MASTER 2

Proposition de stage 2026-2027 - Internship Proposal 2026-2027

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Titre / *Title :* Shaping quantum light with disordered nonlinear nanomaterials

Projet scientifique (1 page maximum) / *Scientific Project (maximum 1 page):*

Non-classical light, such as photon pairs sharing quantum correlations, is the key resource behind emerging quantum technologies for communication, sensing and imaging. The sources used today rely on carefully engineered nonlinear crystals, which must be phase matched and therefore operate at a single wavelength, with little room for miniaturisation or tunability. Disordered nonlinear nanomaterials offer a radically different route: an assembly of nanoscale resonators scatters light randomly, but in doing so provides a wealth of optical modes over a broad spectral range, relaxing the usual phase-matching constraints [1]. The price to pay is degradation in conversion efficiency due to randomness of the emitted light.

Our group has pioneered wavefront shaping, which uses spatial light modulators to control how light propagates through complex media [2]. We have shown that this control can be used to enhance nonlinear optical processes deep inside scattering materials [3], and, more recently, to manipulate quantum light transmitted through them [4]. Within the ANR project NAPOLeON, in collaboration with Institut Langevin and Institut Fresnel, we are now developing disordered assemblies of gallium phosphide nanoresonators, a material with large optical nonlinearities and negligible absorption. The central idea of this project is to use wavefront shaping to turn the randomness of such materials into a resource, programming a disordered sample to behave as a compact and tunable source of non-classical light.

In this internship, the candidate will explore routes to generating correlated photons from these materials and to controlling them by wavefront shaping. Several schemes are open for discussion. One is the parametric generation of photon pairs, where a single pump photon splits into two correlated photons inside the disordered medium. Another is the correlated emission of Stokes and anti-Stokes photons in Raman scattering, where two photons become correlated through a vibration of the material they share [5]. The work will be mainly experimental: building and operating a wavefront shaping setup combining ultrafast lasers, single-photon detectors and coincidence measurements, together with the associated data processing and modelling. Basic experience with programming languages (Python, MATLAB or similar) is expected. We welcome candidates with a background in physics or optics who are curious about quantum optics, nonlinear optics and complex media. Depending on the outcome, the internship could be followed by a PhD project. Informal queries are welcome.

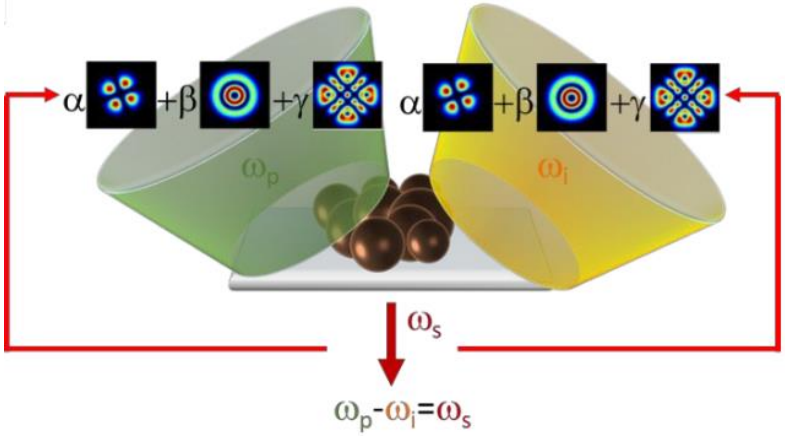


Figure 1. Iterative two-color wavefront shaping with structured laser modes in disordered nanospheres. Here, the frequency conversion scheme uses two non-degenerate colors, a pump beam and an idler beam, to produce a signal beam of phase-matched frequency.

[1] Savo et al., Nat. Photonics 14, 740 (2020); Marino et al., Optica 6, 1416 (2019).
[2] Gigan et al., J. Phys.: Photonics 4, 042501 (2022).
[3] de Aguiar et al., Phys. Rev. A 94, 043830 (2016); Roubaud et al., Nano Lett. 20, 3291 (2020).
[4] Defienne et al., Sci. Adv. 2, e1501054 (2016); Lib et al., Sci. Adv. 6, eabb6298 (2020).
[5] Kasperczyk et al., Phys. Rev. Lett. 115, 243603 (2015); Saraiva et al., Phys. Rev. Lett. 119, 193603 (2017).