PH 481 **Physical Optics** **Winter 2023**

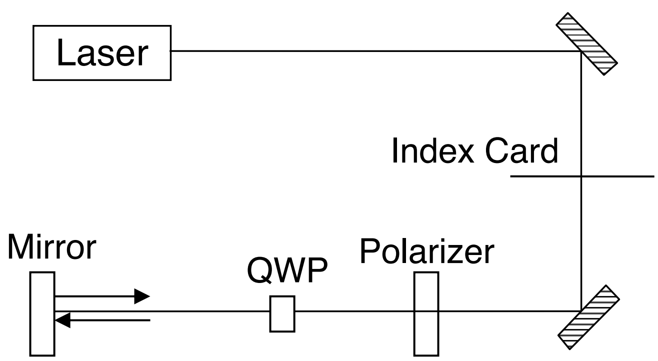
Laboratory #8 Week of March 6

Read: pp. 343-352, 358-364, and 367-372 of "Optics" by Hecht
Do: 1. Experiment VIII.1: Birefringence and Optical Isolation
2. Experiment VIII.2: Birefringent crystals: double refraction

Experiment VIII.1: Birefringence and Optical Isolation

In this experiment the birefringence of a material will be used to change the polarization of the laser beam. You will use a quarter-wave plate and a polarizer to build an optical isolator. This is a useful device that ensures that light is not reflected back into the laser. This has practical importance because light reflected back into a laser can perturb the laser operation.

A quarter-wave plate is a specific example of a retarder, a device that introduces a phase difference between waves with orthogonal polarizations. A birefringent material has two different indices of refraction for orthogonal polarizations and so is well suited for this task. We will refer to these two directions as the fast and slow axes. A wave polarized along the fast axis will move through the material faster than a wave polarized along the slow axis. A wave that is linearly polarized along some arbitrary direction can be decomposed into its components along the slow and fast axes, resulting in part of the wave traveling faster than the other part. The wave that leaves the material will then have a more general elliptical polarization.



A quarter-wave plate is designed so that the fast and slow components of a wave will experience a relative phase shift of $\pi/2$ (1/4 of 2π) upon traversing the plate. Light that enters the plate linearly polarized at 45˚ with respect to the fast and slow axes will then leave the plate circularly polarized.

If this circularly polarized light is reflected by a mirror back through the quarter-wave plate, then the component along the fast axis will accumulate an additional $\pi/2$ phase shift relative to the component along the slow axis. The light is now linearly polarized along a direction 90˚ from the initial direction of polarization, and so will be blocked by the polarizer that produced the original polarized beam.

The figure above shows the arrangement you will use to build the optical isolator. Adjust the polarizer so nearly all the laser light is transmitted. Use an index card with a hole in it to observe the light reflected back toward the laser (make sure to do this between the laser and the polarizer). Adjust the retro-reflecting mirror so the reflected beam is next to the hole in the index card. Now rotate the orientation angle of the quarter-wave plate until the reflected beam disappears. You will probably have to rotate the angle of incidence onto the quarter-wave plate as well as the orientation angle in order to make this work. This is because the phase retardance is proportional to the thickness of material that the light traverses and you can adjust the effective thickness by changing the angle of incidence. It may also be useful to make small adjustments of the input polarizer. Small iterative adjustments of all three angles should allow you to almost completely extinguish the retro-reflected beam. Once you have extinguished the beam, the fast axis of the quarter-wave plate should be 45˚ from the input polarization. To confirm this, perform the following tests:

1) Place a second polarizer between the quarter-wave plate and the retro-reflecting mirror and monitor the intensity of the light output from that polarizer as you adjust its orientation angle to convince yourself that the light is indeed circularly polarized. Explain.
2) Remove the second polarizer and rotate the first polarizer by 45˚. Now the light should be aligned along the fast or slow axis of the quarter-wave plate and therefore not change its linear polarization when traversing the quarter-wave plate. Now what is the retro-reflected beam intensity (bright or dark?). Explain. Use the second polarizer to confirm your understanding.
3) Remove the second polarizer and rotate the first polarizer by another 45˚. Explain.

How many different positions of the wave plate can you find that result in circularly polarized light?

If you have two quarter-wave plates, how do you make a half-wave plate?

Experiment VIII.2: Birefringent crystals: double refraction

Observe double refraction in a birefringent crystal by examining some text. Rotate the crystal around different axes and explain what you see. Now put a polarizer in front of the crystal, rotate it and explain what you see.

Equipment needed:

Item	Qty	Source (part #)
Helium-Neon Laser	1	Melles Griot 05 LHP 121
Al mirror	3	Newport 10D10ER.1
Polarizer	2	Edmund A38,396
Microscope cover slip	1	Edmund A40,002
Rotation Mount	1	Thor Labs RSP1
Filter holder	1	Thor Labs DH1
Photodetector	1	Thor Labs DET1-SI
Voltmeter	1	Fluke 75
Quarter-wave plate	2	MWK F17NS2