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Characterizing Polarization with Cost-effective Techniques and Future Directions

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Theory

Polarimetry is a branch of optics concerned with the measurement and analysis of the polarization state of light. Light, being an electromagnetic wave, exhibits properties of polarization. The polarization state of light can vary depending on factors such as the source of light, the interaction with optical elements, and the medium through which it propagates. In polarimetry, parameters such as the Stokes parameters are commonly used to quantify the polarization state of light. These parameters provide a comprehensive description of the polarization characteristics, including intensity, linear polarization, and circular polarization.

Motivation

By accurately characterizing the polarization state of light, polarimetry enables scientists and engineers to extract valuable information about the properties and behavior of optical systems. Polarimetry serves as a vital tool in this regard, providing insights into the polarization properties of light. However, traditional polarimetry methods can be complex and costly, posing challenges for small space missions like CubeSats. This study seeks to address these challenges by exploring cost-effective alternatives for detecting polarization states. We have focused on leveraging CMOS sensors instead of CCD sensors in polarimetry cameras. CMOS sensors offer advantages, including lower cost and lower power consumption, making them well-suited for space missions and other cost-sensitive applications.

Experimental Setup

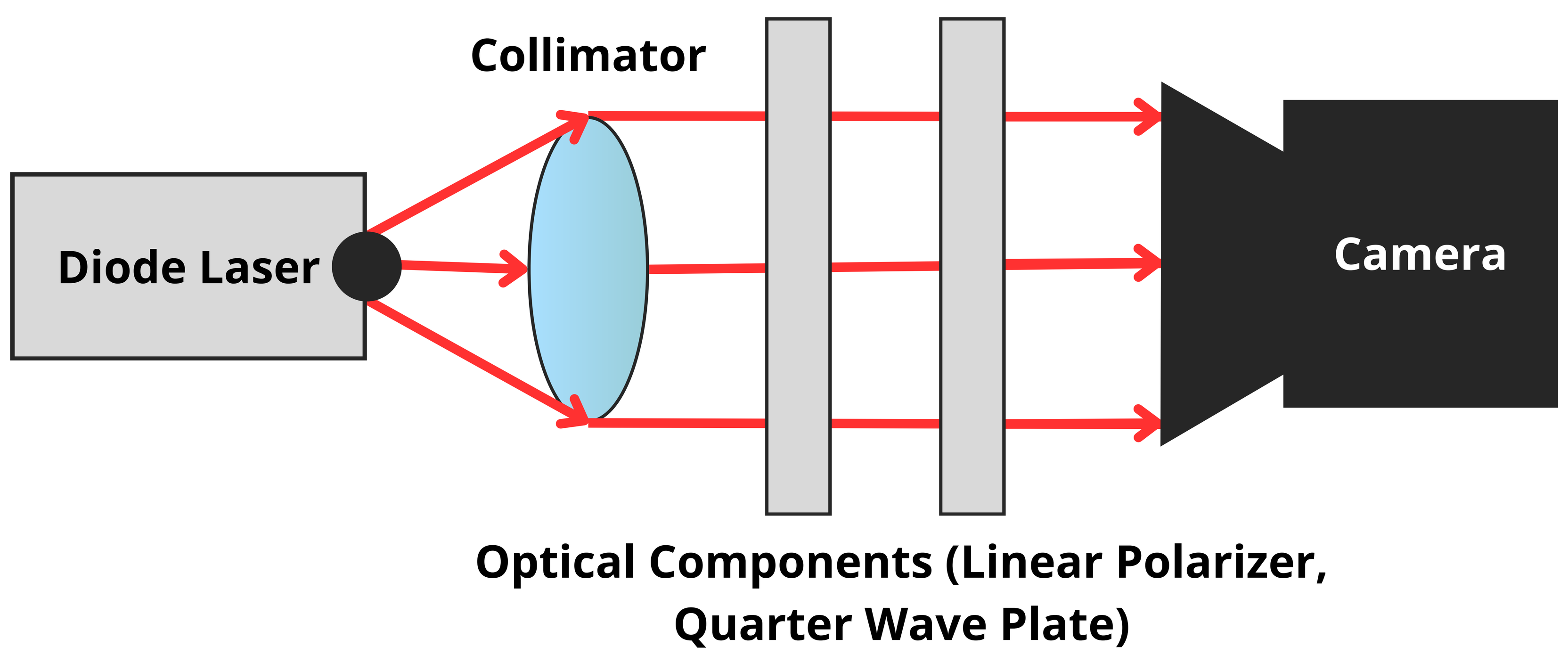

Figure 1. The setup utilized comprised a polarimetry camera (right) equipped with quad-polarization filters and a diode laser (left). The input beam was collimated and then directed through a series of optical components to manipulate the polarization state of the light.

Data Analysis

This study involved processing the acquired polarization data using NumPy and Matplotlib, focusing on determining Stokes parameters from the recorded sensor readings. These parameters enabled quantification of the polarization state of the incident light and enabled the representation of the states. In addition to determining Stokes parameters, the analysis included subtracting background noise to enhance the accuracy of the measurements. The values of the Stokes parameters were then utilized to graph the polarization ellipse (see **Fig. 2** for test in linear polarization and **Fig. 3** for test in elliptical and circular polarization).

Results

Analysis of the collected data provided valuable insights into the polarization characteristics of the investigated light sources. The primary results were on characterizing linear polarization, attempts were made to explore circular and elliptical polarization by introducing a quarter wave plate into the setup. However, due to challenges encountered, particularly in achieving circular polarization, the study primarily succeeded in characterizing linear polarization (see **Fig. 2**). The Results demonstrated consistent and meaningful measurements for linear polarization. This showcases the effectiveness of the experimental setup in characterizing linear polarization and lays the groundwork for future investigations into more complex polarization states.

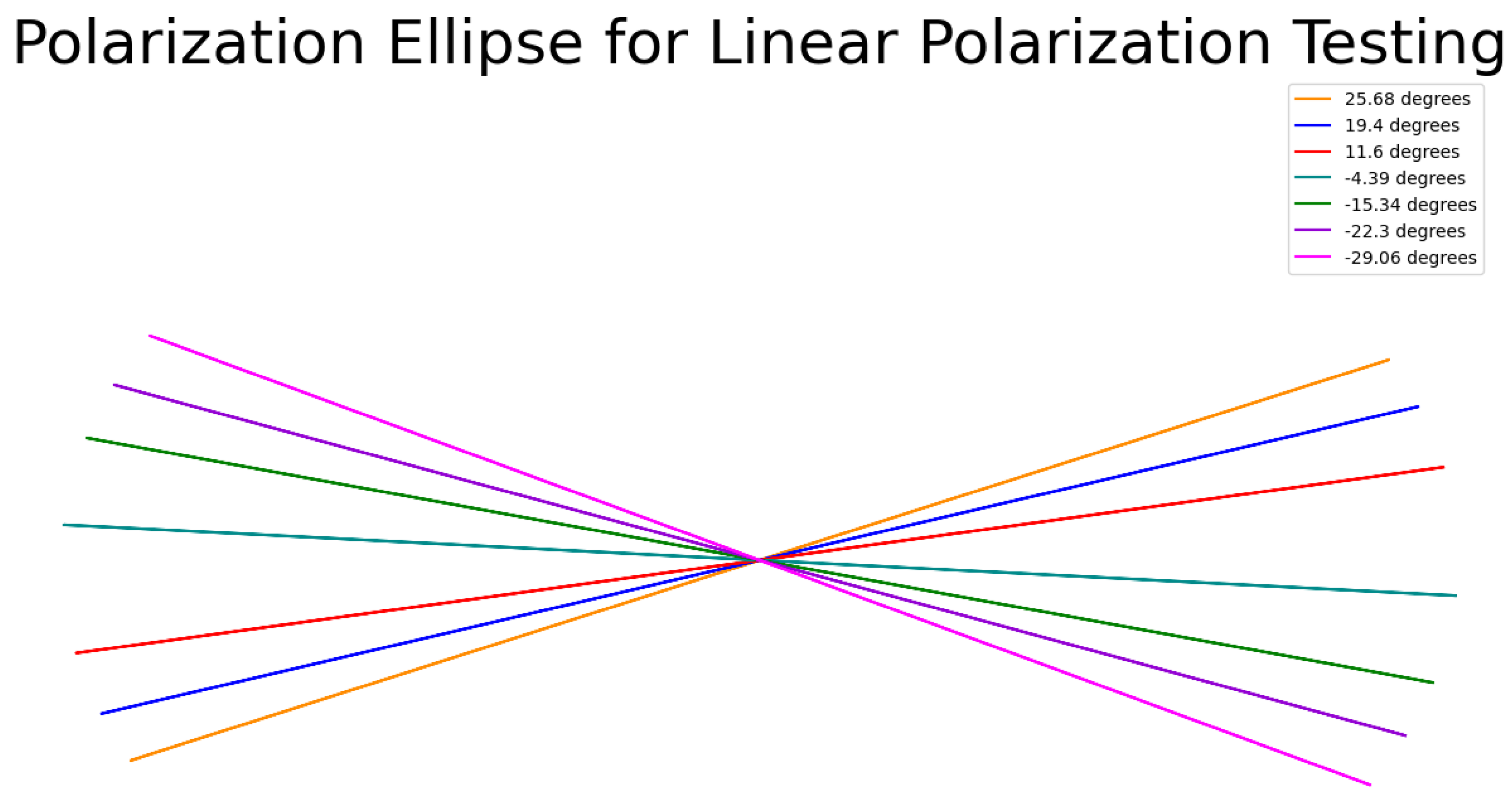

Figure 2. Obtained polarization ellipses for the test on linear polarization. Starting from the top angle, shifts in 10 degrees on the linear polarizer were made; hence, obtaining ~8-11 degree shifts between iteration.

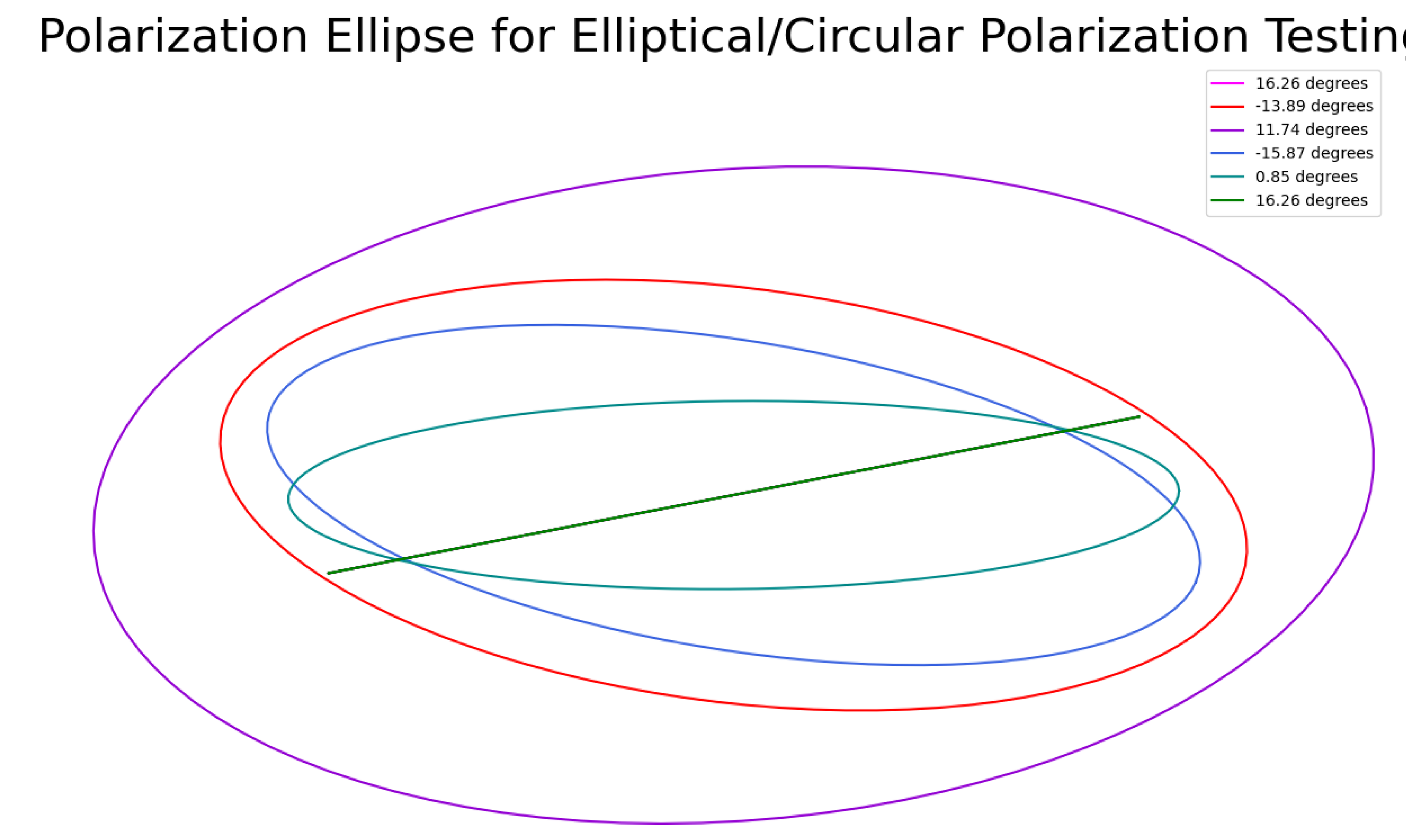

Figure 3. Test with linear polarizer locked at the 0-degree mark with 10-degree shifts on quarter wave plate (QWP). Observe that adding a QWP induced retardation; however, circular polarization was not induced.

Conclusion

This study represents a significant step forward in the field of polarimetry by showcasing the practicality and effectiveness of employing a polarimetry camera equipped with quad-polarization filters to characterize the linear polarization of light sources. The successful exploration of cost-effective alternatives for detecting polarization states offers promising prospects for overcoming the cost limitations associated with traditional polarimetry methods, particularly in the context of space missions. By demonstrating the feasibility of utilizing such technology, this project opens doors to more accessible and affordable polarization characterization

Future Work

Future work will focus on extending the characterization to circular and elliptical polarized light, building upon the insights gained from attempts to characterize circular polarization. Additionally, implementing data correction techniques such as flat field correction could improve the accuracy and reliability of the results. Other considerations in data analysis, such as other noise filtering, could also be explored to optimize the data processing pipeline.

References

Yamazaki et al. (2016), *IEEE*. 8.7.1-8.7.4

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