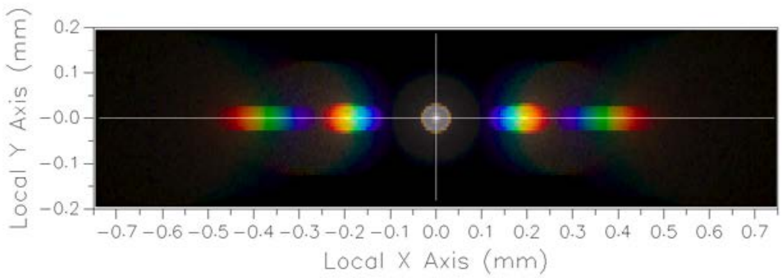
Color Image Analysis of Optical Systems



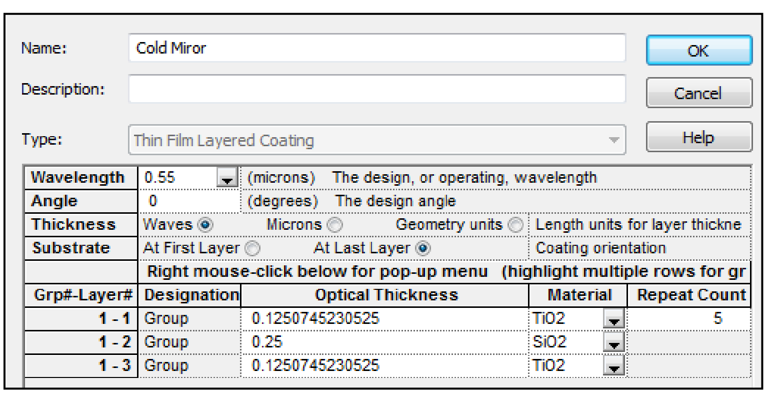
Introduction

The spectral distribution of a broadband light source is important to many optical systems, from white light illuminators to spectrometers. Color Image analysis in FRED produces visualization of color distribution by calculating chromaticity coordinates of each pixel and displaying the resulting RGB values over the surface. Additionally, the color chromaticity diagram is displayed, and chromaticity coordinate of each pixel is indicated when the user moves the cursor across the graph. In this application note, the Color Iimage from two optical systems will be observed. The first system involves a dichroic "cold mirror" to split white light into two wavelength bands. The second system utilizes a linear polarizer and a waveplate to show the wavelength-dependence of birefringent materials.

Examples

Dichroic Cold Mirror

Multilayer filters can be created in FRED by right-clicking *Coatings→Create a New Coating...* Several coating types can be specified, such as a Sampled Coating, Thin Film Layered Coating, Quarter Wave Single Layer Coating, General Sampled Coating (angle of incidence, wavelength, and polarization-dependent), Polarizer/Waveplate Coating (Jones matrix), and Script Coating. In this example, a cold mirror is created using the Thin Film Layered Coating type (Figure 1).


Name: Cold Miror
Description:
Type: Thin Film Layered Coating
OK
Cancel
Help

Wavelength	0.55	(microns) The design, or operating, wavelength	
Angle	0	(degrees) The design angle	
Thickness	Waves ◉ Microns ○ Geometry units ○	Length units for layer thickne	
Substrate	At First Layer ○ At Last Layer ◉	Coating orientation	
	Right mouse-click below for pop-up menu (highlight multiple rows for gr		

Grp#-Layer#	Designation	Optical Thickness	Material	Repeat Count
1 - 1	Group	0.1250745230525	TiO2	5
1 - 2	Group	0.25	SiO2	
1 - 3	Group	0.1250745230525	TiO2	

Figure 1. Cold mirror coating specifications.

The Cold Mirror Coating is applied to one surface of a plane parallel plate. The plate is illuminated with a white light source with even-weighted samples from 400-700 nm. The source rays originate within a small volume located at the focal point of a parabolic mirror. Light reflected by the mirror is quasi-collimated and sent toward the cold mirror, which is rotated 50° relative to the beam. Two absorbing planes are placed to collect light reflected and transmitted by the cold mirror.

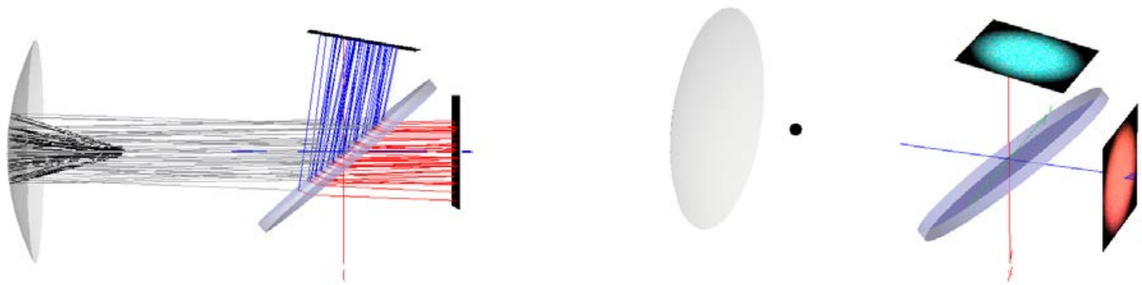


Figure 2. Illuminated cold mirror layout (left). Color image of reflected and transmitted beams (right).

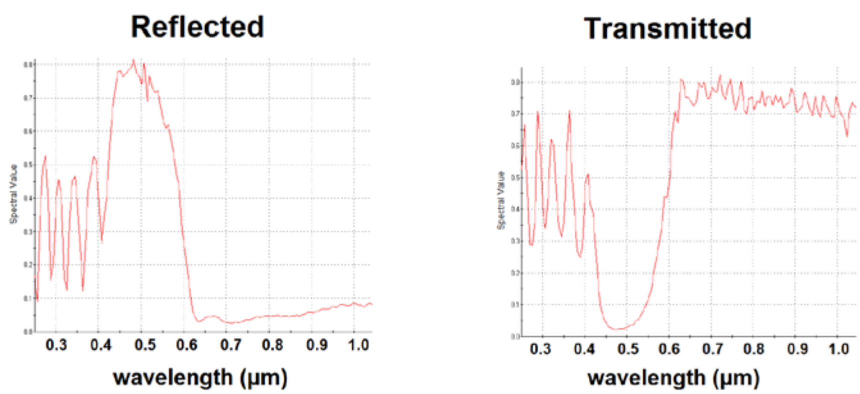


Figure 3. Spectral analysis of light reflected and transmitted by the cold mirror. Note that because the coating was specified for 0.55 μm at 0° angle of incidence, a shorter central wavelength is reflected at this larger angle of incidence.

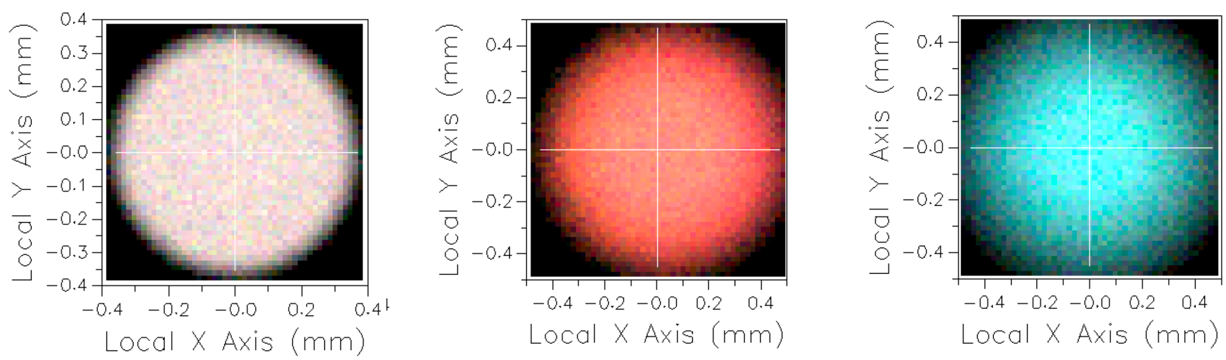


Figure 4. Color Images of the quasi-collimated white light beam (left), transmitted beam (center), and reflected beam (right).

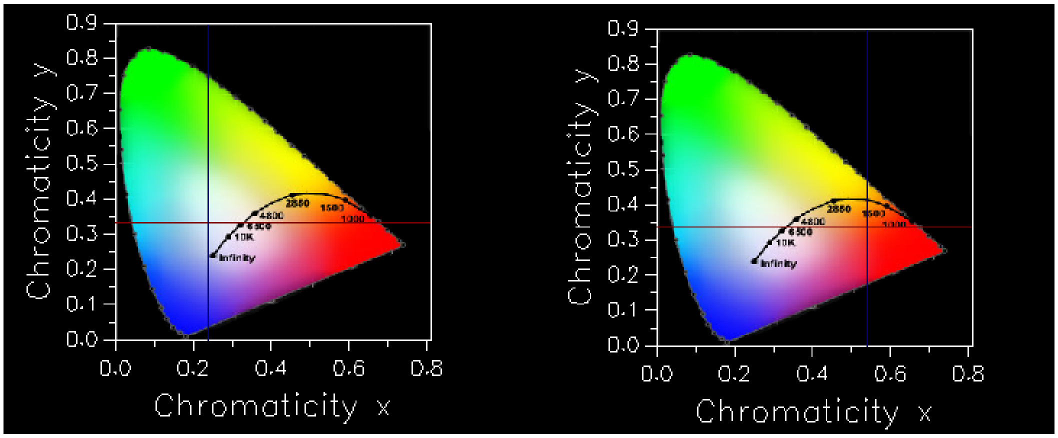


Figure 5. Average chromaticity coordinates for reflected (left) and transmitted (right) components of the beam, indicated by crosshairs in the diagram. This value is determined by reducing the analysis surface to one pixel and evaluating its Color Image.

Waveplate and Linear Polarizer

In this system, coherent horizontally-polarized white light is focused by a lens. A waveplate is placed beyond the focal point, followed by a vertical linear polarizer (Figure 6). Collimated horizontally-polarized light does not pass through the polarizer; however, an expanding beam of horizontally-polarized rays will have some vertical polarization components at each corner which do pass through. The irradiance pattern from the system without a waveplate is shown in Figure 7.

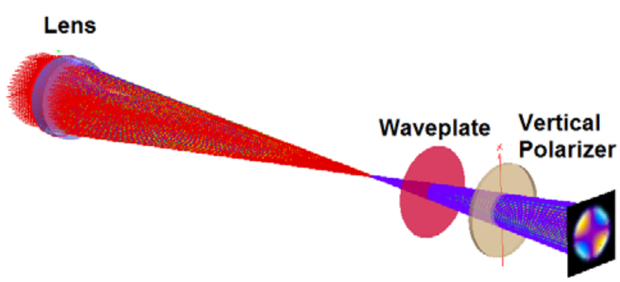


Figure 6. Simplified *Astigmatic Gaussian Beam* specifications.

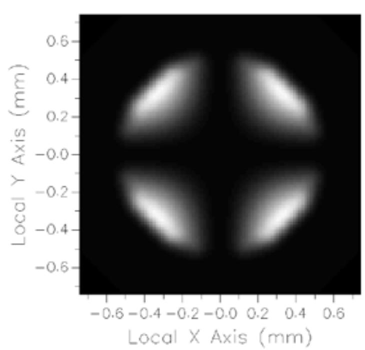
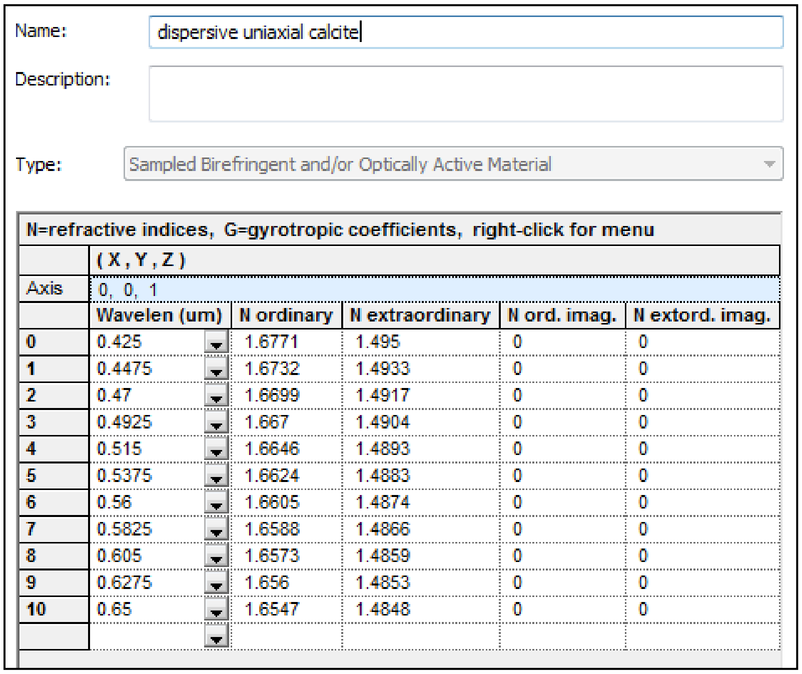


Figure 7. Irradiance distribution beyond vertical polarizer if waveplate is neglected. Vertical polarization components of rays in the expanding beam pass through.

Next, a waveplate is added (0.00304 mm thick plate made from birefringent calcite). To create calcite, right-click *Material→Create a New Material…* and choose the category "Sampled Birefringent and/or Optically Active Material". Specifications for calcite are shown in Figure 8.



Name: dispersive uniaxial calcite

Description:

Type: Sampled Birefringent and/or Optically Active Material

N=refractive indices, G=gyrotropic coefficients, right-click for menu

	(X , Y , Z)				
Axis	0, 0, 1				
	Wavelen (um)	N ordinary	N extraordinary	N ord. imag.	N extord. imag.
0	0.425	1.6771	1.495	0	0
1	0.4475	1.6732	1.4933	0	0
2	0.47	1.6699	1.4917	0	0
3	0.4925	1.667	1.4904	0	0
4	0.515	1.6646	1.4893	0	0
5	0.5375	1.6624	1.4883	0	0
6	0.56	1.6605	1.4874	0	0
7	0.5825	1.6588	1.4866	0	0
8	0.605	1.6573	1.4859	0	0
9	0.6275	1.656	1.4853	0	0
10	0.65	1.6547	1.4848	0	0

Figure 8. Ordinary and extraordinary components of the index of refraction of calcite are specified.

The waveplate provides a differential phase shift for each polarization component of light passing through. The wavelength-dependence of this phase shift means that each color component of the beam obtains a slightly different polarization adjustment. The vertical polarizer again filters out all horizontal polarization components of the light. With the waveplate, irradiance beyond the polarizer shows a reduction in the extinction cross pattern. A more interesting view of the light distribution is its Color Image, which displays an iridescent color distribution.

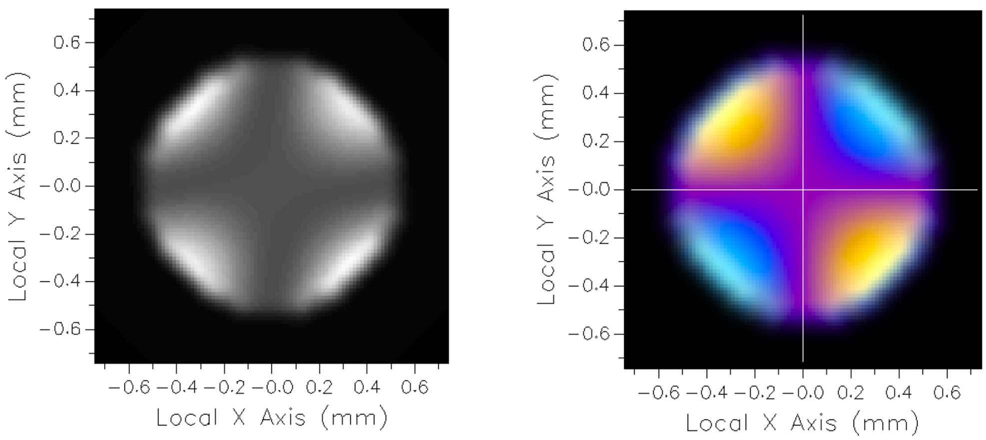


Figure 9. Irradiance distribution (left) and Color Image (right) of light after passing through a birefringent waveplate and vertical linear polarizer.

Photon ENGINEERING Illuminating Ideas

310 South Williams Blvd., Suite # 222 · Tucson, Arizona 85711

Tel: +1-520-733-9557 · Fax +1-520-733-9609 · http://www.photonengr.com