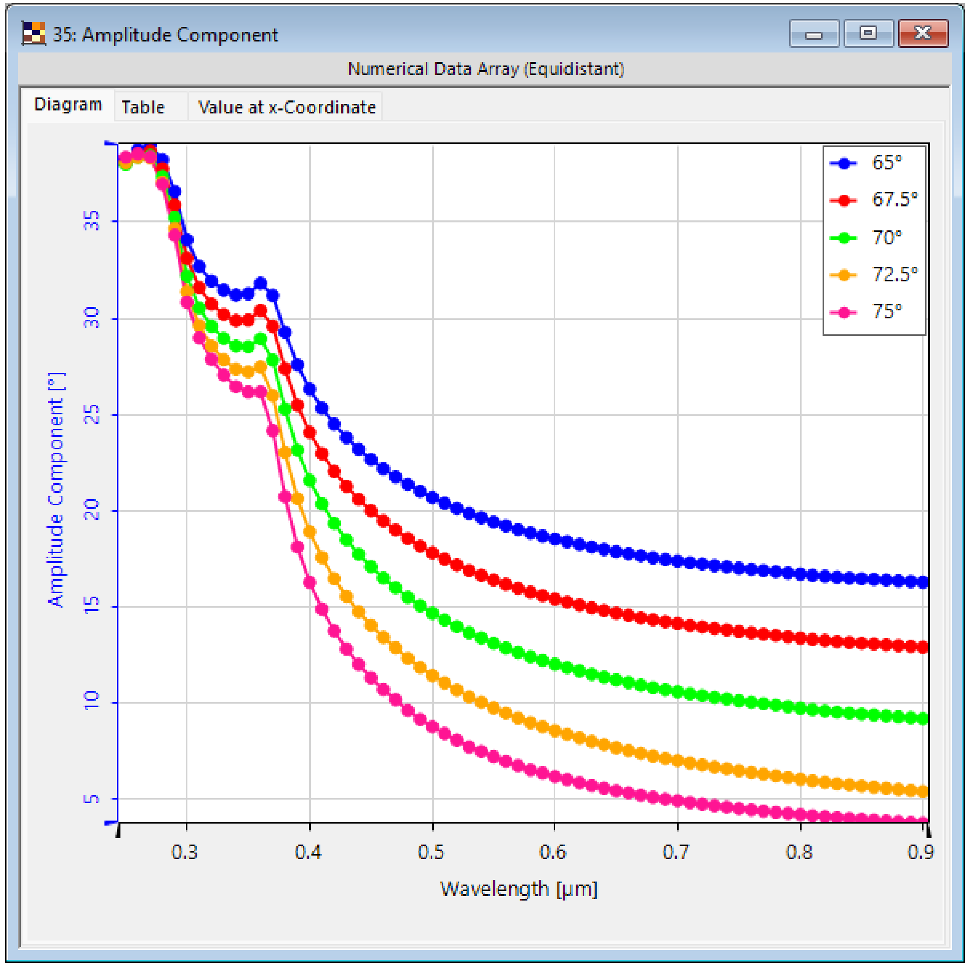
Variable Angle Spectroscopic Ellipsometry (VASE) Analysis of a SiO2-Coating

Abstract

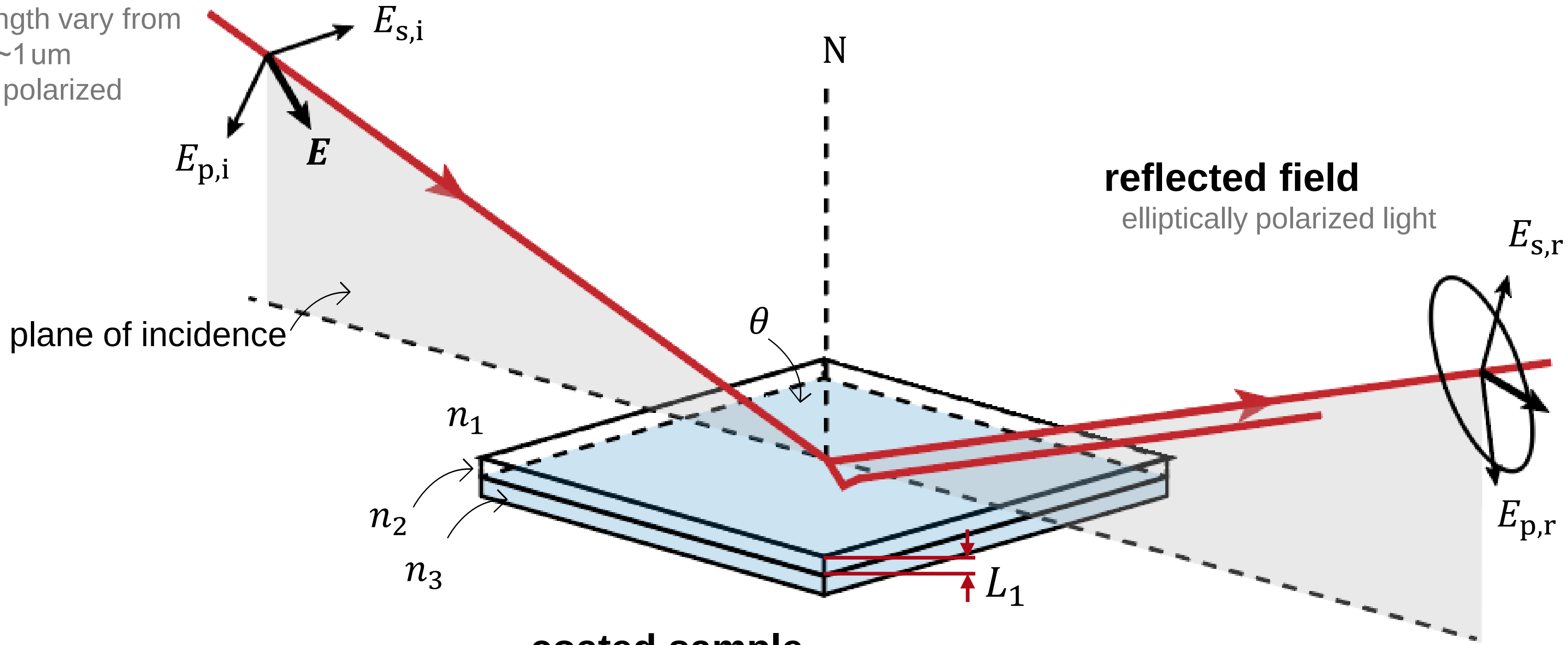


Due to its high sensitivity to small changes in optical parameters, variable angle spectroscopic ellipsometry (VASE) is a commonly applied technology in many applications where thin-film structures are used, such as semiconductors, optical coatings, data storage, flat panel fabrication, etc. In this Use Case we demonstrate the use of the *Ellipsometry Analyzer* in VirtualLab Fusion on a silicon dioxide (SiO_2) coating. For the parameters of the system, we follow the work of Woollam et al. “Overview of variable-angle spectroscopic ellipsometry (VASE): I. Basic theory and typical applications” and investigate how sensitive the method is towards slightly varying layer thicknesses.

Task Description

input field

- ideal plane wave
- wavelength vary from 200 nm~1 um
- linearly polarized



reflected field

elliptically polarized light

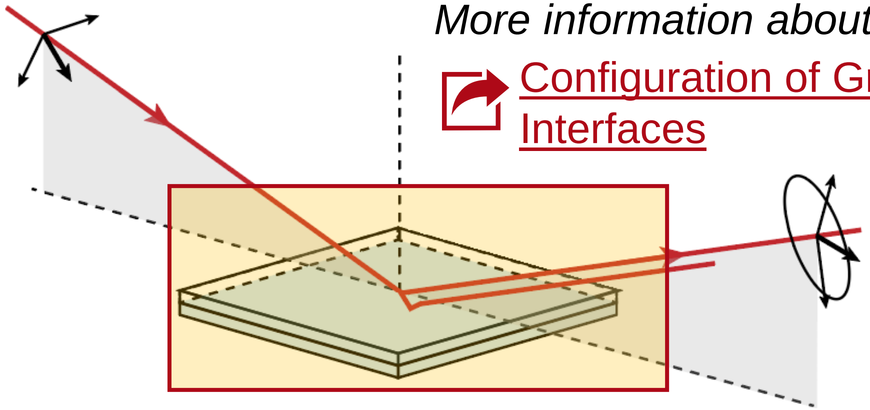
coated sample

- coating: SiO2 thin film
- thickness L_1 : 10 nm±0.1 nm
- base material: Si

How to detect the varied thickness of the coating?

Parameters follow from Woollam et al., Proc. SPIE 10294, 1029402 (1999)

Coated Sample



More information about configuring stacks:

[Configuration of Grating Structures by Using Interfaces]

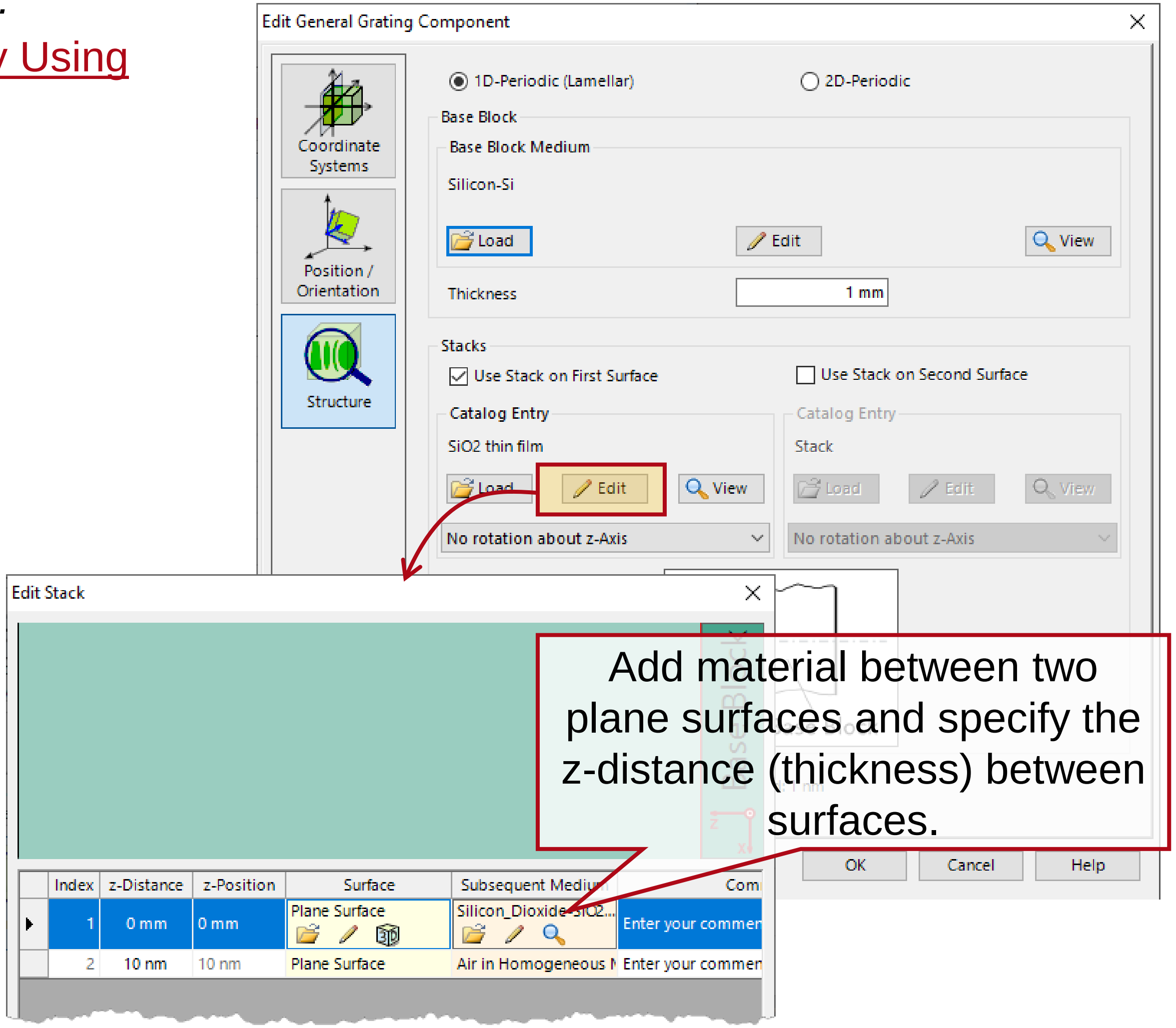
The *General Grating Component* is capable of modeling periodic structures. In case of an isotropic layer, a very small period is used to ensure, that only a 0th order will propagate. The silicon dioxide layer is also defined according to the reference:

- coating thickness: 10nm
- coating Material: SiO2
- refractive index: extended Cauchy model:

$$n_2 = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$$

with $A = 1.44$, $B = 0.00422\,\mu m^2$, $C = 1.89E-05\,\mu m^4$

- base block material: crystalline Silicon
- angle of incidence: 75°



Edit General Grating Component

● 1D-Periodic (Lamellar) ○ 2D-Periodic

Base Block

Base Block Medium: Silicon-Si

Thickness: 1 mm

Stacks

☑ Use Stack on First Surface ☐ Use Stack on Second Surface

Catalog Entry: SiO2 thin film

No rotation about z-Axis

Catalog Entry: Stack

No rotation about z-Axis

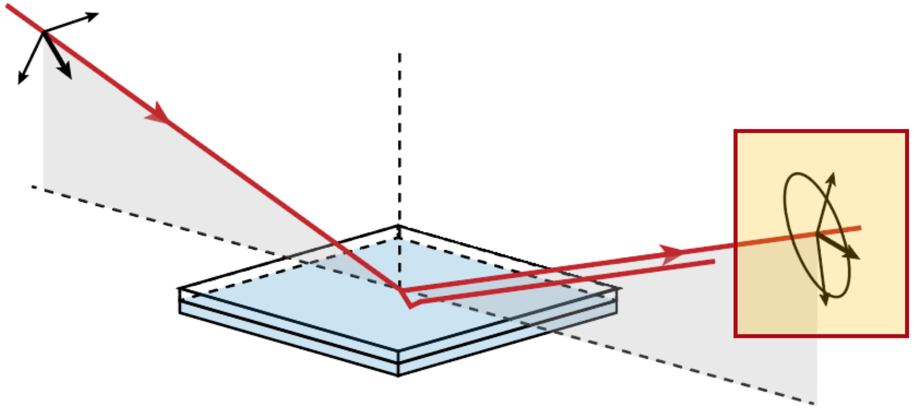
Edit Stack

	Index	z-Distance	z-Position	Surface	Subsequent Mediu	Com
▶	1	0 mm	0 mm	Plane Surface	Silicon_Dioxide-SiO2...	Enter your commen
	2	10 nm	10 nm	Plane Surface	Air in Homogeneous M	Enter your commen

Add material between two plane surfaces and specify the z-distance (thickness) between surfaces.

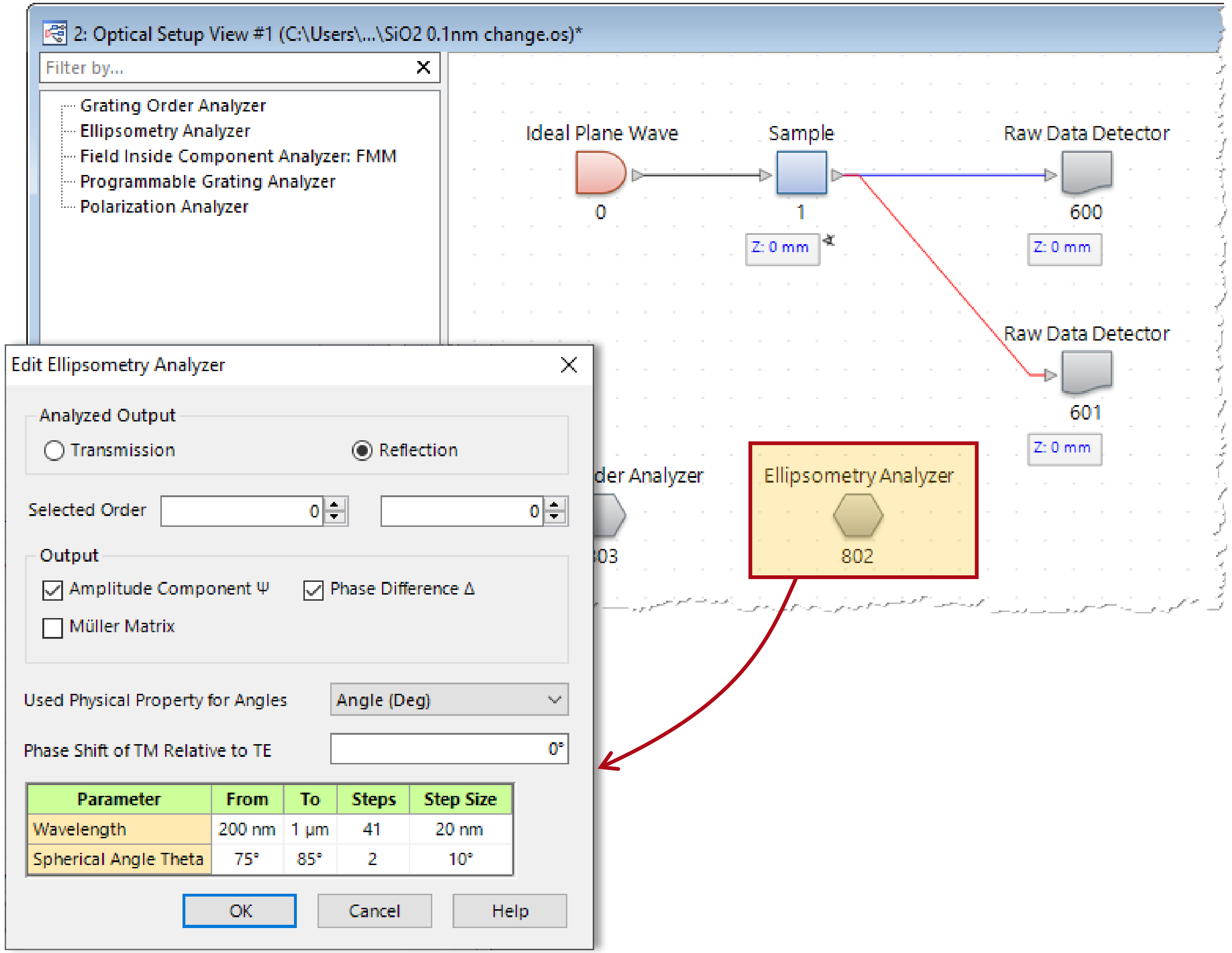
Parameters follow from Woollam et al., Proc. SPIE 10294, 1029402 (1999)

Ellipsometry Analyzer



The *Ellipsometry Analyzer* is used to calculate the phase difference *Δ*, and the amplitude component *Ψ* of the of the reflected beam.

More information about the analyzer can be found here:
[Ellipsometry Analyzer]



Edit Ellipsometry Analyzer

Analyzed Output
○ Transmission ● Reflection

Selected Order 0 0

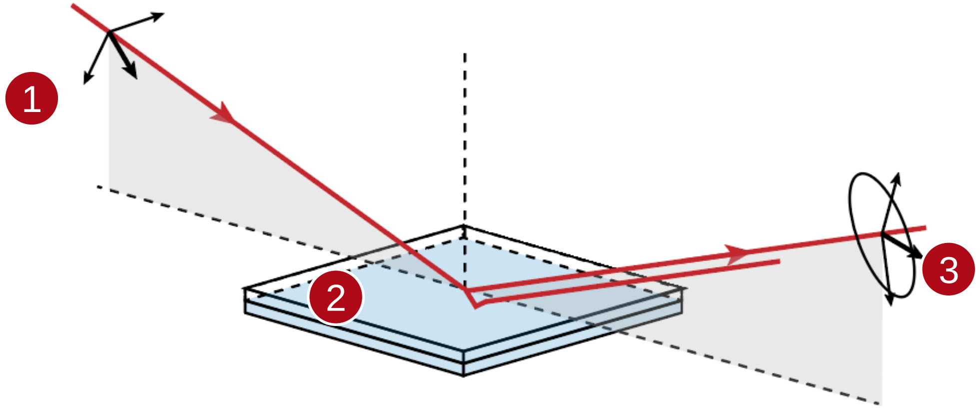
Output
☑ Amplitude Component Ψ ☑ Phase Difference Δ
☐ Müller Matrix

Used Physical Property for Angles: Angle (Deg)

Phase Shift of TM Relative to TE: 0°

Parameter	From	To	Steps	Step Size
Wavelength	200 nm	1 µm	41	20 nm
Spherical Angle Theta	75°	85°	2	10°

Summary – Components...



… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Value
1. source	*Ideal Plane Wave*	ideal Plane Wave
2. coated surface	*General Grating Component*	Fourier Modal Method (FMM) / Rigorous Coupled Wave Analysis (RCWA)
3. detector	*Ellipsometry Analyzer*	Amplitude Component (Ψ) & Phase Difference (Δ)

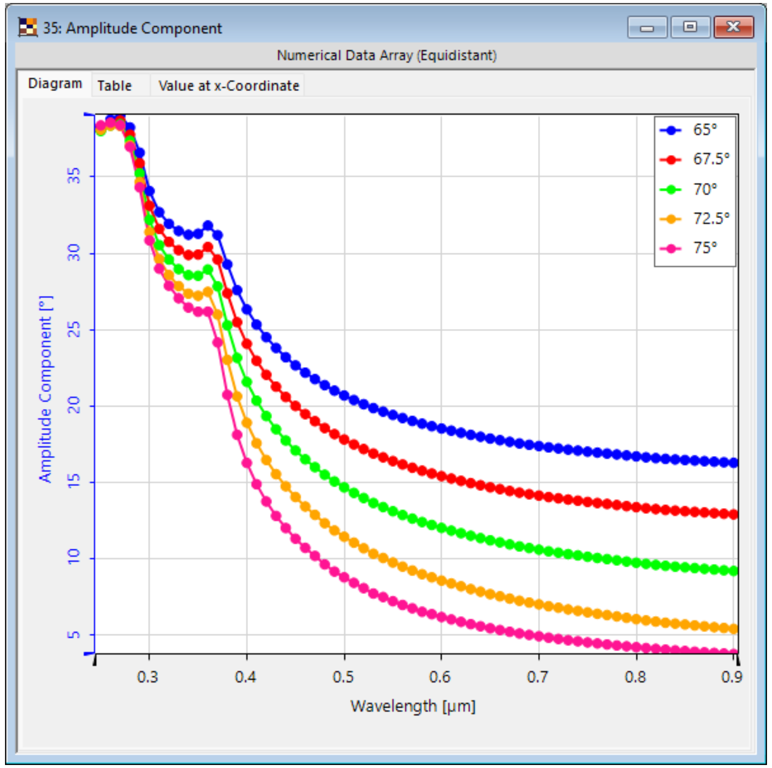
Ellipsometry Coefficients Measurement

The *Ellipsometry Analyzer* measures the ratio ρ of the reflection coefficients (s- and p-polarized components) and outputs the phase difference $\varDelta$, and the amplitude component $\varPsi$ according to

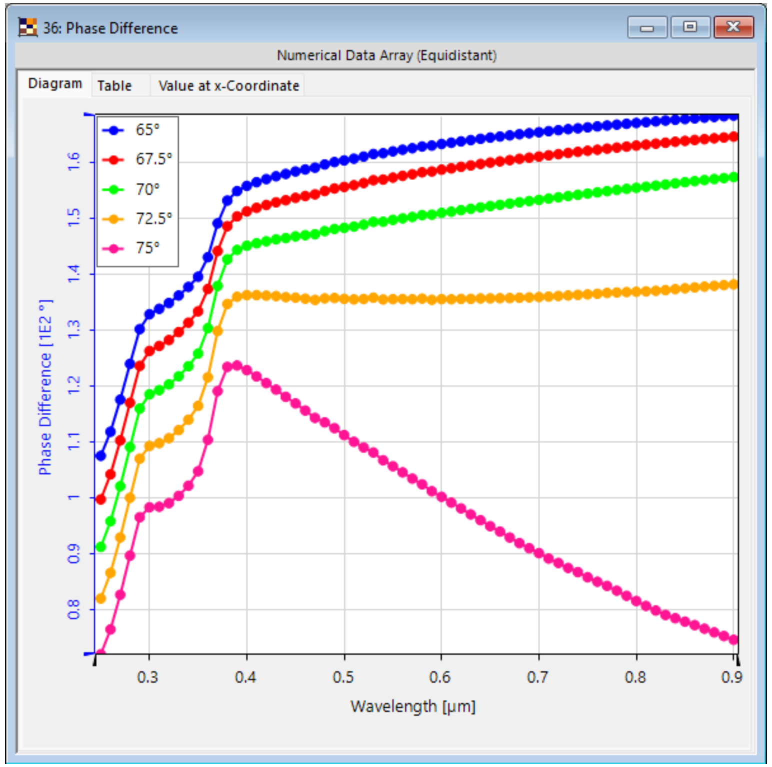
$$\rho = \tan(\varPsi)\exp(i\varDelta) = \frac{R_\mathrm{p}}{R_\mathrm{s}}.$$

In VirtualLab Fusion, the complex coefficients R_p and R_s are calculated by applying the rigorous-coupled wave analysis (RCWA), also known as Fourier modal method (FMM). Hence, these coefficients can also be Rayleigh coefficients for a particular diffraction order in case of a grating sample is investigated.

ellipsometry result of a 10 nm SiO2-layer, angles: 65°-75°



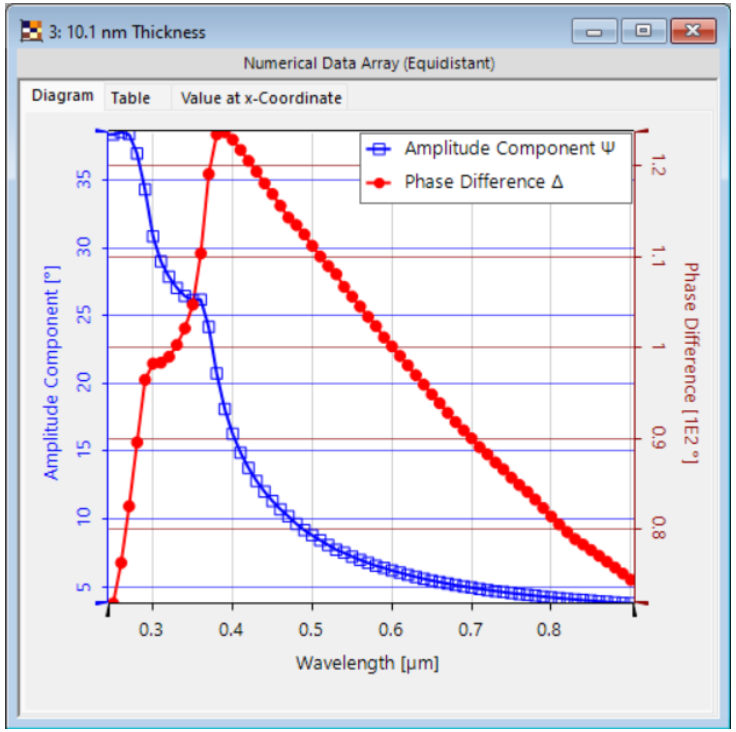
amplitude component $\varPsi$



phase difference $\varDelta$

Sensitivity of Ellipsometry for Small Thickness Variations

In order to evaluate the sensitivity of ellipsometry for even very small changes in the thickness of the coating, results for a 10 nm SiO_2 thick layer and a 10.1 nm SiO_2 thick film are compared. Even for small changes of the thickness, the difference of 1 angstrom is above the resolution of common ellipsometers (0.02° for Ψ and 0.1° for Δ*). Hence, even sub-nanometer variations in the coating can be measured by ellipsometry:



ellipsometry results for 10.1 nm layer

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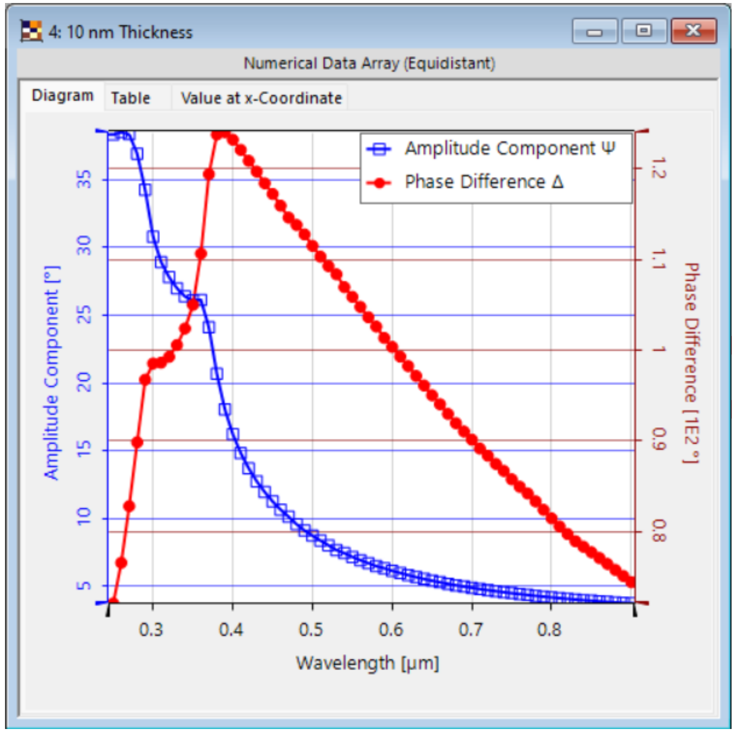

ellipsometry results for 10 nm layer

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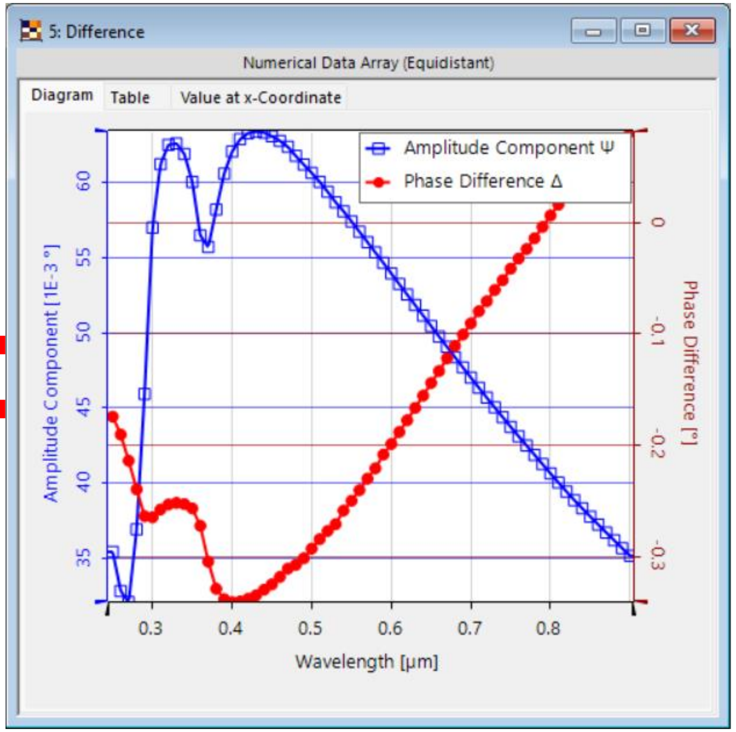
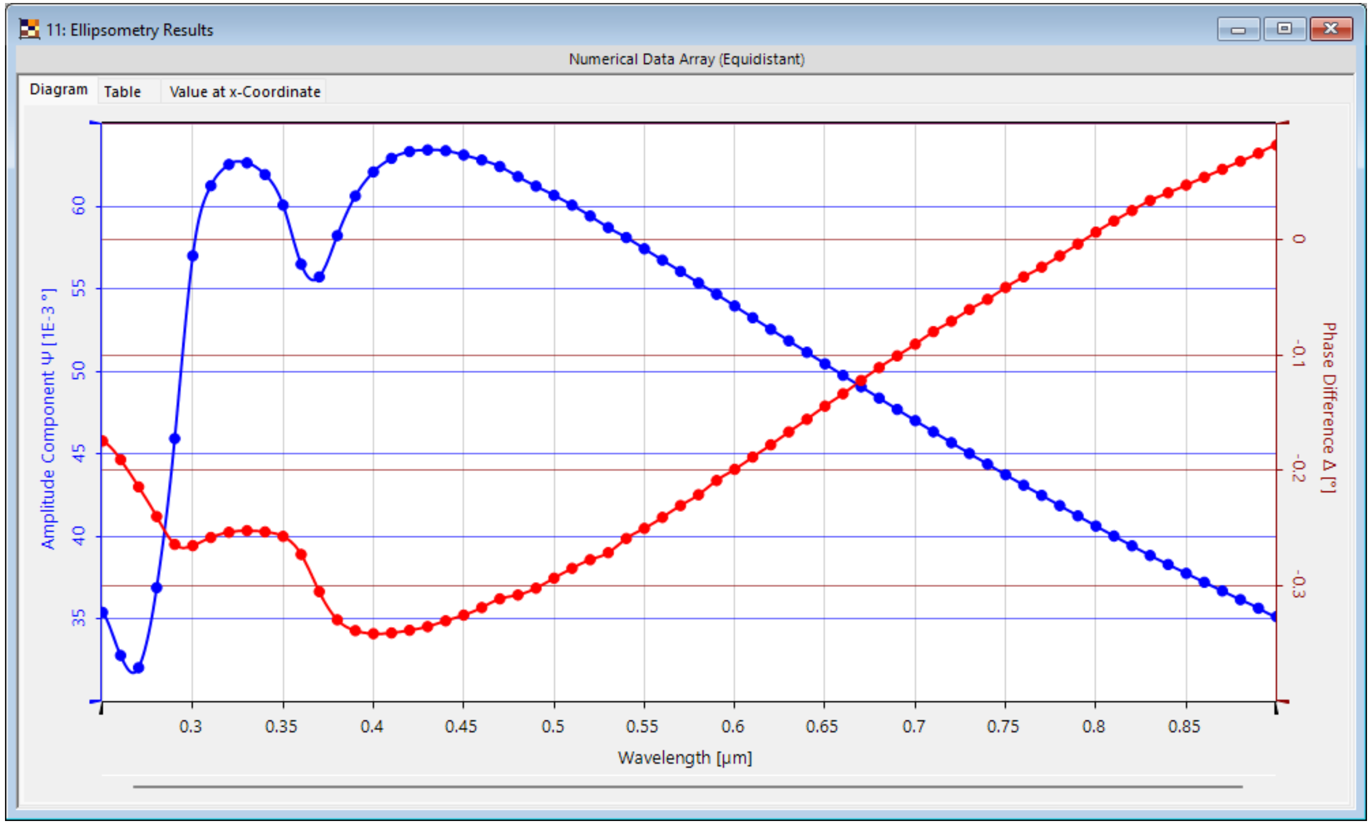


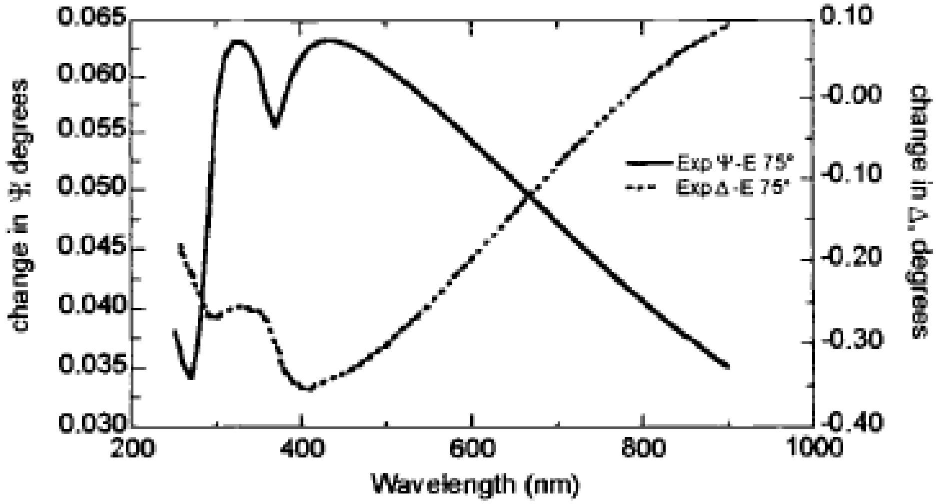
difference

** Values according to Woollam et al., Proc. SPIE 10294, 1029402 (1999)*

Comparison of Simulation Results and Reference

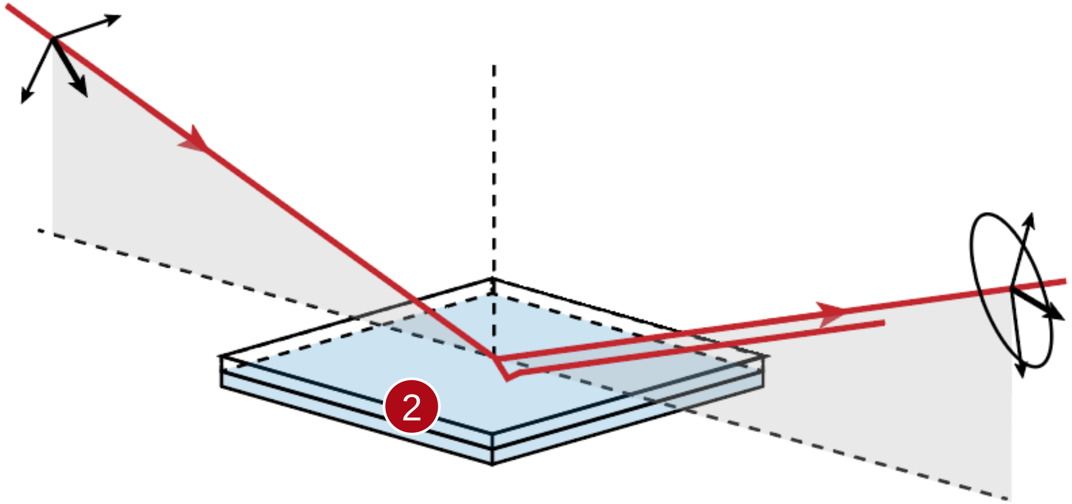
difference of Ψ and Δ for a thickness variation of 1 angstrom of the investigated SiO_2 layer:

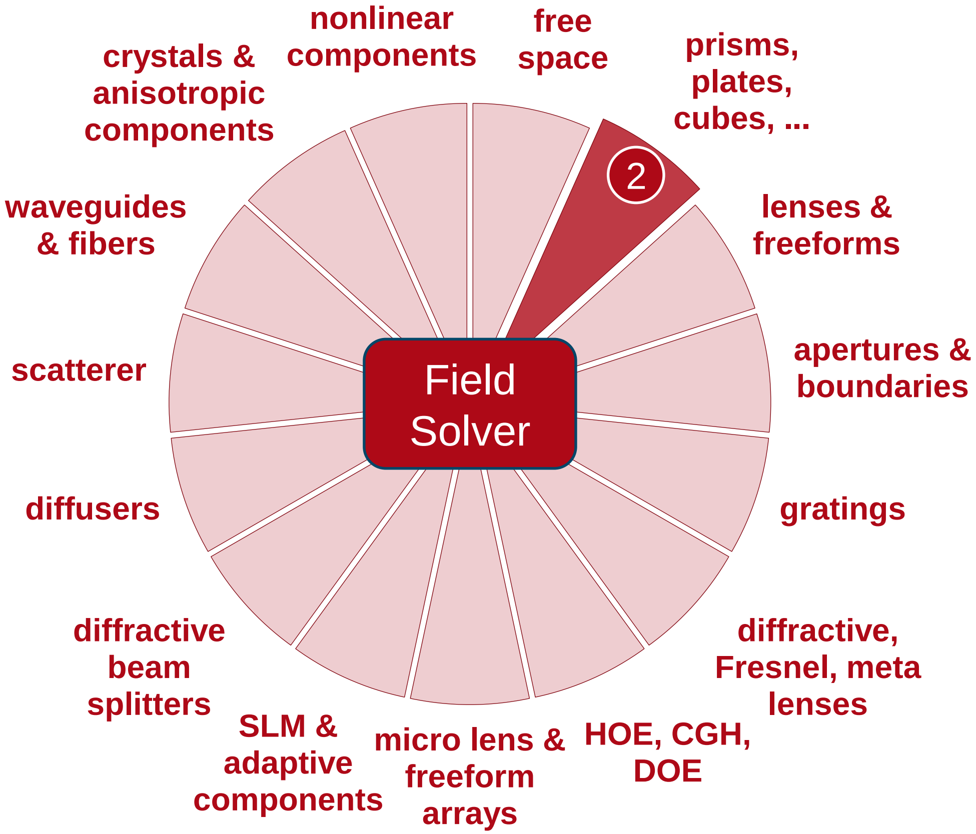




simulation according to Woollam et al., Proc. SPIE 10294, 1029402 (1999)

VirtualLab Fusion Technologies





Document Information

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