Seminar

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Institute for Plasma Research

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Title: Study and Applications of Polarization Characteristics of Optical Media using Stokes/Mueller Matrix Polarimetry

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Abstract

This thesis investigates various aspects of polarization measurement and analysis, with a particular emphasis on the characteristics of optically absorbing materials using advanced techniques such as Stokes-Mueller formalism. Optical phenomena play a pivotal role in various domains, viz. telecommunications, imaging, and laser applications. The knowledge of refractive index is necessary not only to understand the effect of optical elements but also for designing optical components and optimizing system performance. This work introduces novel techniques to determine the refractive index in complex media, particularly in optically absorbing materials like metal reflectors. Moreover, an analytical technique is introduced to retrieve the polarization ellipse from beam intensity measurements. This technique provides physical insights by establishing a point-by-point correspondence between the reconstructed ellipse and the experimentally measured intensities.

One of the key contributions of this thesis is the development of a simple method for characterizing the polarization properties of metal reflectors in terms of Mueller matrix elements, for the prediction of material's optical response to arbitrary polarization. The matrix elements are inferred from the Stokes parameters of both incoming and outgoing beams, enabling the isolation of instrumental polarization from primary measurements. This technique provides a reliable means for estimating the polarization characteristics of any metal reflector, offering a valuable tool for polarization-sensitive experiments in optics and laser applications. The thesis also presents techniques for estimating material properties of metal reflectors, such as optical constants viz. real refractive index (n) and extinction coefficient (k), and hence the complex refractive index/dielectric constant. For this purpose, a simplified pseudo-Brewster angle technique has been presented to determine the optical constants and their uncertainties. The practical usefulness of the technique is demonstrated through measurements on a plane SS304 mirror. Validation has been achieved through comparison of reflectivity curves derived from estimated optical constants with experimental data, as well as through independent fitting of experimental reflectivity curves with optical parameters.

Furthermore, a simple yet cost-effective polarization measuring device (PMD) capable of capturing time-varying measurements of the state of polarization (SOP) is developed. The functionality of PMD is verified on a test bench by using a rotating analyzer. The PMD demonstrates good measurement accuracy, with deviations less than 0.01 for measuring the axes a and b of the polarization ellipse and less than 0.5° for the orientation angle ψ, at the time resolution of few μs. Suggestions for modifications to the PMD are made to enable complete polarization measurement, further enhancing its utility in polarization-sensitive experiments. Overall, this thesis presents a comprehensive suite of techniques and devices for polarization measurement, contributing to the advancement of capabilities in polarization analysis and opening up new avenues of research in optics and laser applications.

References:

[1] Adhiya et al. "Determination of Mueller Matrix for Metal Substrates by Stokes Polarimetry." IEEE Transactions on Instrumentation and Measurement, vol. 70, pp. 1–7, 2021, Art. no. 6009407, doi: 10.1109/TIM.2021.3097863.

[2] Adhiya et al. "A Simple Device for Simultaneous Measurement of Stokes Polarization Parameters," IEEE Transactions on Instrumentation and Measurement, vol. 72, pp. 1–6, 2023, Art. no. 7001606, doi: 10.1109/TIM.2023.3235451.
