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Shaping photon statistics with metamaterial and antenna theory

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Nonclassical light sources are a fundamental element in the development of quantum technologies. In essence, they provide the nonclassical light states needed to trigger different quantum processes that are the basis of those technologies. During recent years, there has been a rapid progress on the development of single photon sources, leading to solid-state sources (e.g., quantum dots and color centers) with excellent performance in terms of brightness, purity and indistinguishability. These sources have enabled a number of successful proof-of-concept demonstrations. However, sources with even better performance and advanced functionalities will be required for the successful implementation an exploitation of future quantum technologies. In our talk, we will discuss how different aspects of metamaterial and antenna theory can be applied to the design of advanced nonclassical light sources.

On the one hand, metamaterials with extreme constitutive parameters induce a strong modification of the photonic environment of a quantum emitter, which can be harnessed to enhance its brightness and indistinguisability. We will discuss some of our recent work demonstrating how media with a near-zero refractive index can qualitatively and quantitatively modify the decay dynamics of a single emitter, as well as the interaction within ensembles of quantum emitters [1, 2, 3].

On the other hand, different elements from antenna theory can also be applied to the design of nonclassical light sources. For example, we will discuss the possibility of using antenna array theory in beamforming photon statistics. As known, classical antenna arrays empower control of the directional properties of the emitted intensity. Quantum antenna arrays provide even additional degrees of freedom, since they allow for the control on the directional behavior of photon statistics of arbitrary order. For example, we will show a configuration in which the emission pattern in terms of the average number of photons is independent of the number and positioning of the emitters, while second-order spatial correlation functions exhibit a strong directional behavior. Therefore, this configuration represents a novel nonclassical light source generating directionally entangled photon bunches.

1. I. Liberal and N. Engheta, "Near-zero refractive index photonics," *Nature Photonics*, **11**, 3, March 2017, pp. 149–158, doi: 10.1038/nphoton.2017.13.

2. I. Liberal and N. Engheta, "Zero-index structures as an alternative platform for quantum optics," *Proceedings of the National Academy of Sciences*, **114**, 5, January 2017, pp. 822-827, doi: 10.1073/pnas.1611924114.

3. I. Liberal and N. Engheta, "Nonradiating and radiating modes excited by quantum emitters in open epsilonnear-zero cavities," *Science Advances*, **2**, 10, October 2016, pp. e1600987, doi: 10.1126/sciadv.1600987.