Photon-pair generation using nanoscale structures

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Abstract. Photon-pairs have evolved as a critical resource for quantum technologies, and many applications in quantum communication, imaging, sensing and computing are based on using such quantum states with judiciously designed properties. For many applications, sources of photon pairs are still based on bulk nonlinear crystals, which due to the need for phase matching enable efficient generation only in limited parameter ranges. In the last years, it was demonstrated that also nanoscale films of second-order nonlinear materials can serve as sources of photons pairs by spontaneous parametric down conversion (SPDC), without the need to achieve phase matching [1]. Structuring these films into resonant nanostructures enhances the generation efficiency while providing a large number of degrees of freedom for controlling the properties of the generated pairs through the geometry of the nanoresonators [2, 3].

In my talk, I will give an overview of our recent activities in the field of photon-pair generation using different nanostructures. Using simple thin films of transition-metal dichalcogenides or lithium niobate, we could show that even these can generate maximally entangled quantum states, which can be tuned by changing the polarization of the used pump beam [4].

Using resonant nanostructures for the generation provides more degrees of freedom for state tuning, however, also makes the theoretical description and controlled design of nanostructures complicated. To tackle this challenge, we developed a complete model, that shows that even single nanoresonators can be sources of maximally entangled states [5].

Experimentally, metasurfaces, planar arrangements of many nanoresonators, preserve the large number of degrees of freedom while enabling a larger generation efficiency by adding up contributions of many nanoresonators. Starting from our first demonstration of photon-pair generation [2], I will show how such metasurfaces can be used to control different degrees of freedom of the generated quantum states, like direction [6] and wavelength.

Finally, I will discuss a theoretical concept that combines SPDC with absorbing matter to change the statistics of the generated states beyond that of Gaussian squeezed states and enables the almost deterministic generation of Fock states with different photon numbers [7].

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