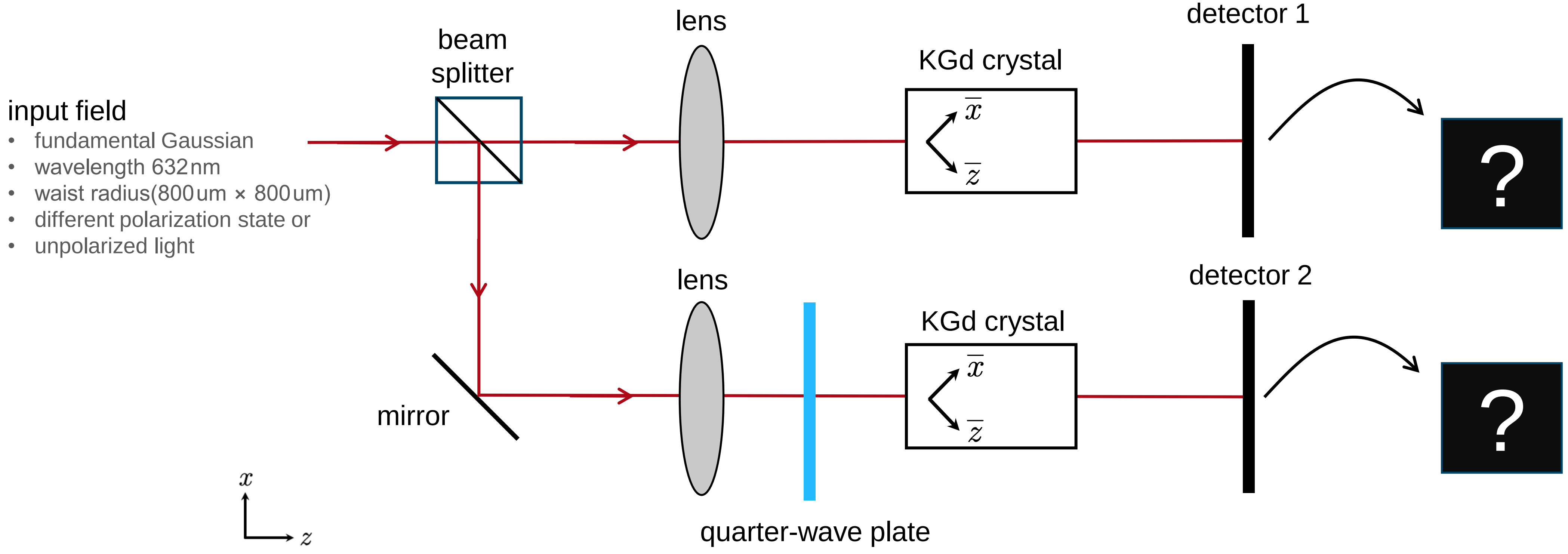
# Simulation of Conical Refraction as a Tool for Polarization Metrology

# Abstract

Conical refraction is a well-know phenomenon occurring in biaxial crystals, whereby an input Gaussian beam is transformed into a light ring whose intensity distribution is related to the incoming polarization. Several applications have been developed based on this phenomenon, polarization metrology among them. In this use case, we demonstrate the design of a polarimeter with two biaxial crystals, one in each arm of the setup, utilizing the fast physical-optics software VirtualLab Fusion.

# Modeling Task

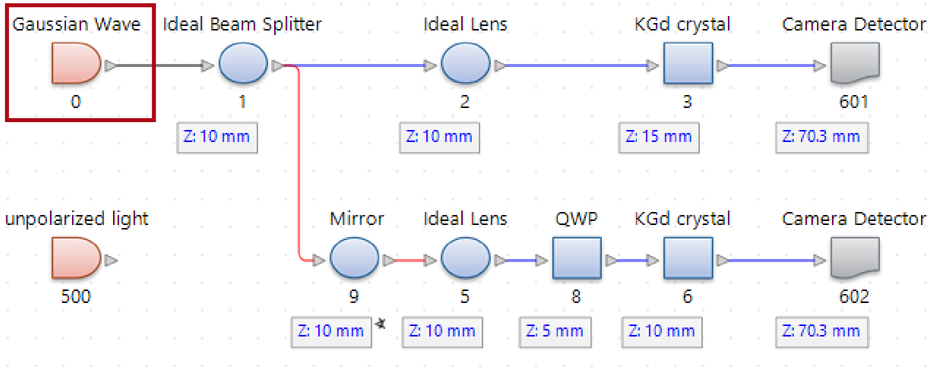
How to identify the polarization state of the incident field from the detected results?



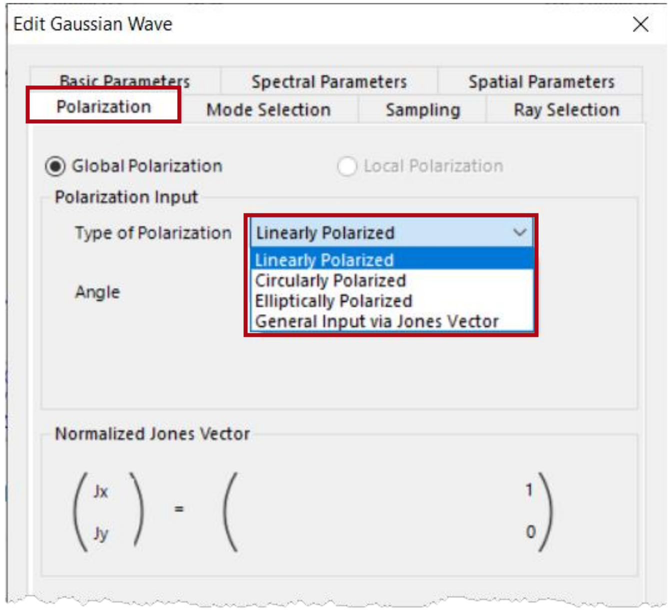

[Conical Refraction in Biaxial Crystals]

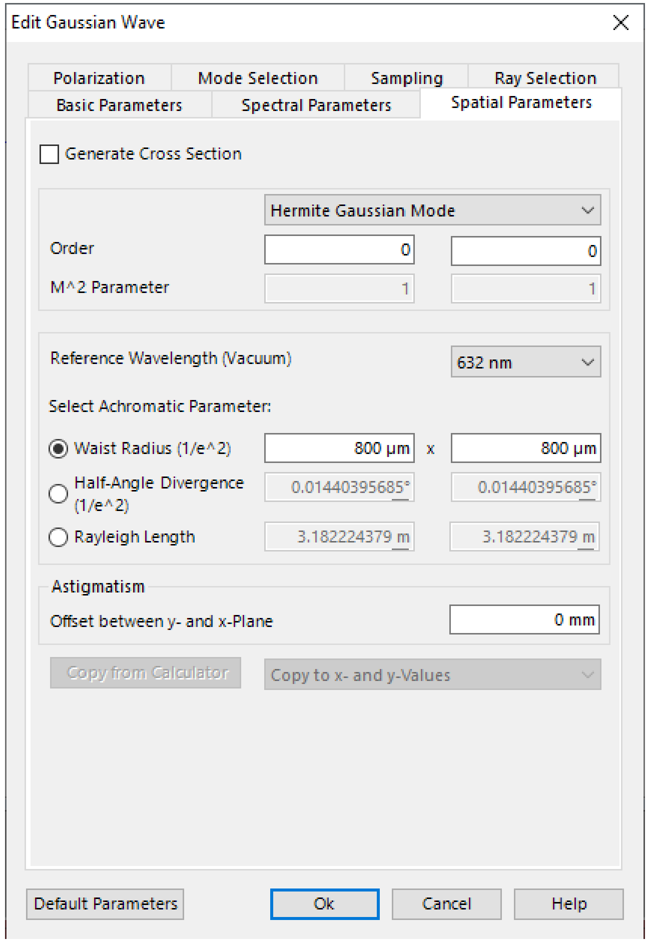
Optical setup follow from Peinado, et al. Optics letters 38.20 (2013): 4100-4103.

# System Building Blocks – Polarized Light Source

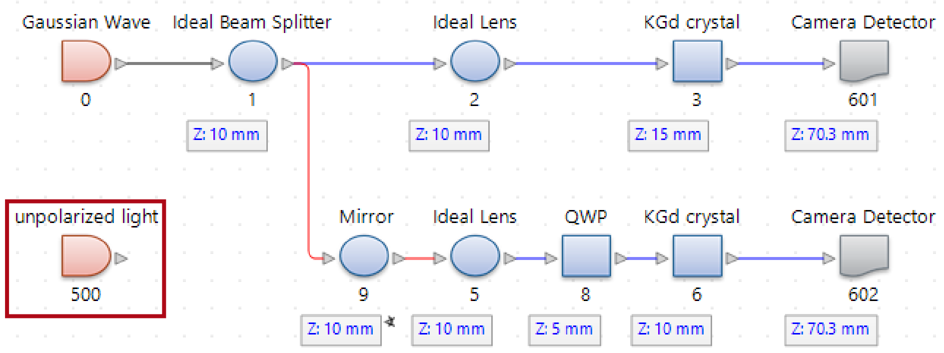


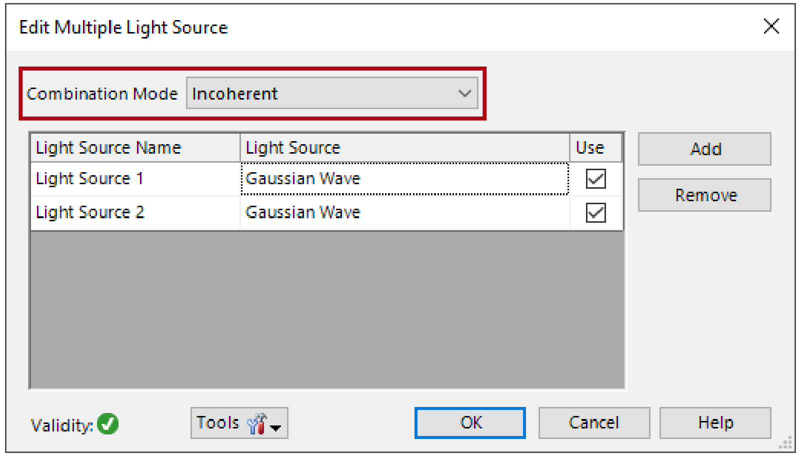

The input field with different (fully polarized) polarization states is modeled by a single *Gaussian Wave*.



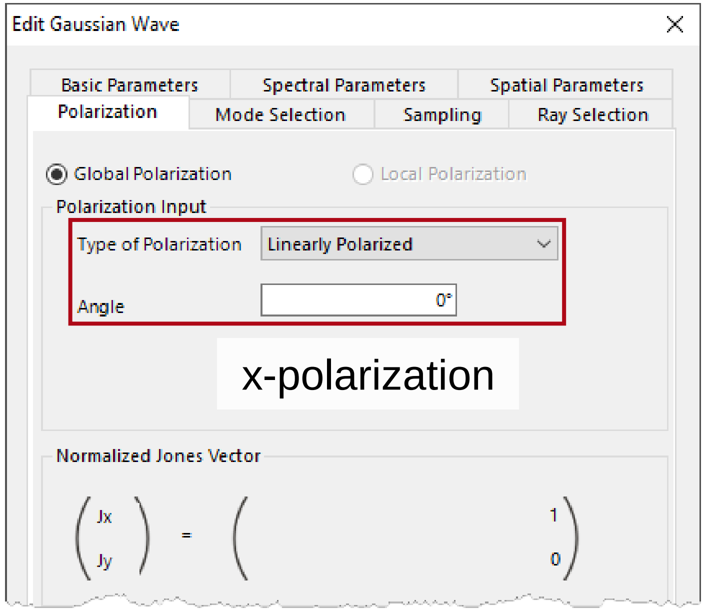



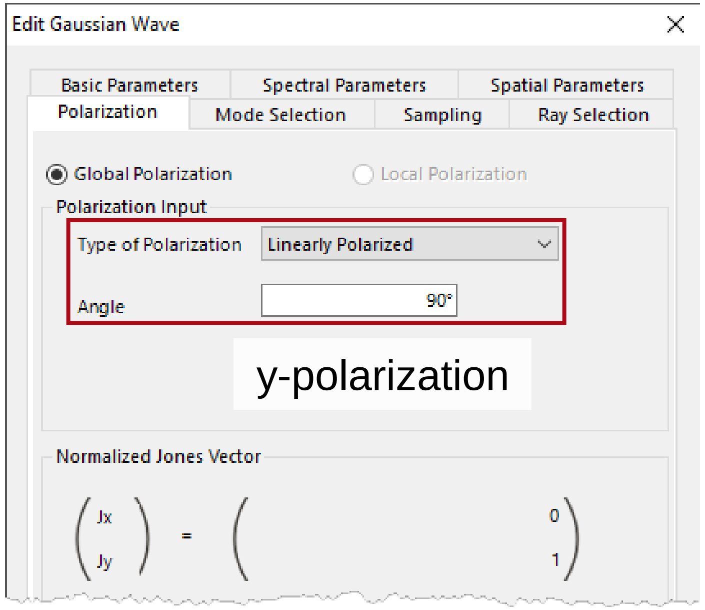
# System Building Blocks – Unpolarized Light Source



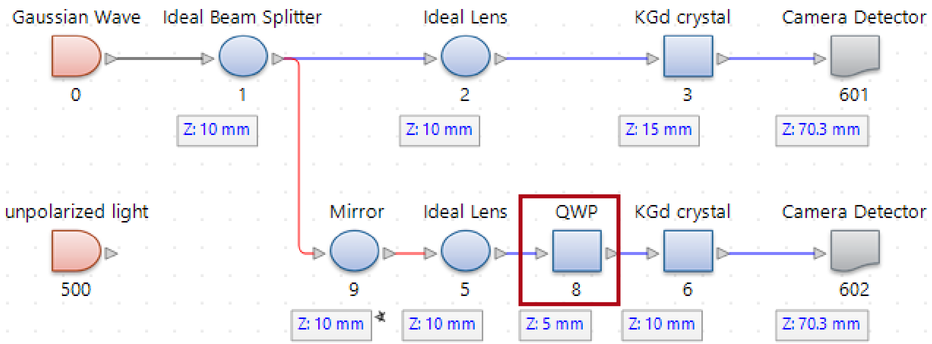




- Unpolarized light gives, statistically, equal projections along any two states forming an orthogonal basis.
- Therefore, we use the *Multiple Light Source* with two Gaussian waves to model the average of the two orthogonal states, in an incoherent manner, to represent unpolarized light.

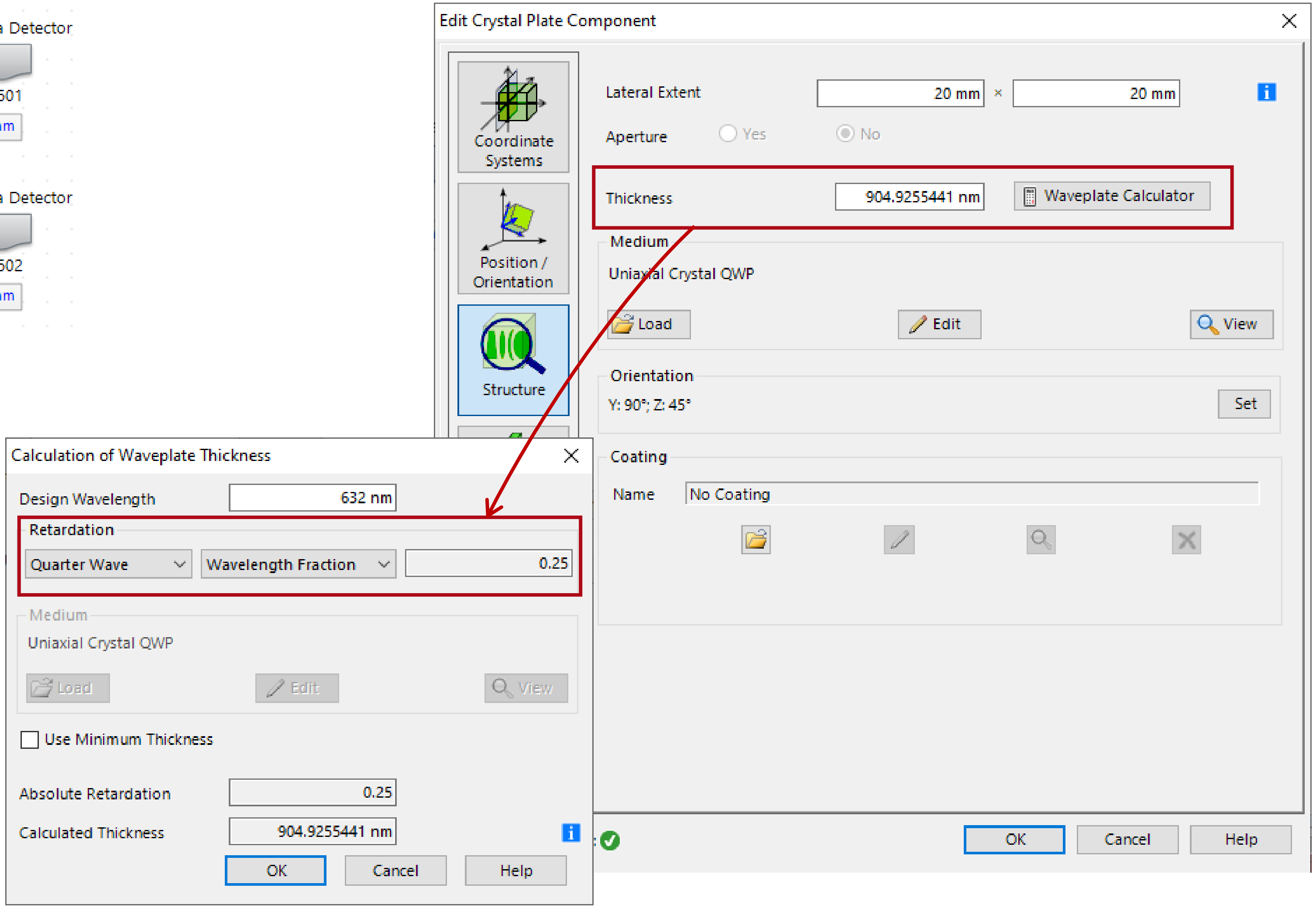


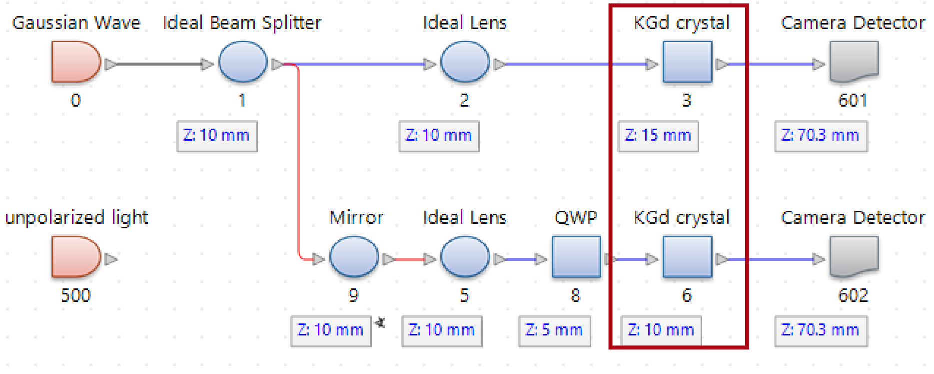
# System Building Blocks – Quarter-Wave Plate

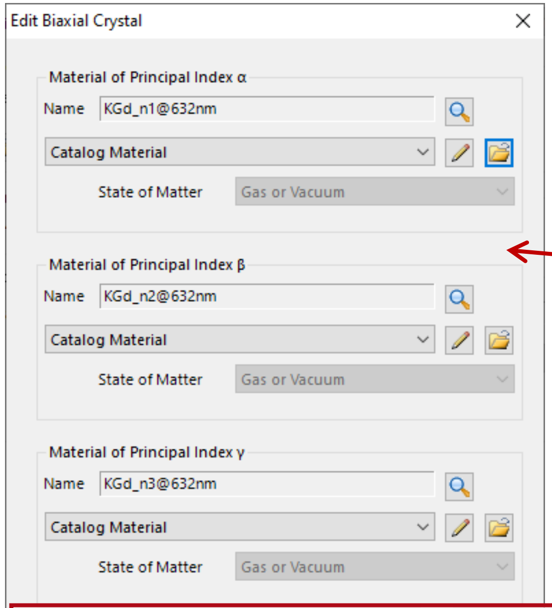


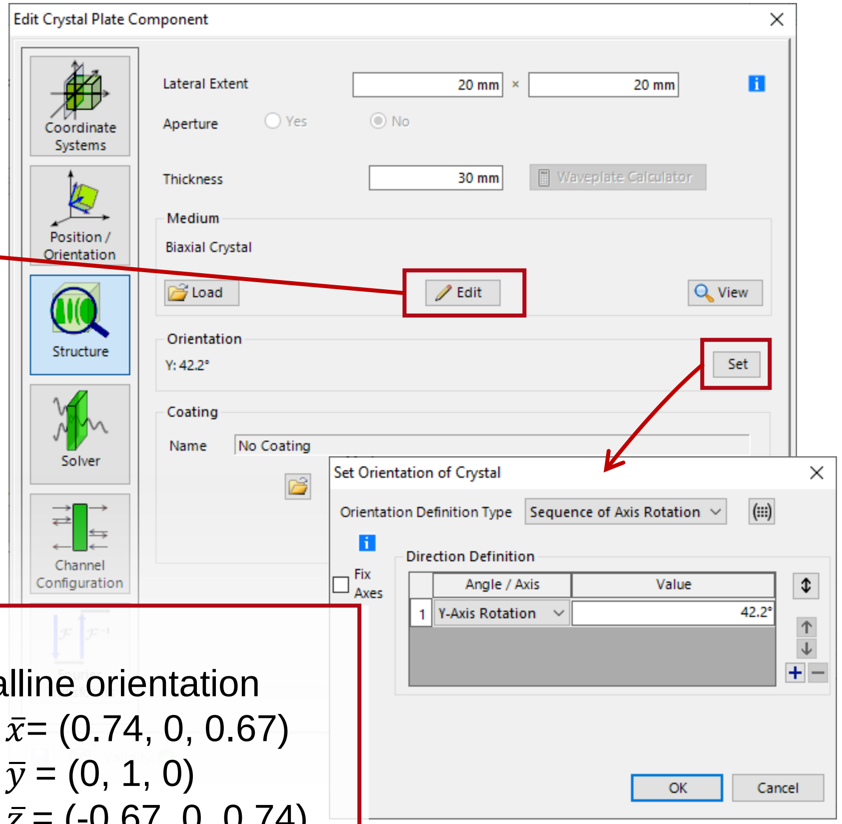

A quarter-wave plate (QWP) is applied in the second arm of the polarimeter and is modeled by the *Crystal Plate Component.* The thickness of the crystal plate can be calculated from the in-built calculator.



# System Building Blocks – Biaxial KGd Crystal



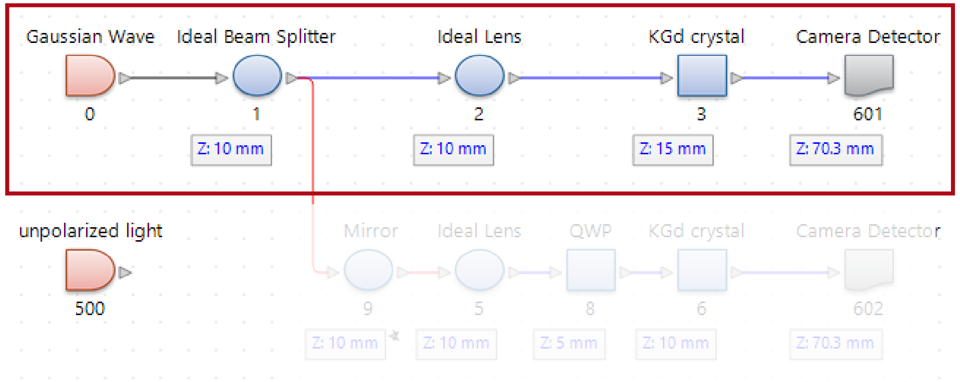

- Use a *Crystal Plate Component* to model the KGd crystal, then select *Biaxial Crystal* from the *Template* category of the *Media* catalog and define the principal refractive indices.
- Set the crystalline orientation according to the reference, so that the input field will propagate along one of the optic axes of the crystal.

**Biaxial Crystal**

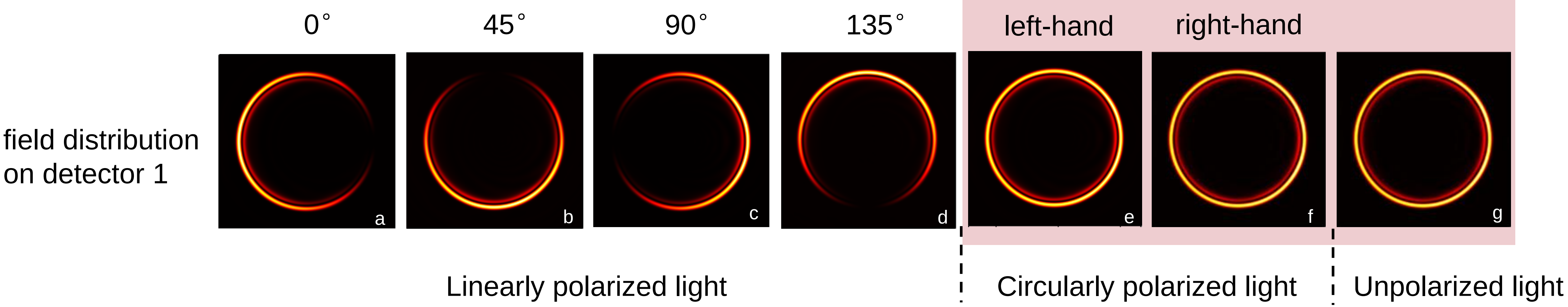
- thickness: 30mm
- refractive indices
  - $n_1$ = 2.013
  - $n_2$ = 2.045
  - $n_3$ = 2.086
- crystalline orientation
  - $\bar{x}$ = (0.74, 0, 0.67)
  - $\bar{y}$ = (0, 1, 0)
  - $\bar{z}$ = (-0.67, 0, 0.74)

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

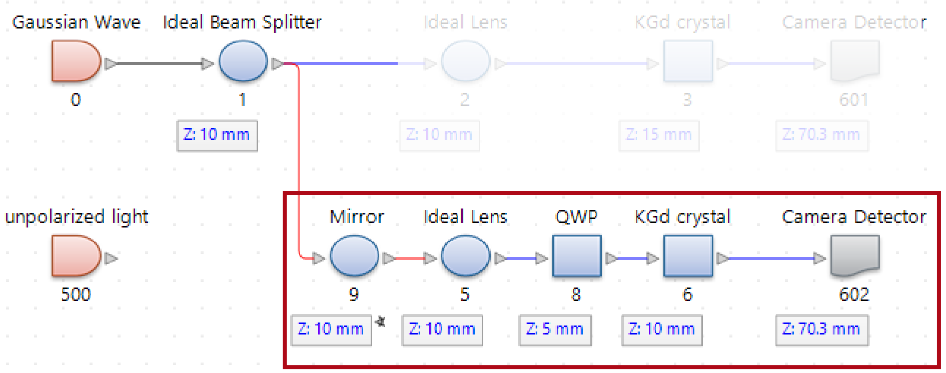
# Simulation Results




- Run the simulation and vary the polarization state of the input source (linearly polarized, circularly polarized, and unpolarized).
- If only arm 1 is used, there is no distinction between right and left circularly polarized light, and unpolarized light. [see figs. e-g].

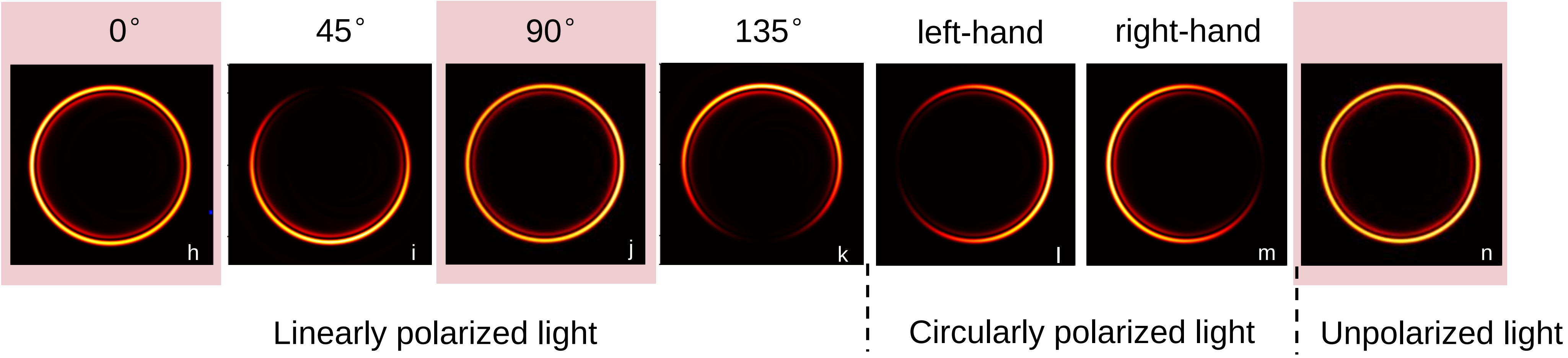


# Simulation Results



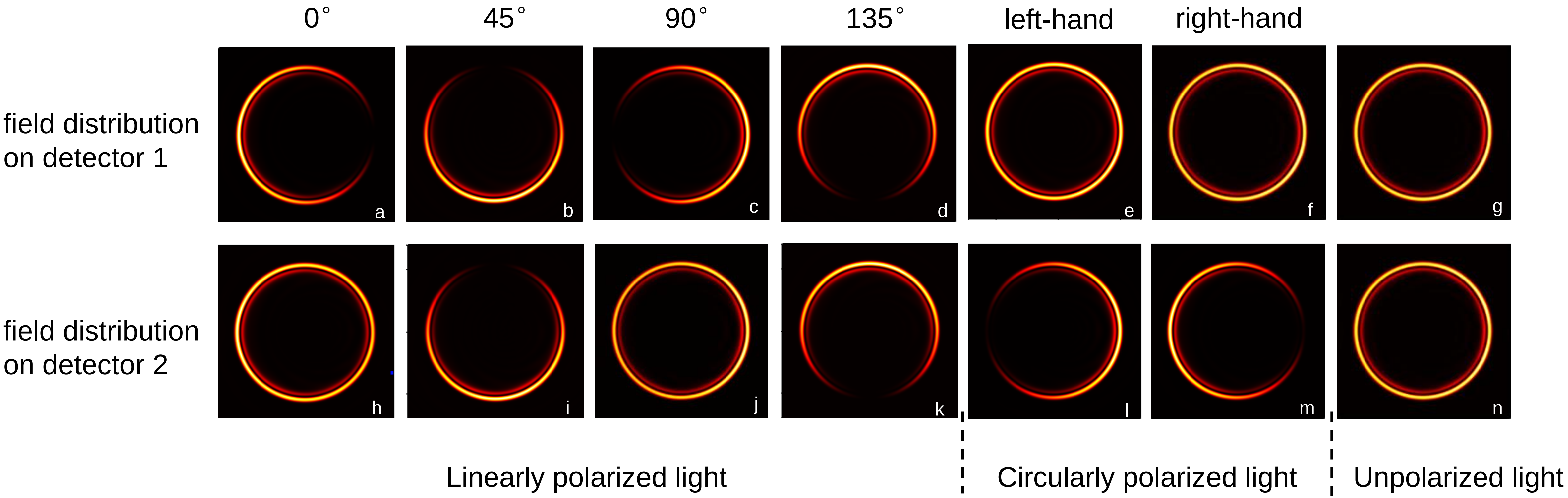

- If the angle between the orientation of the QWP and the input polarization direction is 45º, the linearly polarized beam will change into a circularly polarized one, and vice versa.
- As a result, arm 2 cannot distinguish between linearly polarized light at 0º, 90º and unpolarized light. [see figs. h, j, n].

field distribution on detector 2

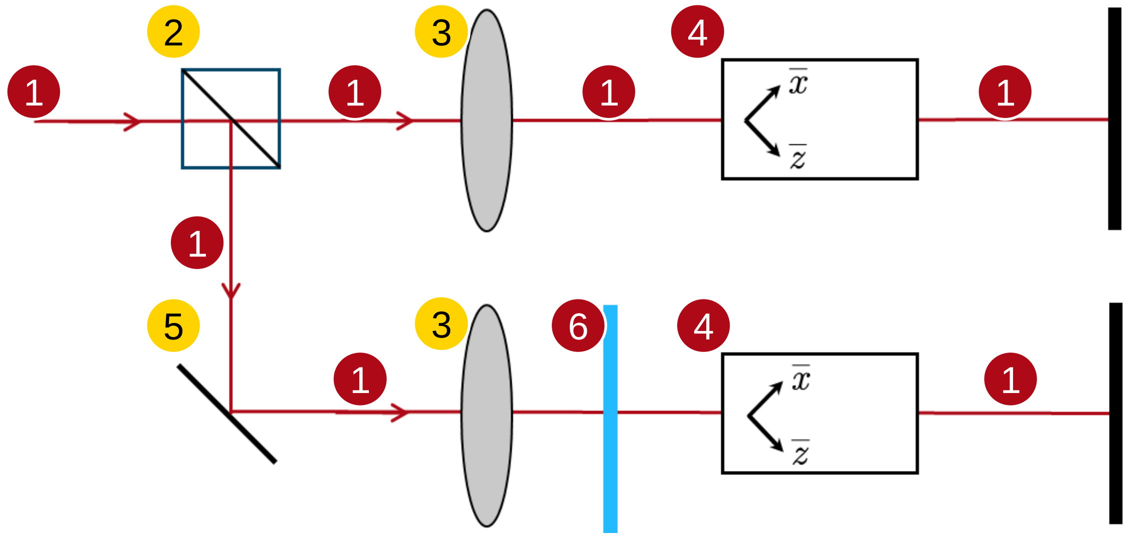


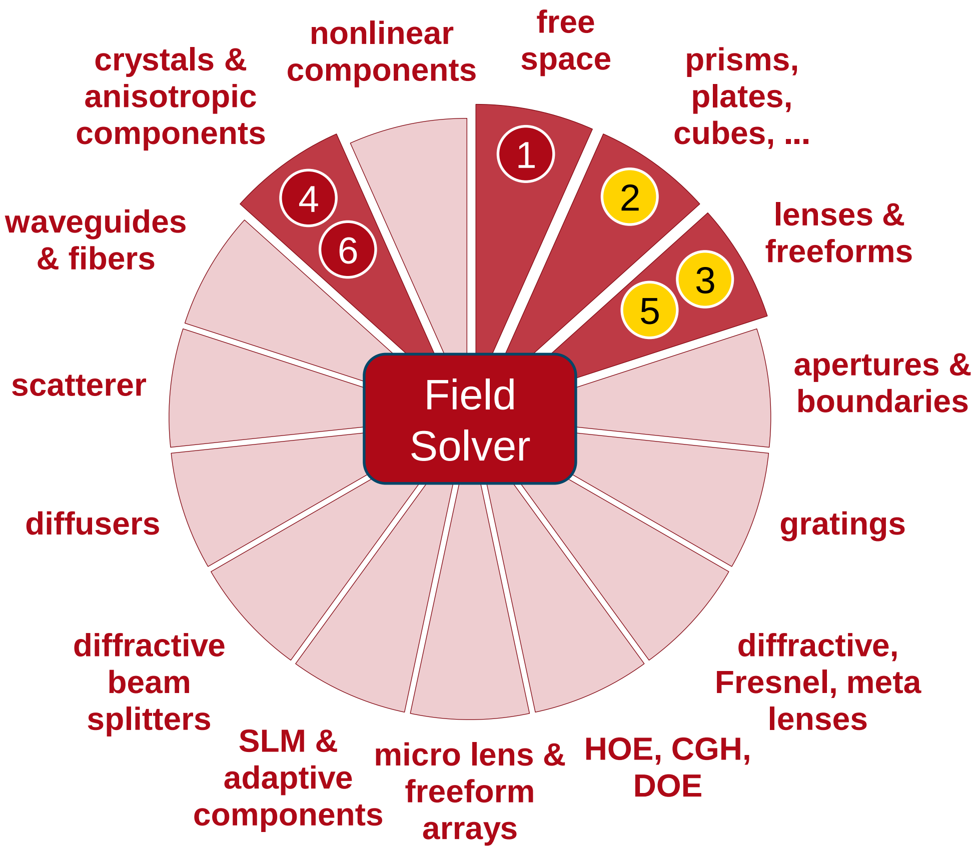
# Simulation Results

By comparing the field distribution on the detectors of each of the two arms, we can distinguish each state of input field polarization, including unpolarized light.



# VirtualLab Fusion Technologies




# idealized component

# Document Information

| | |
|---|---|
| title | Conical Refraction as a Tool for Polarization Metrology |
| document code | USC.0271 |
| document version | 1.0 |
| software edition | VirtualLab Fusion Basic |
| software version | 2021.1 (Build 1.180) |
| category | Application Use Case |
| further reading | - Optically Anisotropic Media in VirtualLab Fusion<br>- Polarization Conversion in Uniaxial Crystals<br>- Conical Refraction in Biaxial Crystals<br>- Birefringence Effect of Anisotropic Calcite Crystal |