Experiment #: 05

Experiment Title: Chromatic polarization

Objectives:

1. Polarization is a fundamental property of light. Understanding the generation and measurement of polarization and its possible applications in astronomy in the goal of this week's lab.

Theory:

One possible application of polarization in astronomy is the characterization of exoplanet and brown dwarf atmospheres. Emitted light from cloudy exoplanet atmospheres can be highly polarized, while starlight itself is virtually unpolarized. When two images taken with orthogonal polarization filters are subtracted, unpolarized starlight is removed, revealing the polarized astrophysical signal. Polarimetry is still largely unexploited despite its information-rich content. Indeed, the direction and amplitude of the emergent polarization signal as a function of color and time enable detailed characterization of the composition, morphology, and dynamics of the scattering clouds. A team at Caltech astronomy and GPS has recently commissioned a high precision near-infrared imaging low-resolution spectro-polarimeter mode for WIRC, the Prime focus wide-field infrared camera of the 200-inch Hale telescope on Mt Palomar. The 200-inch is the largest equatorial-Cassegrain telescope in operation. This configuration is optimal for high precision polarimetry since it introduces little and stable spurious instrumental polarization. Instrumental polarization and how to minimize it will be one of the key lessons of this week's lab.

The lab hardware at your disposal provides several experiments based on real-world uses of polarization to explore fundamental concepts. In the saccharimetry experiment, students can measure how the angle of rotation of linearly polarized light is affected by an optically active sugar solution and use this knowledge to determine the sugar content of soft drinks.

The kit also examines the technology that has been developed to produce stereoscopic images and 3D movies, including red-cyan anaglyph images, linear polarization, and circularly polarized light. Mounted slides, several types of 3D glasses, and a piece of real cinema screen are provided so that you can build you own 3D projection setup.

Background

Light waves have two independent directions of interest; one is their direction of propagation and the second is the direction of the electric field (the magnetic field is perpendicular to both). The direction of the electric field is often referred to as the polarization direction.

There are different “basis vectors” for which you can express polarization. Vertical, horizontal, left circular, and right circular. Linear polarization can be thought of as a combination of right and left circular polarization. For example, vertical polarization is a combination of right and left circular polarization exactly in phase and with equal magnitude; horizontal would be left and right offset by 90 degrees. The most general form is elliptical, where the left and right circular polarizations have both different magnitudes and phases.

We often speak of “unpolarized” and “polarized” light, but these expressions, particularly “unpolarized,” are considered harmful. Every photon is completely polarized. However, we often don’t detect single photons, but bunches of them. Depending on the emission mechanism and the intervening material, streams of photons may have polarizations that vary randomly (stochastically) and we then say the light is “unpolarized”. On the other hand, some emission/absorption mechanisms produce light that is always polarized a particular way, which is then referred to as “polarized” light.

Equipment

The Polarization and 3D Cinema Technology Kit includes components and instructions for building three 3D projection setups. The theory and tools to construct three other experiments that study the interaction of polarized light with optical elements such as wave plates and polarizers are also provided.

List of Equipment:

Apparatus

Circuit Diagram:

Procedure:

Data Collection:

Calculation:

Result: