Title : Novel Modeling of Coherent Multiphoton Microscopy Contrasts

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Research Area : Biophysics, Optics, Mathematical Physics

Methods: Nonlinear Microscopy, Finite differences Time-Domain (FDTD), Second/Third Harmonic Generation (SHG/THG) The project will take place at LOB, and while this is primarily a theoretical and computational project, it will rely on experimental data generated in the lab (Groups of E. Beaurepaire & M-C Schanne-Klein)

PhD track subject:

Coherent nonlinear microscopy techniques such as Second Harmonic Generation (SHG) or Third-Harmonic Generation (THG) relies on the intrinsic nonlinear properties of biological tissues to provide 3D images of unstained biological tissues (such as skin, cornea, brain tissues or zebrafish embryo to name a few studied in the Lab). However this comes at a cost: coherent nonlinear methods have highly non-trivial contrast mechanisms, and current modeling approaches [1] cannot reproduce some experimental measurements, preventing accurate quantification of the images. We recently demonstrated a new approach for THG microscopy based on the Finite Difference time-domain method [2], and the goal of this PhD is to develop this method to apply it more broadly to other types of nonlinear microscopy, and to further improve the method by taking into account more complex optical properties such as non-diagonal tensor elements.

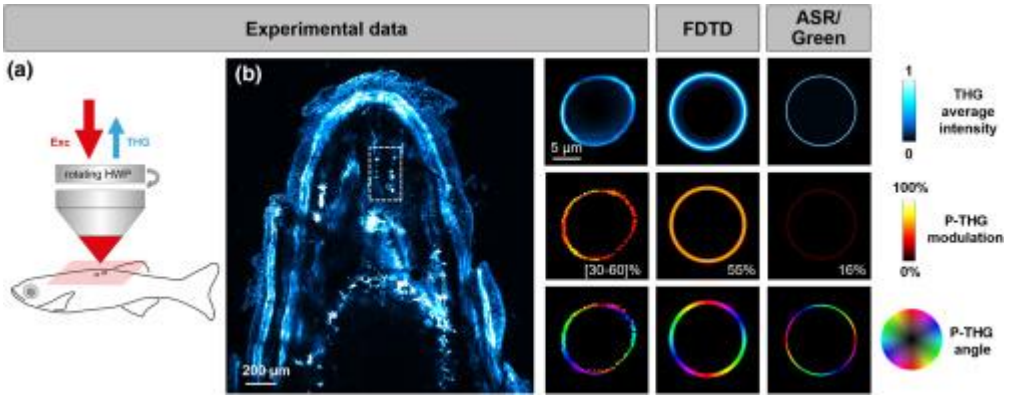

Figure 1: P-THG imaging of lipid droplets in a live adult zebrafish. Left: (a) experimental geometry and (b) THG images of a dorsal region recorded at a depth of approximately 50 µm. Scale bar, 200µm; right: zoomed-in view of a large (≈12µm radius) lipid droplet with the corresponding P-THG modulation and angle maps. FDTD and ASR/Green calculations corresponding to a 15µm diameter spherical oil droplet in water are shown for comparison. Scalebar 5µm. Adapted from [2]

References:

[1] N. Olivier, et al. "Harmonic microscopy of isotropic and anisotropic microstructure of the human cornea." Optics express 18.5 (2010): 5028-5040.

[2] Modeling nonlinear microscopy near index-mismatched interfaces J. Morizet, G. Sartorello, N. Dray, C. Stringari, E. Beaurepaire, N. Olivier *Optica* 8 (7), 944-951 (2021)