Carbon nano-structures as quantum-light sources

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Single-photon sources are a key building block for secured quantum telecommunications or for future quantum information processing. In most protocols, this source is required to be on-demand and to show a large anti-bunching puritytogether with high brightness. In addition, technological integration in long range telecommunication networks requires near-infrared operation. Room temperature operation together with electrical injection would also be highly valuable for large scale integration.

Carbon nano-structures and in particular carbon nanotubes and graphene quantum dots have strong assets in this perspective. They were shown to be excellent single-photon emitters (both at low-temperature and room temperature for chemically grafted nanotubes or graphene quantum dots) [1, 2]. In addition, their emission wavelength can be chosen over a wide range, including the telecom O and C bands for nanotubes, by selecting appropriate chiral species. Finally, electro-luminescence has been reported by several teams [1]. Nevertheless, whatever the excitation scheme, the reported luminescence quantum efficiency is consistently small and the linewidth may be strongly broadened by interactions with phonons or by local environment electrical fluctuations.

Here, we show that these key properties can be drastically improved by coupling the nanostructure to a small volume, high-finesse micro cavity, through the so-called Purcell effect [3].

In order to tackle the so-called spatial and spectral mode matching issues (that become especially critical in high Q applications), we used a tunable cavity designed at the apex of an optical fiber for further integration in telecom networks. We show that the emission rate of the nanotube can be enhanced by a factor 60 leading to an effective luminescence quantum yield of about 40% and a coupling factor close to 100% [4].

In addition, the original tuning capability of our open cavity, allows us to exploit the spectral broadening of the emitter line and to achieve a widely tunable single-photon source. This new feature is possibly valuable for multiplexing applications in telecommunications or for indistinguishability engineering from remote nano-sources for quantum computing [4].

References:

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