Toward Topological Imaging of Skin Lesions: Mueller Polarimetry and Future Integration of Structured Light

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This study explores the use of Mueller polarimetric imaging to characterize structural alterations in biological tissues associated with skin cancer. By reconstructing the full Mueller matrix and applying Lu-Chipman decomposition, we extract polarization-based parameters—diattenuation, retardance, and depolarization—that are highly sensitive to the tissue's microarchitecture. Clinical measurements on benign and malignant skin lesions reveal distinct polarimetric signatures. Notably, melanomas tend to exhibit an absence of directional structure in orientation maps derived from retarder and diattenuation axes, in contrast with benign lesions, which display well-defined anisotropic patterns.

This directional invisibility motivates the introduction of a directional entropy metric, designed to quantify angular disorder in tissue structure. Directional entropy provides a new, non-invasive optical biomarker capable of capturing subtle differences in tissue organization that are not always apparent through conventional scalar parameters.

As a prospective extension of this work, the use of structured light beams carrying orbital angular momentum (OAM) is proposed to enhance the directional sensitivity of Mueller imaging. The topological properties of OAM beams may allow for a more refined mapping of structural disorganization by interacting selectively with anisotropic domains. Integrating OAM-based probing into Mueller polarimetry could thus lead to a novel framework for topological tissue imaging, combining matrix-based polarization analysis with angularly resolved optical interrogation.

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