Experiment 1: Linear Polarization Measurement of a Lab Source

Objective:

To measure the linear polarization of an LED source. Linear polarization is characterized by two numbers: degree of polarization and the angle of polarization, denoted by p and θ respectively. To find p and θ, you have to find the normalized Stokes parameters q and u.

There are two stages of the experiment:

1. Carry out "observations"/polarization measurement exposures of the source in the lab. The output of these exposures will be images in FITS format.
2. Analyze the experiment images using aperture photometry to find the Stokes parameters.

At the end of the experiment, draft a report(one report per group) of your obtained polarization of the source, the associated errors, your analysis methods and any other information that you think is interesting or important about your analysis or the experiment.

Basic Polarimetry:

Normalized linear Stokes parameters q and u are given by the following equations:

$$q = \frac{Q}{I} = \frac{I(0^\circ) - I(90^\circ)}{I(0^\circ) + I(90^\circ)} \tag{1}$$

$$u = \frac{U}{I} = \frac{I(45^\circ) - I(135^\circ)}{I(45^\circ) + I(90^\circ)} \tag{2}$$

The o-beam is polarized along x-axis((0°) and the e-beam is polarized along y-axis(90°).

Let the quantity R be defined as the normalized difference in measured intensities between the o and e beams at the detector.

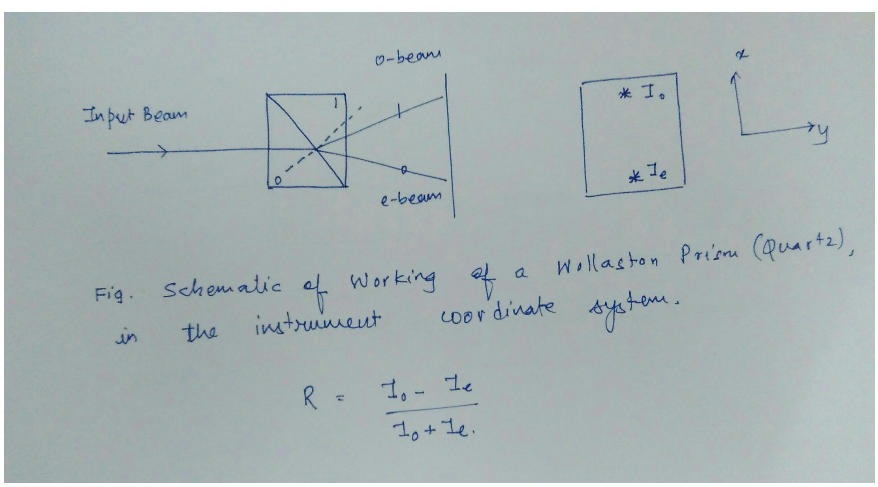

Figure 1: Schematic of working of a Quartz Wollaston Prism to be used in the experiment.

The degree/fraction (p) and angle of linear polarization (θ) for the light source is related to R and the half-wave plate (HWP) orientation α(all measured with respect to the instrument coordinate system) by the following equations:

$$R = \frac{I_o - I_e}{I_o + I_e} \tag{3}$$

$$R_\alpha = \frac{I_o - I_e}{I_o + I_e} = pcos(2\theta - 4\alpha) \tag{4}$$

The normalized Stokes parameters q and u are related to p and θ by the following equations:

$$q = pcos(2\theta) \tag{5}$$

$$u = psin(2\theta) \tag{6}$$

Therefore, to get q and u, we need to make measurements of R with HWP orientations at α of $0°$ and $22.5°$.

*Correction Factor(**K**)*: In addition to measurements at HWP angles of $0°$ and $22.5°$, measurements are generally taken at angles $45°$ and $67.5°$. When HWP is at $45°$ (which rotates the input beam polarization angle wrt instrument by $90°$), the e and o beam intensities are interchanged wrt to the e and o beam intensities at $0°$. Similarly, when HWP is at $67.5°$, the e and o beam intensities are interchanged with respect to to the e and o beam intensities at $22.5°$. These two additional measurements are taken to find any instrumental bias of o beam over e beam as transmission through optical components can be sensitive to input polarization state of light. This is characterized by the following correction factor:

$$K = \frac{I_o}{I_e} \tag{7}$$

$$K = \left(\frac{I_0(0°) \times I_0(22.5°) \times I_0(45°) \times I_0(67.5°)}{I_e(0°) \times I_e(22.5°) \times I_e(45°) \times I_e(67.5°)}\right)^{0.25} \tag{8}$$

Then this correction factor is multiplied with all I_e.

Experiment Procedure

In this experiment, we are going to measure the linear polarization of an LED source. The schematic of the experiment is as shown in Figure 2.

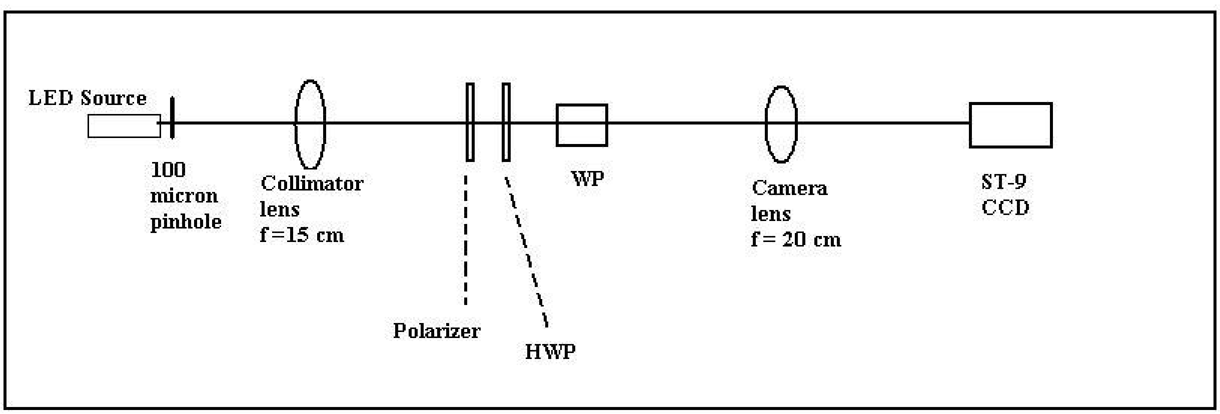

Figure 2: Schematic of the set up for measuring linear polarization of a point source.

Procedure:

1. Switch on the LED source. Check that the e and o images are focused at the the detector.
2. Take an exposure with HWP at $0°$, $22.5°$, $45°$ and $67.5°$.
3. Repeat Step 2 for 2-4 more times.

Data Analysis:

To find intensities of e and o beams on the CCD detector images, use aperture photometry. The CCD image gives the intensity from the source in counts which can be converted to electrons(which is equal to the photons received from the source) by knowing the gain of the CCD. The gain of the ST9 CCD used for the experiment is 2.8 e-/ADU.

Resources on Aperture Photometry:

1. IRAF: IRAF has been as standard go to package for analyzing astronomical data for decades. For this particular task, you may find the following resource useful: http://www.physics.hmc.edu/Astronomy/Iphot.html. For installing IRAF, you can follow the instructions in this page: http://www.astronomy.ohio-state.edu/~khan/iraf/iraf_step_by_step_installation_64bit.

2. Another tool very useful for beginners in the Aperture Photometry module in PhotUtils package: https://photutils.readthedocs.io/en/stable/