Internship / Master's Thesis Project

Optical Engineering for Next-Generation Intraoperative Polarimetric Imaging

Department of Neurosurgery, Inselspital, Bern University Hospital

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The **Department of Neurosurgery at Inselspital** combines clinical practice with translational research. Within the department, the **HORAO project** established the clinical and scientific foundation for using polarization imaging to support real-time, label-free differentiation between healthy brain tissue and tumour tissue during neurosurgery. Building on the clinical needs and scientific insights identified through HORAO, the Department is leading a new instrumentation programme to develop the next generation of intraoperative polarization-based imaging technology.

Project background: Polarimetric imaging measures how tissue modifies the polarization state of light, providing information sensitive to tissue microstructure that may support the identification of brain-tumour boundaries and white-matter fibre organization. Our system combines a polarization state generator (PSG), a polarization state analyzer (PSA), high-speed cameras, calibration methods, and dedicated processing algorithms. The current system supports real-time acquisition and visualization, while ex vivo studies have demonstrated the potential of polarimetric imaging for quantitative brain-tissue characterization [1,2]. The new instrumentation programme introduces alternative optical and acquisition strategies focused on speed, measurement fidelity, robustness, and intraoperative integration.

Project aim: The objective is to design and experimentally evaluate selected polarimetric acquisition strategies for intraoperative brain imaging. You will investigate how the choice and number of polarization states affect acquisition speed, measurement accuracy, robustness, and retained polarimetric information. Candidate strategies will be quantitatively compared with complete Mueller matrix measurements to identify configurations that reduce acquisition requirements while preserving tissue-relevant information.

Materials and methods: You will work with an existing experimental system, optical components, calibration tools, and data-processing methods. The project will include the design and characterization of selected PSG and PSA configurations, modelling of polarization components and imaging conditions, and implementation of calibration and quality-control procedures. Complete and reduced polarimetric measurements will be compared in terms of accuracy, repeatability, spatial uniformity, stability, and acquisition speed. The influence of wavelength, working distance, and acquisition geometry will also be investigated. Selected configurations will be validated using calibrated samples, optical phantoms, and biological specimens. Together, these activities will establish an experimental acquisition strategy, characterize the trade-off between acquisition speed and retained information, refine the calibration workflow, and provide recommendations for the next instrument generation. Depending on your background, the project may emphasize experimental optics, optical modelling, calibration, system characterization, or polarimetric data analysis.

Your profile: Master's student in optical engineering, photonics, applied physics, biomedical engineering, electrical engineering, computational imaging, or a related discipline. Interest in experimental optics and biomedical imaging, basic knowledge of polarization or imaging systems, and experience with Python or a comparable scientific environment are desirable. Experience with polarimetry, optical-design software, calibration, image processing, or light-propagation simulations is advantageous but not required. If you have a strong background in one or more of these areas and are interested in developing complementary skills, we encourage you to apply. You will gain hands-on experience across the translational development workflow, from optical design, calibration, and experimental validation to defining requirements for future intraoperative use, while interacting with researchers and clinicians in optical instrumentation, artificial intelligence, neurorobotics, and neurosurgery.

Supervisors:
Dr. Omar Rodríguez-Núñez
Prof. Dr. med. Philippe Schucht

Institution:
HORAO Lab at the Department of Neurosurgery, Inselspital Bern

Starting date: Upon agreement
Application: Send your CV, academic transcript, short motivation letter, and a brief description of relevant experience to omar.rodrigueznunez@insel.ch.

References:

É. Gros, O. Rodríguez-Núñez, L. Felger, *et al.*, 'Characterization of polarimetric properties in various brain tumor types using wide-field imaging Mueller polarimetry,' *IEEE Transactions on Medical Imaging*, 43(12), 4120–4132 (2024).

[2] C. Hahne, I. Diaz, O. Rodríguez-Núñez, *et al.*, 'Polarimetric feature analysis of matrices for brain tumor image segmentation,' *Optics Express*, 33, 43379–43392 (2025).