Post Doc position in Physics

Quantum and dynamical properties of nanosources for communication, sensing and information applications (24 months)

Research unit: INPHYNI laboratory / Mixed research unit Université Côte d'Azur, National Centre for Scientific Research (CNRS)

Project summary:

Nanolasers are devices at the frontier of miniaturization and essential to make large scale optical data processing environmentally sustainable by reducing energy consumption and thermal load and to enable information processing at the quantum-mechanical level. Due to their scale and the number of quantum emitters contained, their modelling requires an unusual combination of fundamental quantum mechanics and nonlinear dynamics. Depending on the statistics of the emitted light, nanolasers can operate either as coherent switches or as bright incoherent sources [1], but are also able to operate in regimes where the quantum statistics of photons leads to levels of intensity noise below those of a lasers [2].

Objectives

This project aims to develop quantum-mechanical models to determine the effect of nonlinearities on the dynamics of measurable expectation values such as photon correlations. Taking advantage of the simultaneous availability of first-order and second-order autocorrelations [Carroll2023], in addition to the threshold information, we aim to determine the individual properties of these indicators. In this way, second-order autocorrelation measurements, easier to perform and routinely used in all types of nanolasers, can acquire a higher degree of reliability in the determination of the nature of the emitted radiation. We will also identify the control parameter regions where quantum signature are detectable in the temporal dynamics of the emission, opening a completely new way of investigating quantum properties in small scale optical systems.

Methodology

We will combine a fully quantum treatment, based on the explicit description of incoherent and coherent emission processes, together with an analysis based on nonlinear dynamical properties of the equations of motion of expectation values.
The theory will be developed together with Dr. Papoff at the University of Strathclyde, Glasgow (UK). Collaborations with experimentalists to tests the model results are planned.
The ideal candidate will have a PhD in Physics, or related subject, with expertise in theory and simulations. He/She must be interested in quantum optics and nonlinear dynamics, but expertise in both areas is not necessary.

Benefits for the Candidate

The new theoretical approach, developed in the publications referenced below, offers the possibility of predicting various properties (e.g., degree of coherence, dynamical stability, noise sensitivity, quantum features – e.g., photon antibunching) for optical sources which range from the nanoscale all the way to macroscopic lasers. Experimentally observed features – such as spontaneous antibunching [4] or a careful assessment of the degree of coherence [5], which could be previously explained only with *ad hoc* hypotheses – can be reliably predicted in this way [1-3]. This Post-Doctoral experience, conducted in a collaborative effort between the Université Côte d'Azur and the University of Strathclyde – in addition to contacts with other leading institutions in Europe – will allow a young researcher who aims at establishing her/himself as a leader in the field of coherent, semi-coherent and quantum sources, to develop a portfolio of techniques and a fundamental expertise at the forefront of the field.

Hosting team:

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Francesco PAPOFF, University of Strathclyde: f.papoff@strath.ac.uk

[1] M.A. Carroll et al, Thermal, quantum antibunching and lasing thresholds from single emitters to macroscopic devices, Phys. Rev. Lett. 126, 063902 (2021).

[2] M.A. Carroll et al, Photon-number squeezing in nano- and microlasers, Appl. Phys. Lett. 119, 101102 (2021).

[3] M.A. Carroll et al., in preparation.

[4] J. Wiersig et al., Direct observation of correlations between individual photon emission events of a microcavity laser, Nature 460, 245-250 (2009).

[5] J.-S. Tempel et al., Extrapolation of the intensity autocorrelation function of a quantum-dot micropillar laser into the thermal emission regime, J. Opt. Soc. Am. B28, 1404-1408 (2011).