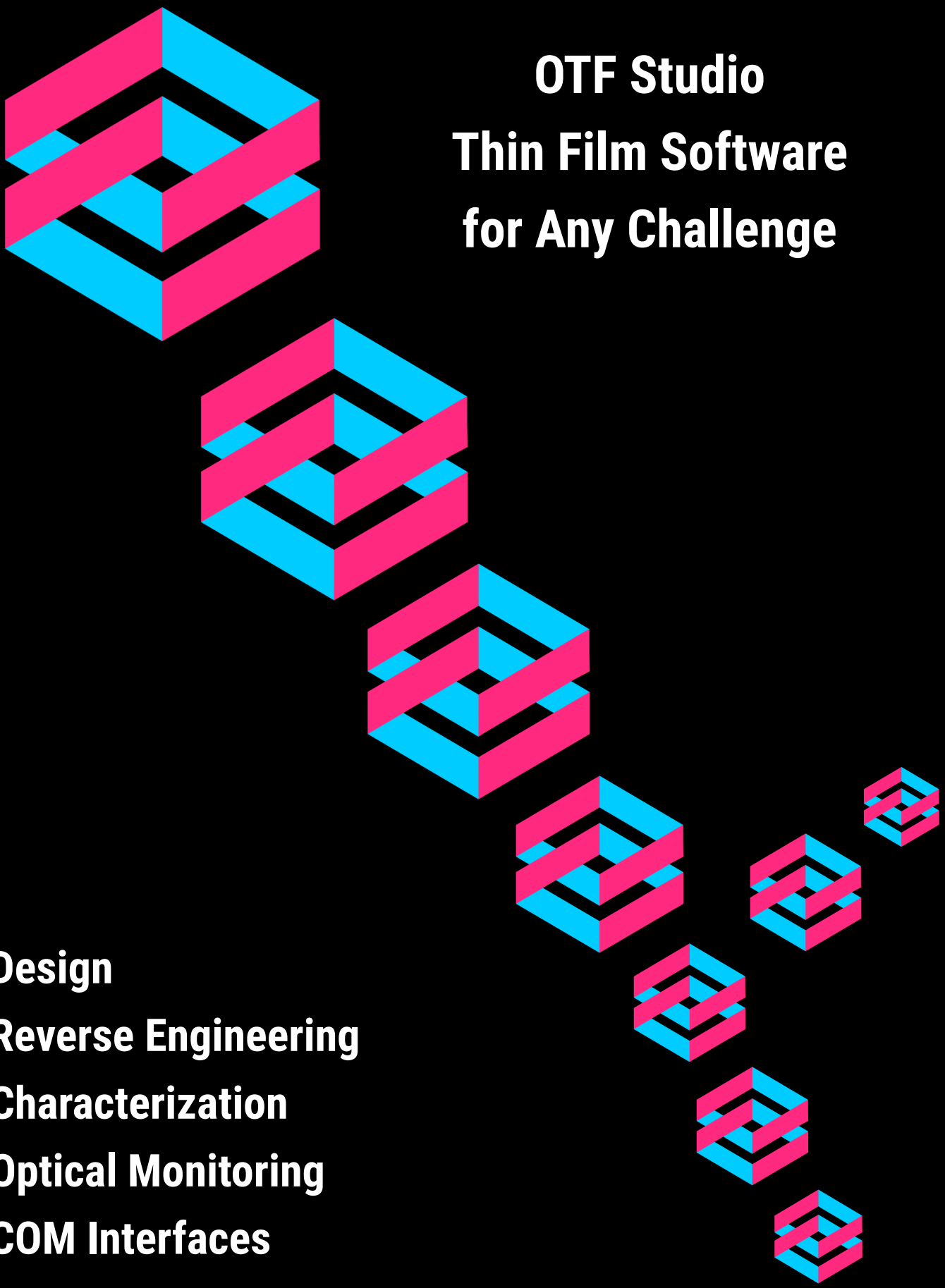
OTF Studio
Thin Film Software
for Any Challenge

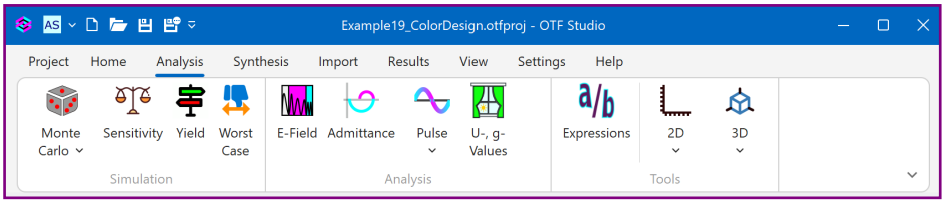


Design
Reverse Engineering
Characterization
Optical Monitoring
COM Interfaces

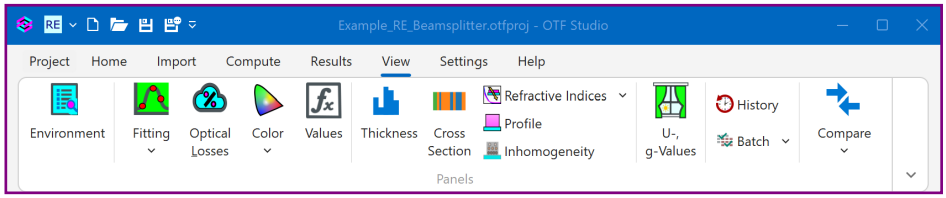
OTF Studio GmbH • Garching, Germany

OTF Studio Thin Film Software General Description

- **OTF Studio** is a comprehensive and user-friendly software that provides powerful, efficient tools supporting 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 multilayers 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 clear icons, a **customizable layout**, a fully configurable chart designer, and flexible **docking** for tables, panels, and plots.



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



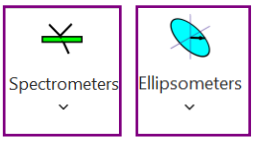
- **OTF Studio** features highly effective, powerful, and fast design algorithms. Its algorithms, based on deep search and elements of machine learning, work alongside well- established synthesis methods such as refinement, needle optimization, and gradual evolution.
- **OTF Studio** includes original, smart, and flexible algorithms and models for accurately determining the actual layer parameters of manufactured coatings.
- **OTF Studio** calculates monitoring runsheets and automatically generates monitoring strategies.
- **OTF Studio** provides external access to nearly all algorithms and parameters through powerful COM interfaces.
- **OTF Studio** supports numerous file formats for import and export.
- **OTF Studio** provides batch import and batch processing for large area coatings.
- **OTF Studio** supports single-sided, double-sided multilayers, stacks, multi-environments, and multi-coating structures.
- 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.
- **OTF Studio** supports IGU-related evaluation, optimization, and characterization features.

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

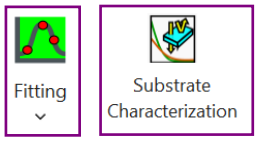
OTF Studio Capabilities

- **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 pre-processed and combined. Batch and multi-scan measurements can be imported. Drag & Drop import.

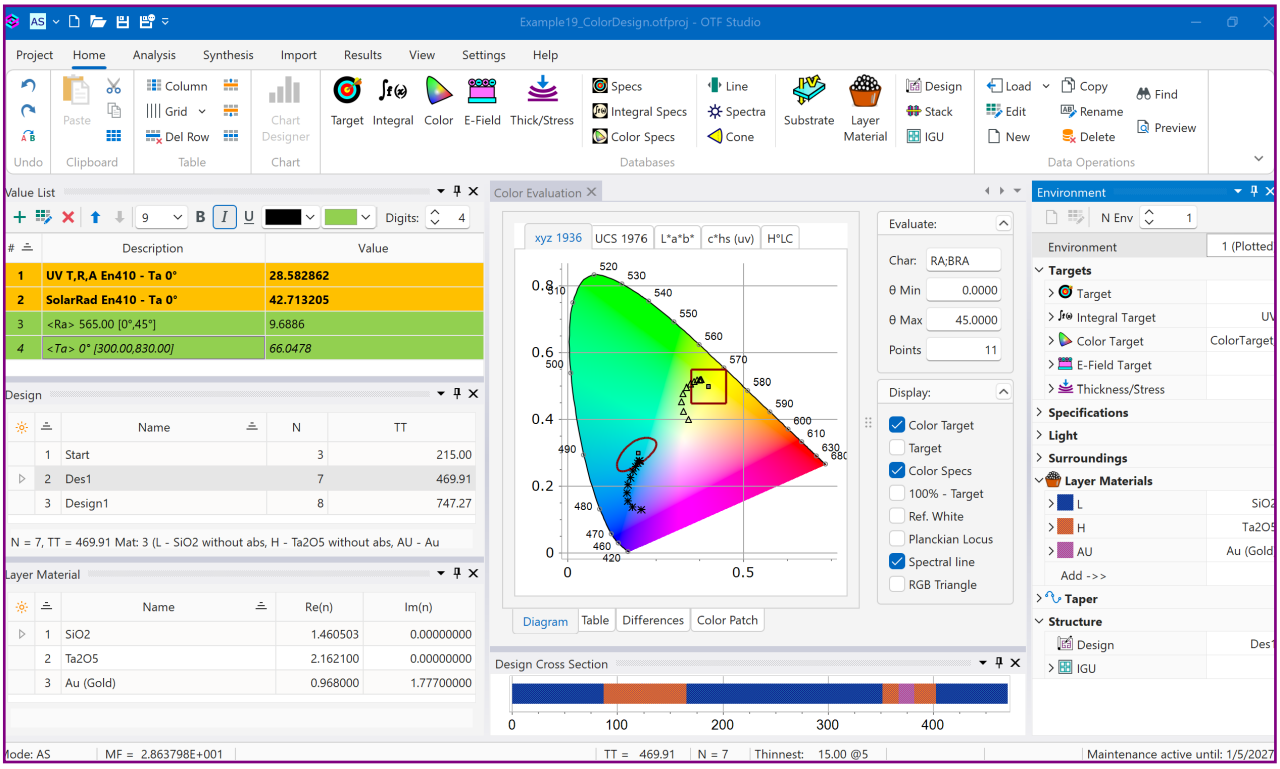


- **OTF Studio** can determine optical parameters (refractive index, extinction coefficient, inhomogeneity, deposited thickness) of monolayers based on spectral photometric/ellipsometric data, as well as perform substrate characterization.



- **OTF Studio** features a modern 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.

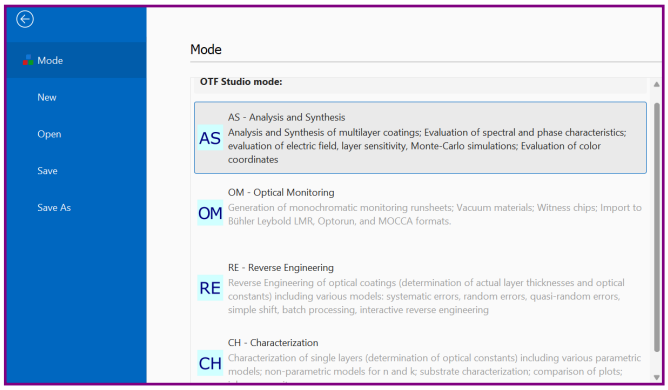
- In **OTF Studio**, the layout is fully customizable, allowing you to arrange plots, tables, and panels to suit your workflow. You can also create your own templates and layouts.



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

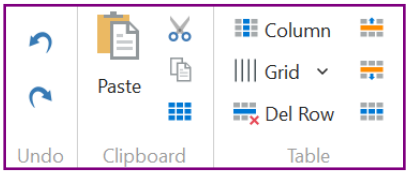
- **Project management** using standard operations (New, Open, Save, Save as) available via the Quick Access Toolbar or a back-stage interface.



Back-stage interface.

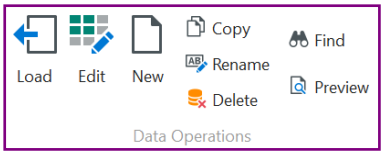
- Modern **ribbon interface** with clear icons and **docking technology** for plots and panels.
- **Hotkeys** for commonly used operations.

- Easy table editing.



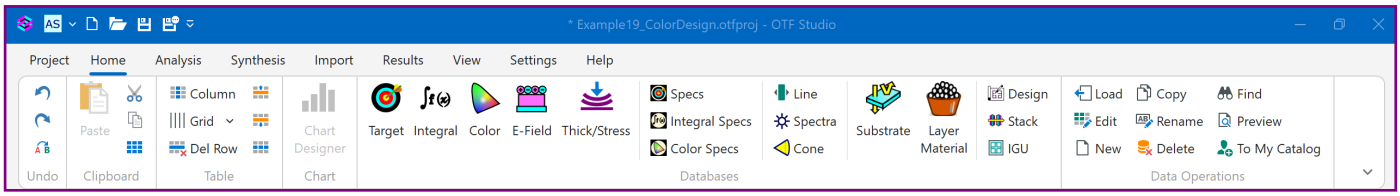
Grid/table editor.

- Standard operations for all elements - New, Delete, Load, Edit, Rename, Copy, and Preview.



Standard operations.

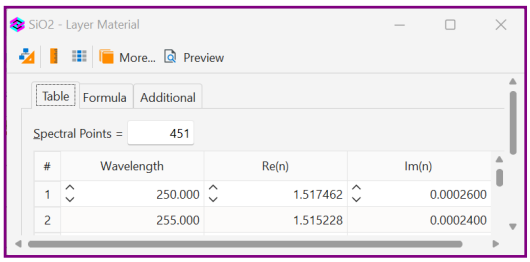
- **In-Memory Editor** allows editing designs, targets, etc. loaded to the memory.
- A dark theme is available.



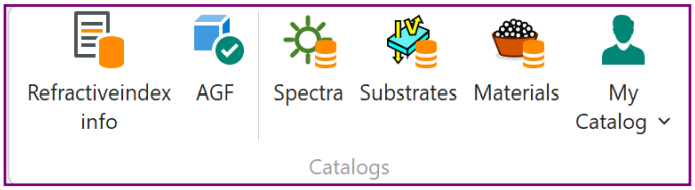
Home ribbon of analysis and synthesis (AS) mode.

Materials and Designs

- Dispersion of optical constants can be specified by tables or formulas.
- **Own catalog** feature.
- Optical constants can be imported from RefractiveIndex.INFO using two clicks.
- Import from AGF format.



Example of a material dispersion table.



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.
- Advanced materials with optical constants dependent on layer coordinate or film thickness are supported.

	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.

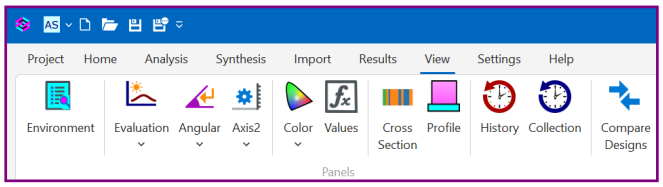
- Designs can be specified as tables or as formulas such as:

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

- Layers can be set by physical thicknesses and quarter-wave optical thicknesses.

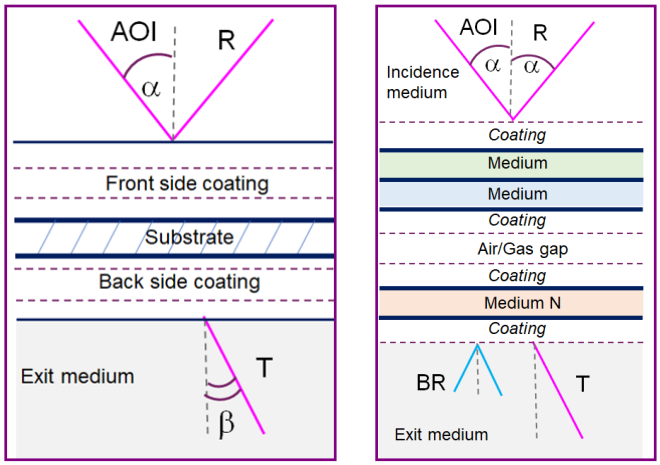
Analysis Features

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



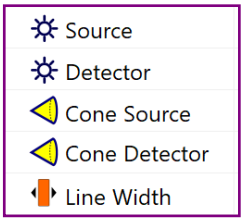
View ribbon in analysis and synthesis mode (AS).

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

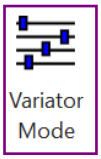


Schematic of a double-sided coating (left) and a stack (right).

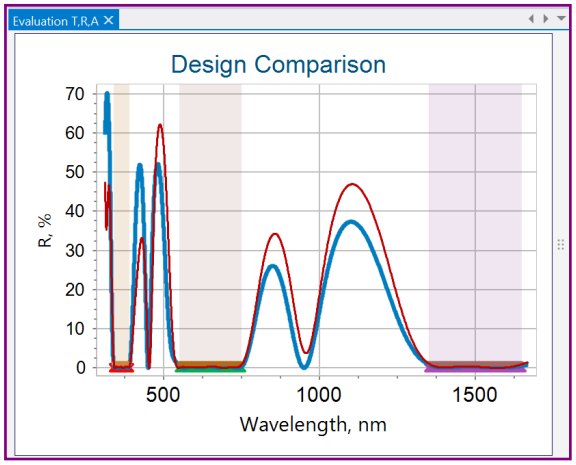
- **OTF Studio** can perform computations taking light source, detector, line width, or cone angles into account.



- **Interactive analysis** instantly shows how changes in the optical parameters of individual layers or layer groups affect spectral performance, color, electric field, and integral values. .



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

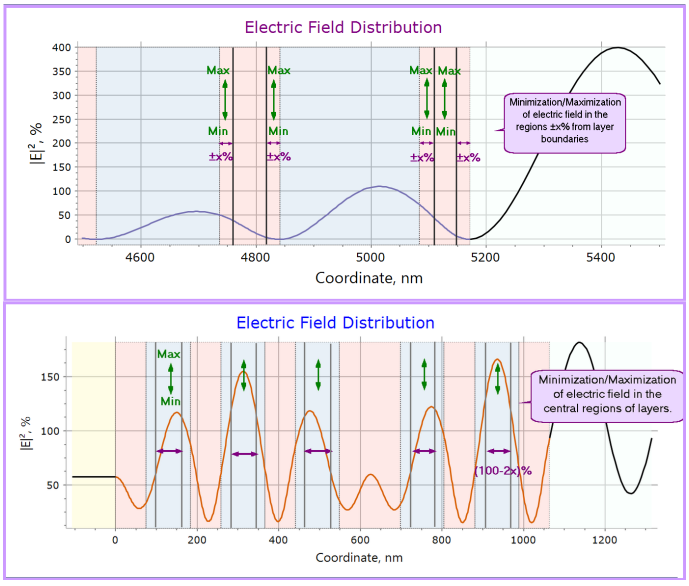


Example: Comparison of reflectance curves of two designs.

- **Monte-Carlo, Worst case, Layer Sensitivity,** and **Yield Analysis** of spectral, color, integral characteristics and electric field estimates design stability to thickness errors as well as to refractive index offsets. .
- **Admittance** diagram with Isoreflectivity.

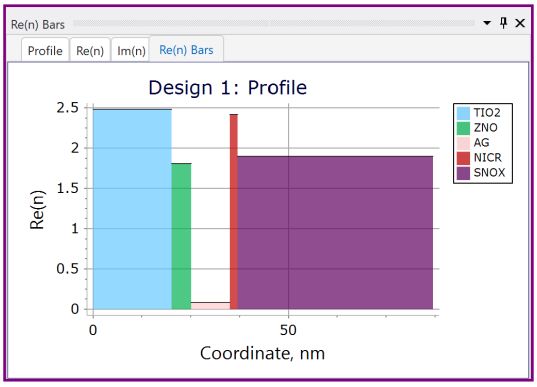
Electric Field

- **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.



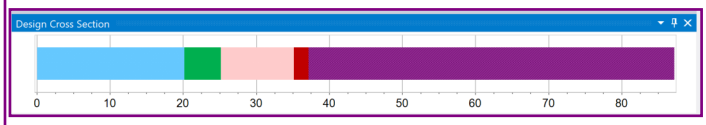
Plots and Diagrams

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



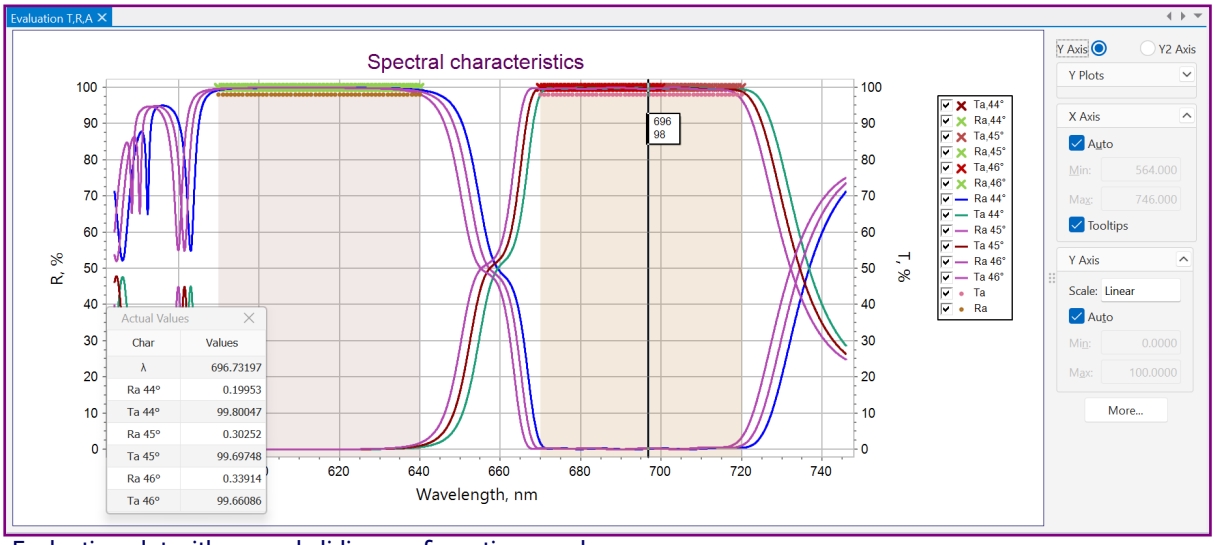
Example of a design structure.

- 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.



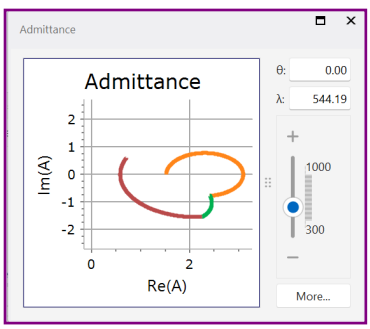
Example of a design cross section.

- 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. Simultaneous plotting in linear and OD scales is available.

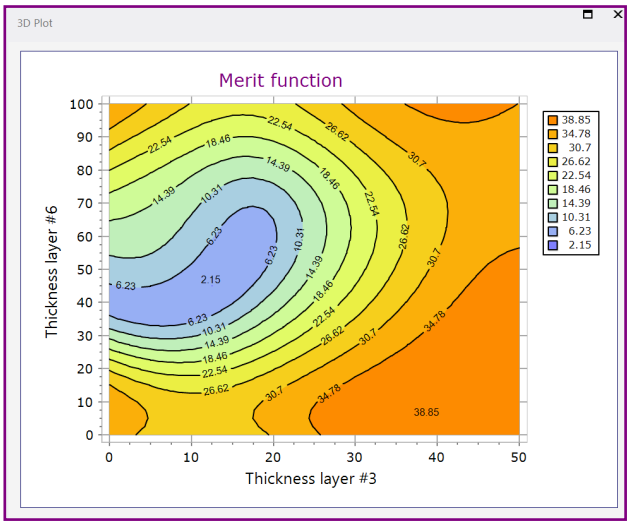


Evaluation plot with opened sliding configuration panel.

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



Interactive admittance diagram.



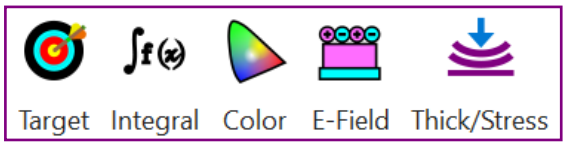
Example of a 3D contour plot.

Optimization Targets and Design Algorithms

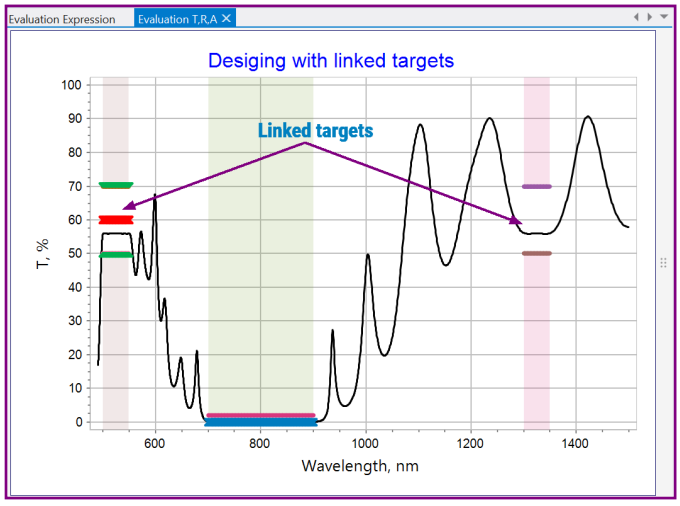
- Flexible target definition using a **generator of grid points** or a **column editor**.
- Target spectral characteristics: R, T, BR at different AOI, for s-, p- , and random polarizations.
- Phase shifts, differential phase shifts on R, T, BR, and phase difference.

Example of a 4-line filter target.

- **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**.

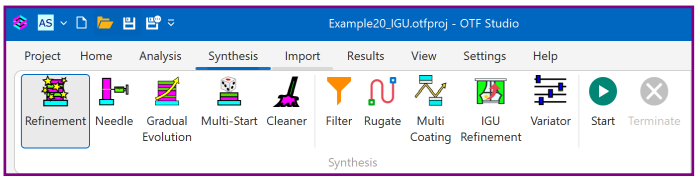


Available types of targets.



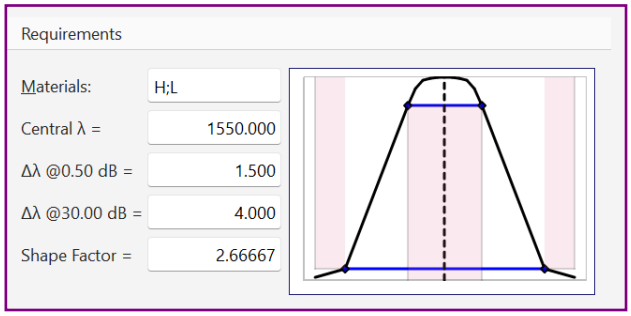
Example of application of linked expressions, conventional targets, and floating constants. Specifications are loaded.

- 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 perfor-



Synthesis ribbon in AS mode.

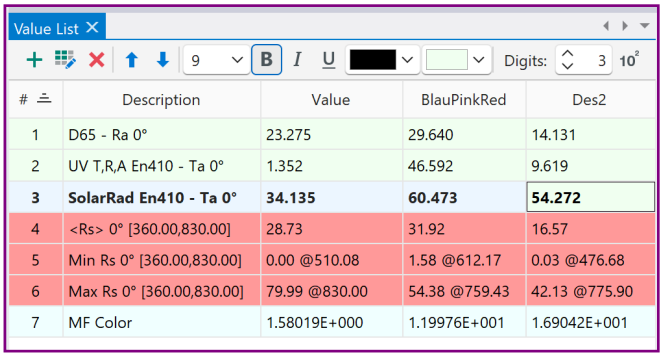
- Targets can be specified in **spectral** or **angular** ranges and switch between them.
- **Fine-tuning** includes selecting allowed materials for the design and defining their sequence.
- Refinement with constraints and groups.
- **BoundTrap** feature in synthesis algorithms.
- **Multi-start** allows 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.
- The **Smart Brush** algorithm removes thin, insignificant, and overly thick layers.
- You can choose between different optimization methods.
- Rugate synthesis
- 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.



Filter requirements

Colors and Integrals

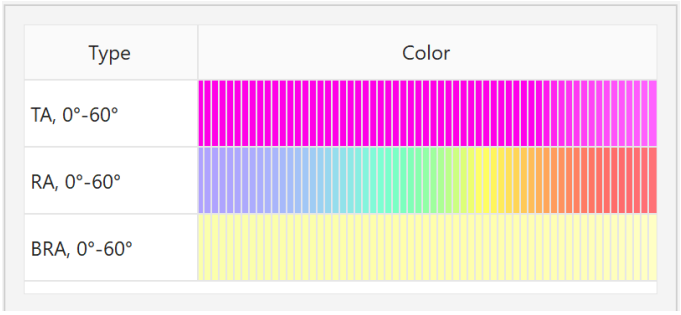
- **Integral values** can be calculated and displayed, and they update continuously during synthesis process.
- Interactive analysis feature operates with integral values and color coordinates.



#	Description	Value	BlauPinkRed	Des2
1	D65 - Ra 0°	23.275	29.640	14.131
2	UV T,R,A En410 - Ta 0°	1.352	46.592	9.619
3	**SolarRad En410 - Ta 0°**	**34.135**	**60.473**	**54.272**
4	<Rs> 0° [360.00,830.00]	28.73	31.92	16.57
5	Min Rs 0° [360.00,830.00]	0.00 @510.08	1.58 @612.17	0.03 @476.68
6	Max Rs 0° [360.00,830.00]	79.99 @830.00	54.38 @759.43	42.13 @775.90
7	MF Color	1.58019E+000	1.19976E+001	1.69042E+001

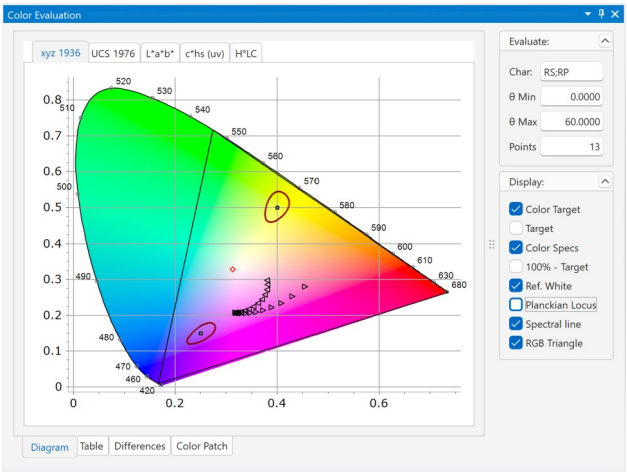
Example of a panel with various integral and color values.

- Evaluation of all integral values can be performed with and without light sources, detectors, line widths, and cone angles.
- Evaluation of integrals of measurements in RE mode is available.

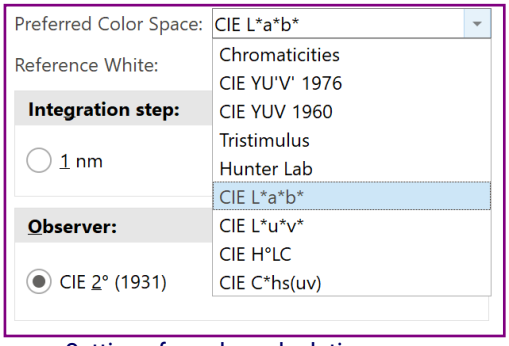


Color patch.

- Compare of color coordinates on Color Diagrams.
- 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.
- Evaluation of **CCT, Duv**, **Yellowness**, and **Color Rendering Index**.
- Evaluation of **color differences** according to CIE76, CIE94, CIEDE2000, CMC 1:1, CMC 2:1.
- Settings for reference white, integration step, and observer, color differences, color patch.
- **Color diagrams** xyz 1936, UCS 1976, L*a*b*, c*hs (uv), H°LC.



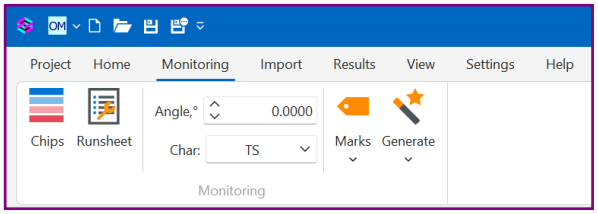
Chromaticities color diagram.



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.

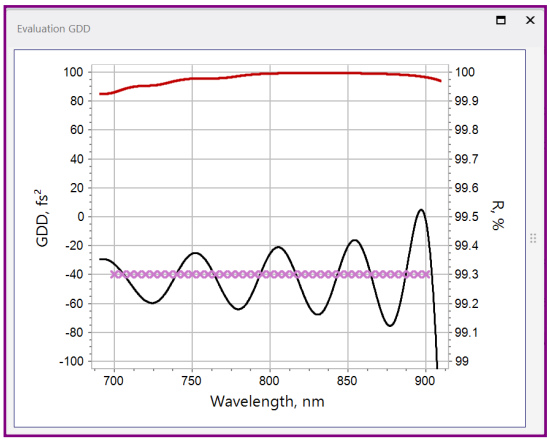


Monitoring ribbon in optical monitoring mode

- Linked wavelengths.
- **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) .

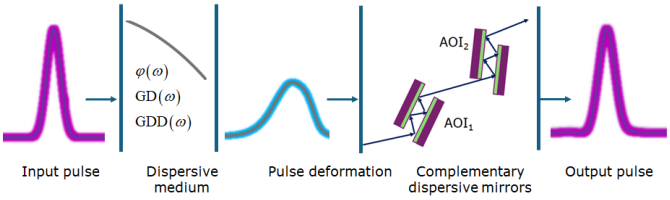
Special Design Options for Ultrafast Applications

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



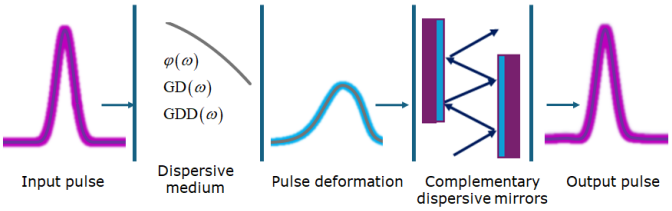
Example of high reflectance and GDD of a dispersive mirror.

- 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.

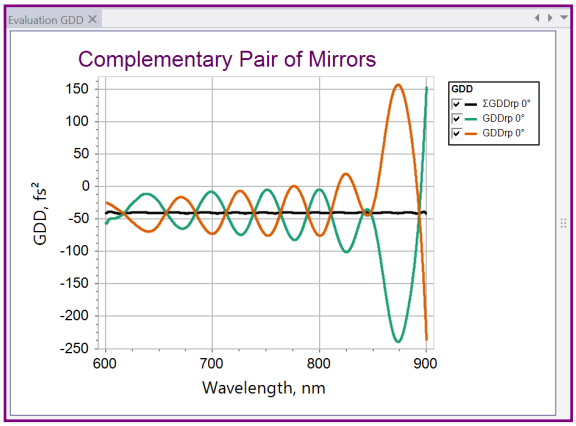


Double angle method (schematic).

- 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).



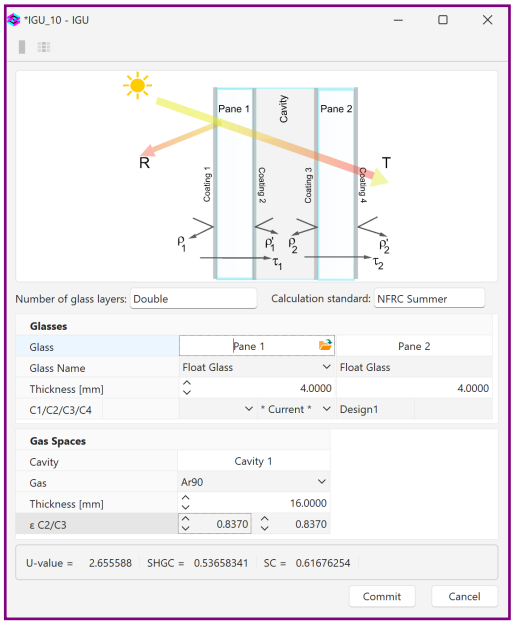
GDD of mirrors in a complementary pair.

Multi Coating

- 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.
- **Pulse Analysis** feature is available.

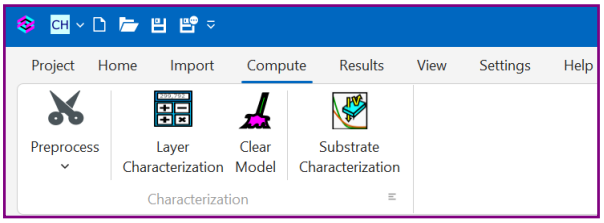
IGU-Related Features and Algorithms

- **OTF Studio** can compute U-values, g-values, SHGC, and SC for single, double, and triple-glazing configurations.
- **IGU configurations** can be saved. Their characteristics can be evaluated and compared.
- The glazing-related values are automatically updated if the interactive analysis (**Variator**) is active.
- **Up to 22 IGU-related integral and color values can be optimized.**
- IGU features are considered in the reverse engineering mode as well.



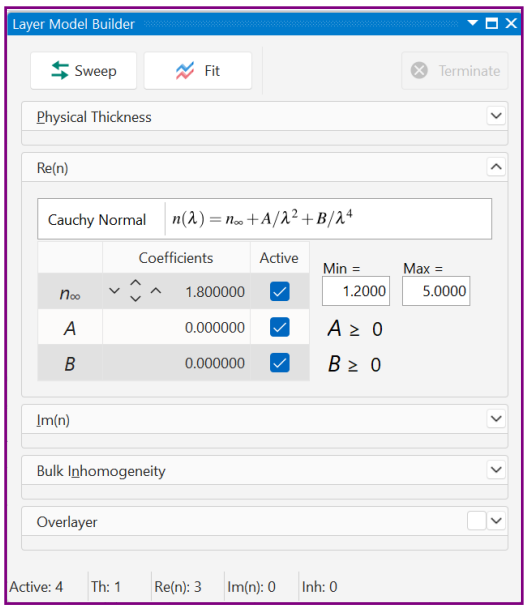
Characterization and Reverse Engineering

- Models and algorithms for characterization of monolayers and substrates.



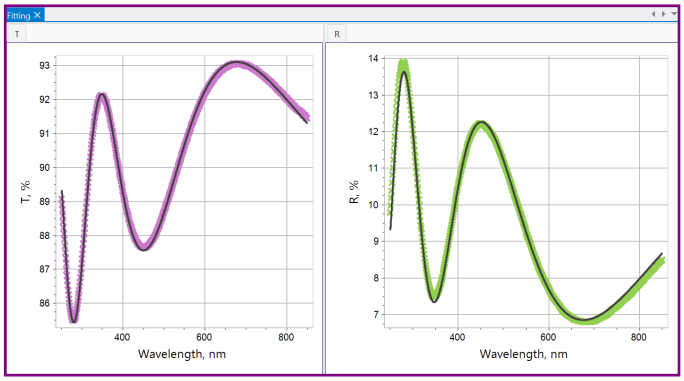
Compute ribbon in characterization mode.

- Configurable **Fitting** and **Partial Discrepancies** plots.
- **Inhomogeneity** and **overlayers** models.
- All models are controlled through centralized **Model Builder** panels.
- **Sweep** and **Fit** operations for layer characterization.



Layer Model Builder panel.

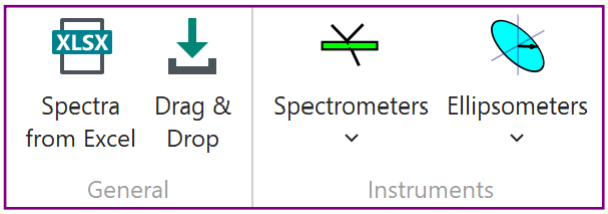
- **Flexible n-k model** for the most complex or/and broadband layer characterization problems.
- **Substrate characterization**.



Example of fitting plots.

MEASUREMENTS:

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

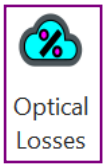


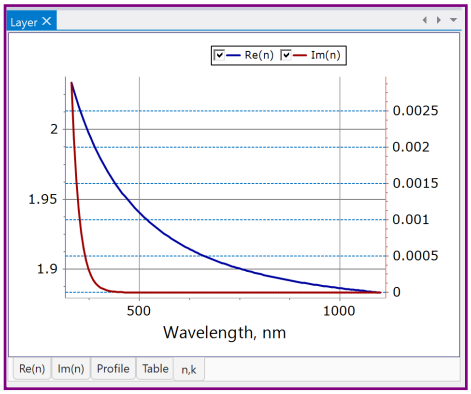
Import ribbon characterization mode.

- The number of points in the wavelength grid is not limited.
- Possibility to combine, compare, and append 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.

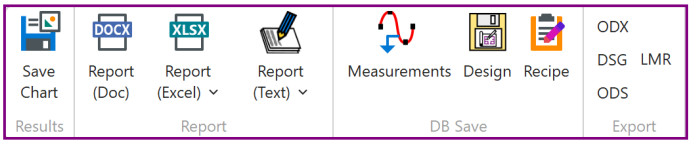




Example of determined optical constants.

REPORTS:

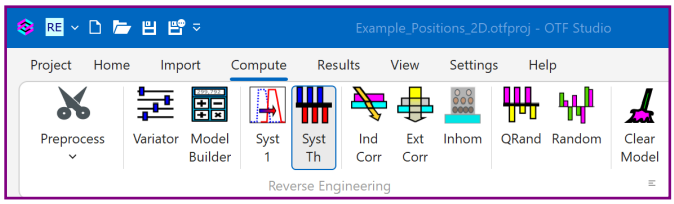
- Characterization reports.
- Saving determined optical constants, also with inhomogeneity.



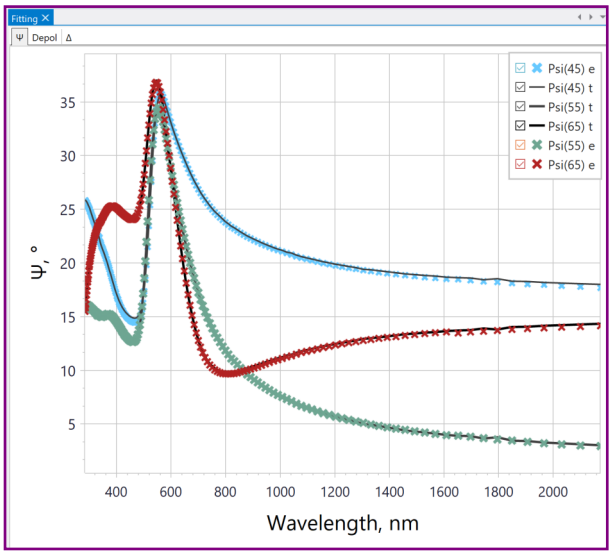
Results ribbon in reverse engineering mode

Reverse Engineering

- Coatings post-production characterization is controlled through a single panel: **Reverse Engineering Model Builder**.
- All algorithms can be flexibly activated, combined, and applied. **Sophisticated combinations of various algorithms are possible.**

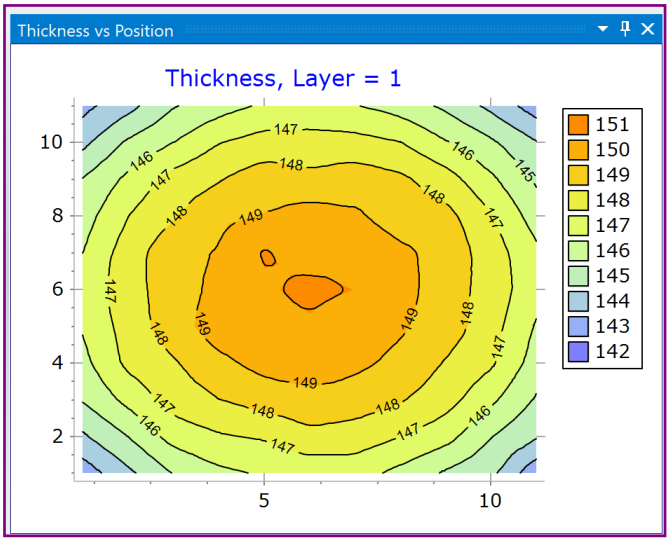


Compute ribbon in reverse engineering mode (RE).



Example of achieved data fitting (ellipsometric 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.

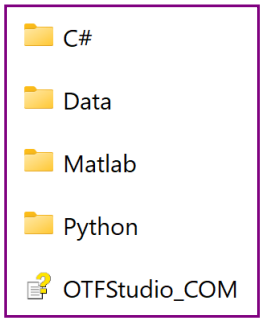


Example of batch processing results.

- Reports in *.txt , Doc, and Excel formats.
- Export to *.DSG, *.ODS, *.LMR, 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.

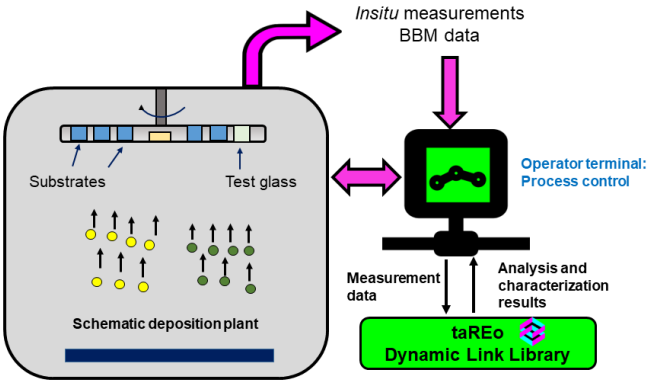


taReo: Automation of Thin Film Deposition

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.

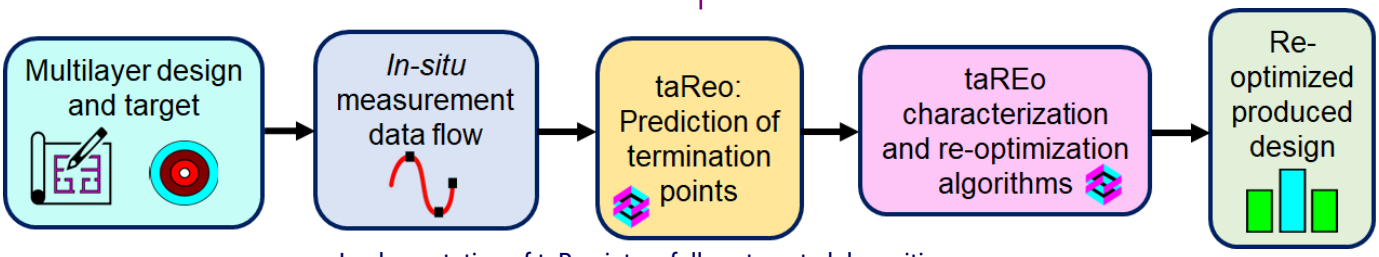
taReo algorithms can be utilized to analyze the continuous data flow of online measurements, to characterize previously deposited layers and the subsequent optimization of the remaining layers.

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.

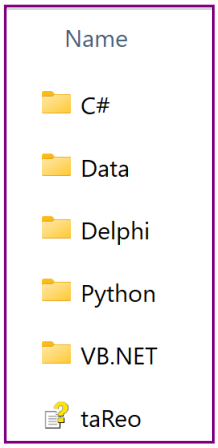
taReo supports all broadband monitoring concepts: with single monitoring substrate or with multiple chips (witness glasses).



Implementation of taReo into a fully automated deposition process.

taReo demonstrates unparalleled computational efficiency, offering several remarkable features:

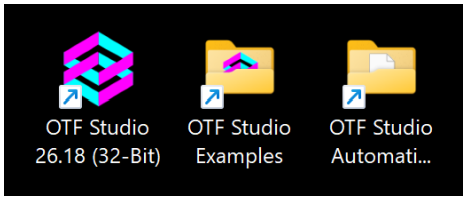
- The **computational speed is exceptionally high**, even when dealing with numerous layers. There is no need to interrupt the deposition process to re-optimize the remaining layers or obtain characterization results.
- The software allows for an **unlimited number of points in the wavelength grid**, 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.



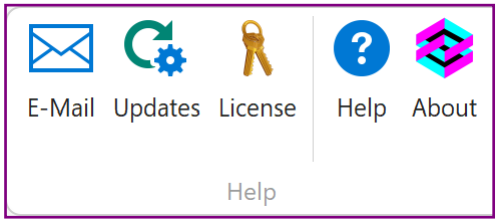
More information: https://www.otfstudio.com/our-products/tareo

Installation, Hardware, Support, Development

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



OTF Studio icons on the desktop.



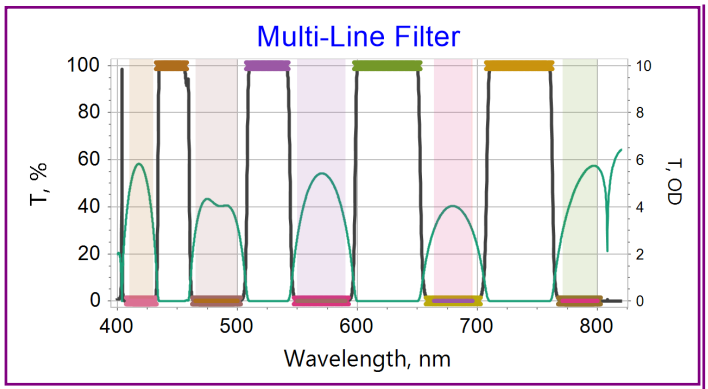
Access to support, updates, and license information.

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

- **OTF Studio** can synthesize multilayers 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.

- Windows 11 (on Intel- and ARM-based processors).
- Apple macOS (including systems with Apple M1-M5 ARM-based CPUs).
- Linux-based operating systems (tested on Ubuntu 24.04.1 LTS).
- Windows 10 is still supported (on Intel-based processors).
- **OTF Studio** uses vectorization in computations.
- **Multi-monitor** configurations and **high-resolution displays** are supported.
- **OTF Studio** uses **Multi-threading** and **parallel** computations.

More information: www.otfstudio.com

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