Quantum Nanophotonics

Quantum phenomena in nanophotonics systems lead to new scales of quantum complexity and constitute the starting point for developing technologies that deliver quantum-enhanced performances. This ambition demands new physical insight as well as cutting-edge engineering, with an interdisciplinary approach and a view towards how such groundbreaking technologies may be implemented.

The scope is to address fundamental challenges in nanoscale quantum optics, increasing the interaction among the communities of nanophotonics, quantum optics and quantum information, and materials science. This will contribute to the discovery of novel phenomena and define new routes for applications in ICT (e.g. single-photon sources and photon number-resolved detectors for secure communication and quantum information, quantum nanophotonics integration), sensing & metrology (e.g., novel nanosensors and quantum-enhanced measurement devices), and energy efficiency (e.g., disruptive approaches for energy harvesting and all-optical signal processing).

The involved research communities have so far generally pursued separately the three application areas targeted here. This fact hinders synergies and the development of innovative solutions addressing common challenges. We have identified four research priorities that deal with problems and limitations in quantum photonics technologies and that may also contribute to the discovery and understanding of novel quantum phenomena for future applications:

- **Generation, manipulation, detection & storage of quantum states of light at the nanoscale:** e.g., advance nanoscale control of optical fields, strongly enhance the interaction of photons with quantum systems, nanophotonics integration including the emerging areas of quantum plasmonics and diamond nanophotonics, novel materials such as graphene and other 2D materials, novel solid-state single-photon sources and detectors like NbTiN superconductive nanowires.
- **Nonlinearities and ultrafast processes in nanostructured media:** e.g., combine the physics of cavity QED with ultrafast dynamics, nanoscale devices that generate correlated photons and squeezed light for quantum-enhanced measurements, develop nanoantenna-based ultrafast spectroscopy to explore single quantum systems, single-photon nonlinearities and ultrafast switching.
- **Nanoscale quantum coherence:** e.g., optical nanostructures and methods to control quantum coherent dynamics such as entanglement creation and distribution, coherent properties of nanophotonics quantum states of light and complex systems, also inspired by nature (e.g., biomimetics, light-harvesting complexes), quantum coherent transport.
- **Tailored cooperative effects, correlations and many-body physics in nanoscale optical fields:** e.g., quantum regimes of light-matter interaction, generation and investigation of strongly-correlated states of light, topological effects in nanophotonics chips, quantum computation and simulation with many-body light-matter systems.

Theory and modelling, novel experiments, new materials and technological developments shall be combined in a synergic interdisciplinary approach that will facilitate scientific exchange and form a platform for:

- Innovative materials and techniques to construct and interconnect quantum systems with a high and reproducible precision.
- Optical methods for investigating and controlling nanoscale quantum light-matter interfaces.
- Theoretical techniques to quantitatively understand these phenomena, including novel computational methods.

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