OTF Studio
Thin Film Software
for Any Challenge

Design

Reverse Engineering

Characterization

Optical Monitoring

COM Interfaces

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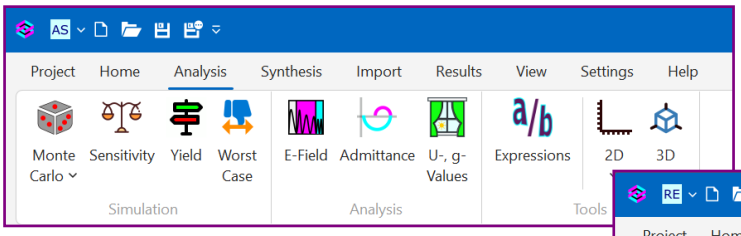
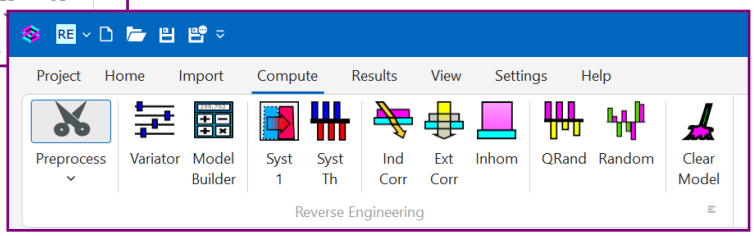
OTF Studio Thin Film Software General Description

- **OTF Studio** is a versatile and user-friendly software solution, offering powerful and efficient tools for the design, analysis, characterization, optical monitoring, and reverse engineering of multilayer optical coatings.
- **OTF Studio** is a desktop software that supports you in all numerical steps from design to production:
  - **Design** of multilayers based on your desired target specifications
  - **Evaluation** of optical multilayers
  - **Characterization** of monolayers based on spectral photometric or/and ellipsometric data
  - **Reverse engineering** of produced multilayer coatings based on spectral photometric or/and ellipsometric data
  - Automatic generation of runsheets for **optical monitoring**
- **OTF Studio** supports any spectral range, from x-rays to far infrared, as well as any angular range. Data is stored in easy-to-use project files.
- **OTF Studio** features a modern **ribbon interface** with comprehensive icons, a **customizable dash-board layout**, a powerful chart designer, and flexible **docking** for tables, panels, and plots.





Examples for ribbons: Analysis in AS (left) and Compute in RE (right).

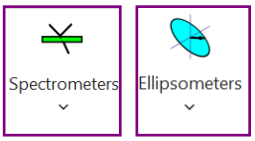
- **OTF Studio** features highly effective, powerful, and fast design algorithms. Its algorithms, based on deep search and elements of machine learning, work alongside well- established classical synthesis methods such as refinement, needle optimization, and gradual evolution.
- **OTF Studio** leverages **multi-threading** and **parallel computations** to enhance performance.
- **OTF Studio** includes original, smart, and flexible algorithms and models for the accurate determination of actual layer thicknesses and optical constants of manufactured coatings.
- **OTF Studio** calculates runsheets and automatically generates monitoring strategies.
- **OTF Studio** provides external access to nearly all algorithms and parameters through powerful COM interfaces.
- **OTF Studio** supports many file types for import and export.
- **OTF Studio** provides batch import and batch processing for large area coatings.
- **OTF Studio** supports single-sided, double-sided multilayers, and stacks.
- The software operates in four modes: AS—analysis and synthesis, CH—characterization of monolayers, RE—reverse engineering of multilayers, and OM—optical monitoring. Switching between these modes can be done via the Quick Access Toolbar or using the back-stage interface.
- **OTF Studio** provides all the tools needed to design multilayers for ultrafast laser applications.

More information: www.otfstudio.com/our-products/otfstudio

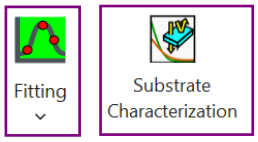
OTF Studio Capabilities

- **OTF Studio** can be used to calculate the spectral characteristics (reflectance, transmittance, phase characteristics) of multilayer coatings composed from layers of various thin film materials.
- In **OTF Studio**, you can specify desired target specifications and design multilayers with performance approximating these target specifications with high accuracy.

- **OTF Studio** harnesses general-purpose design algorithms including simple optimization (refinement), multi-start optimization, needle optimization and gradual evolution with and without deep search function, refinement with constrains, and filter design.
- **OTF Studio** can import measurement data from a wide range of spectrophotometers (Perkin Elmer, Essent Optics, Agilent, VON ARDENNE, Hitachi) and ellipsometers (Woollam, Horiba, Semilab-Sopra, Sentech). Additionally, you can import and export to Excel using a standard copy-paste interface. The measurement data can be preprocessed and combined. Batch and multi-scan measurements can be imported. Drag & Drop import.

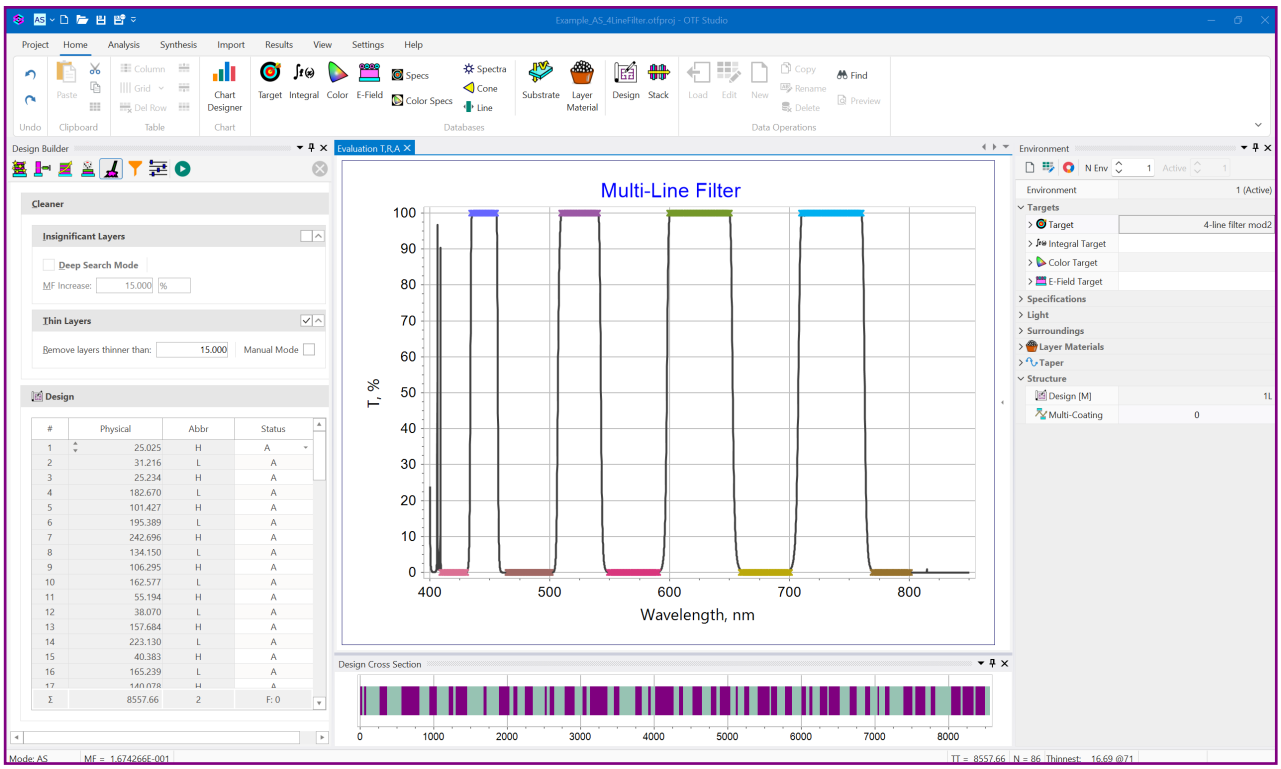


- **OTF Studio** can determine optical parameters (refractive index, extinction coefficient, inhomogeneity, deposited thickness) of monolayers based on spectral photometric/ellipsometric data, as well as perform substrate characterization.



- **OTF Studio** features a modern Reverse Engineering Model Builder for post-production characterization of multilayer coatings. The goal is to reliably determine the actual parameters of deposited layers. Its flexible interface and unparalleled numerical efficiency enable reverse engineering results in fractions of a second, or in complex cases, within several seconds.

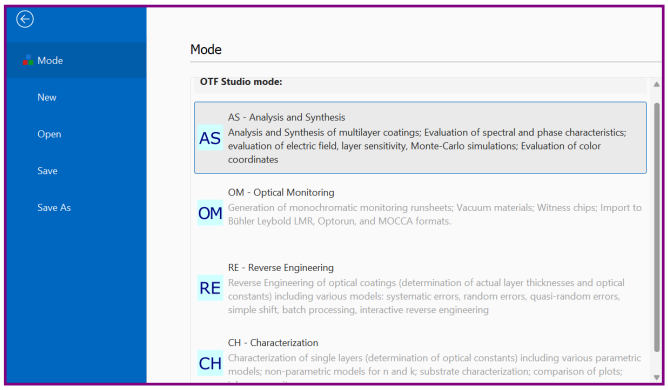
- In **OTF Studio**, the dashboard layout is fully customizable, enabling you to organize plots, tables, and panels in a way that best suits your workflow and preferences. .



This is an example of a possible layout. In the center is an evaluation plot demonstrating the transmittance of a challenging 4-line filter, which can be easily designed using **OTF Studio**.

Modern Interface

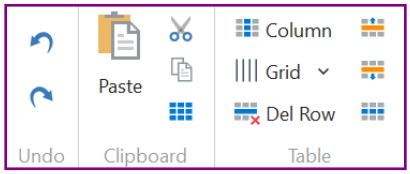
- **Project management** using standard operations (New, Open, Save, Save as) available via the Quick Access Toolbar or a back-stage interface.



Back-stage interface.

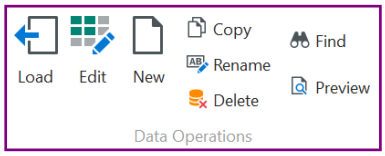
- Modern **ribbon interface** with comprehensive icons and **docking technology** for plots and panels.
- **Hotkeys** for commonly used operations.

- Easy table editing.



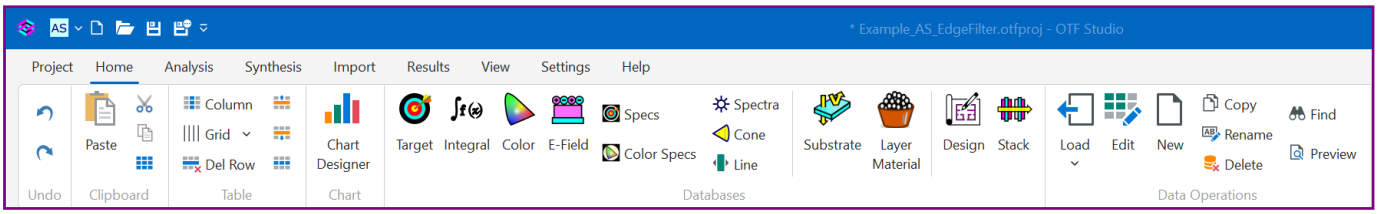
Grid/table editor.

- Standard operations for all elements (designs, measurements, etc.) - New, Delete, Load, Edit, Rename, Copy, and Preview.



Standard operations.

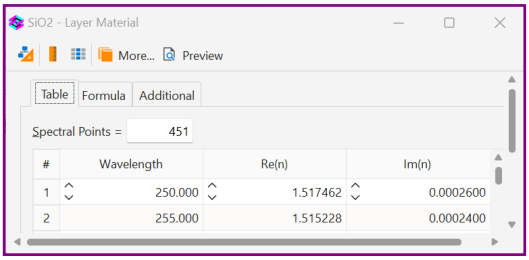
- **In-Memory Editor** allows editing designs, targets, etc. loaded to the memory.



Home ribbon of analysis and synthesis (AS) mode.

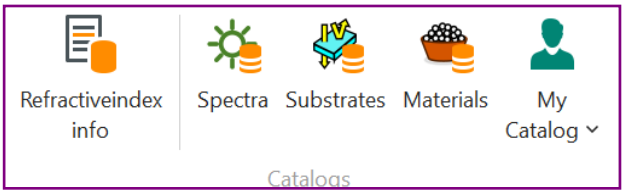
Materials and Design Structures

- Dispersion of optical constants can be specified by tables or formulas.



Example of a material dispersion table.

- **Own catalog** feature.
- Optical constants can be imported from RefractiveIndex.INFO using two clicks.



Import of optical constants and spectra: tabs on the ribbon.

- Layers can be homogeneous, inhomogeneous, mixtures, and composite.
- **Light sources, detectors** can be taken from a catalog or created by you. **Blackbody** illuminants can be created automatically.
- Centralized settings for layer materials.

	Material		Roles		Look
#	Name	Abbr	Needle	GE	Style, Colors
1	TiO2	TIO2	Active	☑	
2	SiO2	SIO2	Active	☑	
3	MgF2	MGF2	Inactive	☐	

Example of the centralized settings of layer materials.

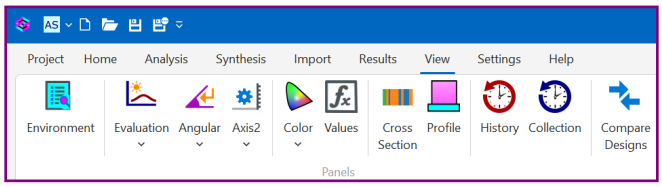
- Designs can be specified as tables or as formulas such as:

$$(\mathrm{aH\ bL})^{n} @ \lambda_1 (\mathrm{cH\ dL})^{m} @ \lambda_2 \ldots$$

- Layers can be set by physical thicknesses and quarter-wave optical thicknesses. Adjustment at incidence angle is possible.

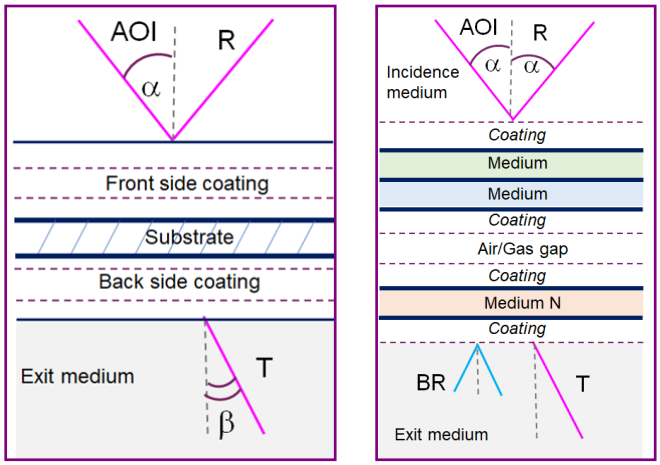
Analysis Options

- **Evaluation** of front- and back-side reflectance, transmittance, absorptance, and phase characteristics.



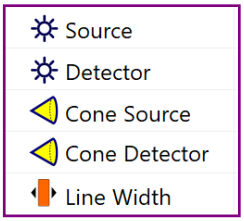
View ribbon in analysis and synthesis mode (AS).

- **OTF Studio** considers one-side, double-side structures as well as stacks.

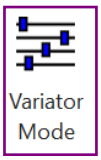


Schematic of a double-sided coating (left) and a stack (right).

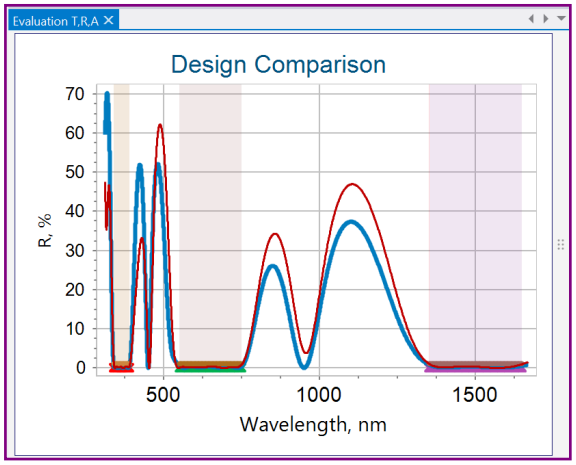
- **OTF Studio** can perform computations taking light source, detector, line width, or cone angles into account.



- **Interactive analysis** (Variator mode) instantly shows how optical parameters of individual layers or groups of layers affect spectral performance, color, electric field, and integral values.



- Spectral characteristics of designs can be compared in one plot.

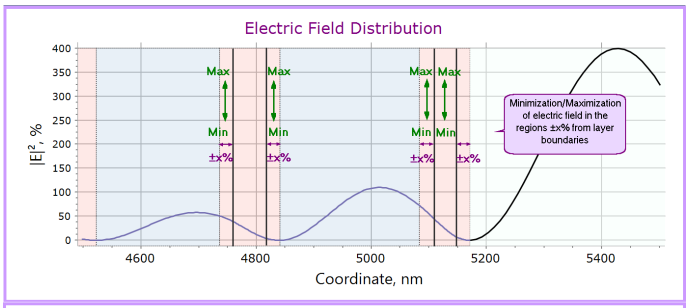


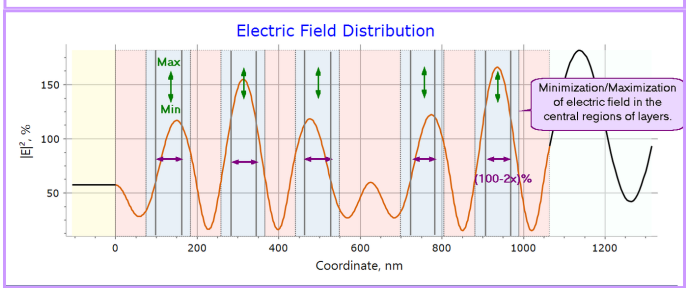
Example: Comparison of reflectance curves of two designs.

- **Monte-Carlo** of spectral, color, integral characteristics and electric field estimates design stability to thickness errors as well as to refractive index offsets. **Yield analysis** and **Worst case scenario.**
- Evaluation of layer sensitivity.
- **Admittance**.

Electric Field

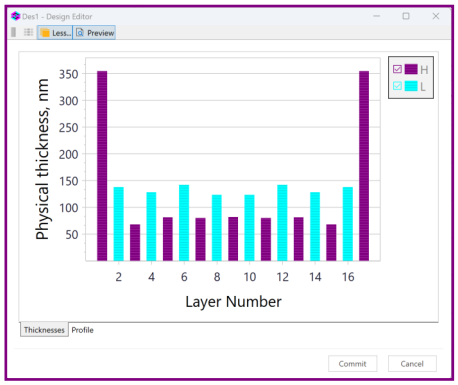
- **OTF Studio** can evaluate **amplitude** and **phase** of the **electric field**. The calculations can be performed for specified incidence angles, wavelengths, and polarizations.
- **OTF Studio** provides flexible algorithms to optimize electric field distribution within multilayer coatings. It is possible to **minimize/maximize field intensity near layer boundaries or in the central part of layers.**
- **3D plots** allows you to display dependence of electric field distribution on two parameters, for example, coating coordinate and the wavelength or AOI.





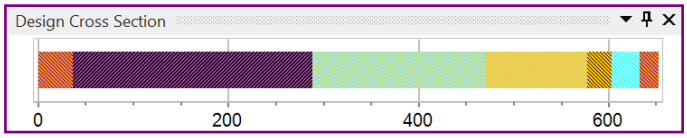
Plots and Diagrams

- **Design structure** as a diagram and a profile as well as Design Cross Section with a hover.



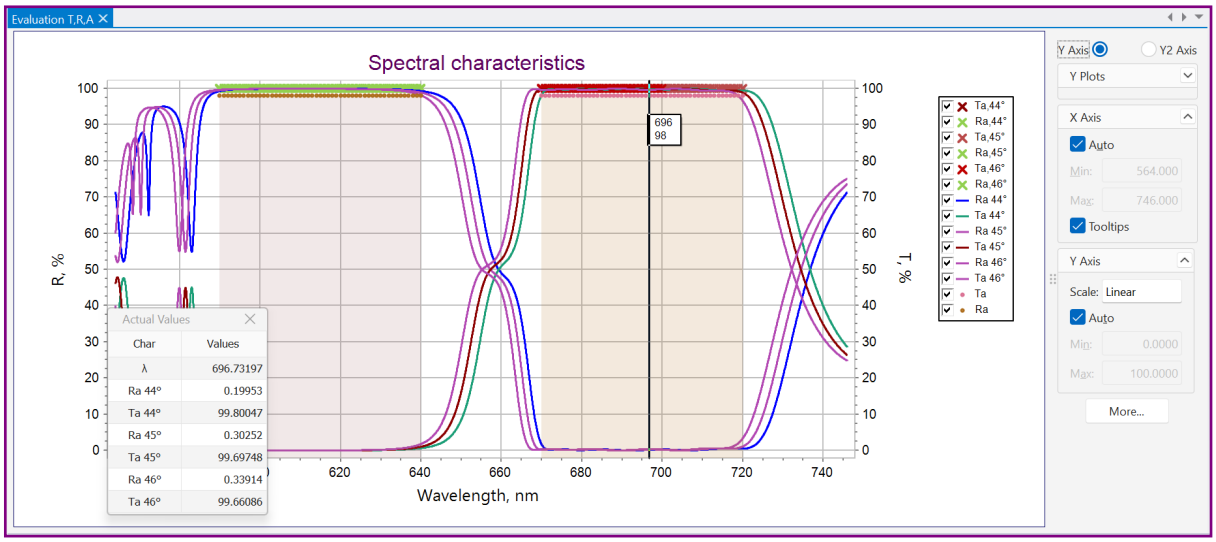
Example of a design structure.

- The design table is shown during synthesis; the thinnest layer and the total thicknesses of separate materials are displayed. .
- Design thicknesses can be represented in physical thicknesses, optical thicknesses, and quarter-wave thicknesses.



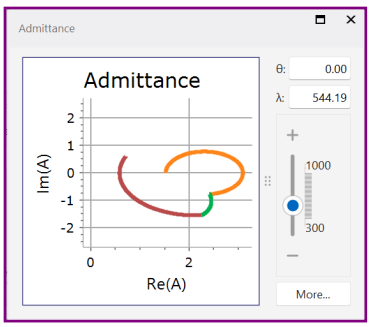
Example of a design cross section.

- Spectral characteristics can be represented in absolute units, in percentage, in dB scale, in Diabatic scale, logarithmic scale, and as the optical density.
- **Multiple evaluation plots** can be operated and adapted to different spectral ranges, angles of incidence , spectral characteristics, and Y-axis settings.
- Informative **tooltips** for all characteristics on the plot; a **second Y-axis** can be added.

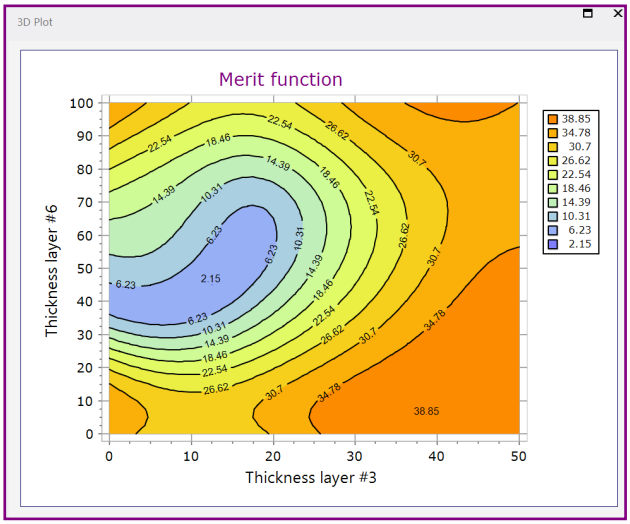


Evaluation plot with opened sliding configuration panel.

- **2D** and **3D plots** (surface and contour).
- **Angular plots** of spectral characteristics.
- Clipboard export of evaluated characteristics to Excel.
- Zoom in and zoom out of plots.



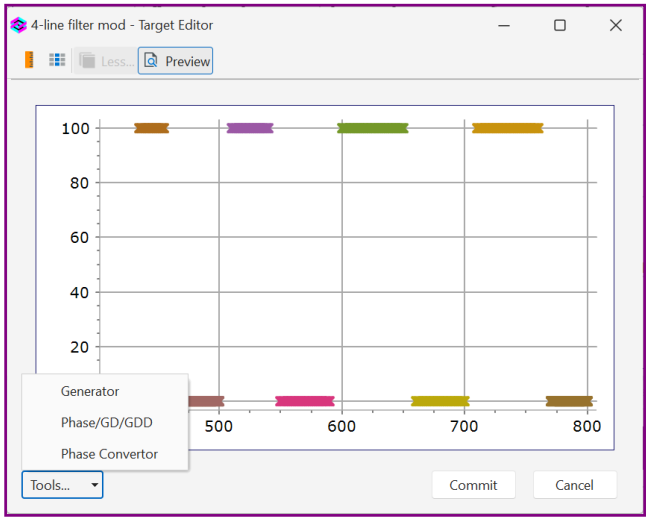
Interactive admittance diagram.



Example of a 3D contour plot.

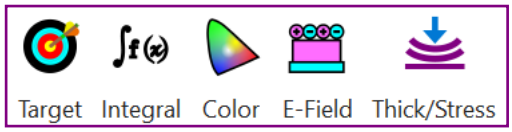
Optimization Targets and Design Algorithms

- Flexible target definition using a **generator of grid points** or a **column editor**.



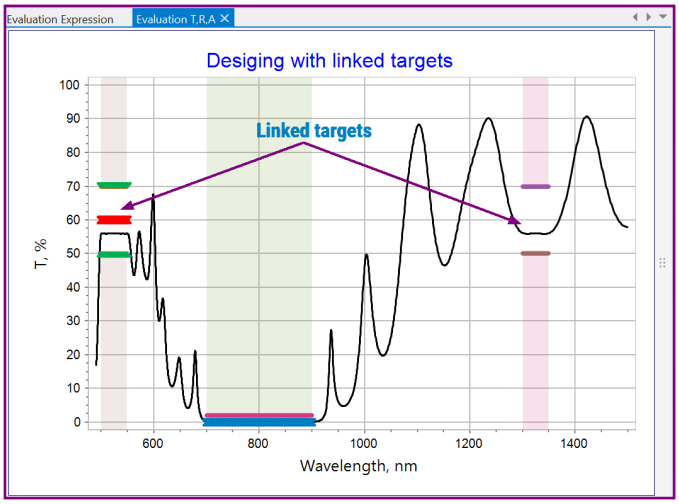
Example of a 4-line filter target specifications.

- Target spectral characteristics: R, T, BR at different AOI, for s-, p- , and random polarizations.
- Phase shifts on R, T, BR, differential phase shifts on R, T, BR (s- and p-polarizations).



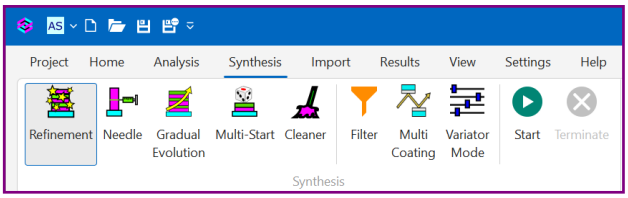
Available types of targets and specifications.

- **Spectral, color, integral, electric field,** and **stress/thickness** targets.
- Tolerances of target values. Weighting of different targets.
- Design **specifications** and **Quality** parameter.
- Convenient **Target Generator**.



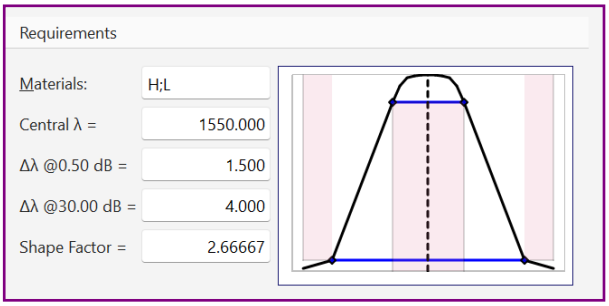
Example of application of linked expressions, conventional targets, and floating constants. Specifications are loaded.

- The **floating constants** concept enables multilayer designs with near-constant, linear, or parabolic spectral characteristics.
- **Expressions** such as Ts:Tp, Rp:Rs, and many others can be evaluated and incorporated into targets. The combinations linked and floating targets facilitates the development of multilayers with sophisticated performance.



Synthesis ribbon in the analysis and synthesis mode.

- Algorithms incorporating **deep search** and **machine learning** elements operate alongside well-established classical methods such as refinement, **needle optimization**, and **gradual evolution**.
- **Fine-tuning** includes selecting allowed materials for the design and defining their sequence.
- Refinement with constraints and groups. **Bound-Trap** feature in synthesis algorithms.
- **Multi-start** allows you to create a vast set of promising designs using adaptive strategies.
- The **Multi-Start Vicinity** approach, with varying settings, allows for exploring better solutions near existing good ones.
- Removal of thin and insignificant layer with the help of **"Smart brush"** algorithm.

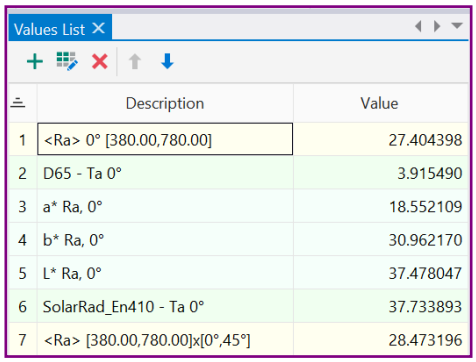


Filter specifications.

- All synthesis algorithms and settings are controlled through a single panel: **Design Builder**.
- Designing simultaneously in **different environments**.
- Special **Filter** option is aimed at designing of WDM and narrow bandpass quarter-wave multilayers.

Colors and Integrals

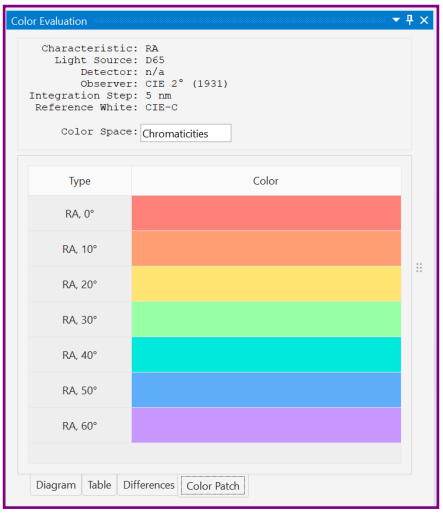
- **Integral values** can be calculated and displayed; the values update during synthesis process.
- Interactive analysis feature operates with integral values and color coordinates.



	Description	Value
1	<Ra> 0° [380.00,780.00]	27.404398
2	D65 - Ta 0°	3.915490
3	a* Ra, 0°	18.552109
4	b* Ra, 0°	30.962170
5	L* Ra, 0°	37.478047
6	SolarRad_En410 - Ta 0°	37.733893
7	<Ra> [380.00,780.00]x[0°,45°]	28.473196

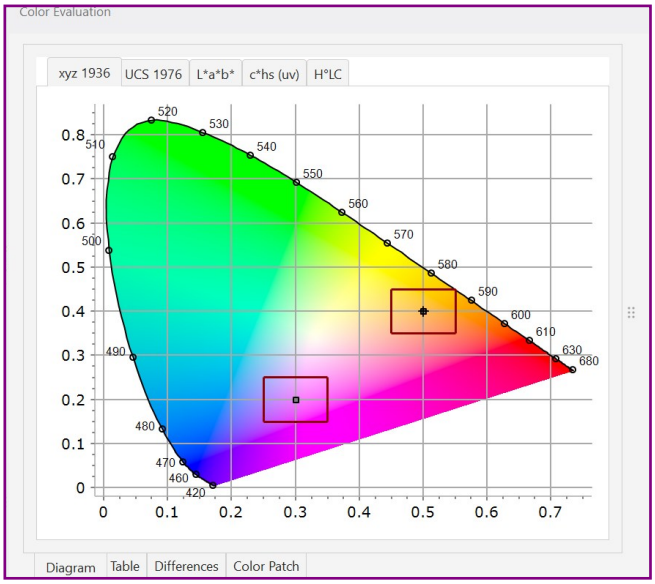
Example of a panel with various integral and color values.

- Evaluation of all integral values can be performed with and without light sources, detectors, line widths, and cone angles.



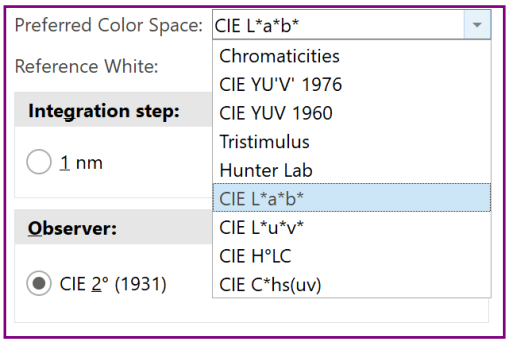
Color patch.

- Evaluation of **color coordinates** in Chromaticities, CIE L*a*b*, CIE L*u*v*, CIE H°LC, CIE YU'V' 1976, CIE YUV 1960, Tristimulus, and Hunter lab spaces.



Color diagram.

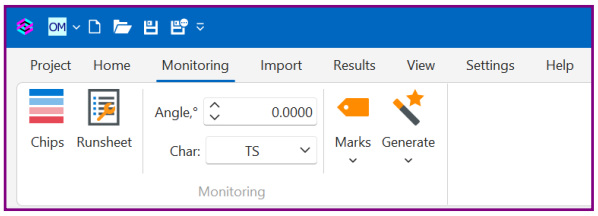
- Evaluation of **CCT, Duv**, and **Color Rendering Index**.
- Settings for reference white, integration step, and observer, color differences, color patch. **Color diagrams.**



Settings for color calculations.

Optical Monitoring

- Calculation of optical **monitoring runsheets** include signals, swing, amplitude, gain, zero, etc.
- **Automatic generation of monitoring strategies** corresponding to specified criteria.

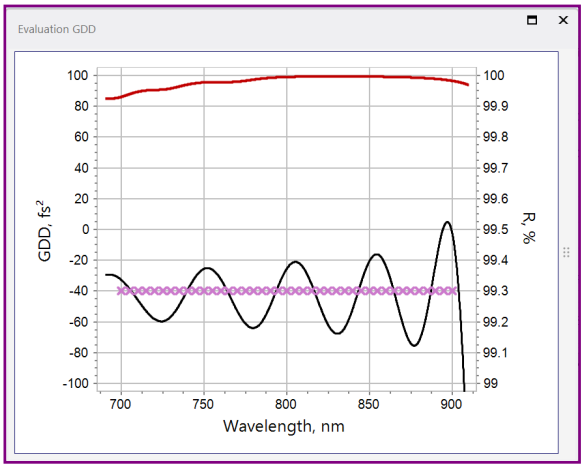


Monitoring ribbon in optical monitoring mode

- **Multiple chips,** their configuration, and tooling factors can be specified.
- **Vacuum materials** for monitoring runsheet.
- Additionally: spectral signal, 3D dependencies of signal on coating coordinate and wavelength.
- **Export of the runsheets** to various coaters (Bühler Leybold, Optorun, MOCCA, Shincron) .

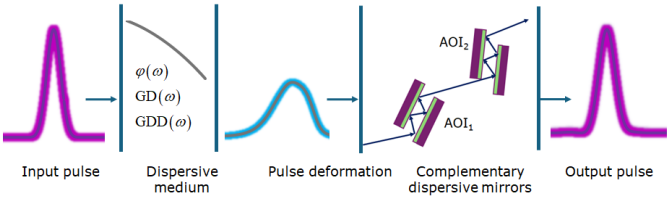
Special Design Options for Ultrafast Applications

- After propagation through dispersive media in laser systems, input pulses become broader, and their shapes deform. Dispersive mirrors allow to compress the pulses and for the compensate accumulated phase.



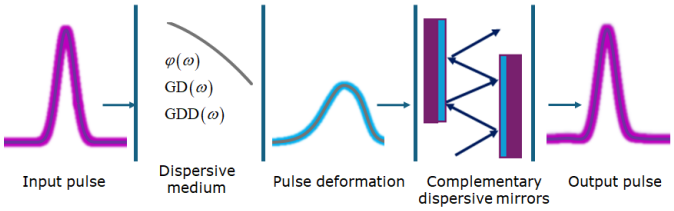
Example of high reflectance and GDD of a dispersive mirror.

- Target specifications of laser-related optical coatings encompass not only desired spectral characteristics but also phase target characteristics like group delay (GD), group delay dispersion (GDD), and phase.
- The **Floating constants** concept of **OTF Studio** streamlines designing of dispersive mirrors.

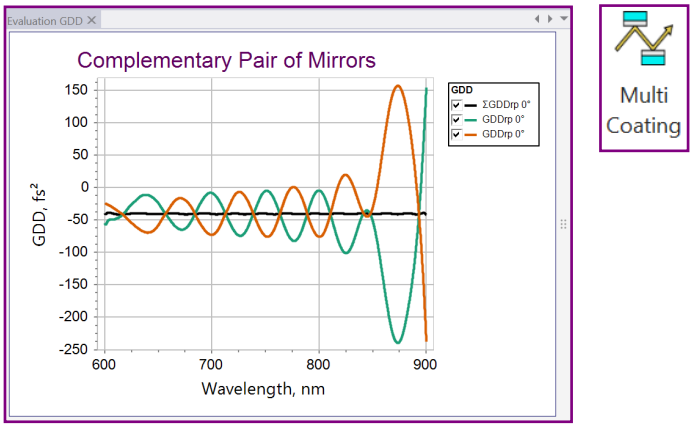


Double angle method (schematic).

- The **Multi-coating mode** has been specially developed to address complex coatings for ultrafast laser applications. In this mode you can design **complementary pairs** of dispersive mirrors or utilize the **double-angle approach**.



Complementary mirrors in a laser setup (schematic).

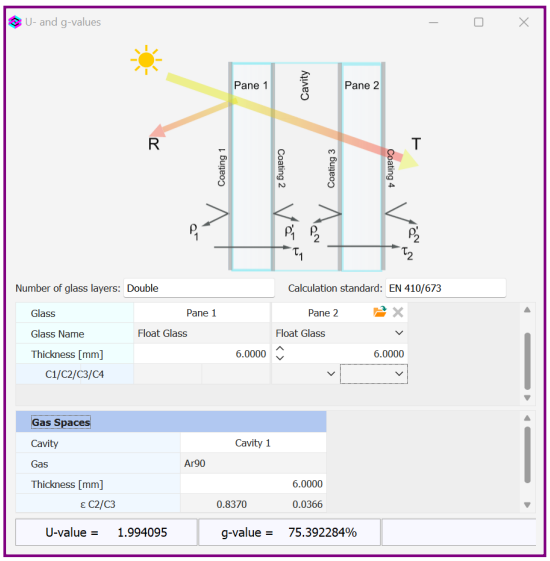


GDD of mirrors in a complementary pair.

- All optimization methods can function in **multi-coating mode.** Plots handle spectral characteristics of multiple coatings as well.
- The **Phase/GD/GDD convertor** simplifies the process by facilitation transformations between GD, GDD, and phase.

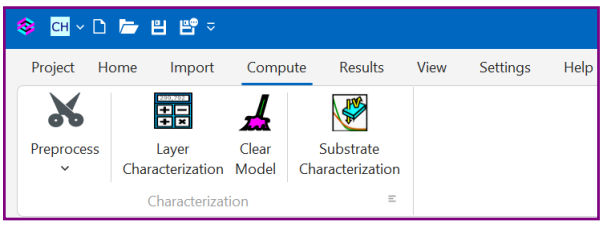
Coating for Architecture Glass

- **OTF Studio** can compute U-values, g-values, Solar Heat Gain Coefficient (SHGC), and Shading Coefficient (SC) for single, double, and triple-glazing configurations.
- The glazing-related values are automatically updated if the interactive analysis (**Variator**) is active.
- Integral values (Solar energy, Visible light, and UV) of transmittance, reflectance, and back-side reflectance of the surface coatings, as well as coating colors, can be optimized.



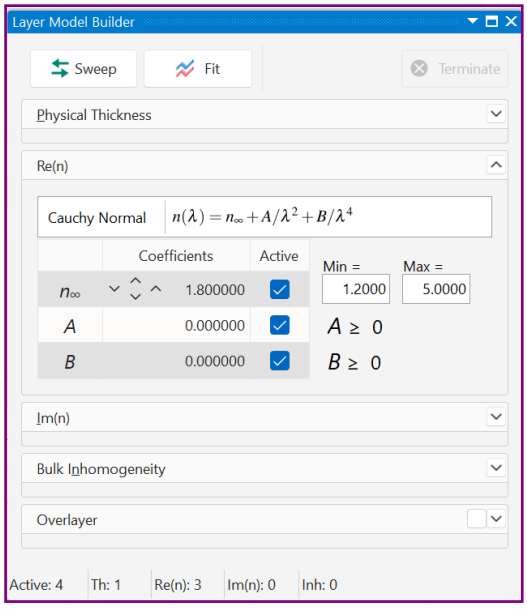
Characterization of Monolayers

- Models and algorithms for characterization of monolayers.



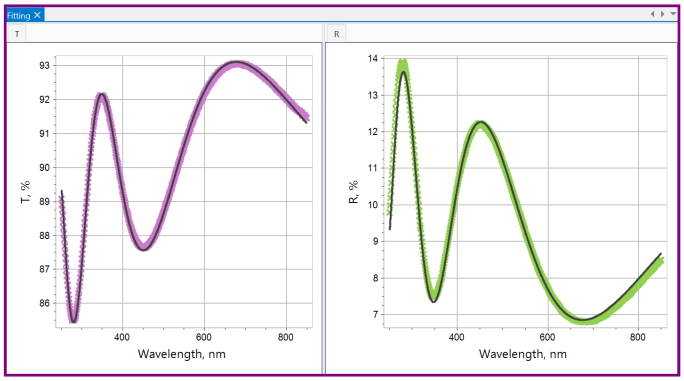
Compute ribbon in characterization mode.

- Data **fitting** plots.
- **Inhomogeneity** and **overlayers** models.
- All models for optical constants are controlled through centralized panels: **Layer Model Builder** and **Substrate Model Builder**.
- **Sweep** and **Fit** operations for layer characterization.



Layer Model Builder panel.

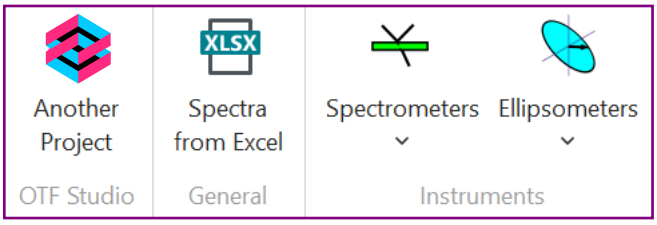
- **Flexible n-k model** for the most complex or/and broadband layer characterization problems.
- **Substrate characterization**.



Example of fitting plots.

MEASUREMENTS:

- Spectral **photometric** and **ellipsometric data**.

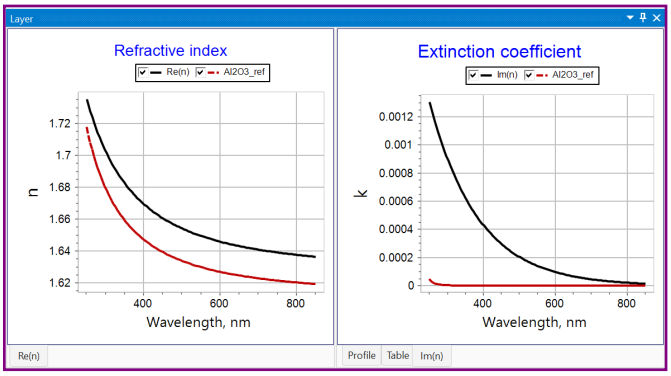


Import of measurements tabs.

- The number of points in the wavelength grid is not limited.
- Possibility to combine measurements.
- **Data preprocessing:** cutting non-informative spectral ranges, reduction of measurement points.
- **Batch import** and **batch processing** for large area depositions.

VERIFICATION TOOLS:

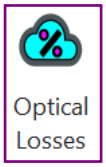
- Total optical losses.
- Plots of deviations between measurement and model data.
- Comparison of optical constants.

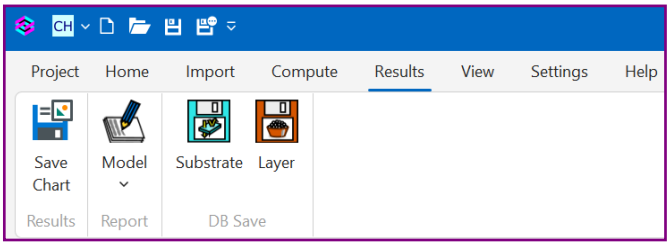


Example of comparison of optical constants.

REPORTS:

- Characterization reports.
- Saving determined optical constants, also with inhomogeneity.

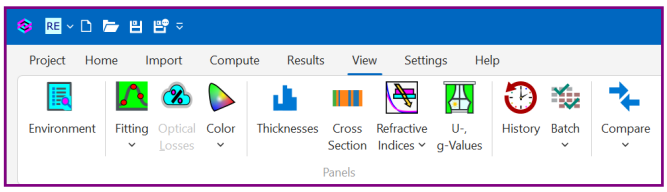




Results ribbon in characterization mode (CH).

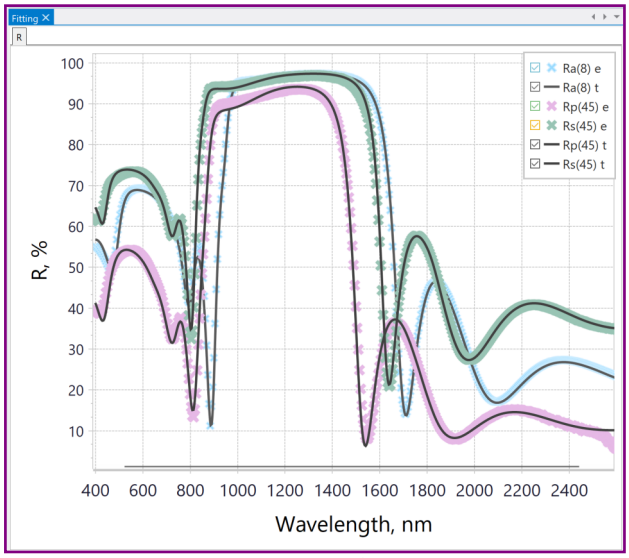
Reverse Engineering

- Coatings post-production characterization is controlled through a single panel: **Reverse Engineering Model Builder**.



View ribbon in reverse engineering mode (RE).

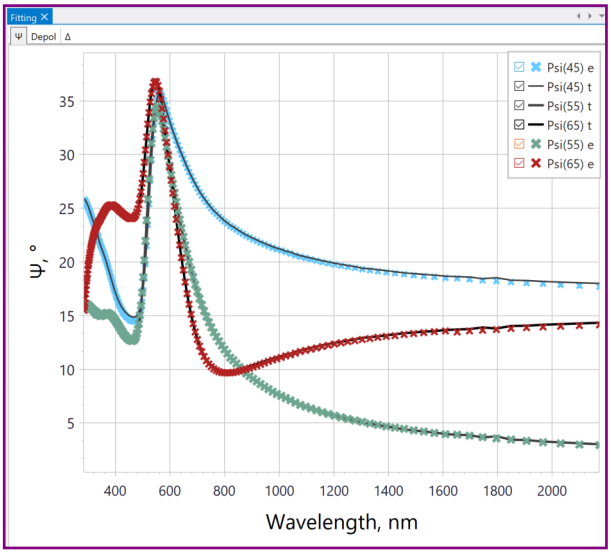
- All algorithms can be flexibly activated, combined, and applied. **Sophisticated combinations of various algorithms are possible.**



Example of achieved data fitting (multiangle spectral photometric data).

- Import and processing of **multi-scan measurements**.

- Thickness errors can be determined in the frame of systematic, random, and quasi-random errors smart algorithms.
- Combining with simultaneous optical constants determination including inhomogeneity is possible.
- Actual design structures can be stored for further use within the project. **Design Recipe** feature.
- Reverse Engineering based on **batch measurements for large area depositions**; visualization of the results.



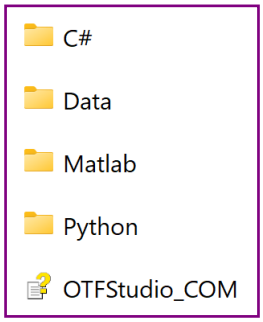
Example of a fitting plot (ellipsometric data).

- Reports in *.txt and Excel formats.
- Export to *.DSG and *.ODX formats.

Integration with external Software: COM Interfaces

- **OTF Studio** provides external access to its almost all algorithms and parameters through powerful **COM interfaces**.
- You can create your own software and call **OTF Studio** algorithms (design, analysis, reverse engineering, characterization).
- You can externally load/unload parameters (layer materials, substrates, targets, measurement data, light sources etc.)
- COM interfaces can be applied to all operations in the **multi-coating mode**.

- You can import measurement data, optical constants and create complex design/characterization/production chains.
- Installation package includes **examples on C#, Matlab**, and **Python** which demonstrate application of COM interfaces, and can be used as starting point for your programs.

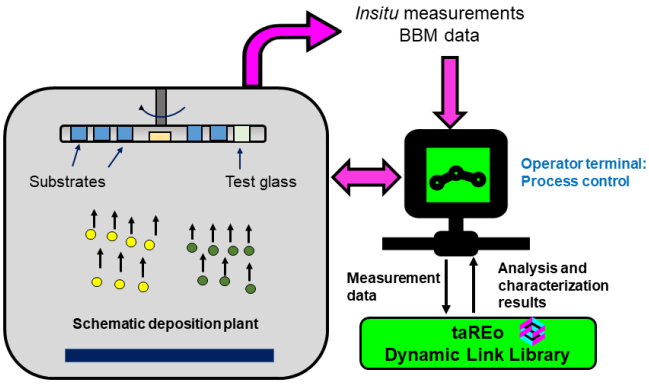


taReo: Automation of Thin Film Deposition

taReo is an advanced software tool designed to aid in the production of multilayer optical coatings in deposition chamber equipped with broadband optical monitoring (BBM). The BBM spectrometer records online transmittance or reflectance data of a sample (or a test glass) during the deposition process.

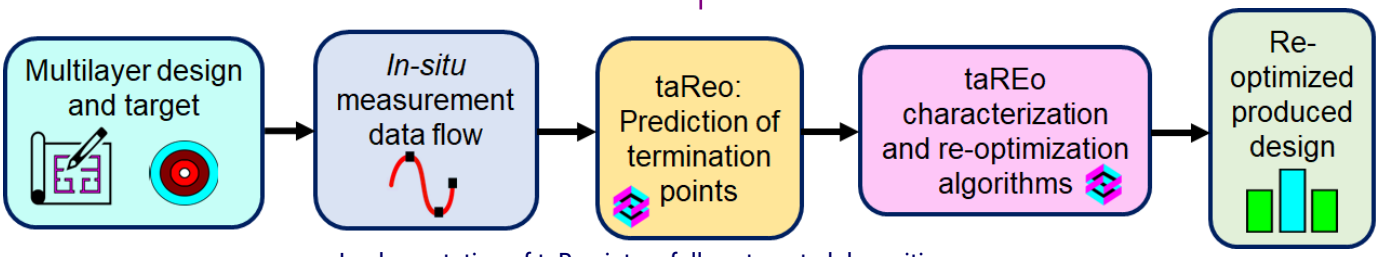
taReo algorithms can be utilized to analyze the continuous data flow of online measurements, to characterize previously deposited layers and the subsequent optimization of the remaining layers.

taReo allows you to consider the differences in refractive indices of layer materials between inline and offline measurements, which can arise from vacuum shifts, thermal shifts, and porosity effects.



Schematic of a deposition plant equipped with BBM and taReo.

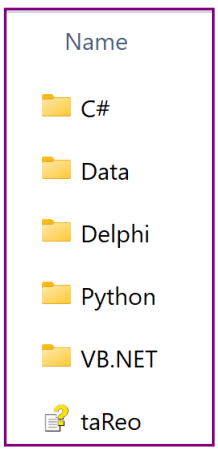
taReo supports all broadband monitoring concepts: with single monitoring substrate or with multiple chips (witness glasses).



Implementation of taReo into a fully automated deposition process.

taReo demonstrates unparalleled computational efficiency, offering several remarkable features:

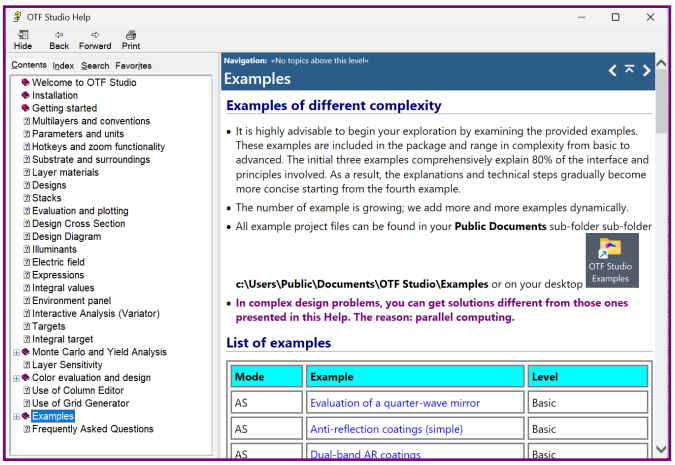
- The **computational speed is exceptionally high**, even when dealing with numerous layers. There is no need to interrupt the deposition process to re-optimize the remaining layers or obtain characterization results.
- The software allows for an **unlimited number of points in the wavelength grid**, enabling precise and detailed analysis across a wide range of wavelengths.
- There are **no limitations on the number of design layers** that can be utilized in the software. Complex coating designs can be easily accommodated.
- **taReo** can be employed to perform inline analysis of measurements and compare them with expected theoretical spectral characteristics. Through this analysis, it becomes possible to determine the appropriate termination time for layer deposition.
- **taReo** can perform **online characterization** based on inline measurement data. Based on the characterization results, deposition parameters can be adjusted and the process can be improved in order to achieve planned spectral characteristics.
- **taReo** can perform **online re-optimization** of the rest of the layers in the case when the deviations between expected theoretical characteristics and experimental characteristics grow.
- **taReo** package includes **examples on C#, Delphi, Python**, and **VB** which can be used as starting point for your own programs.



More information: https://www.otfstudio.com/our-products/tareo

Installation, Support, Development Trends

- **OTF Studio** can be easily downloaded from our website **www.otfstudio.com/downloads**.
- The installation package includes a wide range of practical examples.

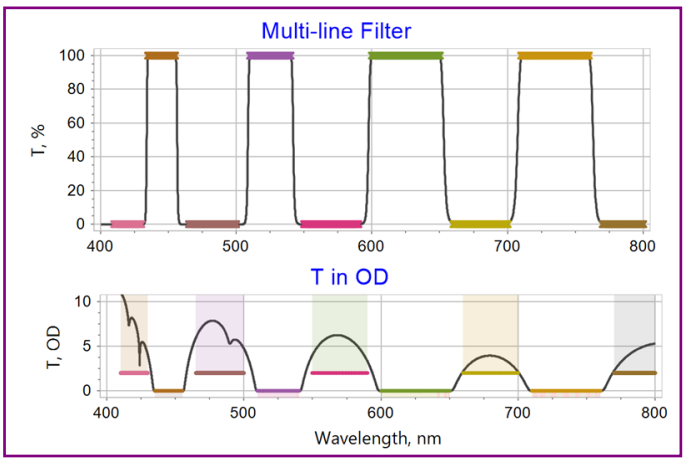


- **Continuous and rapid development of the software.**
- We welcome input and requests from our customers.
- **Workshops** and **trainings** in person and online.
- **Distribution partners** in many countries of the world.

- **OTF Studio** can synthesize multilayer with very sophisticated target specifications. Such as in this example where the silhouette of Neuschwanstein castle was used as a design target.

- E-mail and phone technical **support.**
- YouTube videos.

Hardware, Operation Systems, and Performance



Example: Multi-line filter, 410-800 nm, 0.1 nm wavelength step, 3159 target points. The merit function was 0.08. The design process takes less than 1 minute.

More information: www.otfstudio.com

- Windows 10 (at processors with Intel architecture).
- Windows 11 (at processors with Intel- and ARM-architectures).
- Apple macOS (including new M1-M4 ARM-based CPU)
- Linux-based OS (tested at Ubuntu 24.04.1 LTS)
- **OTF Studio** uses vectorization in computations.
- **Multi-monitor** configurations and **high-resolution displays** are supported.
- **Multi-threading** and **parallel** computations.

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