Laboratoire d'Optique et Biosciences
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Internship proposal

Numerical simulations of pSHG microscopy in cornea.

Multiphoton microscopy has revolutionized three-dimensional (3D) imaging of biological tissues over the past 10 years. Notably, second harmonic generation (SHG) microscopy enables imaging of collagen without any labelling and with unequalled sensitivity in intact tissues [1]. This is directly related to the property of SHG to be nonzero only in dense and non-centrosymmetrical materials. However, the build-up of SHG signals is a complex issue because of its coherent nonlinear nature and of the heterogeneity of collagen distribution in tissues. Collagen is indeed organized as fibrils, which size and 3D organization is specific to each tissue (skin, artery, lung, bone…). Extracting as much information as possible about the structure of a tissue from SHG images is therefore an active research field. In particular, varying the excitation polarization, can yield the collagen orientation in some situations [2]. Nevertheless, numerical simulations are needed to model this polarimetric SHG (pSHG) signal for realistic tissue geometries and reconstruct in a reliable way the collagen disctribution at sub-micrometer scale.

This project aims at **modeling pSHG in the Human cornea** and use these numerical simulations to provide quantitative measurements from pSHG images recorded recently by our group (Fig. 1). Two approaches will be implemented, based on previous work at LOB [3]: (i) a semi-analytical approach based on Green's functions, which considers only nonlinear indices but with complex tensors; (ii) a full numerical approach using Finite Difference Time-Domain (FDTD) to take into account nanometer-scale heterogeneities in the refractive index that may affect the wave propagation. The internship mainly aims at developing Green Function and FDTD pipelines for simulating the anisotropy of collagen fibrils and the heterogeneity of their 3D distribution.

This project will take place in the "Advanced Microscopies" group at the Lab for Optics and Biosciences (LOB), located on the Polytechnique campus in Palaiseau. The LOB is an interdisciplinary lab with both physicists and biologists who develop together new approaches in optics, computational physics, image analysis, cell/developmental biology and biophysics to study biological systems.

This computational project is well suited for a Physics student with strong skills in Computational Physics and an interest in biology.

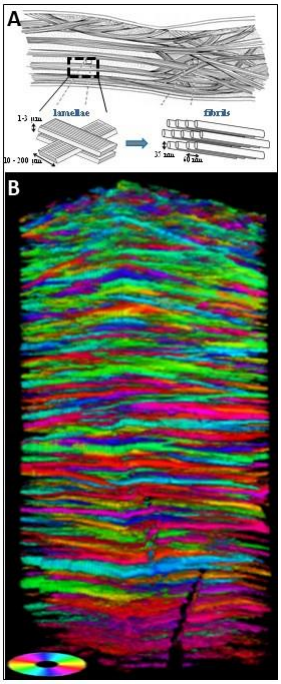

***Fig. 1** : A. multiscale structure of the Human cornea. B. pSHG mapping of the lamellar structure of the Human cornea (the color codes collagen orientation).*

Related recent publications (see also http://www.lob.polytechnique.fr/) :
[1] Bancelin et al, Nat. Commun. 5 (2014) - 10.1038/ncomms5920
[2] Raoux et al, Light Sci Appl 12 (2023) - 10.1038/s41377-023-01224-0
[3] Morizet et al, Optica **8** (2021) - 10.1364/OPTICA.421257

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https://lob.ip-paris.fr/recherche/microscopies-avancees/second-harmonic-generation-skin-and-cornea