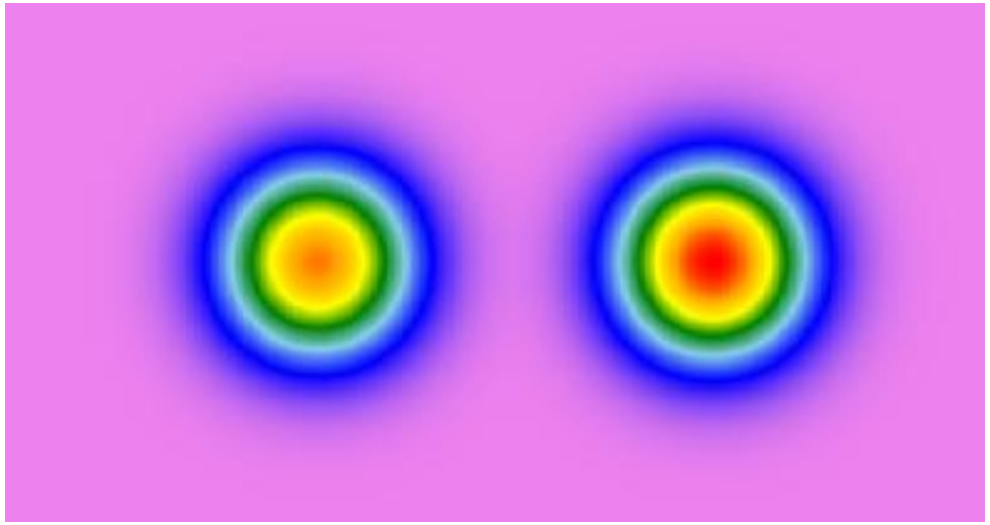
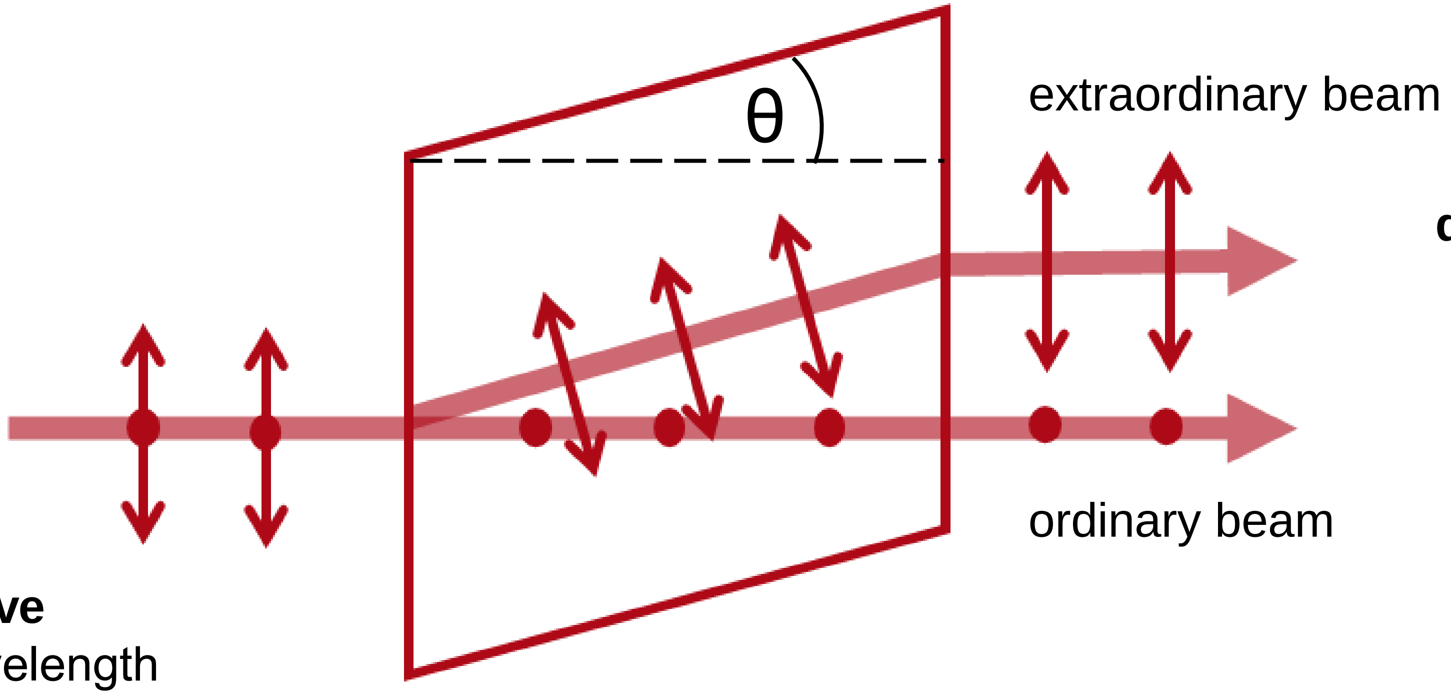
Birefringence Effect of Anisotropic Calcite Crystal

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. Through the help of the Universal Detector, the polarization states of both beams can be investigated.

System Setup



detector

Universal Detector with *Radiant Energy Density* Add-on to detect the field in x and y-component as well as the energy density

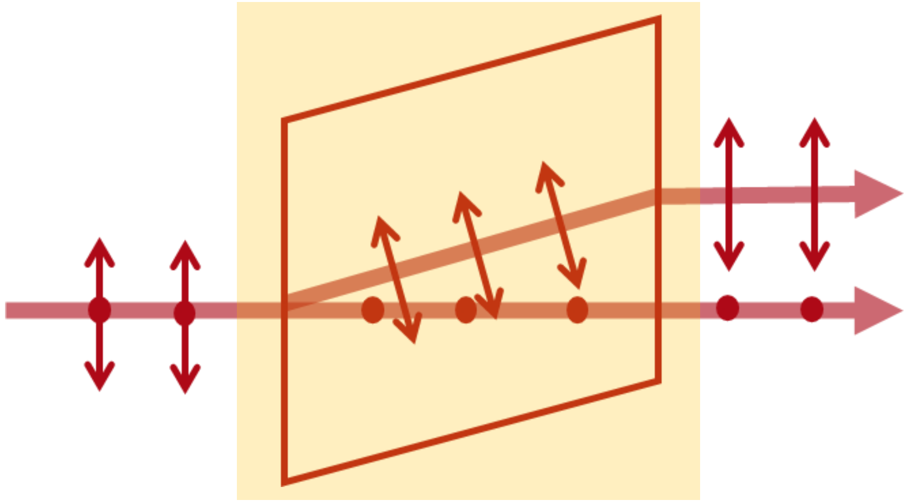
Gaussian wave

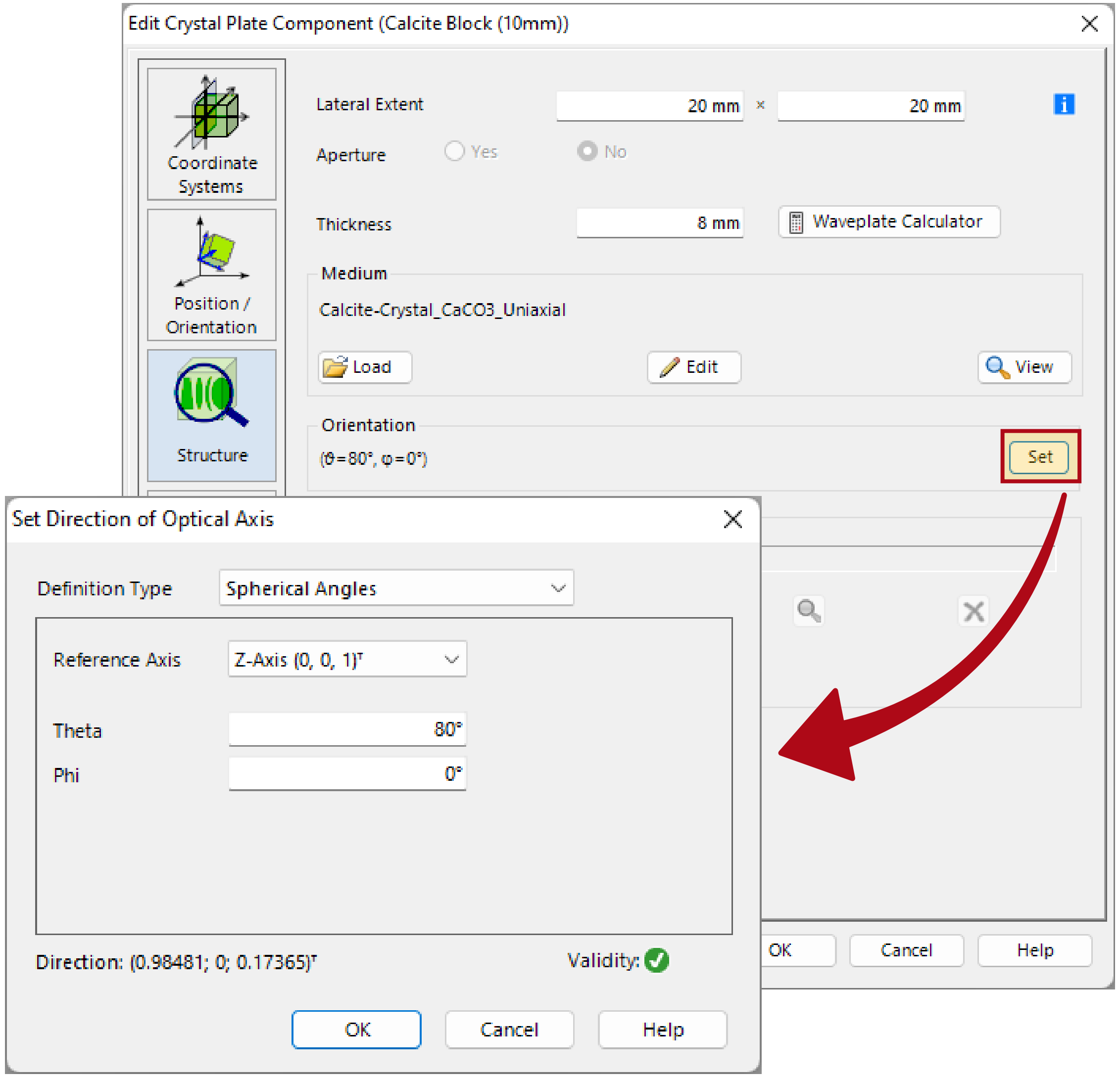
- 532 nm wavelength
- linearly polarized
- Polarization angle: 0°-180°

uniaxial crystal

- calcite crystal
- thickness: 1mm - 10 mm
- orientation: θ=80°

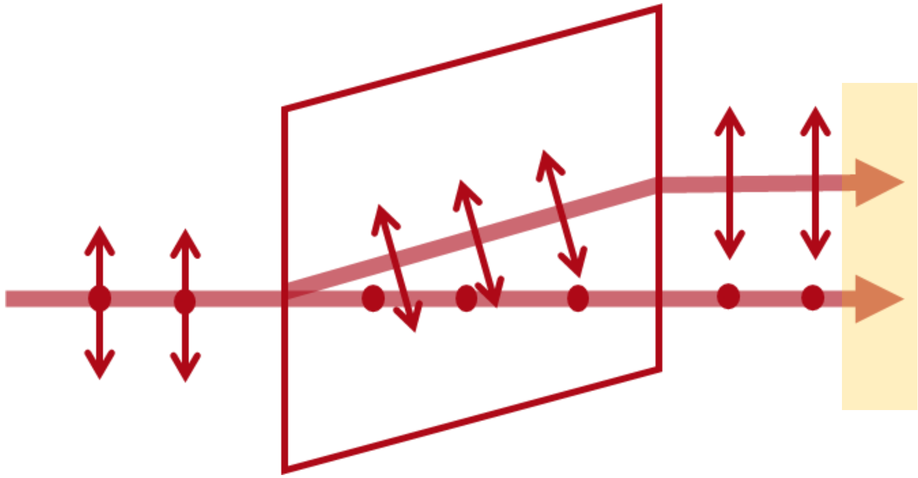
Uniaxial Crystal

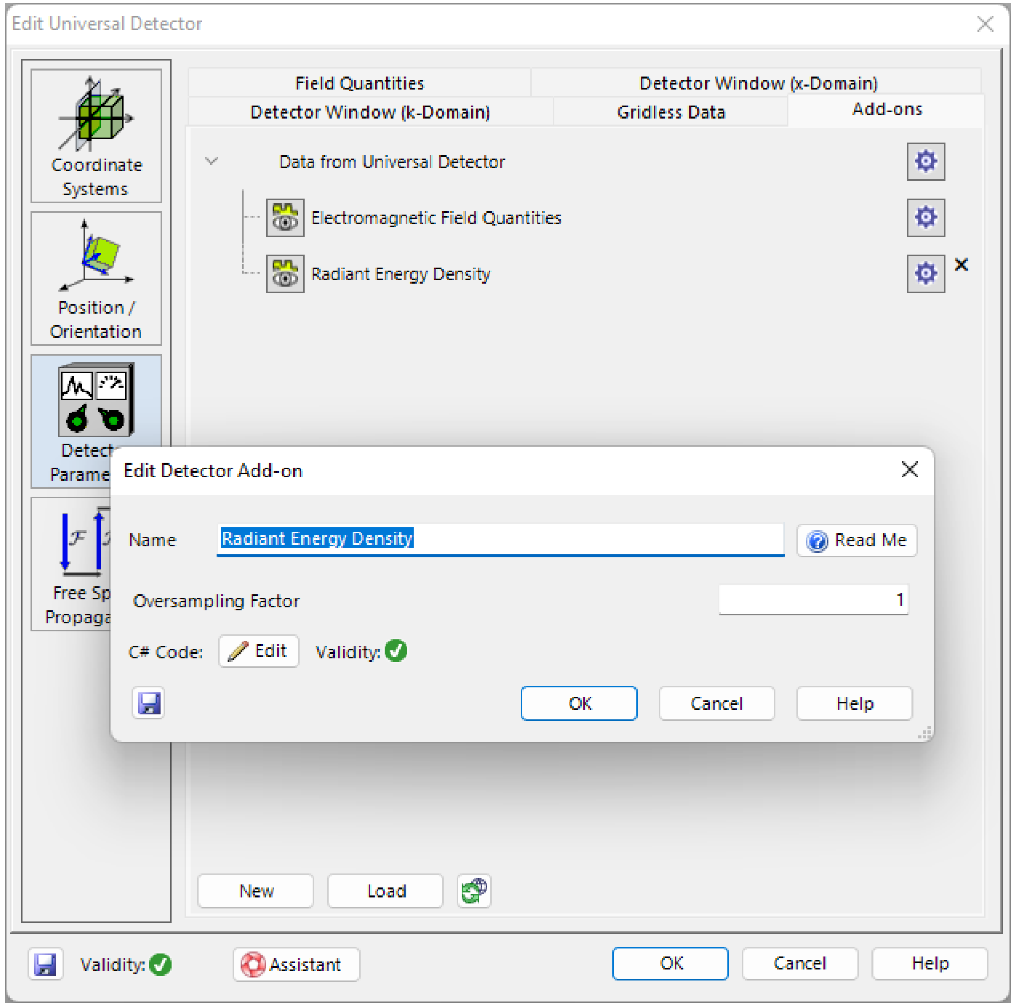




The uniaxial crystal can be modelled using the *Crystal Plate Component*. This component is an container for anisotropic media, which assumes that two plane parallel infinite surfaces. An orientation of the crystal axis in regards to the optical axis can be specified

Universal Detector & Detector Add-ons

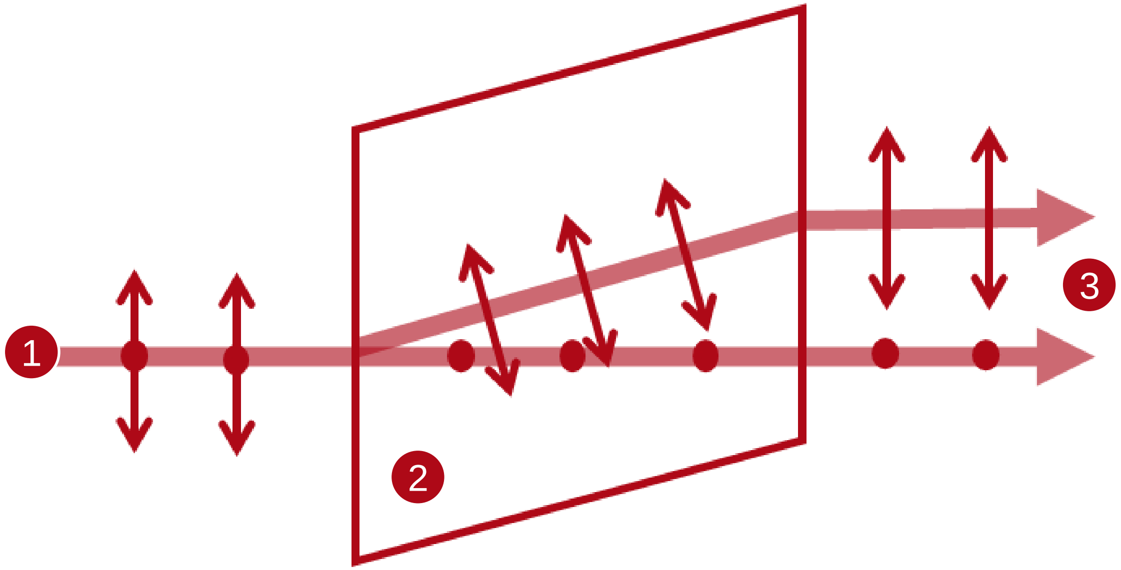




The *Universal Detector* allows to evaluate the impinging field and to calculate various physical quantities by using so-called *Add-ons*. One of the provided *Add-ons* enables to assess the radiant energy density. More information under:

[Universal Detector]

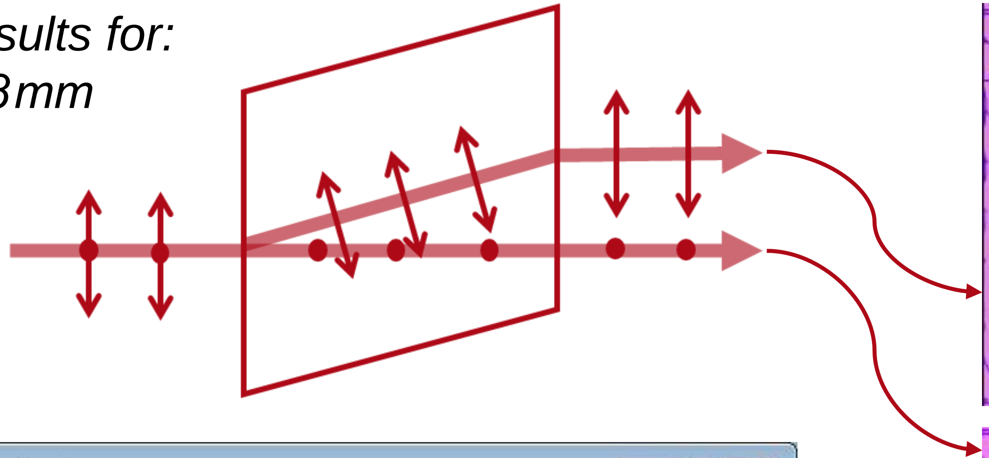
Summary – Components...

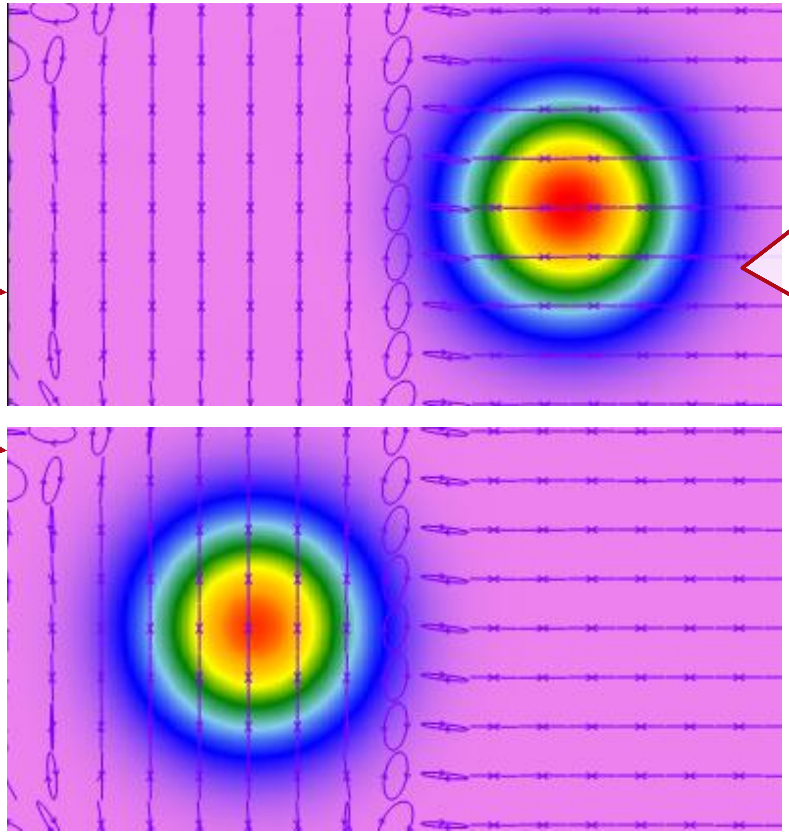


… of Optical System	… in VirtualLab Fusion	Model/Solver/Detected Magnitude
1. source	*Gaussian Wave*	spatial Gaussian function
2. uniaxial crystal	*Crystal Plate Component* with *Anisotropic Medium*	Layer Matrix [S-Matrix]
3. detector	*Universal Detector* with *Radiant Energy Density* add-on	radiant energy density

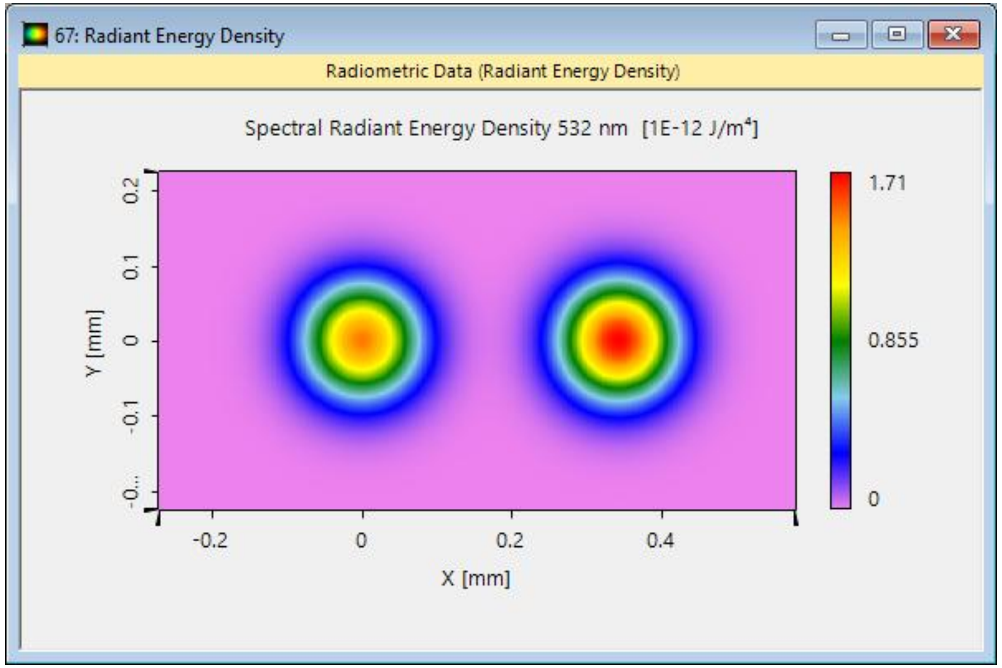
Birefringence Effect in Uniaxial Crystals

depicted results for:
thickness: 8mm
angle: 45°



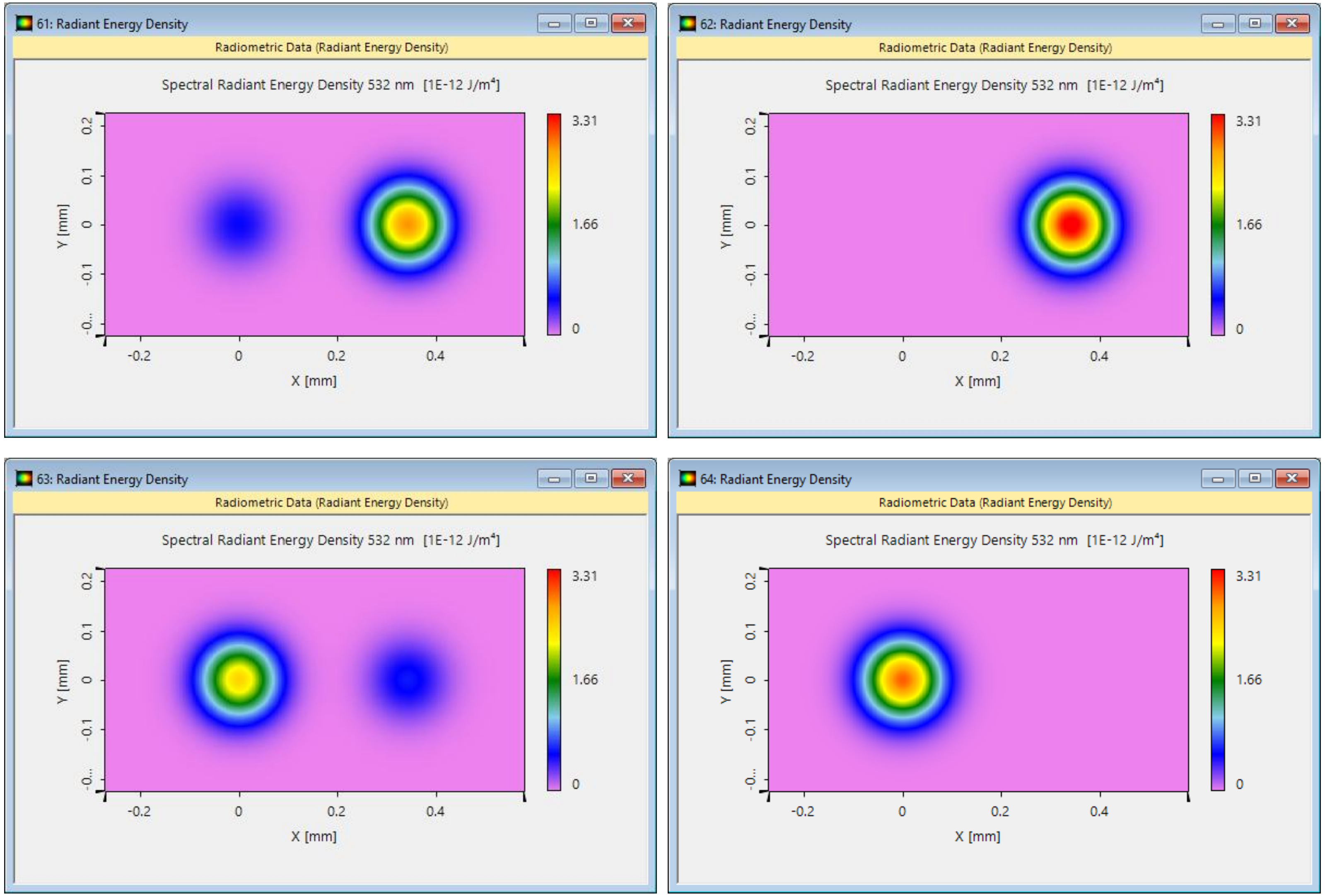


The polarization states of the ordinary beam and the extraordinary beam are perpendicular to each other, which can be visualized using polarization ellipses on the field data.



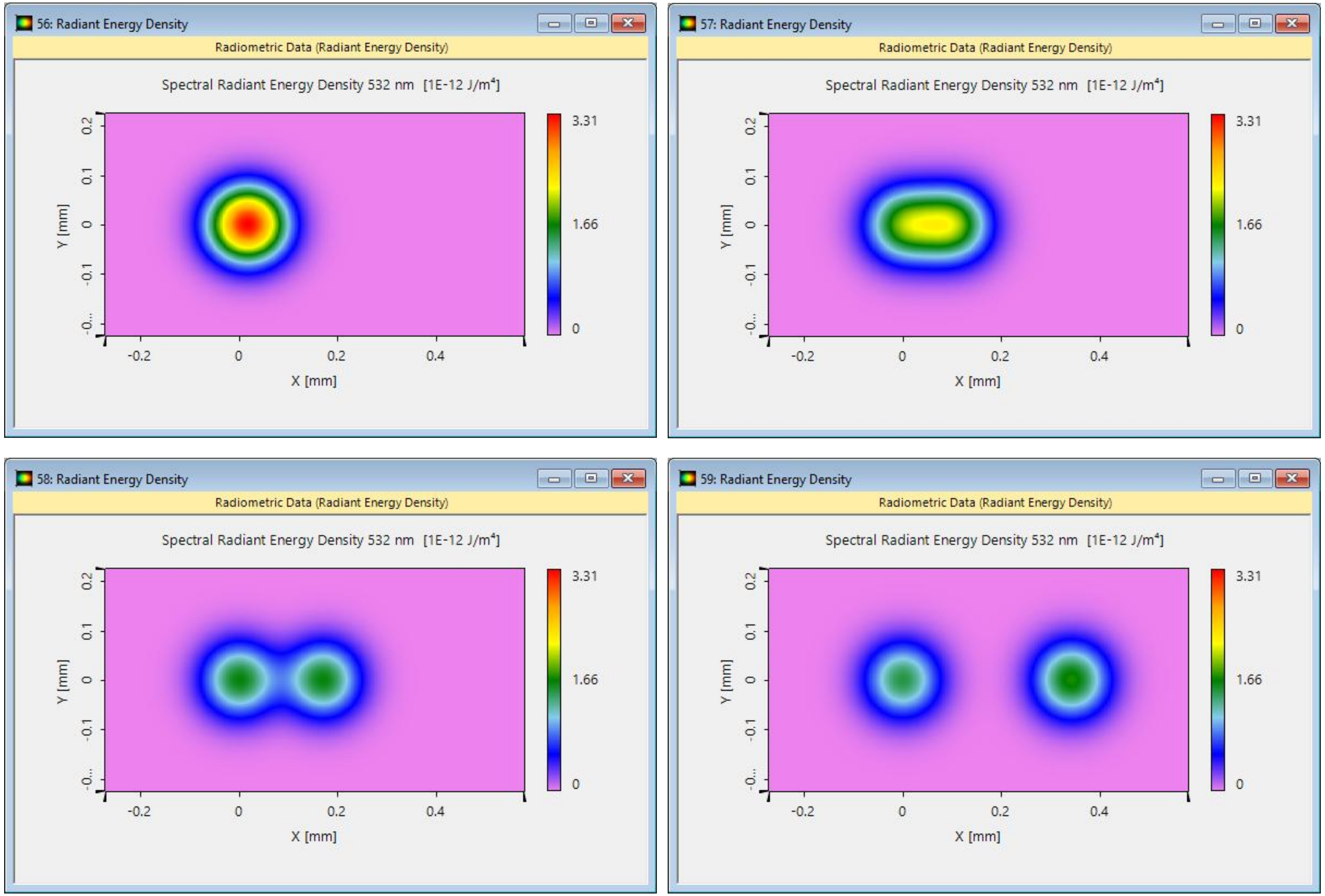
From the field information the radiant energy density can be calculated to compare the two beams directly.

Birefringence for Different Initial Polarization States



When the incident polarization is perpendicular to the crystal 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). Intermediary values will allow both beams to propagate.

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!

Document Information

title	Birefringence Effect of Anisotropic Calcite Crystal
document code	USC.0215
version	2.0
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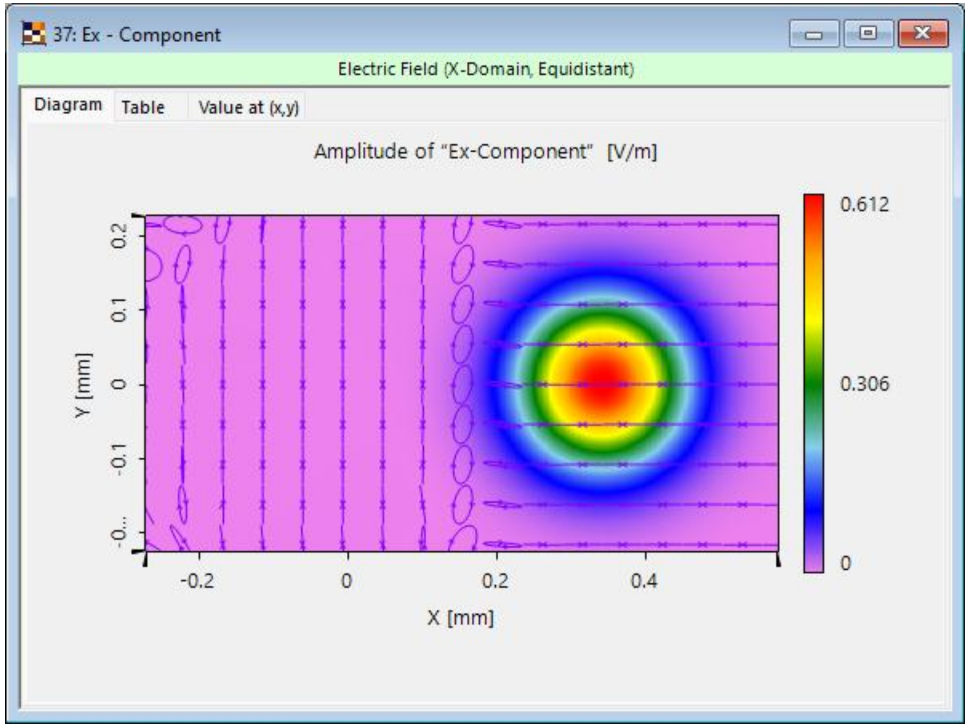
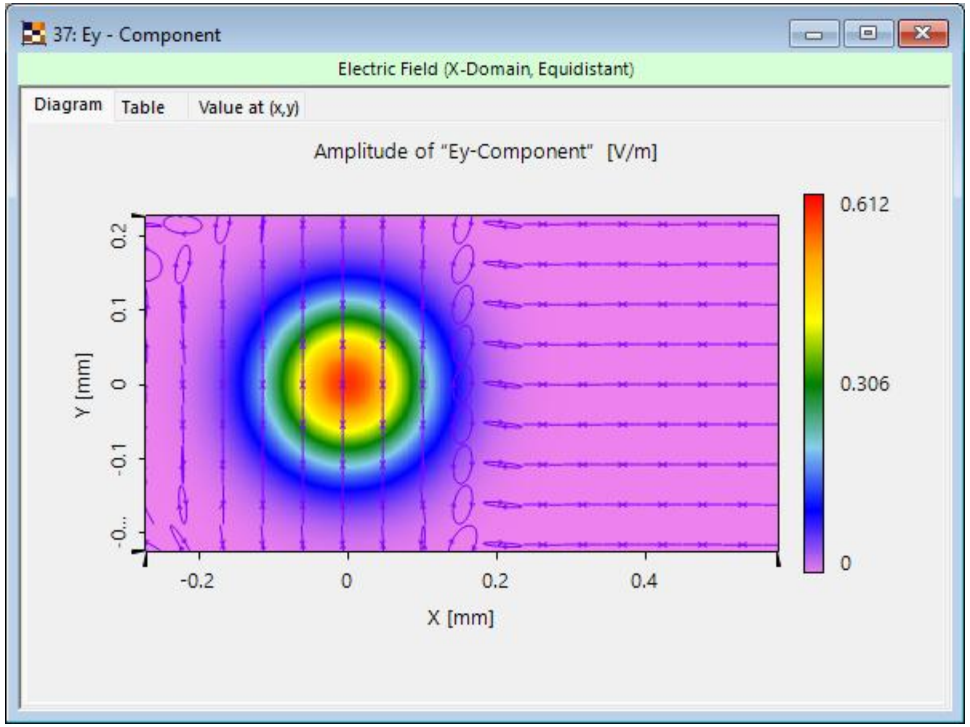
software version	2023.1 (Build 1.556)
category	Application Use Case
further reading	• Optically Anisotropic Media in VirtualLab Fusion • Conical Refraction in Biaxial Crystals • Polarization Conversion in Uniaxial Crystals

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.



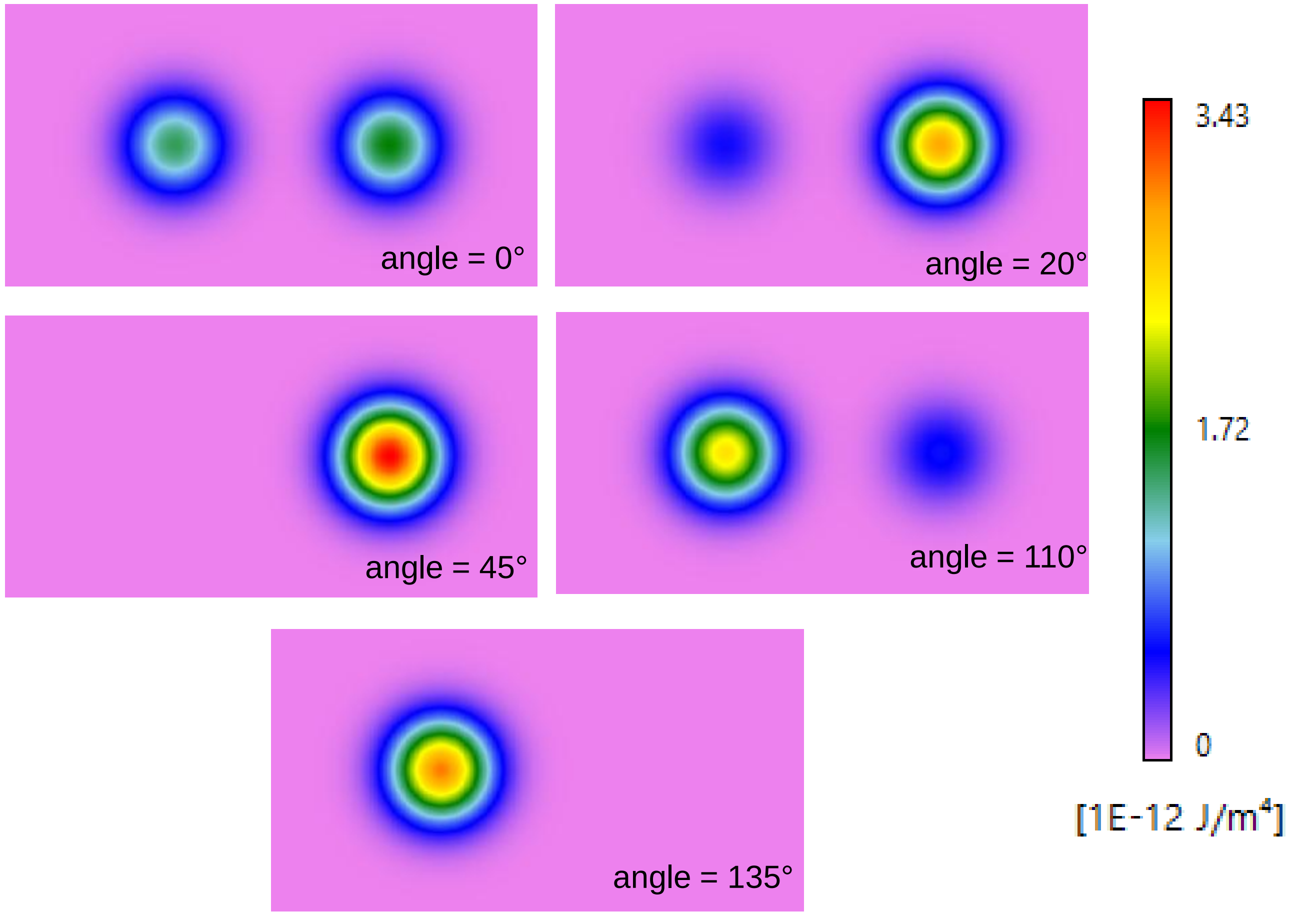
x - component



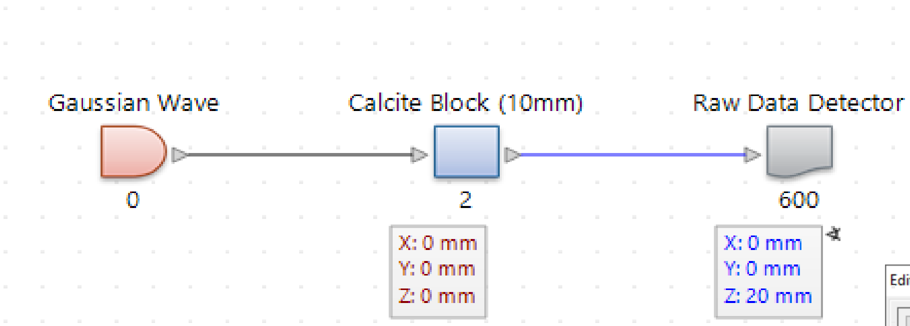
y - component

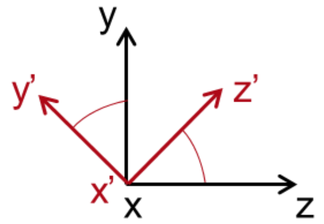
Birefringence for Different Initial Polarization States

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*).

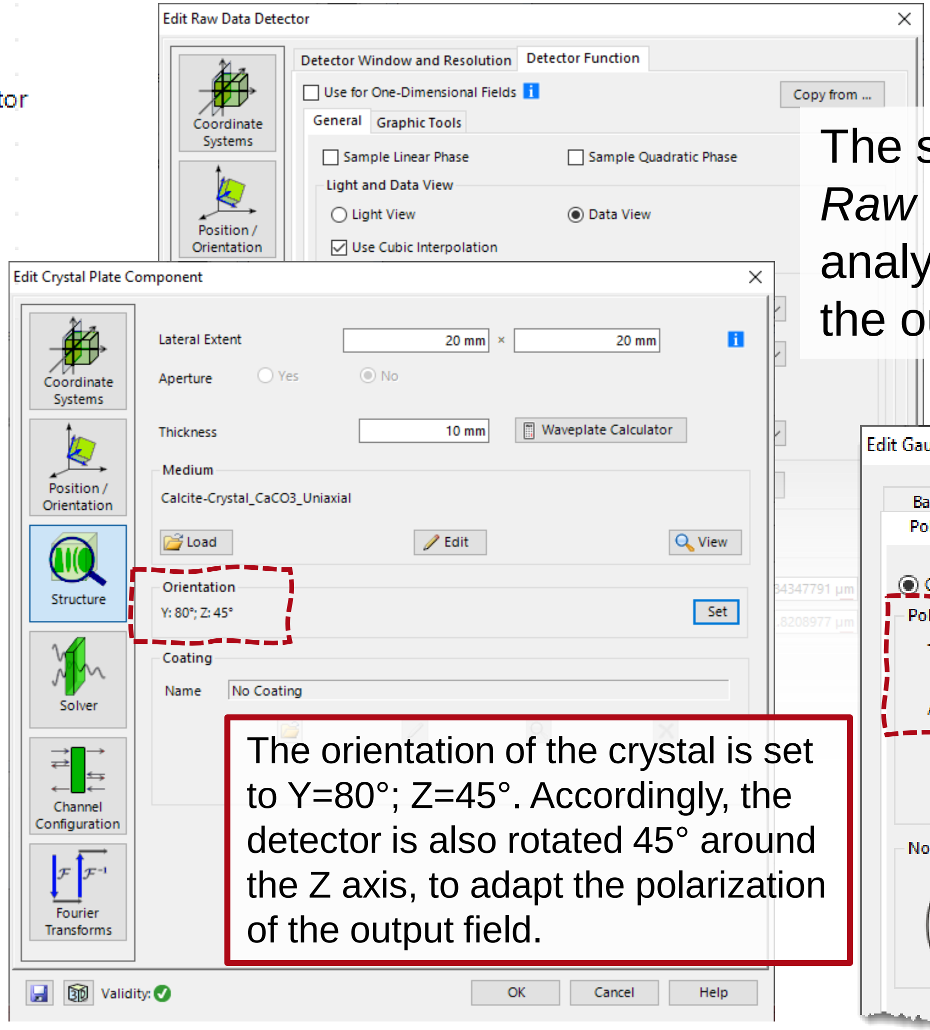


System Building Blocks





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.