

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.



×

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

tu pit he parameter(s) to be varied. u can select one or more parameters which shall be varied as well as the resulting number of iterations. Several modes are available specifying how the parameters are varied per iteration arge Mode Standard Filter by Cobject Category Parameter Vary Prom Stoppen 1 estimate Control (Air in Homogen Medium at "-" Output (Air in Homogen Metrial (Air) (Constant Absorptio Varies from 0° to 1880° Medium at "-" Output (Air in Homogen Metrial (Air) (Constant Absorptio Varies from 1 estimate Polarization Angle 4 estimate 1 estimate Polarization Angle 4 estimate 1										ter Specification	o: Par
u can select one or more parameters which shall be varied as well as the resulting number of iterations. Several modes are available specifying how the parameters are varied per iteration age Mode Standard itter by 2 Object Category Parameter Varie Parameter Vary Form 10 Support of the Varied Para Medium at "-" Output (Air in Homogen Material (Air) (Constant Absorptio Wavelength Varies from 0° to 1880° Using 10 11 18° 0° Iterator to 101 18° 0° Iterator to 1893 mm 1 22+303 mm 0 mm Itateral Offset Y 1 1200000000 1 199999999 31 Number of Rays Y 1 200000000 1 199999999 31 Oversampling Factor 1 E-300 1 1E-300 1									aried.	he parameter(s) to be v	et up t
u can select one or more parameters which shall be varied as well as the resulting number of iterations. Several modes are available specifying how the parameters are varied per iteration age Mode Standard iter by 2 Cobject Category Parameter Air Pressure Polarization Support State Control Air Pressure Polarization Angle Polari											
age Mode Standard											
age Mode Standard itter by)n.	e varied per iterat	eters are varie	ne param	pecifying now ti	s are available sp	n mode	e resulting number of iterations. Severa	ameters which shall be varied as well as th	select one or more pa	u car
age Mode Standard itter by											
ilter by 2 Object Category Parameter Vary Prom Uny Point Category Parameter Vary Point Constant Absorption Weelength Point Category Medium at *- Output (Air In Homogen Metrial (Air) (Constant Absorption Weelength Point Category Point Catego									~	Mode Standard	age I
2 Object Category Parameter Vary Performant Zation Subject Original W Optical Setup Para. Environment Air Pressure Vary Vary <td>arameters</td> <td>Show Only Varied</td> <td>Show C</td> <td>×</td> <td></td> <td></td> <td>-</td> <th></th> <td></td> <td>by</td> <td>ilter</td>	arameters	Show Only Varied	Show C	×			-			by	ilter
Image: Constant Wave" (# 0) Constant Constant Absorption Constant Absorption "Gaussian Wave" (# 0) "Gaussian Wave" (# 0) Material (Air) (Constant Absorption Constant Absorption "Gaussian Wave" (# 0) "Gaussian Wave" (# 0) Total Setup		jie	angle	n a	zatio	'oları		Descustor	C -1	Object	
Oddaal abup Fails Limitorine Alf refsure Variable Variabl	Value	Size Origina	Stepsize	Steps	10	From	Vary	Parameter	Category	Optical Satur Para	2 *
"Gaussian Wave" (# 0) Wavelength 1 32 mm 1 43007 µm 202 mm "Gaussian Wave" (# 0) Polarizance to inout Planse 0 * 101 1.8 * 0 * Lateral Offset X -1E+303 mm 1 2E+303 mm 0 mm 1 2E+303 mm 0 mm Lateral Offset X -1E+303 mm 1 2E+303 mm 0 mm 1 2E+303 mm 0 mm Number of Rays X 1 1 2000000000 1 1 99999999 31 0 ************************************		D 180	° tO ′	าบ	s tron	aries	V	Material (Air) Constant Absorptio	Medium at "-" Output (Air in Homogen	Optical Setup Pala	
"Gaussian Wave" (# 0) Wisight Gaussian Wave" (# 0) Gaussian Wave" (# 0)<	m	7 μm 532	49.807 µm		50 µm	193 nm		Wavelength			
Polinization Angle Ø' 180' 101 1.8.' O'' "Gaussian Wave" (# 0) Dicksoge to input Playsa				-			-	Weight	-		
"Gaussian Wave" (# 0) Distance to inout Plans If E-303 mm IE-303 mm IE-303 mm IE-303 mm Omm Lateral Offset X If IE-303 mm 12 E-303 mm 12 E-303 mm 0 mm Lateral Offset X If IE-303 mm 12 E-303 mm 12 E-303 mm 0 mm Number of Rays X If IE-300 mm 1 200000000 1 19999999 31 Number of Rays Y If IE-300 If IE-300 1 19999999 31 Oversampling Factor IE-300 1E+300 1 16+300 1	- i	8° 0'	1.8°	101	180°	0°	\checkmark	Polarization Angle			
Caussian wave (# 0) Lateral Offset X Image: 1-15+303 mm 1 22+303 mm 0 mm Lateral Offset Y Image: 1-15+303 mm 1 22+303 mm 0 mm Number of Rays X Image: 1-15+303 mm 1 22+303 mm 0 mm Number of Rays X Image: 1-15+303 mm 1 22+303 mm 0 mm Oversampling Factor Image: 1-15+300 mm 1 19999999 31	1	13 mm 0.m	2E±303 mm		1E+303 mm	15+303 mm		Distance to Input Plane	-		
Lateral Offset Y IE+303 mm 1E+303 mm 2E+303 mm 0 mm Number of Rays X I 200000000 1 19999999 31 Number of Rays Y I 1 200000000 1 19999999 31 Oversampling Factor IE-300 1E+300 1 1E+300 1 1E+300	n	/3 mm 0 m	2E+303 mm	1	1E+303 mm	-1E+303 mm		Lateral Offset X		Gaussian wave (# 0)	
Number of Rays X 1 2000000000 1 199999999 31 Number of Rays Y 1 1 200000000 1 199999999 31 Oversampling Factor 16:300 16:300 1 16:400 1 16:400 1	0	/3 mm 0 m	2E+303 mm	1	1E+303 mm	-1E+303 mm		Lateral Offset Y			
Number of Rays Y 1 200000000 1 199999999 31 Oversampling Factor 1E-300 1E+300 1 1E+300 1		99999 31	19999999999	1	200000000	1		Number of Rays X			
Oversampling Factor 1E-300 1E+300 1 1E+300 1		99999 31	19999999999	1	200000000	1		Number of Rays Y			
		300 1	1E+300	1	1E+300	1E-300		Oversampling Factor			
Eisld Cire Exter		200 1	10.200	1	10.200	15 200	- 1	Field Cite Factor			

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* 135^o) 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* 45^o).



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

	ter specification									
et up ti	he parameter(s) to be	e varied.								
u can	select one or more p	parameters which shall be varied as we	ell as the resulting number of iteratior	ns. Several <u>m</u>	odes are availabl	e specifying ho	w the pa	rameters are varied p	per iteration.	
	Mada Standard	~								
agen	vioue standard	*								
Filter	by							X Show Only		meters
		Catagoni	Parameter	Marcu	Cruci	tal th	ick	ness	Original Val	ue
2 *	Object	Category	Falallicter	Wary						
2*	Object	Basal Positioning (Relative)	Angle Zeta	[Crys					
2 * 	Object	Basal Positioning (Relative)	Angle Zeta X		varia	s fro	m	100fm	to	
2 * 	Calcite Block	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y		varie	s fro	m	100fm	to	
 	"Calcite Block (10mm)" (# 2)	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y Z		varie	s fro	m	100fm	to	
	"Calcite Block (10mm)" (# 2)	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y Z Component Size X		varie 10mr	s fro n	m	100fm 12E-103 mm	0° to nm 0 mm 20 mm	
	"Calcite Block (10mm)" (# 2)	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y Z Component Size X Component Size Y Thickness		varie 10mr	s fro n	100 III	1000fm	0° to mm 0 mm 20 mm 	1
2 *	"Calcite Block (10mm)" (# 2)	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y Z Component Size X Component Size Y Thickness		varie 10mr	s fro n	100	1000fm	0° tomm 0 mm 20 mm 20 mm 10 mm	-1
	"Calcite Block (10mm)" (# 2)	Basal Positioning (Relative) Basal Positioning (Absolute)	Angle Zeta X Y Z Component Size X Component Size Y Thickness Drotance@doi.e.		varie 10mr	10 mm 12+303 mm	100 100	26-303 mm 101.010101 µm 225-303 mm	0" to mm 0 mm 20 mm 20 mm 10 mm 0 mm]
	"Calcite Block (10mm)" (# 2) "Raw Data Detector" (# 600)	Basal Positioning (Relative) Basal Positioning (Relative) Basal Positioning (Relative)	Angle Zeta X Y Z Component Size X Component Size Y Thickness Drawnee@dota Lateral Shift X Lateral Shift Y		varie 10mr -1E+303 mm -1E+303 mm	S fro 10 mm 10 mm 12+303 mm 12+303 mm 12+303 mm 12+303 mm	100 100	26-303 mm 1E-103 mm 1E-103 mm 101.010101 µm 2E+303 mm 2E+303 mm	0" tO mm 0 mm 20 mm 20 mm 10 mm 0 mm 0 mm]
	"Calcite Block (10mm)" (# 2) "Raw Data Detector" (# 600)	Basal Positioning (Relative) Basal Positioning (Absolute) Basal Positioning (Relative)	Angle Zeta X Y Z Component Size X Component Size Y Thickness Dritume-eladica Lateral Shift X Lateral Shift Y Spherical Angle Theta		varie 10mr 100 fm -1E+303 mm -1E+303 mm -360'	S fro 16+ 303 mm 103 mm 16+ 03 mm 16+ 03 mm 16+ 303 mm 16+ 303 mm 16+ 303 mm 360'	100 1 1 1	2E+303 mm 1E+103 mm 1E+103 mm 1E+103 mm 2E+303 mm 2E+303 mm 2E+303 mm 720*	0* tO mm 0 mm 20 mm 20 mm 0 mm 0 mm 0 mm 0*	-1

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!

"Calcite Block (10mm)" (# 2) Basal Positioning (Relative) Angle Zeta "Calcite Block (10mm)" (# 2) X Y "Calcite Block (10mm)" (# 2) Component Size Y Z "Component Size Y Thickness Thickness "Detector" (# 600) Basal Positioning (Relative) Lateral Shift X Lateral Shift Y Spherical Angle Theta Contaring Apple Apple	Of systal throwness varies from 100fm to 100mm 100 mm 100mm 100 mm 100 mm 100 throwness 100 mm 100 throwness 100 mm 100 throwness 100 throwness 100 throwness 100 throwness 100 throwness 100 throwness 100 throwness 11E+303 mm 12E+303 mm 12E+303 mm 12E+303 mm 14E+303 mm 12E+303 mm 15E+303 mm 12E+303 mm 14E+303 mm 12E+303 mm 15E+303 mm 12E+303 mm 14E+303 mm 12E+303 mm 15E+303 mm 12E+303 mm 15E+304 mm 12E+303 mm	thickness = 1mm	thickness = 3mm	0.558
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.	thickness = 5mm	thickness = 8mm	thickness = 10mm	0

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