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Master thesis proposal

Laboratoire Matériaux et Phénomènes Quantiques
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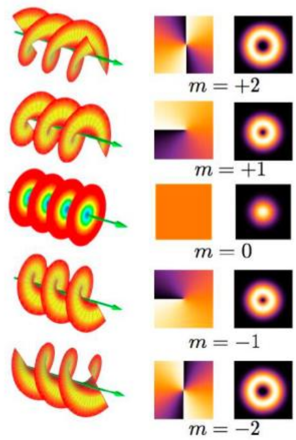
Parametric generation of optical angular momentum in nonlinear metasurfaces

Keywords: OAM, optical metasurfaces, nonlinear optics, quantum optics, nanophotonics.

Scientific description: Linear and spin angular momentum of light have been known for more than a century, the former being associated to the wave-vector ($p = \hbar k$) and the latter to circular polarisation ($\sigma = \pm\hbar$). About thirty years ago, a third mechanical property was also recognized for photons: OAM, orbital angular momentum ($L = \pm\ell\hbar$), which corresponds to a beam with an integer number ℓ of intertwined helical phase-fronts, whose Poynting vector describes a cone along the propagation direction and results in a typical donut-shape transverse intensity profile. OAM beams, described by Laguerre-Gauss modes and also known as vortex beams, exhibit unique topological properties and have recently found applications from particle manipulation and acceleration to trapping of Bose condensates of atoms; from STED microscopy to high information coding for communications in free space, and for creating entangled states of light.



The physics of vortex beams is particularly fascinating in the nonlinear regime, where OAM can be transferred from the pump to the harmonic frequency and optical spin-orbit coupling can occur in exotic fashions [*D. De Ceglia et al., submitted*], even in the generation of two-photon quantum states via SPDC, spontaneous parametric down-conversion [*Y. Wu et al., Optica (2023)*]. In this context, $\chi^{(2)}$ optical metasurfaces are particularly interesting for their inherent capability to generate optical harmonics with on-demand spectral, spatial, polarization and phase properties [*C. Gigli et al., Optica (2021)*], and we already showed that they are versatile SPDC-based sources of two-photon quantum states [*G. Marino et al., Optica (2019)*].

This internship aims at demonstrating a nonlinear metasurface for the synthesis of OAM in SPDC, which has never been attempted to date. To achieve this breakthrough, we will design, fabricate and characterize an AlGaAs-on-insulator source for two-photon quantum states with controlled OAM. To this end, we can rely on solid grounds in both the technological platform (epitaxial growth, wafer bonding, electron-beam lithography) and the theoretical domain (quasi-normal-mode modelling), while possessing state-of-the-art nonlinear and quantum optics experimental facilities, and an international leadership in this research field.

Allowing to generate various kinds of OAM-based entangled photon states, our metasurfaces will disclose a wide range of applications in high-dimensional quantum information processing. This internship will benefit from top-level international collaborations, with Sony and the group of Prof. T. Pertsch at Friedrich Schiller University in Jena (Germany).

Techniques/methods in use: photonic modelling, experimental optics
Applicant skills: educated and motivated master student, with a taste for experimental physics
Industrial partnership: YES (SONY Corporation)
Internship supervisor: Giuseppe LEO (giuseppe.leo@u-paris.fr, 01 57 27 62 27)
Internship location: MPQ, Université Paris Cité (mpq.u-paris.fr)
Possibility for a Doctoral thesis: YES (ANR project MEGAPHONE)