

DESIGN Version 2.30

FILM★STAR

for 32-bit Microsoft Windows

Advanced Optical Thin Film Technology from



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Associates**

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User Guide

Getting Started

Installation

FilmStar requires an IBM-PC compatible running 32-bit Microsoft Windows. 128 MB or more is recommended. To install from CD-ROM, run **..install\setup32.exe** from Start... Run. A password is required. NT/2000/XP users need Administrator privileges. Setup will not overwrite previous data files.

Complete installation as well as update files can be found at

<http://www.ftgsoftware.com/updates.htm>

Please visit this page often to keep your software up-to-date. If you have initial problems installing or running the software your solution may be already be at the Technical Issues page

<http://www.ftgsoftware.com/issues.htm>

A Security ID Module must be attached to the parallel or USB port.

<i>When installing with USB Security ID Module for the first time, DO NOT plug in the module until installation is completed! Windows will automatically locate the new device.</i>

FilmStar provides an extensive set of Help screens. Press <F1> from any menu item or dialog box for context-sensitive help. The help system is identical to this manual's Reference section.

Historical Note

FilmStar 32-bit for Windows (1998) is derived from three previous FTG Software Associates programs: FilmStar for HP-9000 (1981), FilmCalc for DOS (1987), FilmStar 16-bit for Windows (1991).

The organization of the program is adapted from the **DAFT/DAN** (Differential Aadjustment of Film Thickness / Differential Aadjustment of Index) FORTRAN program developed by Dr. AArthur Francis Turner and Bob MacIntyre at Bausch and Lomb in Rochester in the 1960's. This evolved into the now defunct Genesee Films program which was available on Cybernet and later on the IBM-PC.

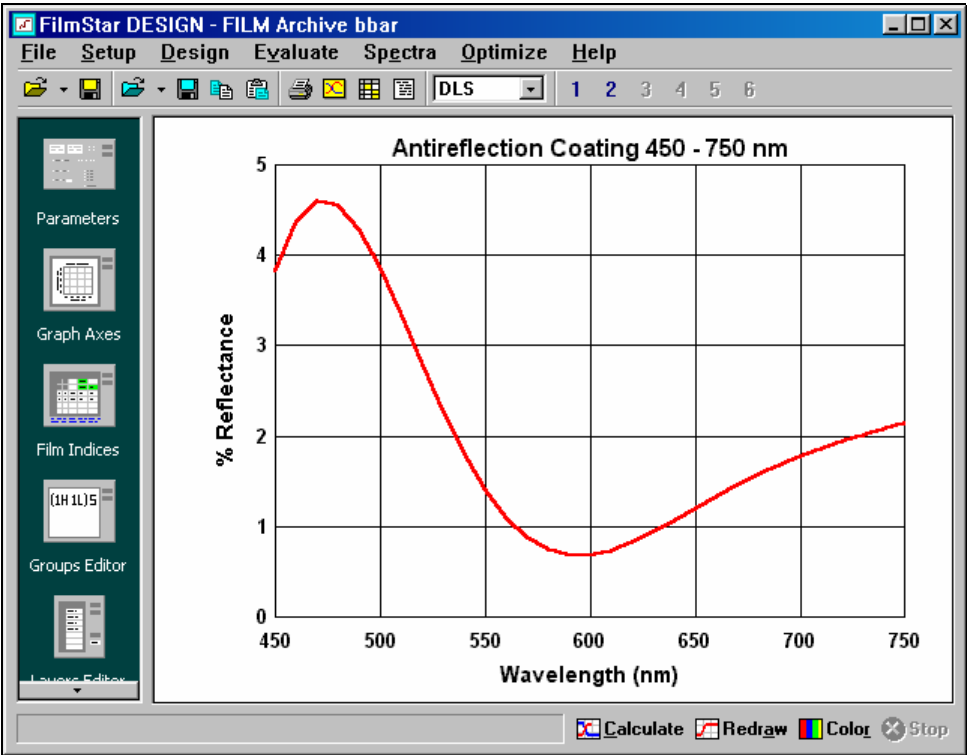
DESIGN Tutorial

BBAR - Example 1

Please be sure that File...FILM Archive Mode is checked

Appearance can be adjusted in File...Toolbars, Spectra...Graph Details & File...Configuration... Preferences.

Assuming that installation has proceeded without difficulty, run FilmStar from the Windows Start menu. Following the welcome screen agreement, the main DESIGN screen appears. Resize the window as necessary. Click **Calculate** <Alt+C> to calculate and plot the spectrum. If it's different from the one below load FILM Archive "bbar" via **File...Open** <Ctrl+F12>.



Starting design for 450-750 nm antireflection coating

Other Review Design formats can be selected.

What was calculated? Click **Design...Review** <Ctrl+R> to display the Review Design screen. The text can be edited, printed to the Windows default printer (set in Control Panel - Printers), or copied to the clipboard and pasted in a word processor document as we did below. Print the review. If it doesn't look right it's possible that a proportional font was selected. Click **Printer** and change to Courier or Lucida Sans Typewriter and try again.

Design Wave 550 nm		FWD ignore Side 2				Angle 0		
Design (from substrate) - FILM Archive bbar								
1 .1H		2 .1L		3 .5H		4 .25L		
Film Indices		Symbols: L,H:QWOT=.25						
Indx	File							
Symb	\$Funct	A(n)	B(k)	C	D	E	F	G
AIR		1.0	0	.	.	.	.	.
SUB		1.52	0	.	.	.	.	.
L		1.46	0	.	.	.	.	.
H		2.3	0	.	.	.	.	.

Layer #1 is next to the substrate.

$QWOT = 0.25$ and $QWOT = 1.0$ are both supported.

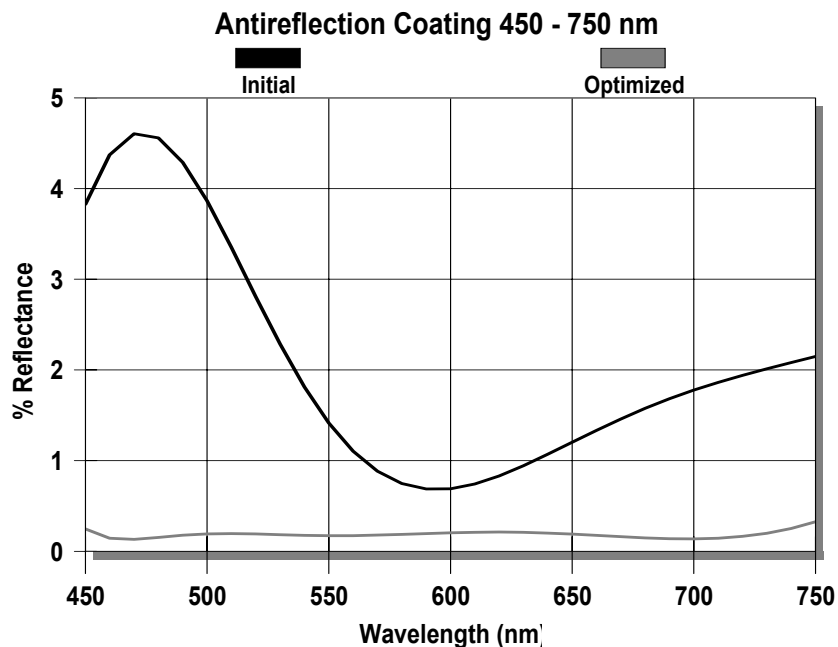
The thin film design $.1H .1L .5H .25L$ is expressed in optical thickness units where $.25$ corresponds to one QWOT (quarter wave optical thickness) at Design Wavelength 550 nm. Each layer includes a numeric value and a one-letter index 1symbol indicating the material index of refraction. The words *Design (from substrate)* remind us that layer 1 is always next to the substrate in DESIGN. Users adapting designs from elsewhere should be aware that layer 1 often refers to the layer next to the entrance medium (air).

The relationship between index symbols and values is given in the table underneath the design. **AIR** (1.0) indicates entrance medium and **SUB** (1.52) indicates substrate. The three materials **L** (1.46), **H** (2.3) and **M** (2.1) also have constant indices. The entry to the right of *Symbols* reminds us that these refer to optical film thicknesses with $.25$ corresponding to one QWOT.

We can improve the antireflection design through optimization (refinement) by clicking **Optimize...Optimize <Ctrl+O>**. The vertical green lines on the screen indicate the location of optimization targets and the X's show current values. Click **OK** to accept default values of 10 iterations and damping = $.671$. At the end of 10 iterations click **Cancel** to return to the Main Menu.

Click **Calculate** to compute the new spectrum. Click **Axes** to draw new axes and replot the spectrum. Click the color button to change the color. Access the Review Design screen to see how optimization has changed layer thicknesses.

Click **Spectra...FSPlot Module <F4>** to access the FSPlot Graphing Module. Click **Plot** to redraw the curve. Return to the Main Menu by clicking in the window or pressing **<Esc>** (as shown below, you can return to FSPlot to add more spectra) or close the FSPlot module with **<Alt+F4>**.

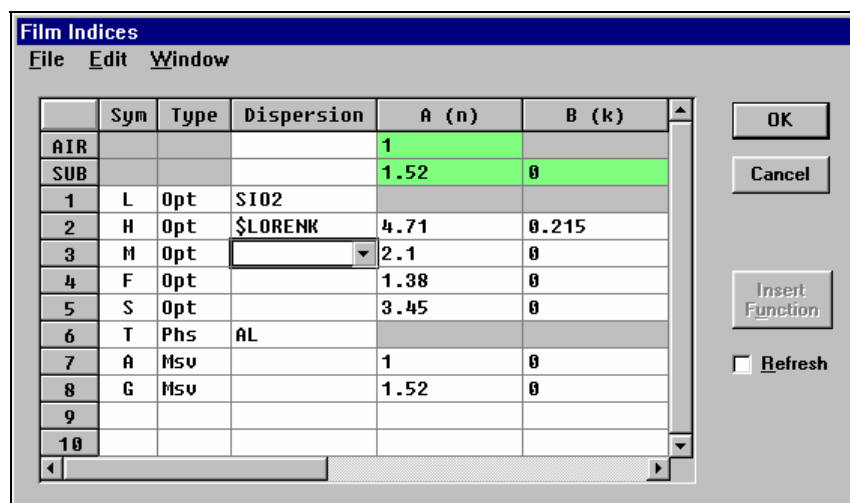


Congratulations, you're now a thin film designer.

Film Indices (see page 37)

Hint: clear the current design before setting up completely new index symbols.

How did we set up the calculation? In general, DESIGN has no "beginning, middle and end". You can do (almost) anything in any order with the exception that *index symbols must be defined in the Index Editor before being used in a design*. While failure to heed this dictum will not crash the program, it will generate the *Design and/or Film Indices error* message. This might happen when you load a design from disk which includes an index symbol not currently defined in the Film Indices editor.



In reviewing how the BBAR problem was set up, we start with the Film Indices editor. Click **Setup...Film Indices <Ctrl+I>** to obtain the dialog box illustrated above. Several FilmStar screens, particularly those with data entry grids, can be resized by dragging edges or by choices in **Window**.

In the grid, use **<Tab>** or arrow keys to move from cell to cell. The grid has the focus when you can see the cell highlight. (**<Ctrl+Tab>** moves the focus from the grid. Or press **<Tab>** in the last editable grid cell.) To edit the contents of a cell, first press **<F2>** or **<Insert>**. To clear a cell press **<Delete>**. Most grids require that you fill each row before proceeding to the next.

DESIGN can automatically convert thickness types.

The **Type** column specifies film thickness type for each index symbol. Select **Opt** for optical thickness, **Phy** for physical thickness and **Msv** for massive thickness in millimeters. The green rows at the top remind you they apply to entrance (AIR) and exit (SUB) media.

To use a dispersive index file or function select from the **Dispersion** list. This list is recreated when ever the Film Indices dialog box is accessed.

For practice, change the index of H from 2.3 to 2.4. Remember to click **OK** instead of **Cancel** in order to keep the change. Return to the Main Menu and recalculate the spectrum. Then select file TIO2 and see the effect.

For further practice, adjust entries in order to reproduce the Review Design screens shown below. If we use a lookup table for H instead of $n=2.3$, the name of the file (i.e. TIO2A appears under **Dispersion** and any numeric values in A-G are ignored. Dispersive tables (n,k vs. wavelength) are created and edited in FilmStar INDEX (not included with the Trial Version).

Indx Symb	File \$Funct	A(n)	B(k)	C	D	E	F	G
L		1.46	0	0	0	0	0	0
H	TIO2A	0	0	0	0	0	0	0

If we use a dispersive index function, the name of the function preceded by '\$' appears under **Dispersion** (i.e. \$LORENK) and the function's coefficients are given in columns **A-G**. We want to use dispersive functions rather than index tables when determining refractive indices from measured data.

Indx Symb	File \$Func	A(n)	B(k)	C	D	E	F	G
L		1.46	0	0	0	0	0	0
H	\$LORENK	4.4398	.45667	336.87	.52305	0	0	0

Groups Design Editor (see page 49)

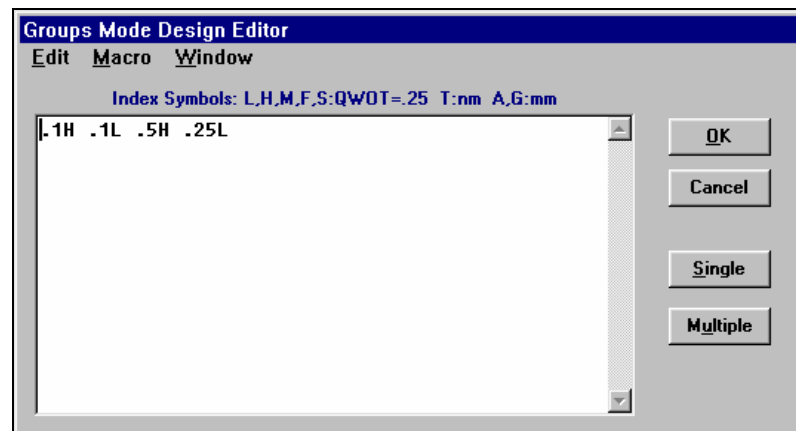
● **Before proceeding, please reload FILM Archive File "bbar".** There may be several prompts asking if you wish to update disk files before proceeding. Click **No** in each case.

From the Main Menu click **Design...Groups Editor <Ctrl+D>** to access the Groups design editor. In this editor layers can be enclosed within parentheses to generate designs such as

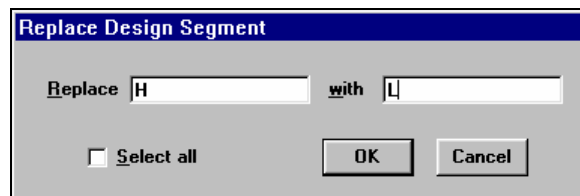
.125L (.25H .25L)10 .288H (.325L .325H)10 .163L

*DESIGN auto
matically converts
.25H .25H to .5H*

The editor works equally well for individual layers. Allowed index symbols (already defined in Film Indices) are displayed on top of the text edit box. Click **Multiple** to display layers on different lines and **Single** to display all layers on one line. The edit box is a normal Windows text box and supports the usual text editing commands.



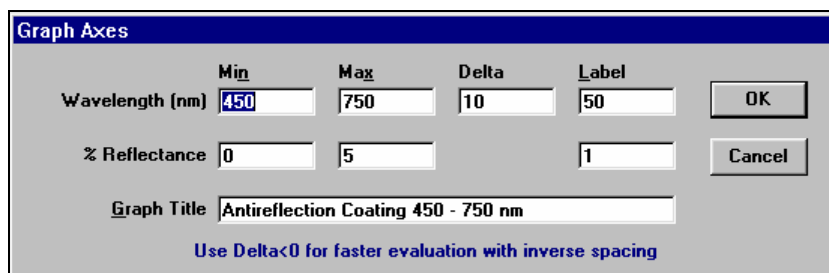
Next, click **Edit...Replace <Ctrl+E>** to activate the Replace Design Segment dialog box. Enter the values shown below and click **OK**.



Upon returning to the design editor click **OK <Enter>** to accept changes or **Cancel <Escape>** to ignore them. If you frequently lose changes by pressing **<Escape>** instead of **<Enter>**, access **File...Configuration... Preferences** and check the box labeled **<Cancel> warning in data editors**. This generates a confirmation dialog box upon pressing **<Escape>**.

Graph Axes (see page 38)

- Before proceeding, please reload FILM File "bbar".

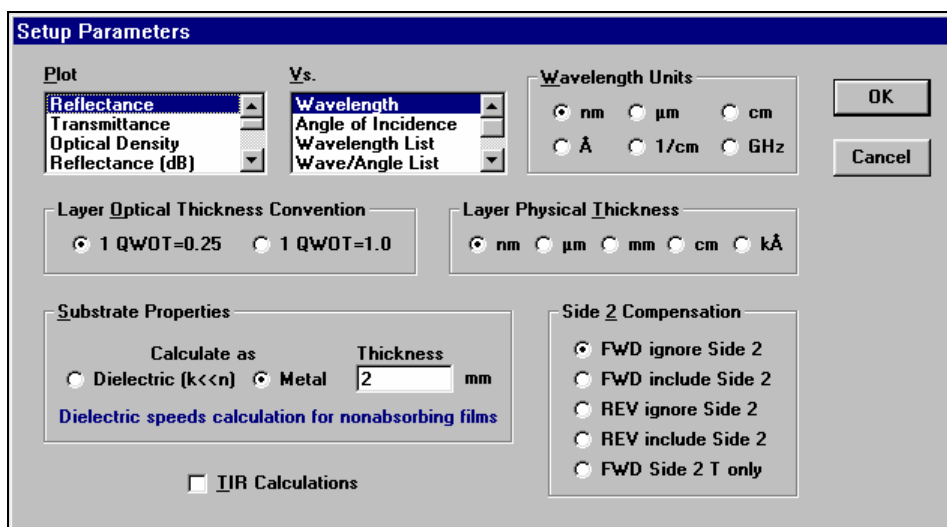


The Graph Axes dialog box has a title bar "Graph Axes". It contains several input fields: "Wavelength (nm)" with "Min" (450), "Max" (750), "Delta" (10), and "Label" (50); "% Reflectance" with "0", "5", and "1"; and "Graph Title" with "Antireflection Coating 450 - 750 nm". There are "OK" and "Cancel" buttons. A note at the bottom says "Use Delta<0 for faster evaluation with inverse spacing".

Click **Setup...Graph Axes <Ctrl+G>** for the Graph Axes editor. Edit fields as shown and click **OK**. Graph axes are automatically redrawn.

Return to the Main Menu, recalculate the spectrum and copy it to the clipboard with **<Ctrl+C>**. Click **Evaluate...Workbook <F3>**. If there is no worksheet visible, click **File...New**. Paste the spectrum with **Edit...Paste <Ctrl+V>**. The difference between the first two wavelengths is 2.0 nm. Press **<Ctrl+Down>** to reach the end of the table and observe that the difference is 6.0 nm.

Setup Parameters (see page 43)



The Setup Parameters dialog box has a title bar "Setup Parameters". It contains several sections: "Plot" with a scroll list (Reflectance, Transmittance, Optical Density, Reflectance [dB]); "Vs." with a scroll list (Wavelength, Angle of Incidence, Wavelength List, Wave/Angle List); "Wavelength Units" with radio buttons (nm, μm, cm, Å, 1/cm, GHz); "Layer Optical Thickness Convention" with radio buttons (1 QWOT=0.25, 1 QWOT=1.0); "Layer Physical Thickness" with radio buttons (nm, μm, mm, cm, kÅ); "Substrate Properties" with "Calculate as" (Dielectric (k<n), Metal) and "Thickness" (2 mm); "Side 2 Compensation" with radio buttons (FWD ignore Side 2, FWD include Side 2, REV ignore Side 2, REV include Side 2, FWD Side 2 T only); and a checkbox for "IIR Calculations". There are "OK" and "Cancel" buttons.

Axis choices are stored with Graph Axes.

Since there's no vertical axis scale choice in the Graph Axes editor, how do we change from Reflectance to Transmittance? This and numerous other choices are implemented through the Setup Parameters editor **Setup...Parameters <Ctrl+P>** illustrated above. Axes selectors at the top left (**Plot** and **vs.**) scroll to reveal further choices.

After changing the **Layer Optical Thickness Convention** from 0.25 to 1.0 verify that the design has changed accordingly and that the spectrum is the same. Try changing **Wavelength Units** from nanometers to microns. Change **Side 2 Compensation** to "FWD include Side 2" and recalculate.

Be sure that "Metal" is selected under **Substrate Properties** if the substrate is actually a metal or semiconductor. Colored filter glass substrates may be accurately treated as "Dielectric".

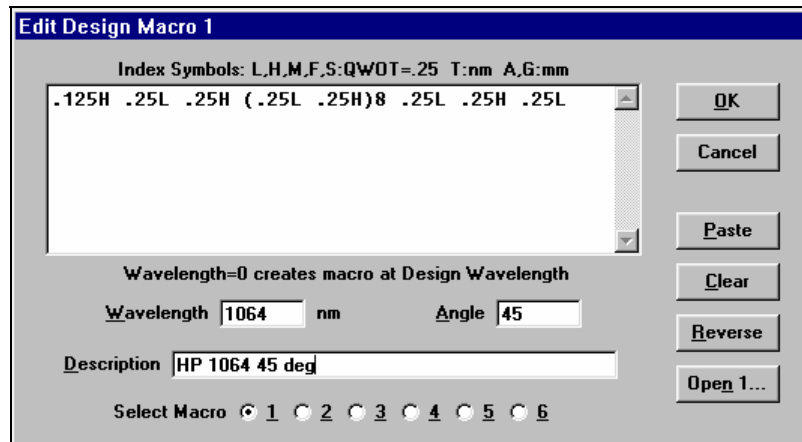
HIGHPASS - Example 2

We'll now move to a different example illustrating further features. Open FILM File "highpass" (**File...Open...FILM File <Ctrl+F12>**).

Design Macros (see page 48)

Access the Groups design editor and copy the entire design to the clipboard using **Edit...Copy All <Ctrl+A>**. (A design fragment is copied by highlighting it and clicking **Edit...Copy**.) Next, click **Edit...Macro <Ctrl+M>** to activate the Design Macro dialog box. This lets you enter up to six designs or fragments which can be adjusted for center wavelength and angle. It is especially useful for multiple stacks centered at different wavelengths.

Rather than type a design we click **Paste** to transfer from the clipboard. Enter the Wavelength, Angle and Description shown below and click **OK**.



This specifies an angle-matched and wavelength-centered design and returns to the Groups design editor. Now press **<Shift+F1>**. The following design will have been pasted into the editor:

.2942H .6401L .5885H (.6401L .5885H)8 .6401L .5885H .6401L

Note that the description is now included in the **Macro** menu. Your results will be different if the original film indices were changed. Click **Multiple** and note that the group in parentheses is displayed on a separate line.

Optimization Targets (see page 59)

- **Before proceeding, please reload FILM File "highpass"**. Prompts will ask you to update disk files before proceeding. Click **No** in each case.

Click **Calculate** to evaluate the spectrum. This is a poor highpass design because there is too much reflection from 580 to 800 nm. DESIGN needs to minimize the reflectance. This is specified through the Optimization Targets editor

Optimize...Targets <Ctrl+T> displayed on the next page.

There are 15 reflectance (**Type** = "% Refl") targets over the **Wavelength** range 580 to 800 nm. Each target is set to **Target** = 0, **Tolerance** = 1, **Angle** = 0 and **Polarization** = "R" (random). Tolerance is an inverse weighting factor - the smaller the number the greater the relative importance of the target. If we are more concerned about performance in the middle of the wavelength range, we could 'loosen' the tolerances at 580 and 800 nm by assigning values **Tol** = 2.

The easiest way to delete all entries is to click the grid's upper left corner and press Delete.

Optimization Targets						
File Edit Window						
	Type	Wave (nm)	Target	Tol	Angle	Pol
1	% Refl	580.000	0.000	1.000	0.00	R
2	% Refl	593.477	0.000	1.000	0.00	R
3	% Refl	607.267	0.000	1.000	0.00	R
4	% Refl	621.378	0.000	1.000	0.00	R
5	% Refl	635.816	0.000	1.000	0.00	R
6	% Refl	650.590	0.000	1.000	0.00	R
7	% Refl	665.707	0.000	1.000	0.00	R
8	% Refl	681.176	0.000	1.000	0.00	R
9	% Refl	697.004	0.000	1.000	0.00	R
10	% Refl	713.199	0.000	1.000	0.00	R

OK
Cancel
Generate...

The editor allows you to change multiple values by copying cells to the clip board and pasting in multiple rows. For example, change the value of the first **Angle** value to 15. Click **Edit...Copy** to copy the value to the clipboard. Now highlight several rows in the Angle column and click **Edit...Paste**.

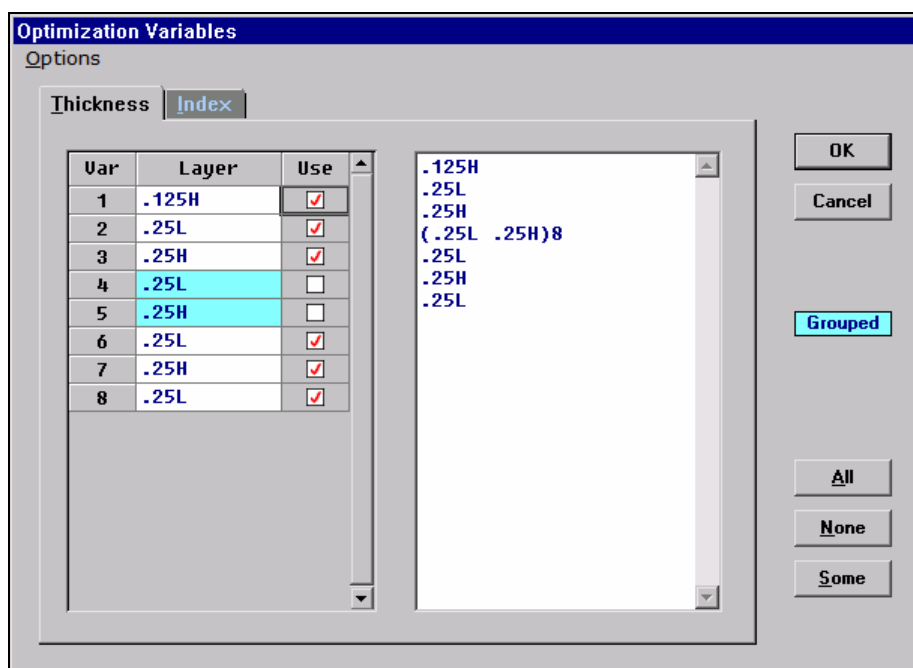
Optimization Target Generator			
☐ Reverse Synthesis mode - convert current spectrum into targets			
Type	Reflectance Transmittance	Wavelength (nm)	Min: 580 Max: 800
		☒ Inverse wavelength spacing (recommended)	
Number of targets	15 (2-285)	Target value	0 Tolerance: 1
Angle (deg)	15	Polarization: ☐ P ☐ S ☒ Random	
		OK	Cancel

Click **Generate** to access the Target Generator (see page). This dialog box provides a very convenient way to input targets over a wavelength range. Targets are spaced inversely in wavelength in order to provide more of them at shorter wavelengths where there are more 'wiggles'. The Target Generator can be used repeatedly to build up a complex list of targets. Adjust values as shown above and click **OK**.

Optimization Variables (see page 60)

- **Before proceeding, please reload FILM File "highpass".**

Once targets are specified we must indicate what layers (and/or indices) should be varied in the search for a solution. Click **Optimize...Variables <Ctrl+B>** to access the Optimization Variables editor.



The program assigns variables as follows: If the design does not include parentheses the thickness variable is the layer number (from the sub substrate). If there are parentheses the variable is the layer number ignoring parentheses:

Design	.125H	.25L	.25H	(.25L .25H)8	.25L	.25H	.25L
Variable	1	2	3	4	5	6	7

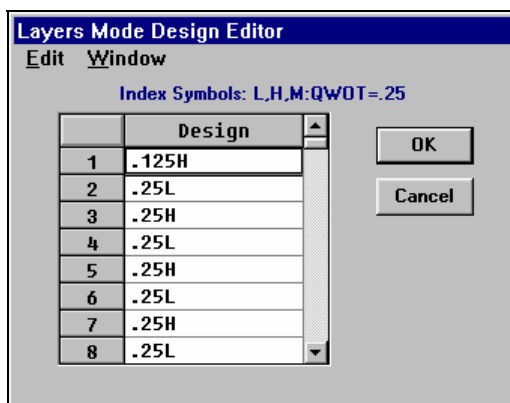
Note that grouped variables 4 and 5 remain fixed during the optimization. This is a typical technique for simplifying optimization problems. Finally, return to the Main Menu and optimize the design for 10 iterations.

Layers Design Editor (see page 51)

- **Before proceeding, please reload FILM File "highpass".**

From the Main Menu click **Design...Layers Editor <Ctrl+L>** to access the Layers design editor. Since the current design includes parentheses a confirmation request is issued. Why remove parentheses? Possibly you need physical thicknesses for monitoring, or you want to convert an optimized design to individual layers for tolerancing with Excel. It's probably a good idea to store the design before converting it to separate layers because there's no automatic way to put back parentheses.

We eventually arrive at the editor shown below. You can delete a block of layers by selecting them and pressing ****. You can insert a single layer by typing its formula into the **Insert** text box and clicking **Insert <Alt+I>**.



FilmStar Workbook

Tolerancing offers an excellent example for the FilmStar Workbook. By tolerancing, we mean estimating coating yields using simulated manufacturing errors. There are several options in FilmStar. The built-in tolerancing generator computes absolute or relative (percent) normally distributed thickness variations and recalculates the spectrum for a specified number of iterations. The tolerancing generator can be accessed from the Main Menu, CIE Color Module, and the FilmStar Workbook.

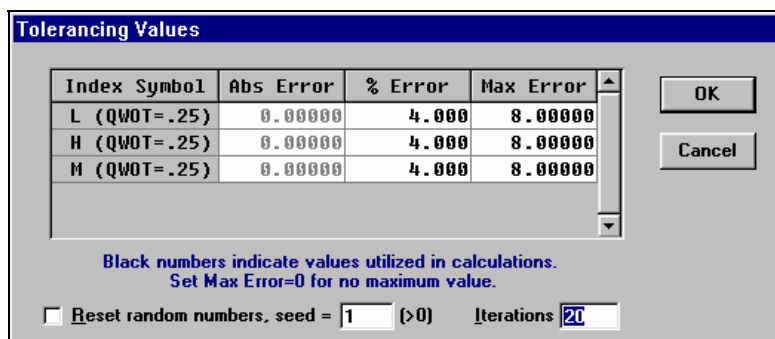
Before proceeding, back up file ..\winfilm\designs\bbar-o.faw in order to protect against unwanted alterations!

- Check that **FILM Archive Mode** is enabled in the File menu and open FILM Archive "bbar-o".

Tolerancing in Main Menu (see page 53)

Click **Evaluate...Tolerancing...Values <Ctrl+N>** to bring up the tolerancing generator, enter the following values, and click **Run <Shift+Ctrl+F9>**.

Here we specify 4% standard deviation with a maximum relative error of 8%. While the resulting overlaid curves are interesting they are difficult to interpret. (You might want to exit and change the graph axes scale to 0-2% Reflectance and try again.)



Tolerancing in FilmStar Workbook (see page 85)

What coating engineers really need to do is predict percent yield for particular specifications. For example, what is the yield if the average reflectance must be less than 0.5% and the maximum less than 1.0% in the range 450-750 nm? Such specifications are easily expressed in the FilmStar Workbook.

Activate the Workbook with **Evaluate...Workbook <F3>**. Close any open work sheets with **File...Close** and open `..\winfilm\workbook\qcbbar.xls`.

	A	B	C	D	E
1	DataType 1				
2					
3	Wave (nm)	% Refl	% Trns		
4	450.000	0.25401	99.74599		
5	460.000	0.14484	99.85516	Average	0.19
6	470.000	0.13047	99.86952	Maximum	0.32
7	480.000	0.15157	99.84843		
8	490.000	0.17658	99.82343	Passed	TRUE
9	500.000	0.19234	99.80766		
10	510.000	0.19655	99.80345		

From the Workbook click **Evaluate...Tolerancing... Values <Ctrl+N>** and enter 100 iterations. Now click **Evaluate...Tolerancing... Run <Shift+Ctrl+F9>**. Note that the spectrum is pasted into the spread sheet during each iteration. The percent yield is given by the number of iterations for which cell *E8* is *TRUE*.

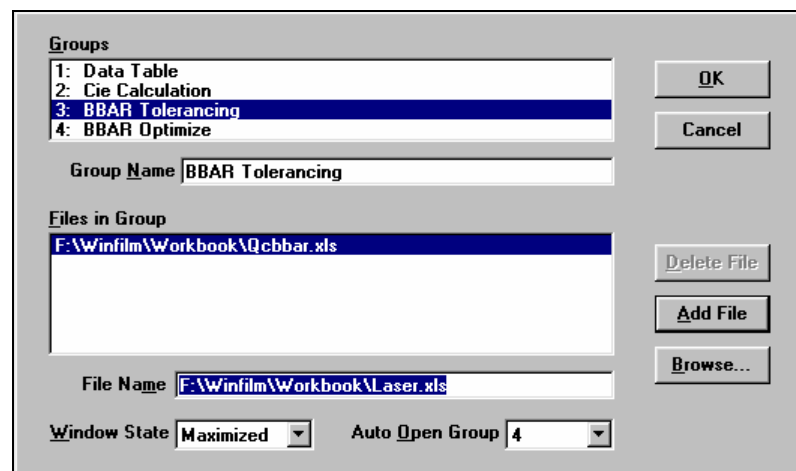
Basic spreadsheet knowledge is required to develop Workbook modules. Tutorials can be found in bookstores. Formulas are similar to those in MS Excel; click <Ctrl+F1> for help.

How does this work? Cell *E8* has been assigned special defined name *Passed*. (The yellow background is automatically applied to cells with special defined names.) The formula for cell *F1* is given by

$$=AND(\$E\$5 \leq 0.5, \$E\$6 \leq 1)$$

which returns TRUE or FALSE depending on whether specifications are met.

Not that worksheet model(s) can be assigned to a single hot-key or opened automatically through **File...Open Worksheet Group...Edit Groups**. This is very useful when working repeatedly with the same worksheet(s). Worksheets can also be opened through FilmStar BASIC.

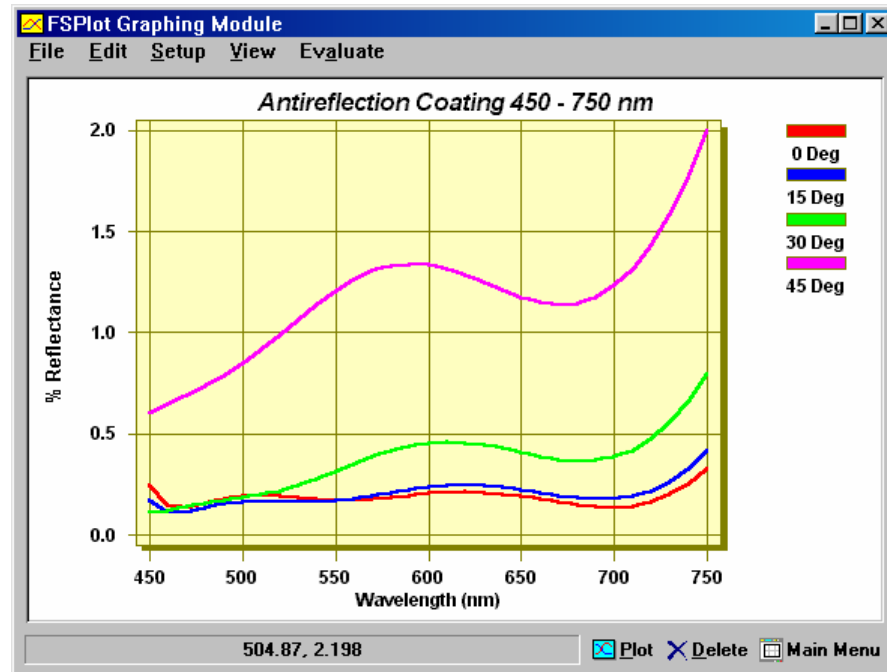


FSPlot Module

- **Before proceeding, close the Workbook and reload FILM Archive "bbar-o"; click Evaluate...Recalculate <F9> to obtain a spectrum on the screen.**

In addition to the main screen graphics, FilmStar provides a second graphics module with numerous capabilities. From the Main Menu, click **Spectra...FSPlot Module <F4>** to bring up the FSPlot Module (see page 90).

Click **Plot <Alt+P>** in the bottom command bar to add the graph; then return to the main screen (click on it or click **Main Menu** on the command bar) and calculate again at 15 deg. Repeat for 30 and 45 degrees. Ultimately the graph will appear similar to the one shown below.



Duplicate the above appearance exactly by experimenting with the different settings in **Setup...Graph Details <Ctrl+H>**. Adjustments are implemented without shutting the dialog. Closing that dialog, adjust font size in Setup Font and legend text and position in **Setup...Legends <Ctrl+E>**.

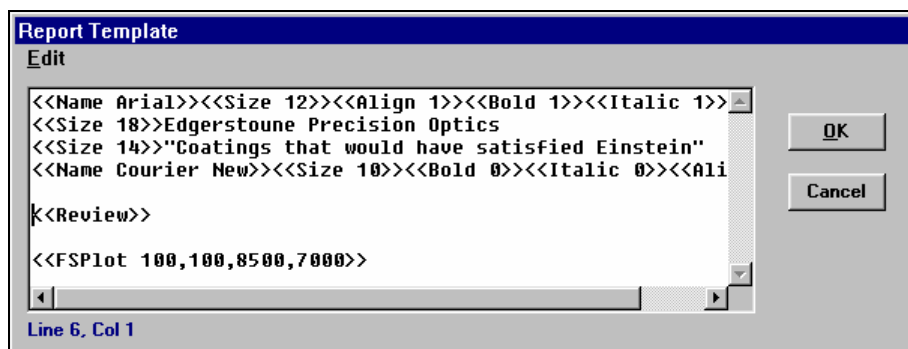
Report Generator

- **Before proceeding, please close the FSPlot Module and reload FILM Archive "bbar-o" and click Evaluate...Recalculate <F9>.**

Power users can generate reports in MS Word.

FilmStar supports printed output combining graphics and test. From the Main Menu, click **File...Report Generator <F7>** to bring up the Report Generator (see page 94). Examine the print preview window and click **Setup** to view margin and other settings. The margins should be 0.75" and line spacing 100%.

Print the report. If it doesn't look right it's possible that font *Courier New* is not installed. From the Report Generator dialog click **Template** and change the font name (<<Name Courier New>>) to an available fixed pitch font.



Actually, it's only necessary to include font information in the Template if multiple fonts are required. For a simple template such as

```
<<Review>>
<<FSPlot>>
```

the font information stored in the Report Setup dialog may be sufficient.

- **If you've altered the template, please reload FILM Archive "bbar-o" before proceeding.**

Going one step further, the Report Generator can include calculated results. Returning to the Main Menu, click **Evaluate...Workbook <F3>** and check that qcbbar.xls is displayed. If not, load it manually. We include the contents of cells E5 and E6 in our report by adding the listed lines to the end of the template. (Note that ← is a line continuation character. That is, the first two lines below are really one long line.)

```
<<Align 1>><<Name Arial>><<Size 16>><<Bold 1>>
←Average = <<WbText E5>>%, Maximum = <<WbText E6>>%
```

FilmStar BASIC

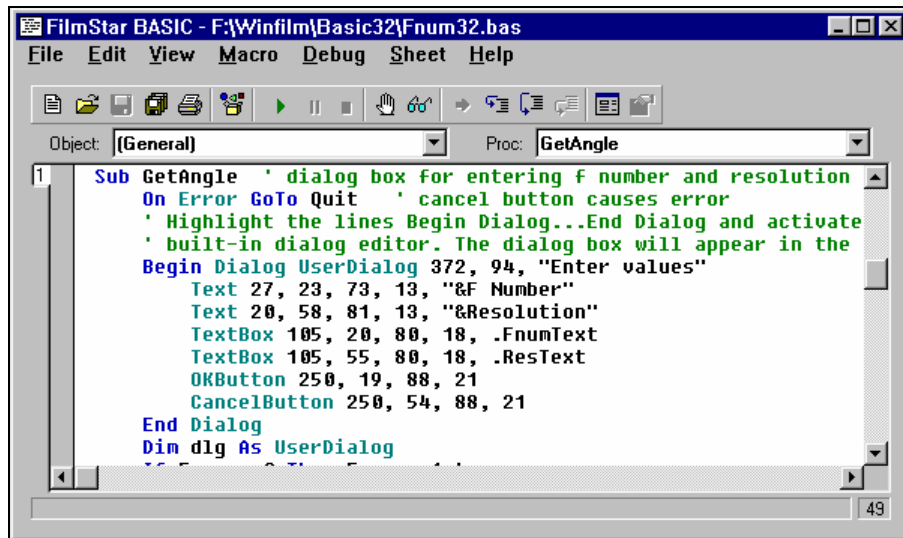
- **Before proceeding load FILM Archive "fnum". Click Evaluate...Recalculate to display the spectrum.**

FilmStar BASIC (see page 64) provides a powerful and flexible environment for automating calculations and simplifying repetitive operations.

Calculations in BASIC

From the Main Menu click **Evaluate...FilmStar BASIC <F6>** followed by **File...Open <Ctrl+F12>**. Open file "..\Winfilm\Basic32\Fnum32.bas". Click **Macro...Run <F5>** or click the icon with the green start icon. If everything is working as it should, an *Enter values* dialog appears; just click OK to proceed.

Up to nine BASIC programs can be opened.



After the calculation is completed you will see that the original square filter has acquired a triangular shape. (If the BASIC editor has obscured the plot, click **Redraw**.) Simulating the effect of a wide cone angle, fnum.bas has repeatedly calculated and averaged the spectrum over a range of angles.

Calculations can be run without viewing the BASIC editor. One way to do this is to assign a macro key. Click **Evaluate...Macro...Edit <Ctrl+Z>** and enter the following (changing the drive letter if required):

Description: FNUM Run

Command: BasRun c:\Winfilm\Basic32\Fnum32.bas;busy 0;

Finally, making sure that the BASIC editor is closed (not just deactivated), click the **Evaluate...Macro** selection corresponding to label **FNUM Run**.

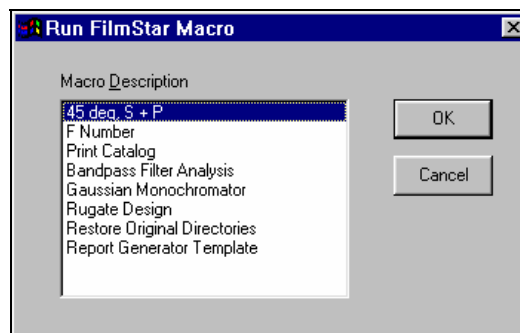
Simplifying Program Operation

Click **Evaluate...Macro...Edit <Ctrl+Z>** and enter the following (changing the drive letter if required):

Description: Macro List

Command: BasRun c:\winfilm\basic\mselect.bas;busy 0;

This brings up the screen shown below. Click Report Generator Template to run program "template.bas"; select AR Coating Specifications. This macro not only opens the correct Workbook sheet but also computes the Report Generator template. In this way, engineers with moderate programming skills can implement new levels of computing power for coating and QC technicians.



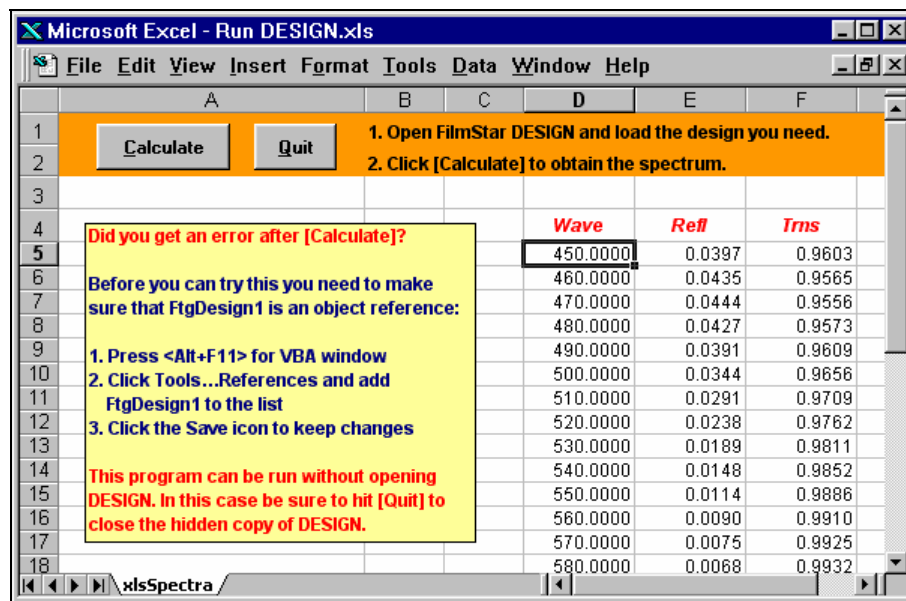
Using DESIGN spectra in Excel 97/2000

- **Before proceeding load FILM Archive "bbar-o". Click Evaluate...Recalculate to display and veify the spectrum. Then close down FilmStar DESIGN.**

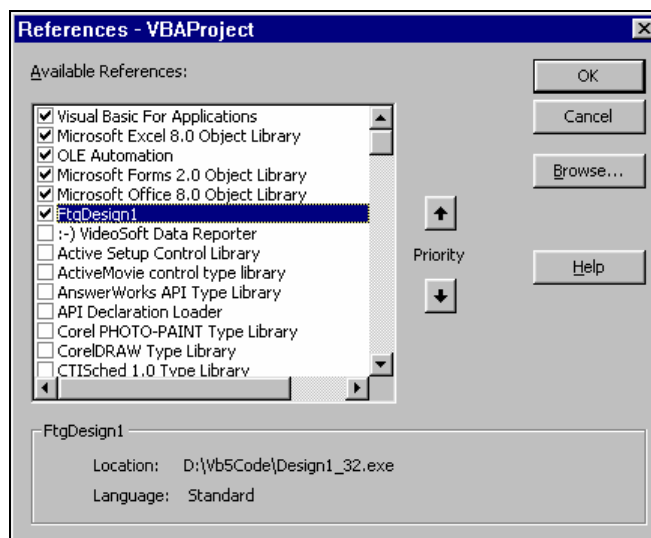
FilmStar is highly compatible with other Windows applications, including MS Office. You can, for example, utilize FilmStar spectra in Excel, or use Word instead of the built-in Report Generator to print documents.

Suppose you want to use Excel instead of the built-in Workbook to analyze thin film spectra. You could do this by copying and pasting but might find it tedious if the calculations are frequently required. In addition, the calculations might need to be performed by personnel who are not familiar with FilmStar.

Start Excel and load C:\Winfilm\Excel 97\Run Design.xls to obtain the screen shown below. Click Calculate to obtain a spectrum calculated in DESIGN.

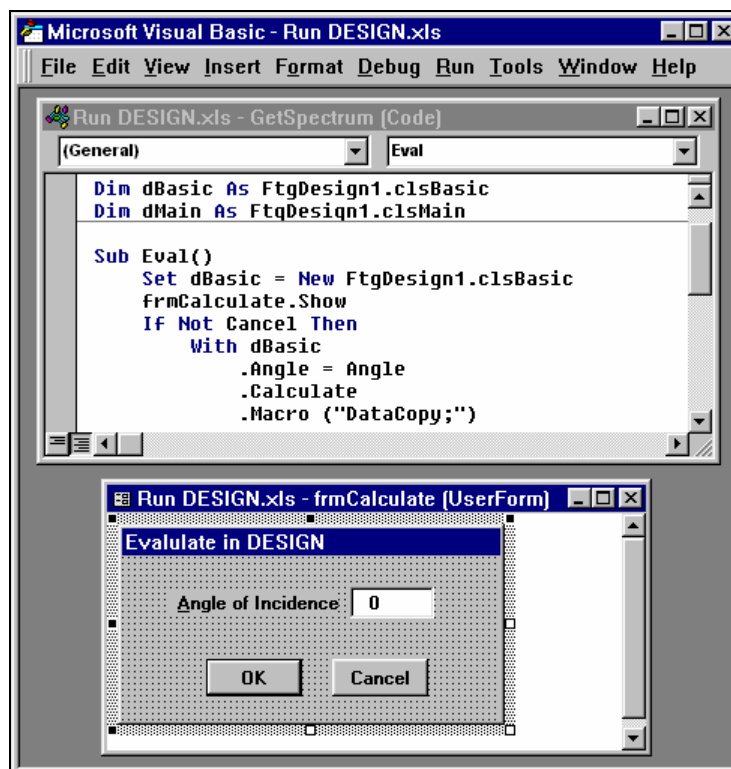


How does Excel know about DESIGN? From Excel click **Tools...Macro...Visual Basic Editor**. Then click **Tools...References**. A reference to **FtgDesign1** should be checked. If not scroll down the list and check it.



How does Excel know about DESIGN? From Excel click **Tools...Macro...Visual Basic Editor**. Then click **Tools...References**. A reference to **FtgDesign1** should be checked. If not, scroll down the list and check it. Next click **View...Object Browser**, select **FtgDesign1** followed by **clsBasic**. You will see that FilmStar BASIC functions are now exposed to Excel.

Finally, examine the code module and form shown below to better understand how objects in DESIGN are utilized in Excel.



FilmStar Database

The FilmStar Database provides means to link FilmStar design and spectral files to an MS Access-compatible database file (.mdb). This is intended for users with large numbers of designs or spectra.

We suggest that you DO NOT install the FilmStar Database unless you actually intend to use it. If you are not sure what it does, visit www.ftgsoftware.com or contact FTG Software by e-mail or telephone.

Configuring the Sample Database

The following procedures illustrate the main features in configuring a database:

1. Install FilmStar Database files with dbase32.exe on FilmStar CD-ROM or downloaded from the FTG support page. *If you do not have an installation password for the Database Module, it is probable that your license does not include it.* Install the Sample Database.
2. Click **Database Configuration** in **File...Configuration...Directories**. Highlight a cell in the **Database Name** column and note that **Edit...Select <F3>** lets you search for data bases on your computer or network. Once a database is selected, highlight the appropriate cell under **Table Name**

and click **Edit...Select <F3>** once again. Click **Edit...Field Names <F4>** to assign special field names: data, data file name and spectrum name.

3. Returning to the Main Menu, locate the *Database* commands in the **File** and **Spectra** menus. Open the Spectra database, click the scroll bar to select records and familiarize yourself with the various menu commands.
4. Note how fields are selected for each row, with field type automatically entered. You may not want to display each field in the database; in that case delete extra rows with **Edit...Delete Row**.

Text cells can be made pull-down by specifying a list as either a text file list (.txt) or as a field in a database (.mdb). When a database field is used, it is necessary to specify table and field names. This is best accomplished with **Edit...Select <F3>**. First select *Database Name* and then *DB Table* and finally *DB Field*. Numeric cells provide further options including range and number of decimal places (*Fix*).

If you mess up the Sample Database and settings beyond the point of no return, it may be reinstalled. To protect against inadvertent actions, you must first delete FilmStar2000.mdb. If you are converting an older FilmStar Database, you need to create new data entry screens. The .mdb file itself is not affected.

If you want to remove the Sample Database, clear *Database Name* entries in the Database Configuration dialog (step #3 above). This does not remove the .mdb file from your computer (you must do this manually); it merely deletes relevant settings from your system in order to remove Database commands from menus.

Adding a New Record

The following are procedures for adding a new design record:

1. Calculate a spectrum. This is used to generate a graphic image in a hidden copy of the FSPlot Module. *The FSPlot Module should be closed.*
2. Activate the design database via **File...Database <F2>**.
3. Click **Edit...New Record <Ctrl+R>**. If you don't do this, the program prompts you to create a new record or over write the current record. There are then two options as listed in 3a and 3b.
- 3a. You already stored the FILM Archive in the main menu and wish to add the file name to the database. Click **Edit...Insert Archive Name <Ctrl+N>** to add that name to the database.
- 3b. You have not stored the FILM Archive, or wish to re-store it in the database directory. Click **File...Save FILM Archive <F12>**. This prompts you for a file name.
4. Click **File...Save FSPlot Graph <F11>** to save the FSPlot graph on your disk and add its name to the database.

Main menu and database directories are different. If you open a design in the database and then save it in the main menu, the default path is the one defined in **File...Configuration...Directories**. This will normally be different from the database path, although it could be the same.

INDEX Tutorial

Index from Measured Data

Optical coating engineers need to understand the dispersive properties of high index films such as TiO₂ in the visible and near UV regions. Faced with this need while employed in industry, we developed a practical technique for determining indices from measured data.

A thick oxide layer is deposited on a transparent substrate such as fused silica - typically 15 to 20 monitor quarter waves. When the part is removed and measured in a spectrophotometer there must be a number of transmission peaks and valleys in the near UV to red regions.

By counting the number of quarter waves on the monitor, the user will also be able to calculate the monitor to substrate tooling factor in program MONITOR.

We take advantage of the facts that the oxides are only slightly absorbing and nearly nondispersive in the red region. In the 'old' days a slide rule was used to find the integral ratio at half wave peaks or quarter wave valleys. Now program INDEX does the same thing.

Physical thickness is calculated according to the number of quarter waves and index determined in the red according to %T max - %T min. The index at shorter wave lengths is then calculated according to the deviation of peaks from their non-dispersive positions. Finally absorption k is calculated.

Here's the step-by-step procedure:

1. Deposit a thick film on a transparent substrate.
2. Measure its transmission at normal incidence in a spectrophotometer and store the data on disk.
3. If you are not using FilmStar MEASURE you will need to translate the file into a DESIGN compatible ".csv" spectral data file. See *File Open and Save* under "Spectra Menu" on page 53.
4. Click **Solve...Open Spectrum <Ctrl+F11>** to open the spectral file. Your hard disk should include the sample file ".\winfilm\spectra\tio2.csv" used here. If it doesn't, generate a file in DESIGN using dispersive index table TIO2A. Here the layer thickness is 1000 nm. Remember to use calculation mode **FWD include Side 2**.

Before proceeding, you should also check that **Solve...Spectrum Type** is set to **Continuous**.

5. Click **Setup...Graph Axes <Ctrl+G>** and adjust entries as shown below.

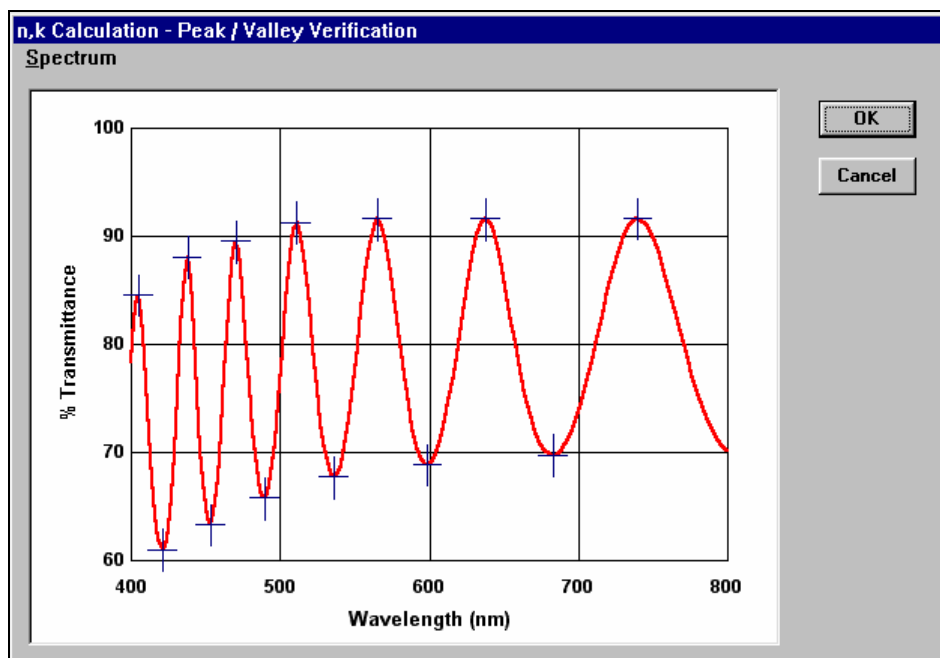
	Min	Max	Delta	Label
Wavelength (nm)	400	800	10	100
Real Index n	2.2	2.5		0.05
Imaginary Index k	-5	-2		1

OK Cancel

Delta utilized in [Function...Create Table].
Use Delta<0 for inverse spacing.

This screen is important because k is fitted differently according to the **k Scale** entry. In oxides where k varies rapidly with wavelength near its absorption edge, select **Log**.

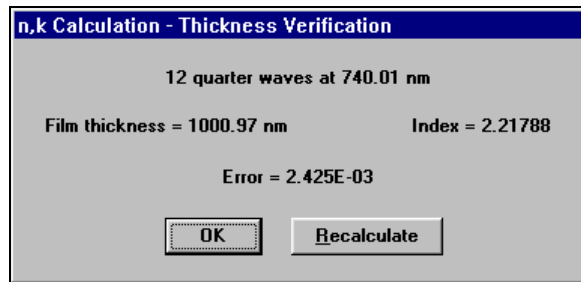
- Click **Solve...Calculate n,k <F9>** and specify **Algorithm 2**. The following screen eventually appears:



The entire data file is used in the calculation. If actual data shows spurious noise peaks, it is likely that the wavelength interval in the data file is too small. Data can be acquired again or Excel can be used to remove points. Click **OK** to proceed or **Cancel** if the data appears incorrect.

- The next screen includes various calculation parameters.

Click **OK** to calculate physical thickness. The idea is to minimize the estimated **Error** in the calculation. Here INDEX found that 10 quarter waves gave minimum error. (Test this manually by returning to the previous screen with Recalculate. Enter **1** in **Use...peaks** followed by **8** in **Fixed # quarter waves**. The error increases by several orders of magnitude.)



Click OK to create a new Index Table.

Verification is extremely important in index calculations! Please do not ignore the next step.

8. Store the new Index Table on disk with a new file name and use it in DESIGN with the calculated film thickness. Overlay your actual measured data. There should be excellent agreement.

Index Functions

The index determination procedures discussed above will meet the requirements of many users. But it is possible to proceed further by fitting a dispersive index function to the data. Following the initial fit in INDEX, functions can be further optimized in DESIGN.

Edit the Index Table generated in the previous section so that only wave lengths illustrated below are displayed. By eliminating 'bad' points we help the curve fitting process.

A dialog box titled "Index Table TI02A.ITW" with a menu bar (File, Edit, Window). It contains a table with 4 columns: Wave (nm), n, and k. The table has 12 rows of data. To the right of the table are "OK" and "Cancel" buttons.

	Wave (nm)	n	k
1	437.670	2.40485	1.20509E-3
2	453.008	2.37599	1.07937E-3
3	470.176	2.34860	7.936E-4
4	489.298	2.32192	5.86901E-4
5	511.078	2.29762	2.03006E-4
6	536.275	2.27696	2.07628E-4
7	565.565	2.26007	1.00005E-4
8	598.903	2.24371	1.73002E-4
9	637.755	2.22998	1.00108E-4
10	683.075	2.21784	1.60989E-4
11	740.009	2.21788	1.00397E-4
12			

Click **Function...Fit Index <Ctrl+F>** and enter the following in the Dispersive Index Functions dialog box.

LORENK A=5, B=1, C=300, D=1, k-Tolerance=10

Click OK to accept these values and return to the Main Menu. To see the effect,, click **Plot <Alt+P>** followed by **Functions...Plot <Ctrl+T>**. The fit is far from optimum. Return to **Function...Fit Index**, click **Fit** and let the refinement proceed for 30 iterations. You should finally obtain the following values:

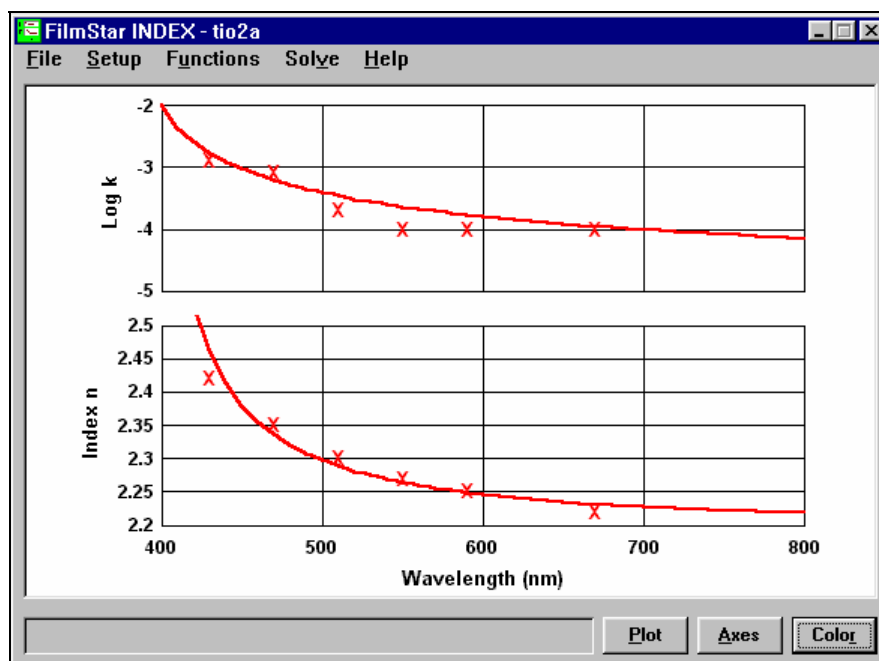
Dispersive Index Functions

Type	Coefficient
BUCH	A 4.510838
CAUCHY	B 0.3162654
DRUDE	C 383.5925
GAALAS	D 0.4788
LORENK	

Iteration: 30/30
Merit: 3.48E-03
Ratio: 0.460%
Damping: 2.51E-04
k-Tolerance: 10

OK Cancel Fit Restore

Once again, return to the Main Menu with **OK** and plot the function with **Functions...Plot <Ctrl+T>**. Your results should resemble those shown below.



If you've gotten this far you might want to plug the index function back into DESIGN and compare it to TiO2A.

DESIGN Reference

File Menu

Five component files are utilized in specifying a thin film design problem:

1. Graph Axes (.axw)
2. Film Indices (.inw)
3. Design (.dew)
4. Optimization Targets (.trw)
5. Optimization Variables (.vaw)

These files constitute a FILM File which can be loaded with a single file name. **Since a FILM File is only a collection of file names, the constituent files must be stored separately.** A FILM File does not have to be updated unless the names of the component files have changed. That is, if you update Graph Axes file "bbar" you do not have to update FILM File "bbar".

As a recommended alternative, a FILM Archive File (.faw) is a single file containing all the data stored as a FILM. This mode is enabled and disabled by clicking **File...FILM Archive Mode**. When enabled it is still possible to load or store separate component files via the keyboard or via macro commands such as **AxesOpen**. MONITOR and CRYSTAL support both file structures via **File...Open...Design** or **File...Open Archive Design** selections.

FILM Component Mode offers maximum flexibility while FILM Archive Mode (recommended) offers maximum security against inadvertent design changes. FILM components can also be loaded and saved in FILM Archive mode.

Two other DESIGN files are accessed from other menus:

1. Spectral data
2. Wavelength List

Finally, dispersive index tables are used by DESIGN but created and edited in separate program INDEX.

File open/save dialogs can be FTG-style (default) or Windows common dialog style.

Open <Ctrl+F12>

The FILM File automatically loads component files. These files can also be loaded individually. DESIGN keeps track of data that has changed and prompts users to update old files before loading new ones. In FILM Archive Mode only one file is loaded.

Save As <F12>

When Archive Mode is disabled this leads to the Save Files dialog box which provides Save and Save As functions for the five components in a thin film design. When FILM Archive Mode is enabled there is only file to save. In FILM Mode check **Auto FILM** to automatically store all component files with the same file name (and description) as the FILM file.

Disable **Overwrite warning** in **File...Configuration...Preferences** if overwrite confirmation messages are annoying.

Save All

Quickly saves the five files constituting a FILM as "work" files in appropriate default directories. These files are automatically loaded at start-up and automatically saved when exiting DESIGN. This function is included for users who experience unrecoverable program or Windows failures and for users who exit Windows by shutting off the computer (not recommended).

Copy Graphics

Copies the current screen graphic to the clipboard for pasting into other applications.

Print Graphics

Print the screen graphic to the current Windows default printer. Best results are obtained with a white background.

Report Generator <F7>

Access the FilmStar Report Generator. This lets you combine text and graphics in multi-page documents

Quick Print Report <Ctrl+F7>

Print a report without accessing the FilmStar Report Generator. Use this when the report has been set up and tested.

Exit <Alt+F4>

Upon exiting configuration file "..\winfilm\config\design1.ini" is updated. Configuration includes **File...Configuration** settings, Graph Details (line thickness, etc.) and position and size of the program window.

Current design, film indices and similar data is automatically saved in files "work.*" (same as selecting **Save All**). This ensures the program will be in the same state upon restarting.

Configuration - Capacity

File...Configuration...Capacity

Users can configure DESIGN for optimum memory utilization (and improved speed in loading forms containing grids) by entering values not exceeding anticipated maxima.

<i>Capacity changes are not implemented until programs are exited and restarted.</i>

Film Indices

52 maximum corresponding to index symbols A...Z and a...z in the Film Indices editor. If 26 or less are specified, index symbols are converted to upper case when entered. Specifying more than 52 materials places DESIGN in *Extended Materials Mode* where letters are replaced by film material numbers within square brackets. That is, .25H might become .25[55].

Coefficients

Dispersive index functions (Sellmeier, etc.) are used to fit n,k values to measured spectra. Some of the more complex index functions require more than the default (7) number of coefficients.

Groups

Maximum number of individual layers or groups of layers. Maximum capacity has not been determined.

Layers in group

Maximum number of layers within a group.

Targets

Maximum number of optimization targets. The maximum number of targets has not been determined.

Variables

Maximum number of optimization variables. The maximum number of variables has not been determined. Note that each index variable adds 1-7 actual variables to the calculation. Enter a value that is a multiple of five.

n,k Wavelengths

Maximum number of wavelengths allowed in a dispersion table (n,k vs. wavelength) created in program INDEX.

Wavelength List

Maximum number of entries which can be edited in the Wavelength List editor. This is not the same as the number which can actually be utilized in an optical thin film calculation.

Wave/Angle List

Maximum number of entries which can be edited in the Wave/Angle List editor.

Configuration - Directories

File...Configuration...Directories

User Name

The user name appears in the Review Design screen.

Directories

Files are stored in four default directories. While files can be loaded from any directory, they can only be stored in the default directories. (Exception: spectral data files can be stored anywhere.)

Data

Film indices (.inw), Graph Axes (.axw), Wavelength List (.wls), Optimization Targets (.trw), Optimization Variables (.vaw), and FILM Files (.flw)

Designs

Thin film Designs (.dew) and FILM Archives (.faw).

n,k Tables

Dispersion tables created in program INDEX (.itw).

Spectra

Spectral data output files (.csv) in 'comma-separated values' format. These files can be loaded as Excel worksheets. Since .csv is not a unique DESIGN extension, users should create unique directories for spectral data files: *i.e.* "c:\excel\mydata".

FilmCalc ".out" files with comma delimiter can be loaded in FilmStar after renaming the extension to ".csv".

Configuration - Preferences

File...Configuration...Preferences

Changes in the following are recorded in "..\winfilm\config\design1.ini" upon exiting DESIGN.

Use Windows message box

Message boxes display **OK Cancel**, **Yes No** and similar messages. There is a choice of Windows default message boxes (centered in screen) or FTG Software message boxes (normally centered in active window). Windows message boxes support Windows sound effects and local languages. You may find FTG message boxes easier to read.

Cancel warning in data entry dialogs

Issues a warning message if you modify a data entry in a dialog box and then click **Cancel** to close the box.

Overwrite warning on file open and save

Issues warning (recommended) when opening or saving a file (*Save*) when relevant changes have been made.

Automatic edit after file open

Access appropriate data editor immediately after loading new file from disk (emulates FilmCalc).

Automatic review design

Display the Review Design screen immediately after loading a new design from disk.

Use FILM Archive (FILM) description for graph title

Normally the Graph Axes title is printed at the top of the main spectral plot. Check this box if you prefer to utilize the file description from the design Save As dialog box.

Use Windows dialogs for all file operations

Replaces FTG-style file open/save dialogs with Windows common dialogs. Each has its advantages. FTG dialogs support a 50 character description field with a file list dialog. With long file names, you may find this feature superfluous. Common dialogs are more standard and make it easier to utilize FILM component files while working in FILM Archive mode.

Display and save file descriptions

When using Windows dialogs, check this box to save and display file descriptions. You might wish to use this temporarily when creating new file names containing information previously in the description field.

The following advanced settings, not included in menu selections, require that users modify "..\winfilm\config\design1.ini" in Notepad or any text editor. Do not type comments (starting with ;) on the same line as a setting.

CIE User-Illuminants

Users can add any number of illuminant files as follows. For further information see "CIE Color Module" on page 88.

```
[CIE Color]
Illum1=Xenon Lamp;arclamps\xenon.csv
Illum2=Fluorescent Cool;fcool.csv
Illum3=Fluorescent Warm;fwarm.csv
```

The first description appearing in the pull-down illuminant list is *Xenon Lamp* and the corresponding file name is *xenon.csv*. Files should be stored the FilmStar program directory (usually c:\winfilm), but an optional subdirectory (arclamps) can be added.

Negative Absorption (Gain)

DESIGN and INDEX will accept negative values of k (corresponding to gain) if the following line is inserted:

```
[Configuration]
AllowNegAbs=-1          ;enable k<0 (gain)
```

Configuration - Miscellaneous

File...Configuration...Misc

Graph Axes Labels

This provides means to replace default English graph axes labels with international equivalents. Labels apply to the FSPlot Module as well as the main screen.

Print Graphics Plot Size

Sets plot sizes for the Print Graphics command in the File menu.

DDE Timeout

DDE (dynamic data exchange) is a (now obsolete) way for Windows programs to communicate. If the connection is not made in the specified time, an error message is generated.

Configuration - Security

File...Configuration...Security

ID Module

An FTG Software Security ID Module must be attached to the parallel (printer) or USB port. The printer can be attached to the parallel module. There are two parallel port module types: Activator (black case) and HASP (ivory case). The appropriate driver for each is loaded during installation. For added security HASP modules are embedded with company name. Users who experience difficulties should visit

<http://www.ftgsoftware.com/issues.htm>

and click *Security ID Module doesn't work* under *Installation & Startup*.

Encrypting designs

An encrypted design cannot be viewed or edited. This allows thin film vendors to supply proprietary designs and index tables to customers while maintaining trade secrets. Users who need this feature should visit

<http://www.ftgsoftware.com/issues.htm>

and click *Encrypting designs* under *DESIGN*.

Do not use this facility casually. Be sure to back up designs and index tables before encrypting! Think before you click!

Macro Commands (DDE)

Programming skills in Excel or other Windows languages may be required to implement some topics discussed below. Please contact FTG Software Associates for assistance.

Dynamic data exchange (DDE) provides means for importing and exporting data and commands across Windows applications. While superseded by 32-bit object-oriented methods (supported by FilmStar), DDE links 16 and 32-bit programs as well as 32-bit programs which do not support objects. Several DESIGN dialog boxes include **Import** and/or **Export** commands as well as **DDE Options**. These are accessed from an **Edit** sub menu.

Import/Export

In Windows jargon these are actually Link Request and Link Poke events. DESIGN uses manual links because topics attached to dialog box forms are unloaded from memory when the form is unloaded. (In an automatic link data is exchanged whenever the linked data changes.)

Options

Each option includes a Topic and an Item. These are automatically stored on disk on quitting DESIGN. Topics for Microsoft Windows applications are as follows:

Application	DDE application name
Microsoft Excel	Excel
Microsoft Word for Windows	WinWord

An example is provided in Excel model "indices.xls" supplied with FilmStar. Here the Topic includes the name "excel" followed by "|" (vertical bar) and the path and file name of the Excel model. The Item **editor** is the name of the defined range \$A\$2:\$J\$14 which is linked to DESIGN's Film Indices editor grid.

Topic	excel e:\excel\films\indices.xls
Item	editor

Consult appropriate reference manuals for DDE application names for other Windows programs.

Macro Commands

As illustrated in the calculation of user-defined index functions, DDE provides means for executing DESIGN commands in other Windows programs. Conversely, DESIGN accepts commands from other applications. The commands and their formats are listed below.

FilmStar BASIC duplicates most macro commands and has the advantage of displaying syntax in an object browser. In addition there are numerous BASIC commands and functions which do not have macro equivalents.

The same commands are used with Main Menu's command macro facility or with macros set up in the FilmStar Workbook. Capitalization is unimportant except where a command contains labels. Multiple commands may be placed in the same line. Each command terminates with a semicolon. In the list below Italics indicate comments and are not part of the command.

AbsorbLayer...Specify layer for absorption vs. wavelength or angle.

```
AbsorbLayer 3;    Absorptance in Layer 3  
AbsorbLayer 0;    Total absorptance
```

Angle...Set angle and polarization (P,S,R)

```
Angle 30 P;
```

ArchiveMode...Set FILM Archive Mode on/off

```
ArchiveMode 0;    Off  
ArchiveMode 1;    On
```

ArchiveNK...Add dispersive index tables to FILM Archive

```
ArchiveNK 0;      Off  
ArchiveNK 1;      On
```

AxesCopy...Copy graph axes settings to clipboard. Excel-compatible format similar to Edit...Copy command in graph axes editor, but the Interval field is not used.

```
AxesCopy;
```

AxesCopyDelta...As above, but includes evaluation interval (delta).

```
AxesCopyDelta;
```

AxesDraw...Draw new graph axes

```
AxesDraw;
```

AxesOpen...Open graph axes. AxesPath or DefaultPath changes the directory; the directory can also be included in the command. If you add an (optional) extension it must be correct. Similar commands: **IndexOpen** (.inw), **DesignOpen** (.dew), **OptiTargOpen** (.trw), **OptiVarOpen** (.vaw), **FilmOpen** (.flw), **ArchiveOpen** (.faw).

```
AxesOpen bbar;  
AxesOpen c:\winfilm\axes\bbar;  
AxesOpen c:\winfilm\axes\bbar.axw;
```

AxesPaste...Paste graph axes from clipboard. Excel-compatible format identical with Edit...Copy command in graph axes editor

```
AxesPaste;
```

AxesPath...Change the default path for retrieving graph axes from disk. Similar commands: **IndexPath**, **DesignPath**, **OptiTargPath**, **OptiVarPath**. Also see **DefaultPath**.

```
AxesPath c:\winfilm\data;
```

AxesSubTitle...Specify FSPlot subtitle.

```
AxesSubTitle This is FSPlot subtitle (small font);
```

AxesTitle...Specify title in main graph and FSPlot.

```
AxesTitle This is main graph and FSPlot title;
```

BasChain...Immediately run FilmStar BASIC program from within another BASIC program.

```
BasChain d:\winfilm\basic\fnun.bas;
```

BasOpen...Open FilmStar BASIC program and display the code in the BASIC IDE. Do not execute this command from BASIC!

```
BasOpen d:\winfilm\basic\fnun.bas;
```

BasRun...Immediately run FilmStar BASIC program without displaying the IDE. Do not execute this command from BASIC!

```
BasRun d:\winfilm\basic\fnun.bas;
```

BasWindow...Set BASIC window state: 0 normal, 1 minimized, 2 maximized. This is useful if you want to get the window out of the way while running BASIC programs.

```
BasWindow 0;
```

Busy...Set mousepointer to hourglass (1) or default (0).

```
Busy 0;
```

Calculate...Evaluate the current thin film design

```
Calculate;
```

Calculate is an Excel VBA keyword. If Excel is a reference, use Macro "Calculate;" rather than the BASIC Calculate command.

CalcPlot...Evaluate the thin film design and display the plot. This command must be preceded by PLOTSTART and followed by PLOTDONE.

```
CalcPlot;
```

CalcRand...Evaluate the thin film design with the random errors specified in **Evaluate...Tolerancing...Values**. The original design is retained in memory. The design must be in Layers Mode (no parentheses).

```
CalcRand;
```

CalcRandSeed...Set random number seed; 0 uses current time.

```
CalcRandSeed 1;
```

CaptionCopy...Copy the main DESIGN caption (title bar) to the clipboard. This is required for Visual Basic's AppActivate method.

```
CaptionCopy;
```

CieWindow...Set CIE Color Module window state: 0 normal, 1 minimized, 2 maximized. Minimizing the Window prevents users from clicking menus while running BASIC programs.

```
CieWindow 0;
```

DataConvert...Convert (interpolate) current spectrum to range defined in Graph Axes (or Range). New range must be within original range.

```
DataConvert;
```

DataConvertRange...Convert (interpolate) current spectrum to specified range (min max interval). Useful for reducing number of data points.

```
DataConvertRange 380 770 5;
```

```
DataConvertRange 400 800 -2;
```

DataCopy...Copy spectrum to the clipboard

```
DataCopy;
```

DataDesc...Description for spectral data. Do not use ';' in the description!

```
DataDesc Say hello to Chuck!;
```

DataExport...Export spectrum via DDE

```
DataExport;
```

DataExportItem...Change DDE export item. In Excel this corresponds to the named range

```
DataExportItem spectrum;
```

DataExportTopic...Change DDE export topic. In Excel 5.0 this corresponds to 'excel' & pipe character (vertical line) & workbook name

```
DataExportTopic excel|book1; or  
DataExportTopic excel|analyze.xls;
```

DataImport...Import spectral data via DDE

```
DataImport;
```

DataImportItem...Change DDE import item. In Excel this corresponds to the named range

```
DataImportItem result;
```

DataImportTopic...Change DDE import topic. In Excel 5.0 this corresponds to 'excel' & pipe character (vertical line) & workbook name

```
DataImportTopic excel|book1; or  
DataImportTopic excel|analyze.xls;
```

DataOpen...Open spectral data file from disk. Use in conjunction with SpecTargets. Adding an extension specifies data format. If a path is not included the default path is used. See **DataPath** and **TypeDataFile**.

```
DataOpen test1;  
DataOpen c:\winfilm\spectra\test1;  
DataOpen c:\winfilm\spectra\test1.csv;  
DataOpen c:\winfilm\spectra\test1.dx;
```

DataPaste...Paste spectral data from clipboard

```
DataPaste;
```

DataPath...Change path for spectral data. Only required if changing from 'Spectra' path specified in **File...Configuration...Directories**. See **DefaultPath**.

```
DataPath c:\excel\spectra;
```

DataSave...Save spectrum to disk. Adding an extension specifies data type. If a path is not included the default path is used. See **DataPath** and **TypeDataFile**.

```
DataSave test1;  
DataSave c:\winfilm\spectra\test1;  
DataSave c:\winfilm\spectra\test1.dx;  
DataSave c:\winfilm\spectra\test1.csv;
```

DataSmooth...Smooth *equally spaced* data with moving average or Savitzky-Golay filter. Moving average is better at reducing noise; S-G is better at preserving structure and peak heights. An *odd number* of points

is required; S-G polynomial orders can be 2, 4, 6. Use this capability to smooth noisy spectral data for n,k determination.

```
DataSmooth 1 11 0;    moving average, 31 points
DataSmooth 2 11 2;    S-G, 11 points, smoothing
                        polynomial order 2
DataSmooth 2 13 4;    S-G, 13 points, smoothing
                        polynomial order 4
```

DefaultPath...Change paths listed in **File...Configuration...Directories** corresponding to **Parameters**, **Designs**, **n,k Tables**, and **Spectra**. All four paths, separated by spaces, are entered in one command and any directories changed by **AxesPath**, **etc.** are changed back to defaults.

```
DefaultPath c:\winfilm\data c:\winfilm\designs
c:\winfilm\data c:\winfilm\spectra;
```

To leave one or more paths unchanged, substitute the word **same** for file name as follows

```
DefaultPath same c:\winfilm\designs same same;
```

DesignAdd...Add quantity (0.01) to all (H) layers with given index

```
DesignAdd H 0.01;
```

DesignConvert...Convert design from optical to physical thickness or *vice versa*; optional second character specifies units.

```
DesignConvert 1;      Opti to phys (current units)
DesignConvert 1 N;    Opti to phys in nm
                        N nm, M μm, L mm, E cm, K kÅ
DesignConvert 2;      Phys to opti (current units)
DesignConvert 2 1;    Phys to opti QWOT = .25
DesignConvert 2 4;    Phys to opti QWOT = 1
```

DesignMult...Multiply all (H) layers with given index by (1.1)

```
DesignMult H 1.1;
```

DesignPaste...Paste design from clipboard

```
DesignPaste;
```

DesignText...Specify design as text

```
DesignText .25H (.25L .25H)10;
```

DesignWave...Set design wavelength in nanometers

```
DesignWave 550;
```

GramsOpen...Import Galactic's GRAMS .spc spectrum file.

```
GramsOpen;
```

GroupsCopy...Copy design to clipboard as single string

```
GroupsCopy;
```

*When executed from the FilmStar Workbook the action is different. The design is pasted in a column starting at named cell **Design** without regard to parentheses. This column is the same as in Thickness Variables*

Numbering Scheme in Optimization Variables. This makes it easy to set up thickness constraints for layers in parentheses.

IndexCopy...Copy Film Indices editor contents to clipboard

```
IndexCopy;
```

IndexPaste...Paste indices from clipboard. Format as in "indices.xls". Non-zero numeric argument forces program to refresh dispersive index file data each time command is executed.

```
IndexPaste 0;
```

LayersCopy...Convert groups to layers and copy the design to clipboard as column. When executed from the FilmStar Workbook the design is pasted in column format starting at named cell **Design**.

```
LayersCopy;
```

LineColor...Change line color as follows: black, Red, Yellow, Blue, Green, Magenta, Cyan, White

```
LineColor R;
```

MainWindow...Set Main Menu window state: 0 normal, 1 minimized, 2 maximized. This is useful if you want to get the window out of the way while running BASIC programs.

```
MainWindow 0;
```

Merit...Compute optimization merit function and copy result to clipboard

```
Merit;
```

Optimize...Optimize the design according to the currently set method, targets and variables. This cannot be used with simplex. Click **Optimize...Parameters** to adjust termination criteria.

```
Optimize;
```

Following the optimization, the design can be retrieved with DDE macro command **LayersCopy** or **GroupsCopy**. Use DDE command **Merit** to obtain the new merit function.

OptiTool...Optimize the design according to the currently set method, targets and tooling variables checked in **Setup...Tooling Factors**. This cannot be used with simplex. Click **Optimize...Parameters** to adjust termination criteria.

```
OptiTool;
```

Following the optimization, tooling factors are copied to the Windows clipboard on separate lines. A typical result might look like

```
1.190345
1.059823
1
1
```

OptiVars...Assign some optimization variables.

```
OptiVars 1,4,5;
```

OptiVarsAll...Assign all layers to optimization variables.

```
OptiVarsAll;
```

PhaseSmooth...Automatically remove vertical jumps in phase shift (radians) data by adding or subtracting 2 PI.

```
PhaseSmooth;
```

PlotDone...Must be issued after the last CALCPLOT command

```
PlotDone;
```

PlotStart...Must be issued before the first CALCPLOT command if multiple graphs are plotted on the Main Menu screen.

```
PlotStart;
```

PlotSelect...Allows plotting R/T/A on the same axes in the Main Menu graph and in FSPlot. PlotType > 0 is equivalent to unchecking **New axes after changing Graph Axes** in **File...Configuration...Preferences**. But here the Select Plot dialog box is suppressed and selection is as below.

```
PlotSelect 0;   As in Setup Parameters
PlotSelect 1;   Plot reflectance
PlotSelect 2;   Plot transmittance
PlotSelect 3;   Plot absorptance (1-R-T)
```

Typical use in FilmStar BASIC is:

```
k = Macro("Calculate;")
PlotClose      ' erase current FSPlot graphs
PlotActivate   ' activate FSPlot window
PlotLegendOn 1 ' turn on plot legends
k = Macro("PlotType 1;") ' select reflectance
PlotLegend(1) = "Reflectance"
PlotNext       ' plot graph 1
k = Macro("PlotType 2;") ' select transmittance
PlotLegend(2) = "Transmittance"
PlotNext       ' plot graph 2
k=Macro("ReportShow;")   ' get Report Generator
```

PlotWindow...Set FSPlot window state: 0 normal, 1 minimized, 2 maximized. This is useful if you want to get the window out of the way while running BASIC programs.

```
PlotWindow 0;
```

Replot...Replot current spectrum. Use with AxesDraw when drawing a new graph.

```
AxesDraw;Replot;
```

ReportPrint (PrintReport)...Print the current report without displaying it. Same as File...Quick Print Report. Use ReportShow to display the Report Generator dialog before printing.

```
ReportPrint;
```

ReportSave (SaveReport)...Save report as a binary printer file (*.prt), Adobe Acrobat (*.pdf), or rich text format (*.rtf) . The report is not displayed. Include path and extension.

```
ReportSave c:\winfilm\reports\test1.prt;
```

ReportShow (ShowReport)...Preview report and optionally print it.

ReportShow;

ReverseDesign...Reverses design

ReverseDesign;

SpecTargets...Convert current spectrum to optimization targets. If New=0 then new targets supplement those already in the target list. If New<>0 then a new list is created. The other quantities are the same as those the optimization targets editor.

SpecTargets New Type\$ Tol Angle Pol\$;

SpecTargets 1 R 1 45 R;

StatusLabel...Display message in status label at screen lower left. Do not include ';' in the label.

StatusLabel Visit Princeton soon;

StatusLabel; *Clears label*

StopCalc...Try this command if you have a problem running DESIGN from other programs. A typical symptom is DDE timeout. StopCalc prevents DESIGN from responding to Windows messages until the current task is completed. The Stop command is the Main Menu is disabled when StopCalc is set to zero.

StopCalc 0; *Turn off DoEvents*

StopCalc -1; *Turn on DoEvents (default)*

TargetsCopy...Copy optimization targets to clipboard.

TargetsCopy;

TargetsPaste...Paste optimization targets from clipboard.

TargetsPaste;

Tooling... Assign values shown in Tooling Factors dialog. Useful for evaluating and optimizing designs averaging over angle and thickness distribution, as in curved reflectors.

Tooling 1.05 1.06 1.10;

Tooling; *Sets all values to 1.0*

TypeContour...Mode for contour data.

TypeContour 0; *Data in matrix*

TypeContour 1; *Data in triplets*

TypeDataCopy...Copy and paste (DDE import/export) spectral data using R/T = 0-100% instead of 0-1. See **Spectra...Format Options**.

TypeDataCopy 0; *R/T 0-1*

TypeDataCopy 1; *R/T 0-100%*

TypeDataFile...Open and save spectral data using .csv or JCAMP format. This can also be selected manually in **Spectra...Format Options**. JCAMP is a 'standard' spectroscopy file format and provides a link to Spectrum 2000 and other software packages

TypeDataFile 0; *.csv ASCII format*

TypeDataFile 1; *JCAMP format*

TypeDataFile 11; *JCAMP, P-E compatible*

TypeDataFile 100; *.csv for Excel*

TypeSide2...Specify Side 2 Compensation. User values 1-5 corresponding to list in Setup Parameters.

```
TypeSide2 2;    FWD include Side 2
```

TypeWaveCopy...Copy and paste (DDE import/export) spectral data using current wavelength units rather than nanometers. This can also be selected manually in **Spectra...Format Options**.

```
TypeWaveCopy 0;    Wavelength in nanometers
TypeWaveCopy 1;    Wavelength in user-specified units
```

WbActivate...Activate FilmStar Workbook module. This is identical to pressing **[F3]** from the Main Menu.

```
WbActivate;
```

WbSetName...(Re)assign Workbook defined name. Especially useful for moving DataMarker in complex models requiring multiple spectral ranges. Reassigning DataMarker resets data looping.

```
WbSetName DataMarker $A$100;
WbSetName DataMarker Test2.vts!$A$100;
```

WbWindow...Set Workbook window state: 0 normal, 1 minimized, 2 maximized. This is useful if you want to get the window out of the way while running BASIC programs.

```
WbWindow 0;
```

Each command is followed by a semicolon (;). Commands may be grouped or sent in separate EXECUTE commands. *Do not use semicolons in text strings!* Spaces separate parameters in some commands.

The following MS Excel 97/2000 macro updates DESIGN ("design1.exe") with the design in the clipboard, sets angle to 30, polarization to random, design wavelength to 525 nm, calculates the spectrum and copies the spectrum to the clipboard. *The command string in DDEExecute must be surrounded by square brackets.* The DDEExecute command is one macro statement on one line.

```
Sub Evaluate(iter As Integer)
    ch = DDEInitiate("DESIGN1","Main")
    DDEExecute ch, "[StatusLabel Iteration"
    & Format$(iter,"0")& ";DesignPaste;Angle 30 R;
    DesignWave 525;Calculate;DataCopy;]")
    DDETerminate ch
End Sub
```

Macro command 'Fred' is useful for making sure that things work!

```
Sub Main
    Ch = DDEInitiate("DESIGN1","Main")
    DDEExecute Ch, "[Fred;]"
    DDETerminate Ch
End Sub
```

Normal error-checking methods may be suppressed when running DESIGN with DDE commands. For example, DataSave overwrites files with the same name.

Command Macros <Shift + F1>...<Shift + F6>

The above DDE commands may also be sent to DESIGN as command macros. Macros are defined in the Macro Editor in the Evaluate menu and are stored with the DESIGN Configuration. The following example calculates S and P spectra with a single keystroke.

Description: 45 deg, S + P

Command: axessdraw;plotstart;angle 45 p;linecolor r;
calcpplot;angle 45 s;linecolor b;calcpplot;plotdone;

Users with suggestions for additional macro functions should contact FTG Software.

FilmCalc Compatibility

Auxiliary program convert.exe (included on FilmStar CD-ROM) converts FilmCalc data files to FilmStar format. This program is run from the Windows Program Manager via

File...Run ".\winfilm\convert.exe"

Note that there are two gray text boxes. The smaller box shows progress during conversion while the larger box shows accumulated errors. If you want to print the errors, highlight the text, copy it to the Windows clipboard with <Ctrl+C> and paste it into Windows Notepad.

Convert

FilmCalc files are opened, converted and saved in FilmStar format. Original files are not erased.

With one exception, all files should convert without any user-attention. But there are difficulties associated with **n,k Tables** (dispersive index files). In FilmStar all parameters are stored in ".itw" files (n,k Tables directory). In FilmCalc the following extensions are used: ".itb" (Index Table in n,k Tables directory), ".axi" (Graph Axes in Data directory), ".itf" (File Functions in Data directory) and ".nkt" (n,k Fit Parameters in Data directory).

After converting the Index Table, CONVERT looks for ".axi", ".itf" and ".nkt" files with the same file name. If the original FilmCalc table is "tio2a.itb", CONVERT will attempt to open "tio2a.axi", "tio2a.itf" and "tio2a.nkt".

Since FilmStar INDEX always displays graphs of n and k vs. wavelength, Graph Axes information (optional in FilmCalc) is required. If no ".axi" file is found, CONVERT examines the Index Table and assign values.

File Types

Check some or all types to be converted.

Duplicate File Names

It is likely that some FilmCalc files ("bbar", "highpass", etc.) have the same names as FilmStar files already on your disk. You can decide whether to overwrite or skip these files.

File...Directories <Ctrl+D>

Enter directories for both programs. CONVERT can be repeatedly run with different directory assignments. CONVERT will not create directories; if you wish to copy to an empty directory, create it first with Windows File Manager or another utility.

File...Exit <Alt+F4>

Program setup is stored in "..\winfilm\config\design1.ini".

Setup Menu

Film Indices

Setup...Film Indices <Ctrl+I>

The Film Indices editor lists the materials used in a thin film design. It is possible to list more materials than those actually used. Layer thicknesses are later specified in the Groups or Layers design editors.

Materials must be defined before being used in a thin film design.

AIR indicates entrance medium (normally air) and **SUB** indicates exit medium (normally the substrate).

To enter new index values:

1. Define a symbol by entering a one letter index symbol 'A' to 'Z' in the **Symbol** column. If more than 26 materials have been allocated (see "Configuration - Capacity" on page 23) then 'a' to 'z' are also used; otherwise all entries are capitalized.
2. Specify film thickness convention:
 - a. **Optical thickness...**Set **Type** to **Opt** (just type O). Specify quarter wave optical thickness $QWOT = .25$ or 1 in Setup Parameters. Optical thickness makes no sense for metals. If the substrate is a metal, select 'Metal' under Substrate Properties (see "" on page 43).
 - b. **Physical thickness...**Set **Type** to **Phs** for layers described by physical thickness. Specify physical thickness units in Setup Parameters. It is possible to automatically convert optical to physical thickness; this updates the **Type** column automatically.
 - c. **Massive thickness...**Set **Type** to **Msv** for massive (thick) layers described by physical thickness in mm. This allows evaluation and optimization for films on both substrate surfaces or with multiple substrates and air gaps. In most cases the user will assign $n=1.0$ to both AIR (entrance medium) and SUB (exit medium).
3. Specify film indices:
 - a. **Constant...**Leave the **Dispersion** column blank and enter constant values for n and k. Columns C-G are disabled (grayed out).
 - b. **Table...**Under **Dispersion** select the name of a dispersive Index Table previously stored in program INDEX. Longer file names may appear truncated, but when pulled down the list becomes wide enough for the longest name. Hovering the pointer over a truncated file name displays the full name as tooltip text. In addition columns may be made wider by dragging at the top. The **Refresh** check box forces the reloading of index tables. Check this if you have altered dispersive index data in INDEX while running DESIGN. Columns A-G are disabled. A dispersive Index Table with an entry at only one wave length is treated as a constant.

- c. **Function...** Under **Dispersion** select the name of an Index Function (starting with \$) rather than a file name. Columns A-G (further columns displayed if more than 7 coefficients are specified) are the relevant coefficients. Index optimization variables are specified by negative numbers in the Optimization Variables editor. Note that unused columns are disabled. **Edit...Copy Function** copies values to the clipboard for pasting into program **INDEX**.
- d. **Function Fit from File...** Under **Dispersion** select the name of a dispersive Index Table previously created and saved in program **INDEX**. If available, the index fit for that table is inserted by clicking **Insert Fit**.
- e. **Description...** The **Description** is utilized in Review Design as well as FilmStar BASIC. By including string "QWOT" (not case sensitive) in the description a corresponding optical film layer is calculated as a quarter wave at *any evaluation wavelength*. If the index of this material is equal to the square root of a massive layer onto which it is deposited, the film layer becomes *unobtainium* - a perfect antireflector at zero degrees.

Graph Axes

Setup...Graph Axes <Ctrl+G>

Horizontal (wavelength, angle, thickness) and vertical (%R, %T, etc.) axes types must be specified before editing this dialog box. (See "" on page 43.) Report Generator templates are stored with Graph Axes.

Interval

When plotting vs. wavelength, use Interval < 0 for faster calculation with inverse wavelength spacing.

For example, let Min=400, Max=1200 and Interval=- 10. During evaluation the wavelength interval changes from 10 at 400 nm to 30 at 1200 nm.

Interval < 0 is not permitted when plotting vs. angle or when the horizontal scale is expressed in wavenumbers.

List Name

When using a wavelength list, Interval is replaced with the name of a Wavelength List file (".wls") stored in the Data directory.

Label

Axis label and grid spacing.

Graph Title

In addition to the graph title, labels may be placed on the graph by pressing <Shift+Click> when the cursor is in the plot area (crosshair shape).

Specify evaluation wavelengths in Wavelength List

When the horizontal axis is physical thickness, check this option to assign different evaluation wavelengths for each layer according to values in the Wavelength List editor. This is useful for optical monitor simulations.

Index Functions - Built-in

Setup...Index Functions...Built-in

This dialog selects built-in index functions to be shown under *Dispersion* in the Film Indices editor. Functions which are never used can be suppressed in order

to simplify choices. In the same way, Index Tables which are never used can be kept in a backup directory.

Opening a FILM or FILM Archive referencing a deselected index function automatically adds that function to the list. A warning is displayed if the number of coefficients exceeds the maximum specified in **File...Configuration...Capacity**.

The specialized GaAlAs function is given below.

GAALAS Ga(1-x)Al(x)As where x=A
M. Afromowitz, SS Comm 15, 59 (1974)
Additional absorption:
 $\alpha = 3e-18 \cdot B + 7e-18 \cdot C + D$
(alpha in cm⁻¹, B n-type doping,
C p-type doping, D extra term)
Temperature variation:
 $n = n \cdot (1 + 7e-5 \cdot E)$
(E: deviation from room temperature)

Index Functions - User Defined

Setup...Index Functions...User Defined

Supplementing built-in index functions, advanced users may define their own index functions as formulas, in FilmStar BASIC, in the FilmStar Workbook, in other Windows applications such as Excel.

The formula evaluator and built-in FilmStar Workbook have calculation speed advantages and should be used when possible. Formulas should be developed in INDEX where they can be verified by plotting.

Click tab **Workbook/DDE** to define index functions in the Workbook or in external programs such as Excel. Click **Formula** to define functions as formulas. The latter is much easier if one line formulas can be written for n and k. Click tab **BASIC** to define index functions in a FilmStar BASIC program.

Be sure that the correct tab for each function is selected before proceeding to the next function with Select Function.

Function

Each function has a name (seven characters maximum) which will be automatically inserted in the dispersion list in the Film Indices editor (preceded by '\$'). You must also enter the number of variables (coefficients utilized) as well as whether or not the function is absorbing.

Coefficients

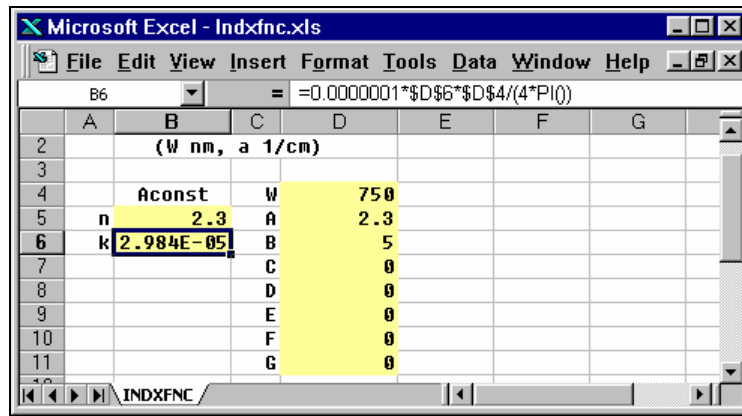
These are exported to the external application as eight lines of text. The first line is wavelength in nanometers and the remaining lines correspond to coefficients A-G.

Indices

These are imported by DESIGN as two lines of text. The first line is n and the second is k.

Execute

In some cases it is necessary to execute a command in the external application. In Excel this corresponds to executing a macro.



Consider an example using Microsoft Excel worksheet "indxfnc.xls". User-function **Aconst** returns n,k for a given absorption coefficient a (alpha) in 1/cm: $k = 1. e - 7 * a * W / (4 * PI)$ for wavelength W in nanometers

D4:D11	AconstCoeff
B5:B6	AconstIndex
B5	=D\$5
B6	=0.0000001*\$D\$6*\$D\$4/(4*PI())

In DESIGN (and INDEX) the function is specified as follows:

Name Aconst	# Coefficients 2	Absorption TRUE
Coefficients	Topic Excel indxfnc.xls	Item AconstCoeff
Indices	Topic Excel indxfnc.xls	Item AconstIndex

In this case it is not necessary to execute any commands by running a macro in Excel. But if it were necessary the following format would be used:

Topic	Excel System
Command	[RUN("INDXFNC.XLM!AconstCalc")]

where AconstCalc is the name of the required macro. The user can verify that this works by implementing a test macro:

```
AconstCalc  =ECHO(FALSE)
             =BEEP()
             =RETURN()
```

A built-in worksheet is treated the same way, but without 'Excel|' in Topic entries:

Name Aconws	# Coefficients 2	Absorption TRUE
Coefficients	Topic indxfnc.xls	Item Coefficients
Indices	Topic indxfnc.xls	Item AconstIndex
Execute	Topic	Command

	A	B	C	D	E	F	G
1		$k=1.E-7*a*W/(4*PI)$					
2		(W nm, a 1/cm)					
3							
4		Aconst	W	750			
5	n	2.3	A	2.3			
6	k	2.9842E-005	B	5			
7			C	0			
8			D	0			
9			E	0			
10			F	0			
11			G	0			
12							

Cells \$D\$4:\$D\$11 are named 'Coefficients' and cells \$B\$5:\$B\$6 are named 'AconstIndex' in the Workbook's **Edit...Define Name** dialog box.

In **Formula** mode we have the following which is considerably simpler.

Formula

Type a formula for n and a separate formula for k. In addition to coefficients A-G, allowed variables are WN for wavelength in nanometers and WM for wavelength in microns.

As an example **Aconfnc** computes n,k for a given absorption coefficient b (alpha) in 1/cm. $k=1.e-4*a*W/(4*PI)$ for wavelength W in microns. Then

$$n=a$$

$$k=.0001*b*wm/(4*3.14159)$$

BASIC

Specify the name of a FilmStar BASIC program which computes indices. Data is automatically transferred to your BASIC program via built-in clipboard functions. Copy the example below, changing Section 2 (User-code) as required.

```
' ACONST.BAS for FilmStar DESIGN
' This program shows how to define
' index functions in FilmStar BASIC.
DefInt I-N
DefSng A-H, O-Z
Dim Aconst(1 To 7)
Sub Main
' 1. Get comma-delimited coefficients from clipboard
s$ = Clipboard$()
Parse s$, wave
For i = 1 To 2      ' 7 maximum
    Parse s$, Aconst(i)
Next i
' 2. User-code to calculate indices
xi = Aconst(1)
xk = .0000001 * Aconst(2) * wave/(4 * 3.14159)
' 3. Copy indices to clipboard
Clipboard Cstr(xi) & "," & Cstr(xk)
```

```

End Sub
Sub Parse (s$, x)
    i = InStr(s$, ",") ' comma delimited
    x = Val(Mid$(s$, 1, i - 1))
    s$ = Mid$(s$, i + 1)
End Sub

```

Mixed

This is similar to Formula except look up values from one or two index tables are utilized. For example, consider index function SI-SIO2 which is a mixture of Si and SiO2. Under Table 1 select SI and under Table 2 select SIO2. Then type

$$n=A*N1 + (1-A)*N2$$

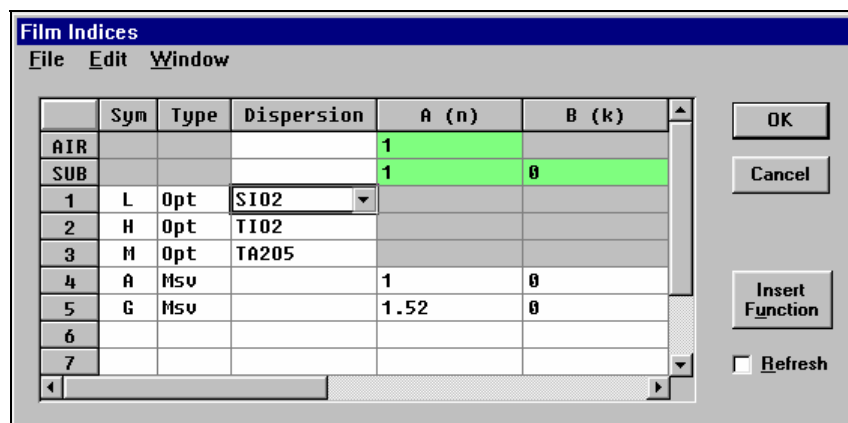
$$k=A*K1 + (1-A)*K2$$

Here the one coefficient A is the mixing ratio. Results can be tested in program INDEX.

Massive Layers

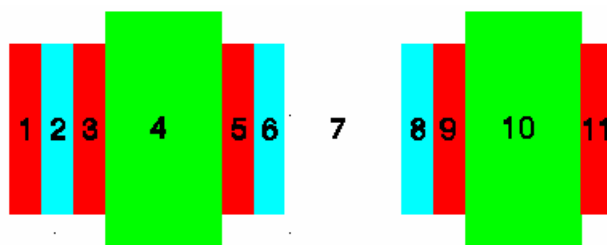
DESIGN allows virtually any number of massive (thick) layers to be included in a thin film design. In order to specify an index symbols as massive, set **Type** to **Msv** in the Film Indices editor.

Massive thickness is expressed in millimeters and **FWD Ignore Side 2** calculation mode is required. While designs containing groups are supported, massive layers cannot be placed within parentheses.



As shown in the above screen image, n=1 for AIR and SUB is usually entered in the Film Indices editor. By defining "A" as a massive layer with n=1.0, we can insert an air gap.

As quite complex film-substrate structures can be designed, users must be very careful with layer numbering when transferring designs into manufacturing processes. The design illustrated below has three massive layers: two glass (4, 10) and one air (7). If layers are numbered from 'left' to 'right', light is incident from the right.



Reversing the design (see "" on page 47) can be very helpful when splitting complex constructions containing massive layers into single surface components.

Users are sometimes surprised when a design containing a nonabsorbing massive glass layer such as

(.25H .25L)10 .25H 2G .25H (.25L .25H)10

does not produce expected blocking. If the transmittance with the coating on only one side is 0.02%, they are surprised that the calculated transmittance with both sides coated is 0.01% - not 0.004% as usually observed experimentally.

The discrepancy is understood upon including absorption in the massive layer... say $k=10^{-6}$ or even less. While this has little affect on the transmittance of an uncoated substrate, it damps multiple reflections between surfaces and profoundly affects the transmittance of a substrate coated on both sides.

Setup Parameters

Setup...Parameters <Ctrl+P>

Plot type

Select Wavelength Range or Angle Range to specify an evaluation range different from the graph axes range. This is intended for calculations where the evaluation range (say 380-770 nm) does not make for pleasing graph axes (350-800 nm).

Select Wavelength List to compute spectra at wavelengths specified in a list (*.wls) stored in the data files directory. This is useful for tolerancing involving discrete wavelengths. when computing tolerancing Select Wave/Angle List to compute spectra at wavelengths, angles and polarizations specified in a similar list (*.wal) . The file name of these lists are used instead of Interval in the Graph Axes editor. Wave/Angle List is automatically selected for ellipsometric calculations.

Select Thickness for monitor and sensitivity plots where the horizontal axis represents physical thickness. Thickness axes are not allowed when the design contains parentheses. (Use the Layers design editor to 'explode' groups into separate layers.)

Wavelength units

Internal calculations are performed in nanometers but displayed in nanometers, microns, Angstroms or inverse cm. This choice does not, therefore, affect spectral data files. Units can be switched at any time.

Optical thickness convention

Quarter Wave Optical Thickness (QWOT) at a given Design Wavelength can be specified in two ways:

1. QWOT=.25 (quarter wave stack: .25H .25L .25H etc.)
2. QWOT= 1 (quarter wave stack: 1H 1L 1H etc.)

Physical thickness units

Physical thickness (Nanometers or Microns) is used for layers when **Phy** is included in the corresponding **Type** column in Film Indices. Otherwise optical thickness is utilized.

**Thickness and wavelength units can be changed at any time.
Unit-dependent quantities will update automatically.**

Substrate properties

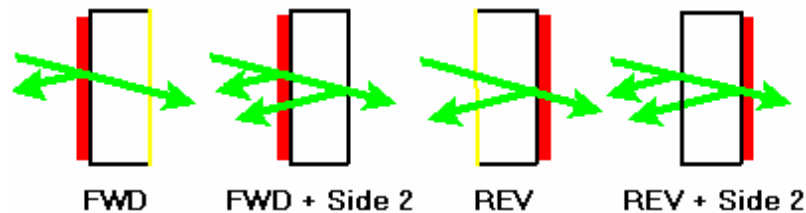
Calculate as...For maximum calculation speed when film layers are non-absorbing, select Dielectric when the absorbing substrate is a filter glass ($k \ll n$). Otherwise select Metal.

Metal gives correct answers for dielectric substrates, but **Dielectric** gives *wrong answers* for metallic substrates. In most cases erroneous results will be very far off; misinterpretation is therefore unlikely.

Thickness...Useful for filter glass substrates. May be ignored for nonabsorbing substrates. Entering 0 for metal substrates produces erroneous transmittance values!

Side 2 Compensation

Modes 1-4...Include or ignore reflection from the second surface. Ignoring reflection is equivalent to a perfect antireflection coating on Side 2. In most transmission measurements, the second surface is not AR coated and Side 2 compensation must be included for accurate results. In reflection measurements, Side 2 effects are often eliminated by grinding the uncoated surface.



Mode 5...This special mode is intended for inverse synthesis. The uncoated surface is included in transmission but ignored in reflection. This corresponds to the practice of grinding the second surface in order to obtain more accurate reflection measurements.

Film on Side 2...This FilmCalc mode was confusing and has been eliminated. It is very easy to compute films on multiple surfaces by treating substrates as massive layers. *Always use Mode 1 when massive layers are included in the design.*

FWD (forward) denotes light incident on the filmed surface (Side 1) and **REV**(reverse) denotes light incident on the uncoated (Side 2) surface.

FWD and **REV** always give the same transmittance but reflectance is only the same when there is no absorption. **DESIGN** adds surface reflections incoherently. While this is applicable to filters and other light-controlling devices, it is incorrect for etalons and similar devices where surface reflections must be added coherently. An etalon can be treated as a thin film assembly with **AIR** and **SUB** indices equal to 1.

If not using **FILM** Archive Mode, Setup Parameters are stored in related disk files as follows:

Plot Type/Axes	Graph Axes
Wavelength Units	Graph Axes
Thickness Convention/Units	Design
Dielectric/Metallic Substrate	Film Indices
Substrate Thickness	Design
Side 2 Compensation	Design

Total Internal Reflection

Preventing a math error, checking this box automatically replaces $k=0$ by $k=10^{-8}$ in nonabsorbing films and substrates.

Select Total Internal Reflection mode *ONLY* when performing TIR calculations.

Tooling Factors

Setup...Tooling Factors

When fabricating a design it is reasonable to suppose that all layers of each material type are too thick or too thin by the same factor. To test this idea users can compute a tooling factor for each material by inverse synthesis optimization. Targets (Target Type = *Equality*) are the actual spectrum and variables are thickness ratios for each material.

If any tooling factor is unequal to 1.0, a warning message is displayed in design editors and the Review Design screen. Loading a new design from disk restores 1.0 tooling factors.

Under **Compute** use the space bar or mouse to insert (remove) the check mark and activate (deactivate) the material in the tooling factor calculation. Check marks are stored with Film Indices.

In order to use this method, do the following: 1. Load the design which will be your 'starting' design for synthesis, 2. Load a spectrum in the **Spectra** menu, 3. Convert it to targets in **Optimize...Targets...Generate**. Then return to the Tooling Factor dialog box and click **Compute**. A spectrum with non-unity tooling factors can be simulated in the **Design...Adjust Design** dialog.

Tooling factor determination can be very useful in reverse-engineering recipes (typically supplied as crystal monitor thickness in $k\text{\AA}$) supplied by coating chamber manufacturers. Such recipes, typical in the ophthalmic AR coating, are related to the thin film design by mysterious fudge factors. Once tooling factors are determined, the 'real' design is generated by clicking **Adjust Design**. This changes tooling factors back to 1.0.

Total Internal Reflection

When the index of the incident medium exceeds 1.0, internal angles beyond the critical angle will cause a mathematical error. If this occurs return to the Film Indices editor and ensure that all materials in the design, except the entrance medium AIR, are absorbing. Enter a small value for k , say 10^{-8} . This forces DESIGN to use the correct algorithm.

Alternatively, check the box Total Internal Reflection in Setup Parameters. This replaces $k=0$ by $k=10^{-8}$ in nonabsorbing films and substrate.

Wavelength List

Setup...Wavelength (Wave/Angle) List...Edit

The Wavelength List editor creates and edits custom lists of wavelengths for evaluation. This is useful for filters which operate in distinct wavelength regions; 'don't care' regions can be skipped. It is also useful when detail is required in one region (*i.e.* bandpass) but not required elsewhere.

The Wavelength List editor is also used for specifying evaluation wavelengths when plotting vs. physical thickness with multi-wave mode enabled (see "" on page 38).

The maximum size of the list is specified in **Configuration...Capacity**. This is *not the same as the size of the list that can be utilized...only the size that can be edited in DESIGN*. A list with 2001 points can be used in a thin film evaluation but cannot be edited if the capacity is set at 101 (default).

One or more wavelengths can be deleted by highlighting and pressing . The entire list is highlighted by clicking the column title ('Wave...').

The file can also be created in Excel or a text editor. File format is shown below. Wavelength entries are always in nanometers. *Click label 'List Name' to view the list of available files.*

Description
of entries
Wavelength #1
Wavelength #2
etc...

An actual Wavelength List file resembles the following:

```
"Top secret laser wavelengths"
3
450.2
490.1
552.8
```

The Wave/Angle List file appears as follows:

```
"Test for ellipsometer"
6
500,45,"R"
500,60,"R"
500,75,"R"
700,45,"S"
700,60,"P"
700,75,"R"
```

In Excel, use **Save As**, select "CSV" format and add extension ".wls". The wavelength list must be stored on disk before it can be used in a thin film calculation. The list's file name is entered in the Graph Axes editor. The file extension for wave/angle lists is ".wal".

Generate

Repeatedly adds new wavelengths.

When Multi-wave mode is utilized for plotting vs. thickness, highlight multiple rows before typing to input the same wavelength for adjacent layers.

Edit...Paste

Pastes an Excel column into the editor.

Design Menu

Review Design <Ctrl+R>

Display current design and indices. Useful for observing progress during optimization. Click **Edit...Copy All** to place the entire text into the Windows clipboard or **Edit...Copy** to copy highlighted text. The review can be edited and printed.

There are three format options for the review. **Option 1** (original) shows index file/function names and coefficients A-G as displayed in the Film Indices editor. **Option 2** show material descriptions as entered in the Film Indices editor (to the right of column G). **Option 3** displays individual layers with material descriptions. Note that this option also converts layers within parentheses to separate layers.

Wavelength <Ctrl+W>

Change current design wavelength, angle and polarization without calculating a new spectrum.

Optical to Physical

Convert layers from optical to physical thickness units in nm or μm as specified in Setup Parameters. This conversion is automatic when optimizing index and thickness simultaneously.

Physical thicknesses should be utilized when studying spectral shifts caused by index shifts. Designs described by optical thickness will give the impression that spectral features are not dependent on indices.

Physical to Optical

Convert layers from physical to optical thickness units in integral or quarter waves as specified in Setup Parameters. Makes no sense for metals.

Reverse Design

Reverse layer numbering in Groups or Layers notation:

SUB (.25H .25L)2 .125H AIR

becomes

SUB .125H (.25L .25H)2 AIR

Reverse Design is useful when computing reverse reflectance in designs containing massive layers and/or in storing design segments.

Adjust Design

Design...Conversions...Adjust Design <Ctrl+J>

This dialog box enables users to modify designs by (repeatedly) performing arithmetic operations on some or all layers. ***Since designs are permanently changed, users should save initial designs on disk.*** Designs containing groups

(parentheses) are supported and layer numbering follows the optimization variables convention.

Design Macros

from Groups Editor: Macro...Edit <Ctrl+M>

A design macro is a wavelength and/or angle-matched design segment which is pasted into the Groups Mode editor at the cursor position. Up to six macros can be defined. A macro is inserted with <Shift+F1>...<Shift+F6>. This facility is especially useful for assembling complex filters. The concept is best explained by example:

	Design	Wavelength
A.	(.25H .25L)10 .25H	1064
B.	(.125H .25L .125H)10	0

For normal incidence and design wavelength = 550nm (L=1.46 and H=2.3), Macro A is inserted as

(.48364H .48364L)10 .48364H

while Macro B remains unaltered.

If Angle = 45 deg Macro A will be inserted as

(.50825H .5528L)10 .50825H

and is centered at 1064nm when evaluated at 45 deg. Macro B is inserted as

(.13136H .28575L .13136H)10

and is centered at the design wavelength (550nm) when evaluated at 45 deg. Note that design macros are stored with the thin film design and that existing designs can be opened as macros.

Design

Enter a design fragment in the large text box. Parentheses are permitted. Only index symbols previously entered in Film Indices can be typed.

Wavelength

Enter 0 to insert the Macro at the current Design Wavelength. A wavelength greater than zero adjusts layers for the Macro wavelength.

Angle

Angle-matching increases thicknesses so that quarter waves occur at designated wavelengths.

Description

The first 24 characters of the description field are displayed in the Groups Mode design editor Macro menu.

Reverse

Reverse the displayed design. This only works if the displayed design is, by itself, correctly entered. Parentheses must be matched and index symbols defined in the Film Indices editor, etc.

Open 1...6

Open an existing design to use as a fragment in the new composite design. If the design contains index symbols undefined in Film Indices a warning is issued but the design is still displayed.

Groups Design Editor

Design...Groups Editor <Ctrl+D>

In this full-screen design editor ()N can be used to repeat a group of layers: *i.e.* (.25H .25L)3 is equivalent to .25H .25L .25H .25L .25H .25L but is evaluated much faster by the Tschebysheff algorithm. A Group is any construction within parentheses or any individual layer not within parentheses.

Layers are written as QD where D is a symbol A...Z (previously defined in Film Indices) designating a film material and Q is the numerical optical or physical thickness of the layer. **Layer #1 is next to the substrate (exit medium).**

Thicknesses are specified in three ways:

1. **Optical Thickness...** .25H (or 1.0H) is 1 QWOT (quarter wave optical thickness) at the design wavelength.
2. **Physical Thickness...** .234.7H (or .2347H) is physical thickness in nanometers (or microns). Enter * (asterisk) under **t** in the Film Indices editor. Design wavelength does not apply.
3. **Massive Thickness...** 2G is physical thickness in millimeters. Enter - (minus sign) under **t** in the Index Editor. Massive layers are treated according to P. Baumeister, et al, *Optica Acta* 19, 853 (1972). Designs can contain any number of massive layers.

Normal Windows text editing commands work in the design editor. A design is deleted by highlighting it and pressing . Copy a design segment to the clipboard by highlighting and pressing <Ctrl+C>. Paste from the clipboard with <Ctrl+V>. This technique is very useful for inserting a design segment elsewhere in the design. To quickly clear the editor use <Shift+Ctrl+End> to highlight the entire design. Designs may also be altered via **Edit...Replace**.

QWOT and physical thickness units can be changed in Setup Parameters <Ctrl+P>. Layers are input from the SUBSTRATE as follows:

.25L .25H .25L .25H .25L .125H

and may be grouped within parentheses:

.25L (.125H .25L .125H)10 .5L (.25H .25L)3 .5H

Parentheses cannot be nested. Groups can be converted to layers (parentheses removed) by accessing the Layers Editor. Retain the original design by saving to disk <Ctrl+Shift+D> before converting. Groups to Layers conversion fails if the total exceeds maximum layer capacity.

Click **Single** to display the design as one long string and **Multiple** to place each group on a separate line.

DESIGN automatically combines adjacent layers with the same index symbol. **Take care when deleting layers while optimizing:** variables may no longer be consistent with your intentions! As it is possible to lose a design (by deleting a currently used index symbol from Film Indices, for example) we suggest that you periodically save your latest design.

When using massive layers, it is usual to enter n=1 for AIR and SUB. Layers are input from left to right and light is incident from the right. When saving designs for later use in MONITOR or CRYSTAL, the total design must be split into layers deposited on each substrate surface. Use **Reverse Design** to store layers in the correct order. For example, the following design

AIR .165H (.33L .33H)2 2G (.25H .25L)2 .125H AIR

must be split into two designs

Design 1: SUB (.33H .33L)2 .165H AIR

Design 2: SUB (.25H .25L)2 .125H AIR

Multiple massive layers are allowed, but massive layers may not be placed within parentheses. Assuming that G represents a massive layer:

OK: AIR (.25L .25H)2 2G .25H 2G .25H .25L AIR

NO GOOD: AIR (.25L .25H 2G)2 (.25H .25L)3 AIR

Access the Layers editor to 'explode' Groups into separate layers.

Edit...Combine Layers

Adjacent layers of the same material are usually combined into a single layer. Click to turn this off. This setting is stored with the thin film design.

Edit...Inhomogeneous <Ctrl+I>

Layers may be subdivided into sublayers with different indices.

Macro...Edit <Ctrl+M>

Create designs or design fragments which are angle-matched and centered at specified wavelengths.

Herpin Equivalent Layers

Design...Conversions...Herpin Equivalent <Ctrl+H>

This dialog box enables users to replace intermediate indices with three layer Herpin equivalents. ***Since designs will be changed, users should save initial designs on disk.*** Designs with layer groups (parentheses) are supported and layer numbering for such designs follows the optimization variables convention. The calculation method is based on M. C. Ohmer "Design of three-layer equivalent films", *J Opt Soc Am* 68, 137-139 (1978).

Herpin equivalent layers are defined at one particular wavelength, angle and polarization. The program compares final reflectance with the value calculated with the original design (before replacement). If values differ by more than the **Accuracy** value (1e-9 to 1e-1, default 1e-7), the solution is rejected as spurious. The value should be increased (try 1e-3) when film materials are absorbing. Herpin replacement assumes $k=0$. If $k>0$ the final calculated reflectance differs from the original value. This adjustment makes it possible to use slightly absorbing dielectric film materials ($k \ll n$) in Herpin calculations; it is NOT intended for metals.

Increasing minimum layer thickness results in different solutions. As in design editors, **Index Symbols** used in the replacement must previously be defined in the Film Indices editor.

Inhomogeneous Layers

from Groups Editor: Edit...Inhomogeneous <Ctrl+I>

This dialog box allows users to replace single film layers by multiple layer groups with graded indices. Each multiple layer group consists of one to five initial layers of specified thickness followed by a final layer of variable thickness. The method is best explained by example:

Suppose we have a filter containing the layer **100H** (physical thickness 100 nanometers). Assume that the index of this film is 2.4 for the first 10 nm, 2.35 for

the next 5 nm and 2.3 thereafter. Assume that the following values are already entered in the Film Indices editor:

A*	2.4
B*	2.35
H*	2.3

Input the following in any row in the Inhomogeneous Layer editor:

Sym	Layer 1	Layer 2
H	10A	5B

Click the left (gray) cell for the row. This highlights the row and enables **OK** - returning the user to the Groups design editor where it is seen that 100H has been replaced by

10A 5B 85H

Other examples:

35H	->	10A 5B 20H
15H	->	10A 5B
12H	->	10A 2B
5.5H	->	5.5A

Upon returning to the design editor, the user can still abort the conversion with **Cancel**.

Obviously it takes careful experiments and inverse synthesis calculations to determine the physical thickness and index of sublayers. If the user can establish this relationship for single layers, it should be possible to more accurately predict the performance of complex designs.

Inhomogeneous Layer setup is automatically saved in "design1.ini" upon exiting DESIGN.

Layers Design Editor

Design...Layers Editor <Ctrl+L>

The Layers design editor is best suited to constructions which have no repeated groups of layers. The editor 'explodes' designs containing layer groups (parentheses) into individual layers. **Save any designs with groups before accessing this editor.**

Layers are written as QD where D is a symbol A...Z (previously defined in Film Indices) designating a film material and Q is the numerical optical or physical thickness of the layer. **Layer #1 is next to the substrate (exit medium).**

Thicknesses are specified in three ways:

1. **Optical Thickness...** 25H (or 1.0H) is 1 QWOT (quarter wave optical thickness) at the design wavelength. Select *Opt* under **Type** in the Film Indices editor.
2. **Physical Thickness...** 234.7H (or .2347H) is physical thickness in nanometers (or microns). Select *Phs* under **Type** in the Film Indices editor. Design wavelength does not apply.
3. **Massive Thickness...** 2G is physical thickness in millimeters. Select *Msv* under **Type** in the Index Editor. Massive layers are treated according to P. Baumeister, et al, *Optica Acta* 19, 853 (1972). Designs can contain any number of massive layers.

QWOT and physical thickness units can be changed in Setup Parameters.

One or more highlighted layers can be cleared with the **** key. To highlight the entire design click the column heading ('Design'). (You can still recover the original design with **Cancel**). Upon exiting the editor adjacent layers with the same index symbol are automatically combined into single layers. *Take care when deleting layers during optimization; variables may no longer be consistent.*

Edit...Ignore Layer <Ctrl+L>

It may be advantageous to evaluate a design with layers ignored. This might be useful when analyzing coatings manufactured in stages. While this can be done by deleting layers, it might be more convenient to temporarily mark them as ignored. Select a single layer or range of layers and repeatedly press **<Ctrl+L>** to ignore and unignore. When layers are ignored, some menus and dialogs are purposely disabled. Settings are temporary and not stored with the film design.

Edit...Combine Layers

Adjacent layers of the same material are usually combined into a single layer. Click to turn this off. This setting is stored with the thin film design.

Replace Design Segment

from Groups Editor: Edit...Replace <Ctrl+E>

This dialog box enables users to quickly modify designs by replacing design strings (100 characters maximum) such as .25 or .25H or (.125L .25H .125L) throughout some or all of a thin film design. If only a partial replacement is required, the enabled portion of the design is first highlighted in the design editor. To replace a string throughout the design, check **Select all** in the dialog box. After making changes, users may still recover their original design by clicking **Cancel**.

Set Zero Layers

Design...Set Zero Layers

This function will not be required by most users. It prevents overflow errors which occur when thick absorbing designs are evaluated at short wavelengths: for example a 10 μm IR reflector evaluated at 0.1 μm .

In such cases eliminating layers (by setting to zero thickness) close to the substrate has no discernible effect on the reflectance spectrum (transmittance will be zero in such cases) and eliminates the overflow error. This is easily verified by manually deleting layers and evaluating resulting spectra. When enabled, a warning *Zero Layers Enabled* appears to the right of the DESIGN toolbar.

Use this function only to prevent the Overflow error message!

Setting zero layers is temporary.

Evaluate Menu

Recalculate <F9>

Calculate a new spectrum without the Calculate dialog box.

Run Macro <Shift+F1>...<Shift+F6>

Run a macro consisting of a series of commands identical to those used with FilmStar BASIC or with other applications via DDE (see "Macro Commands

(DDE)” on page 27). This is useful for reducing repetitive keystrokes, as when evaluating a coating with a series of design wavelengths.

Merit Function <Shift+F9>

Calculate and display the current Merit Function. This is defined as the sum of the squares of deviations

$$\text{SUM}(((\text{Targets}-\text{Value})/\text{Tol})^2)$$

where targets are specified in the Optimization Targets editor.

Tolerancing

Evaluate...Tolerancing...Values <Ctrl+N>

Tolerancing is the estimation of manufacturing yields by assuming random errors in layer thicknesses. Tolerancing is supported in the Main Menu, the CIE Color Module and the FilmStar Workbook. When activated from the Main Menu, there are two modes:

1. Plot mode - spectra are continuously replotted and the user estimates the effects of thickness errors through inspection.
2. Yield mode - % yield is computed using inequality optimization targets as pass/fail criteria. This mode requires that inequality targets are specified in the *Optimize* menu and the *Compute yield...* check box is selected.

In the other cases DESIGN also uses a pass/fail condition to provide a numerical estimate of the yield. When accessed from the CIE Color Module, a scatter plot is obtained on the CIE color scale. Here an acceptance polygon is defined as the pass/fail condition. When accessed from the Workbook, the pass/fail condition is the logical TRUE or FALSE value of named cell 'Passed'.

Enter a non-zero value for **Absolute** or **% Relative** thickness error for each material included in the calculation. This is treated as the standard deviation of the error. In order to prevent errors which are too large, enter an absolute or relative (according to which column is non-zero) **Maximum** value. If this value is zero then errors are not limited.

Spectra Menu

Data Table <F8>

Examine the calculated spectrum. Disabled if there is no data to view. This function can also be implemented in the Workbook.

Convert Table <Ctrl+F8>

Convert the current data table to a new table with the horizontal axis wavelength spacing displayed in the Graph Axes editor. This is useful when comparing measured spectra with calculated results, calculating color coordinates, and using the FSPlot graphing module. Linear interpolation is used. If the spectrum being converted is outside the range of Graph Axes values, an error message is issued, but the spectrum is converted anyway.

Clear Data <Ctrl+E>

DESIGN automatically replots the current spectrum after changing graph axes, etc. This can be annoying at times. Replot is eliminated by clearing the current spectrum from memory.

Copy Data, Paste Data

Exchange spectral data with other applications via the clipboard. Most importantly, data can be easily transferred to and from a range of cells in Excel. When examined with a text editor, data appears as shown below (depending on tab settings):

400	2.676706E-02	.9732329
450	3.414683E-02	.9658532
500	9.240174E-02	.9075983
550	.7369852	.2630148
600	.999822	1.779826E-04

The first column is wavelength (nanometers) followed by reflectance (0-1) and transmittance (0- 1). Columns are TAB (ASCII 9) delimited and lines are CRLF (ASCII 13 + ASCII 10) delimited:

```
400TAB2.676706E-02TAB.9732329CRLF
```

More generally, data columns are arranged as follows according to plot scale:

1. **R,T,OD:** Wave(nm) Refl (0-1) Trns (0-1)
2. **R Phase:** Wave(nm) R-Phase (rad) Refl (0-1)
3. **T Phase:** Wave(nm) T-Phase (rad) Trns (0-1)

Phase is **absolute** when the angle of incidence is zero or when P or S polarization is specified. Phase **difference** is displayed when the angle > 0 and Random polarization is specified. Phase is expressed in radians. (See **Format Options** below.) When plotting vs. physical thickness, the first column is thickness in nanometers from the substrate. Layer boundaries are shown as duplicate thickness values: then last value in layer j and the first value in layer j+1.

Two-column data (wavelength and reflectance OR transmittance) can also be pasted. Data is pasted as reflectance or transmittance depending on graph axes setting.

DDE (Dynamic Data Exchange)

Data can also be exchanged (**DDE...Import** and **DDE...Export**) by dynamic data exchange. This is especially appropriate for Excel models such as CIE which utilize fixed data ranges, say 380-770 X 5 nm. Be sure that the DDE Topic and Item are correct. In Excel the Topic might be *excel|sheet1* while the Item is the named region *spectrum*. Note that the named Excel region must have three columns and sufficient rows.

Format Options

As described above, spectra are normally copied and pasted (DDE transfer) with wavelength in nm (despite the Graph Axes setting). Check **Current units** to copy and paste spectra with the Wavelength Units specified in **Setup...Parameters**. Normally reflectance and transmittance values are 0-1 and phase shift is in radians. Check **R & T in %; Phase** in deg to change this to percent and degrees.

There are two modes for loading and saving spectra. All files are saved in ASCII format and can be read with a text editor. **CSV** (comma-separated values) is DESIGN's default mode. **JCAMP** is a 'standard' which offers compatibility with spectroscopy software from other vendors. **JCAMP + Perkin-Elmer compatible** provides better compatibility when saving P-E JCAMP files. Use this mode to generate Spectrum 2000 'soft instrument'

files for MEASURE. Information about JCAMP is provided in Robert S. McDonald and Paul A. Wilks Jr., *Appl. Spectroscopy* **42**, 151 (1988).

JCAMP stores reflectance or transmittance values, not both. The following method lets you load both into DESIGN: 1. Load reflectance data, 2. Load transmittance or O.D. data with the *same number of data points*. JCAMP cannot be used for non-spectroscopic spectra such as phase shift. Options are stored with Graph Axes.

Some programs deviate from published JCAMP standards or provide incomplete support. Programs frequently fail to support unequally-spaced wavelength data. Users who discover an incompatible JCAMP variation should contact FTG Software.

File Open and Save

Spectra can be loaded from and stored on disk as FilmStar/Excel .csv or JCAMP .dx files. When examined with a text editor, a FilmStar .csv file resembles the following:

```
"FilmStar .csv format example"
31
450,2.468316E-03,.9975317
460,1.44774E-03,.9985523
470,1.326643E-03,.9986734
etc.
```

The first line is an optional description (50 characters maximum); the line is included even if the description is blank. The second line is the number of spectral points. The third and subsequent lines are wavelength (nm), reflectance (0- 1) and transmittance (0- 1). If *For Excel* is checked the following is obtained:

```
450,2.468731E-03,0.9975313
460,1.447442E-03,0.9985526
470,1.325849E-03,0.9986742
etc.
```

In Europe, users might set their computer's number settings (Control Panel Regional Settings) as follows: decimal symbol ",", digit grouping symbol (thousands separator) ".", list separator ";". In this case the Excel file looks like the following:

```
450;2,468316E-03;0,9975317
460;1,44774E-03;0,9985523
470;1,326643E-03;0,9986734
etc.
```

JCAMP and FilmStar .csv formats do not change when European number notation is used. Two-column data (wavelength and reflectance OR transmittance) can also be opened. Data is loaded as reflectance or transmittance depending on graph axes setting.

Quick Save

If there are too many points (~>1000 wavelengths) data transfer via the clipboard may not work. Quick Save stores the current spectrum as "work.csv" in the spectra directory. This file can then be opened in Excel and copied to the appropriate worksheet. *Be sure to close "work.csv" in Excel before returning to DESIGN and repeating the procedure.*

Auto Scale <Ctrl+A>

This command scales the vertical axis to fit the spectrum plotted on screen. It is very useful for expanding the scale of an optimized region. The command is not available when the horizontal axis is physical thickness.

Graph Details... <Ctrl+H>

Several options formerly in menus are now provided in this dialog. Most options include tooltip help messages explaining the function.

To change colors with the keyboard, press <Alt+R>, use left and right arrow keys to select and press <Enter>. <Shift+Enter> changes colors without replotting the spectrum. Colors can also be selected with a single keystroke:

black, Red, Yellow, Blue, Green, Magenta, Cyan, White

Data Table

Spectra...Data Table <F8>

The format of the Data Table depends on plot scale. Select phase if phase information is required. Phase is ABSOLUTE when the angle of incidence is zero or when P or S polarization is specified. Phase DIFFERENCE is displayed when angle > 0 and Random polarization is specified. Phase is expressed in degrees in a 360 region starting at the graph minimum.

The table calculates minimum, average and maximum values over any selected range. Click the column title to select an entire column.

Select **Print** to print data on the Windows default printer. **Printer** provides font and margin options. For more elaborate formatting, return to the main menu and select **Spectra...Copy Data <Ctrl+C>** to copy the spectrum to the clipboard. The spectrum can then be pasted into Excel or a word processor.

Data Table functions can be duplicated and extended in the FilmStar Workbook.

Printer Setup

Most importantly, select a **non-proportional font** such as Courier. Specify Font Size as required. If the size is not appropriate for the font selected, Windows will assign the nearest size. Specify *Left Margin* to add spaces at the left and *Top Margin* to add extra lines at the top of the page.

Optimize Menu

Optimization refines the current thin film design in order to achieve spectral targets. Five algorithms are available: Damped Least Squares (DLS), modified Levenberg-Marquardt least squares, Simplex, a suite of gradient methods called the Numerical Optimization Library (NOL), and genetic evolution.

Optimize <Ctrl+O>

Starts the refinement process. This requires a valid design as well as optimization targets and variables.

1. **Damped Least Squares (DLS)**...Computes derivatives at each target, and is usually the fastest method. A reasonable starting design is required. It is recommended for inverse synthesis. The maximum number of targets times variables is 8192, but DLS method will probably fail with 'Cannot invert singular matrix' well before that number is reached. The number of targets must be greater or equal to the number of variables.

An initial damping factor is suggested. This can be decreased if the design changes very little or increased if there is too much change. Optimization proceeds for a given number of iterations.

2. **Levenberg-Marquardt**...While slower for problems which are also amenable to DLS solutions, this method is similar to DLS but more robust...allowing more targets and variables. A reasonable starting design is required. The number of targets must be greater or equal to the number of variables.

Optimization proceeds until no improvement is possible according to the Tolerance specified in the Parameters dialog. Further improvement is possible by restarting with decreased Tolerance and/or Epsilon values.

3. **Simplex**...A large number of iterations may be required. If the design has reached a minimum, try restarting. (The simplex has become too small to crawl out of the minimum. Restarting creates a new simplex.) Restart by selecting **Cancel** at the '# Iterations?' prompt to leave the optimization loop. Select **Optimize <Ctrl+O>** to start again. This method is useful for improving designs obtained with other methods and for cases where the number of targets is less than the number of variables.
4. **NOL Gradient Method**...This method computes an array of the gradient of the objective (merit) function with respect to thickness variables. For larger numbers of targets and variables are possible and constraints are allowed via the "FilmStar Workbook" (see page 84).

Optimization proceeds until additional iterations provide no further improvement. Further improvement might result from restarting with different parameters.

5. **Genetic Evolution**...Evolution has been determined to be a useful technique for the design of optical coatings. While the method is very slow, it can lead to solutions for problems which cannot be otherwise solved.
6. **Flip-Flop**...This method has been developed and popularized by W. H. Southwell. Layers with high index are alternatively replaced by layers with low index. If the merit function is lower (improved) the layer is kept, if it is higher the original layer is put back. In our modification of the flip-flop method, multiple flip layers may be specified. By adding a zero thickness layer, the algorithm can also remove layers.

In all cases, in-process optimization can be aborted by clicking **Cancel <Esc>**. The best design will be retained, even if the iteration currently displayed on the screen is not as good as previous ones. As keyboard input is only tested at the start of each iteration, there could be a significant delay for large numbers of targets and variables.

During DLS refinement you may get the *Cannot invert singular matrix* error if a selected variable has no effect on one or more optimization targets. Following optimization, press **<Alt+C>** to calculate the new spectrum or press **<Ctrl+R>** to review the new thin film design.

Index/Thickness Limits, Link Variables

Refer to "Optimization Variables" on page 60.

Use All Layers

Optimize...Use All Layers <Ctrl+U>

Click to quickly assign all layers as optimization thickness variables. This is the same as checking **Use** in the Optimization Variables dialog, and is useful after deleting thin layers. Alternatively, check **Auto All Layers** to automatically adjust variables as layers are added or removed.

Synthesis

Optimize...Synthesis <Ctrl+Y>

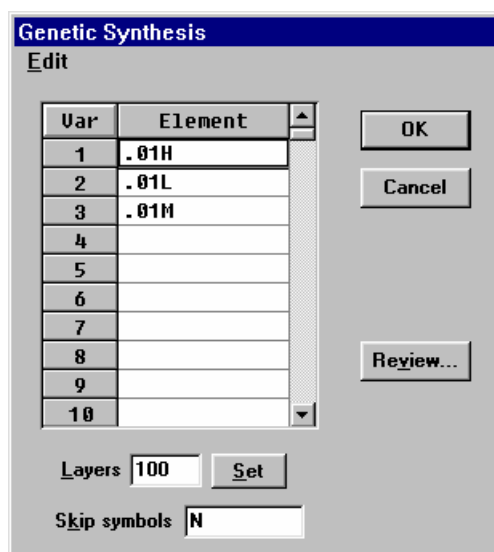
Needle synthesis (A. Tikhonravov), is supported. When adding needles, DESIGN seeks a place within the stack where the merit function is most improved. If the merit function cannot be lowered, the process is repeated with thinner layers. The design may then be refined by DLS, L-M, or NOL methods. *Note that layer materials utilized in needle synthesis are always defined in physical thickness.*

In the needle method, the starting design is typically a thick layer of one of the materials in the film stack. Multiple thick layers are appropriate when there are massive or skipped layers in the design.

Check **Auto-adjust** to update variables automatically and **Auto-synthesize** to continuously insert needles and refine. Massive layers are always skipped during needle insertion. Other layers to be skipped (*i.e.* metallic or active layers) may be specified. Needle synthesis is also possible with an objective (merit function) defined in the FilmStar Workbook *when no constraints are included*. Uncheck **Auto Refine** in the Refinement menu to continuously insert needles without refining layers.

A completely different dialog appears when genetic or flip-flop synthesis is selected as optimization method. Here 'variables' are layer elements. Consider the synthesis elements shown below. Upon clicking Optimize in the Main Menu, the program attempts to generate a 100 layer coating by selecting layers from the following three elements: .01H, .01L, 01M. In genetic synthesis, layers are selected by evolution; in flip-flop layers are replaced one at a time as a lower merit function is sought.

A zero layer, say 0L, can be added to remove layers. Ultimately the design consists of adjacent layers of the same type which can be combined in the Layers Mode editor. Note that the editor does not combine adjacent layers of the same type when the optimization algorithm program is set to genetic or flip-flop synthesis.



If the current design has a number of layers equal to the *Layers* setting, the design becomes the initial design in genetic or flip-flop synthesis. Otherwise synthesis will start with what is effectively a thick layer of the first element in the table. If that layer is zero (say 0L), there is no starting design. Clicking the **Set** button in the dialog automatically sets the number of synthesis layers to the number of layers in the current design (removing parentheses). This makes it easy to enter a starting design without having to determine the number of layers.

Massive layers in a starting design are ignored, as are layers with index symbols listed in the *Skip symbols* box. This could be useful in synthesizing designs containing fixed metallic or active layers. Synthesis is supported in the Workbook under the condition that constraints are not utilized.

Optimization Targets

Optimize...Targets <Ctrl+T>

1. % Reflectance
2. % Transmittance
3. Reflectance dB
4. Transmittance dB
5. Phase in Reflection
6. Phase in Transmission
7. % Reverse Reflectance...useful for designs with massive layers.
Architectural glass is one potential application
8. Ellipsometric Psi ($= \text{Atn}(\text{Sqr}(\text{rfp}/\text{rfs}))$)
Psi and Delta targets for the same wavelength and angle are entered on two consecutive lines.
9. Ellipsometric Delta ($= \text{rpp}-\text{rps}+180^\circ$)
- 10-18. Group Delay and similar functions in reflectance and transmittance

Phase and ellipsometric targets are not permitted in designs containing massive layers.

- 19-24. User defined functions 1-6 are specified in **Setup...User Defined**.
Variables are RFP (refl P pol), TRP (trns P pol), RFS (refl S pol), TRS (trns S pol), RPP (refl phase P pol), TPP (trns phase P pol), RPS (refl phase S pol), TPS (trns phase S pol). Reflectance and transmittance are in percent; phase is in degrees.

Wavelength

Use current wavelength units. Out-of-order entries will be sorted. More than one target can be entered at any wavelength. To delete a target, delete the associated wavelength with ****.

Target

Desired value in units specified in Type. When Target Type = *Inequality*, minimum and maximum values are entered. When Target Type = *Average*, (Min + Max)/2 is used.

Since phase is expressed in a 360 degree region starting at the graph minimum, it is important to select phase Graph Axes when optimizing phase shift.

Tolerance

Inverse weighting (0.1-100). Smaller values tighten the tolerance and increase the importance of the target. When designing an AR from 450-750 nm one might set Tol=2 at 450 and 750 and Tol=1 elsewhere. A global tolerance value is specified when Target Type = *Inequality* or *Average*.

Angle

Angle of incidence (0-90°) in the entrance medium. Independent of evaluation angle.

Polarization

P S R Random (average) denotes .5*(P+S) for %R and %T targets, (P-S) difference for phase targets when Angle>0.

Generate <Alt+G>

Automatic Targets Generator for entering targets spanning a range of wavelengths or angles.

An extremely important optimization rule is summarized in the ***Eleventh Commandment***:

Thou shalt have more targets than wiggles

A band of targets may be required when designing a multilayer AR coating for one wavelength or when reducing the E-field by minimizing absorptance at one wavelength.

Users can enter the same values in all or part of a column by selecting the range before typing values. Select the entire column by clicking the column title. For example to enter 15 degrees in all rows, just click the word 'Angle' and type '15'. Entries can be deleted by selecting *entire rows* and pressing ****. To clear all targets, it is faster to click **Clear**.

Optimization Variables

Optimize...Variables <Ctrl+B>

Design changes can cause a numbering mismatch. Return to Optimization Variables to reassign. Check/uncheck to add/delete a variable.

Designs without parentheses

Optimization layer variables correspond to actual layer numbers starting at the substrate.

Designs with parentheses

Optimization layer variables are numbered as follows:

SUB .25H (.25L .25H)10 (.25H .25L)10 .25H .25L AIR
1 2 3 4 5 6 7

If Layer #1 has the same index as the substrate, it must NOT BE SELECTED as an optimization variable. Its thickness is indeterminate; requesting a solution will cause a mathematical error.

Index variables

Indices defined by functions in the Film Indices editor can be utilized as optimization variables in DLS refinement. The actual number of added variables is the total number of coefficients for the specified materials. That is, if there are 20 layer variables, adding 2 index variables each containing 3 coefficients raises the total to 26.

Symbols

Automatically generate optimization variables corresponding to some or all index symbols. Enter one or more index symbols such as "LH" in the text box (or check the **All** box) and click **Use**.

Thickness and Index Limits

Thickness and index limits are assigned after completing the optimization variables dialog.

Be sure to re-edit limits dialogs after deleting or otherwise changing optimization variables.

Link Variables

Link variables are assigned after completing the optimization variables dialog. A linked variable preserves optical or physical thickness ratio. Links are often utilized to preserve quarter wave stacks.

SUB .25H (.25L .25H)10 (.25H .25L)10 .25H .25L AIR
1 2 3 4 5 6 7

As an example, suppose we specify variables 1, 4, 7 as optimization variables. The following is then entered into the link variables dialog:

Var	Use	Link to Variables
1	x	2,3
4	x	5,6

After optimization we would get a design resembling the following:

SUB .215H (.215L .215H)10 (.324H .324L)10 .324H .227L AIR

Be sure to re-edit the link dialog after deleting or otherwise changing optimization variables.

DLS Parameters

Optimize...Parameters

Damping restricts changes in layer thickness as optimization proceeds. With no damping the design can 'blow-up'. With too much damping too many iterations are required. If no better solution is forthcoming, DESIGN nudges layer thicknesses to climb out of a local minimum. Click **Nudge Parameters** to adjust the amount of nudging or to disable. When disabled, DESIGN performs as in previous versions and will continue optimizing for the requested number of iterations.

Compound damping is recommended. Damping factors are internally adjusted according to the sensitivity of individual variables. Optimum damping parameters must be determined experimentally.

Levenberg-Marquardt Parameters

Optimize...Parameters

This method, a modification of the Levenberg-Marquardt procedure, is adapted from the public-domain Argonne National Laboratory Minpack library. The contribution of the U.S. Department of Energy is gratefully acknowledged.

Initial Step Factor is used in determining the initial step bound. Try decreasing this number if initial iterations are too far from the starting design. A value of 100 is recommended.

Unlike DLS, this algorithm runs until successive iterations are within conditions set in the **Tolerance** field. If this number is too large, optimization will not have converged fully. If the number is too small, the program could be spending too much time attempting further insignificant improvements in the merit function. **Epsilon** determines a suitable step length for the forward-difference approximation used in calculating derivatives. If the value is too small the accuracy of derivatives may be affected. Check **Terminate** to automatically halt the algorithm after $200 * (\text{Variables} + 1)$ iterations.

Example: Using the Boudot Challenge problem, we obtain very good and rapid results with Initial Step Factor=100, Tolerance=0.0001 and Epsilon=0.0001.

NOL Gradient Method Parameters

Optimize...Parameters

NOL Gradient Methods provide optimization routines for a range of problems. An objective function is maximized or minimized while meeting optional constraints.

When NOL is accessed from the Main Menu the objective function is computed from the familiar merit function described in the Optimization Targets editor. Here there are no constraints.

When NOL is accessed from the CIE Color Module the objective function is the photopic response (or average) in transmission or reflection; the two constraints are the required color coordinates. When NOL is accessed from the Workbook, the objective function is the value computed in named cell *Objective*. Optional constraints are contained in an N row by two column region named *Constraint*.

Thickness Limits restrict all variables to the specified range. Enter a large value, say 1.E+15, for **Maximum** if there are no upper limits. As an alternative to general thickness limits (the same for all layers), it is possible to include constraints on individual variables in the Workbook.

Relative and **Minimum Delta Q** are utilized in computing gradients by finite difference steps. A step is equal to relative Delta Q times the current thickness. If that value is too small, the minimum Delta Q is substituted.

There are several choices of **Optimizer** and **1-D Search** algorithms. Experience indicates that the BFGS optimizer works best in most cases. **Scaling** is somewhat problematic and does not seem to help unconstrained problems; it does appear to help when constraints are utilized. The **Merit Exponent** entry appears only when the dialog box is called from the Main Menu. This entry relates the NOL objective function to the merit function calculated from targets. It appears that increasing the value is useful when a solution is nearly reached.

In order to speed up operations when using NOL from the Main Menu, it is suggested that the screen be updated only once every 20 or 50 iterations. Note that the **Update graph** text box is displayed only when Optimization Parameters are accessed from the Main Menu.

Example from Main Menu: Using the Boudot Challenge problem, we obtain good results with Thickness Limits Min = 0.01, Relative Delta Q = 0.001, Minimum Delta Q = 0.00001, Optimizer = BFGS, 1-D Search = GS + Interp, Scaling = OFF, and Merit Exponent = 0.5. Convergence is fairly slow.

Simplex Parameters

Optimize...Parameters

Simplex (Nelder and Mead) is a non-derivative method which systematically varies every layer in the search for a global minimum. Try the simplex method after DLS in order to see if you can locate a better solution.

The size of the Initial Step is important and is best determined by observing the screen during simplex initialization (before the Iterations prompt). If there is no apparent movement, increase the step size; if the movement is wild, decrease the step size.

Genetic Parameters

Optimize...Parameters

Refine current design and **Digital synthesis** offer considerably different functions. The first case provides familiar continuous refinement according to optimization variables and *required* thickness limits. In digital synthesis designs are built up from elements defined in the Synthesis dialog. If the elements are restricted to quarter waves, the final design consists of quarter wave multiples. Use the Layers Mode editor to delete zero layers and combine adjacent layers of the same type.

The genetic algorithm (Genetic Server) has numerous choices which are explained in a separate help file accessed by clicking the **Help** button.

Target Generator

from Targets Editor Setup...Generate <Ctrl+G>

Use the optimization Target Generator to automatically fill in target entries. Inverse wavelength spacing correctly puts more targets at shorter wavelengths (where the density of 'wiggles' is higher). The generator *supplements* existing targets and may be used repeatedly to create multiple band filters.

When the horizontal axis is wavelength, check **Reverse Synthesis** to convert current spectral data, within the specified wavelength range, to optimization targets. Measured data can be loaded from disk in the Spectra menu.

The maximum number of targets which may be generated (2 minimum) is indicated. Select **Cancel** to exit without adding new targets. Click **OK** to generate new targets and return to the Target Editor. If the new targets are incorrect, immediately click **Cancel** to restore original values.

Status Bar Commands

Button Bar

Axes <Alt+A>

Redraw graph axes and automatically replot the current spectrum.

Color <Alt+R>

There are two color palettes: light and dark. Select in **Spectra...Graph Details <Ctrl+H>**. The spectrum is replotted in the selected color. To suppress replotting hold down the shift key while selecting a color.

To change colors with the keyboard, press <Alt+R>, use left and right arrow keys to select and press <Enter>. Press <Shift+Alt+R> to change colors without replotting the current spectrum. Colors can also be selected with a single keystroke:

black, Red, Yellow, Blue, Green, Magenta, Cyan, White

Stop <Escape>

Stop or pause calculation or optimization and return to the Main Menu.

Calculate

Calculate <Alt+C>

Design wavelength

Wavelength where an optical thickness of .25 (or 1 as specified in Setup Parameters) corresponds to an optical quarter wave. The calculated spectrum is independent of design wavelength when all layers are in physical thickness.

Evaluation wavelength

Enabled when the horizontal axis is angle or physical thickness; otherwise disabled.

Plot type

Select Monitor to show the behavior of the thin film assembly as layers are deposited; select Sensitivity to show the behavior of the entire stack when varying each layer from zero to its final thickness.

FilmStar BASIC

FilmStar BASIC is a development environment for customizing FilmStar. Using Sax Basic, FilmStar BASIC adds the special commands and keywords discussed in this section. We have no doubt that users will think of new commands to add. Please contact FTG Software with your suggestions.

FilmStar BASIC is nearly 100% compatible with Microsoft VBA (Visual Basic for Applications). You can get context-sensitive help in the BASIC editor by placing the cursor on a BASIC keyword and pressing <F1>.

FilmStar DESIGN Extensions

Summary documentation for all extensions is provided in the BASIC IDE. Click the Browse Object icon (6'th from left).

Variables can be transferred to and from DESIGN to FilmStar BASIC for various calculations. In addition a number of functions and subroutines are available. Capitalization is not important in the following:

Property AbsorbLayer%...Specify layer for absorption vs. wavelength or angle.

```
AbsorbLayer = 3
```

Property Angle!...Assign/get angle of incidence in degrees

```
x! = Angle
```

```
Angle = 34
```

Note that the following does NOT work:

```
For angle = 0 To 30    ' doesn't work
  CalcPlot
Next angle
```

Instead, you should use

```
For a = 0 To 30 Step 5
  angle = a      ' sets angle in DESIGN
  CalcPlot
Next a
```

Property ArchiveMode As Boolean...Assign/get FILM Archive mode

```
ArchiveMode = True
```

```
k = ArchiveMode
```

Property ArchiveNK As Boolean...Assign/get FILM Archive n,k table mode.

```
ArchiveNK = True  ' store index tables with Archive
k = ArchiveNK
```

Sub AxesAutoScale(Optional xAxis As Boolean, Optional yAxis as Boolean = True)...Auto scale horizontal and/or vertical axes. Especially useful when importing data.

```
AxesAutoScale          ' autoscale y axis
AxesAutoScale True      ' autoscale x & y axes
AxesAutoScale True, False ' autoscale x axis
```

Sub AxesCopy(Optional kInt As Boolean)...Copy axes settings to clipboard, include calculation interval (delta) if kInt is True.

```
AxesCopy          ' copy without interval delta
AxesCopy True      ' include interval
```

Sub AxesDraw...Draw new graph axes.

```
AxesDraw
```

Sub AxesPaste...Paste graph axes from clipboard. Excel-compatible format.

```
AxesPaste
```

Sub BandCtr(wMin!, wMax!, wCtr!, kErr As Boolean, Optional kType%)...
Compute bandpass mean center wavelength $wCtr$ in range wMin to Wmax;
set kType=1 for average center wavelength; returns kErr=True if error.

BandCtr 400, 800, wCtr, kErr

Sub BandMax(wMin!, wMax!, bMax!, kErr As Boolean)...Compute maximum
bandpass value $bmax$ in range wMin to Wmax; returns kErr=True if error.

BandMax 400, 800, bMax, kErr

Sub BandWidth(Level!, wMin!, wMax!, bw!, kErr As Boolean)...Compute
bandwidth bw at a given % Level within range wMin to wMax; returns
kErr=True if error.

BandWidth 50, 400, 800, bw, kErr ' 50% bandwidth
BandWidth 10, 400, 800, bw, kErr ' 10% bandwidth

Sub BasActivate...Return focus to BASIC's IDE (integrated development
environment).

BasActivate

Sub BasChain(file\$)...Immediately run BASIC program from current
program.

BasChain "c:\winfilm\basic32\eval1.bas"

Property BasText\$(0)...BasText\$(15)...Set text variable for use in the Report
Generator with formatting commands <<BasText>> and <<BasBlock>>. Text
can be a fragment or a block of paragraphs. *Note that this is slightly different
from the 16 bit version!*

BasText(0) = "Welcome to FilmStar Programming"

Sub Busy(k As Boolean)...Turn hourglass cursor on/off

Busy False ' turn off hourglass cursor

Sub CalcPlot...Calculate and plot spectrum. For multiple plots, precede by
CalcPlotStart and follow with CalcPlotDone

CalcPlot

Sub CalcPlotDone...Conclude series of multiple plots on same graph (main
screen).

CalcPlotDone

Sub CalcPlotStart...Begin series of multiple plots on same graph (main
screen).

CalcPlotStart

Sub CalcRand...Evaluate design (one iteration) with the random errors
specified in Evaluate...Tolerancing...Values. The original design is retained
in memory. The design must be in Layers Mode (no parentheses).

CalcRand

Sub CalcRandSeed(Optional seed#)...Set random number seed; 0 uses
current time. Set seed<>0 before RndNorm to repeat random numbers.

CalcRandSeed 1.23

Sub Calculate...Calculate without plotting spectrum; this can be noticeably
faster than CalcPlot

Calculate

Calculate is an MS Excel VBA keyword. If Excel is an object reference in your BASIC program, use Macro "Calculate;" instead of Calculate.

Sub CieActivate(Optional kHide%, Optional Title\$)...Activate CIE dialog;
kHide = 1 hide color bars, +2 hide bottom, +4 hide menus, +8 compact graph

```
CieActivate(15, "Reflected Color")
```

Sub CieClose...Close CIE dialog

```
CieClose
```

Property CieParams\$...Get string showing CIE parameters. The same string is displayed in the CIE Graph Axes title.

```
s$ = CieParams ' returns "1931 x,y (2°) Illuminant A"
```

Sub CieWindow(kState%)...Set CIE window state: 0 normal, 1 min, 2 max

```
CieWindow 2
```

Sub ConfigOpen...Reload configuration from design1.ini.

```
ConfigOpen
```

Sub DataClear...Erase current spectrum.

```
DataClear
```

Sub DataConvert(Optional wmin!, Optional wmax!, Optional wint!)...

Convert spectrum range to current axes or range settings; optionally specify min, max and interval. If wmin=0 then use current settings

```
DataConvert ' use current graph axes or range settings  
DataConvert 400,600,2 ' convert data to 400-600x2 array
```

Sub DataConvertList(List\$)...Convert (interpolate) current spectrum to specified Wavelength List file.

```
DataConvertList "LBL Window" ' default directory  
DataConvertList "c:\winfilm\wave\LBL Window.wls"
```

Sub DataCopy...Copy spectrum to clipboard in Excel format.

```
DataCopy
```

Sub DataExport(Optional topic\$, Optional item\$)...Export data via DDE; optionally specify new topic and/or item.

```
DataExport
```

Sub DataImport(Optional topic\$, Optional item\$)...Import data via DDE; optionally specify new topic and/or item.

```
DataImport
```

Sub DataPaste...Paste spectrum from clipboard.

```
DataPaste
```

Sub DataSmooth(kType%, nPoints, Optional kPoly)...Smooth *equally spaced* data: kType=1 moving average, 2 Savitzky-Golay filter; kPoints is *odd number*; kPoly is S-G polynomial order 2,4,6. Moving average is better at reducing noise; S-G is better at preserving structure and peak heights. Use this capability to smooth noisy spectral data for n,k determination.

```

DataSmooth 1 11 ' moving average, 11 points
DataSmooth 2 11 2 ' S-G, 11 points, smoothing
                  ' polynomial order 2
DataSmooth 2 13 4 ' S-G, 13 points, smoothing
                  ' polynomial order 4

```

Function dbActivate%(name\$)...Activate (and open if necessary) database **dbDesign** or **dbSpectra**. Issue this command before other database commands. Returns -1 (true) if successful.

```

k = dbActivate("dbDesign")
k = dbActivate("dbSpectra")

```

Sub dbClose...Close the active database.

```
dbClose
```

Sub dbDelete...Delete the displayed record in the active database. Note that this is done automatically without user-confirmation. *Not available in read-only mode.*

```
dbDelete
```

The following program deletes all records in the selected set and also deletes associated spectra and picture files.

The following program can erase the entire database as well as associated data files!

```

Sub Main
  dbActivate "dbSpectra"
  On Error Resume Next
  Do
    If dbGetText$(0)="No Matching Records" Then End
    Kill dbGetText$(13) ' delete spectrum
    Kill dbGetText$(14) ' delete picture
    dbDelete      ' delete record
  Loop
End Sub

```

Function dbGetText\$(iField%)...Returns text in field number iField. Note that the first field number is zero.

```
s$ = dbGetText$(0)
```

Function dbGetTextField\$(sField\$)...Returns text in field having field name (not caption) sField\$. Field names can be obtained in the Database Viewer or in Layout Mode.

```
s$ = dbGetTextField$("FIELD1")
```

Sub dbListFiles(delim\$)...Generates list of selected files with user-specified delimiter. The list is placed in Windows clipboard. Use chr\$(13)&chr\$(10) to generate a column list.

```

dbListFiles ", "
s$ = Clipboard

```

Sub dbNewRecord...Creates a new blank record in the active database. *Not available in read-only mode.*

dbNewRecord

Sub dbPlotSave(file\$)...Save FSPlot as Windows metafile (*.wmf) in database; include path. Wmf extension automatically added if not included.

```
dbPlotSave "c:\winfilm\graphs\bbar"  
dbPlotSave "c:\winfilm\graphs\bbar.wmf"
```

Property dbRecords&...Get the number of records in the found set. Useful for looping through records.

```
n& = dbRecords
```

Sub dbSelectNext...Select next record in set.

```
dbSelectNext
```

The following code shows how to loop through a record set. The SQL statement starts at the first record.

```
k = dbSqlExec("select * from SPECTRA")  
If Instr(dbGetText$(0)), "No") = 0 Then  
  Do  
    ' statements  
    If LastRecord() Then Exit Do  
    dbSelectNext  
    ' statements  
  Loop  
End If  
Function LastRecord()  
  s$ = mid$(dbGetText(0), 8)  
  k = instr(s$, "/")  
  i1$ = mid$(s$, 1, k - 1)  
  i2$ = mid$(s$, k + 1)  
  LastRecord = (i1$ = i2$)  
End Function
```

Sub dbSetText\$(iField%, text\$)...Puts text into database field. Note that the first field number is zero. *Not available in read-only mode.*

```
s$ = dbSetText$(1, "Visit Princeton")
```

Sub dbSetTextField\$(sField\$, text\$)...Puts text into database field having field name (not caption) sField\$. *Not available in read-only mode.* Field names can be obtained in the Database Viewer.

```
s$ = dbSetText$("FIELD3", "Visit Princeton")
```

Function dbSqlExec(cmd\$)...Execute SQL commands. These are the same as those typed into the SQL editor. Returns -1 (true) if successful.

```
If dbActivate("dbSpectra") Then  
  If dbSqlExec("select * from spectra") Then
```

Sub dbUpdate...Update the current record. This may be required to ensure that changes are registered properly.

```
dbUpdate
```

Sub DefaultPath(Optional pParam\$, Optional pDesign\$, Optional pIndex\$, Optional pSpectra\$)...Change some or all default paths listed in configuration dialog; restore current directories to default.

```
DefaultPath ,,, "c:\dwdm\test004" ' change spectra path
```

Property Design\$...Assign/get film design as continuous string. See **Layers**.

```
s$ = Design
Design = ".25H .25L .25H"
Clipboard$ Design ' copy design to clipboard
```

Sub DesignAdjust(kType, Symb\$, AdjVal)...Adjust (kType=1 add, 2 multiply) layers with index symbol Symbol\$; Symb\$="" adjusts all layers

```
DesignAdjust 1, "H", .02
```

Sub DesignConvert(k, Optional unit As Variant)...k=1 optical to physical, 2 physical to optical; physical unit N nm, M μm , L mm, E cm, K kÅ; optical unit 1, 4;

```
DesignConvert 1, M ' optical to physical ( $\mu\text{m}$ )
DesignConvert 1 ' optical to physical (current units)
```

Sub DesignPaste...Paste design from clipboard.

```
DesignPaste
```

Property DesignPhysUnit\$...Returns design physical thickness unit: *N* nm, *M* μm , *L* mm, *E* cm, *K* kÅ

```
u$ = DesignPhysUnit
```

Property DesignQwotUnit%...Returns design QWOT unit: 1 (QWOT=.25) or 4 (QWOT=1)

```
k = DesignQwotUnit
```

Sub DesignReverse...Reverse the thin film design.

```
DesignReverse
```

Property DesignWave!...Specify/get design wavelength in current wavelength units.

```
DesignWave = 1550
w = DesignWave
```

Sub DispBox(text\$, icon%, title\$)...Display a message box without buttons. This is useful for status messages when no response is required. Use the following icon numbers: 16-Stop, 32-Question, 48-Attention, 64-Information. Use the BASIC MsgBox instruction when a user response is required.

```
DispBox "Waiting for stabilization", 48, "Heater"
Wait 10 ' wait 10 seconds
DispBox "", 0, "" ' remove the box
```

Sub Display(text\$, title\$, wd%, ht%, FontName\$, FontSize!, FontBold%)...Display a multiline text box in a dialog box with width wd% (twips) and height ht%.

```
Display "FTG Software Associates", "Princeton, New
Jersey", 5000, 3000, "Arial", 18, 1
```

Sub EdgeCalc(Level!, wMin!, wMax!, wEdge!, yEdge!, kErr As Boolean)...Compute cuton/cutoff wavelength wEdge and R/T value yEdge at a given % Level within range wMin to wMax; returns kErr=True if error.

```
EdgeCalc 50, 400, 800, wEdge, yEdge, kErr ' 50% cut
```

Property EvalWave!...Specify/get evaluation wavelength in current wavelength units.

```
EvalWave = 854
a = EvalWave
```

Property FileDescription\$(k%)...Assign/get file description: k=1 Spectral Data, 2 Axes, 3 Indices, 4 Design, 5 Targets, 6 Variables, 7 FILM, 8 FILM Archive.

```
S$ = FileDescription(8)
FileDescription(8)= "100% yield DWDM design"
```

Property FileName\$(k%)...Assign/get file name: k=1 Spectral Data, 2 Axes, 3 Indices, 4 Design, 5 Targets, 6 Variables, 7 FILM, 8 FILM Archive

```
s$ = FileName(8) ' FILM Archive file name
FileName(1) = "Mirror"
```

Function FileOpen(file\$, Optional k%) As Boolean...Open file; optional path; use extension or k to specify type: k=1 Spectral Data (.csv, .dx), 2 Axes (.axw), 3 Indices (.inw), 4 Design (.dew), 5 Targets (.trw), 6 Variables (.vaw), 7 FILM (.flw), 8 FILM Archive (.faw). Returns True if successful. All of the following will work:

```
FileOpen "c:\winfilm\data\spec1.csv"
FileOpen "c:\winfilm\data\spec1", 1
FileOpen "spec1.csv", 1 ' default path used
FileOpen "spec1", 1      '      "      "      "

If Not FileOpen("spec1.csv") Then
    MsgBox "Bad file name",vbCritical,"Open"
Exit Sub
End If
```

Property FilePath\$(k%)...Assign/get current file path: k=1 to 8 as above

```
s$ = FilePath(1)
FilePath(1) = "c:\dwdm\spectra"
```

Function FileSave(file\$, Optional k%) As Boolean...Save file; optional path; use extension or k to specify type: k=1 Spectral Data (.csv, .dx), 2 Axes (.axw), 3 Indices (.inw), 4 Design (.dew), 5 Targets (.trw), 6 Variables (.vaw), 7 FILM (.flw), 8 FILM Archive (.faw). All of the following will work:

```
FileSave "c:\winfilm\data\spec1.csv"
FileSave "c:\winfilm\data\spec1", 1
FileSave "spec1.csv", 1 ' default path used
FileSave "spec1", 1      '      "      "      "

If Not FileSave("c:\winfilm\data\spec1.csv") Then
    MsgBox "Could not save",vbCritical,"Save"
Exit Sub
End If
```

Function fMsgBox%(text\$, icon%, title\$)...Similar to BASIC's MsgBox function but will be modal within FilmStar DESIGN. This prevents covering the dialog box by clicking on the DESIGN window.

```
k = fMsgBox("Do you want to proceed?", 36, "BASIC")
```

Property Footer\$...Assign/get report footer.

```
Footer = "Text at bottom of report"
```

```
s$ = Footer
```

Sub GetCie(x!, y!, yy!, Optional yp!, Optional Mode\$) ...Evaluate design and calculate CIE color coordinate triplet (x, y, Y), (u, v, L) or (a*, b*, L*) depending on CIE settings (stored with film design). Optional yp returns photopic response (same as yy if CIE x, y specified) independent of CIE settings. Optional Mode = R or T overrides current program setting.

```
GetCie x, y, yy, yp, "R"
```

Sub GetCieData(x!, y!, yy!, Optional yp!, Optional Mode\$)...Same as **Sub GetCie**, except that the spectrum currently in memory is used. The spectrum must contain 380-770 x 1 nm or 380-770 x 5 nm data

```
GetCieData x, y, yy
```

Sub GetCieTri(X!, Y!, Z!, Optional Mode\$) ...Evaluate design and calculate CIE tristimulus values. Optional Mode = R or T overrides current program setting.

```
GetCieTri X, Y, Z
```

Sub GetCieTriData(X!, Y!, Z!, Optional Mode\$)...Same as **Sub GetCieTri**, except that the spectrum currently in memory is used. The spectrum must contain 380-770 x 1 nm or 380-770 x 5 nm data

```
GetCieTriData X, Y, Z
```

Sub GetIndex(k%, wave!, xn!, xk!)...Calculate film indices for material *k* at wavelength *wave*. Film materials are numbered according to position in the Film Indices editor: AIR=1, SUB=2, first film=3, etc.

```
GetIndex 4, 632.8, xn, xk
```

Sub GetLayers(nLayers%, thick!(), type\$(), desc\$(), Optional kType%)...Get thin film design in layers mode as numeric thickness, materials type and materials description arrays. If kType=1 file names used instead of description. Useful for calculations, reports and export to other programs.

```
Dim i%, n%, q!(), qt$(), qd$()
```

```
Sub Main
```

```
GetLayers n, q(), qt(), qd()
```

```
For i = 1 To n
```

```
    s$ = format$(q(i), "0.0000") & " " & qd(i)
```

```
    Debug.Print s$
```

```
Next i
```

```
End Sub
```

Property Header\$...Assign/get report header

```
Header = "Text at top of report"
```

```
s$ = Header
```

Function IndexCoeff!(row%, col%)...Get index coefficient as displayed in the Film Indices editor.

```
Dim xi!(3 To 5, 1 To 7)
For i = 3 To 5
  For j = 1 To 7
    xi(i, j) = IndexCoeff(i, j)
  Next j
Next i
```

Sub IndexCopy...Copy film indices dialog values to clipboard.

```
IndexCopy
```

Function IndexPaste As Boolean...Paste film indices from clipboard. Returns True if successful.

```
IndexPaste
If Not IndexPaste() Then Exit Sub
```

Function IniString\$(section\$, key\$)...Get user-defined initialization variable from design1.ini.

```
s$ = IniString$("Chuck Vogel","LastFileName")
```

returns "WW098909" if the following is in design1.ini:

```
[Chuck Vogel]
LastFileName=WW098909
```

Property Layers\$...Get thin film design as separate lines of text. Automatically converts groups to layers (removes parentheses). See **Design**.

```
s$ = Layers
Clipboard$ Layers ' copy layers to clipboard
```

Sub LineColor(color\$)...Color\$=K black, B blue, G green, C cyan, R red, M magenta, Y yellow, W white (applies to main graph)

```
LineColor "R" ' red
```

Function Macro(text\$) As Boolean...Run macro commands from BASIC.

```
k = Macro("ReverseDesign;Calculate;")
```

k returns False (0) if there was an error executing the macro. This function is no longer required as BASIC functions now duplicate macro commands.

Sub MainActivate...Return focus to DESIGN's Main Menu.

```
MainActivate
```

Property MainEvents As Boolean....By default, running a program from the BASIC editor (IDE) enables FilmStar keyboard and mouse events. By default, running a program via macro command *basrun* disables FilmStar keyboard and mouse events. This behavior may be changed in a BASIC program by setting MainEvents true or false.

```
MainEvents = True ' respond to keyboard/mouse
                  ' default in IDE
MainEvents = False ' do not respond to keyboard/mouse
                  ' default when run without IDE
```

Setting *MainEvents = True* in a BASIC program run from *basrun* adds an **Abort BASIC** menu command which also aborts the current calculation.

Sub MainWindow(kState%)...Set main window state: 0 normal, 1 min, 2 max.

```
MainWindow 0
```

Property Merit!...Compute and get current merit function defined by Optimization Targets editor.

```
x! = Merit
```

MonoLight(Width!, kErr As Boolean, Optional kType%)...Simulate response to monochromatic (Gaussian) light with 50% bandwidth = hWidth; kType reserved for future use.

```
MonoLight 5, kErr
```

```
Sub Main
```

```
Dim kErr As Boolean
```

```
Calculate
```

```
MonoLight 5, kErr
```

```
If Not kErr Then Replot
```

```
End Sub
```

Property MsgBoxTimer!...Set time interval for automatically clicking Enter in the fMsgBox or sMsgBox message box if the user does nothing. For this to work you must make sure that Use Windows message box is unchecked in **File...Configuration...Preferences**. Since the timer is disabled when the message box is closed, the MsgBoxTimer statement is required before each box containing a timer. The maximum value is 65 seconds.

```
Beep
```

```
MsgBoxTimer=15 '15 seconds timeout
```

```
sMsgBox "Get a cup of coffee!", 48, "Working Hard"
```

Property NumLayers%...Get the number of layers in the current design. If the design contains parentheses the number of groups is returned.

```
n% = NumLayers
```

Sub OptiClear()...Clear all optimization targets and variables.

```
OptiClear
```

Sub Optimize(Optional Mode%)...Mode=0 optimize using current method (not simplex), targets and variables; Mode=1 use tooling variables (Setup Tooling Factors)

```
Optimize 1 ' determine 'tooling' variables
```

Sub OptiVars(Optional Varlist\$, Optional Skip\$, Optional Massive as Boolean)...Assign optimization variables; VarList comma delimited, i.e. OptiVars "2,3"; VarList="" assigns all layers as variables and offers options to skip layers with index symbols in Skip\$ or to include massive layers.

```
OptiVars "2,3,4" ' assign variables 2,3,4
```

```
OptiVars ' assign all layers as variables
```

```
OptiVars "", "M" ' assign all, skip "M"
```

```
OptiVars "", "", True ' assign all, including massive
```

Function PadString\$(text\$, length%, align%)...This function pads a string with spaces to return a string of given length. Spaces are added to the left

(align=0) or right (align=2) or the string is centered (align=1). This function is useful for generating reports.

```
BasText0$ = PadString$(format$(x!,"0.000"),8,0)
```

Property PgmCaption\$...Get main caption (title bar). This is required for Visual Basic's AppActivate method.

```
s$ = PgmCaption
```

Property PgmExe\$...Get the name of the FilmStar .EXE file. This can be useful when you want to use the same BASIC programs for DESIGN and MEASURE.

```
s$ = PgmExe ' returns "Design1"
```

Property PgmPath\$...Get the name of the FilmStar program path. This is useful for opening Workbook files with WbOpen.

```
s$ = PgmPath ' returns "C:\Winfilm"
```

Sub PhaseSmooth...Automatically remove vertical jumps in phase shift (radians) data by adding or subtracting 2 PI.

```
PhaseSmooth
```

Sub PlotActivate(Optional hide As Boolean)...Activate the FSPlot Module.

```
PlotActivate
```

```
PlotActivate True ' activate hidden FSPlot Module
```

Sub PlotAnnotate(kShow As Boolean)...Turn FSPlot annotations on/off; must precede PlotActivate

```
PlotAnnotate False
```

Property PlotAnnotation\$...Assign/get FSPlot Annotation string. Annotations can be customized with BASIC's *Replace* function:

```
s$ = PlotAnnotation
```

```
PlotAnnotation = Replace(s$,"SerNum","45678",1,-1)
```

```
ReportPrint
```

```
PlotAnnotation = s$ 'put back original
```

Property PlotAxesConfig%...Specify additional axes choices. Value can be generated in FSPlot Module.

```
PlotAxesConfig = 6
```

Property PlotAxesFont\$...Specify font for FSPlot axes

```
PlotAxesFont = "Poster Bodini"
```

Sub PlotClear...Clears all FSPlot graphs without closing the module.

```
PlotClear
```

Sub PlotClose...Close FSPlot (clears all graphs).

```
PlotClose
```

Sub PlotColors(Colors\$)...Change FSPlot line color map (max 12 colors). Values are most easily determined by copying values from the LineColors setting in design1.ini. *Note that this definition is different from the original one which only allowed simple colors.*

```
' Change first 4 colors
PlotColors "255 16711680 52736 16711935"
```

Sub PlotConfig(i1%, i2%, i3%)...Set FSPlot configuration. This includes details such as FSPlot background color, grid type, etc. Size is given in **PlotSize**. Other properties are described in the BASIC object browser.

```
PlotConfig 1169, 120, 0
```

Use **File...Create BASIC Setup** in FSPlot to create code lines:

```
' FSPlot setup code for FilmStar BASIC:
PlotConfig 11473, 40, 0
PlotSize 8475, 7185, 82
PlotTitleSize = 120
PlotLegendSize = 100
PlotAxesConfig = 6 ' loaded/saved with graph axes
```

Sub PlotCopy(Optional kType%, Optional Zoom%)...Copy FSPlot image to clipboard; kType=0 metafile (default), 1 bitmap, 2 jpeg; zoom in % (default 100)

```
PlotCopy 1, 125 ' copy as bitmap 125%
PlotCopy ' copy as metafile
```

Sub PlotDataCopy()...Copy FSPlot data to clipboard; same as **Edit...Copy Data** in plot module. Useful for transferring results back to the main program when using the Formulater for normalizing spectrophotometer data. The main application is normalizing spectrophotometer data. **IMPORTANT:** *Before normalization, spectrophotometer data may be < 0 or > 100%. If the range is insufficient, FSPlot data may be clipped. Specify a range -20 to 120% to prevent clipping errors. This requires that you enable **Allow R/T < 0** in Spectra...Graph Details <Ctrl+H>.*

```
Calculate ' create a spectrum
PlotActivate True ' hide the FSPlot dialog
PlotNext ' store data in FSPlot memory
PlotRun "C=2*B; del B" ' run formula
PlotDataCopy ' copy FSPlot memory to clipboard
PlotClose ' close hidden FSPlot
DataPaste ' paste data into memory
```

Sub PlotDataOpen(Optional file\$)...Open FSPlot data. Specify a complete file name (path & ext) or leave blank to activate a file open dialog.

```
PlotDataOpen "c:\winfilm\spectra\filter.csv"
PlotDataOpen ' file dialog
```

Sub PlotDataPaste()...Paste tab-separated (Excel format) FSPlot data.

```
PlotDataPaste
```

Sub PlotDataSave(Optional file\$)...Save FSPlot data in Excel-compatible CSV format. Specify a complete file name (path & ext) or leave blank to activate a file save dialog.

```
PlotDataSave "c:\winfilm\spectra\filter.csv"
PlotDataSave ' file dialog
```

Sub PlotDelete...Delete last FSPlot spectrum.

PlotDelete

PlotLegend\$(1)...PlotLegend\$(12)...Set the text for FSPlot legends 1-12.

```
PlotLegend(1) = "Angle = 0°"
```

Sub PlotLegendOn(k As Boolean)...Turn plot legends on or off.

```
PlotLegend False ' no plot legends
```

```
PlotLegend True ' use legends
```

Property PlotLegendSize%...Set FSPlot legend relative font size (50-150, 100 default)

```
PlotLegendSize = 110
```

Sub PlotNext...Add another graph to FSPlot window. Same as clicking the Plot button.

PlotNext

Sub PlotOpen(file\$)...Open a binary FSPlot test image (.bin extension). This is intended mainly as a debugging tool.

```
PlotOpen "c:\Winfilm\Spectra\plot.bin"
```

Sub PlotRun(Optional formula\$)...Run Plot Formula to modify FSPlot graphs. The formula should be thoroughly tested in the FSPlot Formulator before being used in FilmStar BASIC code. If *formula\$* is blank or missing the Plot Formula currently in memory is utilized.

```
PlotRun ' Run formula currently in memory
```

```
PlotRun "B=if(A>=425 & A<=515, 100*B, B)"
```

Sub PlotSave(file\$)...Save FSPlot graphs to disk as a windows metafile or bitmap. *Include the full path and optionally add .wmf, .bmp, .png or .bin (test file) extension.* If no extension, file type depends on selection in FSPlot Setup. Use this routine to generate reports with multiple FSPlot graphs.

```
PlotSave "d:\winfilm\save1"
```

When creating complex documents with a series of graphs to be plotted later in the Report Generator use the following idea:

```
PlotSize 8000, 6500, 75 ' set graph size
```

```
For i = 1 To 10
```

```
    ' code to calculate designs and draw graph
```

```
    PlotSave "d:\winfilm\psave" & format(i,"00")
```

```
Next i
```

Sub PlotSize(width%, height%, csize%)...Assign FSPlot window size in twips (1440 twips = 1") in order to fix the graph size. This is useful when storing a series of graphs on disk. csize (50-300) is relative character size.

```
PlotSize 8500, 6500, 75
```

Property PlotSubTitle\$...Specify FSPlot secondary title.

```
PlotSubTitle = "Visit Princeton today!"
```

Property PlotTableGrid\$...String specifying table contents in grid format where columns are TAB delimited, rows are CRLF delimited. In the following sample code (generated in FSPlot via **File...Create BASIC Setup**) values such as "550 nm" need to be replaced by functions.

```

PlotTableGrid="Center "& vbTab & "550 nm" & vbCrLf & _
"Maximum " & vbTab & "98.23 %" & vbCrLf & _
"50% Bandwidth " & vbTab & "4.25 nm"

```

Property PlotTitle\$...Specify FSPlot main title

```
PlotTitle = "Fred is great!"
```

Property PlotTitleFont\$...Specify font for FSPlot title

```
PlotAxesFont = "Poster Bodini"
```

Property PlotTitleSize%...Specify FSPlot relative title size (>50).

```
PlotTitleSize = 110
```

Sub PlotWindow(kState%)...FSPlot window: 0 normal, 1 min, 2 max

```
PlotWindow 0
```

Property Pol\$...Assign/get polarization; values are P, S or R (random). Capitalization is not important.

```
Pol = "S"
```

Many more DESIGN variables can be set with BASIC's SendKeys command. For example, the following sequence sets design wavelength to 1064 nm:

```

MainActivate      ' set focus to Main Menu window
SendKeys "%dw1064{ENTER}", 1

```

Sub Replot...Replot current spectrum.

```
Replot
```

Sub ReportPrint...Print the current report without displaying it

```
ReportPrint
```

Sub ReportSave(file\$)...Save report (not displayed) as binary printer file; include path and extension.

```
ReportSave "c:\winfilm\reports\dwdm.bin"
```

Sub ReportShow...Preview report and optionally print it.

```
ReportShow
```

Property Review\$(k%)...Get Review Design screen. Format k = 1 to 3

```
s$ = Review(1)
```

Property RndNorm!...Generate pseudo-Gaussian random number. Use CalcRandSeed to repeat random number sequence.

```
v! = RndNorm
```

Sub SetCieAxes(xmin!, xmax!, xLb!, yMin!, yMax!, yLb!, Optional Toler\$, Optional xTarg!, Optional yTarg!)...Specify CIE axes range; optional tolerance box; optional target circle

```
SetCieAxes .2, .5, .05, .1, .6, .1
```

Sub SetCieMode(mode%, observer%, delta%)...*Mode 1: 1931 x,y; Mode 2: 1960 UV; Mode 3: 1976 L*U*V; Mode 4: 1976 L*a*b*; Observer 1: 2°; Observer 2: 10°; Delta (calculation interval in nm): 1 or 5.*

```
SetCieMode 2, 1, 5
```

Sub SetIlluminant(type%, degrees!)...Assign illuminant (and blackbody temperature in degrees Kelvin) for CIE color calculations. *Type* corresponds to the CIE Setup Parameters Illuminant list as follows: *Type 1* Black Body; *Type 2-6* Illuminants A, B, C, D65, E; *Types 7-9* User 1-3.

```
SetIlluminant 1, 5500    ' 5500 deg blackbody
SetIlluminant 5, 0      ' Illuminant D65
```

Sub SetIndexCoeff(row%, col%, value!)...Assign index coefficient as in the Film Indices dialog

```
SetIndexCoeff 4, 1, 1.95
```

Sub SetIndexFile(row%, name\$)...Assign dispersive file name as in the Film Indices dialog

```
SetIndexCoeff 4, "TI02 Patinal 300C"
```

Sub SetLayers(thick!(), type\$())...Assign layer thicknesses and material types. This can also be done with Design = s\$

```
Redim q!(1 to 2), qt$(1 to 2)
q(1) = .25: qt(1) = "H"
q(2) = .25: qt(2) = "L"
SetLayers q(), qt()
```

Sub sMsgBox(text\$, icon%, title\$)...Similar to BASIC's MsgBox instruction but will be modal within FilmStar DESIGN. This prevents covering the dialog box by clicking on the DESIGN window.

```
sMsgBox "Get a cup of coffee!", 48, "Working Hard"
```

Function SpecTargets(kNew As Boolean, Type\$, Tol, Angle, Pol\$)... Convert spectrum to opti targets; kNew=0 supplements existing targets

```
If SpecTargets(True,"R", 1, 45, "R") Then
    DoSomething
End If
```

Property Spectrum_X As Variant...Assign/get spectral X values (wavelength or angle depending on Setup Parameters)

Property Spectrum_Y As Variant...Assign/get spectral Y values (reflectance, transmittance, etc.)

```
' Transferring spectra from DESIGN
Option Base 1
DefInt I-N
DefSng A-H, 0-Z
Sub Main
    ReDim xd(1), yd(1, 1) ' MUST BE 'SINGLE'
    xd = Spectrum_X ' Get X values
    yd = Spectrum_Y ' Get Y values
    For i = 1 To UBound(xd) ' Rows
        Debug.Print xd(i)
        For j = 1 To UBound(yd, 2) ' Columns
            Debug.Print yd(i, j)
        Next j
    Next i
End Sub
```

```

' Transferring spectra to DESIGN
Option Base 1
DefInt I-N
DefSng A-H, 0-Z
Sub Main
    ReDim xd(17), yd(17, 2) ' MUST BE 'SINGLE'
    For i = 1 To Ubound(xd)
        xd(i) = 400 + 25*(i - 1)
        yd(i, 1) = .3 + .02*(i - 1)
        yd(i, 2) = .5 - .01*(i - 1)
    Next i
    Spectrum_X = xd ' Set X values
    Spectrum_Y = yd ' Set Y values
End Sub

```

Sub StatusLabel(s\$)...Display label in status window.

```
StatusLabel = "Visit Princeton soon"
```

Property StopCalc As Boolean...Default True; set False to prevent DESIGN from responding to Windows messages.

```
StopCalc = False
```

Property SubThick!...Assign/get current substrate thickness (as defined in Setup Parameters) in mm.

```
s! = SubThick
SubThick = 2.5
```

Property SynElements\$...Assign/get synthesis layer elements utilized in genetic and flip-flop synthesis. The string is equivalent to the entries in the synthesis dialog. The format of SynLayers is as follows:

```
SynElements = ".05H" & vbCrLf & ".05L" & vbCrLf
```

As shown here, one use (with SynLayers) is to split layers into thinner layers for further synthesis.

```

Sub Main
    Dim d$, s$
    d$ = Design
    d$ = Replace(d$,".05H", ".025H .025H")
    d$ = Replace(d$,".05L", ".025L .025L")
    Design = d$
    s$ = SynElements
    s$ = ".025H" & vbCrLf & ".025L" & vbCrLf & s$
    SynElements = s$
    SynLayers = NumLayers
    Busy False
End Sub

```

Property SynLayers....Assign number of layers to use in genetic and flip-flop synthesis.

```
SynLayers = NumLayers
```

Sub TargetsCopy...Copy optimization targets to clipboard.

TargetsCopy

Sub TargetsPaste...Paste optimization targets from clipboard.

TargetsPaste

Sub TargetsSelect(wMin!, Optional wMax!, Optional Types\$)...Select targets in range wMin to wMax (optional) with optional type Types\$ (R reflectance, T transmittance, V reverse reflectance). wMin and wMax are in current wave length units.

```
TargetsSelect 500           ' all targets at 500 nm
TargetsSelect 500, 650      ' all targets 500-650
TargetsSelect 500,, "RV"    ' R & V targets 500 nm
TargetsSelect 500, 650, "RV" ' R & V targets 500-600
```

This subroutine makes it possible to isolate particular targets, as in wave length by wavelength n,k determination. Use FileOpen or TargetsPaste to restore targets to the original table for further selecting.

Property Template\$...Assign/get Report Generator template. This should be done before showing or printing the report.

```
s$ = "<<Name Arial>><<Size 24>>" & Chr$(13) & Chr$(10)
Template = s$ & "FilmStar for Windows"
k = Macro("ShowReport;")
```

Use BASIC's file capabilities to load templates from disk:

```
Open "c:\fstemp\catalog.txt" For Output As #1
Print #1, Template
Close #1

Open "c:\fstemp\catalog.txt" For Input As #1
Template = Input$(Lof(1),1) ' do not add '$' here
Close #1
k = Macro("PrintReport;")
```

Property Tooling\$...Assign values shown in Tooling Factors dialog. Useful for evaluating and optimizing designs averaging over angle and thickness distribution, as in curved reflectors.

```
Tooling = "1.05 1.06 1.10"
Tooling = "" ' sets all values to 1.0
```

Property TypeContour%...Assign mode for contour data: 0 matrix, 1 triplets

```
TypeContour = 1
```

Property TypeDataCopy%...Assign spectra copy/paste format: 0 0-1, phase radians; 1 0-100%, phase degrees

```
TypeDataCopy = 0
```

Property TypeDataFile%...Assign spectra file format: 0 .csv, 1 .dx, 11 .dx for P-E, 100 .csv for Excel

```
TypeDataFile = 1
```

Property TypeSide2%...Assign Side 2 (uncoated substrate surface) compensation: 1 Forward, 2 Forward + Side 2, 3 Reverse, 4 Reverse + Side 2, 5 Forward + Side 2 in transmittance

TypeSide2 = 1

Property TypeWaveCopy%...Assign Spectra copy/paste wavelength format: 0 nm, 1 current units

TypeWaveCopy = 1

Property UserName\$...Get User Name (set in File...Configuration... Directories)

S\$ = UserName\$

Sub WaitTillReady()...Wait in a loop until the Main Menu gets the focus. This prevents a BASIC program from proceeding when other DESIGN windows are activated. The following code changes the color scale to 1976 CIE L*U*V*, closes the CIE Color Module and returns to the Main Menu.

MainActivate

SendKeys "^c^p{HOME}{DOWN}{DOWN}%o{F4}", 1

WaitTillReady

Property WaveUnit\$...Get current wavelength unit: *N* nm, *M* μm, *E* cm, *A* Ångstroms, *C* 1/cm, *G* GHz, *T* THz

S\$ = WaveUnit\$

Sub WbActivate...Activate the FilmStar Workbook. This is similar to pressing [F3] from the Main Menu except that the Auto Open Group is disabled.

WbActivate

Sub WbClear(cells\$)...Clear cells with address or named region cell\$. If more than one worksheet is open, use a unique named region or specify the worksheet to ensure the correct cell is cleared.

WbClear "B14:D28" or

WbClear "Sheet7!Average" ' specifies worksheet

Sub WbCopy(cells\$)...Copy contents to clipboard.

WbCopy "B14:D28" or

WbCopy "mtable.xls!Average"

Sub WbCloseAll...Close all open worksheets. This occurs instantly without prompting to resave changed sheets.

WbCloseAll

Sub WbExecute(Optional cmd\$)...Run Workbook macro command. If optional cmd\$ is blank or missing then use macro defined in Workbook.

WbActivate ' make sure that Workbook has focus

' (not required for hidden Workbook)

WbExecute "Angle 45 P;Calculate;Angle 45 S;Calculate;"

WbExecute ' run the macro defined in Workbook

Sub WbExit...Close the Workbook.

WbExit

Function WbGetNum(cell\$)...Get number from a spreadsheet cell. If you use cell references instead of a named region and if more than one sheet is open,

be sure to include the name of the sheet as shown below. Be sure that any cell name you specify actually exists!

```
v! = WbGetNum("Average") ' look in all open sheets
v! = WbGetNum("mtable.xls!Average")
v! = WbGetNum("mtable.xls!g23")
```

Function WbGetText(cell\$)...Get text from a spreadsheet cell. (See WbGetNum for remarks about cell names.)

```
s$ = WbGetText("PassOrFail")
```

Function WbOpen%(file\$)...Open worksheet. Include path and extension. More than one worksheet can be opened. Returns -1 (true) if successful. *Note that this was Sub WbOpen prior to Version 1.8.*

```
k = WbOpen(PgmPath & "\workbook\mtable.xls")
```

Function WbOpenHidden%(file\$)...Open hidden worksheet. Include path and extension. Only one worksheet can be opened. Returns -1 (true) if successful. Hidden worksheets enable users to do looping calculations without annoying flicker and about 250% faster.

```
k = WbOpenHidden(PgmPath & "\workbook\mtable.xls")
```

Sub WbPaste(cell\$)...Paste contents of clipboard.

```
WbPaste "C1"
```

Data can be transferred from one worksheet to another as follows:

```
WbCopy "mtable.xls!b4:b6"
WbPaste "sheet7!a1"
```

Sub WbRecalc...Recalculate all open worksheets.

```
WbRecalc
```

Sub WbResetLoop...Resets Worksheet Data Loop. Useful for hidden worksheet calculations using multiple data columns.

```
WbResetLoop
```

Sub WbSetFormula(cell\$, text\$)...Set formula in a spreadsheet cell. Cell location or defined name can be used. Note that the equal sign is not included in the expression for the formula.

```
WbSetFormula "Average", "AVERAGE $C$3:$C$5"
WbSetFormula "$C$5", "AVERAGE Reflectance"
```

Sub WbSetName(name\$, range\$)...(Re)assign Workbook defined name. Especially useful for moving DataMarker in complex models requiring multiple spectral ranges. Reassigning DataMarker resets data looping. Note that there is a DDE macro version of this command.

```
WbSetName "DataMarker", "$A$100"
WbSetName "DataMarker", "Test2.vts!$A$100"
```

Sub WbSetNum(cell\$, value!)...Set numerical value in a spreadsheet cell. Cell location or defined name can be used.

```
WbSetNum "StdDeviation", 1.45
WbSetNum "$C$5", 1.45
```

Sub WbSetText(cell\$, text\$)...Set text in a spreadsheet cell. Cell location or defined name can be used.

```
WbSetText "Name", "Edgerstoune Optics"  
WbSetText "$C$5", "Edgerstoune Optics"
```

Sub WbWindow(kState)...Set Workbook window state: 0 normal, 1 min, 2 max

```
WbWindow 0
```

Sub WriteIniString\$(section\$, key\$, text\$)...Store user-define initialization variables in design1.ini.

```
WriteIniString "Chuck Vogel", "LastFileName", "WW098909"
```

inserts/modifies the following entry in design1.ini:

```
[Chuck Vogel]  
LastFileName=WW098909
```

FilmStar Workbook

The Workbook is an Excel-compatible programmable spreadsheet (Microsoft Excel not required) for calculations and optimization. This offers great flexibility in setting up optimization problems. The Workbook also supports user-defined dispersive index functions.

The Workbook contains worksheets and menu commands. Each worksheet has its own file. For convenience, several worksheets can be loaded in a group. A group could contain the main calculation worksheet, an index function worksheet, and an illuminant worksheet. Most Excel Version 4.0 spreadsheet formulas are supported and the Workbook is integrated with "" (page 64) and the "" (page 94).

File Menu

Most commands will be familiar to spreadsheet users. Worksheet files can be loaded and saved in native .vts or Excel 5.0/95-compatible .xls format. Worksheet files can be saved in groups and loaded with hot-keys **<Shift+F1>...<Shift+F4>**.

Microsoft Excel files saved in 5.0/95 format can be opened in the FilmStar Workbook. Features from newer Excel versions, such as multiple sheets, are not supported.

Open Worksheet Groups...Edit Groups <Ctrl+G>

This leads to the Edit Worksheet Groups dialog box.

Group Name...Assign a name to appear in the Open Worksheet Groups menu alongside the hot-keys **<Shift+F1>...<Shift+F4>**.

Files in Group...Click on a file name to place it in the **File Name** editor or remove the file from the group by pressing **Delete File**.

Files Name...Typing in this text box activates the **Add File** button.

Printer Setup

Headers and footers can contain text and special formatting codes as follows:

&L	Left-aligns the characters that follow
&C	Centers the characters that follow

&R	Right-aligns the characters that follow
&D	Prints the current date
&T	Prints the current time
&F	Prints the worksheet name
&P	Prints the page number

The following font codes must be placed before the preceding ones.

&B	Bold
&I	Italic
&"fontname"	Use the specified font
&nn	Use the specified font size (2 digit number)

Evaluate Menu

Execute Macro <F8>

Execute DESIGN commands contained in a worksheet cell or group of cells with defined name *Macro*. Functions are identical with those listed under "Macro Commands (DDE)" on page 27. The same macros are automatically executed during optimization or tolerancing. Note that similar macros are available in the Main Menu and can be run from "BASIC" on page 64.

Reset Data Loop <Ctrl+F8>

If looping is enabled (see *Data Type* below) multiple calculations are placed in adjacent worksheet columns. Users can then develop functions of several spectra. This command resets column position to the first column.

Recalculate <F9>

Only the active window is recalculated. Recalculation is automatic during optimization and tolerancing.

Auto Recalculate

Recalculation of all open windows is automatic if this entry is checked. During optimization and tolerancing, however, windows are automatically recalculated and this entry can be left unchecked. This could provide some speed improvement since intermediate calculations are suppressed.

Optimize Menu

Workbook optimization is independent of any optimization targets defined in the Main Menu. See the following section Defined Names for further information. Optimization variables, however, are the same.

Formulas

Many Excel-compatible formulas are supported in the FilmStar Workbook. An A-Z Function Reference is provided in help file wbfs_az.hlp. This file may be accessed from the FilmStar Workbook by clicking **Help...Function Reference <Ctrl+F1>**. Note that Workbook models developed for fixed wavelength or angle ranges will be far simpler than models which allow any range.

Defined Names

A worksheet communicates with DESIGN's calculation and optimization routines through eight special reserved defined names:

Constraint, DataMarker, DataType, Design, Macro, Objective, Passed, Yield

These are assigned to a worksheet file with **Edit...Defined Names**.

Special reserved names must be in a single worksheet.

When a worksheet is utilized for index functions, user-defined cell names are referenced in **Setup...Index Functions**. Index functions are normally defined in a separate worksheet, not the worksheet containing *DataMarker*.

Constraint

The NOL gradient optimizer used by the FilmStar Workbook supports multiple linear and nonlinear constraints. *Constraint* has N rows and two columns where N is the number of constraints. The first column includes constraint formulas and the second includes constraint types. Constraint types are as follows:

- 2 Linear equality constraint
- 1 Nonlinear equality constraint
- 1 Nonlinear inequality constraint
- 2 Linear inequality constraint

In the illustrative BBAR example we design an AR coating with three thickness constraints given in {G5:H7}.

1. Total thickness < 225 nm {G5=F17-225, H5=2}
2. Layer 1 = Layer 2 {G6=F12-F13, H6=-2}
3. Layer 3 = Layer 4. {G7=F12-F13, H6=-2}

DataMarker

	A	B	C	D	E	F	G	H
1	DataType	0	Macro	LAYERSCOPY;CALCULATE;				
2								
3								
4	DataMarker				Objective		Constraint	
5	450.00	0.017	0.983	Average=	0.53008		-0.000	2
6	460.00	0.010	0.990	Max=	2.45529		0.000	-2
7	470.00	0.006	0.994				0.000	-2
8	480.00	0.003	0.997		Passed			
9	490.00	0.001	0.999		FALSE			
10	500.00	0.001	0.999					
11	510.00	0.001	0.999		Design			
12	520.00	0.001	0.999		18.4H	18.40		
13	530.00	0.001	0.999		18.4L	18.40		
14	540.00	0.002	0.998		94.06H	94.06		
15	550.00	0.002	0.998		94.06L	94.06		
16	560.00	0.002	0.998					
17	570.00	0.002	0.998	Total Thickness=		224.92		

Workbook containing worksheet BBAR.XLS. Named regions shown in yellow.

During evaluation and optimization the Workbook calculates required spectra in DESIGN. The spectrum is subsequently transferred to the active worksheet below the *DataMarker* cell as shown in the BBAR example. Data transfer is automatic whenever the Workbook is activated by pressing <F3> or by clicking on it.

If *DataMarker* is not defined, users can paste spectral data manually by copying the data to the clipboard in DESIGN (**Spectra...Copy Data <Ctrl+C>**) and pasting it in the Workbook with **Edit...Paste <Ctrl+V>**.

DataType

This integer contains the following bit values:

<i>Format</i>	Bit 0 (+1)	Formatting enabled
<i>Loop</i>	Bit 1 (+2)	Looping enabled
<i>Phase</i>	Bit 2 (+4)	Phase values included when bit 0 = 0
<i>No Paste</i>	Bit 4 (+16)	Suppress data auto-pasting
<i>PhaseSmooth</i>	Bit 6 (+64)	Smooth phase column (radians)

	A	B	C	D	E
1	DataType 1				
2					
3	Wave (nm)	% Refl	% Trns		
4	450.000	0.24687	99.75313		
5	460.000	0.14474	99.85526	Average	0.19
6	470.000	0.13258	99.86742	Maximum	0.33
7	480.000	0.15336	99.84664		
8	490.000	0.17710	99.82290	Passed	TRUE
9	500.000	0.19164	99.80836		

Automatic column labels in formatted worksheet.

Formatting adds labels and displays percent values for R and T. The *DataMarker* cell now contains the label 'Wave (nm)'.

Looping makes it possible to utilize multiple spectra in the Workbook. Each time the Workbook is activated the new spectrum is pasted to the right of the previous one. To start again, click **Evaluate...Reset Data Loop <Ctrl+F8>** before deactivating the Workbook and returning to the Main Menu.

Looping is automatically enabled when macros are run. If the macro includes multiple calculations, spectra are automatically pasted into adjacent columns without having to set *DataType* bit 0. It is not necessary to include a zero *DataType* cell in a worksheet. If it is missing, it is the same as 0.

Two calculated columns plus the wavelength column are normally pasted into the worksheet at *DataMarker* each time it is activated. Additional calculated columns corresponding to reflected and transmitted phase shift (radians) are available by setting *DataType* bit 2 (+4). This only works when formatting is disabled (bit 0 = 0). If bit 4 (+16) is set, spectral data is not automatically pasted into the Workbook when it is activated.

Design

It is sometimes useful to include layer thicknesses in Workbook calculations. Layers mode designs are automatically pasted into a worksheet by executing macro command *LAYERSCOPY* from a worksheet which includes defined name *Design*. In the 'bbar.xls' example *Design* is defined as cell {E12}; it could also be defined as {E12:E15}.

Macro

A worksheet can 'send' commands to DESIGN. Commands are listed under "Macro Commands (DDE)" on page 27. Commands can be grouped in one cell {D1="LAYERSCOPY;CALCULATE;"} or in a single column (easier to read). Each command is terminated with a semicolon. Macro commands must be assigned defined name *Macro*.

Macros are automatically executed each time the optimizer or tolerancing module calls DESIGN's calculation routines. Click **Evaluate...Execute Macro <F8>** to run command macros manually. When macros containing multiple *CALCULATE* or *CALCPLOT* commands are run, spectra are automatically pasted into adjacent columns.

While there is no macro language in the Workbook itself, it can be accessed from FilmStar BASIC.

Objective

The objective (merit function) is a mathematical expression for the performance of the coating. It may be the only expression (unconstrained problem) or it may be combined with constraint conditions. In the illustrated sample worksheet 'bbar.xls', we minimize average reflectance {E5} subject to constraints expressed in {G5:H7}.

When there are NO constraints, optimization may be terminated early by pressing **<Esc>**. With constraints, early termination might result in loss of the best design.

Passed

A logical function evaluating to *TRUE* if the spectrum passes some specification and *FALSE* if it fails. In 'bbar.xls' *Passed* {E9} is defined as

=AND(E5<0.005, E6<0.01) .

The coating passes if the average is less than 0.5% and maximum less than 1.0%. This allows users to set up tolerancing problems in the Workbook.

Yield

Used in conjunction with **Passed**. Provides a tally in % of the number of passes divided by the number of iterations.

CIE Color Module

The CIE Color Module provides facilities for evaluating and optimizing color coatings where there is a single color specification. More complex cases (*i.e.* color requirements in reflection *and* transmission or color requirements over an angle range) can be set up in the Workbook. The module is activated from the Main Menu by clicking Evaluate...**CIE Color <Ctrl+F9>**. To exit the module, click on the Main Menu or press **<Esc>**. Close the module with **<Alt+F4>**.

There is no need to set Graph Axes for the CIE range 380-770 nm when using the Color Module. It is not necessary to calculate a spectrum before accessing the module.

Colors displayed in the module's status area are approximate and should never be used as a basis for color specifications.

Module parameters, including color optimization targets, are stored with the thin film design.

Setup Menu

Parameters <Ctrl+P>

Modes... Four calculation modes are current supported: CIE 1931, CIE 1964, CIE 1976 L*U*V*, and CIE 1976 L*a*b*.

If you change modes you can get the 'Overflow' error because displayed graph axes are out-of-range for the new calculation. Fix this by adjusting graph axes.

Observer...2° and 10° observers may be selected.

Illuminant...Black body source and illuminants A/B/C/D65/E are included. Users can define any number of additional illuminants as ASCII files stored in the DESIGN program directory (usually \winfilm). Each file includes a single column of numbers giving the relative intensity from 380 to 770 x 5 nm (or 1 nm). Illuminant descriptions and corresponding file names are entered in design1.ini as described in "Configuration - Preferences" on page 25.

User-illuminant files are defined from 380 to 770 x5 nm or x1 nm intervals. There must be 79 or 391 entries.

Calculation Interval...An interval of 5 nm is sufficient for most color calculations. When 1 nm spacing is specified, the module generates 1 nm tables from 5 nm CIE data. The finer interval will only be required if there are exceptionally sharp spectral features in the filter. If there are sharp spectral features in the source, users can construct 1 nm user-illuminant files. (1 nm illuminant files can be utilized in 5 nm calculations.)

Tolerance Box...Acceptability polygon for tolerancing. Color coordinates pass the specification if they are in the box. Enter coordinates in clockwise order for each point describing a convex polygon. Coordinates are comma and line separated as shown. A convex polygon is shown at the left; the concave polygon (one or more sides with internal angle > 180 degrees) will not work.

.27, .27	↑
.29, .33	
.33, .33	
.31, .27	↓



Evaluate Menu

Calculate <F9>

Click if the module fails to recalculate automatically. If you don't see coordinates drawn as a circle, try **Draw New Axes <Ctrl+A>** followed by <F9>.

Tolerancing...Values <Ctrl+N>

This brings up the same Tolerancing dialog as in the Main Menu and Worksheet. If no tolerance box is defined in CIE Setup Parameters, a scatter plot is still obtained, but yield will not be computed.

Optimize Menu

Optimize <Ctrl+O>

During optimization progress is shown on screen. As with all constrained problems, it is recommended that you allow optimization to proceed to its conclusion. Termination by pressing <Esc> could result in the loss of the best design.

Targets <Ctrl+T>

Color optimization targets are independent of the optimization targets defined in the Main Menu.

The NOL gradient optimizer attempts to maximize or minimize photopic response Y (or L* for L*U*V*, L*a*b*) in reflection or transmission while simultaneously meeting CIE color coordinate constraints. Fixed Y, L* values (0-100) are also permitted. Color constraints may be disabled in order to design coatings only meeting photopic response requirements.

If **Minimize (Maximize) Average** is checked, the unweighted average over wavelength range 400-720 is utilized.

FSPlot Graphing Module

The FSPlot Graphing Module creates publication-quality graphs for proposals, reports and publications. It has its own memory and can store spectra independent of the main program. FSPlot graphs may be combined with text in the "" on page 94.

After calculating a spectrum (vs. wavelength or angle) in the Main Menu, click **Spectra...FSPlot Module <F4>** to activate the graphing module. Click **Plot** and the graph is replotted. Each spectrum must have exactly the same horizontal axis values. This can be a problem when importing data from disk files. Use **Convert Table** in the Main Menu to equalize horizontal axis spacing.

File Menu

Save As <F12>

Save the graph as a Windows metafile (.wmf) or bitmap (.bmp, .png). This can then be imported by word processors or graphics programs. Use PNG (Portable Network Graphics) for web graphics; bitmap (.bmp) files are large and should not be posted to web sites or sent as e-mail attachments.

Copy <Ctrl+C>

Copy to the clipboard. The image can be pasted into word processors or graphics packages. The image will be a metafile (vector) or bitmap according to *Graphics Mode* setting.

Zoom

This enlarges the bitmap to match printer resolution.

Create BASIC Setup

Creates FilmStar BASIC code describing the current FSPlot configuration. The code is copied to the clipboard for pasting into the BASIC editor.

Reload Setup

Reloads the FSPlot configuration stored in design1.ini. This is useful if you have temporarily changed colors and wish to return to a standard format.

Disable Save

Normally the current FSPlot configuration is stored in design1.ini upon exiting FilmStar DESIGN. Check this box to disable that function. Save can also be disabled by setting *PlotNoSave=True* in FilmStar BASIC.

Setup Menu

Once a format (including the size of the FSPlot window) is decided upon, it is saved upon leaving DESIGN. Try a dark background for 2x2" slides. For mono chrome printing, enabling Grays may be preferable to Patterns. The lack of thick patterned lines is a Windows limitation.

Plot %T + OD

This mode is supported when Optical Density is selected in Setup Parameters. Here the left hand axis is T = 0-100% while the right hand axis is optical density according to Graph Axes settings. When switching this mode it may be necessary to close and reopen the FSPlot Module.

Legends

Legends and a subtitle are added to the graph in the Graph Legends editor. Note that subtitle font size is fixed relative to title font size.

Table

A table annotation can be added to the graph. This is used to display summary calculated results in a convenient format. As such, it is normally used in conjunction with FilmStar BASIC.

Data Menu

File and clipboard operations make it possible to load and save data associated with multiple plots. Data is saved in Excel-compatible .csv format (no header).

Formulator <Ctrl+F>

Create and edit a Plot Formula for arithmetic operations on displayed data sets. The Plot Formula is stored with Graph Axes or FILM Archive.

Run Formula <Ctrl+R>

Apply an existing Plot Formula to the displayed data. Doing this twice in a row can have unwanted consequences. If that happens and only one data set is being used, click **Delete #1** and **Plot** to recover the original graph.

Annotations

Annotations (stored with Graph Axes) may be added to FSPlot graphs. This is especially useful for quality control.

graph x, y, type, text, color... Draw lines and place text anywhere. When drawing a series of lines *text* is blank and at two or more *graph* statements are required. The first *graph* statement uses the following *type* values:

Thin solid = 38; Dash = 39; Dot = 40
Dash dot = 41; Dash dot dot = 42
Medium solid = 43; Thick solid = 44

Subsequent *GRAPH* statements in a line series use the following *type* value:

Continue line = 45

Other values of *type* add text with numerous optional symbols. Some of these types are indicated below. Other values may be determined by examining the annotation after using the Annotator.

0 none; 1 plus; 2 cross; 4 solid dot; 6 solid square;
37 pointer

Color values are correspond to RGB values 0 to 16777215. This is different from older versions which allowed 16 colors. Older versions are automatically converted, as indicated by header line *VERS2*.

In the example below, *a-d* define the first series of lines, and *e-h* define the second line series. Note that the left-hand axis is used for coordinates *x, y*.

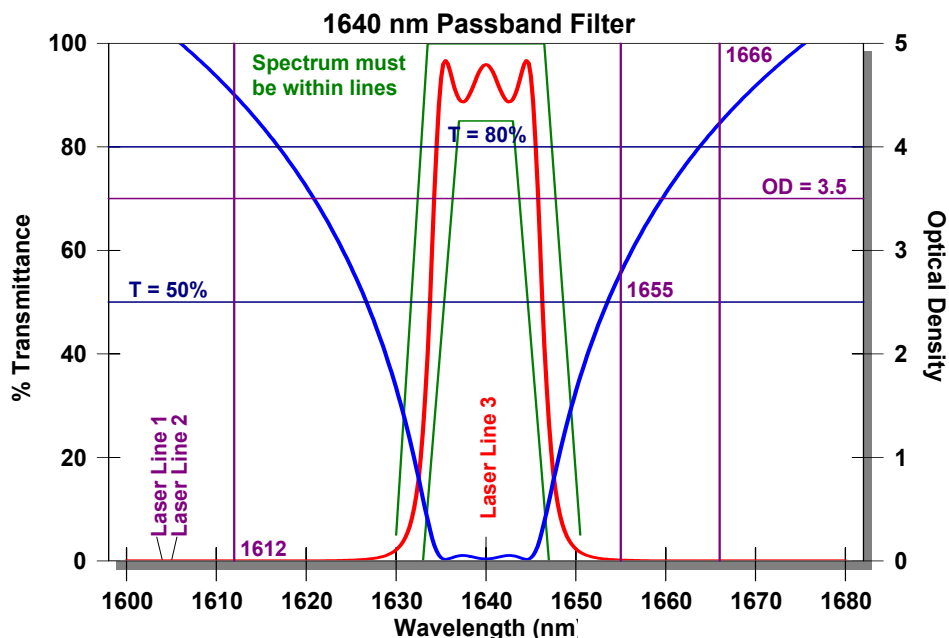
hline y, type, text, color... Draw a horizontal annotated line. Line *type* is as follows:

Thin solid = 0; Dash = 1; Dot = 2
Dash dot = 3; Dash dot dot = 4
Medium solid = 5; Thick solid = 6

In the example below, *k* illustrates the use of *hline*. Colors are as listed above under *graph*.

vlane x, type, text, color... Draw a vertical annotated line. Line *type* is as listed above for *hline*. Illustrated in the example below in lines *l,m*.

xaxis x, text, color... Label special positions on the horizontal axis. As illustrated below in *n,o* closely spaced laser lines can be marked without overlapping text. A similar **yaxis** statement is also available.



Note that letters *a...s* just identify statements and are not actually included in the annotation editor. Do not remove the header line *VERS2*.

VERS2

- a. graph 1630, 5, 43,, 32768;0
- b. graph 1633.5, 99.9, 45,, 32768;1
- c. graph 1646.5, 99.9, 45,, 32768;2
- d. graph 1650.5, 5, 45,, 32768;3
- e. graph 1633, 0, 43,, 32768;4
- f. graph 1637, 85, 45,, 32768;5
- g. graph 1643, 85, 45,, 32768;6

```

h. graph 1647, 0, 45,, 32768;7
i. graph 1614, 94, 0, Spectrum must, 32768;8
j. graph 1614, 89, 0, be within lines, 32768;9
k. hline 70, 5, |rOD = 3.5, 8388736;0
l. hline 80, 5, |cT = 80%, 8388608;1
m. hline 50, 5, |lT = 50%, 8388608;2
n. vline 1612, 5, |b 1612, 8388736;0
o. vline 1655, 5, |c 1655, 8388736;1
p. vline 1666, 5, |t 1666, 8388736;2
q. xaxis 1604, Laser Line 1, 8388736;0
r. xaxis 1605, Laser Line 2, 8388736;1
s. xaxis 1640, \\Laser Line 3, 255;2

```

Hline labels are justified with codes |L (left outside), |l (left inside), |c (center), |r (right inside) and |R (right outside) where "|" is the pipe symbol (shift backslash). *Vline* labels are justified with codes |B (bottom outside), |b (bottom inside), |c (center), |t (top inside) and |T (top outside).

As illustrated in *s*, backslashes ("\") in *text* fields are converted to spaces. In addition reverse quotation marks ("") are converted to commas.

The system automatically adds a semicolon and index number to each annotation. This identifies the annotation to the Annotator.

Annotator

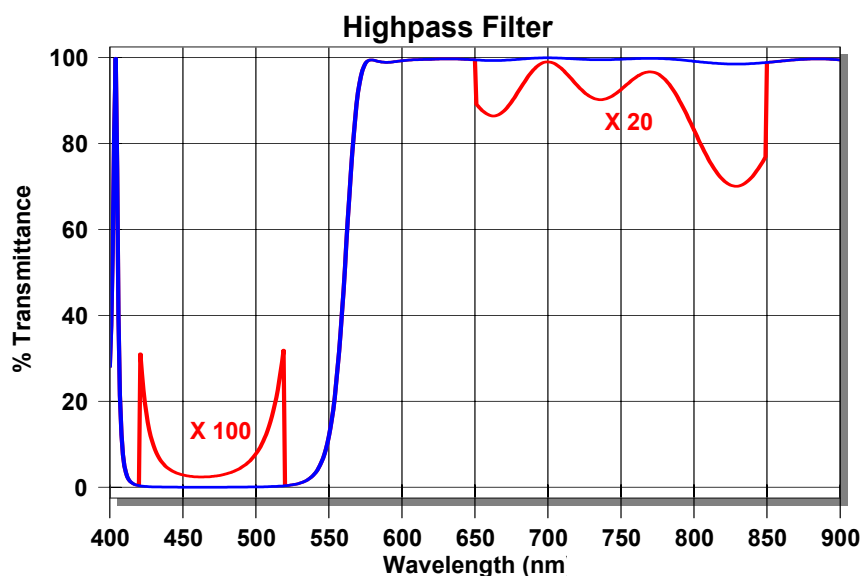
As an alternative or supplement to manual entry, annotations can be added and edited interactively. You can also use the Annotator to edit annotations previously entered manually.

Click on the FSPlot graph region with the left mouse button to bring up the Annotator dialog box. Note that mouse x,y coordinates are automatically transferred. The annotation is actually added when **Add** is clicked. Once the annotation is drawn, return to the graph region and locate it with the mouse. Observe that the cursor changes to a hand shape. Now click again and note that the **Add** button has been changed to a **Replace** button. In addition a **Delete** button becomes visible.

To draw line segments select **Type New Line Segment** and click **Add**, followed by one or more *Continue Line Segments*, clicking **Add** for each new segment. To add temporary annotations (not stored with Graph Axes), clear the **Permanent** check box. In the annotation editor temporary annotations include a tilde ("~") before the annotation line.

Formulator

The FSPlot Formulator modifies data displayed in graphs. Typical applications might include manipulating data values to show detail, averaging curves, plotting difference between curves, etc.



After plotting all required curves, click **Edit...Formulator (Ctrl+F)** in the FSPlot Module. Enter an appropriate formula and click **Apply**. Examine the data in the grid as well as the FSPlot graph; if incorrect click **Revert** to restore the original data array. Finally, click **Close** to exit. In the illustrated example the following formula is used:

```
C=B;
B=if(A>420 & A<520, 100*B, if(A>650 &
A<850, 100-(100-B)*20, B))
```

Multiple formulas are separated by semicolons (;). Letters refer to columns A-M (A is wavelength, B is first data set, etc.). The following operators are supported

- + Addition
- Subtraction
- ^ Exponentiation
- * Multiplication
- / Division
- & Logical And
- | Logical Or

The following functions are also supported:

```
if(X,Y,Z) If X is true Y is returned, otherwise Z is returned
abs(Y) Absolute value
```

Special operator *del* deletes unwanted data columns

```
del C Remove column C
```

For example

```
D=.5*(B+C);del B;del B
```

yields columns A and B where B is the average of the two original columns A and B. Note that *del* is always used at the end of a formula.

Report Generator

Using ComponentOne's VsPrint7.ocx module the Report Generator combines text and graphics in multi-page documents. The Report Generator interacts with the "

Module", "", and the "FilmStar Workbook" to provide great flexibility and many options. It is possible, for example, to publish an entire catalog of filter designs with a single keystroke.

While the Report Generator is not a word processor, it provides many word processor printing features including print preview. Reports may be saved in three formats: binary (.prt) for reprinting in FilmStar, Adobe Acrobat (.pdf), and rich text (.rtf). Rich text may be opened in MS Word and resaved in .doc format.

Report Setup

The options in this dialog box are the default format options for the report. Options can be changed throughout the document by using formatting field codes in the Template.

Header/Footer

Headers and footers are composed of three sections separated by pipe characters ("|"). The first section is left-justified, the second is centered, the third is right-justified. A page number field is embedded by including the code "%d" in the text. In the following example the second section is blank:

```
FilmStar Report Generator||Page %d
```

In the next example only the second section is used:

```
|FilmStar Report Generator Page %d|
```

Headers and footers use default report fonts which can be changed by clicking **Fonts**. In the header or footer fonts are printed italic if the default font is not italic, and vice-versa.

Margins & Line Spacing

Margins are in inches or mm. Line spacing is expressed as percent of font size. Margins should be the same throughout any document.

Metric Paper

When metric paper is selected, margins and some other length settings will be in mm instead of inches.

Color Printer

This toggles whether the print preview shows colors. Memory is saved by displaying monochrome graphics. It does not affect the actual printout.

Auto Preview

This toggles whether print preview is updated automatically whenever conditions are changed. When disabled a **Preview** button appears in the Report Generator main menu.

Show Graphics

This toggles whether graphics are displayed in the preview. When turned off graphics are shown as rectangles. This option saves memory and increases redraw speed. It does not affect the actual printout.

Report Template

The report template includes text and codes. Codes are surrounded by double left and right arrow keys. In the following definitions commands are capitalized and parameters are shown in lower case. When actually typing commands, however, capitalization is unimportant.

Templates are stored with Graph Axes. To keep new templates re-save the Graph Axes file with a different name. Templates can also be assigned in BASIC (see "FilmStar DESIGN Extensions" on page 65).

Action Commands

Action commands insert text and graphics.

<<BASBLOCK value>>...Value 0 to 15. Insert text block paragraph(s) created in FilmStar BASIC by assigning BasText0\$...BasText15\$. See IndentFirst, IndentLeft, and IndentRight. This is useful for paragraphs containing calculated text. Otherwise consider using FileText.

```
<<BasBlock 5>>      ' insert block text BasText5$
```

<<BASTEXT value>>...Value 0 to 15. Insert string created in FilmStar BASIC by assigning BasText0\$...BasText15\$.

```
<<BasText 5>>      ' insert BasText5$
```

<<DRAWLINE>>...Insert a horizontal line between the current margins adjusted by IndentLeft and IndentRight.

```
<<DrawLine>>
```

<<FILETEXT name>>...Insert a text file as a paragraph(s). This is useful for proposals and quotations. See IndentFirst, IndentLeft, and IndentRight.

```
<<FileText d:\winfilm\pro1.txt>>
```

<<FSPLOT zoom, fontsize, width, height>>...Zoom and font size in %, width and height in twips. Insert a graph from the FSPlot module. The graph is inserted at the screen size times zoom in %. Font size can be adjusted by optionally adding relative values in %. The FSPlot window size is adjusted by optionally adding width and height in twips (1 inch = 1440 twips, 1 mm = 56.7 twips). This ensures that graphs are printed at repeatable sizes even if users have altered FSPlot window dimensions.

```
<<FSPlot>>          'zoom=100%, font size=100%
<<FSPlot 75>>        'zoom=75%,  font size=100%
<<FSPlot 75,120>>    'zoom=75%,  font size = 120%
<<FSPlot 105,110,7500,6000>> ' zoom=105%, font size=110%
                        ' ht=7500, wd=6500
```

There are two modes: 1. The FSPlot module is closed when a report is generated and, 2. FSPlot is open (visible). In the first case, each graph automatically plots the latest spectrum. FSPlot operation remains hidden.

If the FSPlot module is open when a report is generated, the displayed graph is placed into the report. In this case FSPlot is not refreshed automatically with the latest spectrum. To automatically include multiple graphs on a plot, use BASIC function PlotActivate to display the module and PlotNext to add new graphs. To plot reflectance and transmittance on the same graph use macro function PlotSelect. Generate a report with k = Macro("ShowReport;"), and use PlotClose to close FSPlot, erasing all graphs.

After font or window size is adjusted, close and open the Report Generator in order to see the changes. To include multiple FSPlot graphs in a report, use BASIC function PlotSave to store each graph as a picture. Then use template function Picture (see below) to print graphs.

<<GRAPH zoom>>...Insert the bitmap graph shown in DESIGN's Main Menu. The graph is inserted at the screen size times zoom in %. An FSPlot graph can also be inserted as a bitmap by checking **File...Bitmap Mode**.

```
<<Graph 70>>      ' zoom=70%
<<Graph>>          ' zoom=100%
```

<<PAGE>>...Insert page break. Page breaks are automatically inserted if a graph is too big for the page.

```
<<Page>>
```

<<PICTURE name, zoom>>...Insert a picture file with .bmp (bitmap) or .wmf (metafile) extension. Pictures are centered between current margins. Zoom is optional and is 100% if not specified. Use Picture in conjunction with FilmStar BASIC's PlotSave to print documents containing several FSPlot graphs. Picture is convenient for printing company letterheads and logos.

```
<<Picture d:\winfilm\ftglogo.wmf, 75>> 'zoom=75%
<<Picture d:\winfilm\ftglogo.wmf>>      'zoom=100%
```

<<REVIEW format>>...Insert the Review Design screen. An optional format number (1-3) corresponds to the numbering in the Review Design screen.

```
<<Review>>      ' format 1 (original)
<<Review 2>>    ' format 2
```

<<TABLE>>...Insert current spectrum as a data table.

```
<<Table>>
```

<<WBTEXT cell>>...Insert string as formatted in Workbook cell. If only one worksheet is open or if the defined name is unique you can eliminate the worksheet name in the cell name. To get required formatting for numerical values, use the Workbook's TEXT function.

```
<<WbText Rmin>>
<<WbText sheet2!Rmax>>
<<WbText mtable.xls!Average>> ' insert BasText5$
<<WbText mtable.xls!b14>>     ' insert BasText5$
```

Format Commands

The simple formatting in the Report Setup dialog box will be sufficient for many applications. Additional formatting is possible with the following template commands.

<<ALIGN type>>...Align text between margins.

```
<<Align 0>>      ' left justify
<<Align 1>>      ' center justify
<<Align 2>>      ' right justify
```

Left justification allows you to format words within a line. In center and right alignment the entire line will have the same formatting.

<<BOLD boolean>>...Font bold or normal.

```
<<Bold 0>>      ' following text is normal
<<Bold 1>>      ' following text is bold
```

<<BORDER value>>...Page border, values 0 to 7: 0 none, 1 bottom, 2 top, 3 top & bottom, 4 box, 5 columns, 6 columns & top & bottom, 7 all. If Border

is not specified, a top border is drawn if there is a header and the bottom is drawn if there is a footer.

<<Border 4>> ' draw box around each page

<<COLOR value>>...Color 0 to 15: 0 black, 1 blue, 2 green, 3 cyan, 4 red, 5 magenta, 6 yellow, 7 light gray, 8 dark gray, 9 blue, 10 green, 11 cyan, 12 red, 13 magenta, 14 yellow, 15 white. 1-6 are dark versions of 9-14.

<<Color 9>> ' text is blue

<<DEFFONTS>>...Returns **Name**, **Size**, **Bold**, **Italic** and **Spacing** to default values.

<<DefFonts>>

<<DEFNAME font>>...Sets new default font name. **DefSize**, **DefBold**, **DefItalic** and **DefSpacing** are similar.

<<DefName Lucida Sans Typewriter>>

<<FOOTTEXT text>>...Overwrite the default footer. *See HdrText below.*

<<FootText |This is the footer - Page 1|>> ' footer text

<<HDRBOLD boolean>>...Header and footer font bold or normal.

<<HdrBold 1>> ' header/footer text is bold

<<HDRCOLOR value>>...Header/footer color. See Color.

<<HdrColor 12>> ' header/footer text is red

<<HDRITALIC boolean>>...Header/footer font bold or normal.

<<HdrItalic 1>> ' header/footer text is italic

<<HDRNAME value>>...Header/footer font name

<<HdrName Arial>>

<<HDRSIZE points>>...Header/footer font size.

<<HdrSize 10>> ' header/footer size is 10 points

<<HDRTEXT text>>...Overwrite the default header.

<<HdrText |This is the header - Page 1|>> ' header text

This is useful for creating multipage documents from single page reports with BASIC as shown in the following code snippet:

```
Sub PrintPage (nPage as Integer)
    t$ = Template$ 'get the template
    p$ = Cstr(nPage) 'page number
    t$ = t$ & "<<HdrText |Catalog - Pg " & p$ & "|>>"
    Template = t$ 'reassign template
    PrintReport
End Sub
```

<<INDENTFIRST length>>...Additional left indent for the first line of a paragraph in inches or mm (metric paper).

<<IndentFirst .3>> ' first indent=.3"

<<INDENTLEFT length>>...Left indent in inches or mm (metric paper).

<<IndentLeft .75>> ' left indent=.75"

<<INDENTRIGHT length>>...Right indent in inches or mm (metric paper).

<<IndentRight .75>> ' right indent=.75"

<<INDENTTAB length>>...Tab spacing in inches or mm (metric paper).

<<IndentTab .5>> ' tab spacing is =.5"

<<ITALIC boolean>>...Font italic or normal.

<<Italic 0>> ' following text is normal

<<Italic 1>> ' following text is italic

<<LINECOLOR value>>...Line color used for borders. See **Color**.

<<LineCoLor 12>> ' borders in red

<<LINEWIDTH points>>...Line width in points used for borders. The default is zero. This may be acceptable for 300 dpi printers but will be probably be too thin for higher resolution printers.

<<LineWidth 1.5>> ' line width 1.5 points

<<MARGINS metric, left, right, top, bottom>>...Set English/metric units and margins. Any non-zero value for the first field sets metric paper. If utilized, Margins should be the first command in a template.

<<Margins 0,.75,.75,.5,.5>> ' English units

This command is useful for templates created and stored through BASIC. Users can then be sure that margins are correct even if the Graph Axes file was overwritten.

<<NAME font>>...Font name. This must correspond to your printer. See also Size, Bold and Italic.

<<Name Lucida Sans Typewriter>>

<<SIZE points>>...Text font size in points (1" = 72 points)

<<Size 10>>

<<SPACEAFTER points>>...Extra space in points (1" = 72 points) to be added after paragraphs.

<<SpaceAfter 8>> ' 8 point space after paragraphs

<<SPACING percent>>...Line spacing as a percent of the current font size. The default can be set in the Report Setup dialog box.

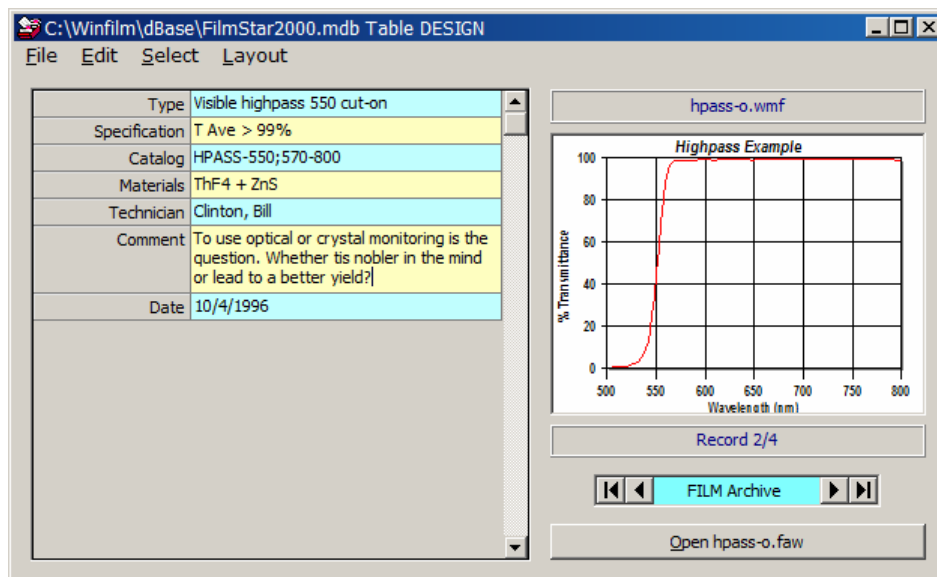
<<Spacing 120>>

FilmStar Database

The FilmStar Database provides means to sort and select designs and measured spectra. Each database contains user-defined fields and three special fields: a date field, and two 'hidden' fields: FILM Archive name (or spectrum name) and picture name. The FILM Archive name is displayed in the **Open** button below the data control and the picture file name is displayed above the picture. Hovering the mouse cursor over these file names reveals the entire name with path.

The database itself must be an MS Access compatible .mdb file. This is created with MS Access (recommended) or by running a FilmStar BASIC program such

as dbCreate.bas (advanced users). The following field types are supported: text, memo, integer, long, date, single and binary. If database terms such as tables, fields and records are unfamiliar, we suggest you seek the help of a colleague familiar with MS Access, or contact FTG Software.

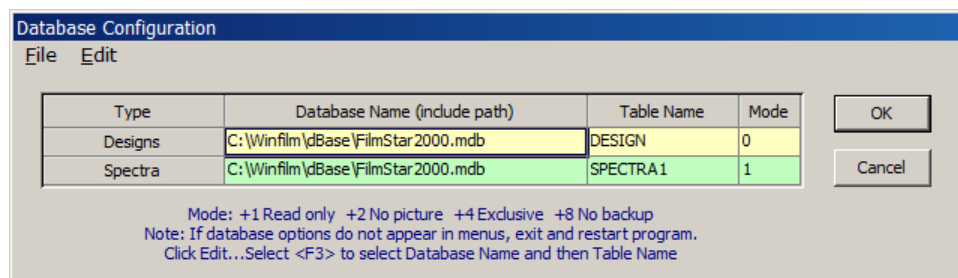


A database is opened from the main menu via **File...Database** (FILM Archive) or **Spectra...Database** (spectra). *Both can be open at the same time.* In the database module, click the database control below the graph to browse records (**First-Prev-Next-Last**) and the **Open...** button to open the FILM Archive or spectrum and return to the Main Menu. Shortcut keys **<F3>** and **<F4>** provide faster browsing.

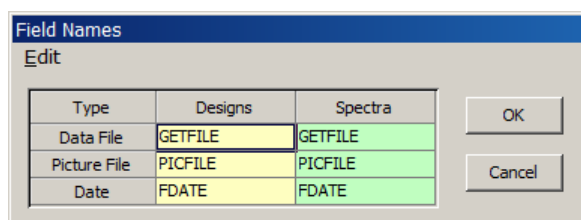
The width of the text entry grid can be adjusted independently of the width of the graph. This is accomplished by moving the mouse cursor to the left of the graph where the pointer changes to a vertical line.

When a database is first opened, the file is copied to a .bak file. If you corrupt the database, close FilmStar and recopy the .bak file to the original. Be sure to back up the database regularly!

Database names are specified in the Database Configuration dialog found in **File...Configuration...Directories**. Designs and Spectra databases need be the same. Placing the grid highlight in the *Database Name* column and **Edit...Select <F3>** to locate the required database (.mdb). After specifying the database, use **Edit...Select <F3>** to access a list of Table Names.



Click **Edit...Field Names <F4>** to assign names for three special field types: *Data File*, *Picture File*, and *Date*. In the *Field Names* dialog, **Edit...Select <F3>** pops up a list of names. (Here they are the same for both Designs and Spectra tables, but they need not be.)



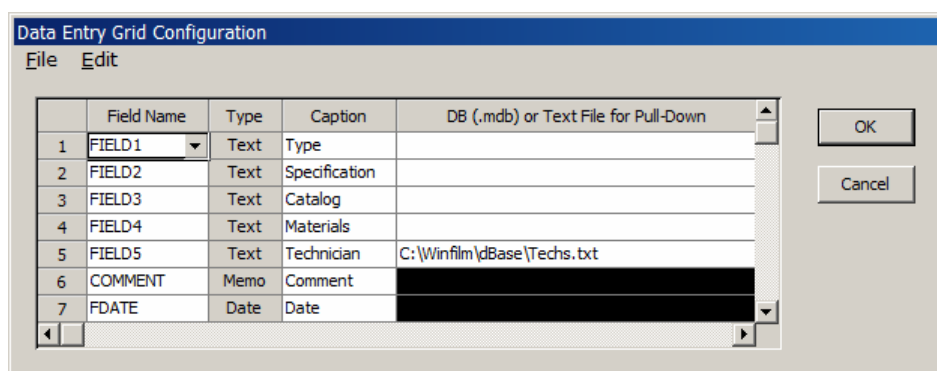
Pictures are generated and stored as .wmf files in the FSPlot module. It is not necessary to have a picture for every record. Pictures can be completely eliminated by adding a *No picture* flag (+2) in the *Mode* column. Each picture requires about 2.5KB. If the database is set to *Exclusive* it cannot be opened in another application simultaneously. Note that the program creates a new backup file (file extension .001 to .004) when first opened. Should the database become corrupted, delete it and rename one of the backup files with .mdb extension. For users with other backup techniques, adding a *No backup* flag (+8) defeats this function.

Users have the responsibility to test the actions and understand the consequences of all database settings.

A networked users might want to analyze MEASURE spectral databases (being created and maintained in the laboratory) in DESIGN on an office computer. In such cases it is important to keep the office computer database read-only. The office user can keep up with updates on the laboratory computer by simply clicking **Select...Find All <Ctrl+A>**.

Once the database is defined in the above configuration dialogs, the next step is to define the data entry grid. This is accomplished via **Layout...Configure Grid** leading to the dialog shown below. The FilmStar view of the database is distinct from the database itself.

Database text fields can have pull-down lists, as for *Designer* in the screen shot at the top of this section. A list may be defined by a text file (.txt) or a data base field. In the latter case Table and Field names are required in addition to the database (.mdb) file name. *Prefixing the file name with '*' suppresses the ability to type text into the pull-down list.*



The FilmStar 32 bit database view is not compatible with previous versions. Databases themselves (*.mdb) are, however, compatible.

File Menu

Save FILM Archive (Spectrum) <F12>

Saves the current design as FILM Archive and inserts the file name into the database record. If the design was already saved in the Main Menu then **Edit...Insert Archive Name** updates the current record without the user having to use the File Save dialog box.

Designs can only be saved as FILM Archive files!

Save FSPlot Graph <F11>

Save the current FSPlot graph as a metafile (.wmf) and add the file name to the current record. If the FSPlot Module is open the displayed graph is utilized. If the FSPlot Module is not open, the graph plus the current spectrum is automatically plotted.

In most cases leaving the FSPlot Module closed is the preferred technique. The graph is automatically generated by the hidden plot module and displayed in the Database window.

Add Picture File <Ctrl+F11>

Add a previously saved picture file (.wmf) to the current database record. Picture files are normally created in the FSPlot module, but could be created in other graphics programs which store Windows metafiles (.wmf). While it is also possible to add a picture previously saved in the FSPlot Module, that procedure is more complicated than **File...Save FSPlot Graph**.

Print Record/Quick Print Record

Prints the current record using a special Report Generator template. This is intended for quick reports. More elaborate reports can be printed with Film Star BASIC.

Print All Records

Quick-prints all records in the current selection.

Open FILM Archive (Spectrum) <Ctrl+O>

Opens the FILM Archive or spectrum displayed in the **Open** button, but does not return to the Main Menu.

Edit Menu

The Edit Menu is disabled when the database is read-only.

New Record <Ctrl+R>

Inserts a new blank record into the database.

Duplicate

Copies grid entries from current record and inserts them into the database as the last record in the set. The date is updated but picture file and data file names left blank. Note that certain fields may be left blank; you cannot, for example, duplicate a field defined as unique.

Delete

Deletes the current record and optionally associated files. Users must confirm each deletion. The FilmStar BASIC routine **dbDelete** quickly deletes records without confirmation.

Insert Archive (Spectrum) Name <Ctrl+N>

As an alternative to saving with the **File...Save FILM Archive (Spectrum)** command, users can save the FILM Archive or spectrum in the Main Menu and insert the file name into the current database record.

Insert Date <Ctrl+D>

Inserts the current date into the date field.

Select Menu

Find <Ctrl+F>

Brings up the Database Find dialog which selects records matching a user-entered string in one of the fields. More sophisticated searches are supported in **Select...Query**.

Sort <Ctrl+S>

Brings up the Database Sort dialog which sorts records according to specified field type. More sophisticated sorting is possible in **Select...Query**.

Make File List <Ctrl+L>

This generates a list of FILM Archive (Spectrum) files in the selected set. The list is copied to the clipboard and appears as follows when pasted into a text editor

```
c:\winfilm\designs\bbar-o.faw
c:\winfilm\designs\hpass-o.faw
c:\winfilm\designs\beam51c.faw
```

Query <Ctrl+F1>...<Ctrl+F6>

Run an SQL query.

SQL Command Editor

Standard SQL (Structured Query Language) commands are supported. While SQL is a complex subject covered in depth elsewhere, only a few statements are required to select and sort records from a single-table FilmStar database.

The main statements and functions illustrated below are **SELECT**, **FROM**, **WHERE**, **LIKE**, **ORDER BY**, and **LCASE**. When combined with **AND**, **OR** and **BETWEEN** we have all that is required for most users.

```
SELECT * FROM spec1
SELECT * FROM spec1 WHERE LCASE(field4) LIKE '*phil*'
SELECT * FROM spec1 ORDER BY fdate DESC
```

DESC denotes descending order. Single or double quotes delimit text strings while dates are delimited by '#'. '*' is a *wild card* which matches any combination of characters before and after the string. '?' is a *wild card* which matches a single character. Examples:

```
'red*' matches 'red shoes'
'*red' matches 'favored'
*red* matches 'nice red shoes'
'?red' matches 'fred', 'bred'
```

Capitalization is unimportant except within quotes.

```
SELECT * FROM spec1 WHERE (fdate = #10/15/1996# AND comment  
LIKE '*FAILS*') OR (fdate = #10/16/1996# AND comment LIKE  
'*PASSES*') ORDER BY field4
```

Single or double quotes delimit text strings while dates are delimited by '#' (pound sign). Capitalization is unimportant except within quotes. The following statements are equivalent:

```
SELECT * FROM spec1 WHERE fdate >= #10/15/1996# AND fdate  
<= #10/18/1996# ORDER BY fdate DESC
```

```
SELECT * FROM spec1 WHERE fdate BETWEEN #10/15/1996# AND  
#10/18/1996# ORDER BY fdate DESC
```

If a statement is too long to fit into the editor, use FilmStar BASIC:

```
Sub Main  
    dbActivate "dbSpectra"  
    dbSQLExec "SELECT * FROM spec1 WHERE..."  
End Sub
```

General Information

Clipboard Functions

The Windows clipboard is supported throughout FilmStar. The terms *Copy* and *Paste* refer to the clipboard and *Import* and *Export* refer to DDE. Experimenting with the clipboard is easier if you activate the Windows' clipboard viewer. Windows shortcuts **<Ctrl+C>**, **<Ctrl+V>** and **<Ctrl+X>** are used throughout, but the data they refer to can be very different. When pasting data, be sure that its source is correct. You would not want, for example, to paste a thin film design into spectral data.

File Manager

FilmStar file commands will be familiar from other Windows applications, but there are some differences because of the number of file types utilized.

Delete

Only a highlighted file can be deleted. The current file cannot be deleted.

List Files

To create a master list of all files, use the **Copy** command and paste the text into Notepad with **<Ctrl+V>**. Repeat for other file types. Lists can be printed.

Show Film

Only available when opening a FILM File. Shows the individual file names (Graph Axes, Film Indices, Design, Targets, Variables) comprising the highlighted FILM File name.

Keyboard Commands

Keyboard commands are generally identical with those in other Windows applications. But the custom grid control and our use of **Cancel** warrant some explanation.

Cancel

Upon selecting **Cancel** <Escape> changes in the dialog box are lost. If you are constantly losing data in this manner you should set a cancel confirmation flag in **File...Configuration...Preferences**.

Grid Control

The Farpoint grid control makes it possible to edit large data sets within a dialog box.

Mouse...Click on the required cell. A single cell is selected when highlighted by a box. Note that the box is sometimes a pull-down list. Multiple cells are highlighted in black by holding down the mouse button.

Keyboard...Use <Arrows>, <Home>, <End>, <Ctrl+Home> and <Ctrl+End> to move the focus and scroll the grid. Hold down the shift key to select multiple cells. <PgUp> and <PgDn> also work. <Tab> navigates to the next available cell. Most grids will not let you enter data more than one row below the last row containing data.

Press or <BkSp> to clear an entry or a selected region. Note that rows can be deleted, inserted and sorted by wavelength. To edit a cell without replacing it (*i.e.* overwrite mode), press <F2> or <Insert>.

The program attempts to prevent erroneous data. In most cases the offending data cell is highlighted in yellow. Additional checks are performed upon clicking the OK button.

Shortcut Keys

There are a number of shortcut keys. Several dialog boxes contain their own shortcut keys (not shown here). File Save <Shift+Ctrl+k> and Save As <Shift+Alt+k> sequences are not displayed in menus. (File short cuts are not really necessary when Windows file dialogs rather than FTG file dialogs are utilized.) Clipboard shortcuts <Ctrl+C> (copy), <Ctrl+V> (paste), and <Ctrl+X> (cut) are used throughout.

<F2>	Design database
<Shift+Ctrl+F2>	Spectra database
<F3>	FilmStar Workbook
<F4>	FSPlot graphing module
<F6>	FilmStar BASIC
<F7>	Report Generator
<Ctrl+F7>	Quick print report without preview
<F8>	View data table
<Ctrl+F8>	Convert spectral data range
<Shift+Ctrl+F8>	Export spectral data via DDE
<F9>	Calculate spectrum (no dialog)
<Ctrl+F9>	CIE color module
<Shift+F9>	Calculate merit function
<Shift+Ctrl+F9>	Run tolerancing
<F11>	Spectrum Save As
<Ctrl+F11>	Spectrum Open
<Shift+F11>	Spectrum Save

<F12>	FILM/FILM Archive Save As
<Ctrl+F12>	FILM/FILM Archive Open
<Ctrl+F1...F4>	Activate Windows application #1 to #4
<Shift+F1...F6>	Execute macro command #1 to #6
<Alt+A>	Draw new graph axes
<Alt+C>	Calculate spectrum (with dialog)
<Alt+R>	Change plot line color
<Ctrl+A>	Auto-scale current spectrum
<Ctrl+B>	Optimization Variables dialog
<Ctrl+D>	Groups design editor
<Ctrl+E>	Erase current spectrum from memory
<Ctrl+G>	Graph Axes dialog
<Ctrl+H>	Graph Details dialog
<Ctrl+I>	Film Indices dialog
<Ctrl+J>	Adjust design (arithmetic operations)
<Ctrl+L>	Layers design editor
<Ctrl+M>	Optimization parameters
<Ctrl+N>	Tolerancing setup dialog
<Ctrl+O>	Optimize
<Ctrl+P>	Setup parameters
<Ctrl+Q>	Quick save spectrum in WORK.CSV
<Ctrl+R>	Review design
<Ctrl+T>	Optimization Targets dialog
<Ctrl+U>	Use all layers as optimization variables
<Ctrl+Y>	Synthesis dialog
<Ctrl+Z>	Edit macros
<Alt+Ctrl+k>	Open
<Shift+Ctrl+k>	Save
<Shift+Alt+k>	Save As
k = B	Optimization Variables
k = D	Design
k = G	Graph Axes
k = I	Film Indices
k = T	Optimization Targets

Graphics Labels

Labels may be placed on the screen by pressing **<Shift+Click>** (left mouse button) when the cursor is in the plot area (crosshair shape). Left, center and right justification may be selected as well as an italic font.

The label will have the same color as the last spectrum. To change the color (before placing the label), select a color from the color button. Simultaneously, hold down the shift key to suppress replotting the last spectrum.

INDEX Reference

INDEX File Menu

Index Tables, Graph Axes, Function Parameters and n,k Calculation parameters are all stored in the same file (*.itw). This is different from FilmCalc INDEX which utilized different extensions for graph axes, etc. User Index Function specifications are stored in configuration file design1.ini upon exiting INDEX.

INDEX Setup Menu

Graph Axes

Setup...Graph Axes <Ctrl+G>

INDEX Graph Axes allows users to plot index data to verify file integrity. In future revisions it will include the ability to plot index functions. Axes parameters are automatically stored with the dispersive Index Table.

Select **k-Scale...Log** when working with film materials exhibiting orders-of-magnitude absorption variations over the specified wavelength range. This changes the display format in the k column in Index Table from fixed to scientific notation.

Interval specifies wavelength spacing in **Functions...Create Table**.

Index Parameters

Setup...Parameters <Ctrl+P>

Wavelength scale

N for nanometers and **M** for microns.

Table type

Choose **I** for n,k Vs wavelength and **F** for filter mode. The latter is intended for absorbing glasses and other materials where $k \ll n$. It is not intended and not suitable for computing k for thin films.

Filter specifications

These apply only if F is selected above: **Table type** in internal transmittance t (as in the Schott catalog) or %T (as measured in a spectrophotometer at normal incidence). Enter substrate **Thickness** in millimeters. When using %T data it is assumed that both surfaces are uncoated.

k-Tolerance > 0 prevents $t > 1$ or $\%T >$ theoretical maximum errors caused by round-off or experimental error. It may be necessary to increase the default value (1.E-8) when utilizing measured spectra. (INDEX assigns $k=0$ when $-kTol < k < 0$.)

Index Table

Setup...Index Table <Ctrl+I>

Users can copy the contents of one cell to many cells. For example, to enter $n=1.52$ in all rows type '1.52' in the first row and copy that entry to the clipboard with **Edit...Copy Cell**. Then highlight the required number of rows and click **Edit...Paste Cell** to duplicate that entry.

Rows can be wavelength sorted at any time by clicking **Edit...Sort**. Upon clicking **OK**, duplicate wavelength entries are flagged. Include more values in regions where n or k vary rapidly with wavelength. Negative entries are not allowed. Each table must have at least three entries.

To prevent out-of-range errors in DESIGN, be sure that INDEX wavelengths encompass the anticipated Graph Axes range in DESIGN.

In Filter mode, the program will not accept internal transmittance values greater than 1 or measured %T entries exceeding the theoretical maximum for two uncoated surfaces. In Index mode the k column uses fixed floating point notation (0.00000) when k -Scale is linear and scientific notation when k -Scale is logarithmic. Select scale type in **Setup...Graph Axes**.

Import Sopra .nk Files

Click **File...Import** to import Sopra .nk files into INDEX. These files are available at www.sopra-sa.com/indices.htm. Follow the download link and store self-extracting nkfiles.exe in c:\winfilm\index\sopra (suggestion). There were 278 index tables available in May 2000.

INDEX Functions Menu

Indices can be described by constants n and k , look-up tables and dispersive functions. Functions are specified in DESIGN by assigning a dispersive 'file name' which is the function name (seven characters maximum) preceded by '\$'.

Fit Index <Ctrl+F>

Select a function type and edit coefficients. It is also possible to determine the best least-squares fit to current index values. Select **Type "-----"** if functions are not utilized for the material.

Plot <Ctrl+T>

Plot the current dispersion function vs. wavelength. In some cases there will be a mathematical error because the function is not valid over the entire plot range.

Create Table

Create or add entries to a dispersive index table using the current Index Function. This can be activated repeatedly with different functions. In some cases a single dispersion function can be used directly in DESIGN. In other cases, the function will not describe the index over a sufficiently wide wavelength range and look-up tables are required.

Note also that user-defined functions transfer data via DDE. As this can be a slow process, calculations may proceed much faster if the functions (once the coefficients have been determined) are ultimately converted to tables. Users who determine that certain functions are useful should contact FTG Software about coding the function as a built-in.

User Defined

Please refer to "Index Functions - User Defined" on page 39 in the DESIGN Reference section.

Dispersive Index Functions

Functions...Fit Index

In DESIGN dispersive indices can be described by Sellmeier and similar functions by entering the function name preceded by \$ under **File/\$Fn** in the Film Indices editor. Examples include \$LOREN and \$QUAD. Each function contains up to seven coefficients (or more if specified in **File...Configuration...Capacity**) which may be deduced from experimental spectral data via 'inverse synthesis'.

To fit these functions in DESIGN, the starting approximation must be reasonably close. INDEX provides an optimization procedure for deducing coefficients from the current Index Table. There are two function categories: built-in and user-defined (see "Index Functions - User Defined" on page 39). User-defined functions are automatically included in the scrolling **Type** list. Click **Edit...Paste Function** to insert a function name and values copied in the **DESIGN** Film Indices dialog.

Click **Fit** to solve for coefficients which provide the best least-squares fit to current index data. Select a small number of iterations, say 5 or 10 and observe the improvement **Ratio** in the merit function.

Compare calculated results with the Index Table by selecting **Functions...Plot <Ctrl+T>** in the main menu. It is essential to match the spectral shape. In many cases it will be necessary to perform piece wise fits over large spectral ranges.

The calculation of k is different when a logarithmic k scale is used; in this case the program solves for log k instead of k. The log k scale is suggested for oxides and other materials with sharp absorption edges. Scale type is selected in **Graph Axes <Ctrl+G>**.

Relative k-convergence can be decreased by increasing (relative) k-Tolerance. That is, if k changes too fast relative to n, increasing k-Tolerance slows changes in k. Users who are not happy with results can click **Restore** to recover original coefficients or **Cancel** to leave the editor.

Sometimes removing a few wavelength points from the Index Table results in dramatic improvements. For example, if the index of a material to be fit with function LOREN is essentially constant from 750 to 2000 nm, leave out this range and fit the function from 380 to 750 nm. Use **Functions...Create Table** to generate a table spaced according to the Graph Axes editor. Later insert points from 750 to 2000 manually.

Sample values which will serve as starting points:

BK7	BUCH	A=1.5184, B=-.044736, C=-.00032737
TA205	LOREN	A=2.7342, B=1.3767, C=212.02
TI02	LOREN	A=4.3603, B=.5034, C=354.23
TI02A	LORENK	A=4.4398, B=.45667, C=336.87, D=.52305

Please contact FTG Software if you have difficulties finding a fit to n,k data. If you supply a table of index values we may be able to locate a suitable function.

INDEX Solve Menu

INDEX includes three algorithms for generating a dispersive Index Table from measured spectral data:

1. The first algorithm requires accurate reflectance and transmittance spectra for a film of known thickness on a nonabsorbing substrate. It calculates n,k values at each point in the spectrum.
2. The second algorithm is valid for nonabsorbing or slightly absorbing films on nonabsorbing substrates; it only requires normal incidence transmission measurements. The film must be thick enough to produce a good number of peaks and valleys in the wavelength range of interest. **The film must also be nondispersive on the long wavelength side.** This algorithm is especially useful for TiO₂, ZnS and similar nearly transparent dispersive materials.
3. The third algorithm is used for determining n,k for colored filter glasses and similar **substrates**.

Determining indices is not a simple task and requires judgment. Users must verify that any dispersive table produced by INDEX gives expected results in DESIGN.

Open Spectrum <Ctrl+F11>

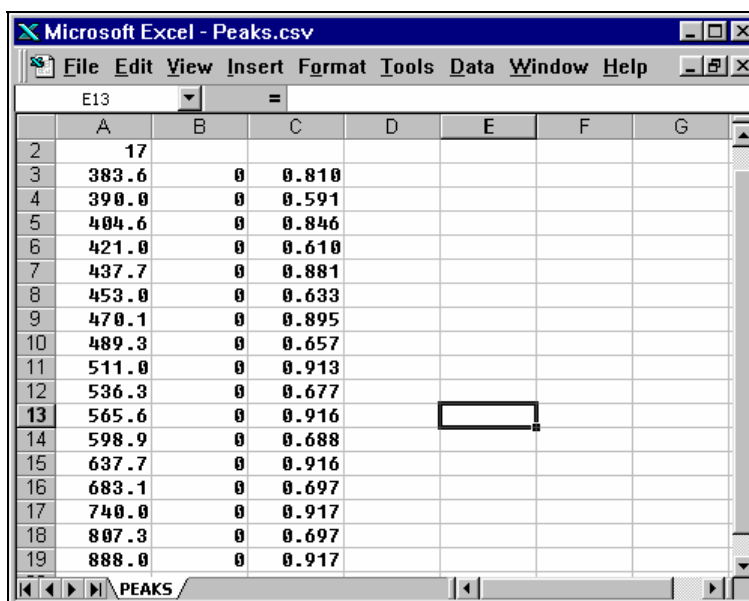
Load spectrum previously stored on disk in DESIGN or MEASURE.

Paste Spectrum <Ctrl+V>

Paste spectrum previously copied to the Windows clipboard in DESIGN or MEASURE.

Spectrum Type...Peaks

Users without computer-compatible spectrophotometers can use Algorithm 2 (discussed below, T known, $k \ll n$) by creating a set of wavelength and transmission values corresponding to measured peaks and valleys. Sample data created in Excel is shown below. Wavelengths must be in increasing order; transmittance values are between 0 and 1 and a blank middle column of zeroes (corresponding to reflectance) must be included.



	A	B	C	D	E	F	G
2	17						
3	383.6	0	0.810				
4	390.0	0	0.591				
5	404.6	0	0.846				
6	421.0	0	0.610				
7	437.7	0	0.881				
8	453.0	0	0.633				
9	470.1	0	0.895				
10	489.3	0	0.657				
11	511.0	0	0.913				
12	536.3	0	0.677				
13	565.6	0	0.916				
14	598.9	0	0.688				
15	637.7	0	0.916				
16	683.1	0	0.697				
17	740.0	0	0.917				
18	807.3	0	0.697				
19	888.0	0	0.917				

Using Excel there are two ways to transfer spectral data to INDEX: 1. Data may be stored on disk as a .csv file. The first line is a description and the second line is the number of spectral points. 2. Data may be copied and pasted. Ignoring the first two rows, A3:C19 is copied to the clipboard.

Calculate n,k <F9>

Enabled when a spectrum is loaded.

n & k Algorithm 1 (R, T and t known)

This algorithm requires accurate reflectance and transmittance spectra for a film deposited on a nonabsorbing substrate. The physical thickness of the film must be known. The algorithm determines n,k at each wavelength point, using values at the previous wavelength as a new starting guess.

One way to test this algorithm is to create spectral files in DESIGN and to see whether INDEX can recover the actual n,k table used in the calculation. The problem here is that calculated data may be too accurate and provide a false sense of security. Users can simulate measured data by adding experimental error to calculated spectra in Excel and noting whether INDEX still converges to the starting n,k table. Of course, experimental accuracy is not the only problem; inhomogeneity can also cause spurious solutions.

The user must choose film thickness wisely.

Side 2 Compensation

Select **None** if the second surface has an antireflection coating. Select **Transmission only** if the second surface was ground or coated for the reflection measurement but untreated for the transmission measurement. Select **Transmission and reflection** if both measurements were performed with an untreated uncoated surface.

Start at high wavelength

The calculation should be started in the spectral region where Starting Values are likely to be most accurate.

n & k Algorithm 2 (T known, k<<n)

This algorithm is extremely useful for high index oxides and other widely utilized films which are slightly absorbing over the wavelength range of interest and nondispersive at long wavelengths. Only normal incidence transmission values are required. The substrate must be nonabsorbing and the film thick enough to produce a fair number of spectral peaks and valleys (where n,k will be calculated) in the wavelength region of interest. The calculation assumes that films are homogeneous and that the substrate is uncoated on the reverse side. This corresponds to calculation mode **FWD include Side 2** in DESIGN.

The **Peak/Valley Verification** screen shows the wavelengths at which n,k will be calculated. INDEX determines peaks and valleys by scanning sets of points and looking for a best fit. Spurious results are possible when there are too many (noise peaks) or too few data points. (Suggested settings for MEASURE: discrete scan mode and inverse wavelength spacing. For example: 400 to 800 by -2 nm.)

The algorithm first computes film thickness by fitting peak positions in the nondispersive (long wavelength) portion of the spectrum. Users may specify the number of peaks (default 3) used in the thickness calculation as well as a starting number of quarter waves (default 3). This starting value must be less than the actual number of quarter waves at the maximum wavelength. n is determined from $T_{\max}-T_{\min}$ at the maximum peak wavelength in the spectral data set.

Values of n at shorter wavelengths are computed at peak and valley positions. k is finally computed with an optimization routine. Computed n, k values can be used in fitting LORENK and similar dispersive index functions in INDEX and in DESIGN.

Spurious solutions are possible! Once an index table is generated it should be verified in DESIGN.

If the calculated spectrum does not match the measured spectrum it is likely that the calculated number of quarter waves (and film thickness) is incorrect. Manually enter a fixed value for the number of quarter waves by first entering '1' for "peaks for film thickness calculation". Try a new value that differs by a multiple of 2 from the value calculated by INDEX. (When film index is greater than substrate index a transmission peak corresponds to an even number of quarter waves, while a transmission minimum corresponds to an odd number. When film index is less than substrate index a transmission peak corresponds to an odd number of quarter waves, while a transmission minimum corresponds to an even number.)

n & k Algorithm 3 (Substrate $k \ll n$)

This algorithm computes n, k for colored glasses and other slightly absorbing materials where $k \ll n$. It will not work for metals. Reflectance and transmittance values are required in the same data file. Use Excel to combine two separate MEASURE data files which have the same wavelengths. (Actually it is not necessary to create new data files; clipboard paste can be used instead.)

Reflection measurements must be taken at (or near) normal incidence with the substrate second surface ground to eliminate reflections from that surface. Transmission measurements at normal incidence are made with an uncoated substrate. This corresponds to calculation mode **FWD Side 2 T only** in DESIGN. Use this mode to create test files.

If the sample is too thick to provide accurate transmittance values, use a thinner sample. If you only have transmission measurements or catalog internal transmittance values, and know n , use Filter Mode in the main index editor to convert t or %T values to k .

FilmStar BASIC (INDEX)

FilmStar BASIC is a development environment for customizing FilmStar. Using Sax Basic, FilmStar BASIC adds the special commands and keywords discussed in this section. BASIC is accessed via the Evaluate Menu. Two macro commands are supported: BasOpen and BasRun.

INDEX Extensions

Summary documentation for all extensions is provided in the BASIC IDE. Click the Browse Object icon (6th from left).

Capitalization is not important in the following:

Sub AutoAxes... Compute axes range and replot; use when importing data

AutoAxes

Sub BasActivate... Return focus to BASIC's IDE (integrated development environment).

BasActivate

Function fMsgBox%(text\$, icon%, title\$)...Similar to BASIC's MsgBox function but will be modal within FilmStar INDEX. This prevents covering the dialog box by clicking on the INDEX window.

```
k = fMsgBox("Do you want to proceed?", 36, "BASIC")
```

Sub IndexConvert(Optional wmin!, Optional wmax!, Optional wint!)... Convert spectrum range to current function range settings; optionally specify min, max and interval. If wmin=0 then use current settings

```
IndexConvert ' use current or range settings
IndexConvert 400,600,2 ' convert data to 400-600 x2
```

Sub IndexCopy...Copy index table to clipboard (Excel format)

```
IndexCopy
```

Property IndexList\$...Get index table as text list

```
s$ = IndexList$
```

Sub IndexOpen(file\$)...Open index table file

```
IndexOpen "c:\winfilm\data\TiO2.itw"
IndexOpen "c:\winfilm\data\TiO2"
IndexOpen "TiO2.itw" ' default path
IndexOpen "TiO2" ' " "
```

Sub IndexPaste...Paste index table from clipboard (Excel format)

```
IndexCopy
```

Property IndexName\$...Get/assign name to index table file

```
s$ = IndexName$
IndexName$ = "TiO2 Chamber 3"
```

Property IndexPath\$...Get/assign path for index table files

```
s$ = IndexPath$
IndexPath$ = "c:\winfilm\import"
```

Function IniString\$(section\$, key\$)...Get user-defined initialization variable from design1.ini.

```
s$ = IniString$("Chuck Vogel","LastFileName")
```

returns "WW098909" if the following is in design1.ini:

```
[Chuck Vogel]
LastFileName=WW098909
```

Sub MainActivate...Return focus to INDEX's Main Menu

```
MainActivate
```

Property nIndex%...Returns number of wavelengths in current index table

```
K = nIndex
```

Property nkTable as Variant...Assign/get index table

```
' Transferring n,k table from INDEX
Option Base 1
```

```

DefInt I-N
DefSng A-H, 0-Z
Sub Main
    Dim i, j
    ReDim xIndx(1, 1)    ' MUST BE 'SINGLE'
    xIndx = nkTable      ' Get table
    For i = 1 To nIndex ' # of data points
        For j = 1 to 3
            Debug.Print xIndx(i, j)
        Next j
    Next i
End Sub

' Transferring n,k table to INDEX
Option Base 1
DefInt I-N
DefSng A-H, 0-Z
Sub Main
    Dim i
    ReDim xIndx(10, 3) ' MUST BE 'SINGLE'
    For i = 1 to 10     ' make up some data
        xIndx(i, 1) = 400 + 20 * i
        xIndx(i, 2) = 1.52 -.002 * (i-1)
        xIndx(i, 3) = 0
    Next i
    nkTable = xIndx      ' transfer to INDEX variables
    AutoAxes    ' plot index values
End Sub

```

Sub sMsgBox(text\$, icon%, title\$)...Similar to BASIC's MsgBox instruction but will be modal within FilmStar INDEX. This prevents covering the dialog box by clicking on the INDEX window.

```
sMsgBox "Get a cup of coffee!", 48, "Working Hard"
```

Sub WriteIniString\$(section\$, key\$, text\$)...Store user-define initialization variables in design1.ini.

```
WriteIniString "Chuck Vogel", "LastFileName", "WW098909"
```

inserts/modifies the following entry in design1.ini:

```
[Chuck Vogel]
LastFileName=WW098909
```

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