Institut Langevin
ONDES ET IMAGES

ESPCI PARIS | PSL

MASTER internship (+ PhD)

Digital holography in non-linear regime for enhanced 3D microscopy for nano/micro structures

Training location : Institut Langevin, ESPCI Paris, PSL, CNRS, 1 rue Jussieu, 75005 Paris
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Collaboration : Institut Langevin (Y. De Wilde) – Institut de La Vision (G. Tessier)

Digital holography is an imaging technique that enables a 3-dimensional reconstruction of the electromagnetic field scattered by an object in both amplitude and phase. With our collaborator from Institut de la Vision (G. Tessier), we demonstrated its use in microscopy for the full 3-D mapping of the field scattered by single nanostructures such as nano-antennas [1] and near-field probes [2]. Holography is an interference process, which can be obtained at the laser illumination wavelength, but also with Second Harmonic Generation (SHG) since it is produced in a coherent process [3].

During this training, we propose to pursue the development of a harmonic holographic microscope for single-shot mapping of the second harmonic 3D radiation pattern near samples with nonzero second harmonic susceptibilities. The knowledge of the scattered field (amplitude and phase) in a given plane (that of the camera) allows its reconstruction in any other plane using e.g. the angular spectrum representation of optical fields [4], and assuming propagation in homogeneous media, a process called 3D numerical back-propagation [5]. The method can also be used for imaging samples of biological interest.

In addition to providing 3D reconstruction, thus enhancing the imaging capabilities beyond those of back focal-plane imaging, the harmonic holography microscope also benefits from an amplification effect since the signal from the sample is multiplied by an intense reference in the interference term, making the method particularly well suited to measure the weak SHG signals produced by metallic or dielectric nanostructures, or by some biological tissues.

After a first validation on dielectric samples made of nonlinear micro-crystals and collagen from cornea and tendon tissues, we are currently implementing it to unravel the SHG field radiated by nanostructures such as plasmonic nano-antennas and non-linear resonant structures.

The training will be performed under supervision of Yannick De Wilde (CNRS Research Director at Institut Langevin) and co-supervision of his PhD student Serena Goldmann and our collaborator Gilles Tessier (Professor at Sorbonne University, working at Institut de la Vision). We plan to continue it with a thesis which will be directed by Yannick De Wilde and Gilles Tessier.

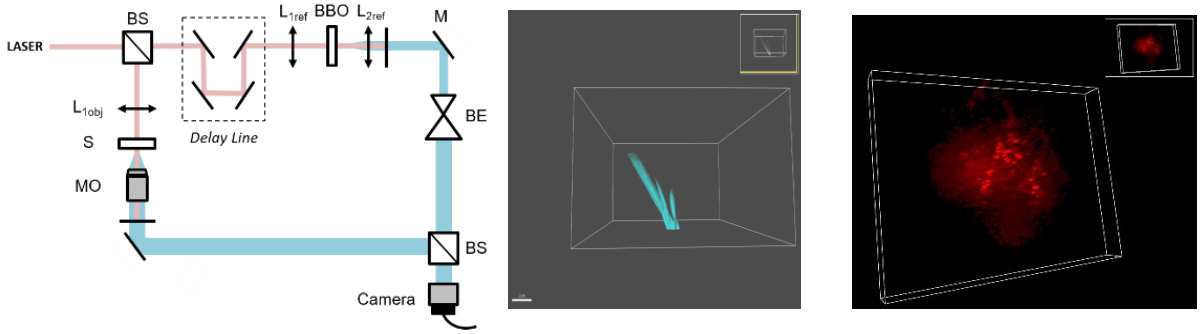

Figure: (left) Non-linear digital holographic setup and reconstruction of the field radiated by (center) a BBO microcrystal, and (right) collagen tissues within a pork cornea.

[1] Suck, S. Y.; Collin, S.; Bardou, N.; De Wilde, Y.; Tessier, G. 2011. Optics Letters, 36, 849−851 [2] Rahbany, N., Izeddin, I., Krachmalnicoff, V., Carminati, R., Tessier, G., De Wilde, Y. 2018. ACS Photonics, 5, 1539-1545.
[3] Shaffer E., Pavillon N., Kühn J., Depeursinge C. 2009. Optics Letters, 34, 2450-2452
[4] Novotny, L., and Hecht, B. Principles of Nano-optics. 2 006. Cambridge University Press.
[5] Hu, C., Field, J.J., Kelkar, V. *et al.* Harmonic optical tomography of nonlinear structures. *Nat. Photonics* **14**, 564–569 (2020).