Laboratory for Optics and Biosciences
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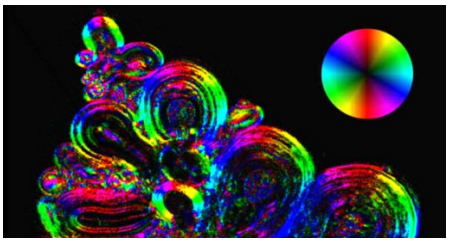
M2 Research internship proposal / Proposition de stage 2019

3D mapping of biomaterials anisotropy with polarimetric nonlinear microscopy

Keywords : nonlinear optics, microscopy, polarization, beam shaping, biomedical imaging



Nonlinear optical microscopy makes it possible to study biological tissues in 3D over depths of a few hundreds of micrometers with subcellular resolution. Polytechnique LOB is pioneering the use of endogenous nonlinear optical signals (third-harmonic generation, second-harmonic generation, fluorescence, polarization) to study the structure and evolution of healthy and pathological tissues.

In particular, third-harmonic generation microscopy (THG) highlights optical heterogeneity and provides detailed images of cells and tissue morphology. Our lab recently found that THG imaging combined with polarization control can also reveal materials anisotropy at the sub-micron scale (Zimmerley 2013, Morizet 2018). Two applications of this contrast mode are particularly promising. First, it can be used to characterize ordered lipidic structures (see image), which make it interesting to study myelin-related neuropathologies. Second, it can be used to detect biocrystals in tissues, with possible applications in developmental biology and biomedical research.

In the current status of the technique, polarization is rotated only in the imaging plane, which limits it to the detection of in-plane anisotropy. To further develop the method and its applications, it will be interesting to have more control of the 3D polarization state at the focus of the microscope.

The Master project will explore the implementation of advanced beam shaping methods to achieve this goal. This project will make use a liquid-crystal-based modulator able to produce nonstandard states of polarization, and on numerical simulations to predict and analyze the experimental observations. The work will take advantage of the availability of (i) a functional scanning THG-SHG microscope optimized for live tissue studies and (ii) Matlab simulation codes developed for studies of beam focusing and nonlinear microscopy. Experiments will be performed first on model samples (lipid vesicles, microparticles), and then in biological environments such as live fish embryos. The internship can be followed by a PhD thesis on the development of advanced beam control and novel biomedical applications of label-free nonlinear optical imaging.

Environment: The work will take place in the «Advanced microscopies» pole of the Lab for Optics and Biosciences at Ecole Polytechnique (LOB). Our team has a well-known expertise in the field of multiphoton microscopies and their applications to tissue studies. The work will involve daily interactions with a group of ~4-5 people, within a local microscopy team of ~20 persons and an active collaborative network (Institut du Cerveau, L'Oréal, etc). The project will involve experimental nonlinear microscopy, numerical simulations, and biological samples manipulation.

Some related references from our group:
Zimmerley, Phys Rev X (2013); Morizet (2018, submitted);
https://portail.polytechnique.edu/lob/en/research/advanced-microscopies-tissue-physiology

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