VirtualLab Fusion's Applications, Technology & Workflows

Modeling Crystals & Anisotropic Media with VirtualLab Fusion

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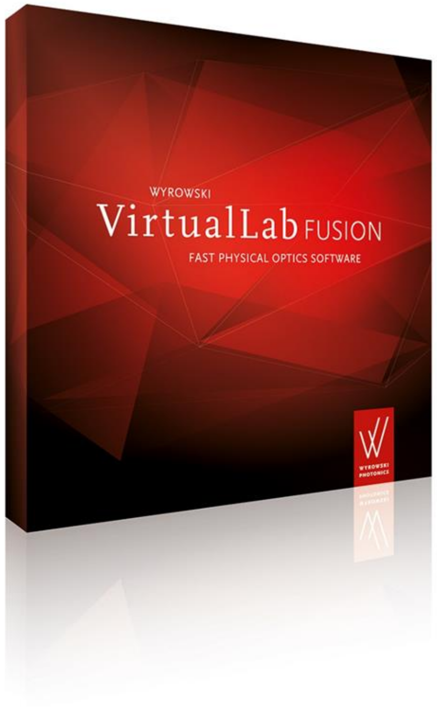
One Platform, Many Solvers

Fast physical optics simulations…

… made possible by **connecting field solvers**!



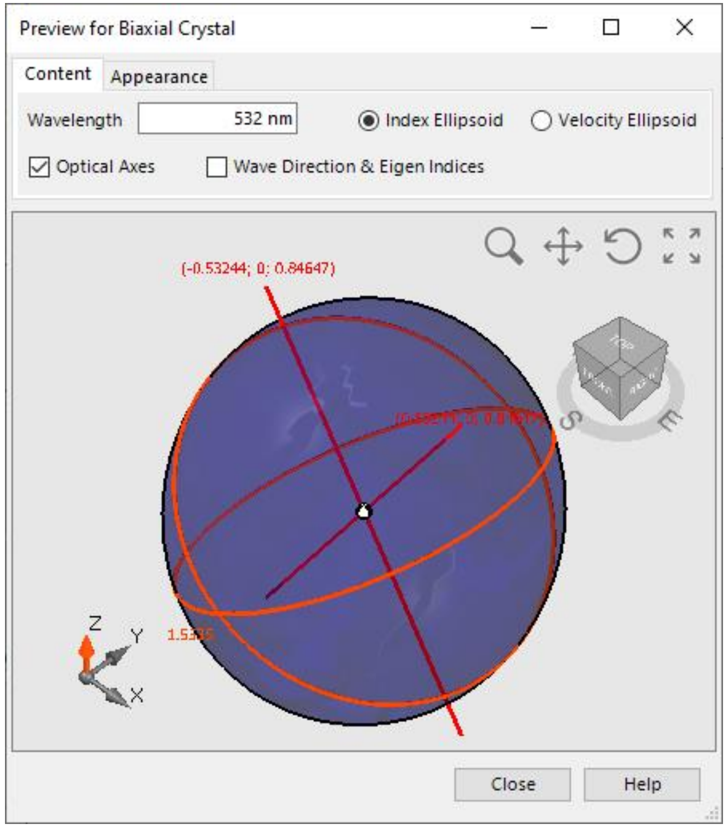
VirtualLab Fusion acts as a software platform to connect electromagnetic field solvers in a **seamless, fully non-sequential manner**

→ **solving Maxwell's equations for the whole system!**

M. Kuhn, F. Wyrowski & C. Hellmann, **'Non-sequential Optical Field Tracing'**, *in* Thomas Apel & Olaf Steinbach, ed., 'Advanced Finite Element Methods and Applications', Springer Berlin Heidelberg, pp. 257-273 (2013)

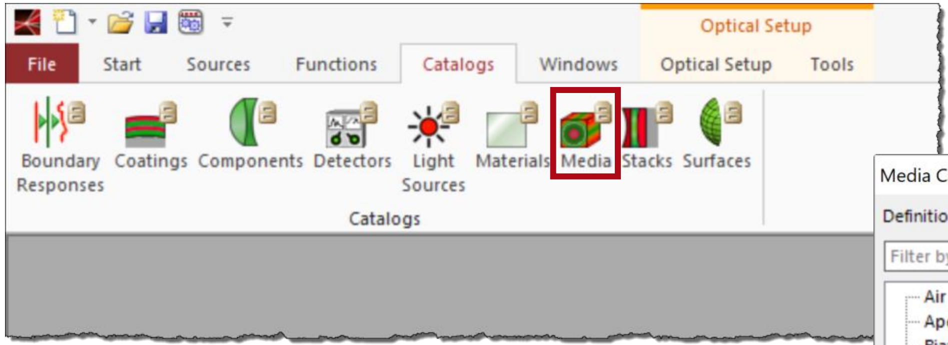
Optically Anisotropic Media in VirtualLab Fusion

Abstract



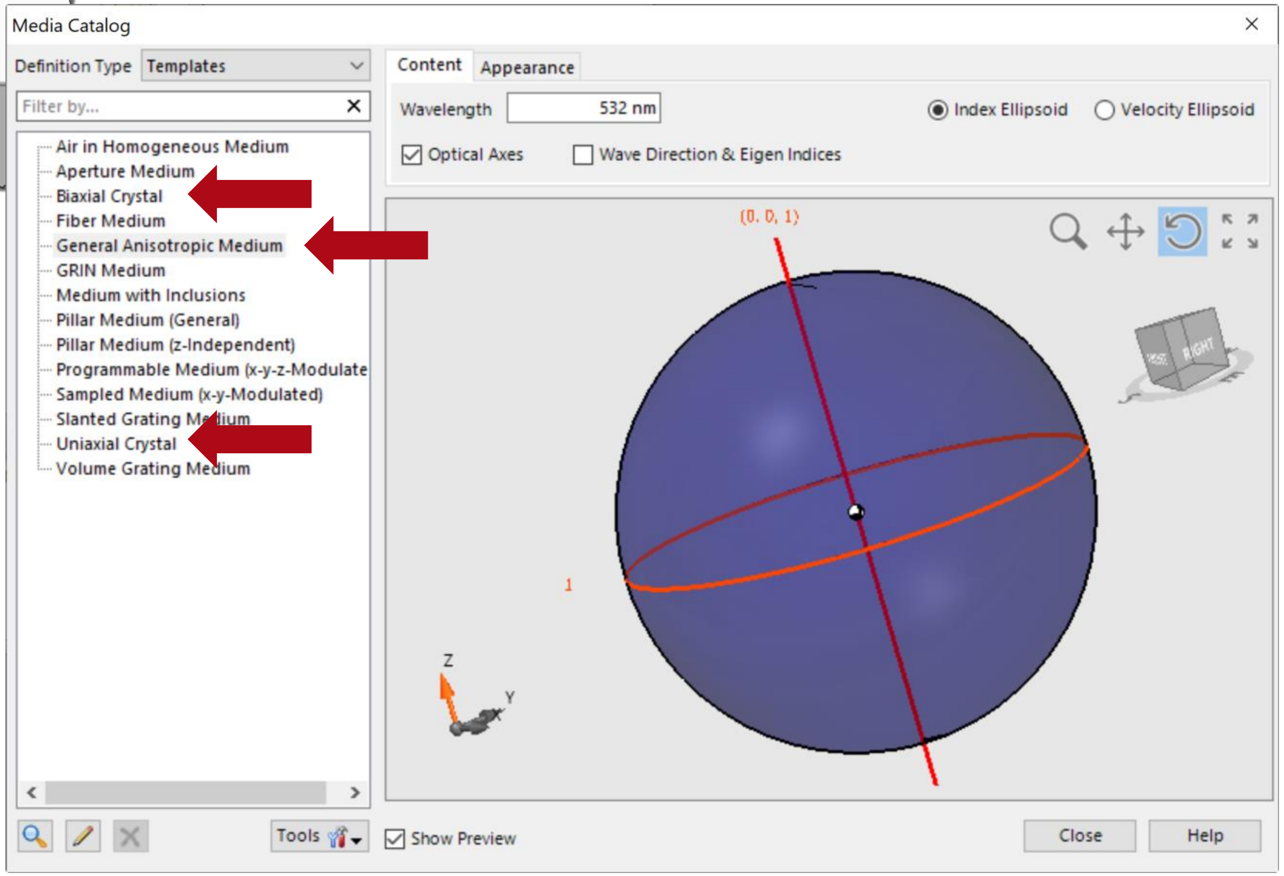
Optical anisotropy, also known as birefringence, is the reason for various optical phenomena and the related applications. VirtualLab Fusion provides a fast and rigorous field tracing analysis algorithm which applies an S-matrix solver and works in the k-domain. In this use case, the basic configuration of an anisotropic medium is introduced.

Anisotropic Media in Catalog

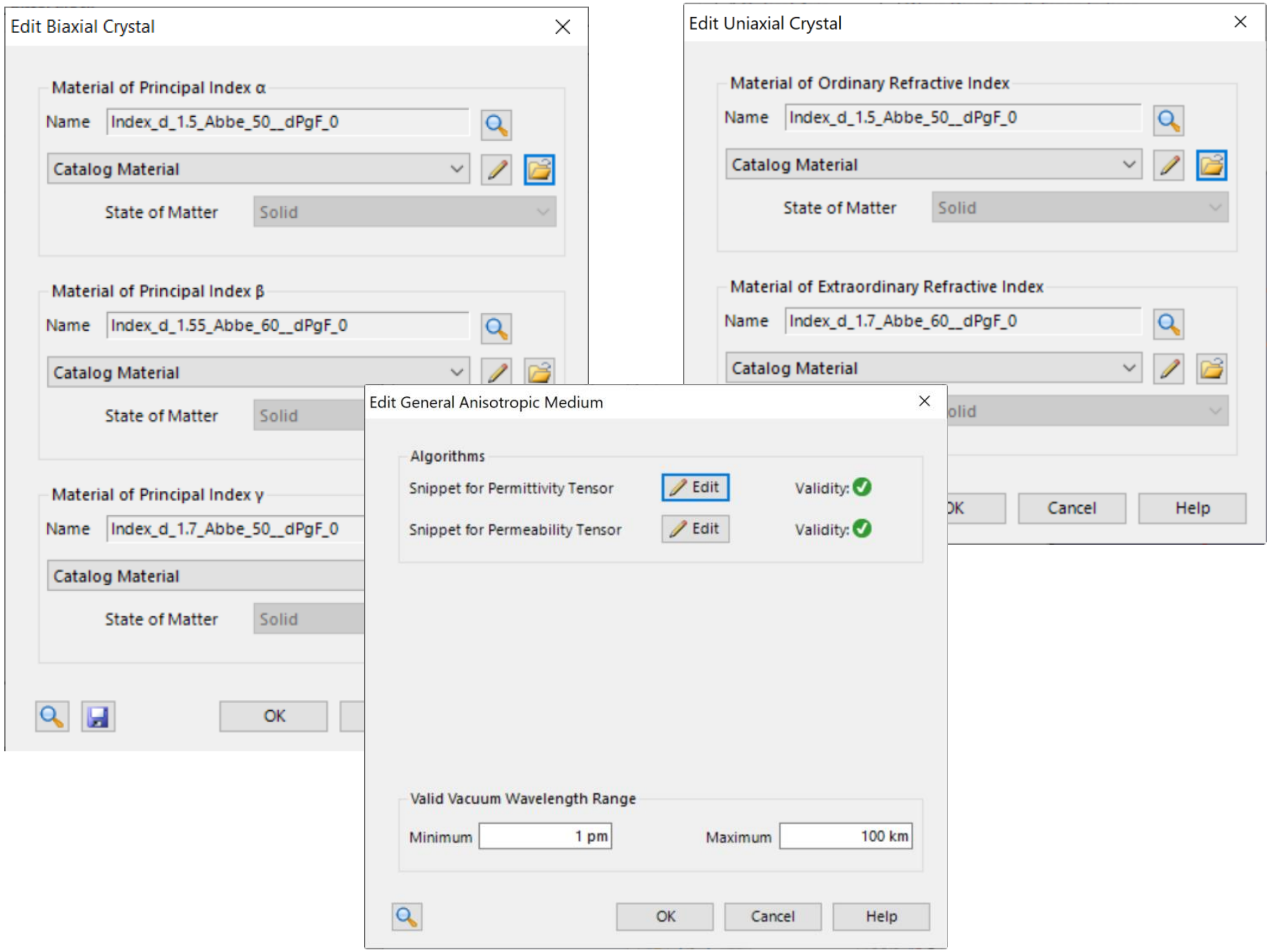


In the new version three different kind of anisotropic media can be found in the media catalog:

- Uniaxial Crystal
- Biaxial Crystal
- General Anisotropic Media



Defining the Anisotropic Media

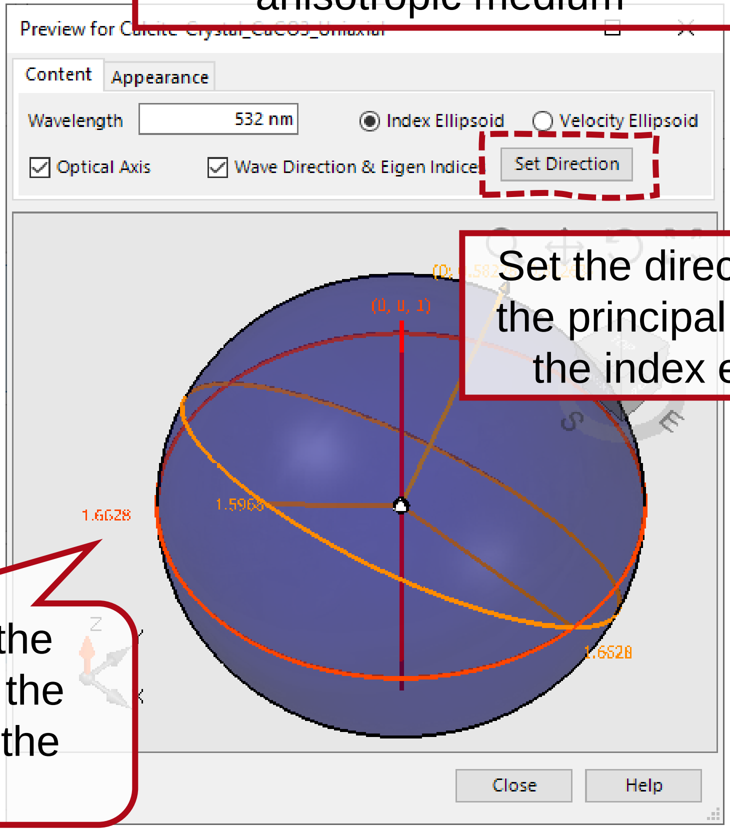


- The Biaxial Crystal is defined by the principal indices of three directions
- The Uniaxial Crystal is defined by the ordinary and extraordinary refractive indices
- General Anisotropic Media can be set up by directly defining the permittivity tensor

Preview of the Anisotropic Medium

The preview of an anisotropic medium can be displayed through index ellipsoid or velocity ellipsoid, which makes it easy and intuitive to study the properties of the media.

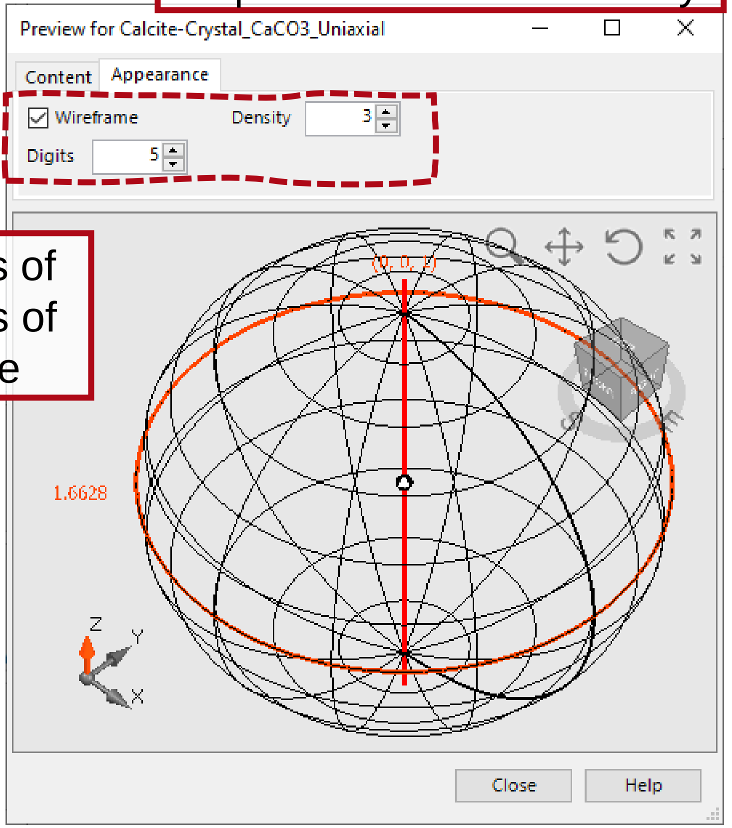
In the Content tab, the user can select between the index/velocity ellipsoid of the anisotropic medium



Set the directions of the principal axes of the index ellipse

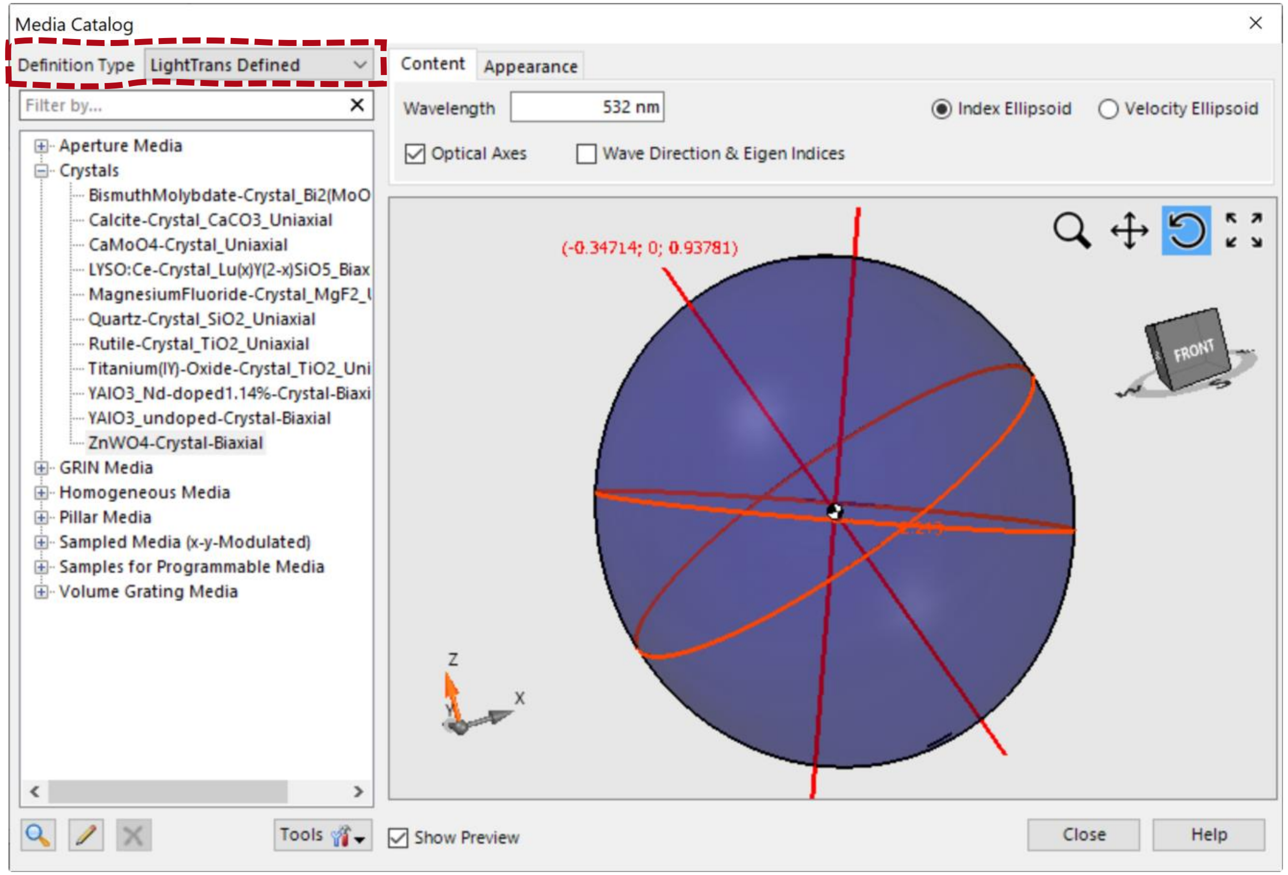
The half-lengths of the principal axes equal the refractive indices of the normal modes

In the Appearance tab, the user can show the wireframe of the selected ellipsoid and edit its density



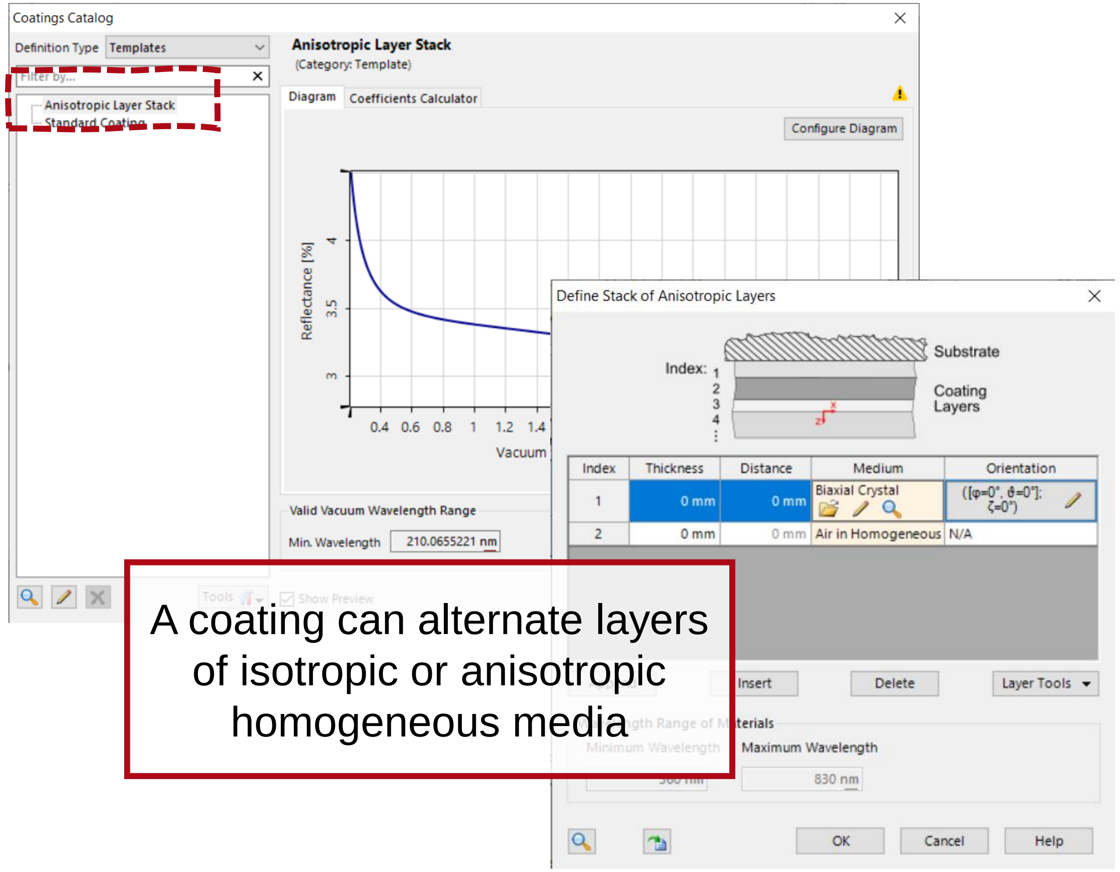
Preconfigured Crystals

VirtualLab Fusion comes with a series of pre-configurated crystal media which can be accessed from the media catalog. The user also can import & export his own defined media to the catalog.

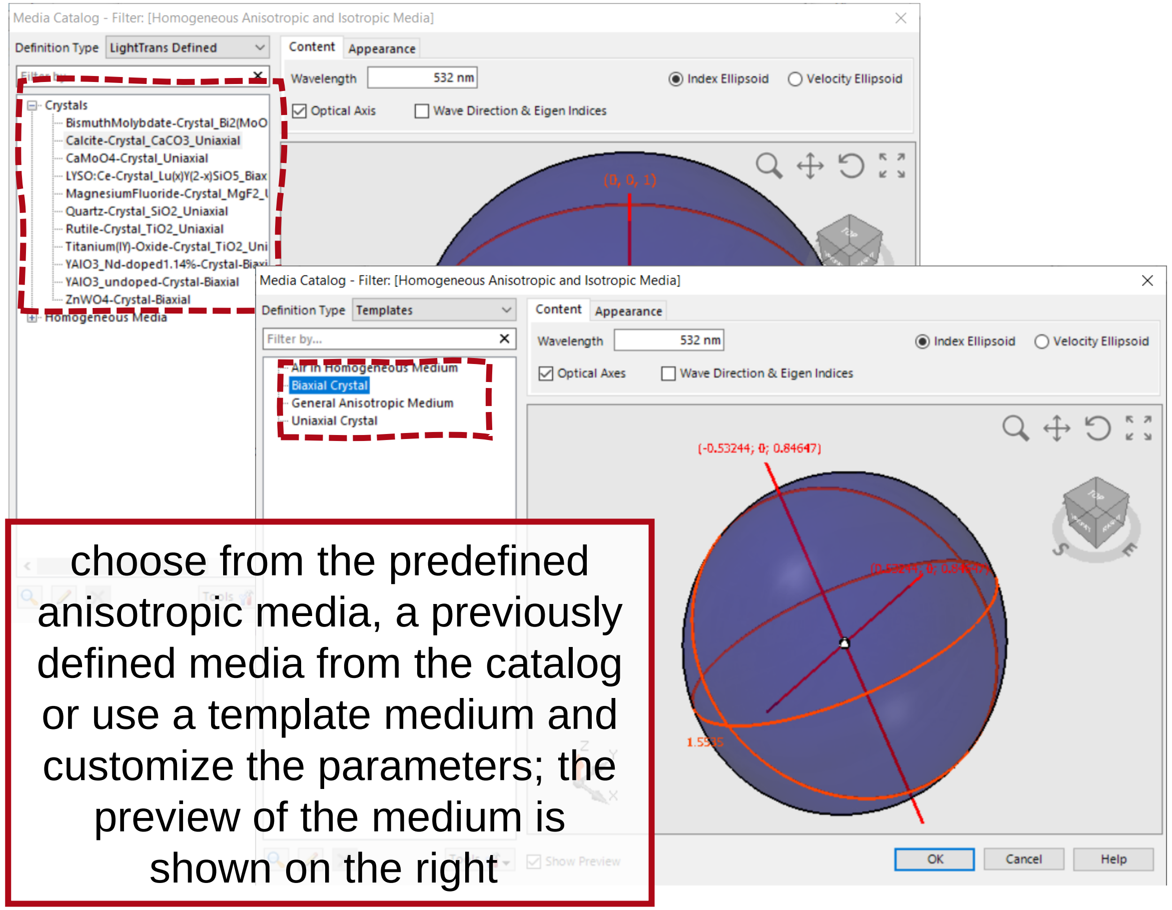


Anisotropic Coatings

Anisotropic coatings can be found in the coating catalog and applied to all optical surfaces in VirtualLab Fusion.

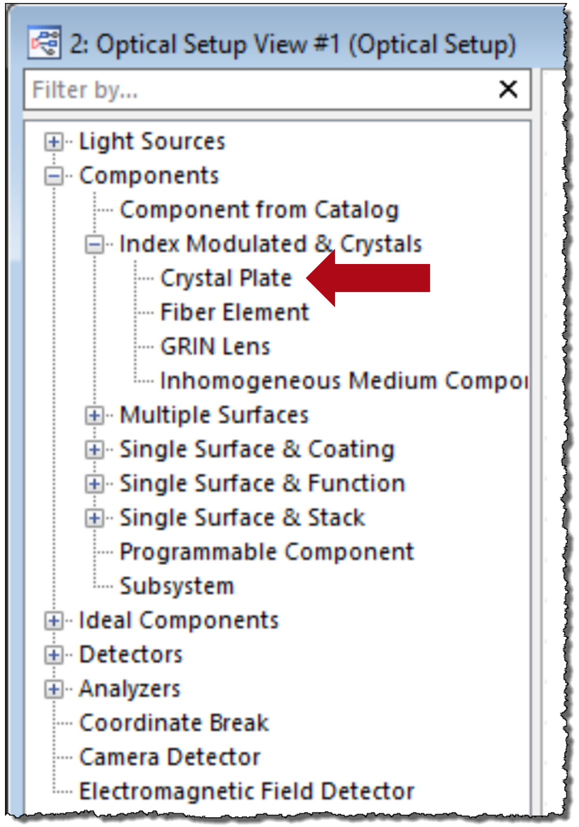


A coating can alternate layers of isotropic or anisotropic homogeneous media

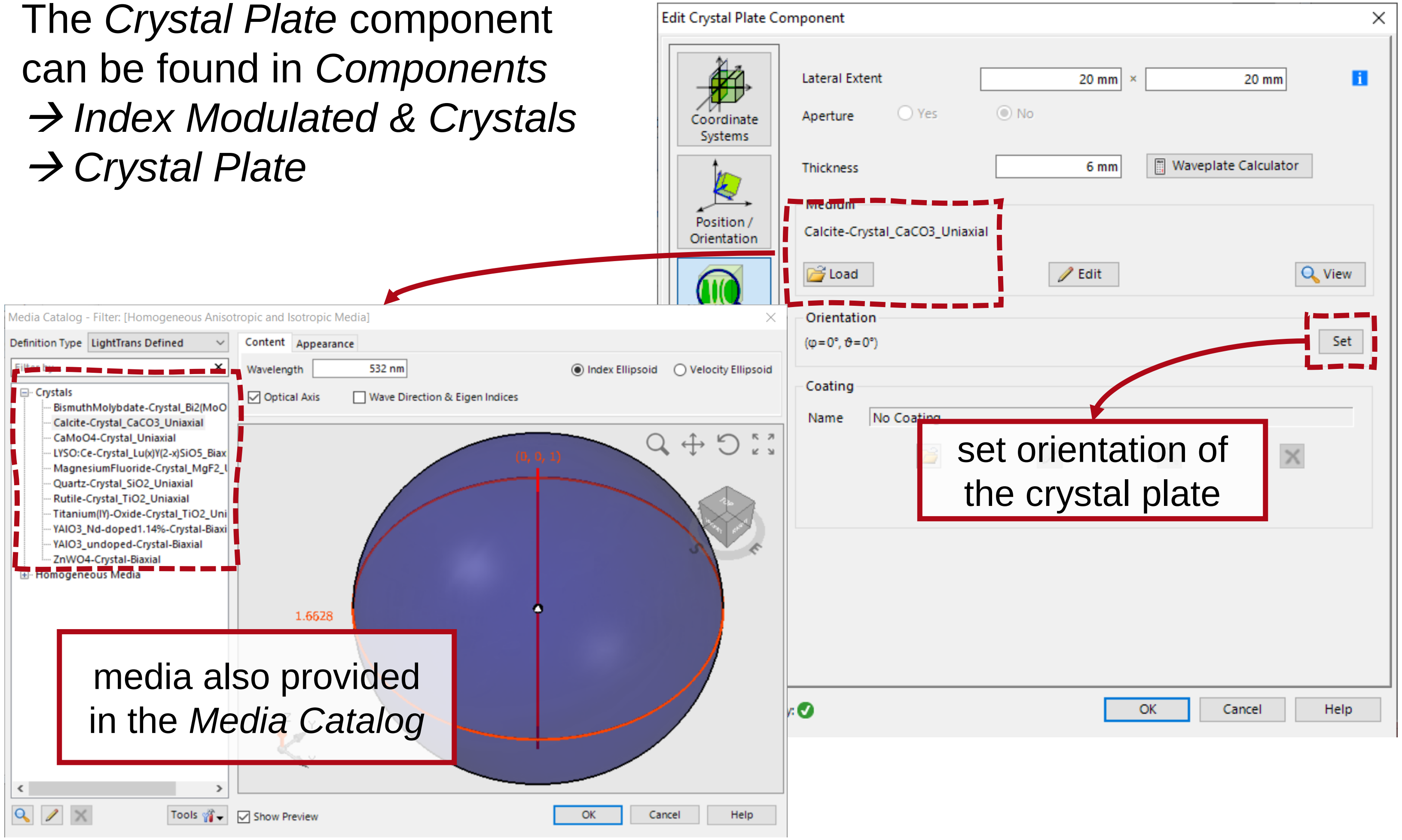


choose from the predefined anisotropic media, a previously defined media from the catalog or use a template medium and customize the parameters; the preview of the medium is shown on the right

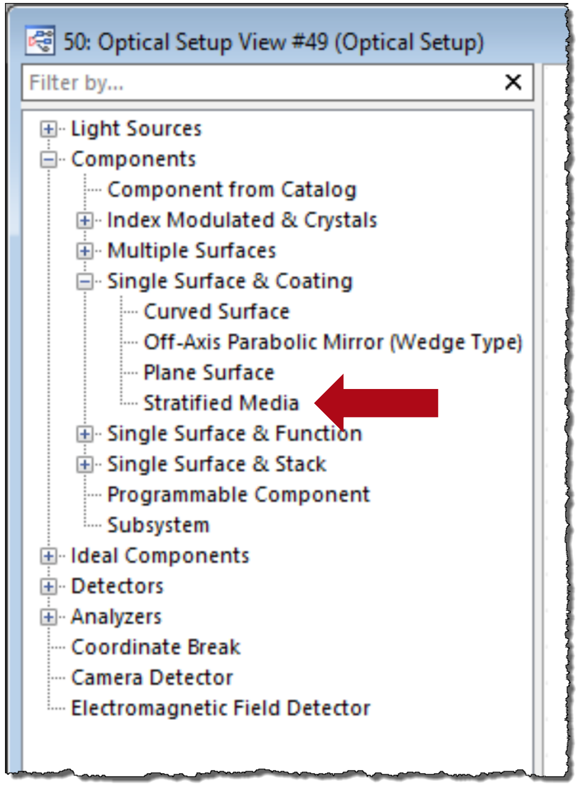
Anisotropic Crystal Plate

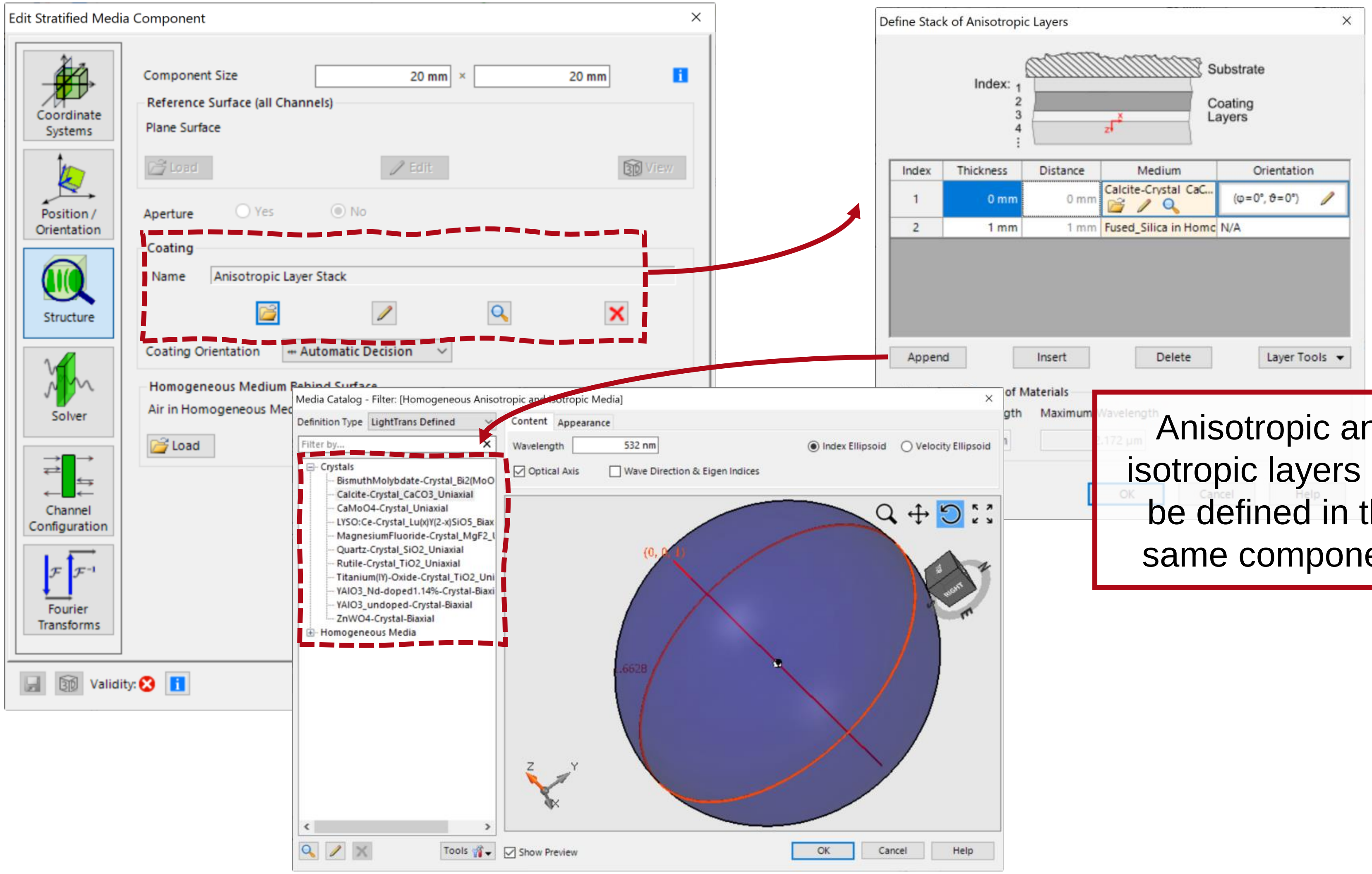


The *Crystal Plate* component can be found in *Components*
→ *Index Modulated & Crystals*
→ *Crystal Plate*



Anisotropic Stratified Media Component

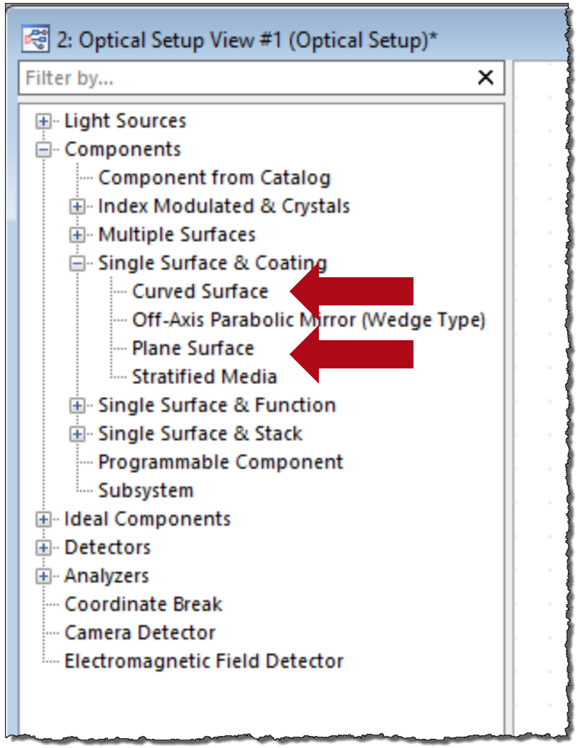


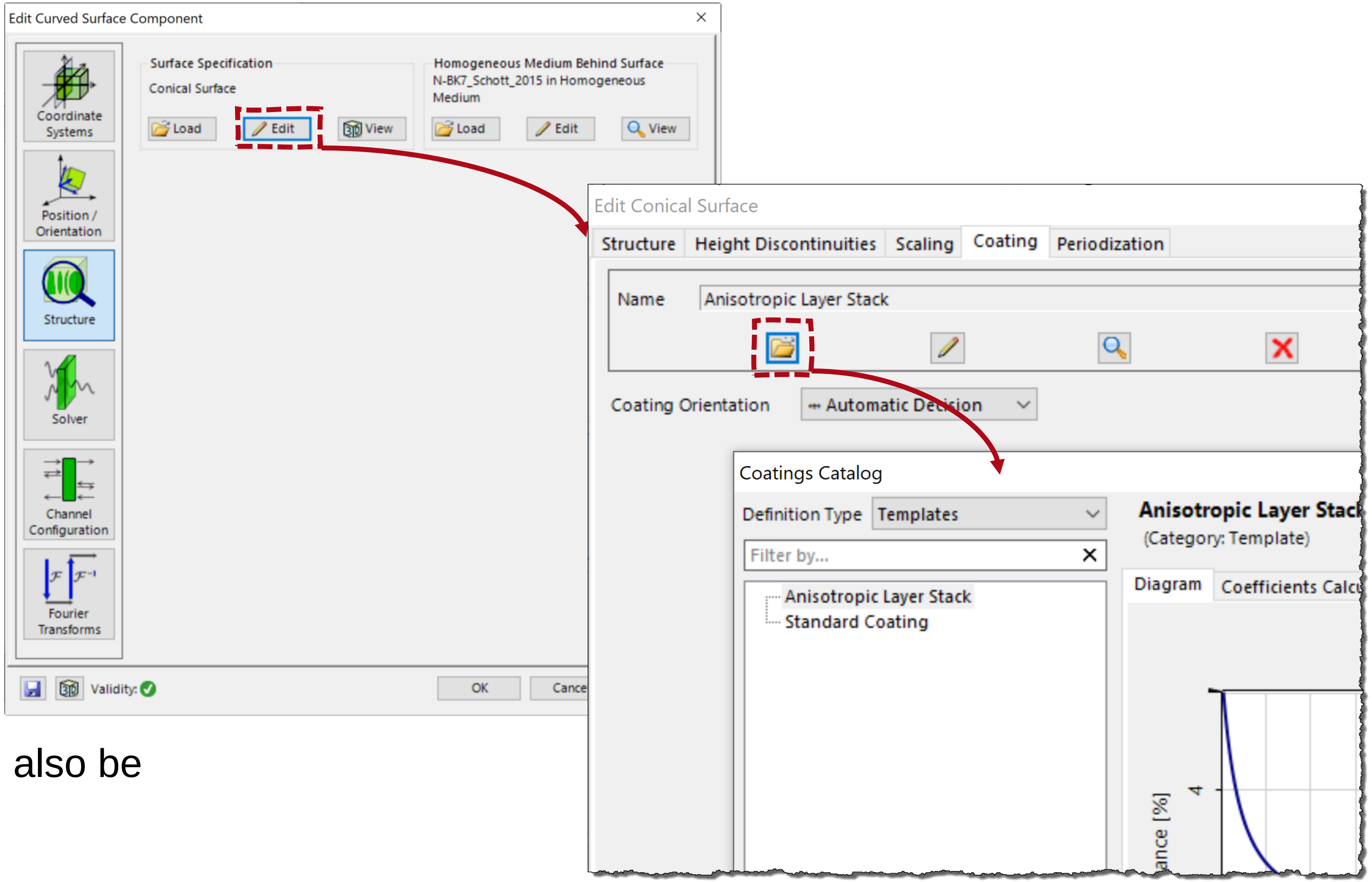


Anisotropic and isotropic layers can be defined in the same component

The *Stratified Media* component can be found in *Components* → Single Surface&Coating → *Stratified Media*

Anisotropic Surfaces

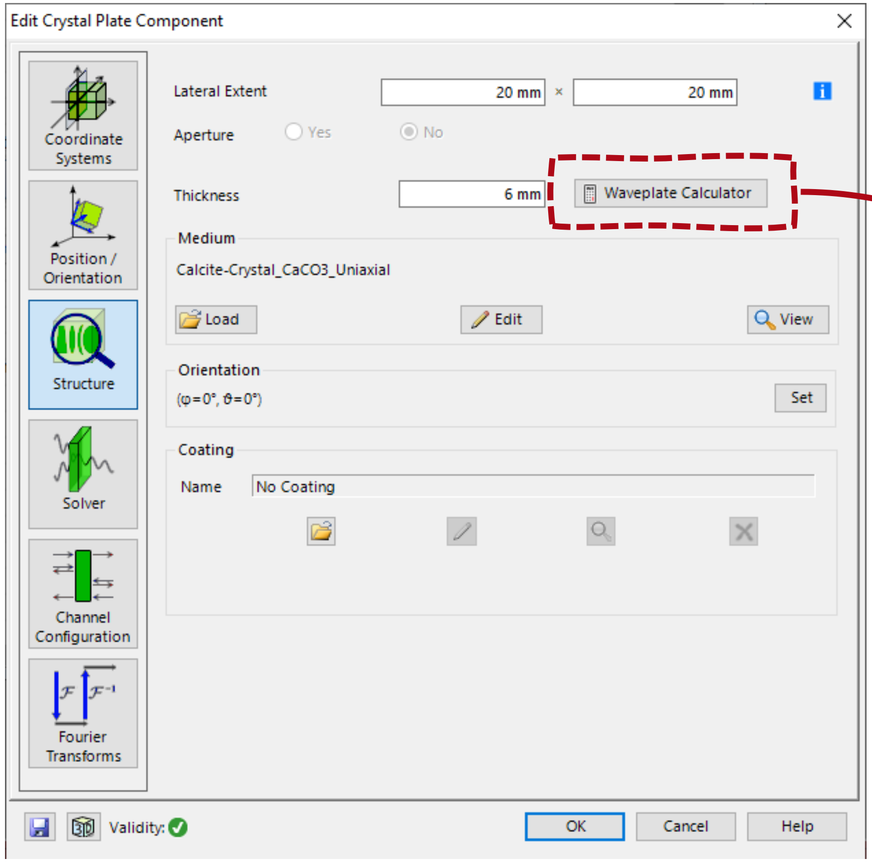


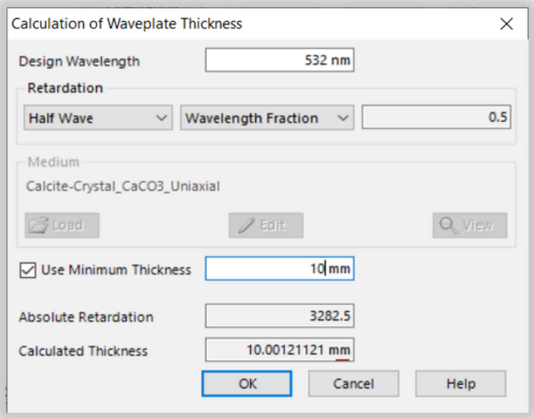


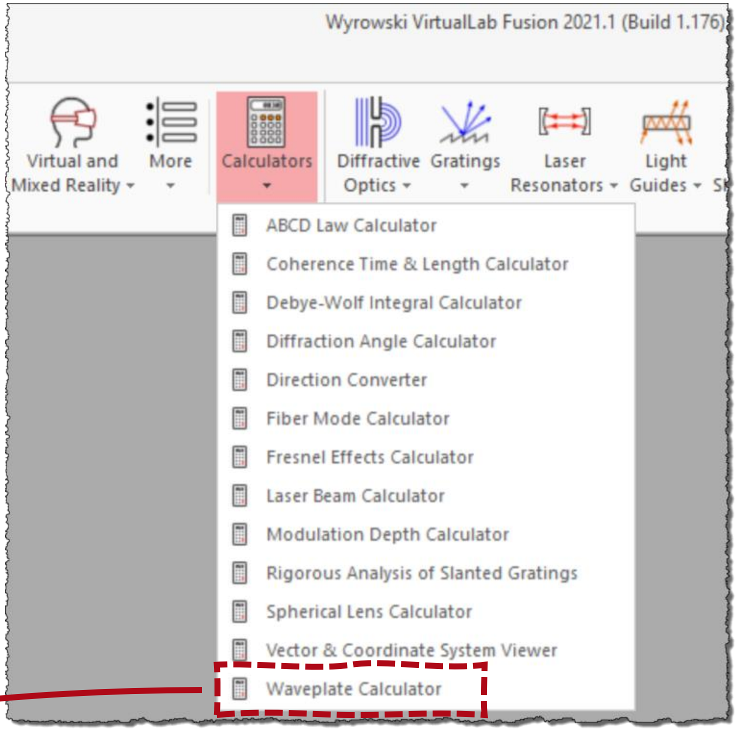
The anisotropic coatings can also be attached to the surfaces.

Waveplate Calculator

The *Crystal Plate Component* as well as the *Calculator* Section of the Main Window allows access to the *Waveplate Calculator* which can be used to determine the thickness and retardation of a waveplate with given characteristics.







Document Information

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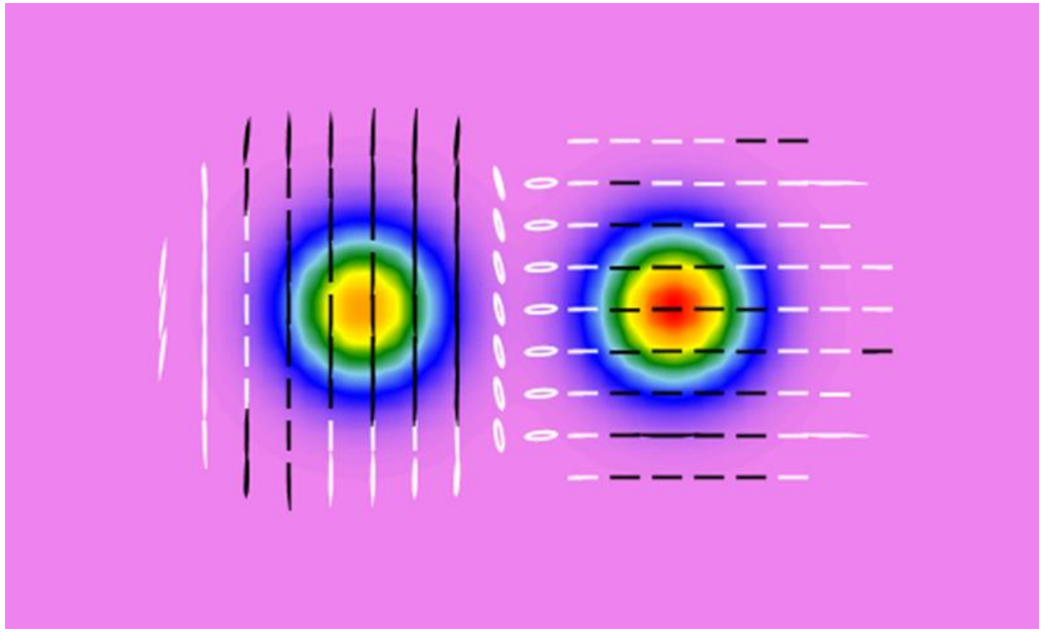
software version	2021.1 (Build 1.176)
category	Feature Use Case
further reading	- Conical Refraction in Biaxial Crystals - Polarization Conversion in Calcite Crystal - Multilayer Birefringent Reflective Polarizer

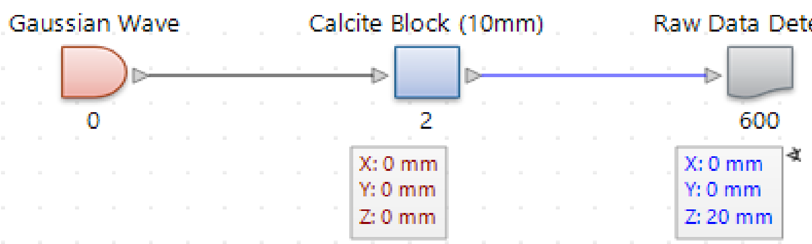
Birefringence Effect of Anisotropic Calcite Crystal

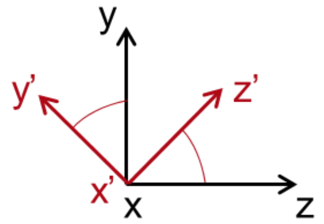
Abstract



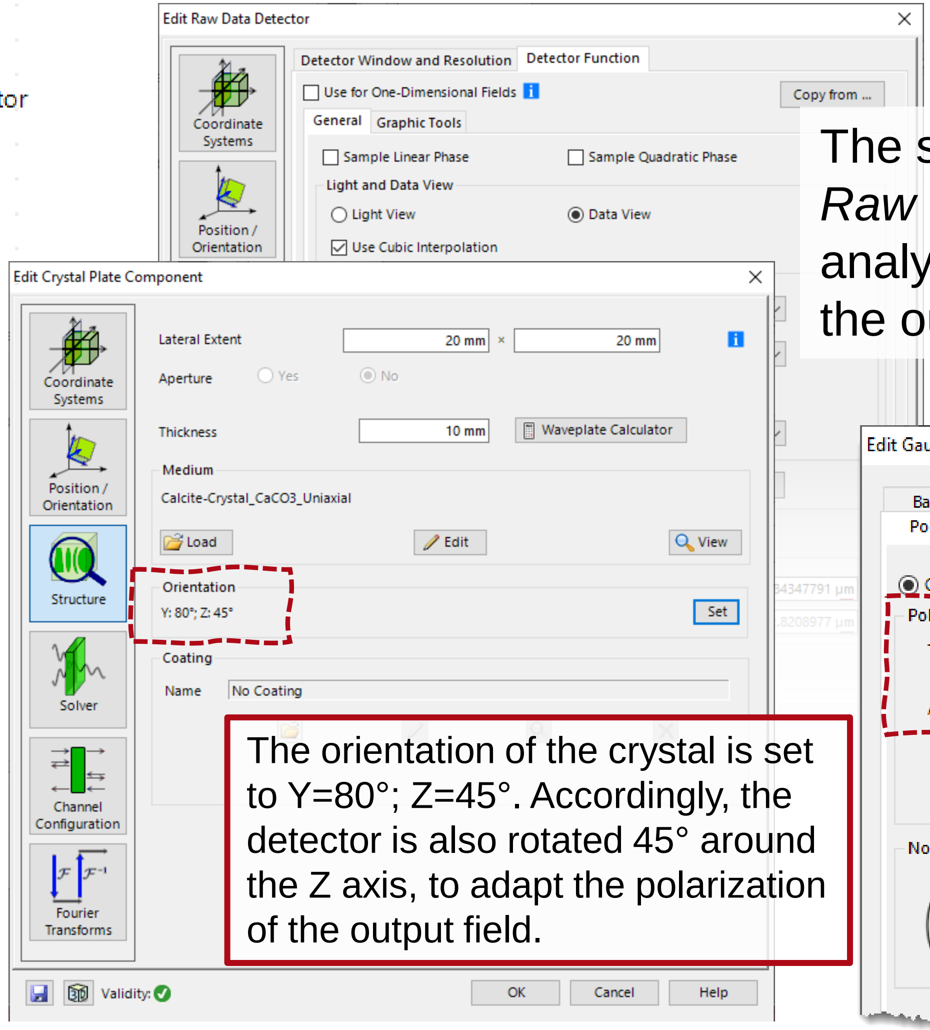
Birefringence is the most famous optical property of anisotropic materials and is widely used in many optical devices. When an input wave impinges upon a birefringent material, it will be split by polarization into two beams taking slightly different paths, known as ordinary beam and extraordinary beam. In this use case, the simulation of the birefringence with VirtualLab Fusion is demonstrated, and the dependence of the effect on input polarization and crystal thickness analyzed.

System Building Blocks



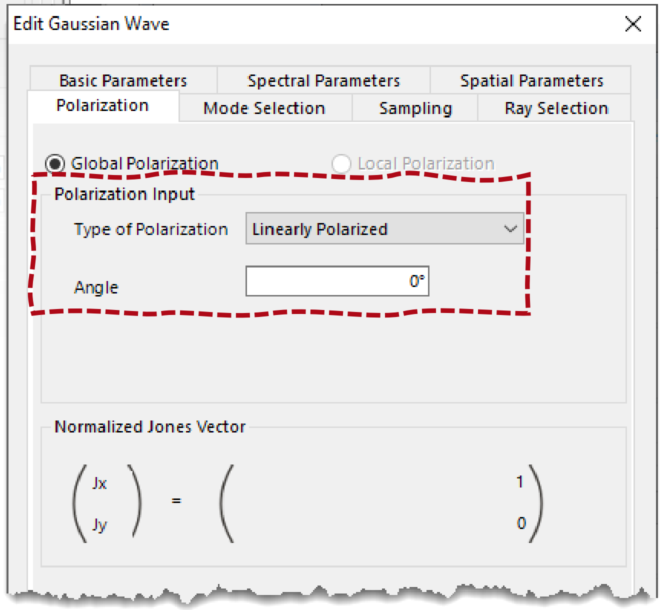


The orientation of the optic axis (marked in red) of the crystal needs to be adjusted in order for the birefringence to be observed.

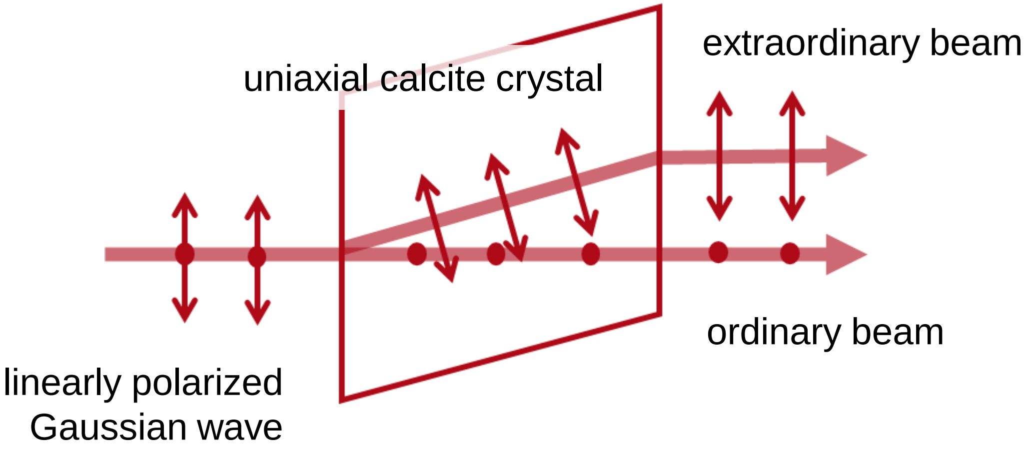


The orientation of the crystal is set to Y=80°; Z=45°. Accordingly, the detector is also rotated 45° around the Z axis, to adapt the polarization of the output field.

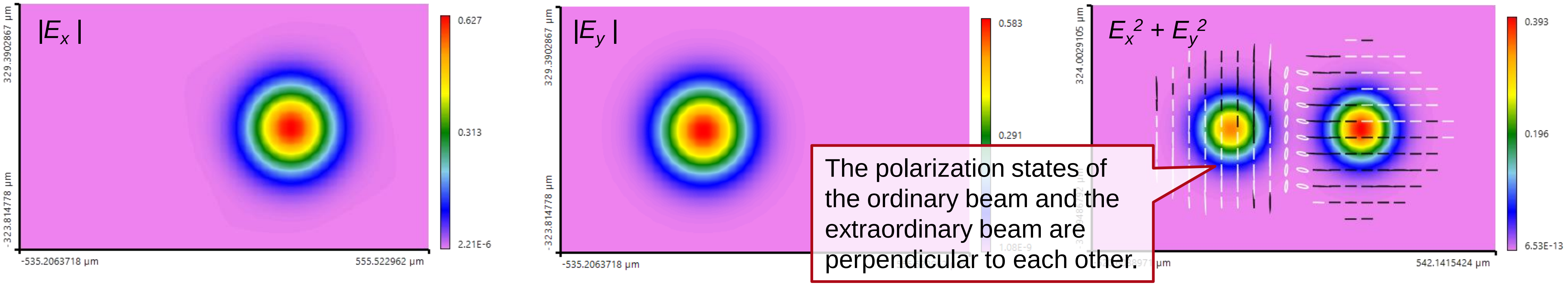
The source is linearly polarized. A *Raw Data Detector* is used to analyze the polarization state of the output field.



Birefringence Effect in Uniaxial Crystals

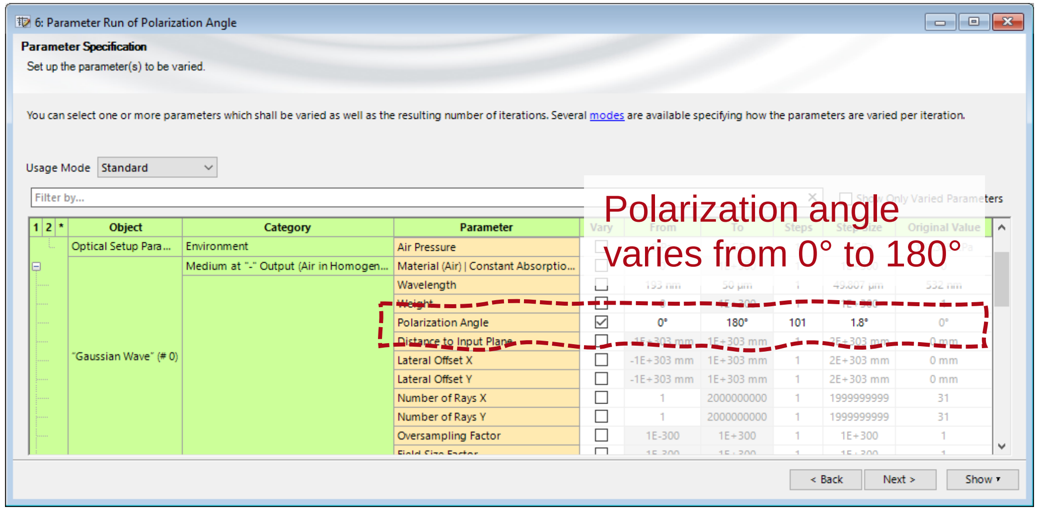


When a beam which propagates along the optic axis of the crystal (and whose field vector therefore lies in the perpendicular plane to the optic axis) impinges on the crystal, it will not “see” the birefringence, and will pass through the crystal at a single velocity. However, when the beam propagates at an angle with respect to the optic axis, it will be refracted into two different modes (ordinary and extraordinary) as it enters the crystal. The two modes propagate with different velocities inside the crystal and their polarization is perpendicular to each other. This is the phenomenon known as double refraction or birefringence.

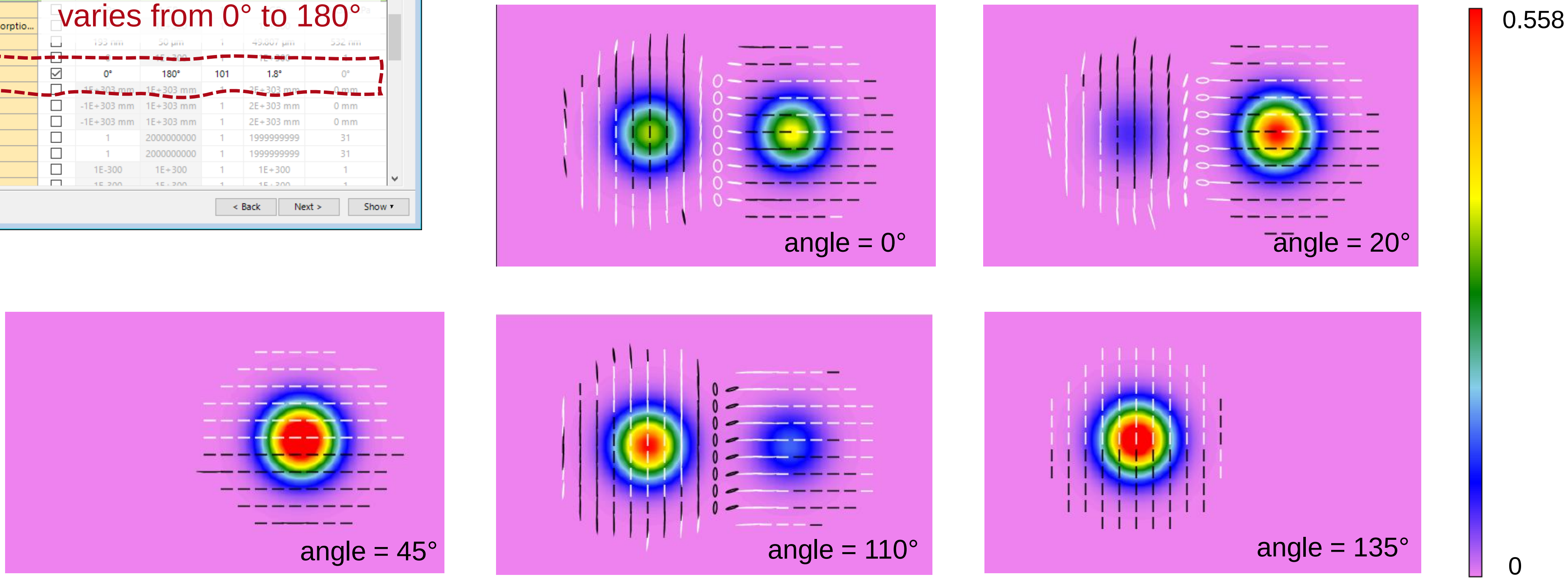


Field tracing result on the detector plane; please note that, the detector window is rotated to adapt the polarization direction.

Birefringence for Different Initial Polarization States

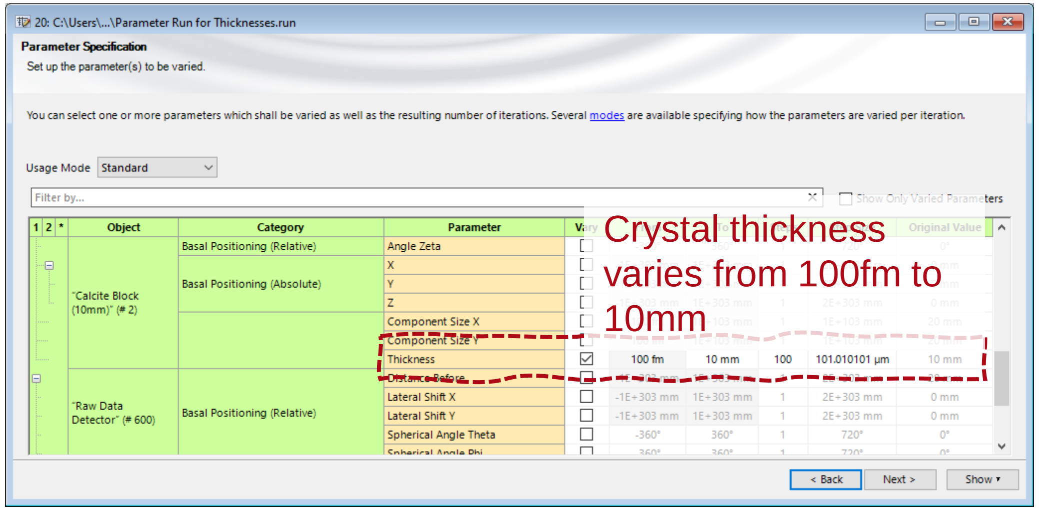


With the orientation of the crystal fixed, the polarization angle of the incident Gaussian wave is scanned with a Parameter Run. As the field tracing results show, the incident beam is distributed into two normal polarization states inside the crystal. When the incident polarization is perpendicular to the optic axis (here, *Polarization Angle* 135º) only the ordinary beam will propagate inside the crystal. When the incident polarization lies along the projection of the optic axis on the entrance plane of the crystal, however, only be the extraordinary beam will be observed (here, *Polarization Angle 45º*).



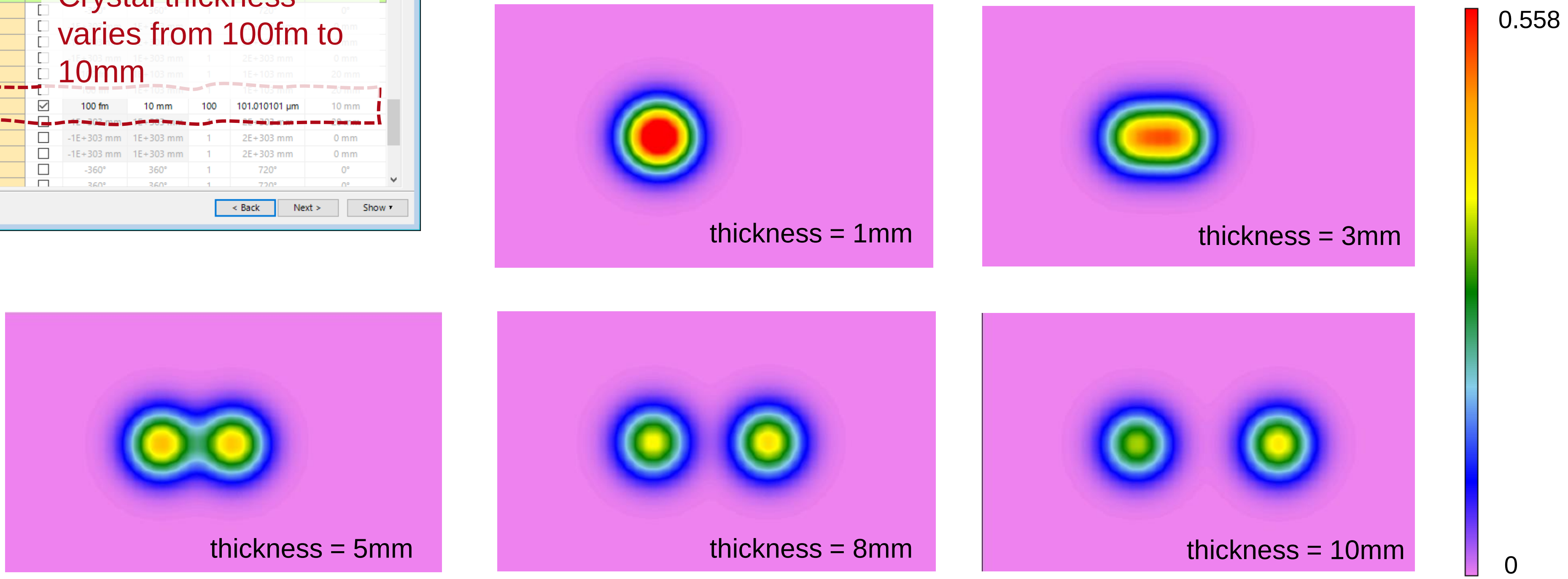
Field tracing results from parameter run, the animation of the varying results is available in the sample file. Please note that the detector is rotated 45° to adjust the polarization direction.

Birefringence for Varying Crystal Thickness



By varying the thickness of the crystal, the shift of the extraordinary beams is observable. As the field tracing results show, the thicker the calcite crystal, the larger the lateral separation between the two beams!

Field tracing results from parameter run, the animation of the varying results is available in the sample file. To be noticed, the detector window is rotated to adapt the polarization direction.

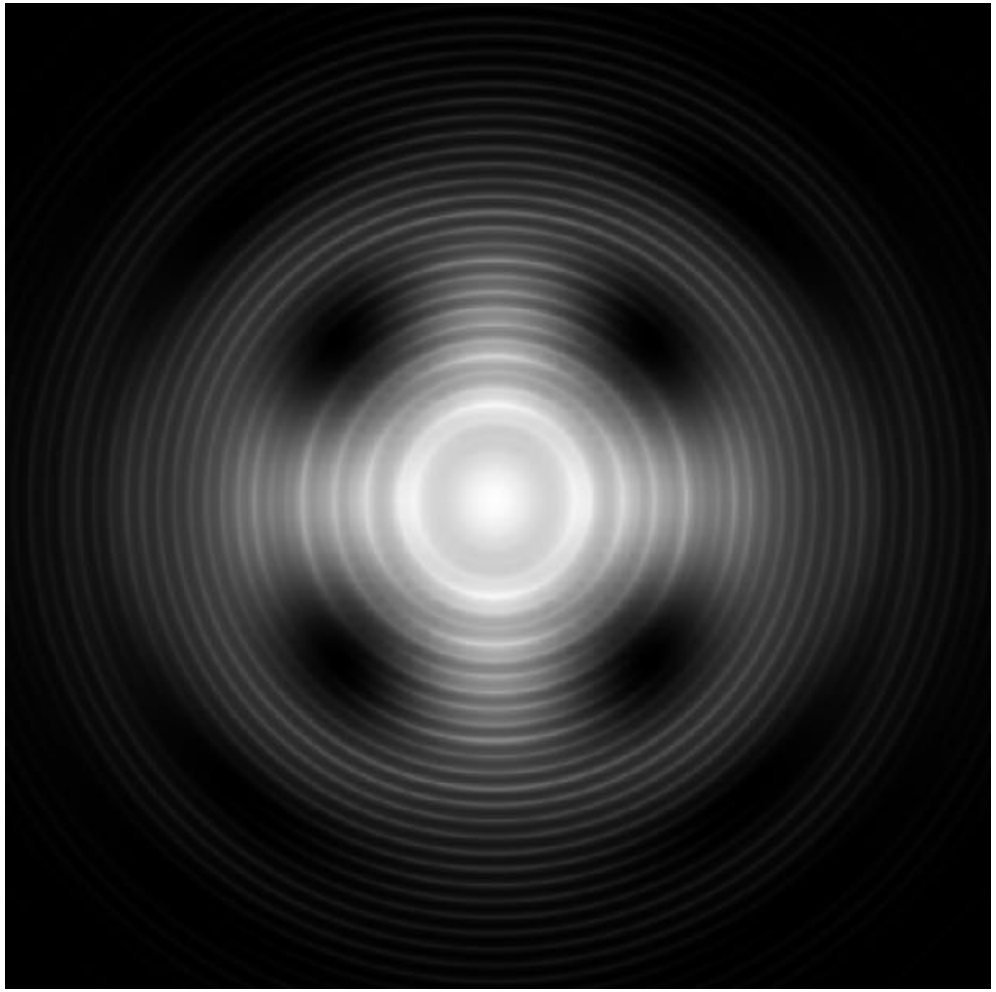


Document Information

title	Birefringence Effect of Anisotropic Calcite Crystal
document code	CRO.0005
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Application Use Case
further reading	- Optically Anisotropic Media in VirtualLab Fusion - Conical Refraction in Biaxial Crystals - Polarization Conversion in Uniaxial Crystals

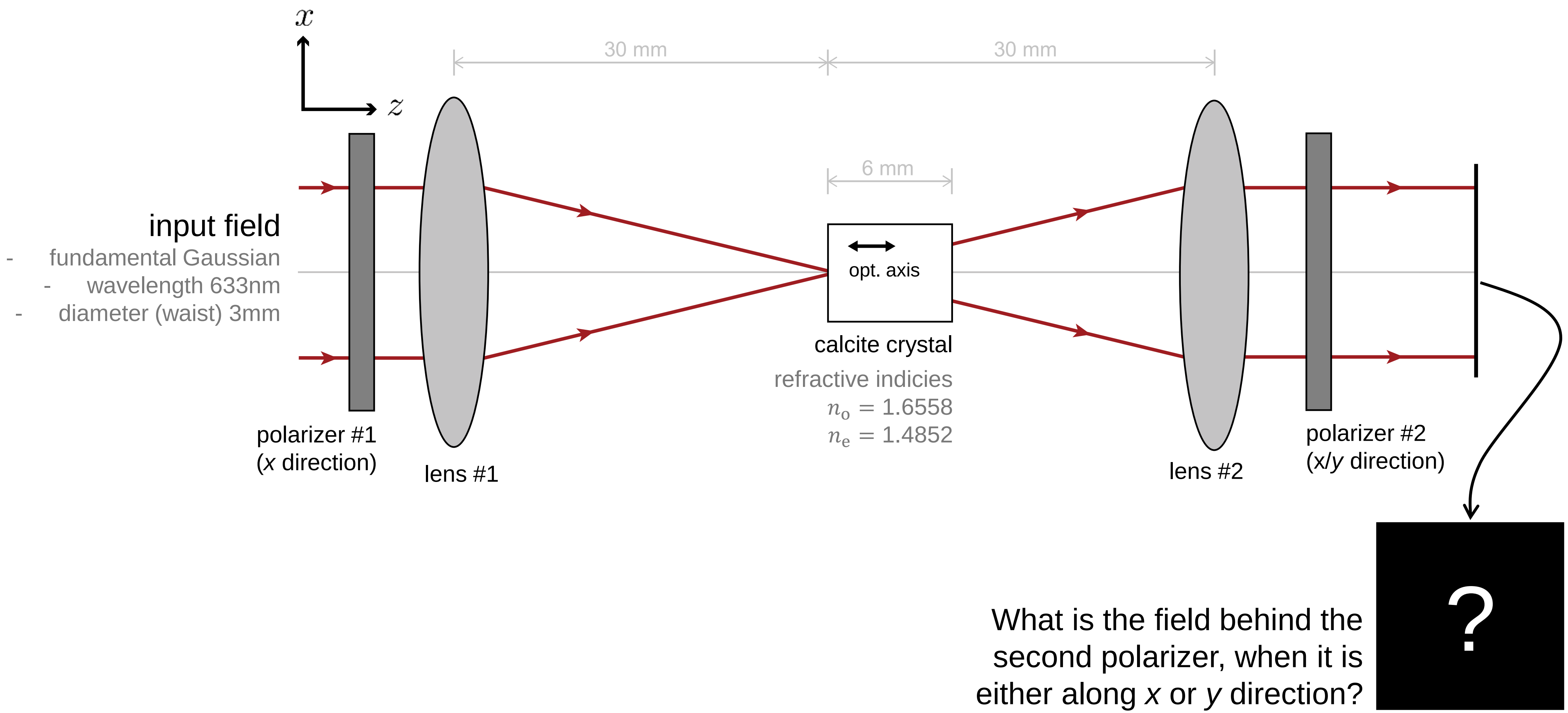
Polarization Conversion in Uniaxial Crystals

Abstract



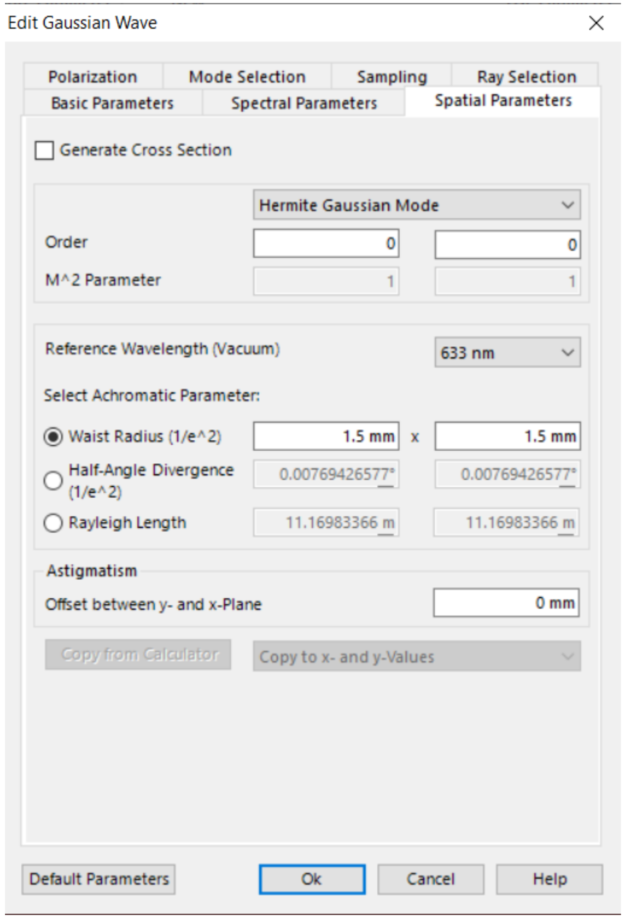
When a linearly polarized beam is focused and then propagated through a uniaxial crystal, even when along the optic axis, complicated conversions may take place between different polarization components. Such an effect can be utilized for e.g. generation of optical vortices. Taking calcite crystal as an example, the conversion of polarization in uniaxial crystals is demonstrated in VirtualLab Fusion. The optical vortices generated within the process are visualized.

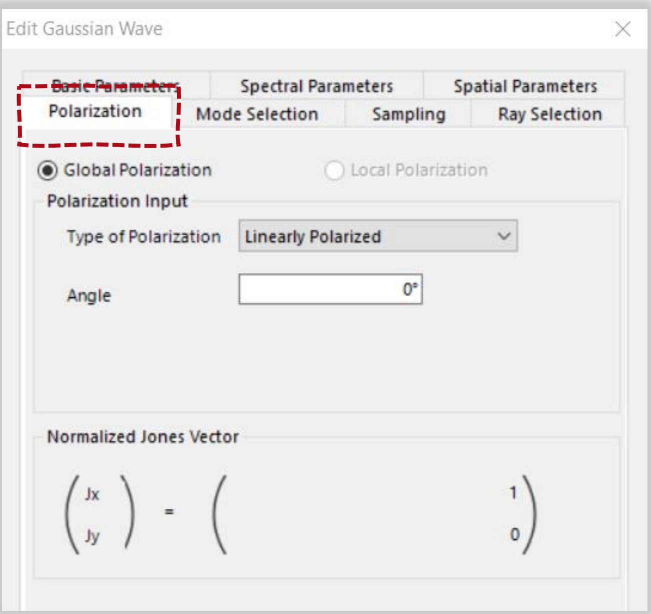
Modeling Task

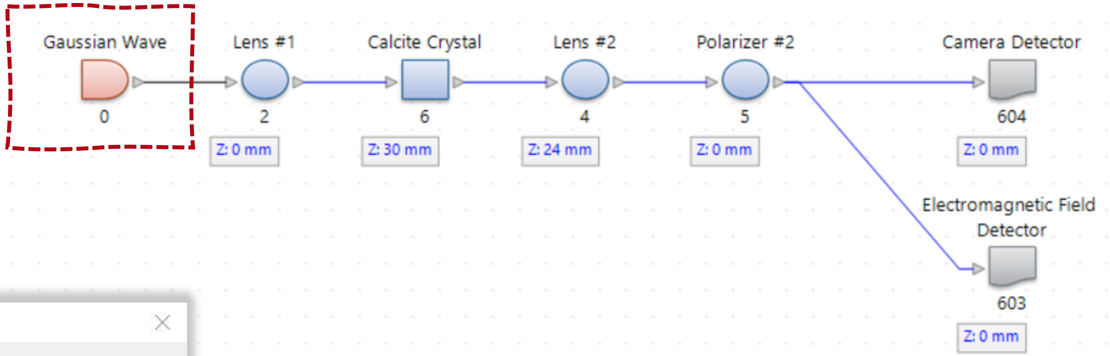


What is the field behind the second polarizer, when it is either along *x* or *y* direction?

System Building Blocks – Source

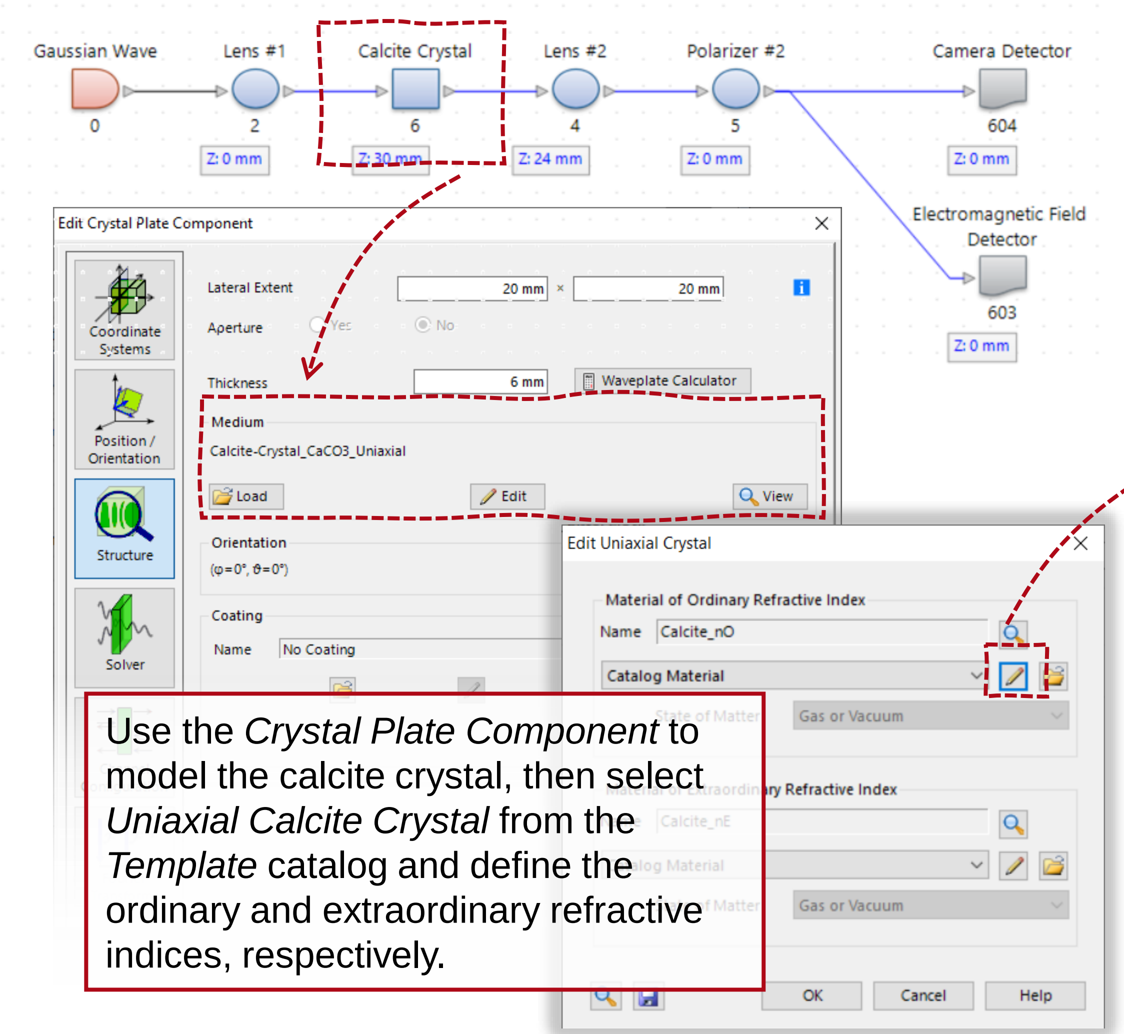




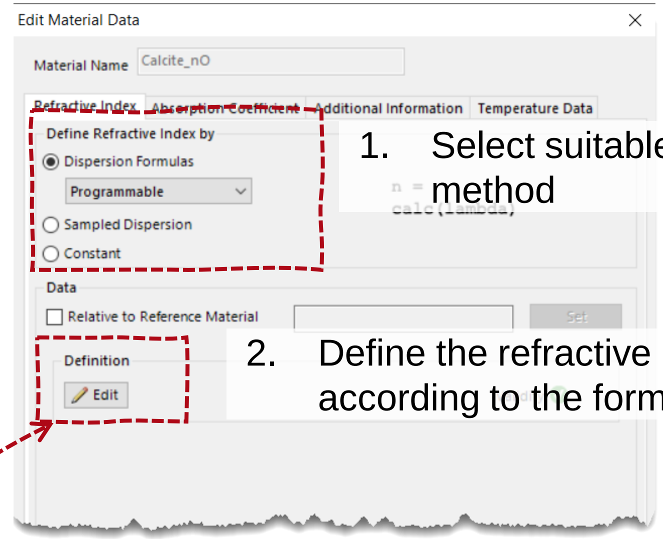


The 1st polarizer changes the Gaussian wave into x polarized. We assume this as the starting point for our system, so the corresponding polarization state (linearly polarized along x) is directly defined in the source.

System Building Blocks – Uniaxial Calcite Crystal



Use the *Crystal Plate Component* to model the calcite crystal, then select *Uniaxial Calcite Crystal* from the *Template* catalog and define the ordinary and extraordinary refractive indices, respectively.



1. Select suitable definition method
2. Define the refractive index according to the formula

Tips: after configuring the material, use the *Save* tab to save the new material to the *User Defined* material catalog and load it easily for the next simulation.

Uniaxial Calcite Crystal

- Thickness: 6mm
- Ordinary refractive index

$$n_o = \left(2.69705 + \frac{0.0192064}{\lambda^2 - 0.0182} - 0.0151624\lambda^2\right)^{1/2}$$

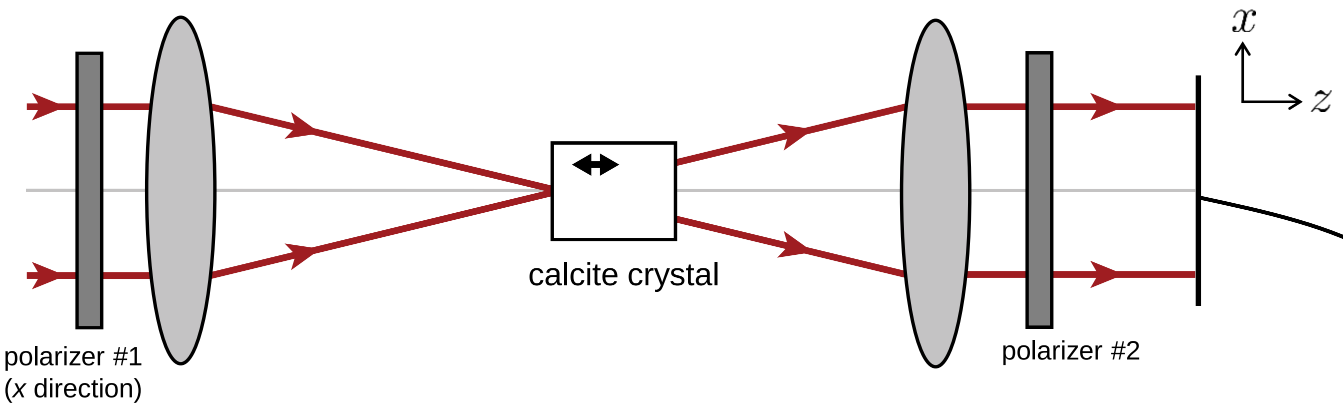
- Extraordinary refractive index

$$n_e = \left(2.18438 + \frac{0.0087309}{\lambda^2 - 0.01018} - 0.0024411\lambda^2\right)^{1/2}$$

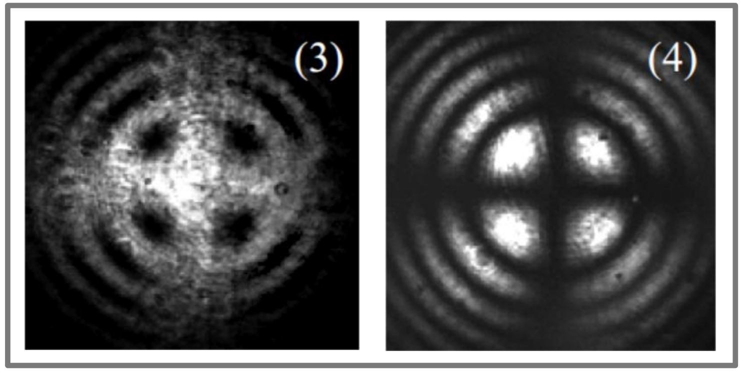
with λ in micrometers.

Parameters follow from Y. Izdebskaya *et al.*, Opt. Express **17**, 18196-18208 (2009)

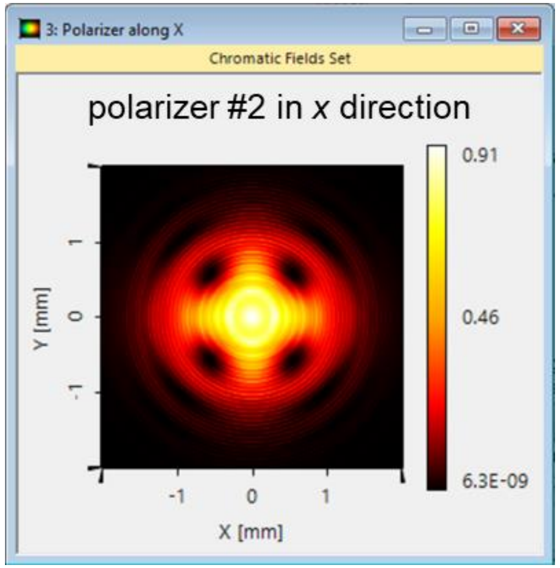
Results

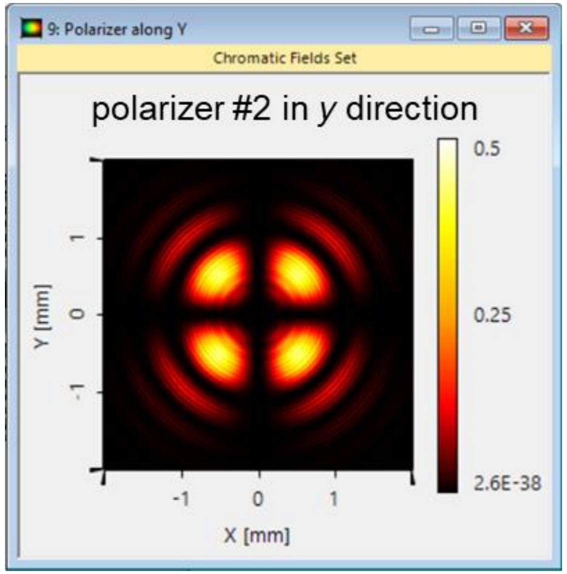


Physical-optics simulation of complete system includes birefringence and interference effects.

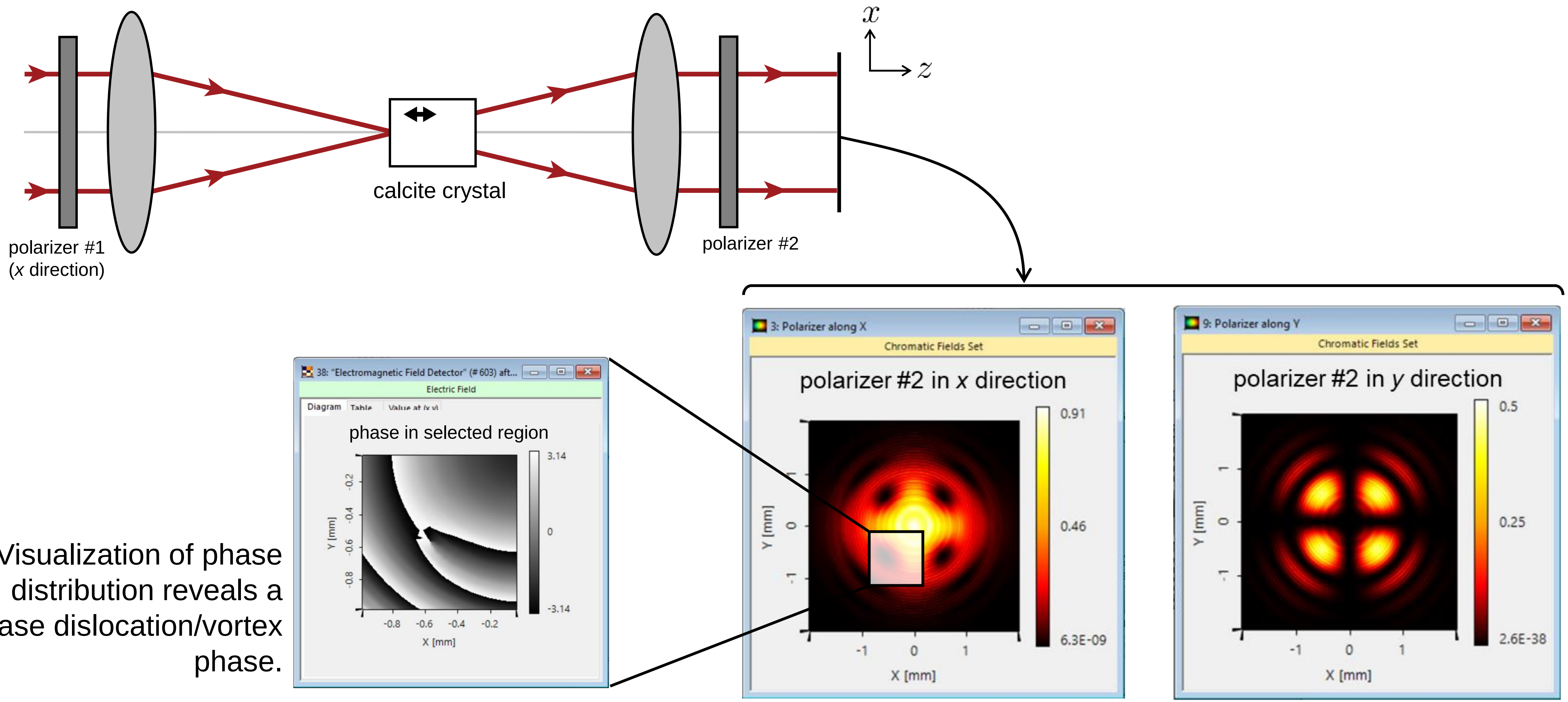


Experimental measurements from Y. Izdebskaya *et al.*, Opt. Express **17**, 18196-18208 (2009)



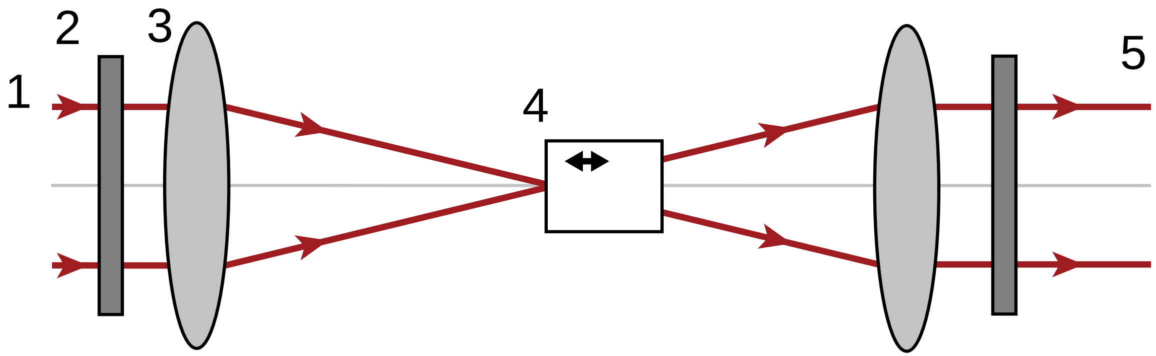


Results



Visualization of phase distribution reveals a phase dislocation/vortex phase.

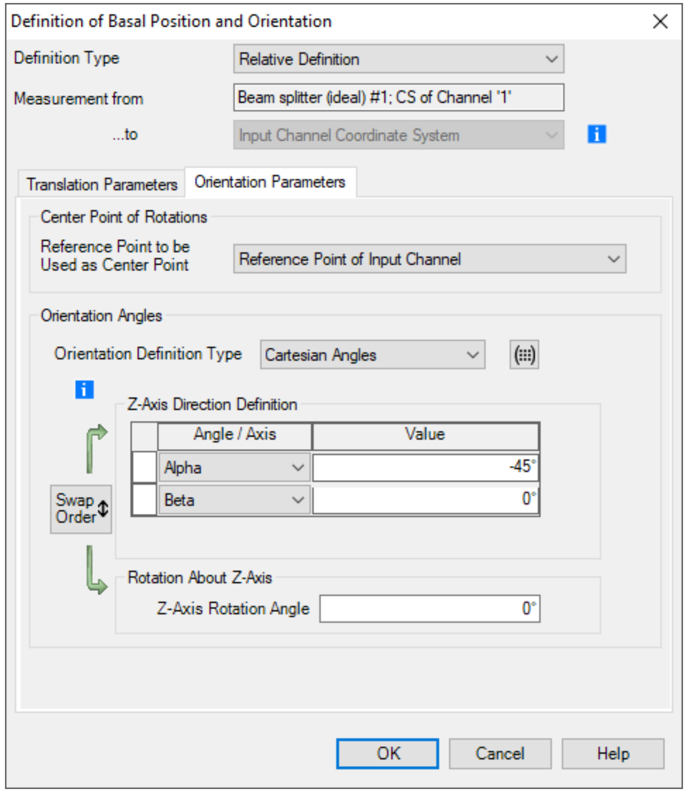
Summary – Components...



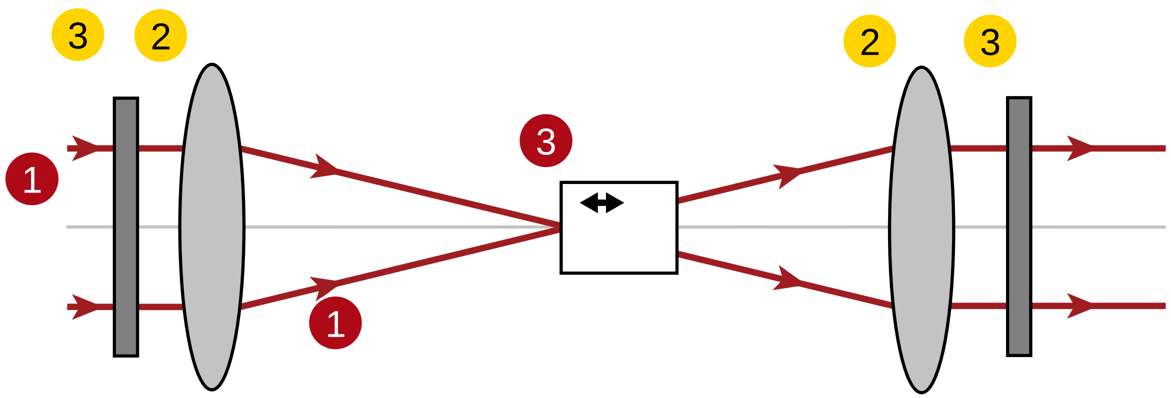
… of Optical System	… in VirtualLab Fusion	Source Model/Component Solver
1. Source	Gaussian Source	
2. Polarizer	Polarizer	-
3. Lens	Ideal Lens	
4. Calcite Crystal	Crystal Plate	Layer Matrix [S-Matrix]
5. Detector	Camera Detector	-

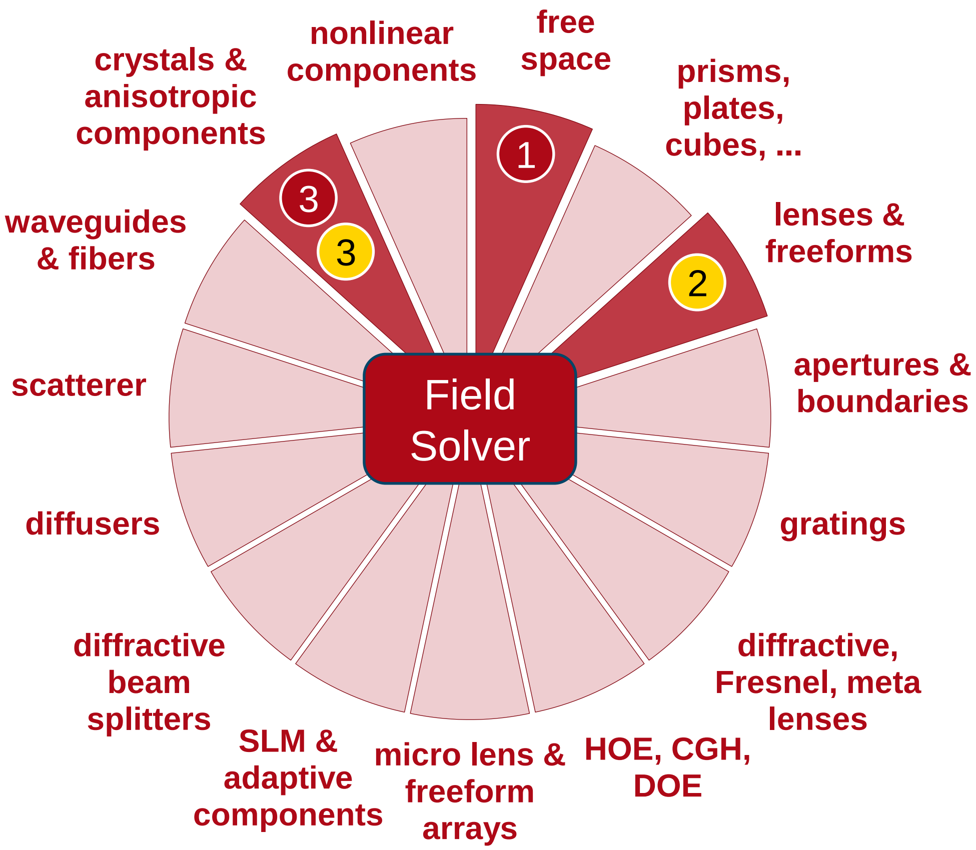
Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Construct real components using surfaces
- Set up Uniaxial Calcite Crystal
  - Optically Anisotropic Media in VirtualLab Fusion [Use Case]
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]



VirtualLab Fusion Technologies





idealized component

Document Information

title	Polarization Conversion in Uniaxial Crystals
document code	CRO.0003
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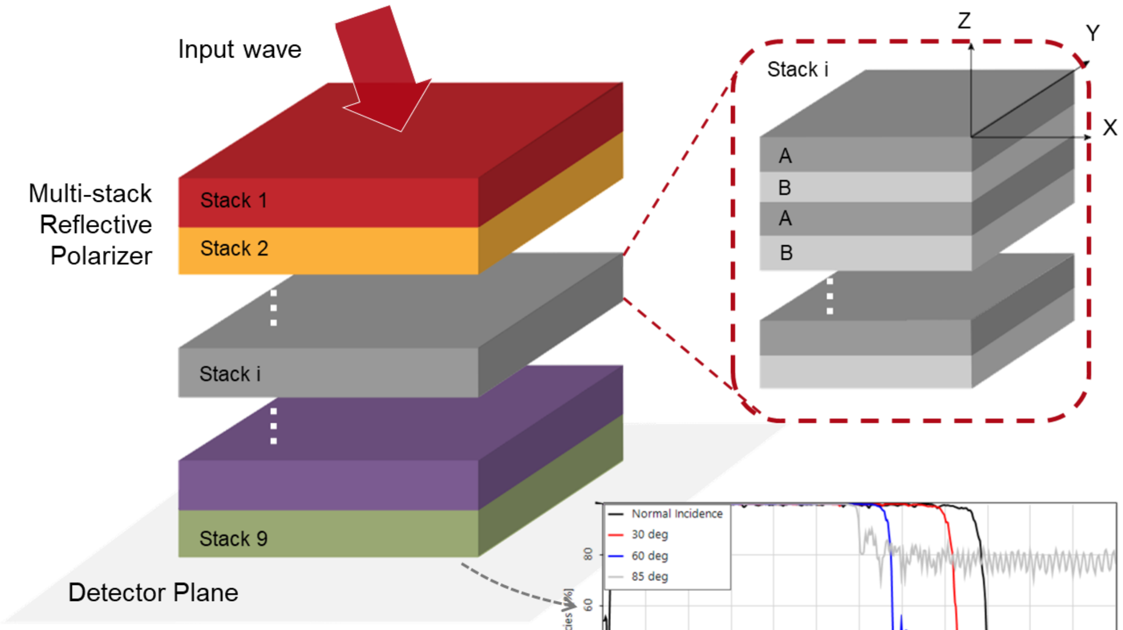
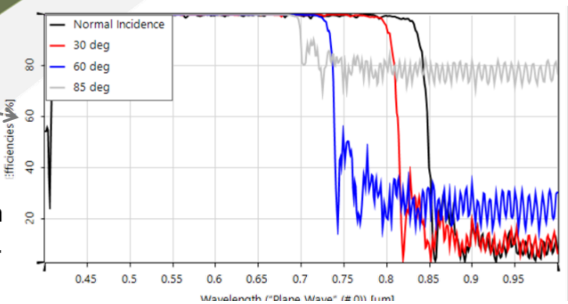
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.176)
category	Application Use Case
further reading	- Optically Anisotropic Media in VirtualLab Fusion - Conical Refraction in Biaxial Crystals

Simulation of Multilayer Birefringent Reflective Polarizer with VirtualLab Fusion

Abstract





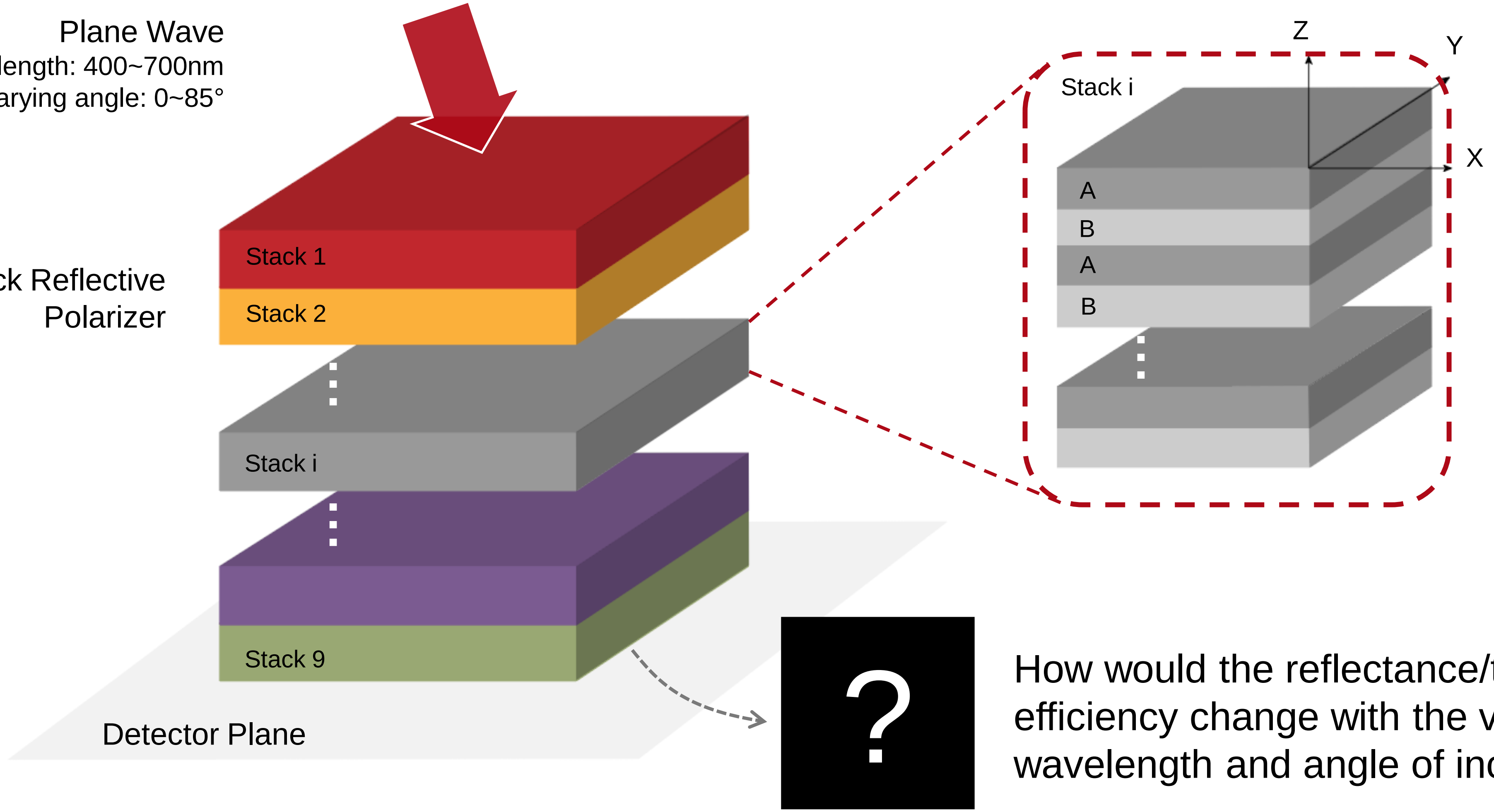
The variation of reflectance efficiency with different wavelengths and incident angles.

Multilayer birefringent reflective polarizers have big advantages in liquid crystal display (LCD) applications. They can recycle the backlight so as to improve the optical efficiency of LCDs. In this use case, we reproduce the experiments in Li et. al. J. Display Technol. 5, 335-340 (2009) to explore the relationship between the number of alternate birefringent layers and the Bragg reflection condition in VirtualLab Fusion. Then the variation of the reflectance efficiency with different wavelengths and incident angles is further investigated.

Task Description

Plane Wave
- wavelength: 400~700nm
- varying angle: 0~85°

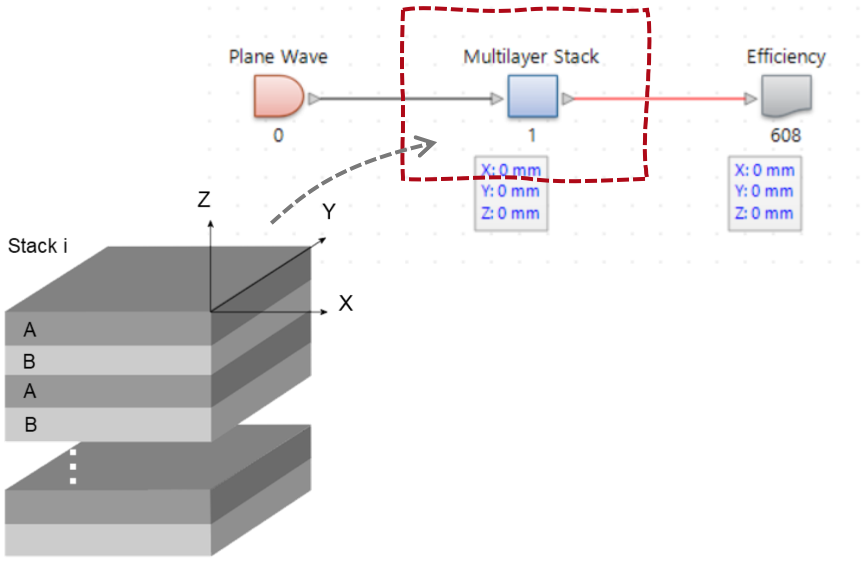
Multi-stack Reflective Polarizer



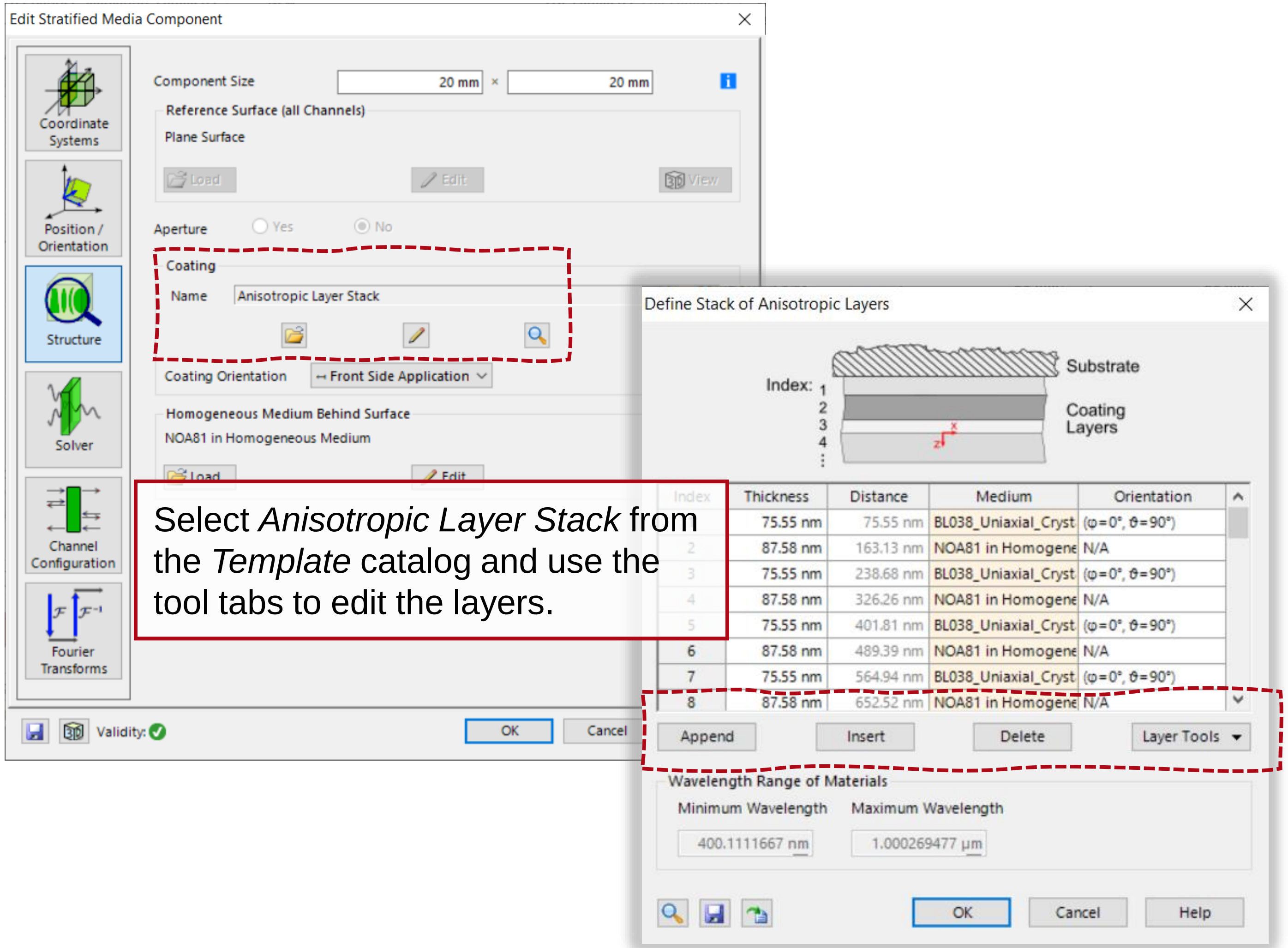
Multilayer Stack
- A: birefringent layer (BL038)
- B: isotropic layer (NOA81)
- $n_x = n_e$
- $n_y = n_z = n_o$

How would the reflectance/transmittance efficiency change with the variation of the wavelength and angle of incidence?

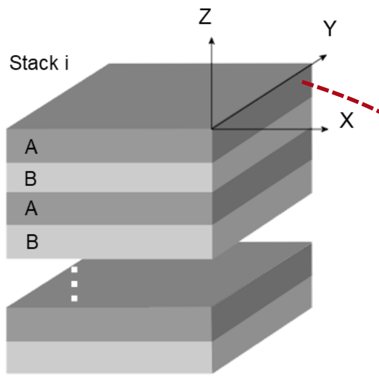
Modeling of the Multilayer Stack

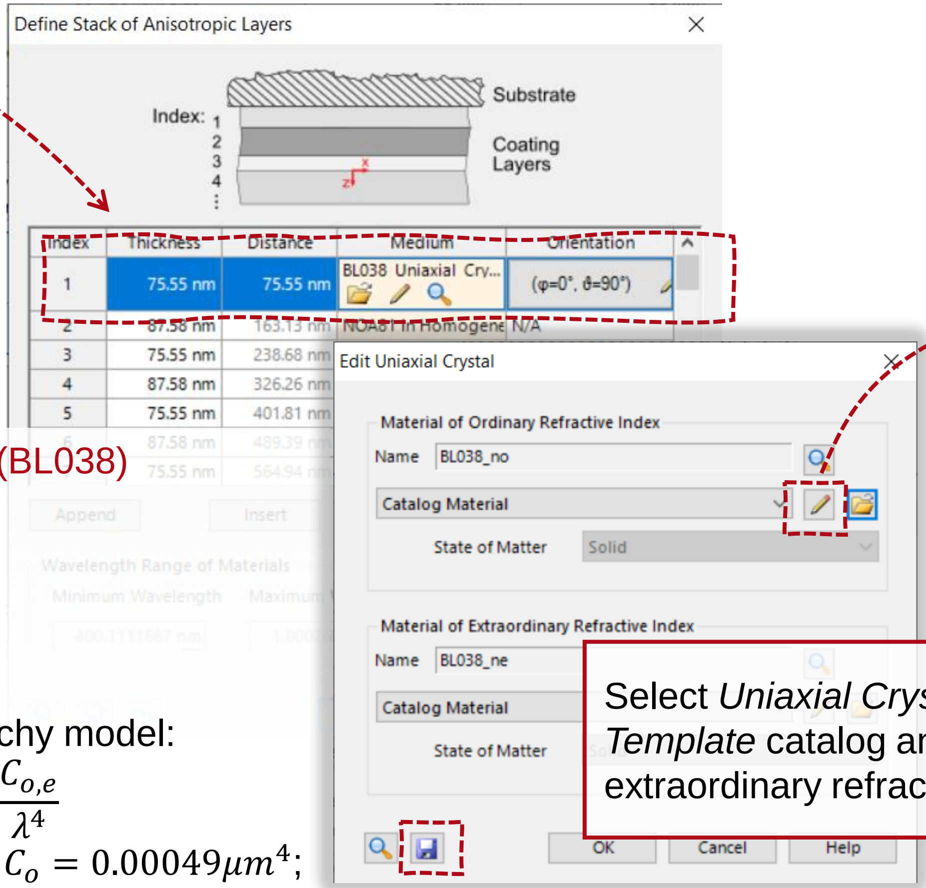


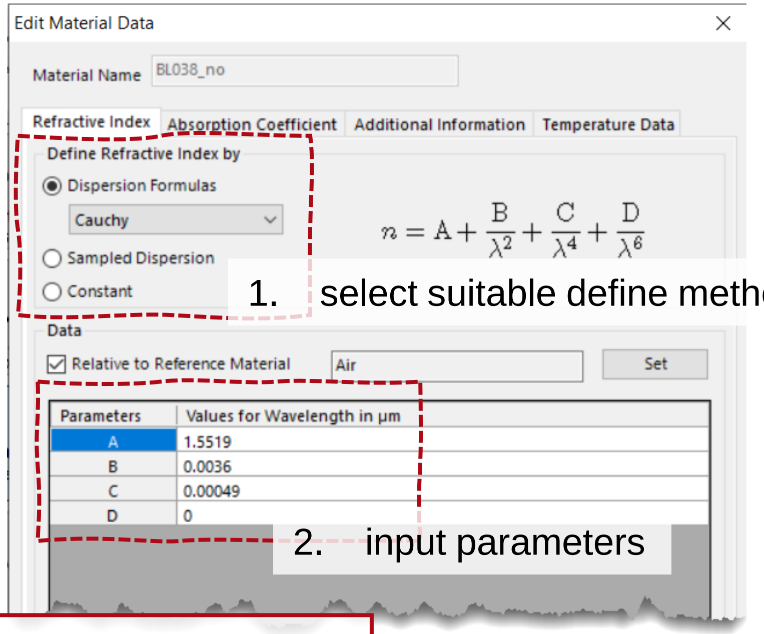
A Stratified Media Component is used to model the multilayer stack.



Layer A: Birefringent Uniaxial Layers (BL038)







1. select suitable define method

2. input parameters

Select *Uniaxial Crystal* media from the *Template* catalog and define the ordinary and extraordinary refractive indices, respectively.

Layer A: birefringent uniaxial layer (BL038)

- Layer thickness: 75.55nm
- Ordinary refractive index

$$n_o = n_y = n_z$$

- Extraordinary refractive index

$$n_e = n_x$$

- According to the extended Cauchy model:

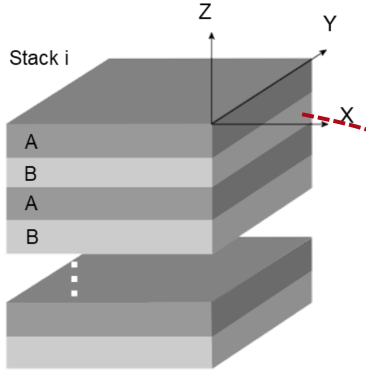
$$n_{o,e} = A_{o,e} + \frac{B_{o,e}}{\lambda^2} + \frac{C_{o,e}}{\lambda^4}$$

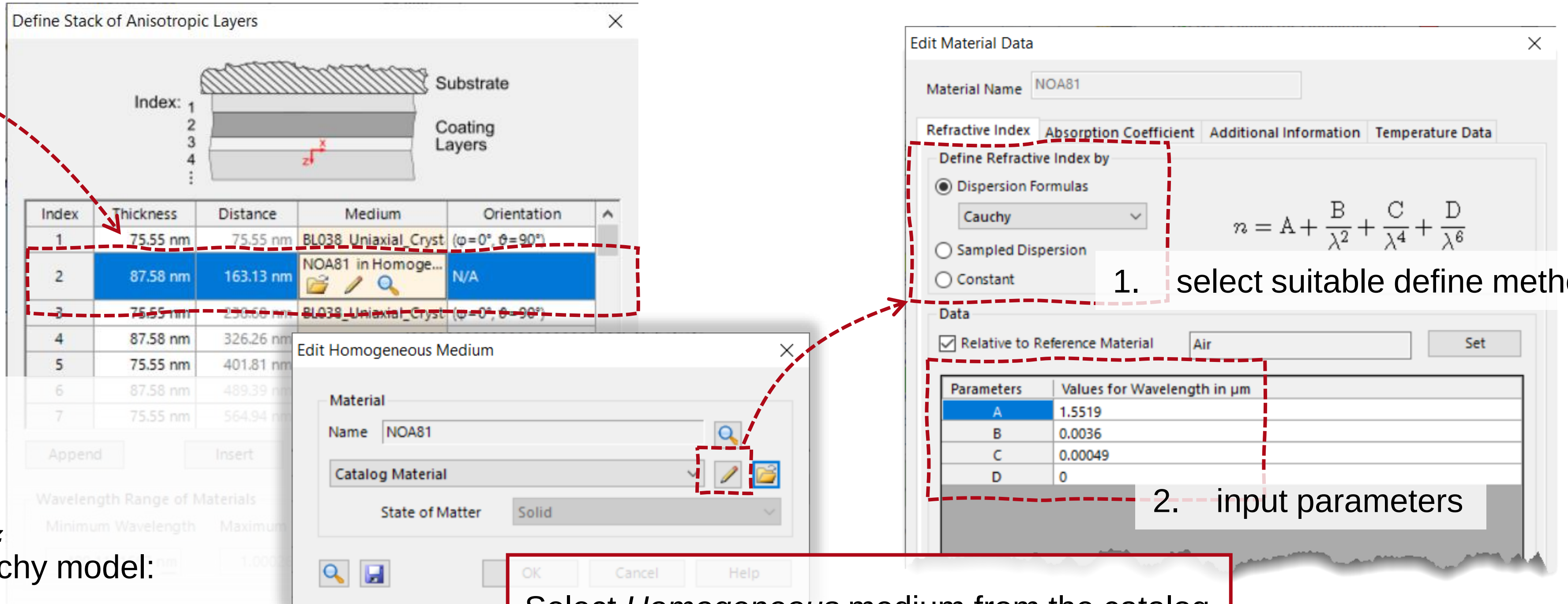
and $A_o = 1.5519$, $B_o = 0.0036\mu m^2$, $C_o = 0.00049\mu m^4$;
$A_e = 1.74775$, $B_e = 0.01184\mu m^2$, $C_o = 0.00303\mu m^4$

Tips: after configuring the material, use the *Save* tab to save the new material to the *User Defined* material catalog and load it easily for the next simulation.

Parameters follow from Li et. al. J. Display Technol. 5, 335-340 (2009)

Layer B: Isotropic Layers (NOA81)





Layer B: isotropic layer (NOA81)

- Layer thickness: 87.58nm
- Refractive index

$$n = n_o = n_y = n_z$$

- According to the extended Cauchy model:

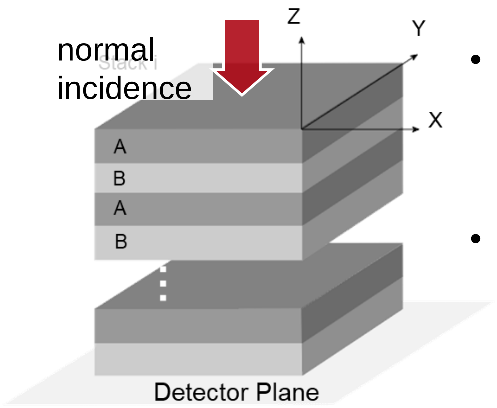
$$n = A + \frac{B}{\lambda^2} + \frac{C}{\lambda^4}$$

and $A = 1.5519$, $B = 0.0036\mu m^2$, $C = 0.00049\mu m^4$.

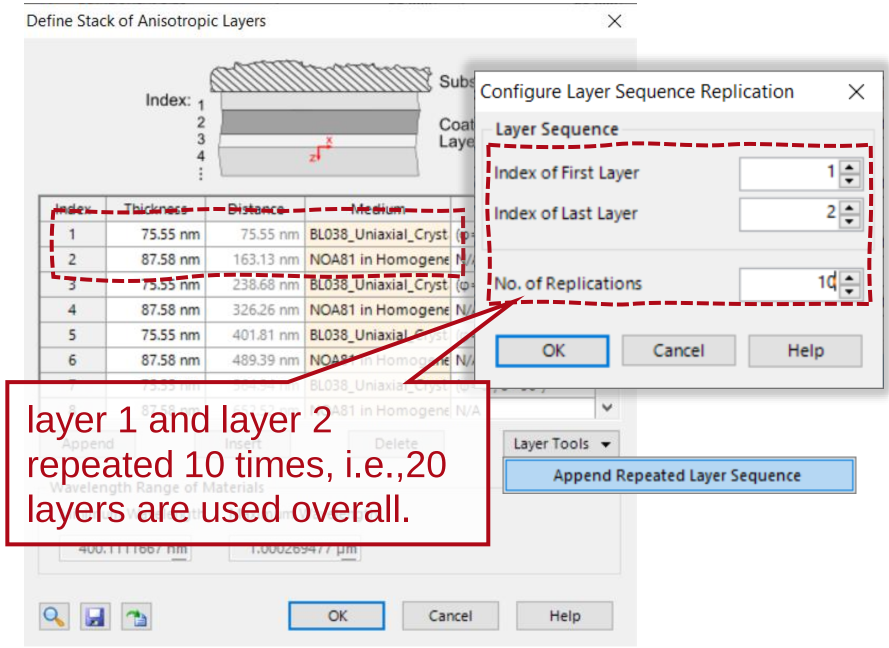
Select *Homogeneous* medium from the catalog and define the refractive index according to the Cauchy formula. Here, the designated isotropic material's refractive index is the same as the uniaxial material's ordinary refractive index.

Parameters follow from Li et. al. J. Display Technol. 5, 335-340 (2009)

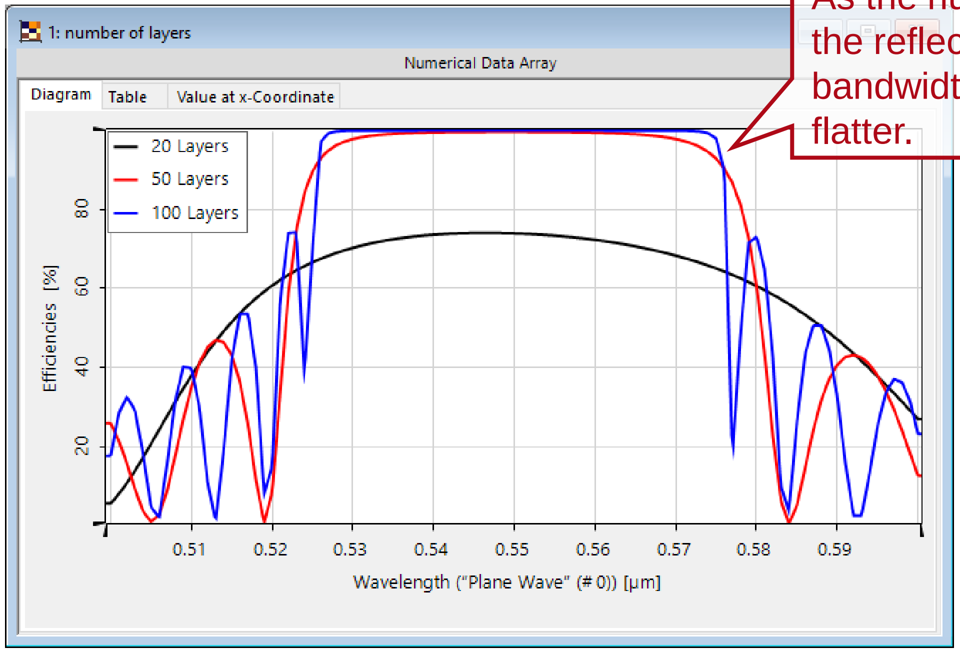
Number of Periodic Layers to Establish Bragg Condition



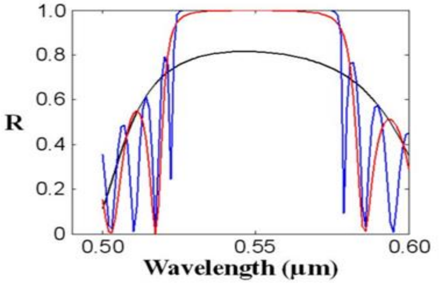
- When the unpolarized plane wave hits the reflective polarizer, one direction of linear polarized light will pass through while the other component will be reflected back and depolarized, then it will be reflected again for another cycle. After several cycles, more and more light will be able to pass through the polarizer and therefore the energy efficiency is enhanced.
- In order to achieve the highest possible efficiency, the aim is to fulfill the Bragg reflection condition. Therefore, a minimum number of periodic layers is required. We used a *Parameter Run* to scan the wavelength range and calculate the efficiency with 20 layers, 50 layers, and 100 layers respectively.



layer 1 and layer 2 repeated 10 times, i.e.,20 layers are used overall.

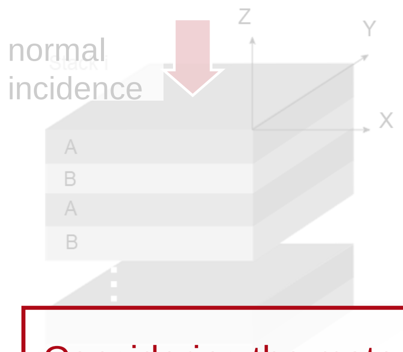


As the number of layers increases, the reflectance within the desired bandwidth becomes higher and flatter.



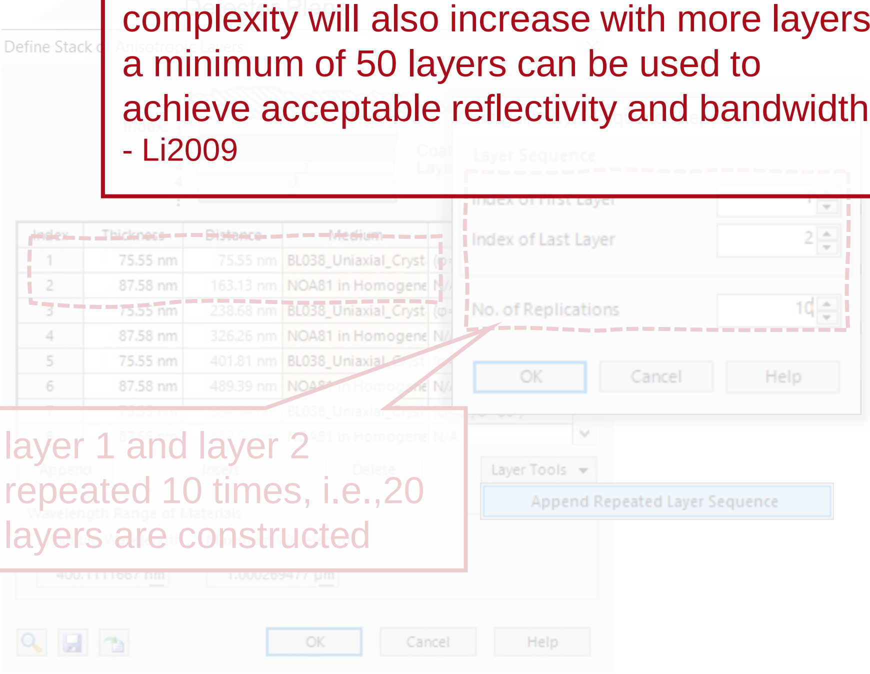
simulation result compare with Li et. al. J. Display Technol. 5, 335-340 (2009)

Number of Periodic Layers to Establish Bragg Condition

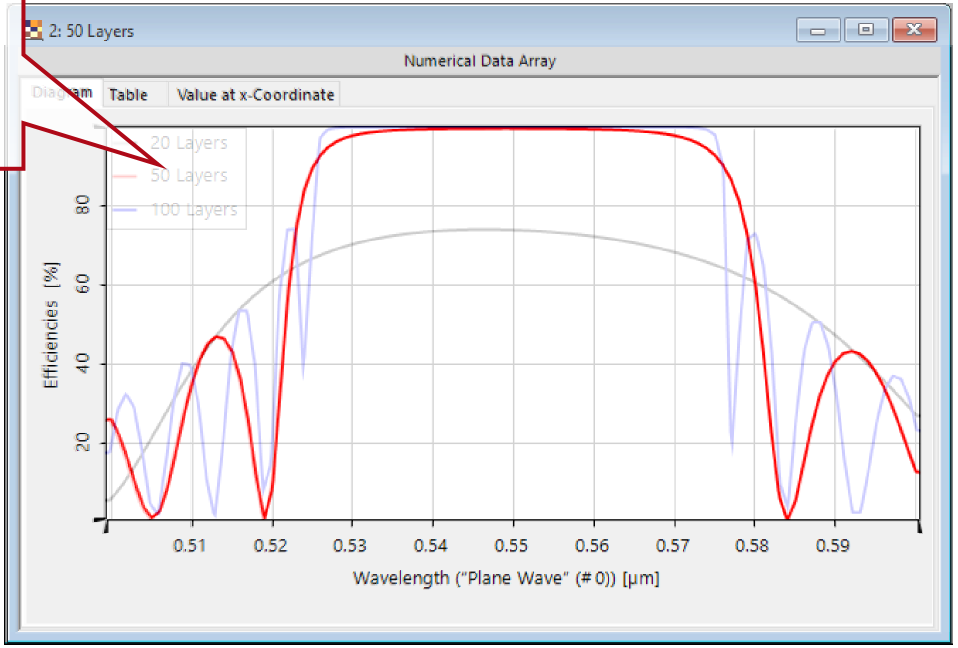


- When the unpolarized plane wave hits the reflective polarizer, one direction of linear polarized light will pass through while the other component will be reflected back and depolarized, then it will be reflected again for another cycle. After several cycles, more and more light will be able to pass through the polarizer and therefore the energy efficiency is enhanced.
- In order to achieve the highest efficiency, the Bragg reflection condition is aimed to establish here. Therefore, a minimum number of periodic layers is required. We used *Parameter Run* to scan within the wavelength range and calculate the efficiency with 20 layers, 50 layers, and 100 layers respectively.

Considering the material cost and fabrication complexity will also increase with more layers, a minimum of 50 layers can be used to achieve acceptable reflectivity and bandwidth.
- Li2009

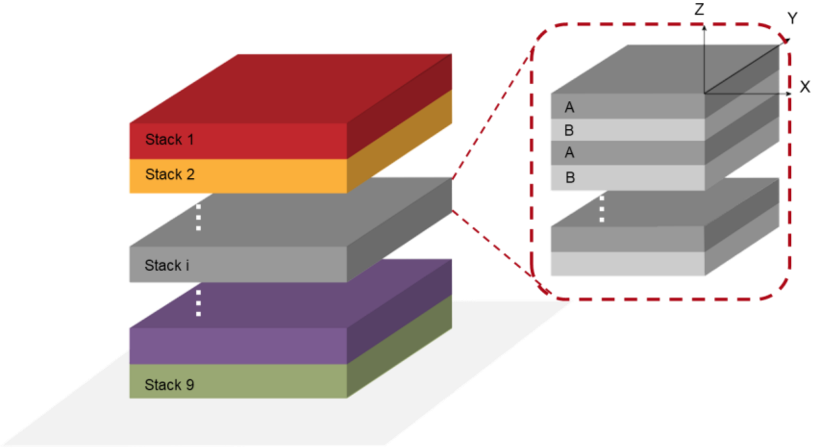


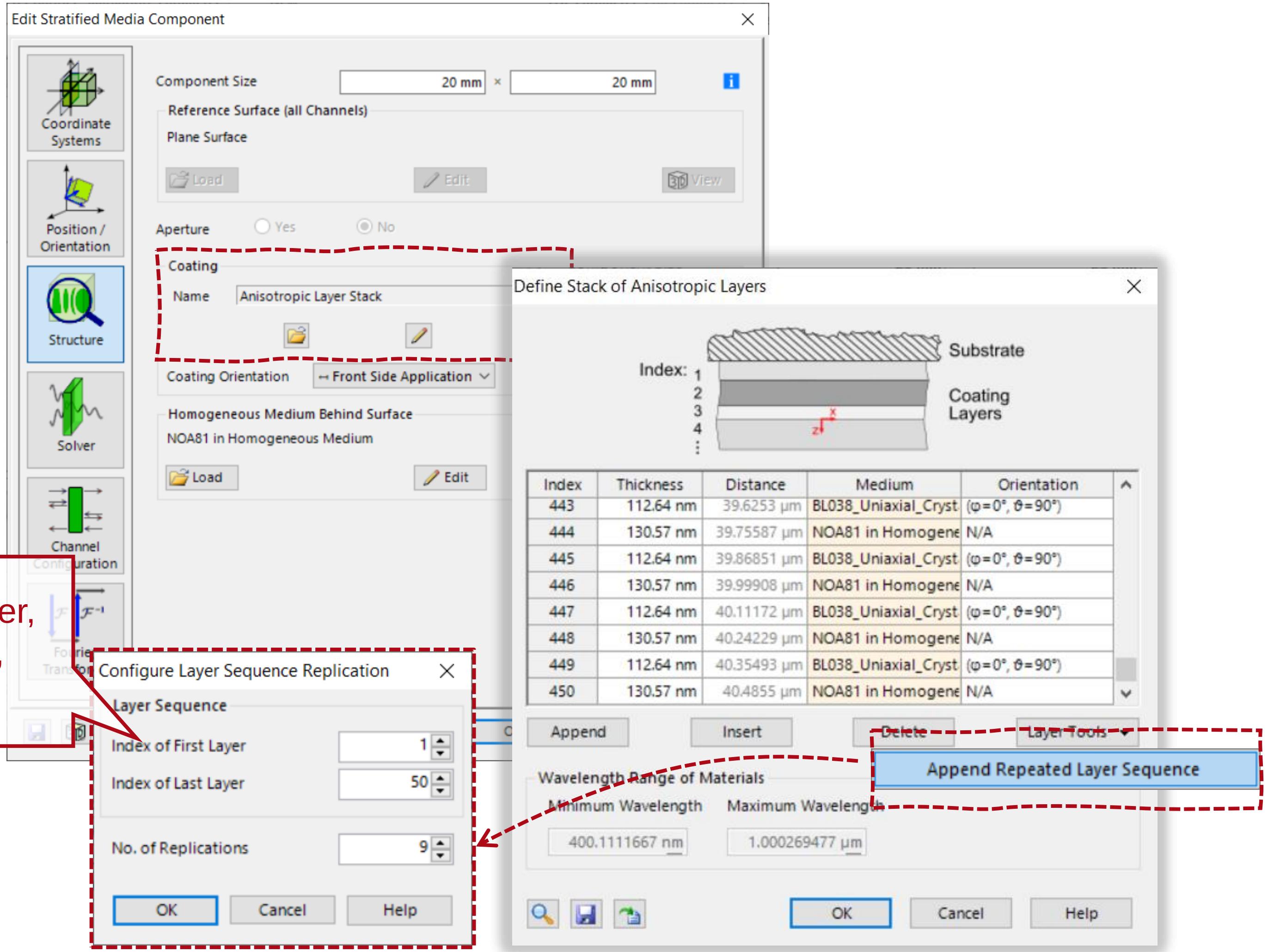
layer 1 and layer 2 repeated 10 times, i.e.,20 layers are constructed



simulation result compare with Li et. al. J. Display Technol. 5, 335-340 (2009)

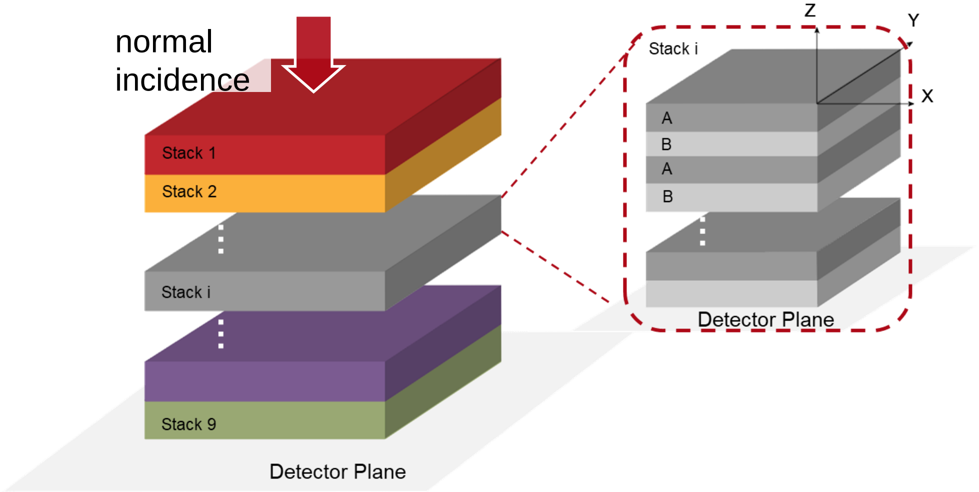
Modeling of Multi-Stack Reflective Polarizer



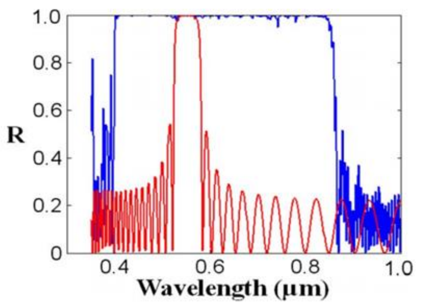


Nine stacks in the reflective polarizer, each stack with 50 alternate layers, hence 450 layers in total.

Expanded Bandwidth by the Multi-Stack Method

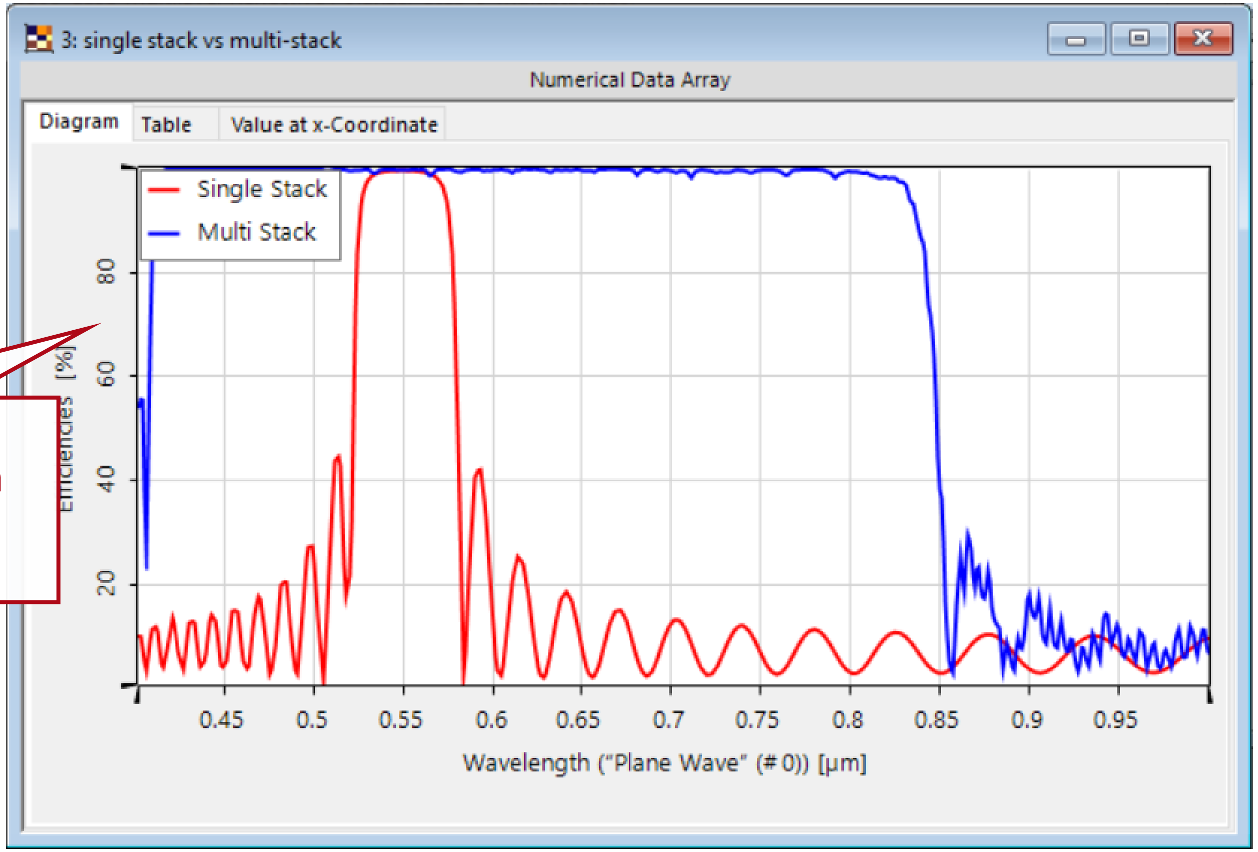


The reflection efficiencies of single-stack and multi-stack structures were calculated under wavelength scanning. The simulation shows that, compared with the single stack, an expanded bandwidth is achieved through the multi-stack method.

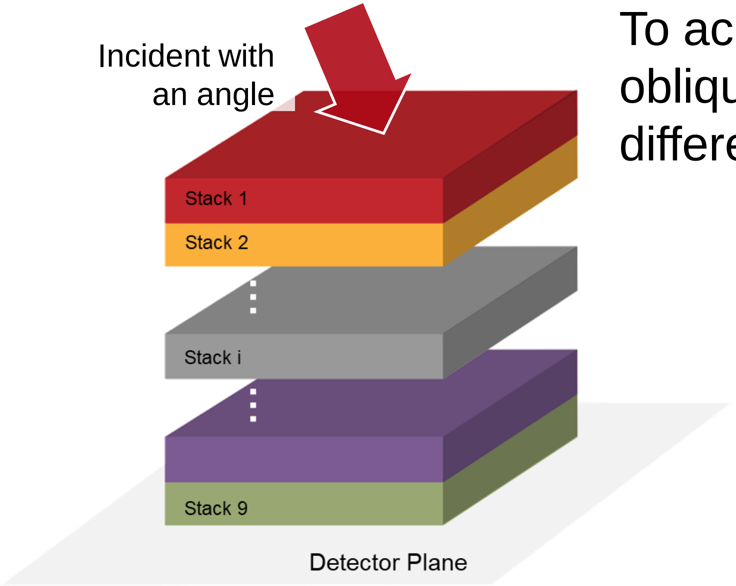


simulation result compare with Li et. al. J. Display Technol. 5, 335-340 (2009)

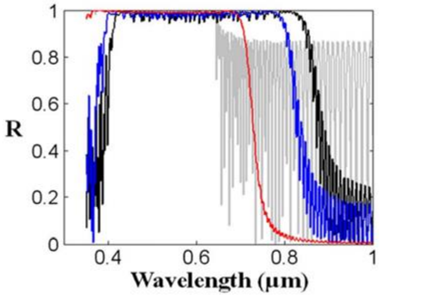
Multi-stack structure achieves reflectance ~ 100% for a much broader bandwidth when compared to a single stack.



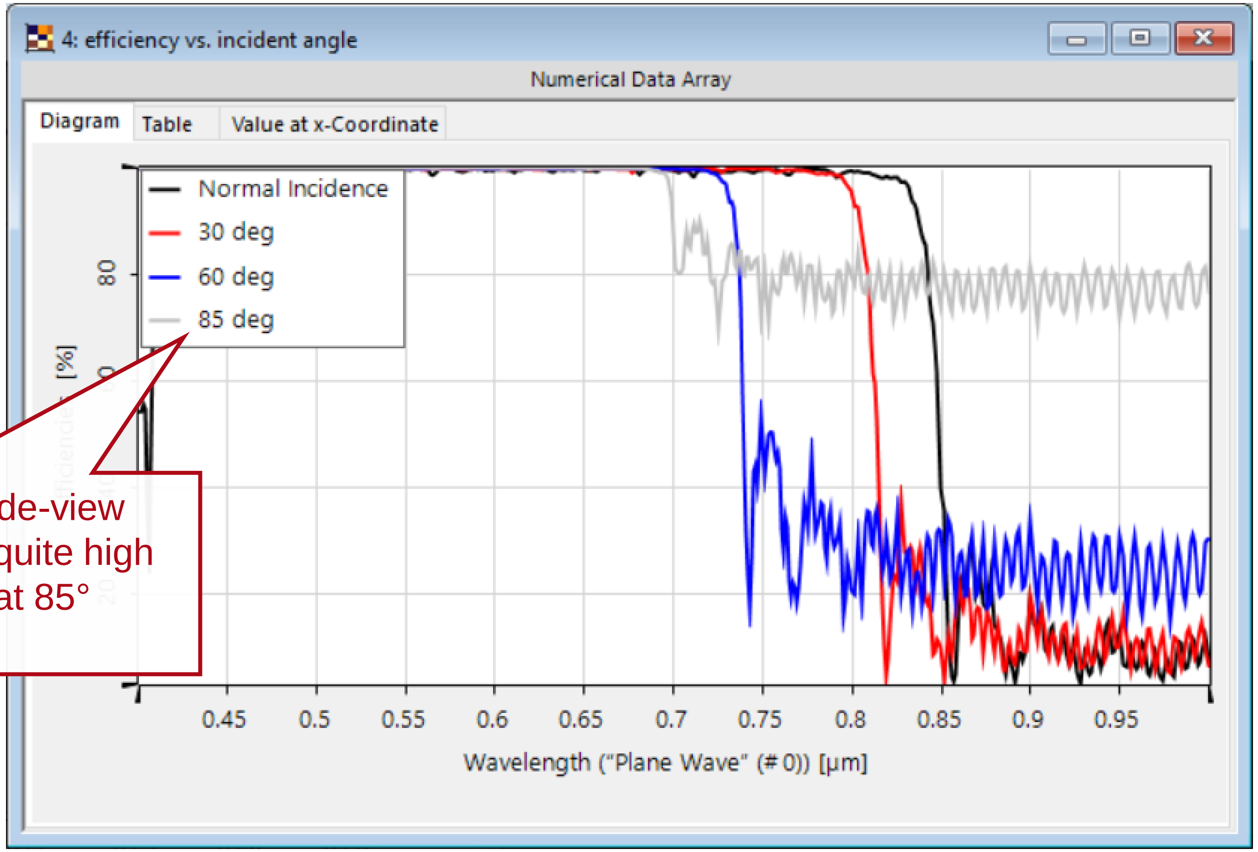
Investigation of Reflectance Efficiency with Different Incident Angle



To achieve a wide-view LCD, the reflective polarizer should also be designed for oblique incidence. Therefore, the performance of the reflective polarizer at different incident angles is further investigated.

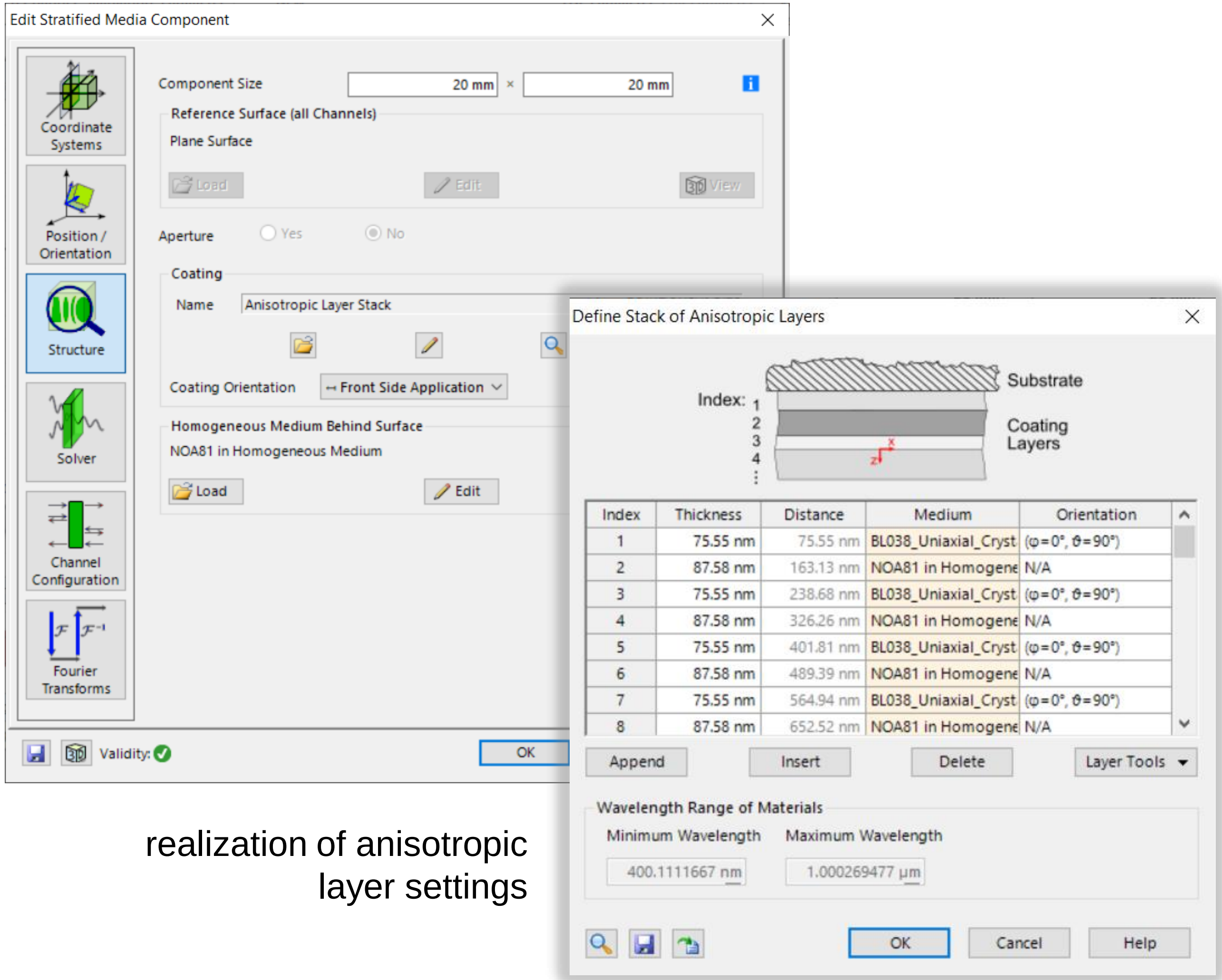


simulation result compare with Li et. al. J. Display Technol. 5, 335-340 (2009)

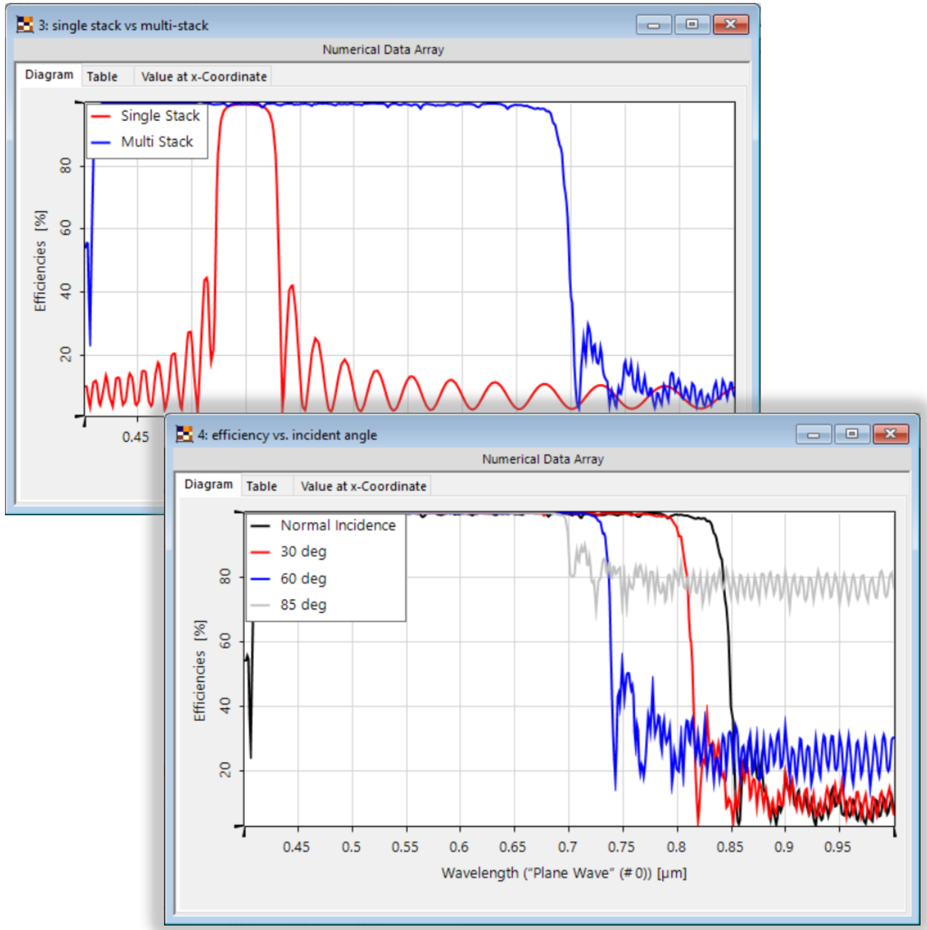


For the application of a wide-view LCD reflectance remains quite high in the visible region even at 85° incident angle.

Peek into VirtualLab Fusion



realization of anisotropic
layer settings



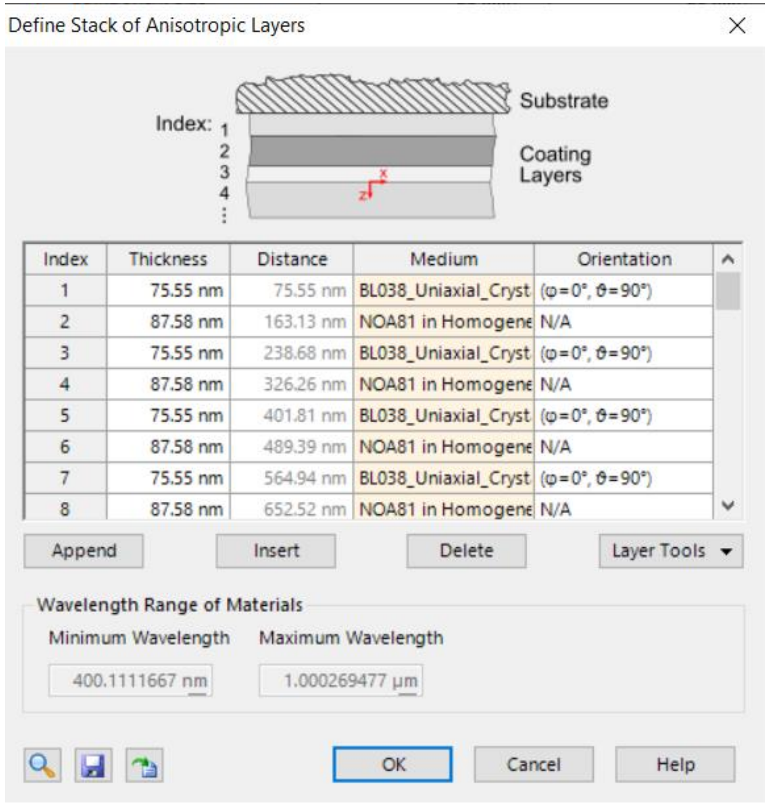
convenient parameter scanning
and result comparison

Workflow in VirtualLab Fusion

- Set the plane wave light source
  - Basic Source Models [Tutorial Video]

- Set the anisotropic layer component
  - Optically Anisotropic Media in VirtualLab Fusion [Use Case]

- Use Parameter Run to investigate the variation of reflectance efficiency with different wavelengths and incident angles

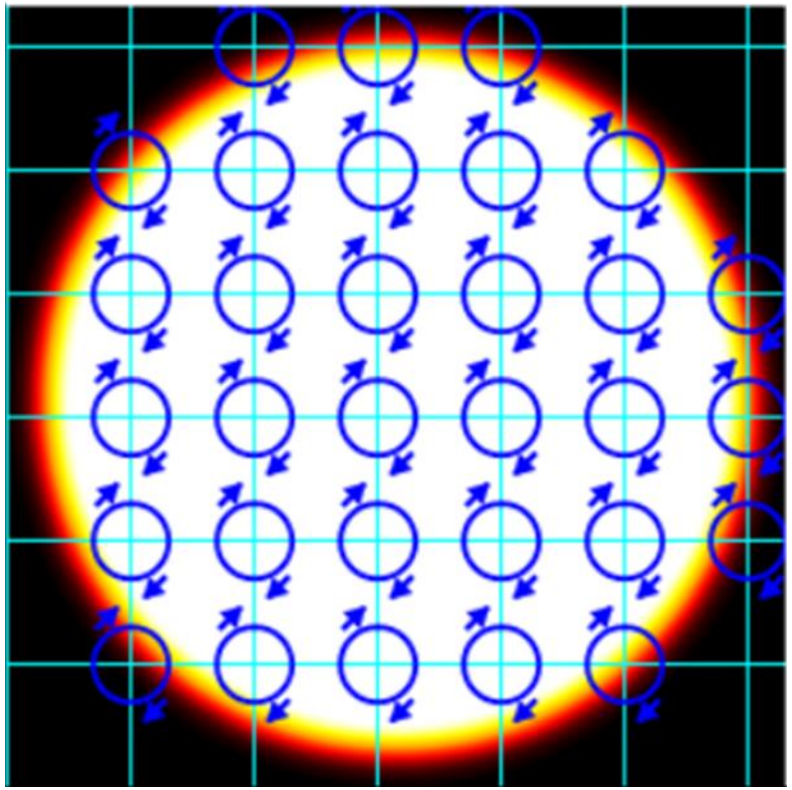


Document Information

title	Simulation of Multilayer Birefringent Reflective Polarizer with VirtualLab Fusion
document code	CRO.0001
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.176)
category	Application Use Case
further reading	- Optically Anisotropic Media in VirtualLab Fusion - Conical Refraction in Biaxial Crystals - Polarization Conversion in Uniaxial Crystals

Simulation and Analysis of Anisotropic Coating on Plane and Curved Surface

Abstract



VirtualLab Fusion provides the capability to add birefringent coatings, that is, layers of anisotropic media, to the surfaces of optical components, in order to exploit the extra freedom of polarization control and multiplexing in optical systems. In this example, we introduce this feature – adding anisotropic coatings on surfaces – and investigate the polarization conversion of a lambda/4 coating on a plane surface and a curved surface, respectively.

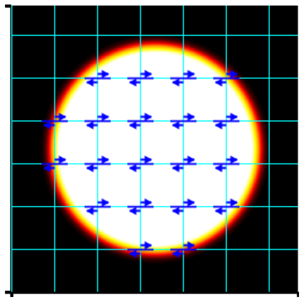
Quarter-Wave Plate Coating on Plane Surface

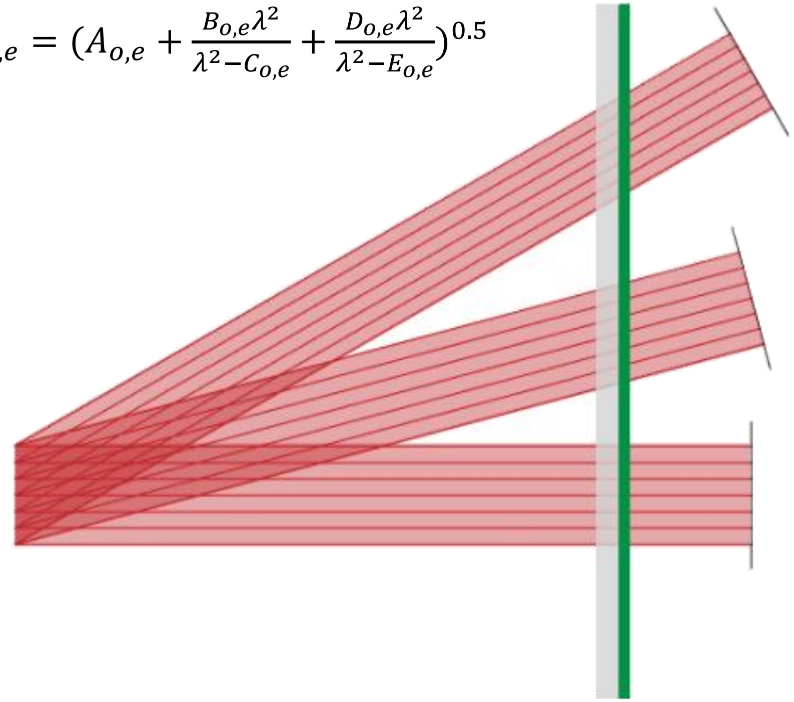
anisotropic coating

- lambda/4 wave plate
- Calcite crystal (uniaxial)
- $n_{o,e} = (A_{o,e} + \frac{B_{o,e}\lambda^2}{\lambda^2 - C_{o,e}} + \frac{D_{o,e}\lambda^2}{\lambda^2 - E_{o,e}})^{0.5}$

plane wave

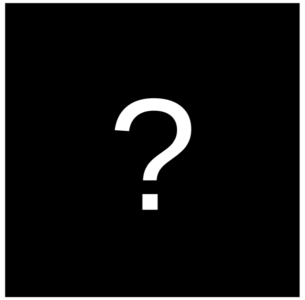
- wavelength: 532nm
- polarization state: linearly polarized along x
- off-axis angle: 0°, 15°, 30°





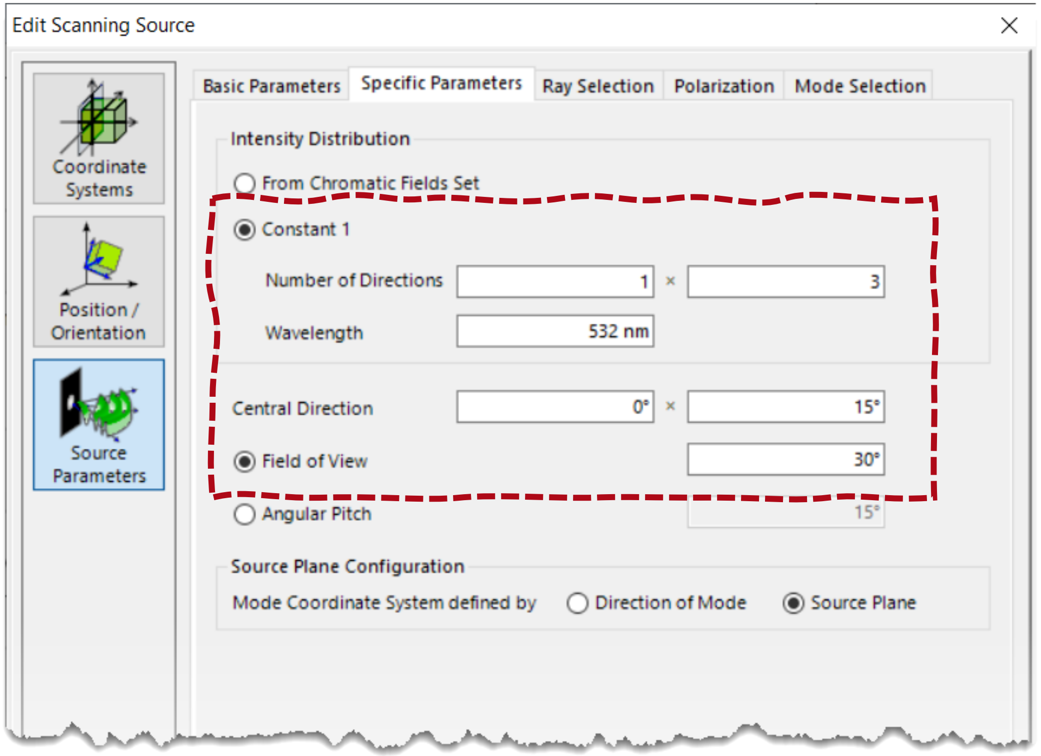
detectors

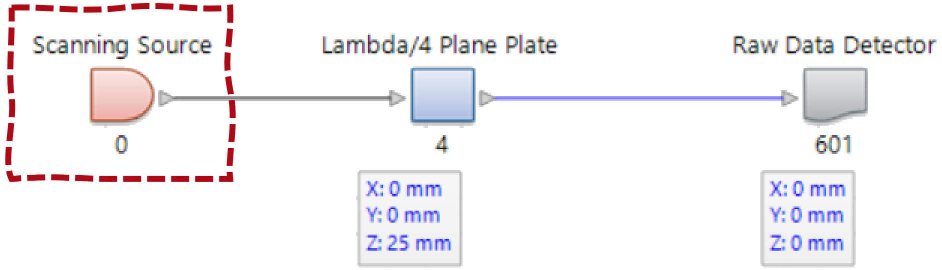
- perpendicular to beam directions

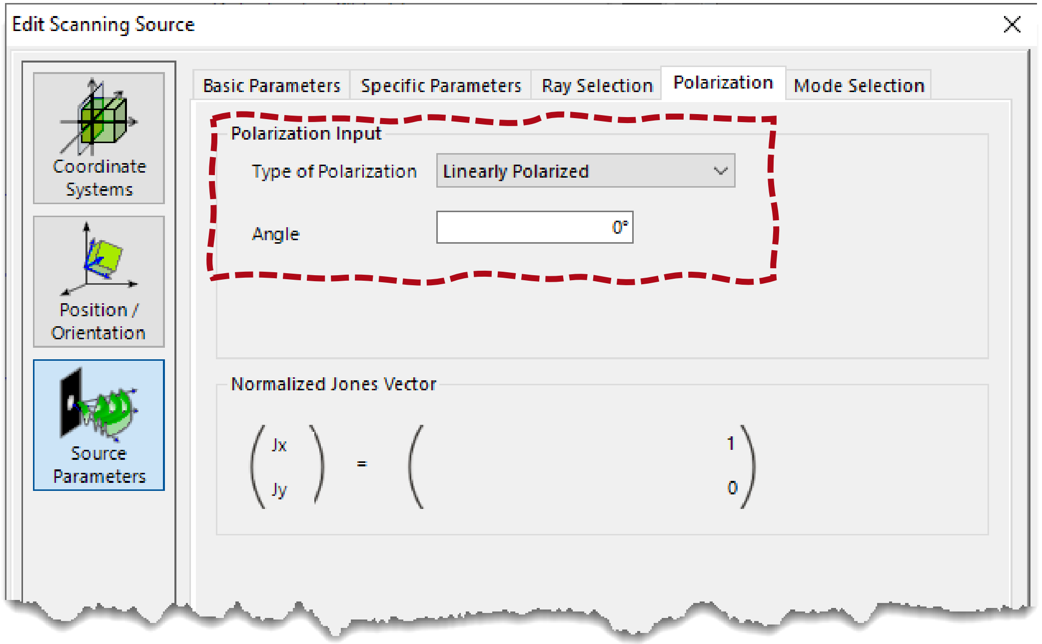


How does the polarization state of the input field with different incident angles change after passing through the quarter-wave coating?

System Building Blocks – Source

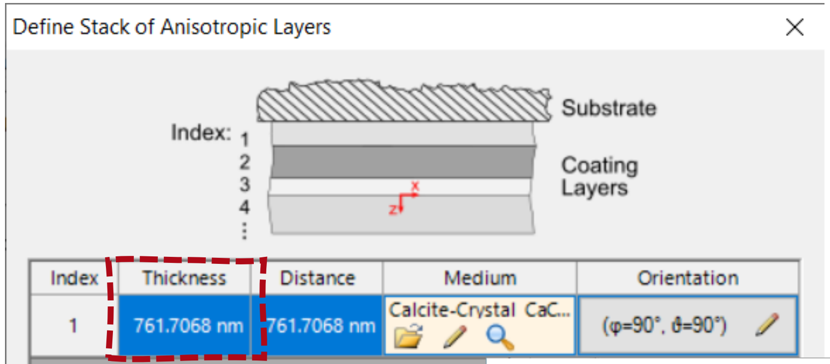


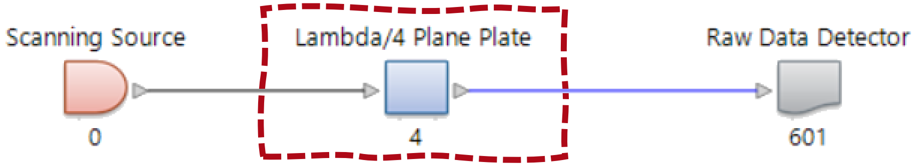




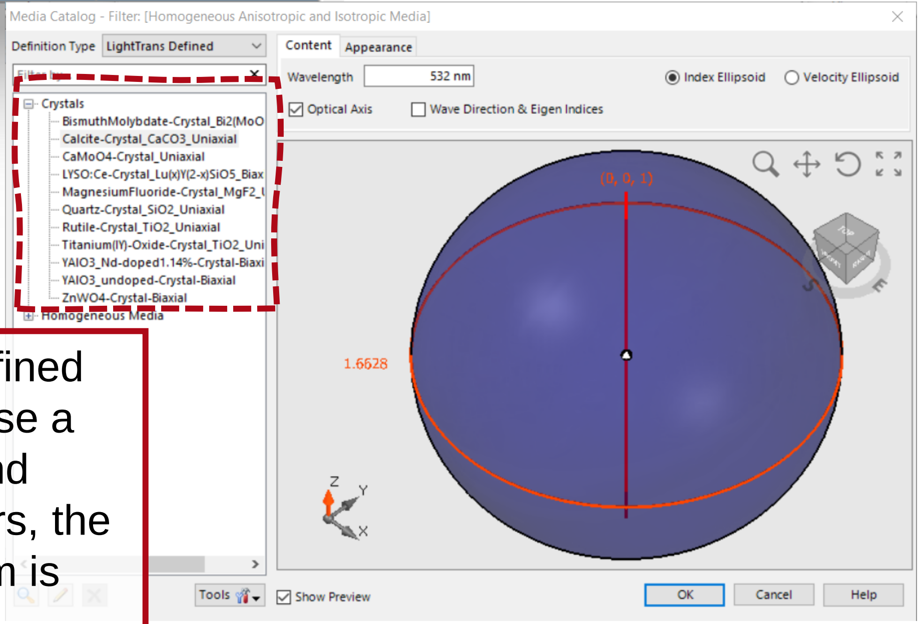
A *Scanning Source* is used to model the input plane waves. It is a convenient tool for the specification of several directions simultaneously and for polarization management.

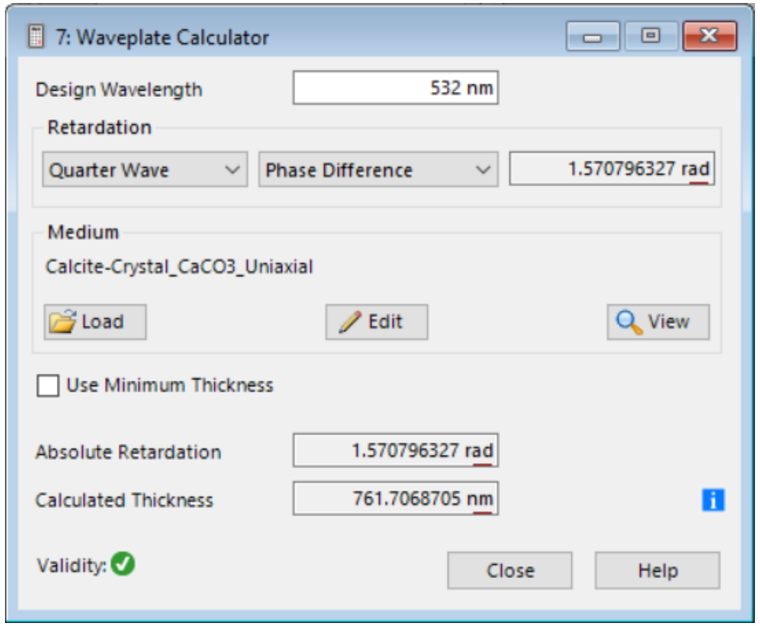
System Building Blocks – Coating on Surfaces





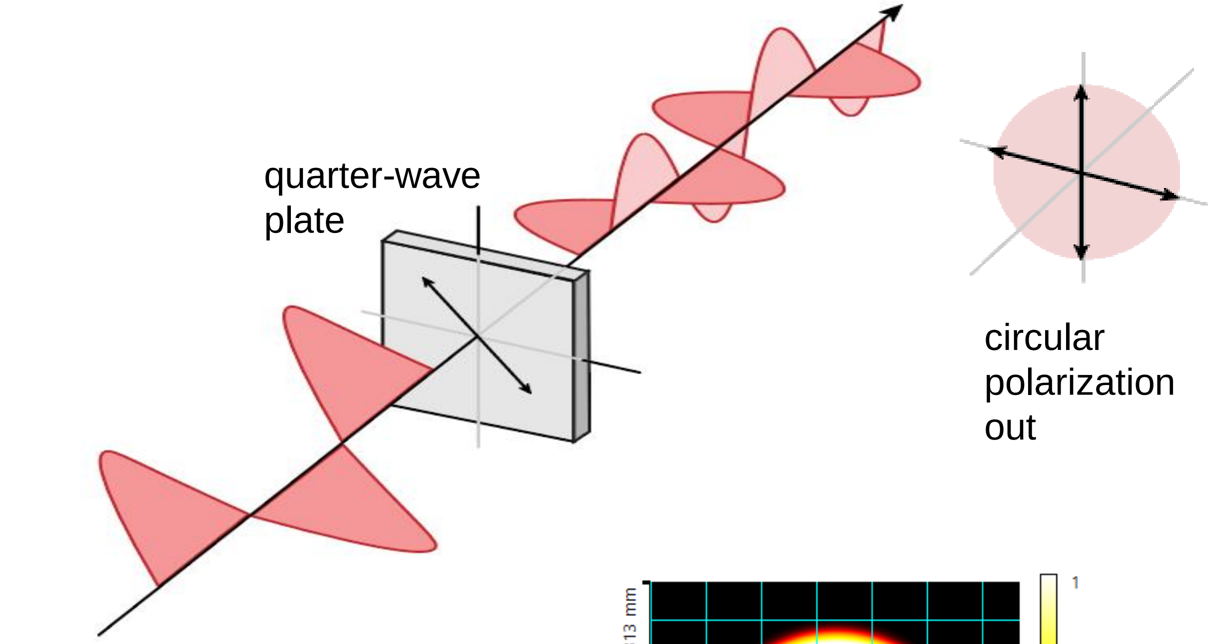
With the help of the *Waveplate Calculator*, the thickness of the coating layers can be calculated to achieve the desired retardation between the field components.

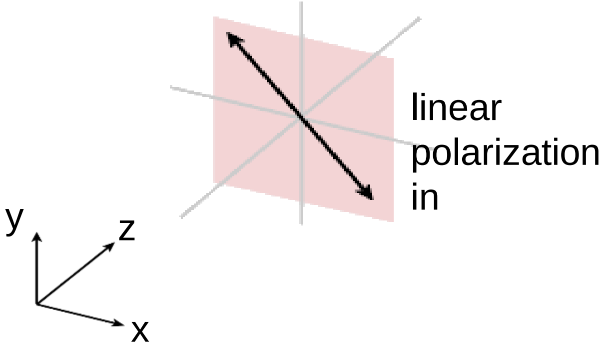


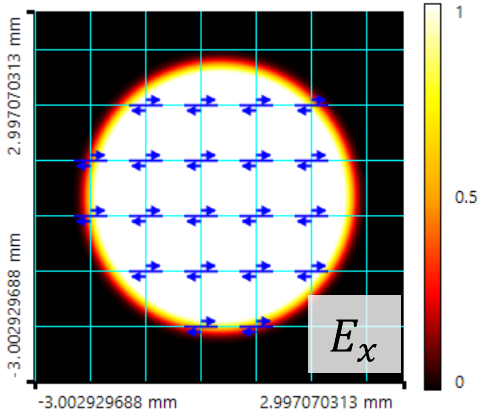


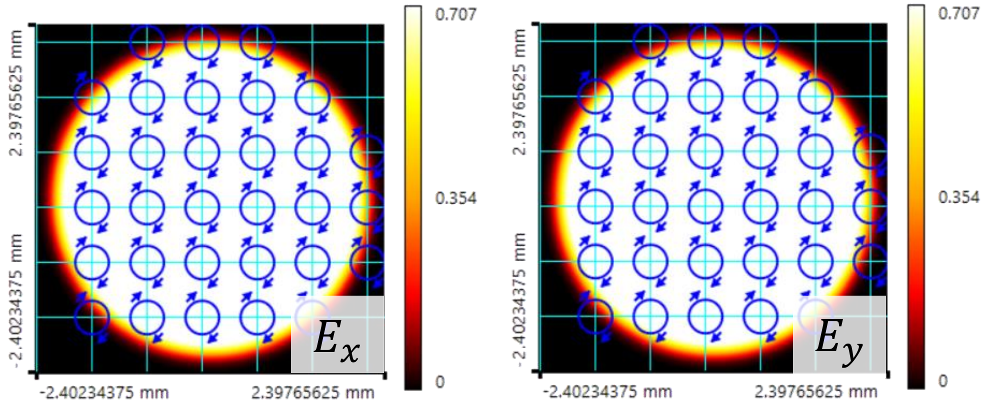
choose from the predefined anisotropic media or use a template medium and customize the parameters, the preview of the medium is shown on the right

Polarization Conversion at a Quarter-Wave Plate





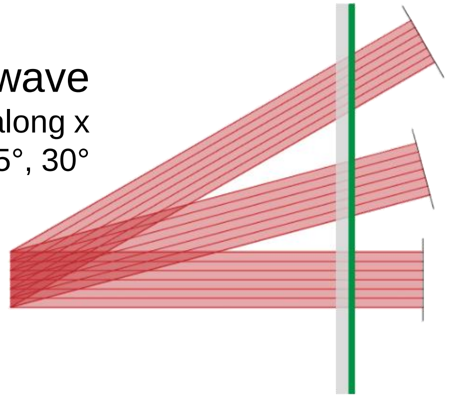


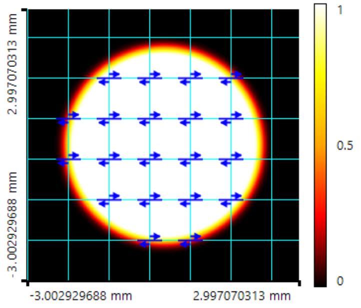


In the idealized situation, when linearly polarized light impinges on a quarter-wave plate at 45° to the optic axis, the transmitted light is divided into two equal electric field components. One of these is retarded by a quarter wavelength and the overlap of both beams at the exit plane of the plate generates circularly polarized light. And vice versa: if the incident light is circularly polarized, it will be transformed into linearly polarized light.

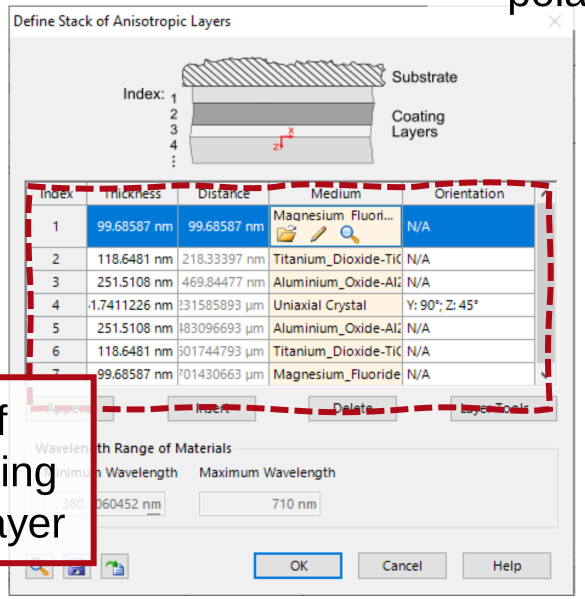
Influence of Fresnel Effect Deviation

plane wave
- linearly polarized along x
- off-axis angle: 0°, 15°, 30°



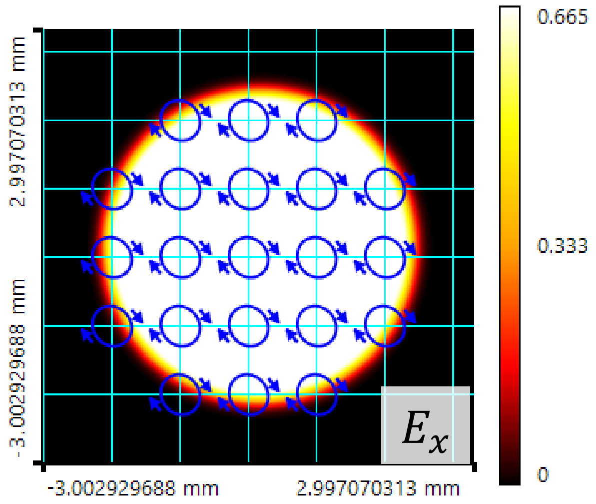


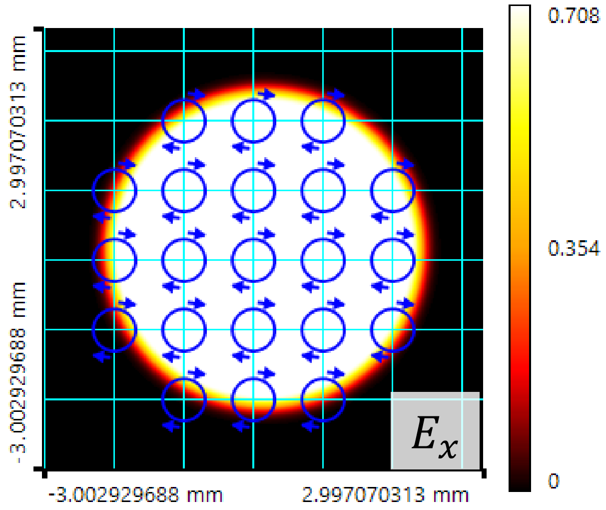
- However, when a real quarter-wave coating is configured, the two divided electric field components will face different refraction indices inside the crystal.
- Hence, the Fresnel effect when leaving the crystal will differ for the two electromagnetic field components as well, and the polarization state of the transmitted light will form an ellipse instead of a perfect circle.
- In order to eliminate this influence, an additional anti-reflection coating is applied together with the crystal coating. Then the perfect circularly polarized light is observed.



combination of isotropic AR coating and anisotropic layer

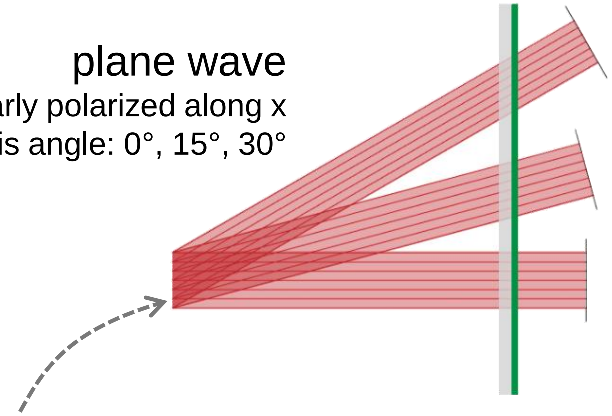
E_x after real structured quarter-wave plate with & without AR coating

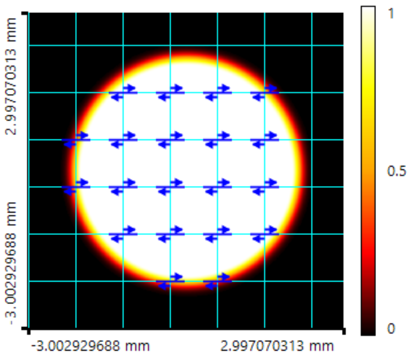




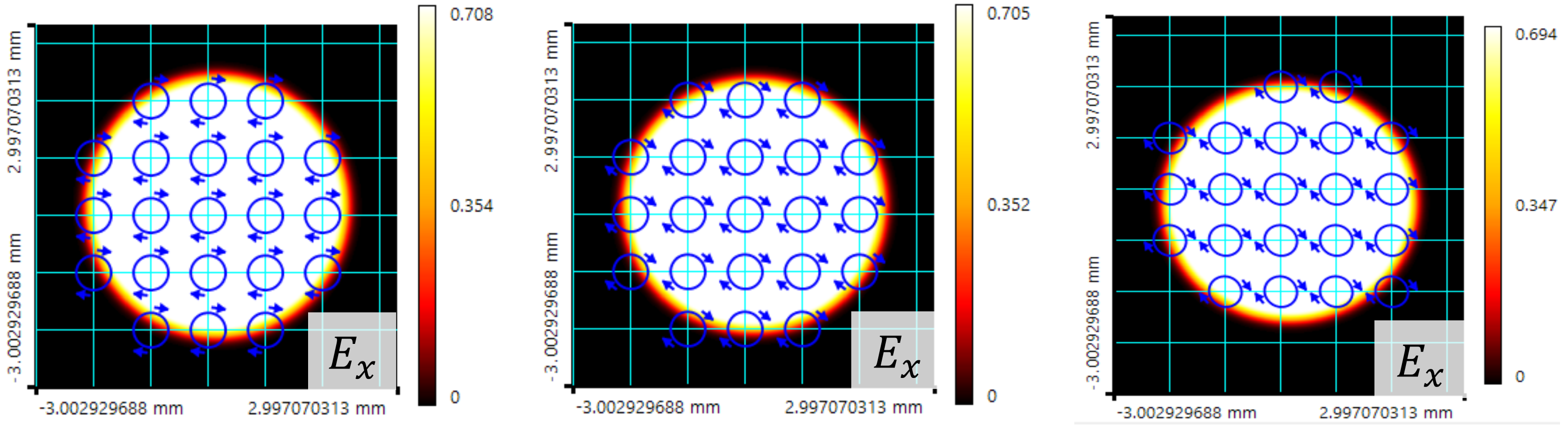
Quarter-Wave Plate Coating on Plane Surface

plane wave
- linearly polarized along x
- off-axis angle: 0°, 15°, 30°





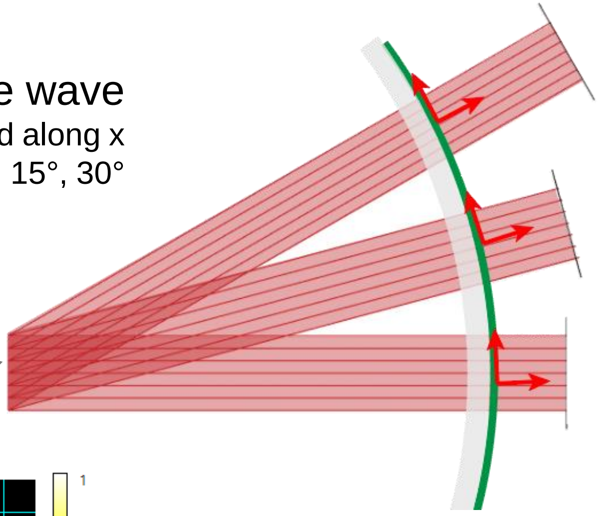
E_x after real structured quarter-wave plate with 0°, 15° and 30° of incidence

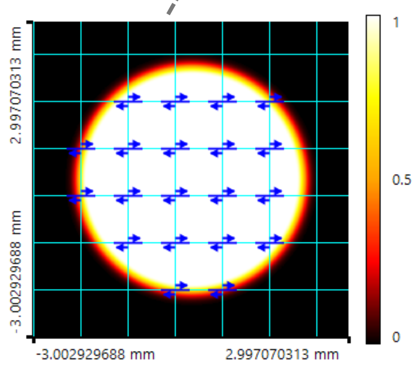


Another additional effect that might influence the polarization conversion is the angle of incidence. Due to the projection of the components of the field on the plane of the plate, the resulting polarization state will become more elliptical with increasing angle.

Quarter-Wave Plate Coating on Curved Surface

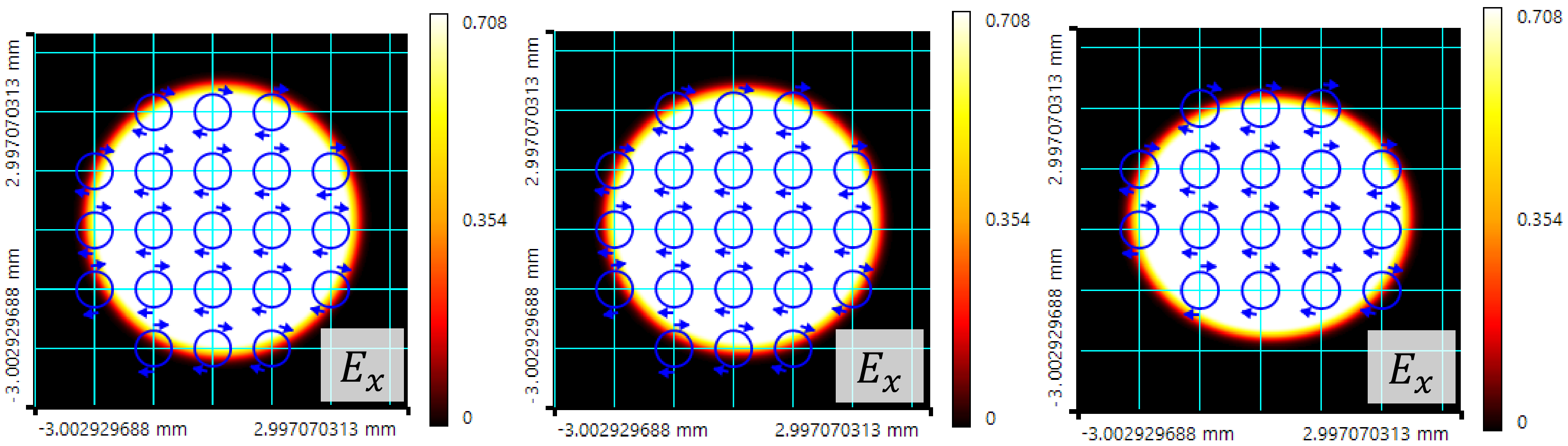
plane wave
- linearly polarized along x
- off-axis angle: 0°, 15°, 30°





If a quarter-wavelength coating is applied to a curved surface instead, which curvature allows the light to propagate along the normal vector of the surface, the effect of different projections of the field components can be avoided. This results in perfect circular polarization for all angles of incidence.

E_x after real quarter-wave coating on curved surface with 0°, 15° and 30° of incidence



Document Information

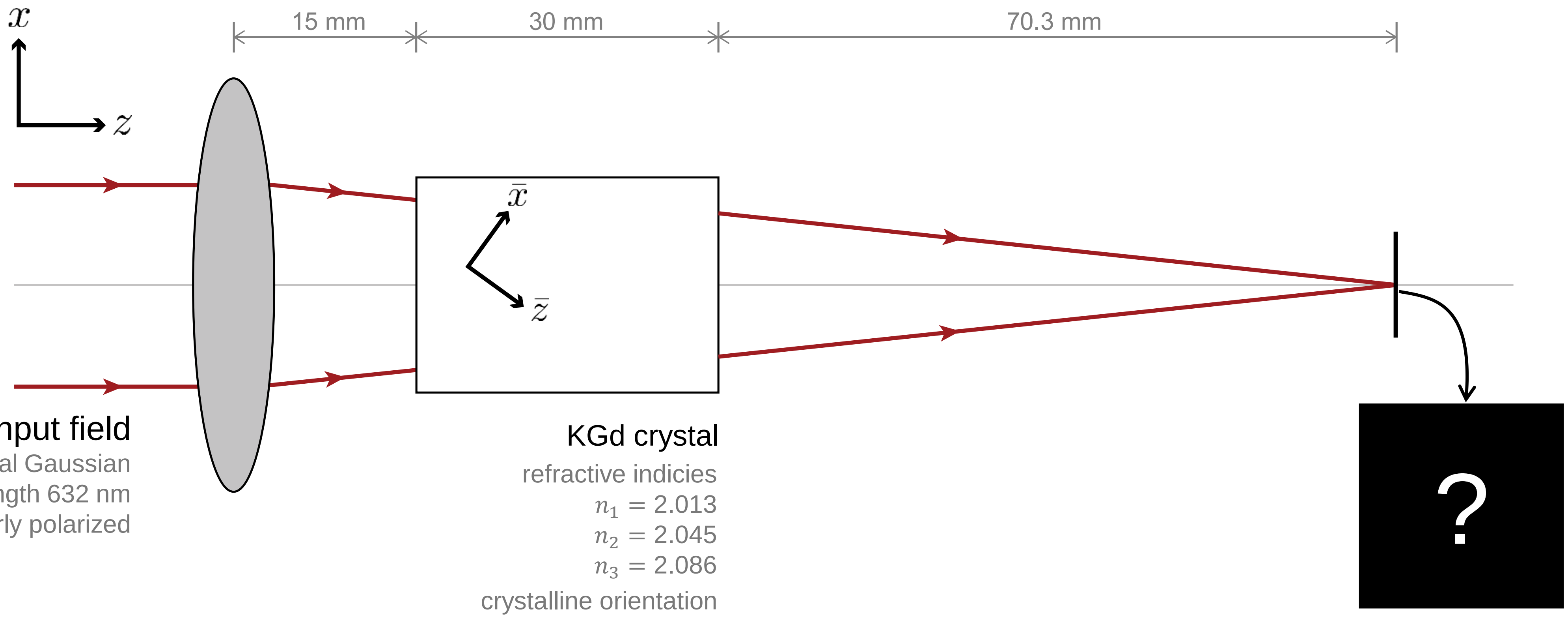
title	Simulation and Analysis of Anisotropic Coating on Plane and Curved Surface
document code	CRO.0006
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.180)
category	Feature Use Case
further reading	- Optically Anisotropic Media in VirtualLab Fusion - Conical Refraction in Biaxial Crystals - Polarization Conversion in Uniaxial Crystals

Conical Refraction in Biaxial Crystals

Abstract

When circularly polarized light propagates through a biaxial crystal along one of its optic axes, the transmitted field evolves into a cone, a phenomenon which is known as conical refraction. Several applications have been developed based on this effect, such as Bessel beam generation and optical tweezers. With the fast-physical-optics simulation technology in VirtualLab Fusion, conical refraction from a KGd crystal is demonstrated.

Modeling Task



input field
- fundamental Gaussian
- wavelength 632 nm
- circularly polarized

KGd crystal

refractive indicies

$n_1 = 2.013$

$n_2 = 2.045$

$n_3 = 2.086$

crystalline orientation

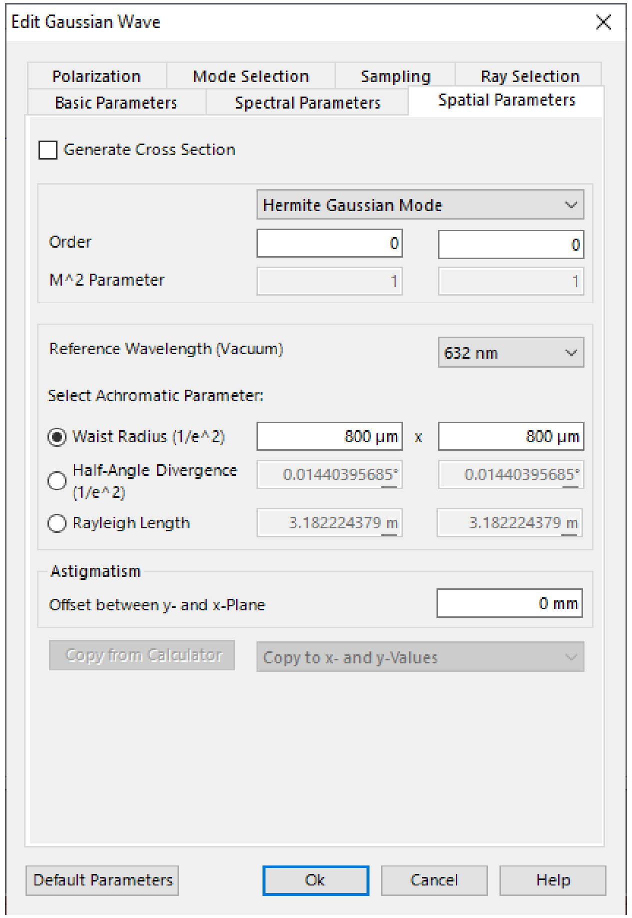
$\bar{x} = (0.74, 0, 0.67)$

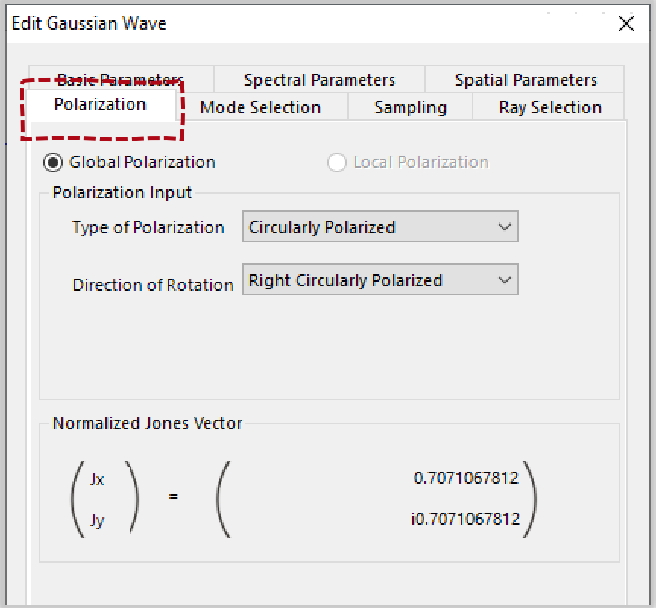
$\bar{y} = (0, 1, 0)$

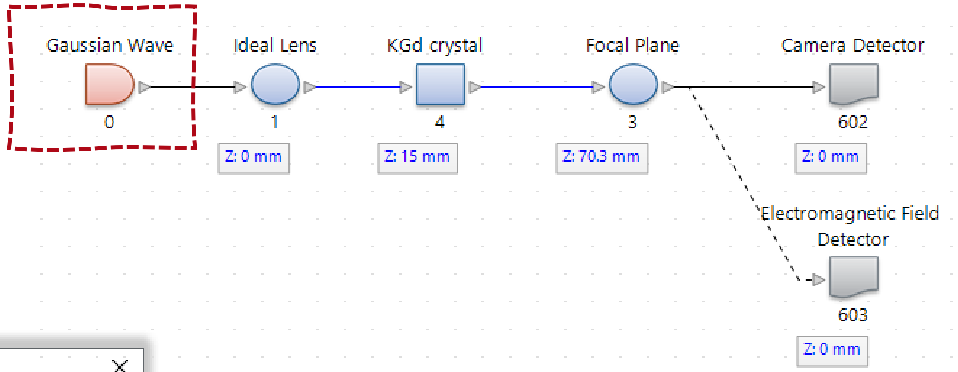
$\bar{z} = (-0.67, 0, 0.74)$

What is the field after being focused and propagating through a biaxial crystal?

System Building Blocks – Source

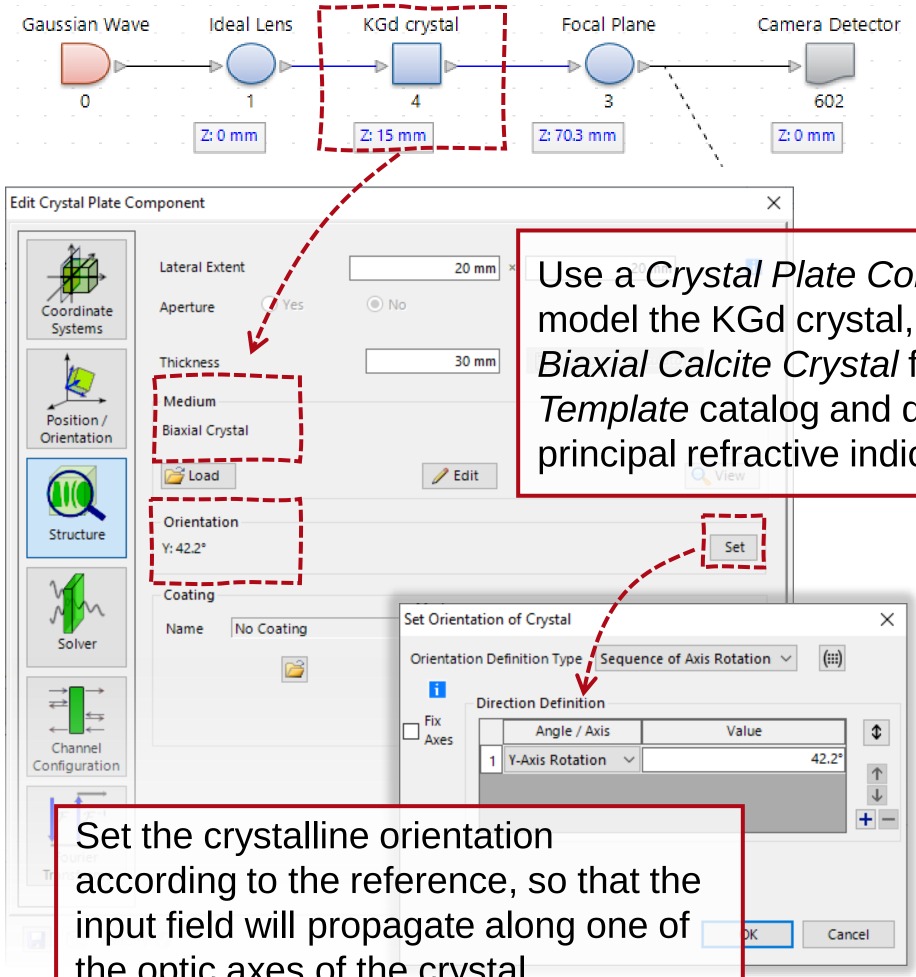






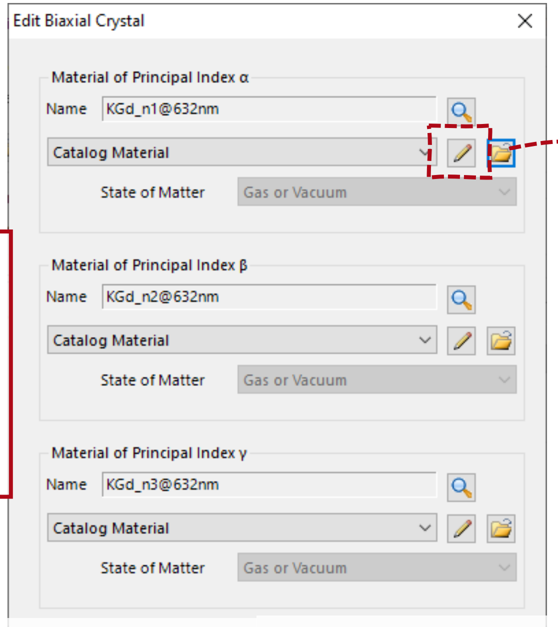
A linearly polarized Gaussian field, with a wavelength of 632 nm, is employed as the input. It first passes through a quarter-wave plate, which converts the linear polarization to circular. This effect is included in the source model directly.

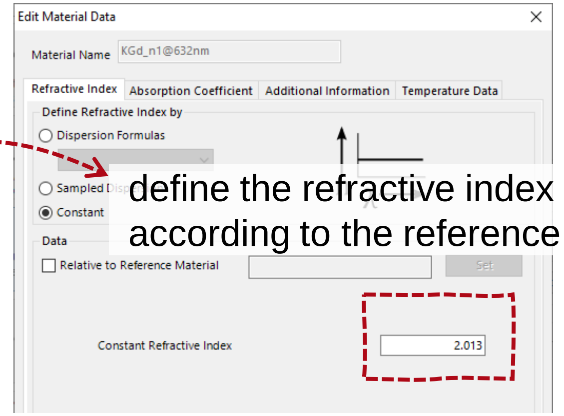
System Building Blocks – Biaxial KGd Crystal



Use a *Crystal Plate Component* to model the KGd crystal, then select *Biaxial Calcite Crystal* from the *Template* catalog and define the principal refractive indices.

Set the crystalline orientation according to the reference, so that the input field will propagate along one of the optic axes of the crystal.





define the refractive index according to the reference

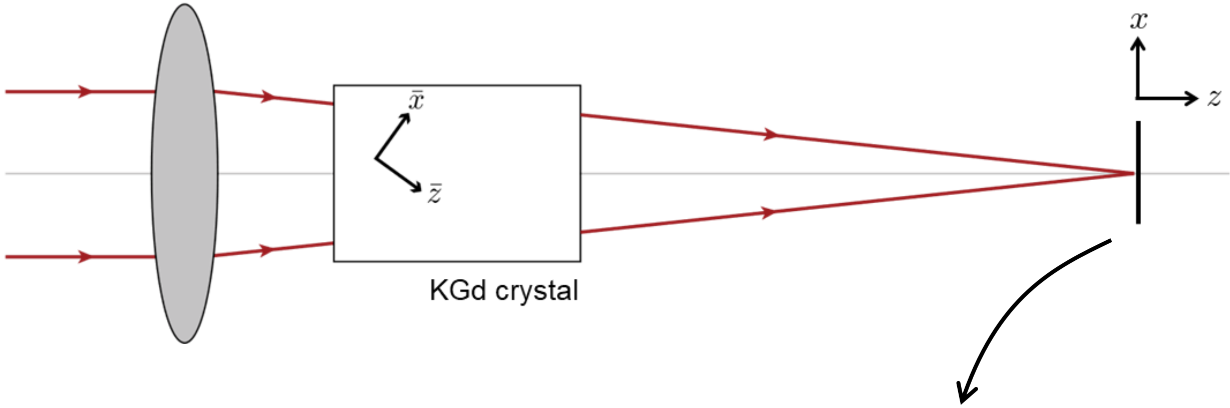
Tips: after configuring the material, use the *Save* tab to save the new material to the *User Defined* material catalog and load it easily for the next simulation.

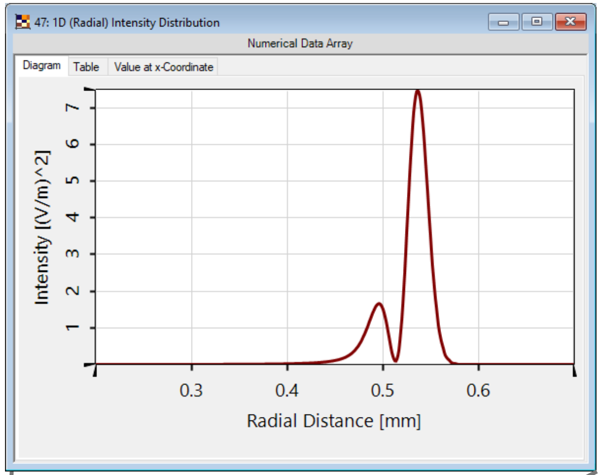
Biaxial Calcite Crystal

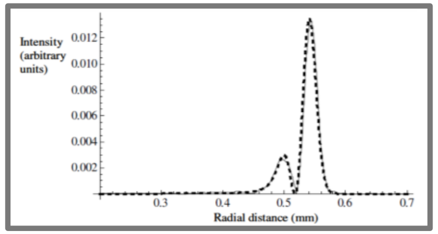
- Thickness: 30mm
- refractive indices
  - n_1= 2.013
  - n_2 = 2.045
  - n_3 = 2.086
- crystalline orientation
  - $\bar{x}$= (0.74, 0, 0.67)
  - $\bar{y}$ = (0, 1, 0)
  - $\bar{z}$ = (-0.67, 0, 0.74)

Parameters follow from C. F. Phelan et al., Opt. Express 17, 12891-12899 (2009)

Simulation Results

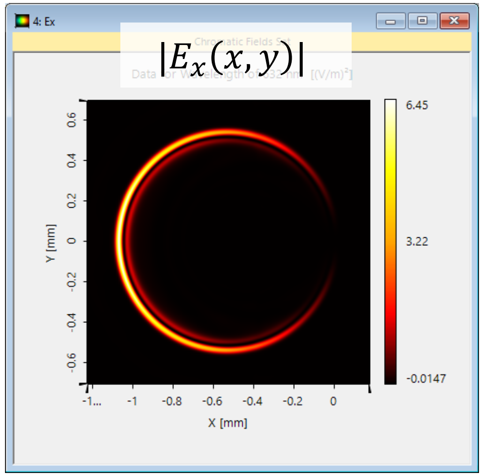


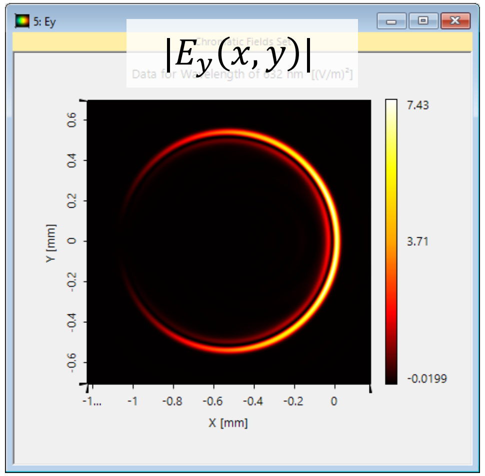


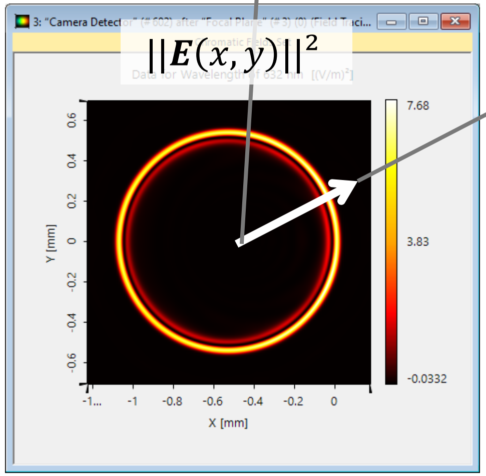


Experimental measurements from C. F. Phelan *et al.*, Opt. Express **17**, 12891-12899 (2009)

Field Distributions in Image Plane

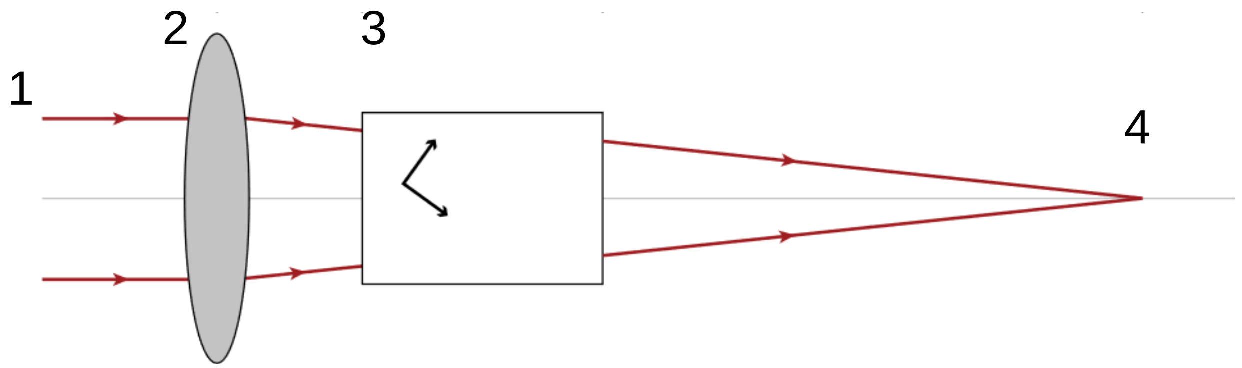






Both the E_x and E_y components of the field distributions in the focal image plane are in double-ring patterns, with missing parts on the right and left, respectively. Consequently, in the summed squared amplitude, a complete double-ring pattern is observed.

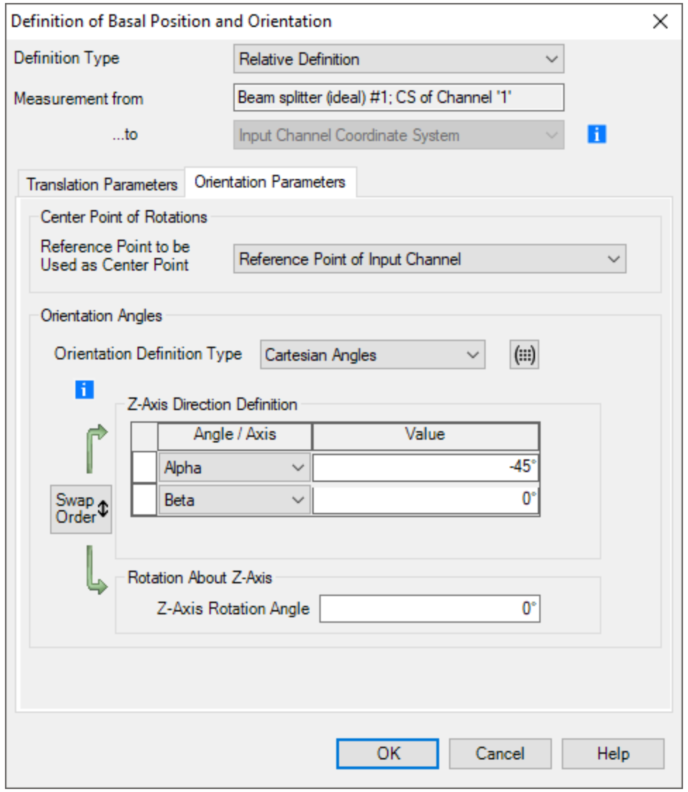
Summary – Components...



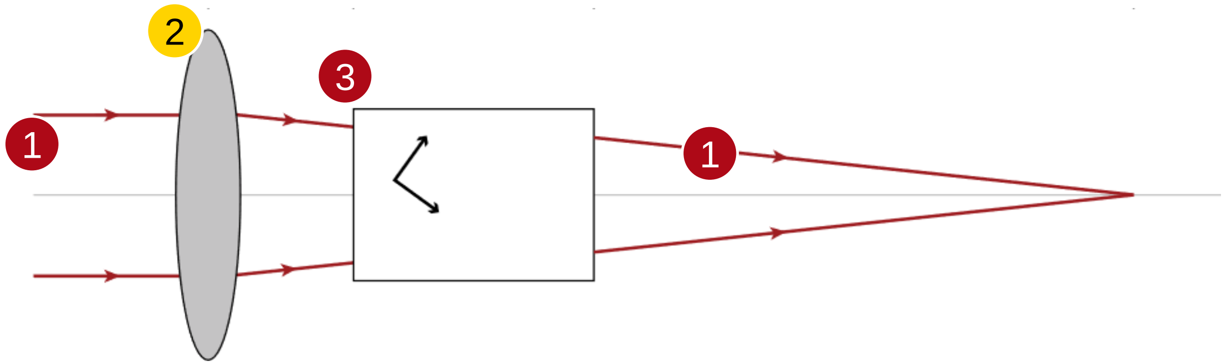
… of Optical System	… in VirtualLab Fusion	Source Model/Component Solver
1. Source	Gaussian Source	
2. Lens	Ideal Lens	
3. KGd Crystal	Crystal Plate	Layer Matrix [S-Matrix]
4. Detector	Camera Detector	-

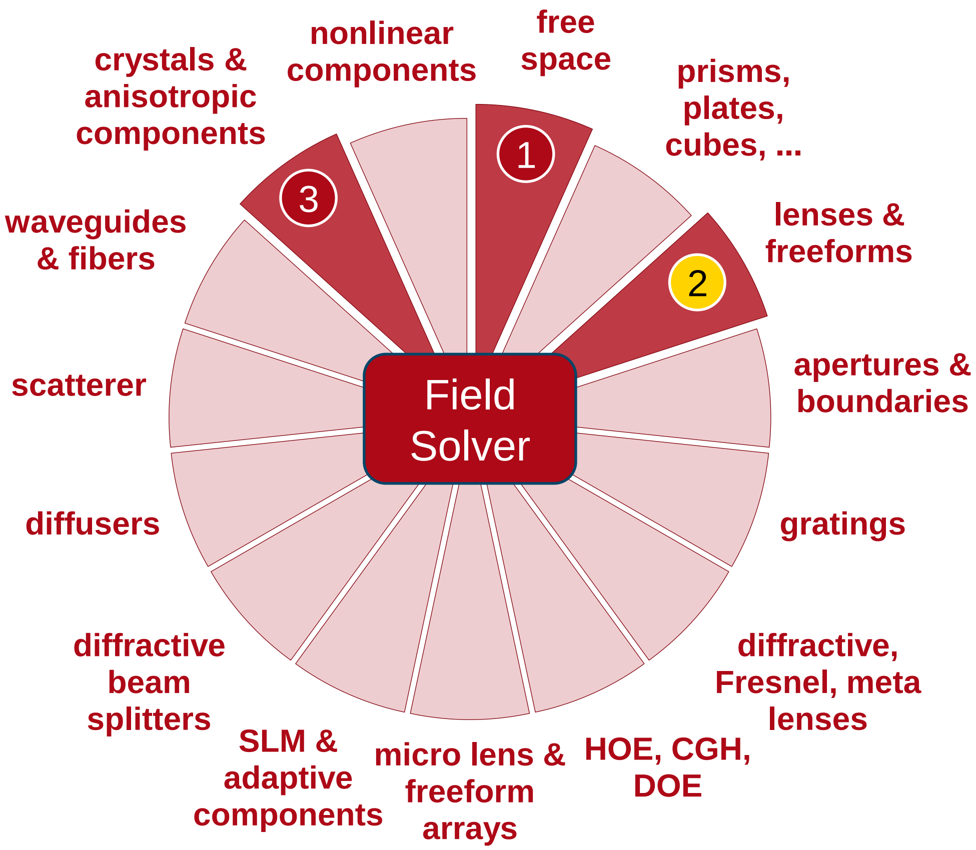
Workflow in VirtualLab Fusion

- Set up input field
  - Basic Source Models [Tutorial Video]
- Construct real components using surfaces
- Set up Biaxial Crystal
  - Optically Anisotropic Media in VirtualLab Fusion [Use Case]
- Define position and orientation of components
  - LPD II: Position and Orientation [Tutorial Video]



VirtualLab Fusion Technologies





\# idealized component

Document Information

title	Conical Refraction in Biaxial Crystals
document code	CRO.0001
version	1.0
edition	VirtualLab Fusion Basic
software version	2021.1 (Build 1.176)
category	Application Use Case
further reading	- Optically Anisotropic Media in VirtualLab Fusion - Polarization Conversion in Uniaxial Crystals

Appendix

- Electromagnetic field solver for anisotropic media
- Additional information about field tracing