

# FILMETRICS F10-RT-UVX

Version: October 29, 2024

FILMETRICS F10-RT-UVX is a thin-film analyzer system. The Filmetrics system illuminates a sample with a halogen and deuterium Lamps from 190 nm to 1700 nm with an effective measurement range from 1 nm to 150  $\mu\text{m}$ . This is supplied via a fiber optic cable from an external light source. The light reflected by the sample is then captured by the FILMETRICS unit. The reflectance and transmittance spectrum of the sample is compared to an internal mathematical reflectance and transmittance spectrum for the given sample. A calculated curve is fitted to the measured curve and the corresponding thickness of the calculated model is reported. **This technique is dedicated mainly for transparent and defined refractive index samples.**



## F10-RT-UVX System Specifications

Wavelength range	190–1700 nm
Wavelength accuracy	0.5 nm
Wavelength reproducibility	0.1 nm
Wavelength resolution	2.5 nm
<b>Thickness measurement range</b>	<b>1 nm – 150 <math>\mu\text{m}</math></b>
Min thickness to measure $n$ & $k$	50 nm
Accuracy	1 nm or 0.2%
Precision	0.02 nm
Stability	0.05 nm
Eternal light source	D2+Halogen
<b>Probe spot size</b>	<b>6 mm</b>
Sample orientation	face down
Lamp warmup time for high precision	15 min

## Performing a Measurement

① Switch OFF the yellow room light, use only the white room light.

② Switch ON the F10-RT-XUV system and Switch ON light source, the switches located in the back side where ON/OFF marks are taped.

Switch ON Halogen Lamp, Deuterium Lamp and the Shutter, all three must be always ON during measurements.

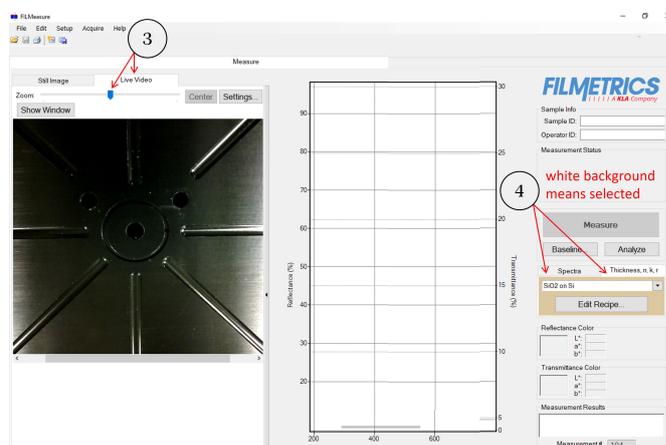
Light source button on the front panel of the FILMETRICS should be ON (never switched OFF).

The light source should be allowed to stabilize at least 10-15 minutes for high precision before the baseline is taken.

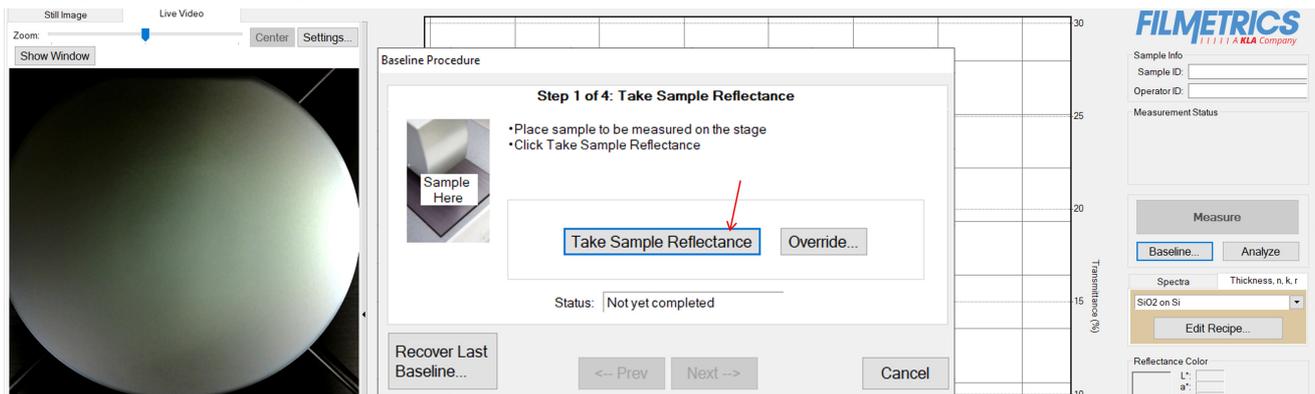
③ Start the software FILMeasure, press Live Video (adjust the camera only when the software is newly installed), camera zoom should be about the middle, by default you will have the last camera adjustment, do not change it.

In the software you have possibility to measure Spectra (Reflectance and Transmittance) or Thickness. By default, it will be on the mode used lastly on the software.

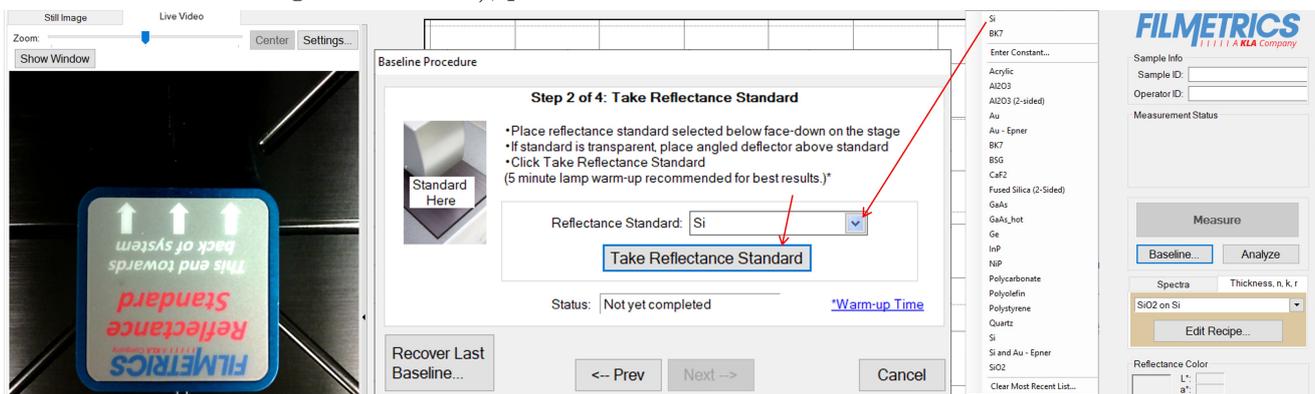
④ Go to **Thickness,  $n$ ,  $k$ ,  $r$  mode**. Press **Baseline** (baseline measurement must be done every time you switch ON the system, software will guide you), 4 of 4 step message will start communicating with you. This is to define the reflectivity of the sample(s) and can be used for all measurement during the day.



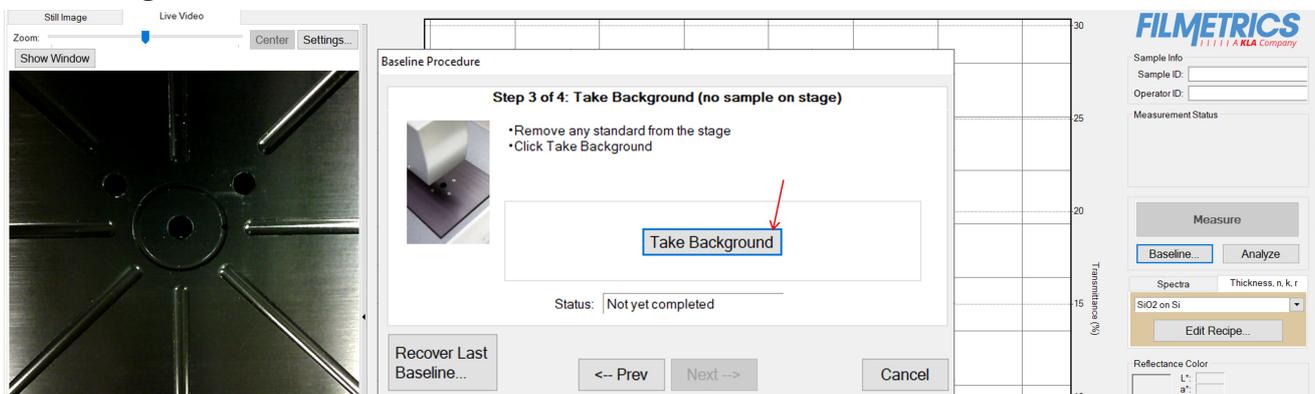
**Step 1 of 4: Take Sample Reflectance**, put your sample on the stage, in this case a SiO<sub>2</sub> on silicon wafer, press **Take Sample Reflectance**.



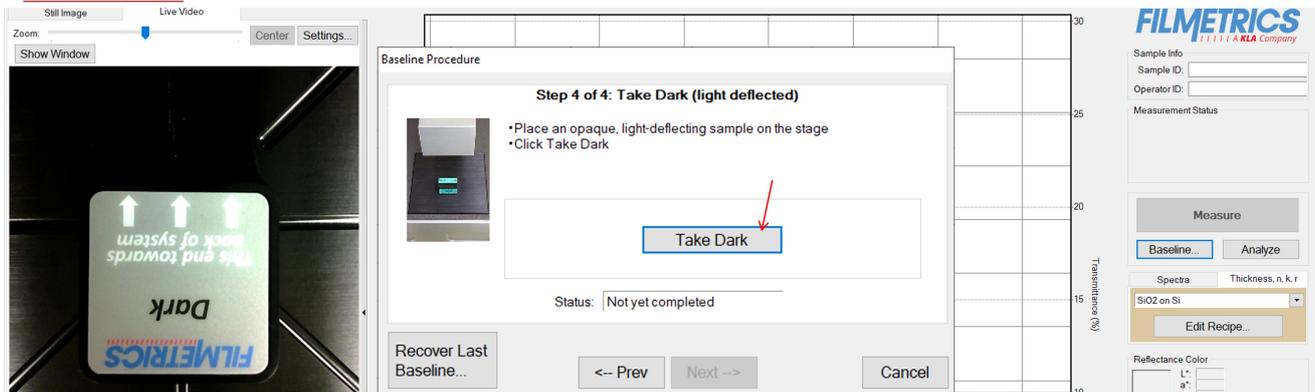
**Step 2 of 4: Take Reflectance standard**, chose Reflectance Standard from the list (Si for silicon substrate and BK7 for glass substrate), press **Take Reflectance standard**.



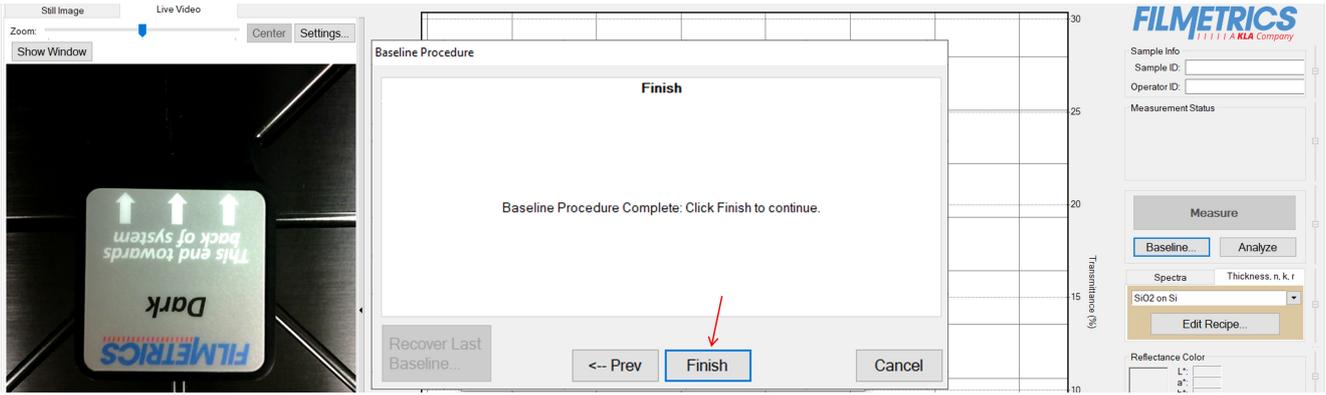
**Step 3 of 4: Take Background**, remove the standard from the stage (nothing on the stage), press **Take background**.



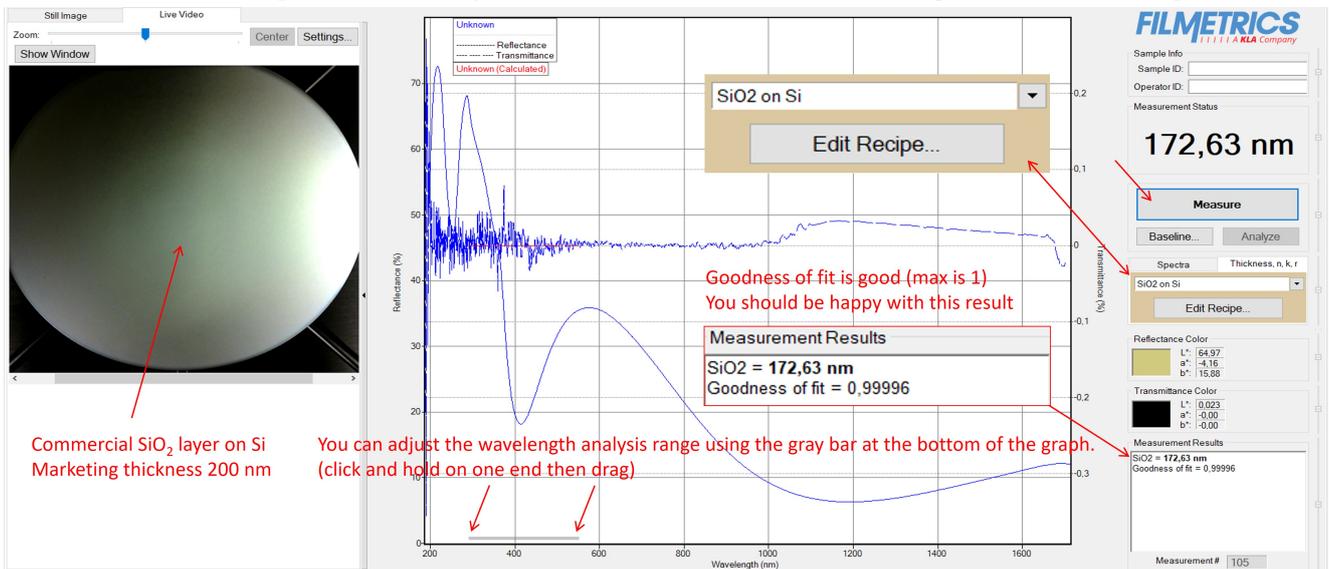
**Step 4 of 4: Take Dark** (light deflected), place Dark standard on the stage , press **Take Dark**.



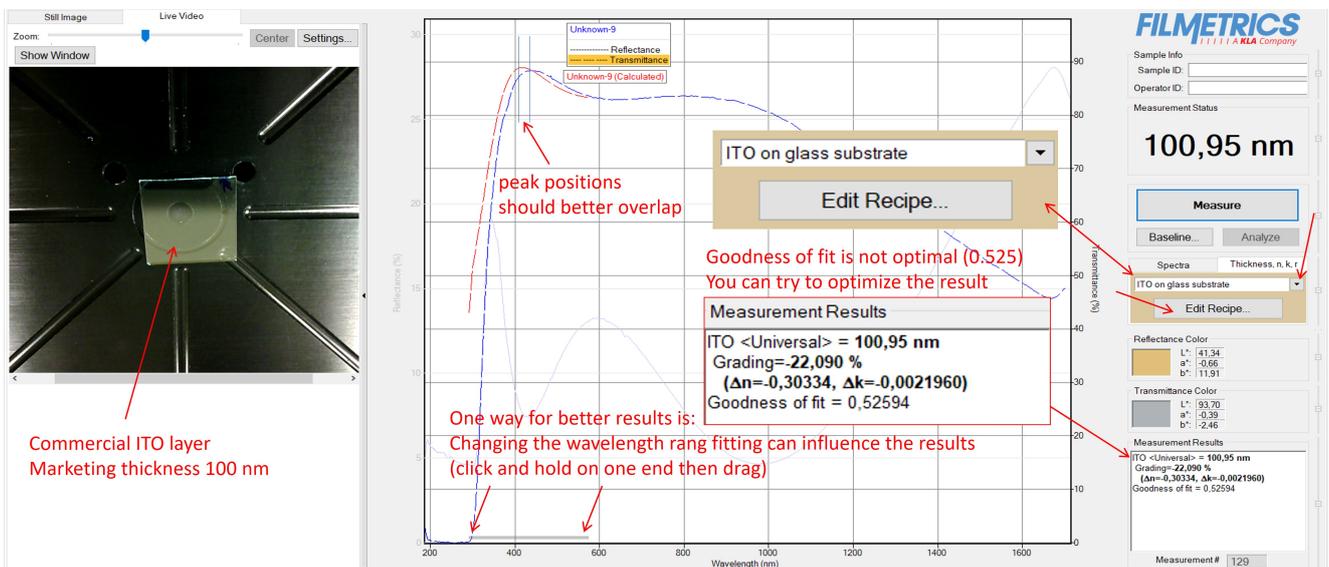
When done press **Finish**, only now the **Measure** button is activated.



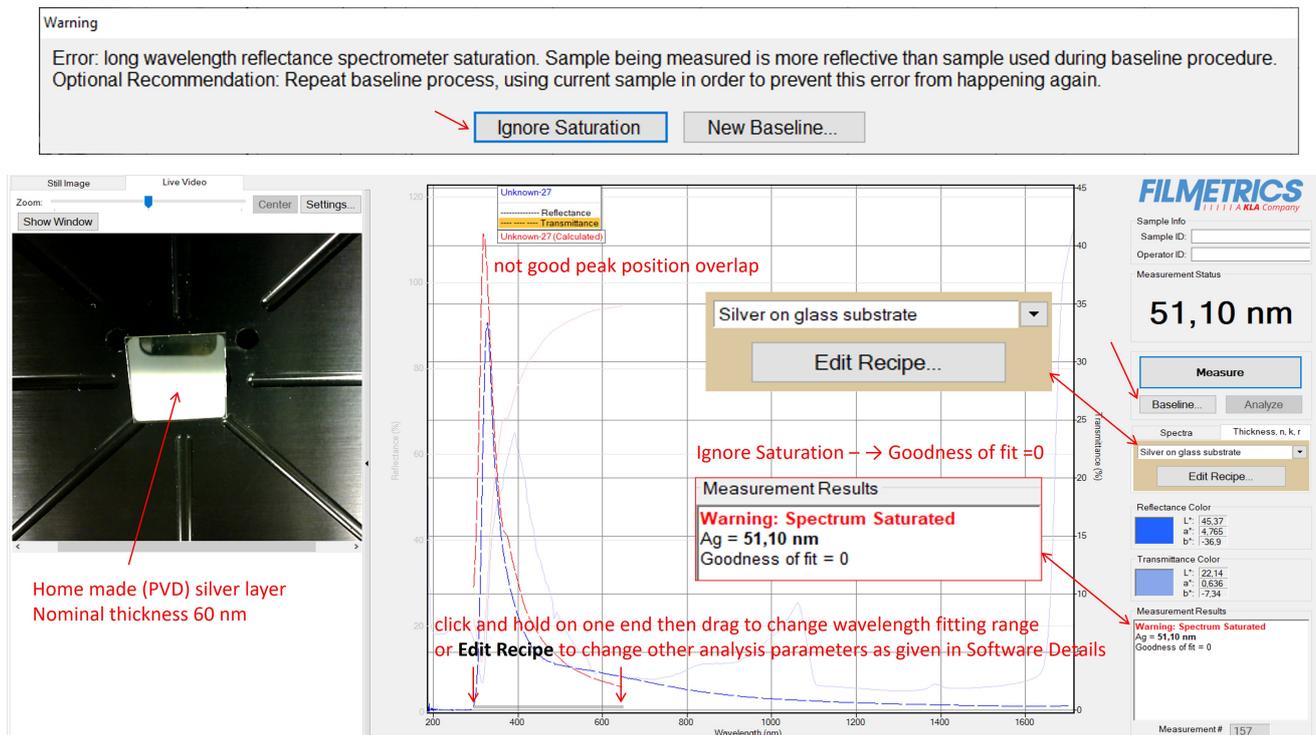
⑤ Remove Dark standard and do a test measurement, put Si sample on stage, select  $\text{SiO}_2$  on Si and press **Measure**. Both **Reflectance** and **Transmittance** spectra and the layer thickness will appear on the screen. The measurements Results will appear on the right/down corner " $\text{SiO}_2=172,63$  nm, Goodness of fit= $0.99996$ ". It is possible to analyze the data if the thickness deviating much from the expected value.



⑥ Now you can measure thickness of other samples (**surface down**), like ITO on glass substrate or metal layers on glass. You have to **Select Recipe** (choose any pre-written recipe) directly from recipe menu just above Edit Recipe, finally press **Measure**. It is possible to compare the measured spectra with Reflectance or transmittance calculated spectra. Measure on different points on your sample.



⑦ Probably you will get a warning message when measuring on highly reflective layer, as below, you may repeat **Baseline** measurement procedure as described earlier (the software will guide you to repeat Baseline from Step 2 of 4) by using a more reflective standard than provided with the system (silver or gold mirror) or you **ignore** the warning, you may still get a good result but with no fitting results, as below. New baseline can be taken even later by pressing **Baseline** button.



⑧ When you are done with the measurement: Close the software and power OFF the light source and the FILMETRICS unite from the backside switches. Do not turn off the computer.

## Software Details

### The Edit Recipe Window (Thickness, $n$ , $k$ , $r$ mode)

The Edit Recipe window is used to define the film stack and to set analysis and acquisition parameters, all for better thickness results.

① These buttons allow you to (from left to right): Open a saved recipe, Start a new recipe, Save the current settings, Save the current settings as a new recipe, Delete the current recipe.

② Opens a drop-down list for quick access to saved recipes.

③ Allows you to select between **Film Stack**, **Analysis Options**, **Alarms**, & **Acquisition Settings** tabs.

**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, it is best suited for measuring the thickness of single-layer films greater than 150 nm thick) or **FFT** (Thickness Only) is checked (Requires UPG-RT-to-Thickness), only the Data Selection settings will be accessible.

④ The desired thickness units ( $\text{\AA}$ , nm,  $k\text{\AA}$ ,  $\mu\text{m}$ ) are chosen here.

⑤ Here the materials and parameters to be solved are defined (important when new recipe is defined). When measuring a layer of the known material, the incident medium, layer-material and substrate must be entered into the proper fields in the Edit Recipe dialog box.

⑥ Multiple layers can be measured (up to 4 layers). Additional sections to the recipe can be defined by pressing the  $\oplus$  button, and unwanted sections can be removed by pressing the  $\otimes$ .

⑦ For F10-RT-UVX systems with the thickness upgrade (as ours) you can measure layer thickness based on  $n$  and  $k$  values, if this option is chosen the main FILMeasure screen will show both the acquired spectrum and the dispersion curves for both  $n$  and  $k$ .

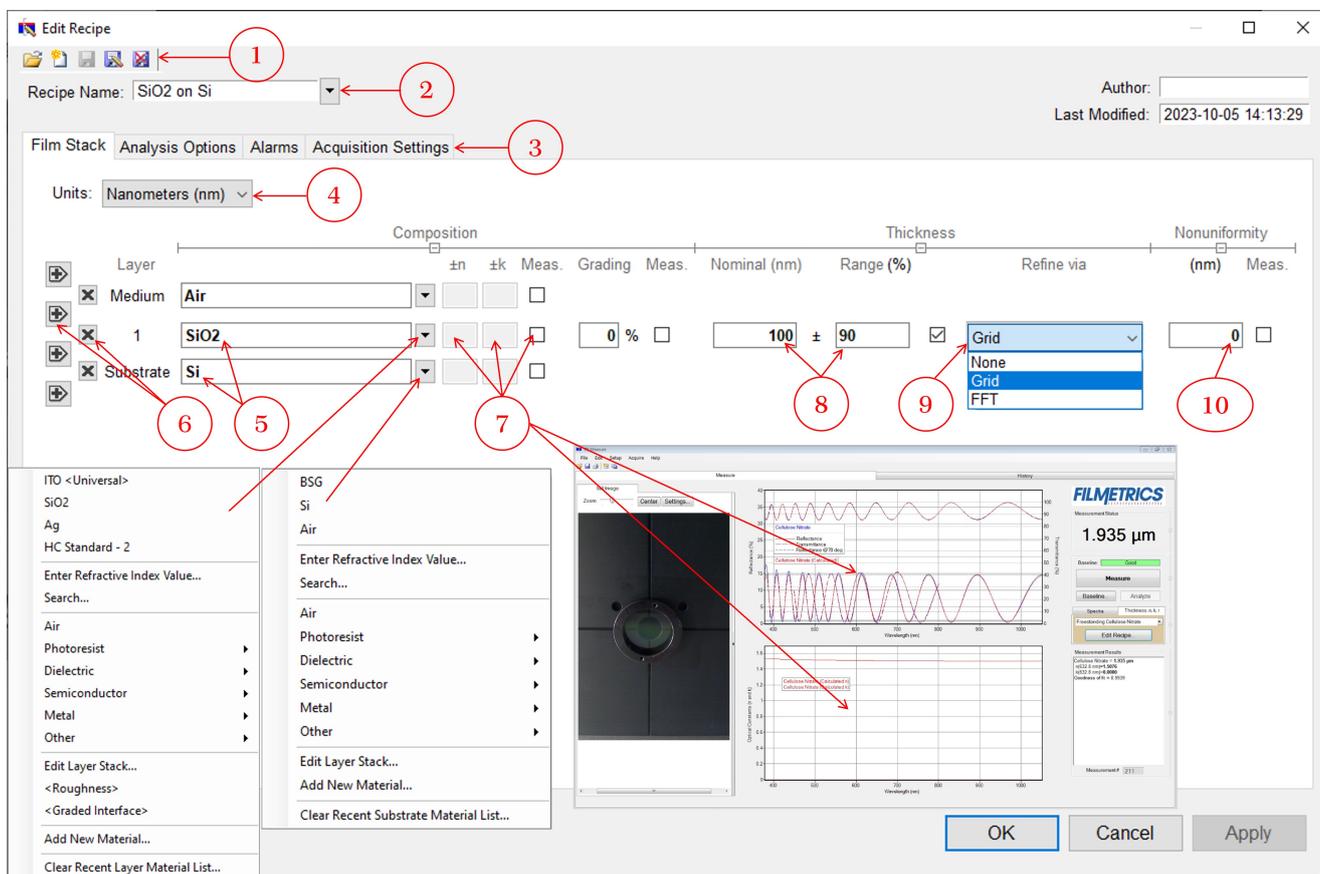
If only thickness is measured, then the dispersion curves are not displayed (as in the snapshots in steps 5 to 7 in previous section), and the main window will look the same as the F10-RT-UVX with the thickness upgrade only.

If this function desired, click on **Meas.** and enter the  $n$  and  $k$  values. 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.

8 When measuring a layer thickness, the nominal thickness of the known films must be entered into the proper fields in the Edit Recipe dialog box, this can be like an initial guess for the values to be measured, the rang % can set high as 90%.

9 Choose any initial thickness for analysis or measuring thickness when the approximate thickness is not well known. Unless otherwise specified, FILMeasure 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 **FFT** of determining approximate thickness may be applied. See Editing Film Structures (page 35 in official manual) for more details. Fourier Search for Thickness: The **FFT** option in the Refine via drop-down list is an alternative option to let FILMeasure 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.

10 Selecting the **Nonuniformity** 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.



### The Edit Recipe Window (Spectra Mode)

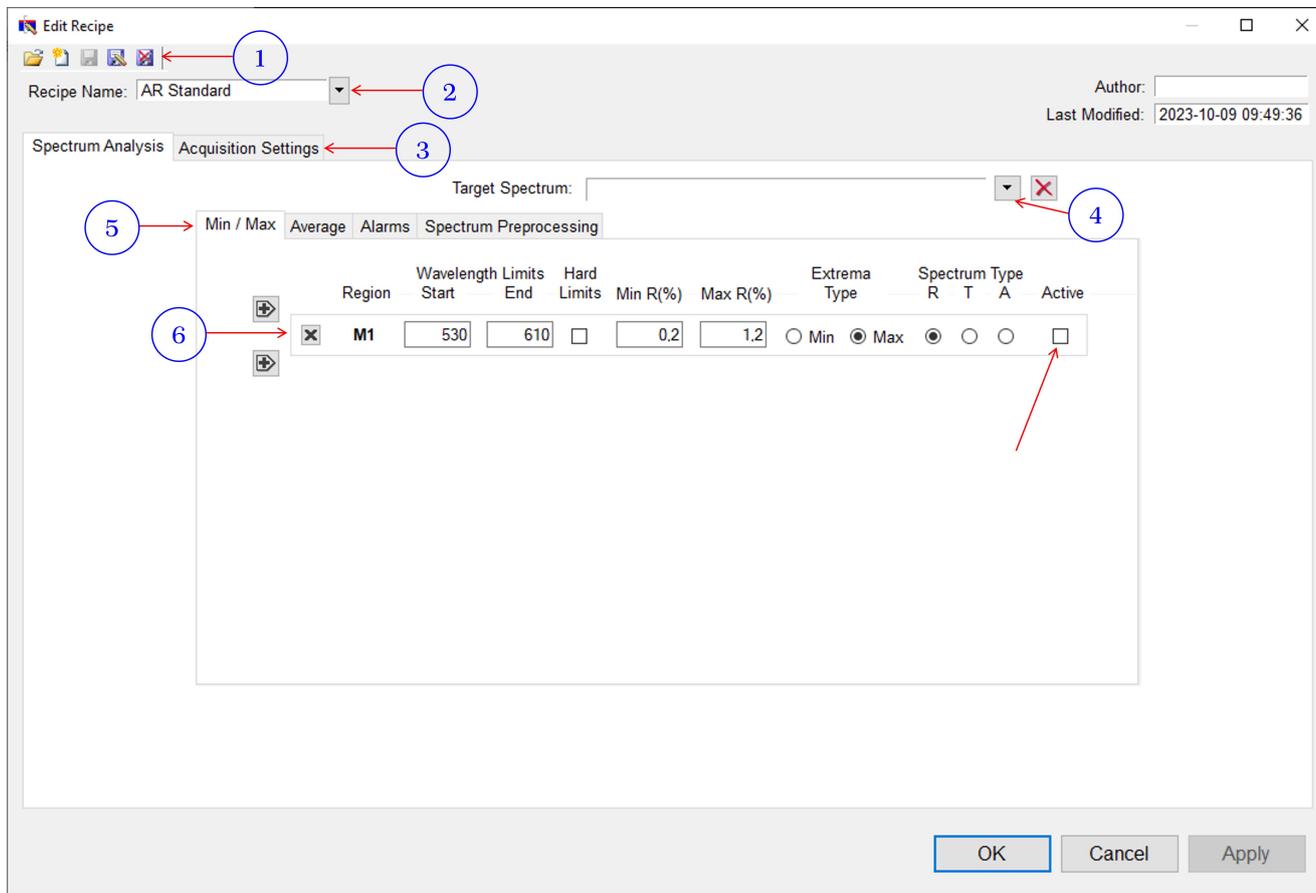
- ① These buttons allow you to (from left to right): Open a saved recipe, Start a new recipe, Save the current settings, Save the current settings as new recipe, Delete the current recipe.
- ② Opens a drop-down list for quick access to saved recipes.
- ③ Allows the user to select between the Spectrum Analysis and Acquisition Settings tabs.
- ④ Users can select a representative or Target Spectrum to compare newly acquired spectra to. The selected spectrum will appear in the main FILMeasure screen.
- ⑤ Allows the user to switch between the Min/Max, Average Reflectance, Alarms, and Spectrum Preprocessing tabs.

**Average:** When analyzing spectra, it is useful to know the average reflectance at certain wavelength ranges. The **Average Reflectance** tab of the Edit Recipe window allows the user to define areas for analyzing average reflectance. Desired wavelength and reflectance ranges entered in the recipe will show up as labeled boxes with solid outlines in the main graph window. Results that fall outside these windows will trigger an alarm to alert the user that the measurements are outside of the desired range. The region will not be analyzed until the corresponding **Active** checkbox is selected.

**Min/Max:** Local minima and maxima can be found by inputting values in the proper dialog boxes. The **Region** refers to the label that will be appended to the dataset as defined by the values entered in recipe.

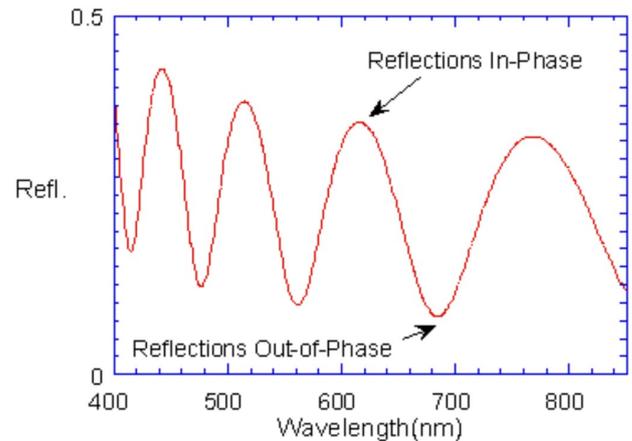
**Wavelength Limits Start** and **End** are used to set the wavelength range over which to find the minima and maxima. To set minimum and maximum reflectance criteria, values can be entered into the **Min R** and **Max R** boxes (1=100% reflectance if Y axis as percent is disabled underneath **Graph Limits**). If there isn't a minima or maxima within the range selected, **Hard Limits** can be enabled to show the highest or lowest point within the defined range. Selecting **HC Correction** will account for the effect of a hardcoat on the spectrum if a film is present. The region will not be analyzed until the corresponding **Active** checkbox is selected.

- ⑥ Controls for the currently selected spectrum analysis mode are shown here. Specifics on how to use these controls can be found under Editing Film Recipes → Spectrum Analysis.



## Measurement Theory

The instruments measure thin-film characteristics by either reflecting 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  $\lambda = (2nd)/i$ , where  $\lambda$  is the wavelength,  $n$  is the refractive index,  $d$  is the film thickness, and  $i$  is an integer). The result is characteristic intensity oscillations in the reflectance spectrum (see figure). In general, the thicker the film, the more oscillations there are in a given wavelength range.



## 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, FILMeasure calculates a reflectance spectrum that matches as closely as possible the measured spectrum. FILMeasure 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 FILMeasure varies the parameters it is solving for until the calculated reflectance spectrum matches the measured data. Mathematically, this procedure is complicated by the fact that as the thickness of the films in the calculation is varied there can be many near matches. Therefore, an approach that simply homes in on a solution by finding successively better approximations will not work unless the starting guess for optical thickness is within approximately 1000 Å if the actual thickness.

FILMeasure 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 for the thickness of the films to be measured.

## The Baseline Measurement

The baseline measurement allows the FILMeasure 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, FILMeasure 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

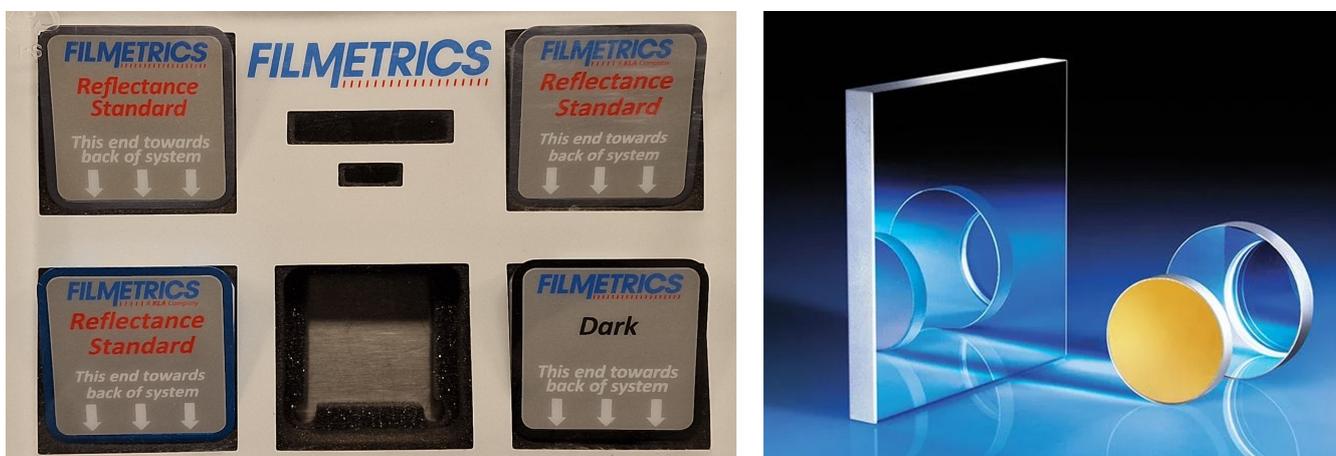
spectrometer when a sample of zero reflectance is measured. To simulate a sample with zero reflectance during a “dark” measurement, a specularly reflecting sample can be held at an angle with the light source turned on, or in many cases the light source may simply be turned off momentarily during the dark measurement.

Due to drift in the light source and temperature of the spectrometer electronics, it is a good idea to take a baseline periodically.

## Reflectance standards

To **Take Reflectance Standard** as in **Step 2 of 4 of Baseline** measurement. A selection of reflectance standards are provided with the system. Which reflectance standard should be used depends on the sample to be measured. In general **BK7** can be used for films with a max reflectance of 0-12 %, **Si** for films between 12-60 % reflectance, **Fused-silica** for films with reflectance 60-90% and **Al** for samples 60-100 % reflectance. The reference material file that corresponds with the Reflectance Standard used should be selected from the drop down list.

Currently Al reflectance standard is not available, instead you may use one of the mirrors below.



## Reflectance standards (Mirrors)

Dimension (mm)	Thickness (mm)	Coating (type and thickness)	Coating specification
25.0 × 25.0	3.00	Enhanced Aluminum (450-650nm)	$R_{avg} \geq 95\%$ @450-650nm @45°
25.0 × 25.0	3.00	Protected Silver (450-10000nm)	$R_{avg} \geq 98\%$ @450-10000nm
25.0 × 25.0	3.00	Protected Gold (700-10000nm)	$R_{avg} \geq 96\%$ @700-10000nm
			$R_{avg} \geq 98\%$ @2000-10000nm

Iron 65%, magnesium 74%, aluminium 70%, silicon wafers reflect around 55% of 800nm

## Maximum thickness able to measure for different materials

Metal	Max Thickness	approx. %T Peak position (nm)
Ag (Silver)	360 nm	320
Ti (Titanium)	260 nm	1700
Cr (Chromium)	230 nm	1700
Au (Gold)	200 nm	500
Cu (Copper)	135 nm	575
Al (Aluminum)	53 nm	900
Nb (Niobium)	135 nm	750
W (Tungsten)	133 nm	1500