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Non-classical states of light and matter in state-of-the-art semiconductor photonic crystal platforms

The design and fabrication of hybrid quantum solid-state systems, involving photons, electronic states and mechanical vibrations, has made a tremendous progress in recent years. Stimulated by this progress, several proposals have been made to extend the basic paradigms of quantum optical systems - like e.g. the Jaynes-Cummings, Kerr-Hubbard, and opto-mechanical models - to photonic arrays. These might operate as driven-dissipative quantum simulators, provided a strong enough optical nonlinearity, as compared to the dissipation rates, is present. However, current state of the art semiconductor systems still display weak to moderate optical nonlinearities.

I will show that, by combining accurate design optimisation and unconventional optical protocols, quantum systems based on current state of the art in semiconductor nanotechnology can be conceived, able of generating highly nonclassical states of light, electronic and mechanical states, in presence of currently achievable optical nonlinearities. I will present in particular a protocol for the automated optimisation of the quality factor of photonic crystal cavities, that recently resulted in a ten-fold improvement the measured quality factors in three independent experiments. Based on these optimal designs, I will present schemes for generating single photons in a weakly nonlinear silicon cavity dimer, and for the heralded generation of macroscopically entangled mechanical states at several-micron distance. I will discuss possible generalisations of these schemes to more extended photonic arrays.

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