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Polarimetric Characterization of Unique Optical Elements

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RCEU 2022 Project Proposal

Project Title

Polarimetric Characterization of Unique Optical Elements

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Instructions are on the last page.

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I. Project Description

Polarimetry is the science of measuring the polarization state of light and the polarizing properties materials. It can be used to characterize new materials or identify unknown materials; making it a useful instrument in fields such as optics, astronomy, and medicine. The result of a full optical characterization of a material is expressed in a 4 x 4 matrix known as the Mueller Matrix. Polarimeters utilize retarders, which introduce a phase difference between two orthogonal components of a polarized beam, in order to generate different polarization states for interrogating the sample. Common retarders include quarter and half-wave plates, liquid crystal retarders, and Fresnel-Rhomb retarders. Recently, a new generation of these optical elements, known as vortex retarders, has become available, but their properties are not well known.

Vortex retarders are similar to half-wave plates that have a constant retardance of 180 degrees, but instead of a unidirectional fast axis, these retarders have a fast axis that rotates over the area of the optic, generating a beam that travels in a helical path (i.e., a vortex-shaped beam). This type of beam has important uses in high energy lasers, coronagraph technology, optical tweezers, nanolithography, microfluidic pump controls, and optical communication technology. As such, understanding the polarization properties of the vortex retarder is crucial. While some research on these properties has been performed, very little is known about the full scope of the element's behavior—especially over a broad wavelength range. To this end, this project aims to quantify the properties of two such vortex retarders across a broad band of wavelengths using UAH's well-established and calibrated Mueller matrix spectropolarimeter.

Commented [EJ1]: Is this paragraph too technical?

Commented [EJ2]: Could I say something about holograms?

II. Student Duties, Contributions, and Outcomes

a. Specific Student Duties

1) Become familiar with the existing spectropolarimeter and associated control software
2) Perform new transmission polarimetric measurements to determine the full Mueller matrix of each vortex retarder
3) Interpret Mueller matrix element values and associated measurement errors
4) Quantify alternating linear and circular retardance behavior
5) Quantify depolarization properties via depolarization index and average degree of polarization
6) Mathematical/Mueller matrix description of a half-wave retarder with varying fast-axis orientation
7) Directly measure phase delay in vortex retarders using an existing Michelson interferometer

Commented [EJ3]: Those are just questions I have about the results we have so far—not sure if those are feasible to answer at this point

b. Tangible Contributions by the Student to the Project *(10% of Review)*

Further characterization of vortex retarders through the duties described in Section IIa will contribute material for publication in a peer-reviewed journal. The findings reported in this

paper will assist future manufactures of vortex retarders for use in high energy lasers and other applications listed in Section I. Polarimetry is an ongoing research topic and this research will contribute to proposals written for external funding in the future.

c. Specific Outcomes Provided by the Project to the Student *(30% of Review)*

The student selected for this project will gain experience and skills that are crucial in a science or engineering career. The student will gain general laboratory experience and experience specific to experimental/practical optics, data analysis, presentation of research to peer groups, and basic electronics needed for building test equipment. The student will also refine ancillary skills such as technical writing, troubleshooting, and verbal scientific communication.

III. Student Selection Criteria

The student selected for this program should have completed the physics electromagnetic theory classes (PH 431/432) and the physics intermediate labs (PH 310/311). Experience in taking and analyzing data to include error analysis will be an advantage, as will be a cumulative GPA of 3.50 or better.

IV. Project Mentorship *(30% of Review)*

In addition to frequent meetings with the student, the mentor will

1. Provide an audience of graduates and undergraduates the student can present results to for criticism and discussion
2. Introduce student to former students who have done research using the equipment provided
3. Provide student the opportunity to contribute to a technical paper to be submitted to a refereed journal