**. Click **Save**.

Step 5: Import the Map Pattern

In FILMapper, select **Edit >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** is also set here according to the values used for the coordinate scale. If fractional values are used, set the Wafer Diameter/Width, and Height for rectangular samples, to 2 (-1 to 1). If whole values are used, enter the sample dimensions. Click **OK** when finished.

Step 6: Save the Pattern File

The new pattern file is displayed in the **Edit Map Pattern** window. Confirm it matches the expected pattern and 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.

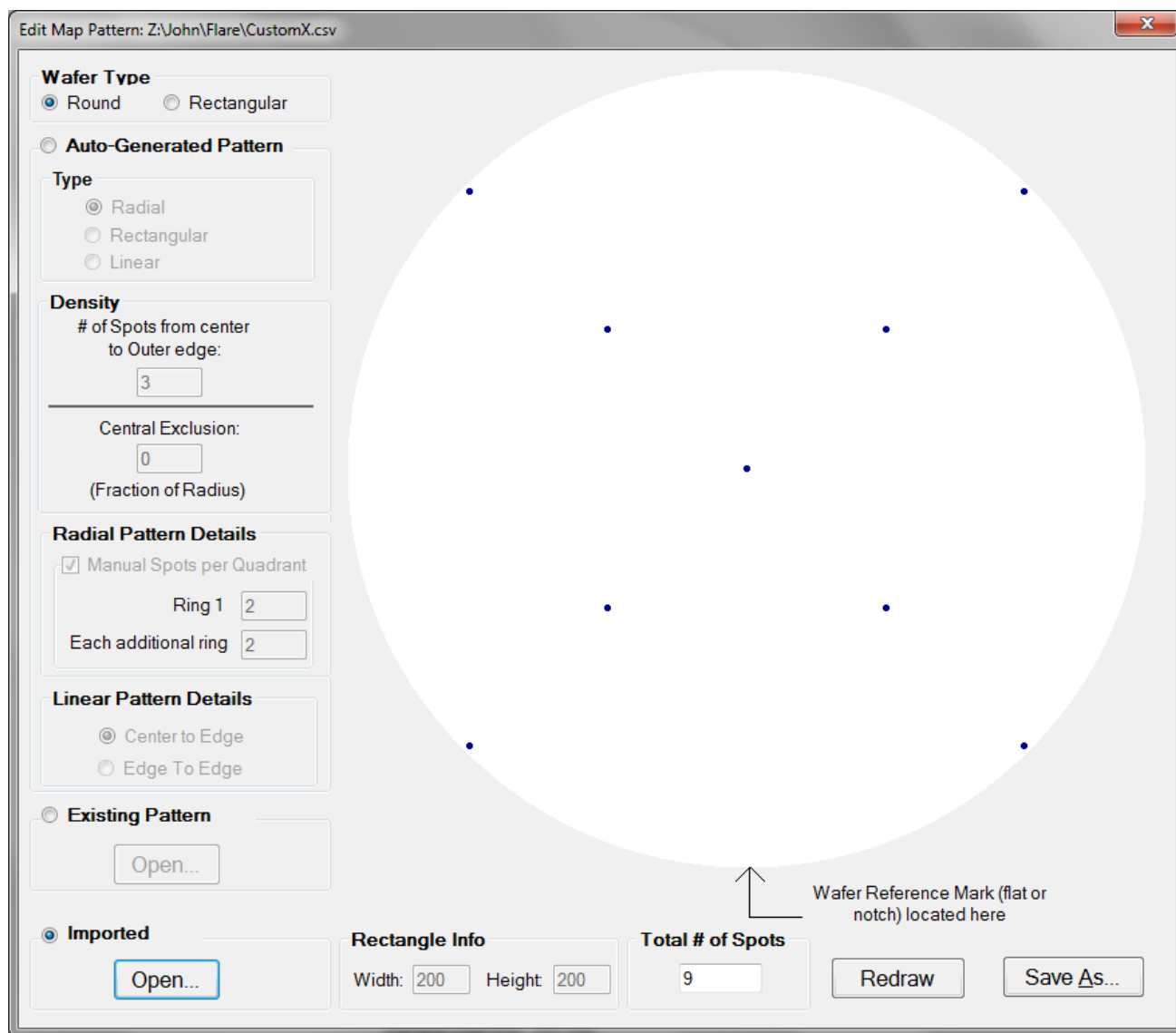


Figure: "X" pattern created using Excel.

Step 7: Load map pattern in FILMapper

In FILMapper, click the **Edit...** button next to the **Recipe** pull-down menu on the Wafer Map tab, or **Edit Recipe** if you are in the Measure tab. Click the [Wafer Map](#) tab in the recipe window and select **Custom** for the **Coordinate System**. All custom map file names will be listed under **Custom Name**. 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 in the recipe.

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

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.

This section describes how the instrument works, as well as the theory the measurements are based on.

[Measurement Theory](#)

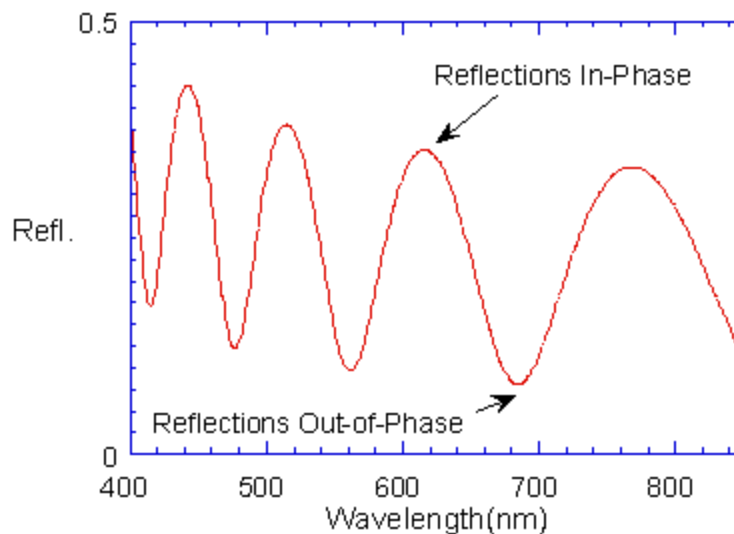
[Thickness Measurement Details](#)

[Hardware Operation](#)

[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 $\lambda = (2 \cdot n \cdot d) / i$, where λ 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 of 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 F54-XY-200 Hardware Operation

The F54-XY-200 performs two distinct functions: data acquisition and data analysis. Data analysis specifics are discussed in [Software Overview](#). In this section we describe how the F54-XY-200 acquires accurate spectral reflectance data.

For systems using the F54-XY-200 internal light source, light is supplied by a tungsten-halogen bulb that generates light from approximately 375 nm to 3000 nm. This light is delivered to and collected from the sample through a fiber-optic cable bundle and a lens. The intensity of the reflected light is measured at different wavelengths with a spectrometer. The F54-XY-200 spectrometer uses a diffraction grating to disperse the light and a linear photodiode array to measure the light at the different wavelengths. After a user-selectable integration time, the accumulated charge in each photodiode is read by the computer. Because a longer integration time results in a larger charge, it is the integration time that determines the sensitivity of the spectrometer. Adjustment of the integration time is used to obtain the proper signal level. Too short of an integration time results in a weak, noisy signal, while too long of an integration time results in a saturated signal.

6.4 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.

Performance Specifications

Measurement Specifications	F54-XY-200-UV	F54-XY-200-UVX	F54-XY-200	F54-XY-200-EXR	F54-XY-200-NIR
Thickness Range with 5X Objective*	-	-	20 nm-40 μm	20 nm-120 μm	100 nm-40 μm
Thickness Range with 10X Objective*	4 nm-35 μm	4 nm-115 μm	20 nm-45 μm	20 nm-115 μm	100 nm-115 μm
Thickness Range with 15X Objective* ¹	4 nm-35 μm	4 nm-115 μm	20 nm-45 μm	20 nm-115 μm	100 nm-115 μm
Thickness Range with 50X Objective* ¹	-	-	20 nm-2 μm	20 nm-4 μm	100 nm-4 μm
Min. Thickness to Measure n and k* ²	50 nm		100 nm		500 nm
Accuracy*: The Greater of ¹	1 nm or 0.2%		2 nm or 0.2%		3 nm or 0.4%
Precision ³	0.02 nm				0.1 nm
Stability ⁴	0.05 nm				0.12 nm

General Specifications					
Spectrometer Wavelength Range:	190-1100 nm	190-1700 nm	380-1050 nm	380-1700 nm	950-1700 nm
Light Source:	External D2 + Halogen		Internal Halogen		
Dimensions:	472 mm x 561 mm x 391 mm				
Weight:	26.3 kg				
Power Requirements:	100-240 VAC, 50-60Hz, 1.3A				

Spot Size	500 μ m Aperture	250 μ m Aperture	100 μ m Aperture
5x Objective:	100 μ m	50 μ m	20 μ m
10x Objective:	50 μ m	25 μ m	10 μ m
15x Objective:	33 μ m	17 μ m	7 μ m
50x Objective:	10 μ m	5 μ m	2 μ m

200mm Chuck	
Sample Size:	\leq 200mm diameter
	5 points - 5 sec
Speed (Typical with Vacuum Chuck):	25 points - 14 sec
	56 points - 29 sec

Computer Requirements	
Processor Clock Speed:	1.4 GHz min
Interface:	USB 2.0

Operating System

PC: Windows 10 (64-bit)

Mac: OS X Lion - Latest Mac OS running Parallels

* Material dependent

¹ Reflective objective

² Using 5X objective

³ 1σ of 100 measurements of $1\text{ }\mu\text{m SiO}_2\text{-on-Si}$. Value is average of 1 over 20 days

⁴ 2σ of daily average of 100 measurements of $1\text{ }\mu\text{m SiO}_2\text{-on-Si}$, measured over 20 days.

Light Bulb Replacement

NOTE: These instructions apply to VIS, NIR, and EXR systems only. For UV and UVX systems, please see the separate users manual for the external light source.



*** * Warning: * * Hazardous voltages are present within the unit. Never attempt any maintenance without disconnecting the power cord.**

Step by step:

1. Exit FILMapperprogram and turn off your computer.
2. Disconnect power cable from the F54-XY-200 from the back of the unit.
3. Open the *Light Source Access* by unscrewing the two screws on the back panel.

*** * Warning: * * Caution, avoid touching any interior components, other than the lamp, lamp base, and housing.**

4. Loosen lamp set screw (counter clockwise to loosen).
5. Insert new lamp fully into lamp housing. Do not touch the lamp glass.
6. Secure lamp with setscrew (clockwise). Do not over tighten.
7. Plug new lamp into the lamp power connector. Do not test lamp with lid removed.
8. Replace the assembly into the *Light Source Access* opening and fasten the screws. Insert cord into wall supply and test light.
9. The lamp should illuminate and the fan should turn when power is restored. The light switch on the front of the F54-XY-200 box must be turned on.

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