FilmMaker2
User Manual

For users of Intellemetrics
Dual Beam Integrated Optical Monitor Systems

for Precision Optical Coating

FilmMaker2 USER MANUAL

User Manual

This documentation is provided as an instruction manual to Intellemetrics Global's customers and potential customers **only**.

Read this manual before you install and use the IL55x Optical Monitor.

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1. FilmMaker2 Overview

The following text refers to FilmMaker2.

FilmMaker2 is supplied with every Intellemetrics optical monitoring system. It allows customers to do the following general tasks;

- Create a filmstack design from scratch or read one in from a 3rd party design package (e.g. TFCalc, Macleod, Optilayer, Filmstar, etc).
- Model the filmstack design.
- Create an optical monitoring scheme from the filmstack design.
- Use a range of tools to analyse the performance of the optical monitoring scheme in a real-life coating process before committing to doing an actual coating run.
- Analyse the data from previous coating runs to help optimise future coating runs.

The main new features of FilmMaker2 include;

- Full incorporation of substrate dispersion into all modelling engines.
- Full incorporation of test glass changes into FilmEditor and FilmSimulator.
- Tooling factors and deposition rates incorporated into materials databases.
- Automatic optimisation of QWFactors on a layer-by-layer basis with further automatic fine tuning on a complete filmstack basis.
- Resultant film characteristics shown on the test glass or on the product.
- Streamlined FilmEditor and FilmSimulator for faster, interactive design of optical monitoring schemes with instant visual feedback.
- Streamlined project creation, saving and transferring to FilmDirector.
- Runs on Windows7, both 32bit and 64bit.
- Backward compatibility with Projects created in previous FilmMaker versions.

2. Getting Started

2.1. Some Definitions

We will refer to an individual deposited layer as a film, while a sequence of such layers will be termed a film stack. We can work on the definition of only one film stack at a time, so it makes sense to organise things on a project basis where a new project is assigned for each film stack we define. Thus we may talk about projects, and film stacks interchangeably.

2.2. About Databases

Each project or film stack definition is represented by its own unique database. A database is a collection of files contained within a folder and registered with a database engine using this folder name. The process of registration also allows us to associate a project name with each database. In everyday use, all we have to concern ourselves with is this straightforward project name, and let the database engine worry about the actual location of the database folder.

If you are unfamiliar with working with databases the following points should be noted.....

- Don't expect to find a **File|Save** or **File|SaveAs** on the menu. Data is directly entered to the database as you work. Moving up or down on the grid or closing the form will post the data you have just entered to the underlying database.
- Don't expect to be able to copy a design from one PC to another by simply putting a file on a memory device. You **can** transfer a *project* by memory device, or access a *project* on another PC via a network, but you need to move or access the entire folder, and then register it with your PC.
- A useful technique to ensure preservation of a valid project when attempting to make slight modifications to a known good project is to use the 'Copy As' function to create a copy of the project. 'Copy As' stores and preserves the integrity of the original project for example test.proj, whilst the new project test1.proj is immediately available on the desktop for editing. In this way if anything goes badly wrong with project test1 then project test is always preserved intact.

2.3. A Quick Look Around

Let's start by having a look at the main windows that you will see when you open FilmMaker2.

In the top left-hand corner you will see a main menu section with a n umber of dropdown menus that allow you to access most of the FilmMaker2 features. Underneath this there is a toolbar containing icon shortcuts to most of these features.

Underneath the main menu section is a Ribbon Menu. This contains most of the information that will be common to all of your processes and is largely defined by the equipment you have and the monitoring configuration you have. So in effect, once you have set the parameters in this section you will most probably use them for all of your projects going forward.

Below the ribbon menu is the main FilmBuilder area. This area houses all of the parameters for your particular filmstack and your optical monitoring scheme on a layer by layer basis. At first this area can seem daunting to a new user because there are a lot of columns and a lot of parameters. However, the vast majority of the parameters are either calculated automatically by FilmMaker2, or can be entered in an intuitive graphical manner in another part of the software (FilmEditor). So for the time being just note that the FilmBuilder area holds a record of all of the layers, materials, thicknesses, monitoring wavelengths, etc in a table.

To the left of the FilmBuilder window is the Materials Database area. In the image below this is shown in its collapsed state so that you can concentrate on the other windows. To open the Materials Database section you can simply press the > symbol above the "Show Materials" text. The Materials Database section contains all of the information related to all the materials you will wish to use. This information include n and k at as many different wavelengths as you wish, deposition rate and tooling factors. (see the section on Materials Database for more information.

Below the FilmBuilder window you will see the warnings and information areas. This area gives you hints and tips about the entries in the table above, and also gives warnings if some of the values you have entered do not make sense. Hovering the mouse over a particular cell, or clicking in it, will show the information relating to that cell. A very useful feature to help you understand the significance of each cell.

Finally, at the bottom of the window is an area for entering default values for layers. Entering data into this area is one of many ways to enter data into the FilmBuilder window and is described in more detail in the section on “Entering a Filmstack”.

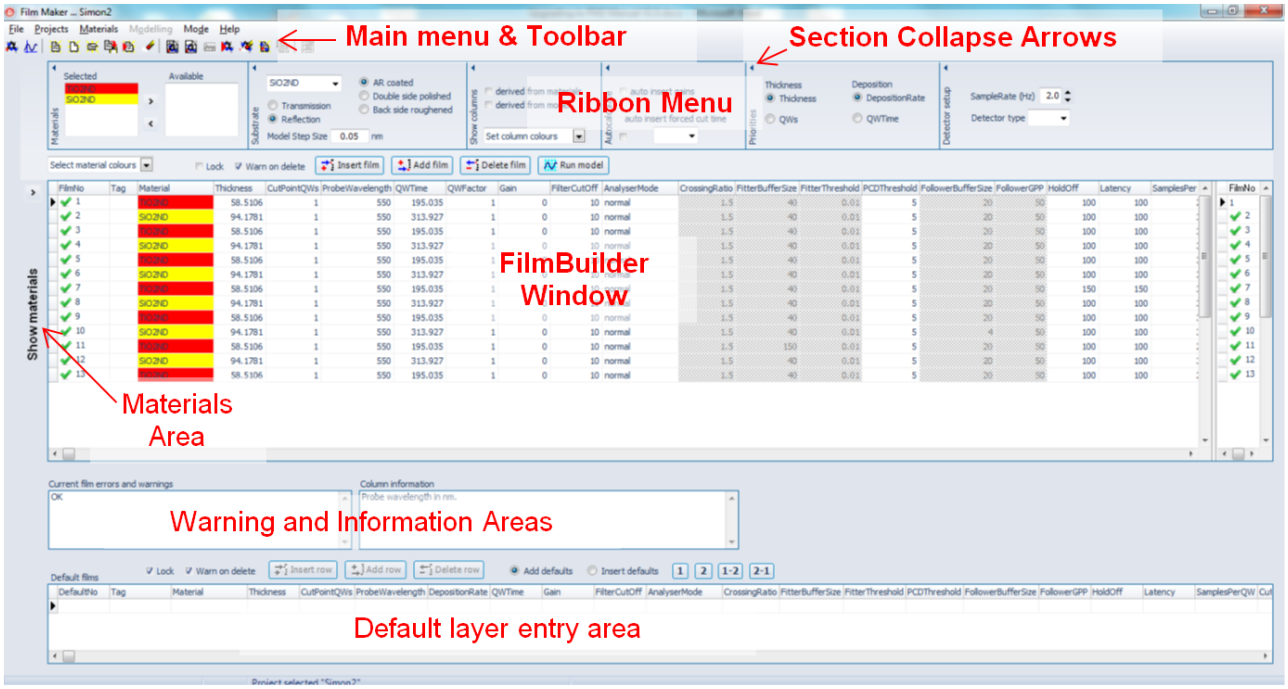

Figure 2-1 An overview of the FilmMaker window.

3. Projects

FilmMaker's film stack, materials data and monitoring configuration are kept in project folders, one folder per film stack. A project name is associated with each folder, and used by the database engine to access the relevant data. Thus we can think of a film stack definition or work space and a project as being interchangeable ideas.

You have the choice of using either existing Public Materials Databases, which can be shared by any number of projects, or Private Materials Databases, which are stored with individual projects.

Projects created on another PC on a network, or copied onto a disk, can be registered and accessed from you PC.

3.1. Opening an Existing Project

 Projects can be opened in any of the following ways:-

- Select **Projects|Open existing project** on the main menu
- Click the **Open existing project** toolbar button
- Pressing **Alt + P**, then **O** on the keyboard.

Choose an existing project from the 'Open Project' dialog box, and press **OK** to open. If another project or a public materials database is already open, it will be closed before the new project is opened.

When the project opens, the Materials form and Build Films form will open automatically, if they are not open already. The application window will display the project name in its caption, and the materials form will show the associated materials database name in its caption.

3.2. Creating a New Project

 Create a new project to start a new film stack specification. This does three things. a) It creates a new folder to hold all the files associated with the project, b) it assigns a project name which will be used when you access the stack specification and c) it assigns a materials database to the project.

New projects can be created in any of the following ways:

- Select **Create new project** on the **Projects menu**
- Click the **Create new project** Toolbar button
- press **Alt+P**, then **N** on the keyboard

Enter a unique project name in the Enter Project Name dialog.

The next dialog to open needs to know the materials database that will be associated with the project. You can choose an existing public materials database or choose to keep the materials data private to the project.

The new project will then be opened, closing any other project or materials database that happens to be open at the time. The Materials Form and Build Films form will open automatically if not already open.

3.3. Closing Projects

 Projects can be closed in any of the following ways:-

- Use the **Close project** Toolbar button
- Select **Close project** from the **Projects** menu
- Press **Alt+P**, then **C** on the keyboard

- Open or create another project or a public materials database

3.4. Deleting Projects

 Projects can be deleted in any of the following ways:-

- Selecting **Project|Delete** project on the main menu
- Clicking the Delete project Toolbar button
- Pressing **Alt+P**, then **D** on the keyboard.

In the Select Project to Delete dialog, select the project that you wish to delete by typing in its name or select it using the down arrow.

NB Projects cannot be deleted while they are open. Use Project Close before proceeding.

3.5. Copying a Project from Media to FilmMaker

Projects need to be registered with FilmMaker before they can be used or opened. Each project exists in a unique folder, the folder name being the project name. If a project folder exists on your hard disk or on a memory device, or even on a network drive, then you can register it with FilmMaker by using the Copy Project from Media to FilmMaker feature.

In this context, Media refers to any hard disk, memory device or networked location that is accessible through the normal Windows browse feature. Copying the project from the media to FilmMaker does the following;

- *It checks the project is a valid FilmMaker2 project, and warns you if it finds a problem.*
- *If everything is OK then it copies the project folder to the default location for FilmMaker projects which is C:/Users/Public/Public Documents/Intellemetrics/FilmMaker/Projects/.*
- *It registers the project so that it can be opened from within FilmMaker*

You can Copy a Project from Media to FilmMaker in the following ways:

- Select **Projects|Copy Project from Media to FilmMaker** from the main menu
- Click the **Copy Project from Media to FilmMaker** toolbar button 
- Press **Alt+P**, then **P** on the keyboard.

Select the path of the project you want to copy to FilmMaker in the 'Browse for folder' dialog.

3.6. Copy This Project to Media

If you wish to copy a project from FilmMaker to another location, maybe to the Controller Module, then it is best to use the Copy This Project to Media function. Make sure you have modelled the project before saving it to another location using the Run Model button.

Copying a project from FilmMaker to Media can be done in one of the following ways;

- Select **Projects|Copy This Project to Media** from the main menu
- Press **Alt+P**, then **M** on the keyboard.

3.7. Copy a Project As ...

A copy can be made of an open project in the following ways:

- Select **Projects|Copy Project As** from the main menu
- Click the **Copy project as ...** Toolbar button 

- Press **Alt+P**, then **A** on the keyboard.

Enter a unique project name in the Enter Project Name dialog.

If the project you are copying from was linked to a public materials database, then the new one will automatically be linked to the same one. Otherwise a private materials database will be created for it.

The new project will then be opened, closing the original one.

3.8. Updating Old Format

If you try to register or open a FilmMaker project from an older version, then FilmMaker will ask for confirmation before converting to the latest version. This process may require some parameters to be given default values. It is recommended that you check the parameters in the FilmBuilder window before continuing.

3.9. Locating a Project Folder

For maintenance reasons you may want to locate the folder associated with a particular project. All FilmMaker projects are held within the following folder;

C:/Users/Public/Public Documents/Intellemetrics/FilmMaker/Projects/*projectname*

where *projectname* is the name of the project.

3.10. Transferring a Project from FilmMaker to FilmDirector

Given the information above, it is useful to outline how to do a few common tasks. The first of these will be transferring a project from FilmMaker on your design PC to the Controller Module that is connected into your coating system so that you can perform a coating run using the project. We will assume that you have created a model, run it through FilmEditor, run it through FilmSimulator, and concluded that it is a 'good' project to proceed with. At this stage you should do the following;

- *Make sure the project is open in FilmMaker and it has been modelled using Run Model. If in doubt, press Run Model before the next stage.*
- *Use the Copy This Project To Media function to copy the project to a USB memory stick, or alternatively directly to the Controller Module if it is networked to your PC.*
- *Copy the project folder onto the Controller PC. The location can be anywhere* ***except*** *the C:\Users\Public\Public Documents\Intellemetrics\FilmMaker\Projects folder. For this reason we suggest you create a folder called PROJECTS and create a shortcut to it on the desktop. Then you can simply drop the project folder into this folder.*
- *On the Controller Module open FilmMaker2 and select Projects|Copy Project from Media to FilmMaker. The project is now registered and available to be used with FilmDirector.*

3.11. Sending a Project to Intellemetrics

Intellemetrics is happy to help you design projects for your particular applications, or to analyse projects and run data that you have created. If you want to send a project to Intellemetrics (or anyone else for that matter), then do the following;

- *Make sure the project has been modelled using the Run Model feature. Close FilmMaker2.*
- *Locate the project folder in the C:\Users\Public\Public Documents\Intellemetrics\FilmMaker\Projects folder.*
- *Using Windows Explorer, click the right mouse button and select Send to|Compressed (zipped) Folder.*
- *If you are using a Public Material Database then create a compressed copy of the Materials Database folder found in the C:\Users\Public\Public Documents\Intellemetrics\FilmMaker\Materials folder.*
- *The zipped file(s) can then be emailed to Intellemetrics.*

4. Materials Databases

Material databases contain all of the information related to the particular materials that you will be depositing. These parameters include;

- *Material Name:*
  - *You can define as many different materials that you want as long as each material has a unique name.*
- *Refractive index information as a function of wavelength:*
  - *Define as many n and k values at as many different wavelengths as you want for each material. Different materials can have different numbers of wavelength values. Filmmaker2 will interpolate a straight line between data points to work out the n and k values at intermediate wavelengths. Wavelengths are defined in nm.*
  - *TIP: The FilmMaker software will use the n,k,λ data to calculate the expected T% or R% as a function of thickness for each layer, and will also use it to calculate the T% or R% as a function of wavelength on both your test glass and your final product. Therefore you should ensure that you define the n and k data over a range of wavelengths that is wider than the range of wavelengths you will monitor the coating at, and wider than the range of wavelengths you wish to see the characteristic of (see section on FilmSimulator for more details).*
- *Deposition Rate:*
  - *Each material will have a deposition rate associated with it which is defined in units of nm per second (nm s^{-1}).*
  - *It is important to define the deposition rate as close to the value that you will achieve as possible because this value is used in multiple ways to calculate subsequent values in the FilmBuilder window which help optimise parameters used during the actual coating run.*
  - *If you deposit the same material but at two different deposition rates depending upon application, then simply define two materials with identical n,k,λ values, for example SiO2-low-rate and SiO2-high-rate.*
- *Tooling Factor:*
  - *This factor allows you to correct for the difference in deposition rate of each material on the piece being monitored (usually a test glass) and the product that you are coating (maybe mounted on a rotating calotte).*
  - *If you are directly monitoring the piece of interest then the tooling factor can remain equal to 1.*
  - *However, if the deposition rate of the material on your test glass is 1.5x higher than the deposition rate on your product (on the calotte for instance) then set the tooling factor to be 1.5.*

ToolingFactor = (Dep Rate on Test Glass) / (Dep Rate on Product)

- *Material Number:*
  - *It is possible to associate up to 10 different materials with Material Numbers. These are related to digital IO outputs. When doing an actual deposition run, the Material Number of the present layer being deposited is output from the digital IO.*
  - *This feature is rarely used and is not recommended unless it is absolutely necessary to have such a feature in your integrated chamber system.*

To view or edit the Material Database associated with a project do one of the following (see figure below);

- *Press the "Show Materials" icon* 
- *Press the > symbol located just above the "Show Materials" text (Clicking the < symbol will minimise the window again)*

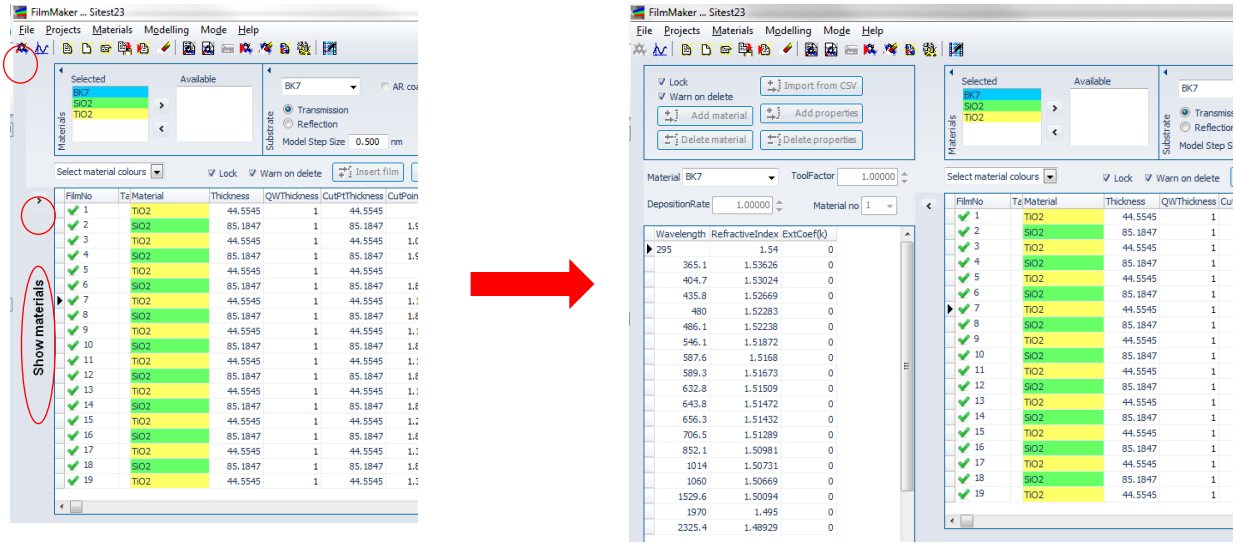

Figure 4-1 Opening the Materials Database window.

4.1. Private and Public Material Databases

FilmMaker2 allows the use of two types of Material Database; Public or Private.

Public materials databases are free-standing (not exclusive to a project), and can be accessed by any number of projects. Private materials databases are held within the project folder, and cannot be accessed by anything other than the project to which they belong.

The advantage of the public materials database is that you can build a library of materials and their properties for future use. The disadvantage is that any changes made to entries in the database will impact all projects that use them.

A private materials database, on the other hand, has the advantage that, being part of the project folder, it can be archived, moved about the place etc., with no impact on the inherent design. The only overhead is that you have to load the materials and their properties for each project you elect to use with a private materials database.

Unlike the private materials database, the public materials database can be created, opened, or deleted in its own right. However, because they are associated, each with their own folder, and have to be registered with the database engine in a similar manner to projects, you cannot freely copy them from one PC to another. Instead you have to follow the procedure described in registering a public materials database.

When a project is created, you have the choice of using an existing public materials database, or having a private one created within your project. You can also change to another materials database, either public or private, at a later stage.

4.2. Managing Public Material Databases

4.2.1. Opening Public Materials Databases

Public materials databases can be opened in the following ways:-

- Select **Materials|Open public materials database** from the main menu
- Click the **Open public materials database** Toolbar button 
- Press **Alt+M**, then **O** on the keyboard.

In the 'Enter materials database name' dialog, enter the name of the materials database you would like to open, or select it from the drop-down list.

The Materials Form will be opened automatically, and any other materials database or project which is open at the time will be closed. The name of the database is shown in the caption of the form.

4.2.2. Creating Public Materials Databases

New public materials databases can be created in any of the following ways:

- Select **Create new public materials database** from the **Materials menu**
- Click the **Create new public materials database** Toolbar button 
- Pressing **Alt+M**, then **N** on the keyboard

Enter a folder name for your new materials database in the Create **Film*Maker*** Public Materials Database Folder dialog, then enter a unique materials database name in the Enter Materials Database name dialog.

The new materials database will then be opened, closing any other materials database or project open at the time. The Materials Form will open automatically if not already open. The database name will be shown in the forms caption.

4.2.3. Closing Public Materials Databases

Public materials databases can be closed in any of the following ways:-

- Click the **Close public materials database** Toolbar button 
- Select **Close public materials database** from the **Materials menu**
- Press **Alt+M**, then **C** on the keyboard
- Open or create another public materials database or a project

There is no explicit save operation required, as the data you have entered has been posted to the database as each entry is made.

4.2.4. Deleting Public Materials Databases

Public Materials Databases can be deleted in the following ways:-

- Select **Delete public materials database** from the Materials menu
- Use the **Delete public materials database** toolbar button 
- Press **Alt+M**, then **D** on the keyboard.

In the Select Public Materials Database to Delete dialog, select the materials database that you wish to delete by typing in its name or selecting it using the down arrow.

Public materials databases cannot be deleted while they are open.

NB: Deleting a public materials database which is in use by any existing projects will result in film verification errors in those projects. If you cannot be sure if you have any projects referencing a database, it is better not to delete it.

4.2.5. Registering Public Materials Databases

Registering a public materials database which resides on a disk or a networked PC will make it accessible from your PC and available for use by any projects thereon.

Suppose you have a public materials database which you wish to export to another PC. There are two ways to do this.

1. Locate the folder that contains the database, and copy **all** the files onto a floppy disc. Take this disc to the second PC and copy from it into a new folder. Note that the folder name can be different from the original if you so desire. Then follow the instructions below to register this folder as a public materials database on the new machine.

2. If the PCs are connected by a network, and the second PC has access rights to the database folder on the first PC, all that is required is to click on the **register public database** menu using the second machine, navigate through the network to the right folder in the first machine and proceed as per the instructions below.

Public materials databases can be registered in the following ways:-

- Select **Materials|Register public materials database** from the main menu
- Click the **Register public materials database** Toolbar button 
- Press **Alt+M**, then **R** on the keyboard.

Select the path of the public materials database you wish to register in the 'Browse for folder' dialog, and enter a name for the public materials database in the 'Enter materials database name' dialog.

Once a public materials database is registered, it can be opened the same as any other public materials database.

4.2.6. Deregistering Public Materials Databases

Public materials databases whose name you want to remove from you PC, rather than deleting them entirely (e.g.. a public materials database on the network or on a disk, which you have previously registered on your PC and no longer need to access) can be deregistered in the following ways:-

- Select **Deregister public materials database** from the **Materials menu**
- Click the **Deregister public materials database** Toolbar button 
- Press **Alt+M**, then **G** on the keyboard

In the 'Enter materials database name' dialog, enter the name of the materials database you want to deregister, or select it from the drop-down list.

Please ensure before deregistering a public materials database that no other projects registered on your PC are using it, as without the registration it will not be possible to open these projects.

NB: Public materials databases cannot be deregistered while they are open. Use close public materials database before proceeding.

4.2.7. Changing Materials Database

A project can change its materials database from public to private, private to public or from one public one to another by any of the following:

- Select **Change materials database** from the **Project menu**
- Click the **Change materials database** Toolbar button 
- Press **Alt+P,** then **H** on the keyboard

NB: Care should be taken to ensure that the new database contains the correct materials and optical properties data for any film data already entered in the project.

4.3. Editing Material Databases

At some point you will want to enter your own material databases reflecting the material properties that you expect to achieve in your particular processes. This data could be derived from standard published data, or better still from measurements taken on your own material using a spectrophotometer or an ellipsometer. If you are under any doubt as to how to obtain such information related to your particular materials then please feel free to contact Intellemetrics for advice.

Note that the Material Database should contain n,k,λ data for your substrates as well.

Managing material databases can be done in a number of different ways, outlined below, depending on what you are doing. Some methods are slow and cumbersome, and others a fast and simple. They all have their uses and so we describe them all below.

4.3.1. Changing Values of a Pre-Existing Database

The figure to the right shows what you will see when you open a typical Material Database.

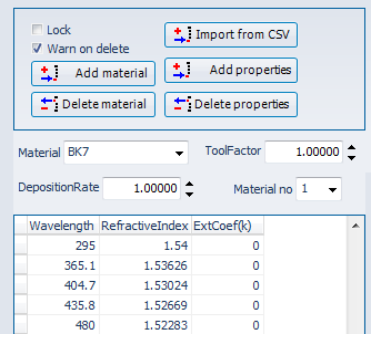

Figure 4-2 Material Database Features

If you try to enter data into one of the cells then you will be given a warning telling you that the table is locked (a useful safety feature). Make sure you un-tick the “Lock” box at the top of the form. From now on changes that you make will automatically be changed in the Material Database.

To edit one of the existing cell entries simply click into that cell and change the value.

If you want to add an additional line of n,k,λ data then click on the “Add Properties” button. This will give you a blank line at the bottom of the list in which to enter your data.

If you wish to delete a line of data then click the mouse within that line of data and then click the “Delete Properties” button.

To see a list of all of the materials in this database click the down arrow at the edge of the dropdown list for “Material”. Selecting a different material name will show the all of the associated values for that material.

If you wish to add a new material to the database then click the “Add Material” button. You will be asked for a material name, and then you can enter values as required.

If you wish to delete a material, then select that material name from the Material dropdown box list and press the “Delete Material” button.

The above method is relatively slow and manual in nature, but it does allow you to quickly add a new material or change a value for testing purposes.

4.3.2. Entering a Completely New Database

The section above shows you how to edit a pre-existing database, but very soon you will want to create a database of your own. The sections below show you different ways of doing that.

4.3.2.1. Line by Line

It is possible to enter a complete material database line by line using the editing techniques described in the section “Changing Values of a Pre-Existing Database”. Basically you would open the Material Database window, un-lock the window and then enter material names, n,k,λ values, deposition rates and tooling factors line by line.

This method is generally only recommended if you have very few n,k,λ values, or if you wish to be able to change values rapidly to test the impact, or you simply have plenty of time on your hands.

4.3.2.2. Import from CSV

The recommended method for creating a Materials Database is to import one from a CSV (comma separated variable) file. This allows you to rapidly enter large numbers of materials and large numbers of n,k,λ values and to make changes quickly.

The first stage is to create a database in a CSV file. The CSV file can be created using Microsoft Excel or a range of other software packages. The format of the database should be as shown on the right. The main features are;

	A	B	C	D	E
1	MaterialName	Wavelength	RefractiveIndex	ExtCoef(k)	
2	Ti2O3	295	2.927	0.758	
3	Ti2O3	300	2.953	0.657	
4	Ti2O3	400	2.5987	0.556	
5	Ti2O3	500	2.4	0	
6	Ti2O3	2000	2.2	0	
7	SiO2	295	1.48	0	
8	SiO2	500	1.45	0	
9	SiO2	800	1.43785	0	
10	SiO2	2000	1.41984	0	
11	BK7	340	1.5276	0	
12	BK7	550	1.5198	0	
13	BK7	880	1.503	0	
14	BK7	1500	1.4999	0	
15					
16					

Figure 4-3 CSV Format for Importing to a Material Database

- *The column heading must have exactly the same text as shown in the figure with the same capitalisation.*
- *There can be as many different material names and as many different lines as you wish.*
- *No lines within the list can be blank. As soon as FilmMaker2 sees a blank line it will assume that is the end of the list.*
- *n,k,λ values do not need to be in ascending or descending wavelength order, Filmmaker2 will sort them automatically.*
- *Material names do not need to be grouped onto adjacent lines. For instance, in the above example it is OK to enter more Ti2O3 entries on lines 15 and 16. Filmmaker will automatically group them together.*
- *If you enter a material name in a particular row then the rest of that row must be populated with n,k,λ values. Do not leave a cell blank, even if its value is zero.*
- *Extinction coefficients can be expressed in decimal point notation (e.g. 0.00123) or in scientific notation (e.g. 1.23E-3).*
- *Wavelength values cannot be entered outside of the range 190nm to 30,000nm.*

Note that the material database shown above is a simple one with just three materials specified at a few wavelengths. However, it is likely that you will have a much longer list containing many materials specified at many different wavelengths. Using the CSV file lets you rapidly copy and paste values derived from your own measurement equipment, from your filmstack design package (e.g. Essential Macleod, FilmStar, Optilayer, etc) or from published data on the internet.

Now that you have a CSV file it is simply a case of pressing the “Import from CSV” button at the top of the Material Database window. You will first be given a warning explaining that if you proceed then you will over right any values that you previously have in this particular database. If you select OK then you will be given a standard windows browse window to select the relevant CSV file.

Once you have selected the CSV file the Materials Database will be populated with all of the materials and n,k,λ data that was in that file.

Note that changes made to the original CSV file will not be reflected in the Materials Database unless you import the CSV file again using the “Import from CSV” button.

Using the above method it is very easy to create a large database of materials, to change these quickly, and to import those changes in Filmmaker2.

4.3.2.3. Copy Project As

Once you have created a Materials Database then it is highly likely that you will want to use the same values for many different projects. The simplest way of creating a new project is to use a previous “good” project as a template and selecting **Projects | Copy Project As** from the main menu.

This will copy the present project to a new project name that you can define, and it will naturally include the complete materials database and all of the other parameters that will be standard to your projects, and therefore this is a much recommended method.

5. Main Menu and Toolbar

The FilmMaker2 main menu and toolbar are shown below.

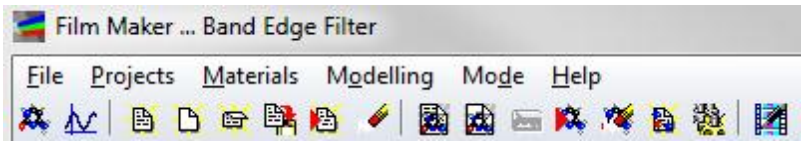

Figure 5-1 The FilmMaker2 Main Menu and Toolbar

The structure of the main menu drop down lists is shown below;

File		
Open >	Materials Window	
	FilmReviewer	
Export >	ModelStack >	To CSV
	FilmStack >	To Excel
Import >	Film Stack >	From Excel
		From CSV
	Materials >	From CSV
Exit		

Projects
Open Existing Project
Create New Project
Close Project
Copy Project from Media to FilmMaker
Copy This Project to Media
Delete project
Copy Project As ...

Materials
Open Public Materials Database
Create New Public Materials Database
Close Public Materials Database
Copy Materials Database from Media to FilmMaker
Delete Public Materials Database
Change Materials Database

Modelling
FilmSimulator
FilmEditor

Mode
Basic
Advanced

Help
About ...
Licence

Figure 5-2 The Main Menu Structure

The various buttons perform the following tasks;

- opens the Materials form; corresponds to **File|Open|Materials form**
- opens FilmReviewer; corresponds to **File|Open|FilmReviewer**
- opens an existing project; corresponds to **Projects|Open existing project**
- creates a new project; corresponds to **Projects|Create new project**
- closes an open project; corresponds to **Projects|Close project**

 creates a copy of the open project; corresponds to **Projects|Copy project as ...**

 makes a project accessible to a PC; corresponds to **Projects|Register project**

 deletes a project; corresponds to **Projects|Copy Project from Media to FilmMaker**

 opens an existing public materials database; corresponds to **Materials|Open public materials database**

 creates and opens a new public materials database; corresponds to **Materials|Create new public materials database**

 closes an open public materials database; corresponds to **Materials|Close public materials database**

 makes a public materials database accessible to this PC; corresponds to **Materials|Register public materials database**

 deletes a public materials database; corresponds to **Materials|Delete public materials database**

 associates a different public materials database with a project; corresponds to **Materials|Change materials database**

 opens FilmSimulator; corresponds to **Modelling|FilmSimulator**

 opens FilmEditor: corresponds to **Modelling|FilmEditor**

6. Ribbon Menu Settings

Underneath the main menu section is a Ribbon Menu. This contains most of the information that will be common to all of your processes and is largely defined by the equipment you have and the monitoring configuration you have. So in effect, once you have set the parameters in this section you will most probably use them for all of your projects going forward. We will describe each section in turn.

6.1. Materials Section

The figure on the right shows the Material section of the Ribbon menu. When you create a Materials Database (create from scratch, import from CSV or link to a (Public Materials Database), then the "Available" box shows a list of all the material names within the database.

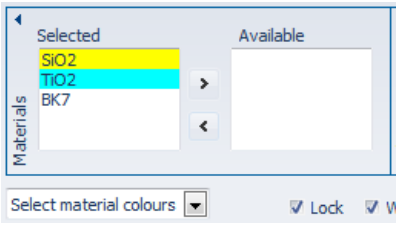

Figure 6-1 Materials section of the Ribbon menu.

Click on the particular material names that you will use in this particular project and press the < symbol to populate the "Selected" box. The "Selected" box should include all the material names that you wish to use, including the substrate material. It can include extra names if you wish, or you can select a material and press the > symbol to move it out of the "Selected" box into the "Available" box.

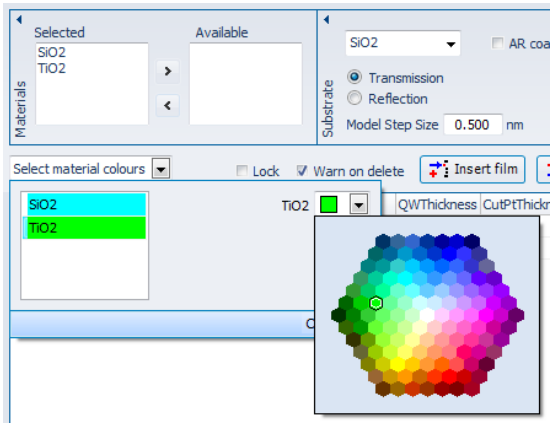

Figure 6-2 Select Material Colours section.

Underneath the "Selected" box is a dropdown menu to select the colours assigned to each layer. Assigning colours to each layer will assign those colours to the Material names in the FilmBuilder window, in the Model, and in the live graphing windows in FilmDirector2.

6.2. Substrate Section

The figure on the right shows the Substrate section of the Ribbon menu. This is where you define the substrate material that you will be using to monitor the growth process, as well as the monitoring configuration.

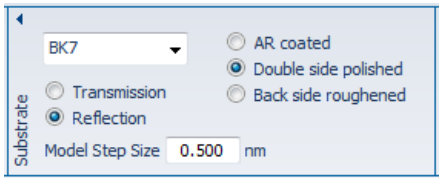

Figure 6-3 Substrate section of the Ribbon menu.

The dropdown list contains a list of all of the Material names in the Material Database. Select the one that corresponds to the material you will be monitoring.

Select either the Transmission or Reflection option depending upon your monitoring configuration. Depending upon your selection, you will have the following options;

- *In Transmission Mode*
  - *AR not selected: This indicates that you will be monitoring in transmission through a double side polished substrate.*

- *AR selected: This indicates that you will be monitoring in transmission through a double side polished substrate which has an AR coating on one side. The AR coating is assumed to be 'perfect' at all wavelengths.*

- *In Reflection Mode*
  - *AR selected: This indicates that you will be monitoring in reflection from a double side polished substrate which has an AR coating on one side. The AR coating is assumed to be 'perfect' at all wavelengths.*
  - *Double side polished: This indicates that you will be monitoring in reflection from a double side polished substrate. This option can be used whether you are monitoring from the front face or through the back face of the substrate.*
  - *Back side roughened: This indicates that you will be monitoring in reflection from a substrate with a polished face on the side to be coated, and a roughened back face. This assumes that there will be no reflections from the back surface. This option only makes sense when using front side reflection monitoring. It can also be used if you are monitoring in reflection mode onto an opaque substrate because there will be no contribution from the back surface of the substrate.*

The "Model Step Size" sets the step size in nm for subsequent modelling steps. The default value is 0.5nm, and unless you receive any warning messages then this value should be fine. However, during some of the subsequent processing stages (after pressing "Run Model" or during use of the FilmEditor) you may receive a warning message indicating that "The resolution set by the acquisition rate exceeds the resolution set by the model. Increase the model resolution". If you see this message then decrease the Model Step Size to 0.1nm and remodel. Modelling stages will take longer with smaller step sizes, so there is a playoff between resolution and speed.

6.3. Show Columns Section

The figure on the right shows the Show Columns section of the Ribbon menu. This area allows you to colour code the main FilmBuilder window so that the relationship between the different fields can be seen easier.

Click on the various tick boxes, or set the colours using the "Set Column Colours" dropdown menu.

The effects will be seen immediately in the FilmBuilder window.

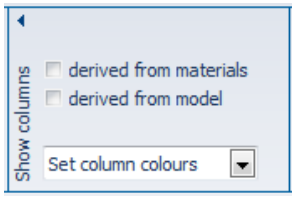

Figure 6-4 Show Columns section of the Ribbon menu.

6.4. Autocalculate Section

The figure on the right shows the Autocalculate section of the Ribbon menu. This area lets you control how FilmMaker2 will auto calculate some of the parameters in the FilmBuilder window.

In the main FilmBuilder window there is a column called "ForcedCutTime". Values in the column are specified in units of seconds and can be entered on a layer by layer basis.

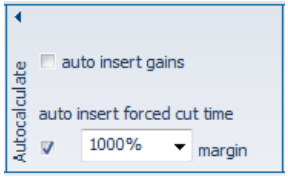

Figure 6-5 Autocalculate section of the Ribbon menu.

During a deposition process, for a particular layer once the ForcedCutTime has elapsed from the beginning of that layer then FilmDirector2 will send a cut signal and will stop monitoring. Usually this does not occur because the optical monitor will make a cut before this time based on monitoring the optical signal. This is obviously a powerful feature and must be used carefully.

The ForcedCutTime is useful in a number of ways, these being;

- *If for a particular layer that layer is intended to be cut using the optical monitor signal, then the ForcedCutTime can be used as a safety margin feature. For instance if we wish the optical monitor to cut after the second turning point, which we expect to be after approximately 300 seconds (based on deposition rate), then we may wish to set the ForcedCutTime to 400 seconds as a safety feature.*

This means that if the second turning point is not detected by 400 seconds, then FilmDirector will stop that layer anyway.

"Auto insert forced cut time" behaves in the following manner;

- *If you leave the tick box unticked and you have not entered a value into the ForcedCutTime column then when you press "Run Model" it will enter a value that is 10x longer than the expected cut time for that layer thickness / deposition rate combination. If you manually enter a value then it will hold that value after subsequent "Run Model" iterations.*
- *If you tick the "auto insert forced cut time" box and select "0%" from the "margin" drop down menu then it will insert a value of the expected cut time. Usually you do not want to do this because you are telling the optical monitor to never let this layer go longer than the exact time expected if the deposition rate is exactly as expected and the optical properties of the layer are exactly as expected.*
- *If you tick the "auto insert forced cut time" box and select "5%" from the "margin" drop down menu then it will insert a value that is 5% more than the expected cut time.*

In this manner it is very simple to automatically enter a given margin of safety into the ForceCutTime function.

6.5. Priorities Section

The figure on the right shows the Priorities section of the Ribbon menu. This section may look deceptively simple, but is in fact a very powerful feature when entering filmstacks, and when designing optical monitoring schemes. To explain its use (and its potential) we need to consider two of the columns in the main FilmBuilder window, namely;

Figure 6-6 Priorities section of the Ribbon menu.

- *Thickness: This is the physical thickness of a layer in units of nm. This value does not depend on wavelength or any other optical parameter. It is the physical thickness that you would measure with a crystal controller, or with a surface profilometer.*

- ***QWThickness**: This is the optical thickness of a layer and is defined as (Thickness x 4n)/λ, where n is the refractive index (at a particular wavelength) and λ is the wavelength.*

The above two parameters are interdependent in that changing one will affect the other. And under certain circumstances one can vary whilst the other can remain constant. The issue is that we need to have a way of making one of the values fixed whilst allowing the other to vary, and which one we pick depends upon what we are try to achieve.

- *If the Thickness box is ticked: Physical thicknesses will be fixed. Therefore values of physical thickness entered into the Thickness column will remain fixed and QWThickness will be calculated depending upon other parameters.*

- *If the QWs box is ticked: Optical thicknesses will be fixed. Therefore values of optical thickness entered into the QWThickness column will remain fixed and physical thicknesses will be calculated depending upon other parameters.*

To understand how this works, let's look at a few examples.

Example 1:

Let's assume that we wish to define 2 layers in terms of optical thickness, i.e. we wish to define a layer stack as layer 1 is 1QW of TiO2, and layer 2 is 1QW of SiO2. And let's assume that these quarter wave thicknesses of material are defined at 500nm. We simply add TiO2 and SiO2 into the

Material column, enter 1 and 1 into the QWThickness column, enter 500nm into both rows of the ProbeWavelength column and tick the QWs tickbox in the Priorities section.

Now when we press “Run Model” FilmBuilder will consider the QWThickness to be fixed and will calculate the physical thicknesses of each layer using the QWThickness value, the wavelength and the refractive index at that wavelength. We now have two perfect quarter waves of material defined at 500nm.

If we now change the wavelength from 500nm to 600nm, then pressing “Run Model” will again fix the quarter wave thicknesses at 1QW each, but it will recalculate new physical thickness values using the new wavelength of 600nm and the refractive index of each material at 600nm. And so we now have two perfect quarter waves of material defined at 600nm.

Example 2:

Let’s assume that we wish to define 2 layers in terms of physical thickness, i.e. we wish to define a layer stack as layer 1 is 59.34nm of TiO2, and layer 2 is 43.96nm of SiO2. Maybe we obtained these thicknesses from a 3rd party optical design package.

We simply add TiO2 and SiO2 into the Material column, enter 59.34 and 43.96 into the Thickness column, enter 500nm into the ProbeWavelength column and tick the Thickness tickbox in the Priorities section.

Now when we press “Run Model” FilmBuilder will consider the physical thicknesses to be fixed and will calculate the optical thicknesses of each layer using the Thickness value, the wavelength and the refractive index at that wavelength.

Now if we vary the wavelength from 500nm to 600nm for each layer, and press Run Model, then FilmBuilder will fixed the Thickness values and recalculate the new QWThickness values.

Note that using the QWs priority setting is a very useful way to enter a filmstack design from scratch, especially if the filmstack is made up of multiple integer QWs. For instance a simple bandedge filter may consist of 5 pairs of alternating TiO2/SiO2 pairs with each layer being defined as 1QW at a particular wavelength. Entering the material names in the material column, followed by the a list of 1s in the QWThickness column, and the design wavelength in the ProbeWavelength column, allows you to press Run Model and automatically calculate the correct physical thicknesses for each layer.

Once the physical thicknesses have been calculated, you may wish to change the monitoring wavelength. If you have QWs priority ticked then the whole design will be maintained, but shifted to a different wavelength, i.e. a QW will still look like a QW, but the underlying physical thickness will have been modified. However, if you have the Thickness priority ticked then the design remains the same (physical thicknesses remain the same) but the signal will change from a single QW to a different value.

There are many tricks and uses for the Priorities settings and they can have a profound effect on the FilmBuilder window. So make sure you are aware of the Priority setting before you press Run Model, especially if you regularly swap from one setting to the other.

6.6. Detector Setup Section

The figure on the right shows the Detector Setup section of the Ribbon menu. These values are related to the detector setup that you have. If you only have one detector module then these values will be set once and then remain the same for all subsequent projects. The entries are;

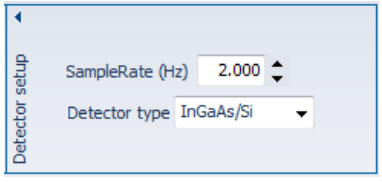

Figure 6-7 Detector Setup section of the Ribbon menu.

Sample Rate (Hz):

This is the sample rate at which your particular detector module will send measurements to the Controller Module. The detector module will take measurements at a much higher rate (typically around 1.3kHz), but these

high speed measurements are stored and processed within the detector module before a processed data point is sent to the Controller Module.

The actual rate that should be set varies from system to system depending upon the firmware settings in the detector module, the detector type, and whether the detector module is monitoring a stationary test glass or a moving test piece.

Your Intellemetrics contact will tell you the best value to use for your system.

Detector Type:

This is the detector type that is used in your system. The drop down menu allows you to select from PMT, Si, InGaAs/Si and PbS.

7. The Main FilmBuilder Area

The following sections will describe in detail what each of the columns in the main FilmBuilder area mean. This area can look extremely complex and daunting, but many of the values are calculated automatically by FilmMaker2 when you press Run Model, and many of the values will default to 'known good' values on pressing Run Model. And if you need to change any of the values then the majority of them can be set in the FilmEditor (see the following section on FilmEditor) in an intuitive and graphical manner. So for many users, the only interaction with the FilmBuilder area will be to enter material names, and physical or optical thicknesses of layers. But here we will give a complete description of each column in term for completeness.

7.1. User Modes

Firstly let us note that there are two user modes that can be selected and these will effect what we can see in the FilmBuilder area, and what is automatically calculated. On the top line menu there is a MODE option which allows you to select BASIC or ADVANCED mode.

The BASIC mode will only show a small subset of the available columns. These are the minimum that you would need to enter. Parameters not shown are calculated automatically when Run Model is pressed.

In ADVANCED mode all of the available columns are shown. Again, the majority of parameters will be automatically calculated, or default values entered when Run Model is pressed. However, seeing the whole table allows you to see what parameters have been entered and also to change any values that can be changed.

For the subsequent sections we will assume that the ADVANCED mode has been selected.

7.2. FilmNo

This is the film number, or layer number. Film 1 is the first layer to be deposited on the substrate. Values are automatically entered when new films are inserted or added.

7.3. Tag

This column allows you to optionally enter a description into each layer (e.g. Cavity). This box will accept up to 12 ascii characters.

7.4. Material

This column holds the material name of each layer. Material names must correspond to material names in the Material Database. Clicking the left mouse button in one of these cells opens a drop down menu to select a material name from the selected material list.

7.5. Thickness

The Thickness cells hold the physical thickness of each layer before any tooling factors have been applied. This is generally the thickness of each layer that you are trying to achieve on the final product, i.e. the design thickness. It is in units of nm.

7.6. CutPtThickness

This cell holds the physical thickness after any tooling factor has been applied. It therefore represents the physical thickness that the optical monitor will observe. If the tooling factor is equal to 1 then this will be the same as the Thickness. This value in this cell is automatically calculated when Run Model is pressed.

7.7. QWThickness

The QWThickness cells hold the optical thickness of each layer expressed in terms of quarter waves. The QWThickness is defined as;

$$\text{QWThickness} = (\text{Thickness} \times 4n / \lambda)$$

where n is the refractive index (of that particular material at a particular wavelength) and λ is the wavelength.

7.8. CutPtQWs

This cell holds the QWThickness after the tooling factor has been applied. These values are automatically calculated when Run Model is pressed.

7.9. ProbeWavelength

This is the monitoring wavelength for each layer expressed in units of nm. If the cells are left blank, then pressing Run Model will result in default values of 500nm being inserted in all rows.

This value is generally set from within FilmEditor.

7.10. QWTime

This is the time it should take for a single quarter wave of material to be deposited given the deposition rate given in the Material database. This value is automatically calculated.

7.11. QWFactor

The QWFactor is a factor applied to each layer to account for the phase delay between the live raw data and the smoothed data. The default starting value is 1. Features within FilmEditor and FilmSimulator enable the automatic optimisation of this value for all layers, and generally values of around 0.90 to 0.98 will be seen. The important point is that these values are automatically calculated.

7.12. SkipThickness

This value is generally set from within FilmEditor.

7.13. Gain

Gain settings can be applied to each layer. The default value is 0. Ticking the Auto Insert Gains tickbox in the Ribbon Menu before pressing Run Model will result in FilmMaker automatically inserting optimised gain values into each cell.

The gains applied here are analogous to an integration time setting, in that higher values result in lower noise and smaller quantisation between levels. Gains are typically applied to layers with small values of T% or R%. Gains are automatically calculated after pressing Run Model if the Auto Insert Gains tickbox is ticked in the Ribbon Menu.

7.14. FilterCutOff

The FilterCutOff value sets the degree of filtering that is applied to the raw live data. The sinusoidal-like data stream coming from the detector has a fundamental frequency associated with it. This can be derived at setup from the estimated quarterwave time. The filter needs to pass this frequency and reject higher frequencies. A normalised setting of 1.0 would achieve this perfect filtering, but the consequential phase delay would be far too large. To get workable phase delays, we normally have to use settings of 7.5 or higher (i.e. cutting off frequencies 7.5 times the signal fundamental and higher). The linear algorithms require more filtering (7.5 to 15) than the curve fitting fitter algorithms (25 to 100) discussed later.

Note that the filter cut-off parameter is normalised, and a given parameter value will have much the same effect regardless of the actual film being built. However, the quarterwave time needs to be estimated to within +/- 20% for this to be so.

The main benefit of filtration is in improving the reliability of the termination. On the negative side, filtration introduce a phase delay in the monitored signal that results in late (but reliable) termination. The phase delay can be predicted and is effectively eliminated by the application of the QWFactor.

As a general rule of thumb, the best results are achieved when filtration is reduced to a point where the filtration is set just high enough to prevent system noise from causing unreliable termination of layers.

However, with a new process the best way of achieving success is to initially set a high level of filtration and thereby ensure that the OMS proceeds through the process without error, and then to repeat the coating build with progressively reduced filter sets.

7.15. AnalyserMode

The AnalyserMode determines the method that will be used for each layer to determine the position of turning points and to determine the subsequent endpoint condition. Clicking the left mouse button within a cell results in a drop down menu for selecting one of the following modes;

- *Normal*
- *FilterCrossing (not used)*
- *Fitter1*
- *Fitter2*

7.15.1. Normal Mode (Linear)

This is a Simplex algorithm that looks for a number of sample points to be distributed across an turning point. This is the most robust method and in that it is highly immune to deposition rate variations during a run.

The data set should be monotonic, i.e. that is smoothly increasing to the maximum, then smoothly decreasing to the minimum and so on, with no backward steps. This demands quiet data, which often means higher levels of filtering and thus phase delay. Typically the default FilterCutOff value of 10 should be used as a starting point.

7.15.2. Fitter 1 (Quadratic)

Fitter 1 employs a parabolic curve fitter that operates over a window of the most recent data points to determine turning points in the optical monitor signal. The size of the analysis window is set by the Filter Buffer Size column, which is automatically calculated from within FilmEditor. The greater the buffer size, the better the inherent filtering of the fitter, and thus the better the ability to handle noisy data. However, typical optical monitor curves approximate a parabolic for only a limited extent either side of the turning point, so will give erroneous results if the buffer size is too large.

Because this algorithm inherently filters, the FilterCutOff column can be increased to very much higher values than you would use with the Normal mode. A good rule of thumb is to increase the FilterCutOff by a factor of at least the square root of the buffer size.

The FitterThreshold parameter is applied to the quality-of-fit, and thus sets the point at which the fitter will consider itself 'locked' to the incoming signal. Only for very noisy data is there any point in increasing this value.

The fitter is predictive, and 'knows' when an turning point is approaching. It writes its prediction of the time of the next turning point to the Process Screen as shown below.

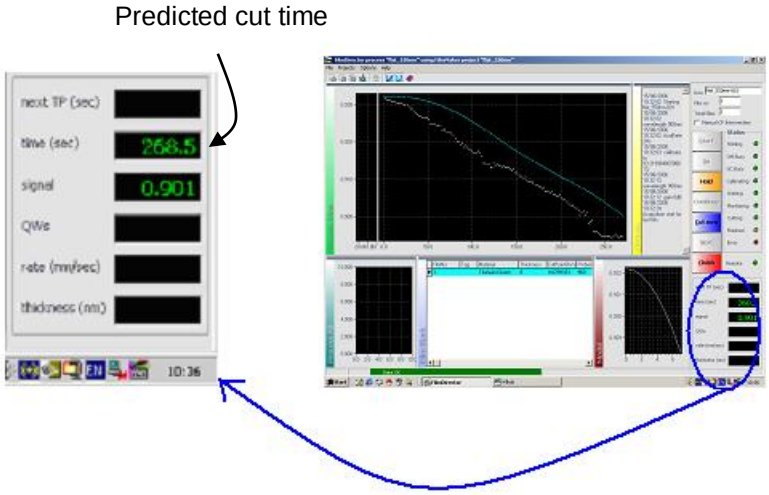

Figure 7-1 Predicted cut time using the Fitter mode.

Because the fitter is predictive, it creates absolutely no phase delay. However, because it is being fed filtered data, there will still be the phase delay of the basic noise filter.

Therefore, by setting the FilterCutOff some 10 to 20 fold higher than is usual, and compensating for the noisier data by using a large Filter Buffer Size, it is possible to terminate in this mode with almost no delay.

7.15.3. Fitter 2 (Quadratic)

Similar to Type 1 fitter with the exception that it works on the reciprocal of the data stream. The reason for this being that in certain specialised cases it fits over a wider extent at the turning point than the Fitter 1 algorithm, and thus allows larger buffer sizes to be employed without the size introducing errors discussed above.

Use fitter 2 in situations where the maxima are clearly much sharper than the minima. A typical application where this occurs is when building filters which employ pairs of QW stack reflectors to produce a high finesse resonant cavity. Where the maxima and minima are similar in terms of sharpness, use fitter 1.

7.15.4. Increasing the Robustness of Turning Point Detection

All four turning point detection algorithms are sensitive to noise spikes to some degree, and erroneously assigning a turning point to a noise spike effectively ruins the run. Because we know in advance the approximate timing of the turning points, it is possible to block out all turning points until one is due.

- The ***Holdoff*** parameter sets the delay after the start of the run before the algorithm accepts a turning point. It is set in units of sample points.
- The ***Latency*** parameter sets the interval after finding an turning point that must expire before another turning point will be accepted. It is set in units of sample points.

Although these parameters suppress the acceptance of turning points, they do not suppress processing, and thus the recovery from the ***Holdoff*** and ***Latency*** periods is instantaneous. For example if we have set 100 ***Samples per QW***, we can happily set the ***Holdoff*** at 80 and still be sure of picking up the first turning point.

7.16. HoldOff

All four turning point detection algorithms are sensitive to noise spikes to some degree, and erroneously assigning a turning point to a noise spike effectively ruins the run. Because we know in advance the approximate timing of the turning points, it is possible to block out all turning points until one is due.

The Holdoff parameter sets the delay after the start of the run before the algorithm accepts a turning point. It is set in units of sample points. It is easiest to set this value from within FilmEditor.

Although this parameter suppresses the acceptance of turning points, it does not suppress processing, and thus the recovery from the Holdoff period is instantaneous.

7.17. Latency

The Latency parameter is very similar to the HoldOff except that it sets the interval after finding a turning point that must expire before another turning point will be accepted. It is again set in units of sample points and is easiest to set from within FilmEditor.

Although this parameter suppresses the acceptance of turning points, it does not suppress processing, and thus the recovery from the Latency period is instantaneous.

7.18. SamplesPerQW

This column shows the number of samples that will be taken during the QWTime. The value used here is generally automatically calculated within FilmEditor to the maximum allowed given the SampleRate value entered in the Ribbon Menu and the QWTime calculated by FilmMaker.

7.19. CutUsing

The clicking the left mouse button in the CutUsing cell opens a drop down menu with the following options;

7.19.1. Optical

This is the default setting. If this cell is left blank then FilmMaker will automatically insert Optical into this field when Run Model is pressed.

If this option is selected then the optical monitor will cut the layer based on the optical signal it is tracking and the endpoint conditions it has for that layer. If you are using the optical monitor then this is generally the option you want for the vast majority of layers.

7.19.2. Manual

If the Manual mode is selected then the optical monitor will monitor the layer, but it will not make the cut itself. It will continue monitoring until either the Cut Now button is pressed on the FilmDirector2 screen, or an McCut signal is received from an external source.

A typical use for the Manual mode would be if a particular layer is very thin then it may be better to cut is based on the thickness from a crystal controller. In this case setting the CutUsing to Manual will ensure that the optical monitor does not make the cut, but instead waits for an external signal to come from the crystal controller.

7.19.3. Time

If the Time mode is selected then the optical monitor will monitor the signal, but will not make the cut based on the optical signal. Instead it will simply cut after the ForcedCutTime has elapsed.

7.20. ForcedCutTime

The ForcedCutTime value is the time after which the optical monitor will cut a layer assuming that no other reason to cut has occurred so far. If the Auto Insert Cut Time tick box in the Ribbon Menu has been ticked then this value will be automatically entered after pressing Run Model with a value that depends upon other settings. If you wish to override these values and enter your own ones, then untick the Auto Insert Cut Time box and enter new values.

7.21. GlassNo

This shows the test glass number for the current layer. The default value is 1. If you don't use a test glass changer then leave this value as 1 for all layers. All projects should start on test glass 1, and the next logical

test glass would be 2 and so on. If you are using an Intellemetrics carousel based test glass changer then it is possible to go back and forth between test glasses within a design.

The test glass number is not to be confused with the test glass position in a carousel based test glass changer. For instance an Intellemetrics test glass changer may have 16 positions for test glasses which have engraved numbered positions on the carousel body. When a project is run that has GlassNo 1 and GlassNo 2 in, then the Intellemetrics test glass changer will move to the next available un-used position and assign this as GlassNo 1, even if it is test glass position 5.

In other words, it makes perfect sense to design all of your projects starting on GlassNo 1 and incrementing by 1 every time a test glass change is required. The Intellemetrics test glass changer will handle the assignments of these to test glass positions.

7.22. ForceCalib

The ForceCalib parameter has values of TRUE or FALSE and determines when calibration routines take place. The default value is FALSE.

At the beginning of a coating run, after the START button has been pressed, or an external McSTART command has been sent, the optical monitor will perform a calibration routine. This involves looking at all of the wavelengths required in the particular project being run, and calibrating the T% or R% to the desired value at all of these wavelengths.

If the project involves only one test glass, or if the project involves direct monitoring on the piece being coated, then this calibration stage will only occur once at the beginning of the process. If the project involves more than one test glass then calibration will be done on each bare test glass.

The above behaviour (calibration on each new test glass) over rides any settings in the ForceCalib cells. This is the behaviour that the vast majority of users will wish to use. Therefore in the vast majority of cases the value should be left at the default setting of FALSE.

However, if TRUE is selected on any layer that is not the first layer and is not the first layer on a new test glass, then the optical monitor will force the starting value of that particular layer to be the theoretical value as determined using Run Model.

There are very few (if any) cases where you would want to change this from the default value of FALSE.

7.23. CFAvgCount

During the calibration routines a number of sample measurements are automatically taken at each wavelength to determine the calibration factor for that wavelength. By default the routines take 5 measurements and average these to obtain a value used in subsequent calibration factor calculations.

If the raw data is noisy, and / or you want higher precision in these values, then it is possible to increase the number of measurements taken by entering a higher number in this column.

Note that increasing the value will naturally increase the amount of time it takes to perform the calibration stages. These stages are performed before the run starts and on every test glass change, and for all wavelengths in the project. Therefore if you only have one wavelength in your project, and the SampleRate is fast (maybe 2Hz), then increasing the CFAvgCount from 5 to 20 will add approximately 7.5 seconds to the calibration time. However, if you have 20 different wavelengths in your project, and you are monitoring on a rotating calotte with a rotation rate of say 30 rpm (SampleRate = 0.5Hz), then increasing the CFAvgCount from 5 to 20 will add at least 10 minutes to the calibration time.

8. Entering a Filmstack

In this section we shall describe different ways in which you can fill out the required data to populate the FilmBuilder window. You will have already seen that FilmMaker2 is very flexible and in that way there are a number of different ways to do things depending upon your personal preferences and what you are trying to achieve.

8.1. Method 1: Manually

The most basic way to enter a filmstack is to do it manually. We will assume that you already have a materials database selected, and you have selected the materials you want to use, and you have selected a substrate material and configuration in the Ribbon Menu.

The first thing to do is untick the Lock tickbox just above the FilmBuilder window; this allows you to change parameters within the FilmBuilder window.

If we know we have a 6 layer project then simply press the Insert Film (or the Add Film) button six times to generate 6 empty layers.

Now go to the Material column of each row and select a material for each layer.

Now, assuming the Thickness option is selected within the Priorities section of the Ribbon menu, then enter a thickness value for each layer. Alternatively, if the QWs Priority is set then enter values into the QWThickness column.

Now press Run Model. You should see a Model Output graph at this stage. Close the graph and you will notice that the FilmBuilder table has been populated with either default values, or values that have been automatically calculated from ones you have entered. You will also note that every layer has a red exclamation mark in the FilmNo column. The red exclamation mark is giving you a warning, so looking in the “Current Film Errors and Warnings” box shows that a number of parameters have been automatically entered using default values. Pressing the Run Model button again will regenerate the Model Output graph and change all the red exclamation marks to green tick indicating that all of the parameters are ‘good’ and no errors have been found and no warnings are needed.

If you are happy with the default values that have been entered for all of the layers then that is all you need to do.

If however you wish to change any of the parameters then you are free to enter them on a line by line basis. If you want to change a whole column to a single value, then left click the mouse in a cell with that value, then left click the mouse on the column title. A message box will appear giving the option to replace every row in that column with the same value.

Alternatively, the best way to select the best parameters for each layer is to open FilmEditor which offers an intuitive and interactive graphical interface to select the best parameters for each layer. See the section on FilmEditor.

8.1.1. Data Grids

Data in all the grids is protected by using the 'Lock table' check-boxes, which have to be unchecked to allow editing.

New rows are entered by using the 'Insert row' or 'Insert film' buttons on the Build Films form, or the 'Insert optical property' button on the Materials Form. Default films can also be entered into the Build Films grid by using the Enter Default buttons. Numbering of films and default rows is automatic.

Rows are deleted by using the 'Delete row' or 'Delete film' buttons on the Build Films form, or the 'Delete optical property' button on the Materials Form.

Once a row has been inserted, values can be typed straight in. Some columns in the Build Films form grids have pick-lists which are activated when the column is entered. Values can be entered in these columns by using the down-arrow, or by typing in the first letter or number. Moving materials from the 'Materials

available' list box to the 'Materials selected' at the top of the Build Films form will make those materials available as a pick list in the 'Material' columns.

8.1.2. Tips

- *Columns can be resized by moving the mouse over the border of the column title until the cursor changes to a double headed arrow, holding down the left mouse button and dragging.*
- *Columns can be dragged to a new position by holding down the left mouse button over the column title.*
- *To apply a value to every row in a column in any of the grids on the Build Films form, select the value within the column that you want to use, and click on the column's title.*
- *You can view two different sections of a film stack by moving the splitter between the two main grids.*
- *All column properties are saved with your project when it closes, and will be the same next time you open it.*

8.2. Method 2: Using Default Layers

This method is ideal if you wish to create a filmstack consisting of many repeating layers, such as a typical quarter wave stack for a narrow band filter or a bandedge filter. Each of these repeating layers will have the same parameters and therefore we can create a default set of parameters for each film.

In the Default Layer Entry Area, which is located below the Current Film Errors and Warnings area, there is an area that is very similar to the main FilmBuilder area. In this section you can add all of the details that you want for two materials. So let's assume we are going to be creating lots of quarter wave stacks using SiO2 and TiO2, then we would unlock the Default Layer Entry Area and enter two rows, enter SiO2 in row 1 and TiO2 in row 2 of the Materials column, and then enter whatever other parameters we wish into the other columns (or leave them blank).

To the upper right of this area are a number of buttons labelled 1, 2, 1-2 and 2-1. If we press 1 then all of the parameters for SiO2 are added (or inserted) into the main window. Pressing 1 again adds another layer of SiO2. Pressing 2 adds a layer of TiO2. Pressing 1-2 adds a layer pair of SiO2/TiO2, whereas pressing 2-1 adds a layer pair of TiO2/SiO2.

In this way it is very simple to create filmstacks with many tens of layers with a few clicks of the insert or add buttons. This is especially useful if the majority of the layers have the same properties, especially the same Thickness or QWThickness.

8.3. Method 3: Import from Excel or CSV

This method is ideal for more complex wafer stacks, especially ones with many layers and where layer thicknesses vary from layer to layer. Basically you simply go to File on the top menu and select Import | Filmstack | From Excel (or From CSV). This will populate the FilmBuilder window with whatever information is contained within the Excel or CSV file, which could be the parameters for every column, or it could just be a subset of these.

The Excel file or the CSV file containing the relevant information can either be output from a 3rd party design package (e.g. TFCalc, Essential Macleod, FilmStar, Optilayer, etc) or can be created using Excel or a similar package.

The easiest way to understand the format required is to export a filmstack from FilmMaker using File | Export | Filmstack | To Excel. This will create an Excel file containing a table with all of the visible rows and columns of the present project. The first row contains the titles of each column. The Excel file can be edited and resaved and then imported into FilmMaker2.

It is important to note that many of the columns in the exported file can be deleted. It is only necessary to have the FilmNo, Material and Thickness columns present to perform a successful import. FilmMaker2 will use the titles in the first row to match the column parameters to those in the FilmBuilder window.

8.4. Method 4: Copy Project As

The simplest way to create a new project is to modify one that you have already created and are happy with all of the parameters. Selecting Projects | Copy Project As allows you to create a copy of the present project with a new name. Then all you need to do is change the few parameters that will be different between the old project and the new project.

Note that this method is recommended even if you intend to use the “Import from CSV” method, because using a previous known good project as a template will mean that the Materials Database is present, and all of the Ribbon Menu settings are correct.

9. FilmEditor

The FilmEditor offers a powerful tool to enable you to intuitively pick the best values for the various parameters in the FilmBuilder window via an interactive graphical interface. The FilmEditor cannot be used until a project has been modelled using Run Model, and if any values have been changed within the FilmBuilder window since the project was last modelled then it needs to be remodelled by pressing Run Model again.

At this point you can open FilmEditor in one of the following ways;

- *From the top line menu select Modelling | FilmEditor.*
- *From the standard tray of icons select* 

9.1. FilmEditor Overview

On opening the FilmEditor you should see a window similar to that on the right.

The main feature of the interface is the large graph. At this point it is showing the %T or %R (depending upon your settings in the Substrate section of the Ribbon menu) as a function of thickness for layer 1.

Note that a black circle on the trace indicates a turning point, and a black X indicates the endpoint.

Note also that right clicking the mouse within the graph region results in a drop down menu appearing allowing you to zoom into the graph, save the graph to the clipboard or save the graph to a Windows Bitmap file.

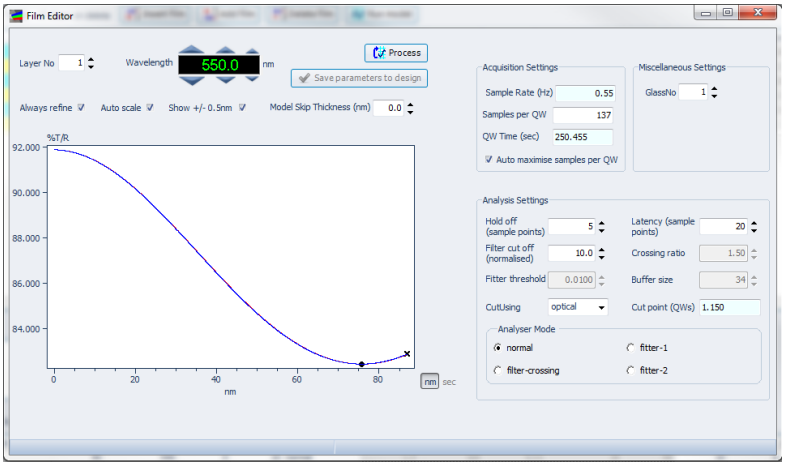

Figure 9-1 The FilmEditor interface.

In the top left hand corner there is an indicator for Layer No. Press the up and down arrows to see the trace for each layer in the filmstack.

On the right hand side of the FilmEditor interface you will see three groups of settings, namely Acquisition Settings, Miscellaneous Settings and Analysis Settings. The values in these boxes are reflecting the values in the FilmBuilder window, and moving the layer number up and down will change the values in these boxes correspondingly.

Any values that are shown with a light blue background (such as Sample Rate) are shown for information purposes only and cannot be edited. Values shown with a grey background (such as Crossing Ratio) cannot be edited also.

9.2. Changing Wavelength

Next to the Layer No indicator there is a Wavelength indicator as shown on the right. This will show the monitoring wavelength that is used for each layer. The largest up/down arrows allow you to change the wavelength in 50nm steps, the medium sized up/down arrows in 10nm steps and the smallest up/down arrows in 1nm steps. These changes will be instantly reflected in the main graph allowing you to see the shape of the trace and the intensity swing as a function of

Figure 9-2 The Wavelength selection area

wavelength. Using this feature you can rapidly chose wavelengths that give you the features you need for each layer.

Note that if you keep increasing or decreasing the wavelength you will eventually be met with an error message saying “Wavelength out of bounds of RIGenerator”. This indicates that you are now trying to operate at a wavelength that is outside of the range that you have entered for at least one of the materials in your Materials Database. If you really want to go to these wavelengths then edit your Material Database to include wavelengths outside of the above range.

9.3. Layer Sensitivity

The “Show +/- 0.5nm” tickbox is a way of graphically seeing the sensitivity of monitoring the present layer at the present wavelength. Un-ticking this box will result in a single black line being shown, and ticking it shows additional red and blue lines showing the result of monitoring the filmstack so far with wavelengths that are +/- 0.5nm from the chosen wavelength.

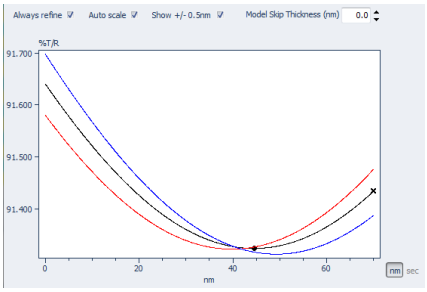

Figure 9-3 Layer Sensitivity

If the three lines are effectively on top of each other (they will often look like a single line) then monitoring the stack so far at the chosen wavelength can be said to be relatively robust in that small changes in wavelength will have little or no effect upon the endpoint thickness of the layer.

However, when the lines diverge, as in the figure on the right, then clearly the layer thickness will be very sensitive to the wavelength. In reality the wavelength is not the problem because this is extremely reproducible, but small variations in the refractive index of the material being deposited will have a similar effect. In fact there are many parameters that can have a similar effect on the optical trace such as deposition rate, temperature, etc. So when the lines diverge this is telling you that the layer cut will be very sensitive to a range of possible process variations, and therefore it is best to avoid monitoring wavelengths where this occurs, or even choose a different cut strategy for any sensitive layers.

A typical example of this would be the coupling layers between cavities in a multicavity quarter wave stack design for a narrow band filter. These coupling layers are typically extremely sensitive, to the point where small process variations can lead to the optical signal going up or down at the beginning of these layers. In this case there are two options; either change monitoring wavelength for the coupling layers to a place where the trace becomes stable, or cut these layers using the crystal controller reading, and return to optical cuts for the subsequent layers.

9.4. Process & Save Parameters to Design

At the top right of the graph window there are two buttons, Process and Save Parameters to Design as shown in the figure on the right.

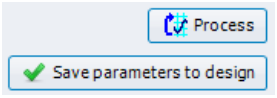

Figure 9-4 The Process and Save Parameters to Design buttons

So far, when you have been changing wavelength and layer number you have been seeing the theoretical %T or %R versus thickness of each layer.

Now when you press the Process button, FilmEditor shows you what you will see when you do the actual coating run for this layer. (see the figure below).

The purple curve shows the result of processing the expected data stream from the detector module, given all of the material parameters, acquisition settings, analyser settings and analyser mode.

The green section of the curve at the beginning of the layer represents the HoldOff period; if you change the HoldOff value and press Process again, then this region will correspondingly change. If you make it large enough, so that it goes over the first turning point, then the first turning point will not be detected and there will be a large overshoot and large error. You will see the large overshoot and the large error…..you are seeing the effects of your choices!

The green section of the curve shown after the turning point (and shown after every subsequent turning point) represents the Latency period. Again, you can edit this value and see its effects immediately by pressing Process again.

Note that the phase of the two curves is different because of the effects of the filtering. Change the FilterCutOff value, press Process and see the changes.

Also, after pressing Process, the horizontal axis of the graph changes to Seconds. You can switch between Seconds and nm by pressing the two buttons in the bottom right hand corner of the graph.

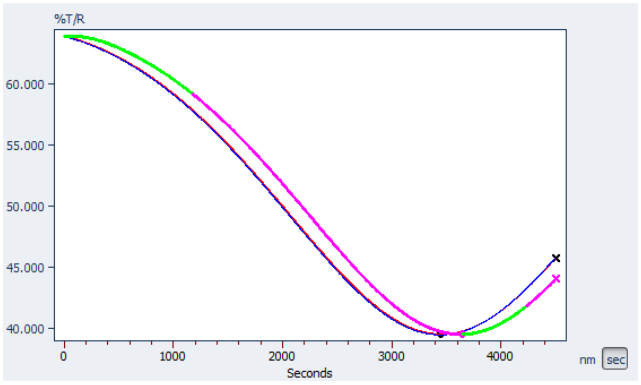

Figure 9-5 The FilmEditor graph AFTER Process has been pressed.

Note also that something else has happened in the background. When you pressed Process, the program calculated the processed curve and then calculated an optimised QWFactor for the layer to ensure that the layer error was minimised. (The actual layer error value achieved is shown in the centre of the bottom bar of the FilmEditor window). This means that all of the QWFactors are now calculated automatically for each layer after pressing Process for each layer.

> *[You can see the effects of the optimisation by making sure that all the QWFactor values in the Film Builder table are set to 1.00, pressing Run Model, and then going back into Film Editor and unticking the AutoRefine box. If you now press Process you should see an overshoot and a large value of error reported. Now retick the AutoRefine box and press Process again. The overshoot should have been eliminated and the error value should have decreased.]*

Once you are happy with all of the parameters related to that layer press the “Save Parameters to Design” button to save all the parameters on this page to the FilmBuilder table. Repeat for each layer, remembering to press the “Save Parameters to Design” once you are happy with the parameter set for each layer.

Note that you are not entering values directly into the FilmBuilder table now, rather you are using FilmEditor as an interactive method of designing a process with instant visual feedback. However, you can still edit values directly in the FilmBuilder table if you wish.

10. FilmSimulator

10.1. FilmSimulator Overview

The FilmEditor offers a powerful tool to enable you to intuitively pick the best values for the various parameters in the FilmBuilder window via an interactive graphical interface.

After running FilmEditor and picking good values for the parameters associated with each layer, then running FilmSimulator lets you investigate the overall performance of the optical monitoring scheme by simulating complete coating runs from beginning to end.

The FilmSimulator allows you to enter noise parameters reflecting the performance of your coating system, along with parameters specific to your optical monitor system. These are then combined with the optical monitoring trace for each layer to reflect the true signal characteristics that will be received by the Controller Module from the detector modules. These signals are processed and analysed using the exact methods and parameters that have been designed into the optical monitoring scheme on a layer by layer basis using the FilmBuilder and FilmEditor tools. The cut for each layer is determined, and from this the error in each layer can be determined. The film thickness errors from previous layers are included in the analysis of subsequent layers, thereby filmstacks are built layer by layer, much in the same way as a Monte Carlo simulation would be performed.

The resultant film stacks are then used to determine the spectral characteristics of the resultant coating runs against the theoretical design.

In this way it is possible to investigate the spectral characteristics of large numbers of runs to check the optical performance and the run to run variability (i.e. yield) of a given optical monitoring scheme.

The FilmSimulator can be accessed in one of the following ways;

- *From the top line menu select Modelling | FilmSimulator.*
- *From the standard tray of icons select* 

The main FilmSimulator window is shown in the figure below;

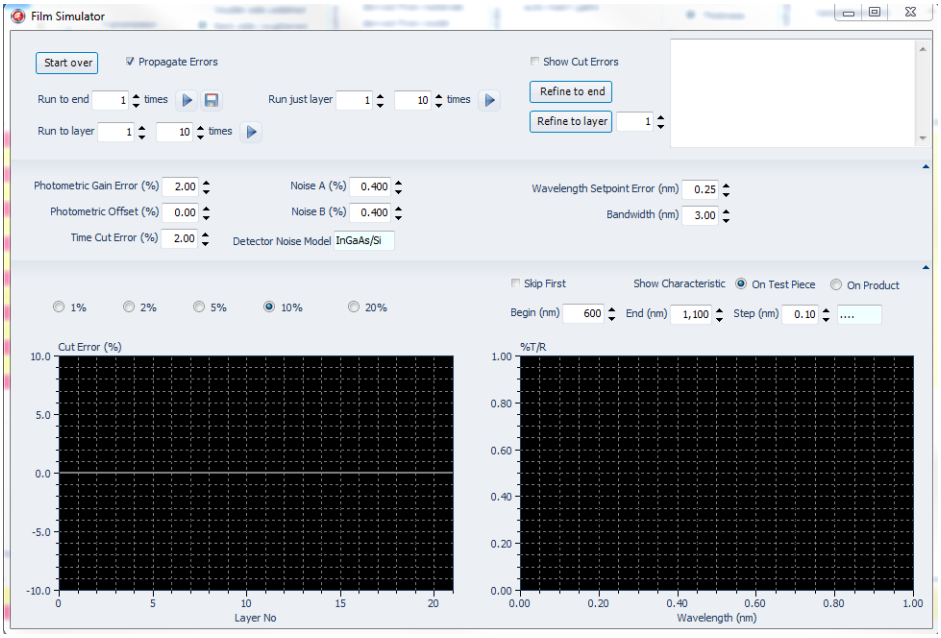

Figure 10-1 The FilmSimulator window.

At the bottom of the window are two graphs. The first of these shows the cut errors of each layer expressed as a percentage of the total thickness of each layer. Positive values correspond to layers that are thicker than the design, and negative numbers correspond to thinner layers than the design.

The 1%, 2%, 5%, 10% and 20% options shown above this graph allow rescaling of the vertical axis.

The right hand graph shows the spectral characteristics of each completed film stack simulation as well as the theoretical target characteristic. The vertical axis will either be transmission or reflection depending upon the monitoring mode selected in the Substrate section of the Ribbon menu in the FilmBuilder window.

10.2. Plotting Target Characteristics

Pressing the START OVER button will generate a spectral characteristic of the filmstack design entered into the FilmBuilder window as a green line as shown in the figure below. The Begin and End values determine the upper and lower wavelength bounds of the graph. Changing these figures and pressing START OVER will replot the graph.

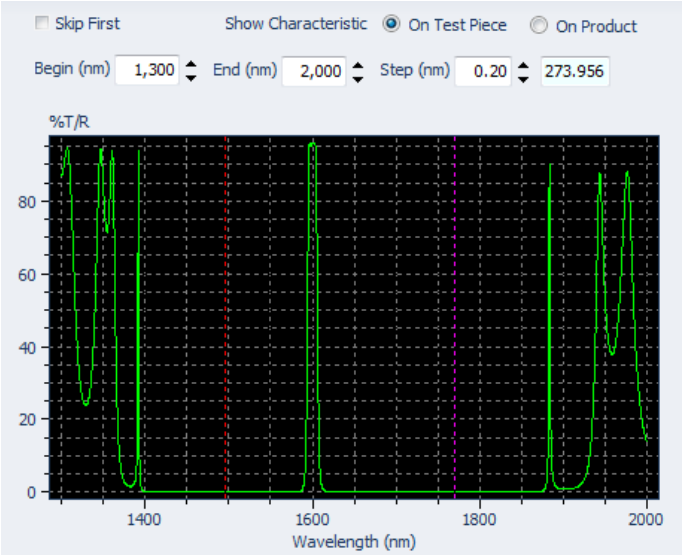

Figure 10-2 The Characteristics graph.

Note that entering a wavelength limit that is outside of the wavelength range defined in the Material Database for any of the materials used in the present design will result in a Wavelength Out of Bounds of RI Generator error. If you receive such a warning then either change the Begin and End values to be inside the range defined in your Material Database, or modify your Material Database to include suitable wavelengths.

The Step (nm) value can be edited to change the graph resolution. Smaller values increase resolution but take longer to plot.

Superimposed on the graph window are two vertical dashed lines. Placing the mouse cursor over either line and holding down the left mouse button allows you to move these two lines. The value shown in the box on the far right indicates the distance in nm between the two lines.

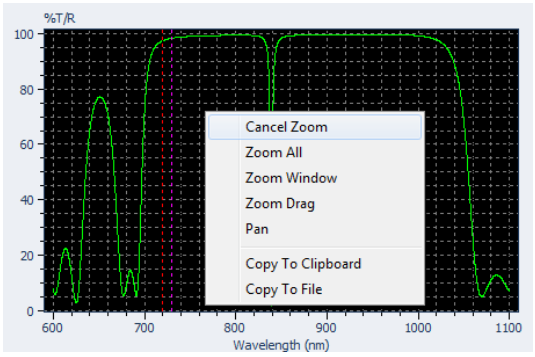

Figure 10-3 The Zooming and Saving Drop Down Menu.

Placing the mouse cursor anywhere within the graph window and pressing the right mouse button reveals a drop down menu, as shown in the figure on the left, allowing various zooming and saving functions.

By default the Show Characteristic On Test Piece option is selected. This means that the characteristics shown in the graph will be those relevant to the ones grown on the test piece, i.e. the substrate that is being observed by the optical monitor. This relates to the layer thicknesses after the Tooling Factors have been applied. If you are using a test glass changer then this will be the characteristic that you should see on the test glass. If you are directly monitoring the actual workpiece then this will be the characteristic that you would get on the workpiece.

If you select Show Characteristic on Product, then the characteristics will relate to those on the product that you wish to manufacture, i.e. the design thicknesses before Tooling Factors are applied. So if you have a test glass changer then these characteristics will relate to those on the product that you are coating on the rotating calotte or planetary.

If the Tooling Factors for all the materials in the film stack are all equal to 1.000 then both sets of characteristics will be the same.

The Skip First tickbox allows you to plot the characteristics without the presence of the first layer. By default this box is not ticked.

10.3. Refining QWFactors

The Refine section is found in the top right hand portion of the FilmSimulator window, as shown in the right hand figure. It is present in the FilmSimulator to allow automatic fine tuning of the QWFactors for each layer taking into account each layers position within the filmstack and the propagated errors up to that particular layer.

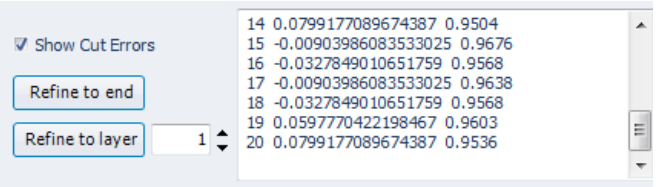

Figure 10-4 The Refine section.

In the FilmEditor, assuming that the Always Refine tickbox was ticked, then pressing Process resulted in an optimised QWFactor being automatically calculated for each layer. Remember that the QWFactor is a factor applied to the theoretical trace to account for the phase delay between the raw data and the filtered data, thereby minimising the errors arising from this phase delay. The actual value of the QWFactor is dependent upon a large number of parameters, mainly the FilterFactor but also the shape of the signal trace, including its starting and ending positions.

In FilmEditor the optimised QWFactors are calculated assuming that each layer exists in isolation, i.e. there are no propagated errors effecting the overall shape of the trace.

However, the Refine to End button in FilmSimulator allows the automatic fine tuning of these QWFactors taking propagation of errors on previous layers into account. This step should be performed in all cases where non-quarter wave monitoring utilising QWFactors is being used.

Assuming that the Show Cut Errors box is ticked, then pressing the Refine to End button will start the refining process. The text box to the right of the button will become populated. Under normal operation three numbers will appear on each row. The first number is the layer number, the second number is the cut error for that layer, and the final number is the QWFactor for that layer.

The QWFactors are automatically saved into the FilmBuilder QWFactor column.

The Refine to Layer button enables you to perform the refining process up to a given layer within the stack.

10.4. Noise Parameters

A powerful feature of the FilmSimulator is that is can incorporate noise parameters that will be present on your particular setup. These noise factors are applied in a random manner from sample to sample, from layer to layer and from run to run. The effects of noise on layer 1 will affect the cut of layer 1 and will therefore effect the thickness of layer 1. Layer 2 is then built on layer 1 including this random error element and so on until the whole filmstack is built.

The noise parameters allow you to see the effects of the optical monitoring scheme that you have designed when applied to the optical monitor and coating system that you have. It is therefore important to apply noise parameters that reflect your actual process, and therefore an understanding of these parameters is important.

10.4.1. Noise A and B (%)

Noise A (%) refers to the optical noise observed on the raw data (i.e. unfiltered data) that you obtain from your particular optical monitor in its particular monitoring configuration. There best way to estimate the correct value to use is to do a dummy run in FilmDirector. Setup a project with a single layer and monitor the test glass with no coating being done. Obtain a few minutes worth of data. Zoom in on the raw data and estimate the peak to peak range. This is the Noise A (%).

The majority of filmstack designs use alternating layers of two materials. For this reason Noise A(%) applies to the odd numbered layers and Noise B (%) applies to the even numbered layers. In the majority of cases is realistic to just use the same value for both factors.

> **HINT:** If you use realistic noise factors and obtain good results whilst performing a large number of simulations then you can assume that the monitoring scheme will be robust. If you wish to test its robustness further then try increasing the noise factors further and redoing the simulations.

The noise values you use will depend greatly upon the optical monitoring system you have and the monitoring configuration you have. For example an IL551 optical monitor direct monitoring on a rotating calotte, taking a single triggered measurement in 3ms, may exhibit a noise of around 0.4% peak to peak. However, the same optical monitor used on a stationary test glass may exhibit a noise of less than 0.01% peak to peak.

10.4.2. Photometric Gain Error

Photometric gain error refers to the error present when applying gains to the signal levels. This is a linear process and would have the effect of making expected levels of 1% and 10% into 1.1% and 11% respectively.

When calibrating at low percentage reflection, e.g. calibrating at the first layer or off a new test glass, it is possible to generate relatively large errors in instrument gain. For instance, if an actual reflectance of 8.1% is taken as 8.0% during calibration, then a percentage gain error of +1.25% will result. To simulate this condition, a figure can be entered in the photometric gain error edit box. A value of 1.25% means a random gain error of up to +/- 1.25% will be introduced on the first layer and on every subsequent test glass change.

10.4.3. Photometric Offset

Entering a value of say 2 in this edit box, will cause a random photometric offset up to the value of +/- 2 %R or %T to be added to the simulated signal at every test glass change. Provided the instrument is operating within its dynamic range energy-wise, photometric errors are not a significant source of error.

10.4.4. Time Cut Error

Time Cut Error is only applied to layers where the CutUsing parameter is set to Time or Manual. If your project has all layers cut using the optical monitor then this noise factor can be left at zero or any other value; its value will have no effect.

In the majority of cases where this factor is used, it will be to simulate the error obtained when using a crystal controller to cut a particular layer.

If you know the error range that you would expect to achieve with your particular crystal controller, then enter that value. In the absence of this knowledge then a value of 2 to 3% would be a good starting point.

> **HINT:** It is quite easy to simulate a project using only a crystal controller by replacing all values in the CutUsing column in the FilmBuilder window with TIME, pressing Run Model and then running FilmSimulator.

10.4.5. Detector Noise Model

The Detector Noise Model box cannot be edited from within FilmSimulator, it is purely present to indicate the Detector Type entered into the Detector Setup section of the Ribbon menu.

10.4.6. Wavelength Setpoint Error

The Wavelength Setpoint Error reflects the uncertainty in setting the wavelength each time the wavelength is changed. Each system is calibrated at the factory against wavelength standards, and then all wavelengths are indexed using stepper motors. For this reason the wavelength reproducibility of each detector module is extremely high. However, if we take a worst case scenario as the wavelength having an error of half a stepper motor step then this gives recommended Wavelength Setpoint Errors of;

Detector Type	Wavelength Setpoint Error (nm)
IL551	0.12
IL552	0.18

IL553	0.25
IL555	0.37

If your detector module type is not listed above then contact Intellemetrics for guidance.

10.4.7. Bandwidth

The Bandwidth (nm) parameter represents the bandwidth of the detector module. Again the values used depend mainly on the detector module model as shown below;

Detector Type	Bandwidth (nm)
IL551	2.2
IL552	3.3
IL553	4.3
IL555	6.4

If your detector module type is not listed above then contact Intellemetrics for guidance.

10.5. Running Simulations

The Run section of the FilmSimulator window is shown on the right.

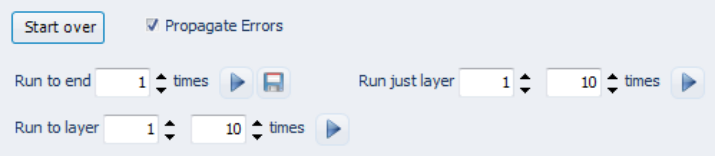

Figure 10-5 The Run section.

The Propagate Errors tickbox is ticked by default. This indicates that the final thickness for layer 1, including its thickness error, will be used as the starting condition to build layer 2 on, and so on through the film stack. In this way the effect of errors propagates in a realistic way through the filmstack, reflecting what will happen during the coating process. In the vast majority of cases users will want to leave this box ticked.

As previously described, the START OVER button populates the Characteristic graph with the theoretical trace (shown in green). Pressing the START OVER button again will clear the graph and replot the characteristic with any new parameter values that have been entered.

10.5.1. Run To End

The pressing the blue arrow to the right hand side of the Run to End box will perform a simulation through the whole filmstack. Increasing the number in the Run to End box will correspondingly increase the number of simulations performed. The graph below shows the state of the graphs after 10 simulations have been run.

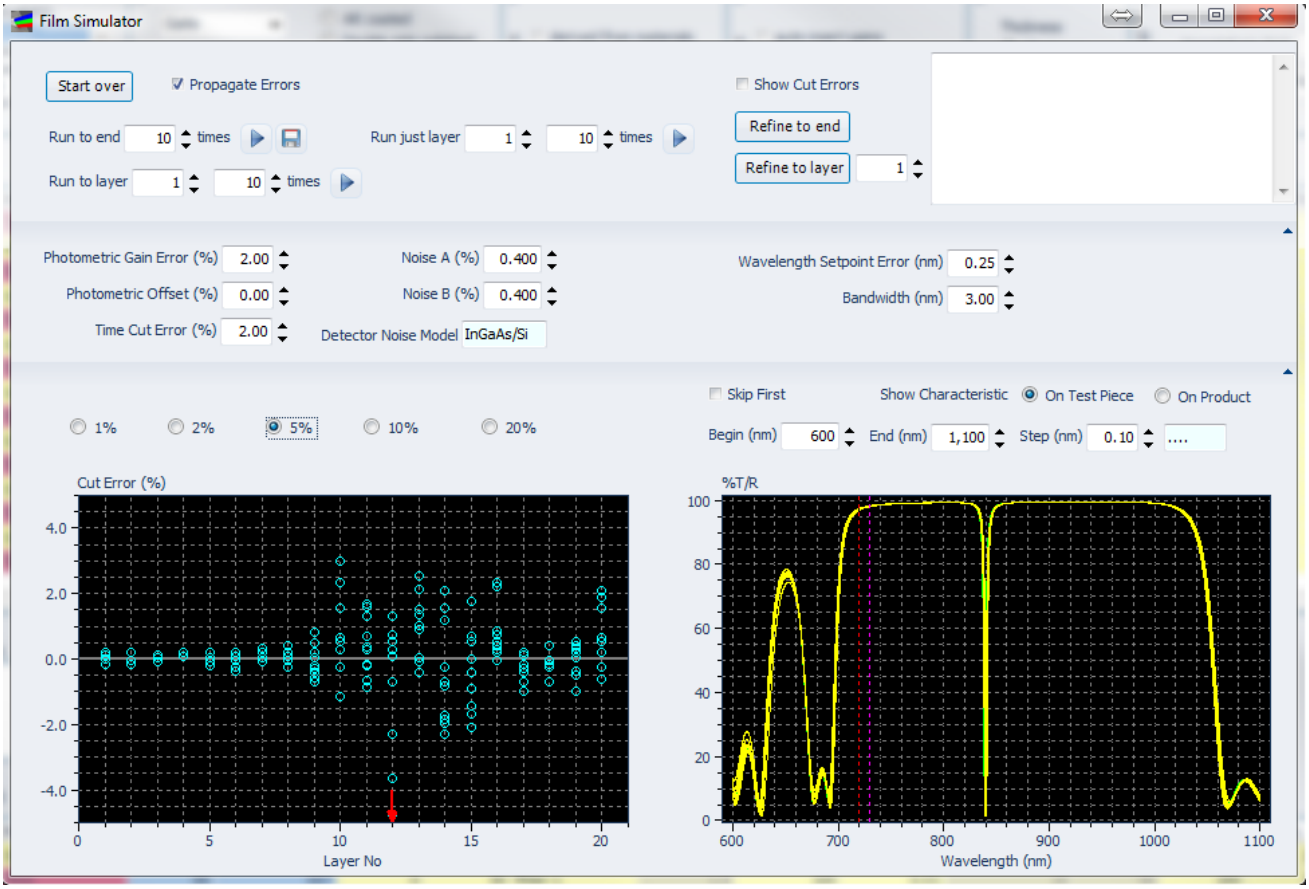

Figure 10-6 Running 10 Simulations.

The main points to note are;

- *The Run to End value has been set to 10 times and the blue arrow has been pressed.*
- *The fact that the noise parameters have non-zero values means that each run will be slightly different.*
- *The Cut Error graph has been populated with the layer errors for all ten runs. This not only shows you the magnitude of the errors on a layer by layer basis, but also the spread in errors between the various layers.*
- *The Cut Error graph has a red arrow on layer 12 pointing to the lower axis. This indicates that at least one of the data points for this layer is below -5%. Changing the full scale progressively to 10% and then 20% may show the outlier.*
- *The Characteristics graph is now populated with the original design trace (in green) as well as the result of the ten simulation runs (in yellow). These runs can be seen more clearly using one of the zoom functions as in the image on the right.*

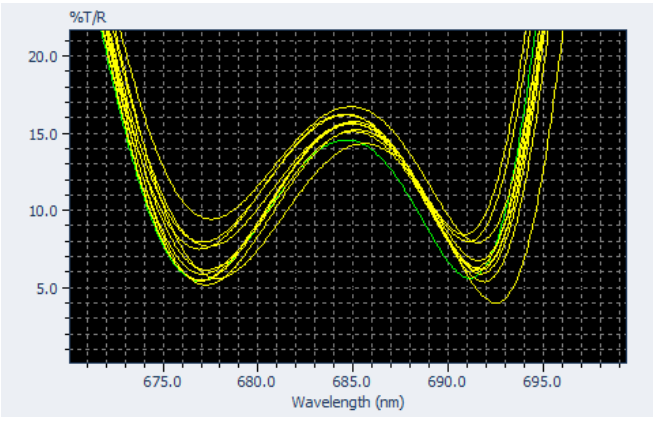

Figure 10-7 Zoomed region showing the target (green trace) and the 10 Simulations (yellow traces).

Pressing the blue arrow to the side of Run to End will superimpose another 10 simulations on the graphs. Pressing START OVER will clear the simulations.

Two other Run To options are given, namely Run To Layer and Run Just Layer. These are usually used for debugging a process.

10.5.2. Run To Layer

Let's assume that you have a 48 layer project and simulations are indicating an unacceptable mismatch between the target characteristic and the simulated characteristics. You note that layers 1 to 6 have small and reproducible errors but layer 7 has large errors.

Selecting Run To Layer 7 10 times will result in the full simulation, including propagation of errors occurring for the first 7 layers, with all subsequent layers assumed to be 'perfect', i.e. the same as the design thicknesses.

This is a quick way to probe the effects of various layers on the overall characteristics of the resultant film stack.

10.5.3. Run Just Layer

Using the above example, but selecting Run Just Layer 7 10 times will result in just layer 7 being simulated 10 times. The Cut Error plot will show the distribution of errors on that layer assuming that all preceding layers are 'perfect' i.e. the design thicknesses.

10.6. Saving Data

The Cut Error and Characteristic graphs can be saved to the clipboard by placing the cursor within one of the graphs, pressing the right mouse button and selecting Copy To Clipboard from the drop down menu.

It is also possible to save the data contained within the Cut Error plot by pressing the floppy disk icon to the left of the Run To End section, as shown in the figure to the right. The data is saved in a CSV (comma separated variable) format and can be opened in Microsoft Excel or a similar package. An example Cut Error output from 5 simulations of a 10 layer project can be seen below.

Figure 10-8 Saving the Cut Error data.

	A	B	C	D	E	F
1	Layer	Run 1	Run 2	Run 3	Run 4	Run 5
2	1	0.128594	-0.14667	0.128594	-0.00904	-0.00904
3	2	-0.03278	0.19262	-0.03278	0.19262	-0.03278
4	3	-0.07786	-0.07786	0.059777	-0.21549	0.128594
5	4	0.19262	0.079918	0.079918	0.079918	0.079918
6	5	-0.07786	0.059777	0.335045	0.197411	-0.07786
7	6	0.530728	0.079918	0.079918	0.079918	0.418026
8	7	-0.28431	-0.07786	0.197411	0.335045	-0.07786
9	8	-0.03278	0.079918	0.079918	-0.03278	0.079918
10	9	0.472678	-0.55958	0.747946	-0.07786	0.059777
11	10	1.094241	1.657754	-0.14549	0.19262	3.122888

Figure 10-9 Cut Error data format.

The values in cells B2 to F11 are the cut errors for each layer and each run expressed as a percentage of each film thickness.

The Cut Error output can be used to feed into 3rd party design software to recreate the simulated layer stacks allowing further investigation of the film stack properties.

11. FilmReviewer

11.1. FilmReviewer Overview

FilmReviewer is used after you have monitored an actual run and logged run data using FilmDirector. It is designed to allow you to analyse the raw data that was obtained for each layer during the run. This is useful for QA purposes, but also when setting up new materials etc.

FilmReviewer also allows you to select any particular layer, and then to change the monitoring parameters (such as filtering etc) and rerun that layer using the already collected raw data. This allows you to optimise many of the important optical monitoring parameters found in the FilmBuilder window. Once you are happy with the values you have tried, then it is easy to enter these into the relevant parts of the FilmBuilder window, thereby optimising future deposition runs based on real run data obtained.

You can open FilmReviewer in one of the following ways;

- *From the top line menu select File | Open | FilmReviewer.*
- *From the standard tray of icons select* 

11.2. Run Data File Location

11.2.1. On The Controller Module

During a coating run, after each layer has finished, a Run Data file (.dat) for that layer will be saved on the Controller Module. The Run Data file stores the raw data for that layer, i.e. the measured T% or R% vs time, as well as the main FilmMaker parameters for that layer (e.g. SampleRate, FilterFactor, HoldOff, Latency, etc).

The Run Data Files are automatically saved to the following location;

C:\Users\Public\Documents\Intellemetrics\FilmDirector\

The Run Data files are given the following naming scheme;

ProjectName-DateTime-LayerNo.dat

where

- *ProjectName is the FilmMaker project name*
- *DateTime is the date and time that the layer finished. This is in the following format;*

  YearMonthDayHrMin

  So 1403150942 was saved on 15th March 2014 at 9:42am.

- *LayerNo is the layer number expressed as a three digit number with preceding zeros. So 005 is layer 5 and 014 is layer 14.*

11.2.2. On Your Own PC

After a run has been completed, then you are free to transfer the saved Run Data files to any other PC running FilmMaker. FilmMaker will only search for Run Data files within the Users\Public\Documents folder, as well as any of its subfolders. Therefore it is important to copy any Run Data files to that folder or a subfolder of that folder. For simplicity we suggest you create a folder;

C:\Users\Public\Documents\Intellemetrics\FilmDirector\

to mimic the location on the Controller Module, but you are free to create other folder names if you wish.

11.3. Viewing Run Data Files

To view Run Data files do the following;

- *Press the Select Directory button and browse to the folder containing the Run Data files.*

- *The Run Data files contained in the folder will appear in the left hand text box as shown in the figure on the right.*
- *Select an individual file by clicking the left-hand mouse button on the file name. A selected file will be highlighted in blue.*
- *To select multiple files use the Shift or Control keys in combination with pressing the left-hand mouse button.*
- *Press the Load File(s) button. The image on the right shows the FilmReviewer window with the first 7 layers loaded of a narrow band filter run.*
- *To clear the graph ready for loading a different selection press the Clear Graph button.*
- *To save the contents of the graph to a CSV file press the Save As CSV button.*
- *To zoom or copy the graph window to the Windows clipboard or to a BMP file then right click the mouse within the graph window.*

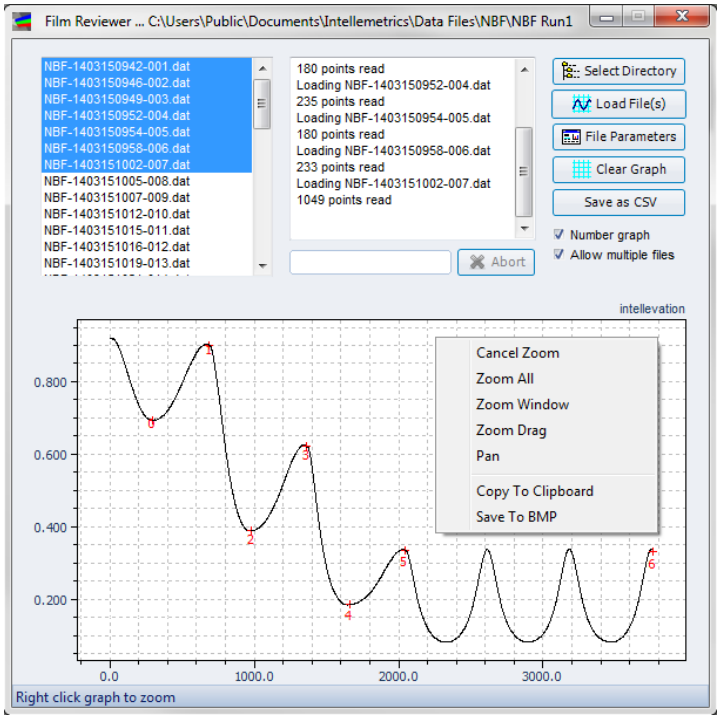

Figure 11-1 The FilmReviewer window.

11.4. Reprocessing

The section above shows you how to view the raw T% or R% run data as a function of time for single or multiple layers. However, the Run Data for each layer also contains many of the FilmMaker parameters for each layer. FilmReviewer allows you to view the layer parameters, to change the parameters, to reprocess the layer with the new parameters and to see the effect that changing the parameters has. This is therefore a powerful tool to aid with process optimisation and also to diagnose issues.

To view the FilmMaker parameters press the File Parameters button to reveal a side panel to the main FilmReviewer window as shown in the image below.

The side panel shows the parameters used with that layer. Ticking the Allow Edit box will allow you to make changes to the various parameters. Press the Reprocess button to reprocess the data using the currently displayed set of parameters.

Once you are happy with the features of the reprocessed trace then you can use the file parameters in the next iteration of the project.

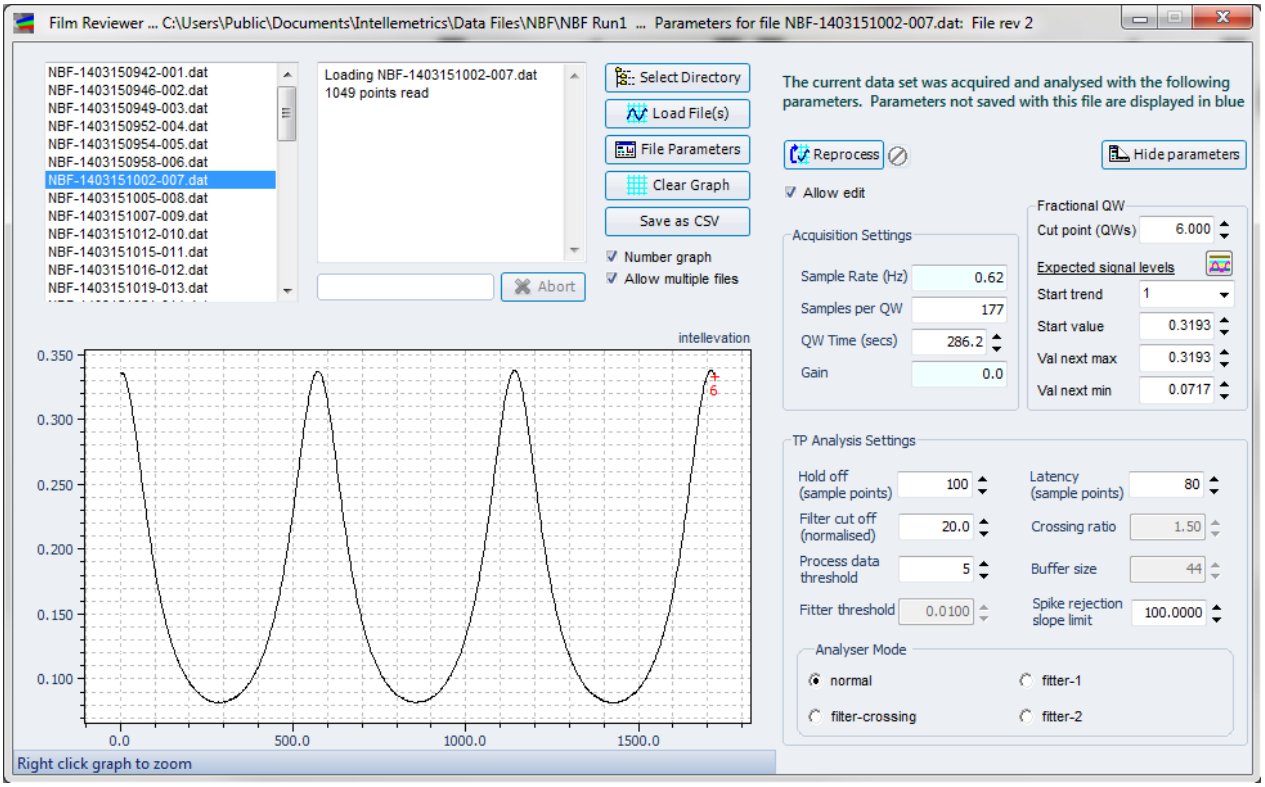

Figure 11-2 The FilmReviewer window with File Parameters selected.