Full-field multispectral Mueller polarimetric imaging for improved surgery of neurological malignancies

Keywords: *Optical imaging - Polarized light; Mueller polarimetry - Signal processing - Cancer surgery - Surgical microscope - Surgical exoscope.*

Laboratory: Laboratoire de Physique des Interfaces et des Couches Minces (LPICM), Ecole Polytechnique, 91128 Palaiseau (France).

Postdoctoral fellowship (2 years, start – April 2024) at LPICM, Ecole polytechnique, Palaiseau, France within the framework of the SNF Sinergia HORAO project https://horao.eu/

Problem. Surgery is the crucial step in the treatment of brain tumors, in particular gliomas. While some well-defined tumors, such as metastases, can be removed en bloc, the majority of gliomas, which tend to grow infiltrative in the white matter of brain, are removed in piecemeal. During the surgery, it is essential to identify and respect the boundary between brain tumor and surrounding healthy brain tissue in order to carry out a radical resection of the pathological parts while preserving neurological function. However, solid tumor tissue is often difficult to differentiate from infiltrated white matter during surgery, even using a state-of-the-art intraoperative microscope. A non-complete tumor resection due to poor visualization of tumor margins leads to a worse prognosis for the patients, as the tumors invariably grow back from the remnants. Several imaging techniques (e.g. fluorescence imaging, ultrasound and magnetic resonance imaging) have been implemented for the intraoperative visualization of brain tumors tissue, but all have some drawbacks. In summary, the efforts to visualize brain tumor and reliably identify the interface between healthy and pathological areas during neurosurgery have so far failed for many intrinsic brain tumors.

Approach. Imaging Mueller polarimetry is an optical technique that has been widely used for the studies of biological tissues representing complex depolarizing and optically anisotropic media. This technique is very sensitive to microstructural changes in biological tissues induced by pathology. It is known that brain tumors destroy the highly anisotropic structure characteristic of healthy white matter, made up of very dense, well-organized axon fibers. Accurate detection of the healthy white matter can help surgeons to better identify, by contrast, the pathological areas. In recent years, the optical team of LPICM developed several Mueller polarimetric imaging systems (e. g. multispectral Mueller Colposcope, Mueller laparoscope) that have shown great promise for improving in vivo detection of cancerous lesions, as well as for accurately defining the resection margins of pathological areas during surgery. Prior results of a study conducted within the framework of SNF Sinergia HORAO project by the LPICM, Ecole polytechnique, France and Bern University Hospital, Bern, Switzerland demonstrated that wide-field Mueller imaging system can provide detailed maps of the axonal fiber orientation in healthy brain and can effectively distinguish between healthy and cancerous areas of the brain in just a few seconds. The miniaturized Mueller imaging system based on polarization-sensitive camera will be built for real-time intraoperative use during neurosurgery.

Responsibilities. The main objective of the postdoctoral fellow's work is to develop a wide-field Mueller polarimetric imaging system to improve the detection of surgical margins of neurological cancers *in vivo*. The post-doctoral fellow will design and build a first prototype of a miniaturized Mueller polarimetric imaging system using polarization-sensitive camera. This work will include:

- extensive characterization of polarization-sensitive camera,
- design of a new optical system for polarization modulation of incident light,
- development of electronic control for the image acquisition.
- optimization of the illumination and detection arms for the instrument miniaturization,
- adaptation of a miniaturized system to mechanical robotic arm for in vivo acquisition in operating room.
- transfer of the developed prototype instrument to the University Hospital of Bern, Switzerland
- assisting a neurosurgeon in collecting data in vivo, processing the acquired polarimetric images and comparing them to the results of histological analysis of a neuropathologist.

Expected competences: Strong expertise in optics, optical instrumentation, design of polarimetric systems and signal processing. Strong motivation for the team work in a multidisciplinary environment, continuous interaction with the medical doctors. Basic knowledge of matrix algebra will be a plus.
Linguistic skills: good knowledge of English.
Informatics skills: good knowledge of Matlab, Python, Labview.

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