In this lab you will learn about an important property of electromagnetic waves: they are transverse waves that can have two independent polarizations.

Background preparation

- *Jones matrices*: Peatross & Ware, Sections 6.4-6.6.

You should understand the following ideas:

- The electric field amplitude $\vec{E}_0$ for a plane wave is perpendicular to its $\vec{k}$-vector. So it can be written as $\vec{E}_0 = E_i\hat{\imath} + E_j\hat{\jmath}$ where $\hat{\imath}, \hat{\jmath}$ are unit vectors in the plane perpendicular to $\vec{k}$.
- The optical power measured by a detector is $P \propto \vec{E}_0 \cdot \vec{E}_0^*$, where $\vec{E}_0$ is the complex electric field amplitude.

1: Polarizers (40 mins)

a) Locate two polarizers from your kit. Carefully holding them (with gloved hands, and only along the rim) visually try looking through them individually, and together, at various orientations. Record your observations for your report.

b) Mount the two polarizers in rotary mounts. Send the laser beam through the pair of polarizers onto a power detector, as shown in Figure 1.

   You can either use the photodiode from your kit (connected to a voltmeter) as a power detector, or use the camera from Lab 0 and take its pixel values as a measure of the power. Either way, **make sure** you know how to measure a quantity that is proportional to the optical power incident on the detector. Talk to a TA if you want any feedback on your detector setup. Make a sketch of your setup, and also record how you set up your detector, for your report.

c) Rotate the first polarizer so that it passes the maximum amount of light through (as seen on a piece of card), then vary the angle of the second polarizer. Record the signal from your detector as a function of the angles of the polarizers. In your report show appropriate plots and summarize what you learnt. Locate the configuration of the two polarizers that passes the minimum amount of light through.

   Note: it is **always** a good idea to sketch a rough preliminary plot from your data as soon as you record it in the lab, so that you can be confident that you made usable measurements. If you realize after leaving the lab that you did not make adequate measurements, there will be no way to fix your mistakes.

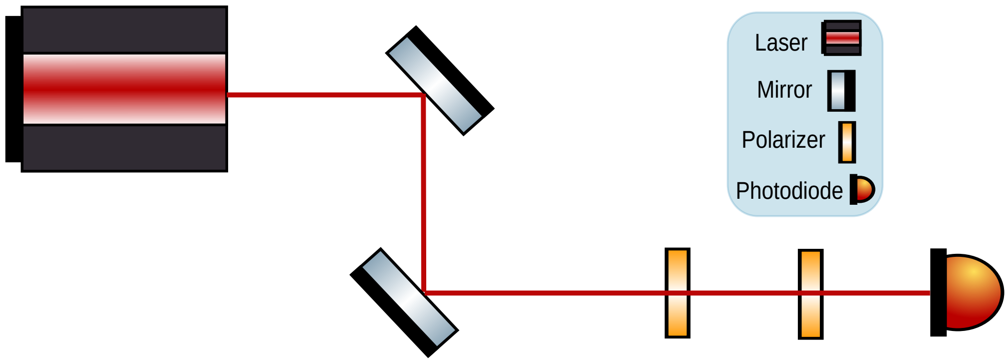

Figure 1: *Studying polarization of light. Laser light is reflected off two mirrors for alignment purposes (to set the height and the direction of the beam) and then hits two polarizers at set angles. The transmitted light is detected in a photodiode. Waveplates can be placed between the two polarizers.*

2: Waveplates (40 mins)

a) Take two polarizers and arrange them so that they pass the minimum amount of light through. Both polarizers do not need to be in rotary mounts: one of them can be in a lens tube attached to your detector.

   Locate the quarter-wave-plate (QWP) from your kit. Carefully handling it, mount it in a rotation mount, and place this mount between the two polarizers.

b) Vary the angle of the QWP and measure the detector signal as a function of the waveplate angle. Make sure you record enough data that you can construct a useful plot of detector signal versus angle. In your report, explain your observations using a Jones matrix calculation.

c) Replace the quarter-wave-plate with a half-wave-plate (HWP) in the rotary mount. Leave the polarizers fixed and vary the angle of the HWP. Record your detector signal of the waveplate angle, and again explain your observations using a Jones matrix calculation (you can construct a fit function for your data from Jones matrices).

d) Show that, even when the polarizers (without a waveplate between them) are arranged to pass the minimum amount of light, you can make them effectively transparent by tuning the HWP to an appropriate angle.

e) Experimentally, investigate whether the effect from 2d) works with a QWP. Explain what you observe.

f) Extra credit: Can you use a third polarizer instead of a waveplate to have a similar effect? Investigate this experimentally. Explain what you observe.

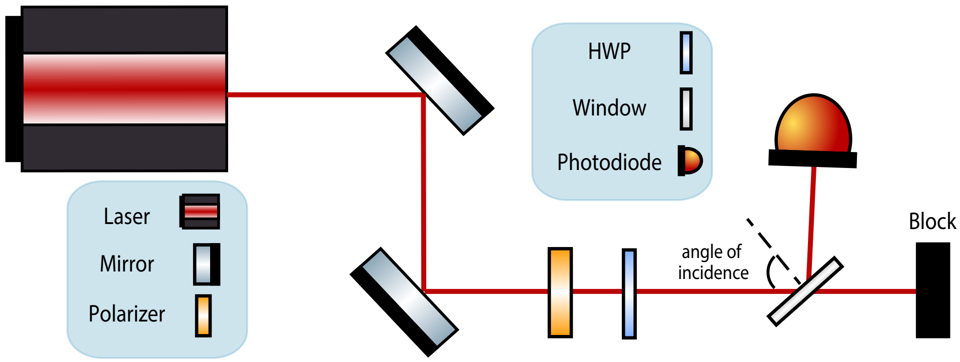

Figure 2: *Studying reflections. The polarization of the laser output is set with a polarizer and a half-wave plate before being reflected off a glass window at some angle of incidence. The intensity of the reflected beam from the glass window is measured on a photodiode.*

3: Investigating reflections from a dielectric (60 mins)

a) Arrange a polarizer and HWP so that you create linearly polarized light, and have full control over the angle of polarization. See Figure 2. Locate the glass window from your kit and mount it, placing it at some angle of incidence to the laser light. Estimate the angle of incidence. Align the reflected beam onto a photodiode.

Does the polarization of the incident light change the amount of light reflected from the window? How does it change?

b) Can you describe the polarization of the *reflected* light? How "polarized" is the reflected light?

c) Does the angle of incidence affect how "polarized" the reflected light is? *Bonus*: At what angle of incidence is the reflected light the most "polarized"?

Tips:

- You can count holes on the breadboard and use trigonometry to estimate the angle of incident light on the window.
- If you mount the window in a mirror mount, you can use the knobs to control the alignment of the reflected beam onto the photodiode.
- You may want to discuss with your TA how to estimate the degree to which the light is "polarized".
- Make sure to block the transmitted beam.