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).

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 infiltratively 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 vizualization 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.

Mueller polarimetric imaging is a technique using the polarization of light, which has been widely used for the exploration of biological tissues, optically very complex systems where scattering and anisotropy effects are present at the same time. This technique is very sensitive to microstructural changes in biological tissues generated by pathological conditions. In recent years, it has shown great promise for improving the detection of cancerous lesions, as well as for accurately defining the resection margins of pathological areas during surgery. Biomedical research activities at LPICM focus on the development of innovative Mueller polarimetric imaging systems to improve the management of different types of cancer ex vivo and in vivo. In particular, a multispectral Mueller Polarimetric Colposcope has been built to improve in vivo imaging of cervical cancer. Recently, a first prototype of Mueller polarimetric laparoscope, for the exploration of the internal organs of the human body, has been also developed at LPICM.

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. A study conducted by the LPICM, in collaboration with the Department of Neurosurgery at Berne University Hospital, on samples of fresh and fixed brain tissue has shown that full-field Mueller polarimetric imaging can provide detailed mapping of the axonal fiber orientations in healthy white matter over a macroscopic field of view in just a few seconds (https://horao.eu/). In addition, this technique can effectively distinguish between healthy and cancerous areas of the brain.

The main objective of the engineer's work is to develop an interface (electronics + software) for managing a miniaturized Mueller polarimetric imaging system based on polarized cameras, intended to be used in vivo by a surgeon in the operating room. To this end, the engineer will work in close collaboration with a postdoctoral fellow who will be in charge at LPICM of the development of the hardware part for the new imaging system.

In particular, the software interface of the new imaging system must be capable of managing the electronics dedicated to the synchronized acquisition of polarimetric images (modulation and analysis of the light polarization, triggering of the camera, variation of lighting, etc.).
In addition, it must allow the integration of deep learning algorithms capable of providing the practitioner with relevant information in less than a second.
Finally, the development of a "user friendly" graphical interface will be necessary to allow easy and rapid use of the new imaging system in the operating room.
The engineer will also have to interact constantly with other people involved in the project and in particular with neurosurgeons in order to understand their real needs in the operating room as well as with researchers working on the development of deep learning algorithms in order to integrate them efficiently in the management software of the new imaging system.

Desired profile or skills: programming skills for the management of measuring instruments, computer programming skills, electronics skills, elements of physics and algebraic calculation. A very strong motivation in continuous interaction with the medical world and to work in a multidisciplinary context is required.

Linguistic skills: good knowledge of English.

Informatics skills: good knowledge of different langages of programmation (Matlab, Phython, etc.)

Advisors:

Angelo Pierangelo, *Laboratoire de Physique des Interfaces et des Couches Minces,* Ecole polytechnique, Route de Saclay, 91128 Palaiseau, France.

Phone : +33-1-46-69-43-69
E-mail : angelo.pierangelo@polytechnque.edu

Tatiana Novikova, *Laboratoire de Physique des Interfaces et des Couches Minces,* Ecole polytechnique, Route de Saclay, 91128 Palaiseau, France.
Phone : +33 6 72 14 46 58, +33 1 69 33 43 41
Tatiana.novikova@polytechnique.edu