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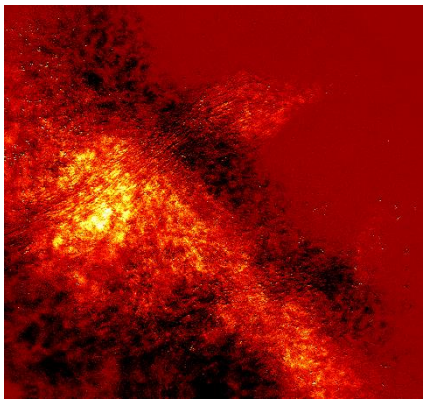
Development of a FDTD Pipeline for Modeling Coherent Nonlinear Microscopy



Coherent nonlinear microscopy is a family of optical microscopy methods that rely on the intrinsic nonlinear properties of biological tissues to generate high resolution 3D images [1]. Due to the coherent nature of the nonlinear interaction, these methods have non-trivial contrast mechanisms, and extracting as much information as possible – for example by changing the excitation polarization - is an active research field [2].

In this project, we want to develop a new FDTD [2] pipeline for simulating numerically realistic sample geometries for a variety of second and third-order nonlinear processes (SHG, THG, FWM). Starting from an existing pipeline using a commercial FDTD software (Lumerical), the first task will be to optimize the convergence and speed on some known geometries so as to be able to study a broad range of conditions. In a second time, you will try to generate a new type of materials for the simulations which have non-diagonal nonlinear tensors properties that mimic real materials more closely. This is based on an existing preliminary model for SHG.

This project is mostly computational project combining different languages (Scripting in Java/Python/Matlab, some C++) and is well suited for a student with a major in Applied Mathematics with an interest in optics/biophotonics.

References:

[1] Olivier, Nicolas, et al. "Cell lineage reconstruction of early zebrafish embryos using label-free nonlinear microscopy." Science 329.5994 (2010): 967-971.
[2] Morizet, Joséphine, et al. "High-speed polarization-resolved third-harmonic microscopy." *Optica* 6.3 (2019): 385-388.
[3] Yee, Kane. "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media." IEEE Transactions 14.3 (1966): 302-307.

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