Open PhD position

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Nonlinear quantum metasurfaces

Scientific project:

Optical metasurfaces are arrays of coupled optical antennas, with sub-wavelength size and separation. While in the past two decades, their optical properties have been mostly demonstrated with either metallic or linear dielectric nanostructures, AlGaAs nanoparticles are presently attracting a great deal of interest because of their huge non-resonant quadratic nonlinearity.

AlGaAs metasurfaces can control light thanks to their low losses and high optical $\chi^{(2)}$ nonlinearity generating optical harmonics with on-demand spectral, spatial, and polarization properties. We aim to unlock their full potential to control light-matter interactions at the nanoscale and obtain versatile sources of two-photon quantum states based on spontaneous parametric down-conversion (SPDC). We will demonstrate ultrathin quantum state synthesizers allowing to tune all properties of photonic states by control of size, shape, orientation and spatial distribution of the nanoresonators. Such sources can be optimized for several applications, disclosing new horizons in quantum sensing, imaging and spectroscopy. To reach this breakthrough, we will develop a technological platform to attach such nanostructures to any host substrate.

This internship addresses the foundations of one of the missing key elements for the diffusion of quantum optics in viable applications: an ultra-thin metasurface for the synthesis of two-photon quantum states. To target a broad use, such sources will provide control over polarization, spectral and spatial properties of the entangled photonic quantum states and will be compatible with existing optical technologies, e.g. generated states will be transmittable by free-space optics or optical fibers. To achieve this breakthrough, we propose a qualitatively new type of source for photon pairs based on nanoscale resonators made of semiconductor and dielectric materials with strong nonlinearity arranged in 100's of nm-thick metasurface.

Our ambition is to boost and control nonlinear frequency conversion processes to establish new and sophisticated ultra-broadband quantum light sources, from visible to mid-infrared. Metasurfaces, in contrast to bulk natural materials or thin-films, are amenable to having their optical properties tailored to a specific task and thus may become the most versatile source of entangled photon pairs available. Allowing to engineer space, frequency, and polarization entanglement by the metasurface design will render our sources suitable for a wide range of applications. Spatial entanglement is specifically relevant for quantum imaging.

This PhD thesis will take place in the framework of top-level collaborations at both national (Ph. Lalanne of LP2N; Jean-Michel Gérard of INAC-CEA) and international level (D. Neshev of ANU ; C. De Angelis of the University of Brescia ; G. Cerullo, G. Della Valle and M. Celebrano of Politecnico di Milano).

Methods and techniques: theoretical modelling, numerical simulations, experimental nano-optics and quantum optics, clean-room nanofabrication.

Fellowship: ANR NANOPAIR Project