Using electrostatic forces to tune the emission wavelength of a quantum dot embedded in a nanowire antenna

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A single-photon source is a device that emits a light pulse containing exactly one quantum of electromagnetic energy in response to a trig signal. Such a device is a key building block for the future developments of quantum information technologies, which could also find application in the metrology of faint light fluxes. In the solid-state, single-photon sources based on semiconductor quantum dots (QDs) embedded in tapered nanowire antennas have recently demonstrated appealing performances [1, 2]. However, their use in quantum information protocols involving more than two sources has been hindered so far, by the dispersion in energy of different QDs. This dispersion is due to their intrinsically random, self-assembly fabrication process, such that two QDs are never alike. In this context, it is highly desirable to implement a “control knob” in the source, in order to tune the QD emission wavelength.

In this work, we propose an original approach to tackle this issue. With a couple of integrated electrodes, we generate a controlled electrostatic force that bends the nanowire. As a result, a strain field is applied to the QD, which shifts its emission wavelength. Numerical simulations, conducted with a finite element software, show that a tuning range of 10 nm is achievable for a modest driving voltage (below 50 V). Importantly, this tuning strategy preserves the excellent optical properties of the nanowire antenna. We will also present on-going work on the fabrication and characterization of a first generation of devices.

Beyond tunable single-photon emission, the large transverse gradient of the generated strain field will make it possible to bring two QDs located in the same wire into resonance, opening the way to the observation of collective effects such as superradiance. In addition, the device can also be operated in the dynamical regime: the electrodes can also be used to excite the mechanical vibrations of the nanowire, which efficiently couples to the QD emission energy [3].

[1] J. Claudon et al., Nature Photonics 4, 174 (2010).
[2] M. Munsch et al., Physical Review Letters 110, 177402 (2013).
[3] I. Yeo et al., Nature Nanotechnology 9, 106 (2014).

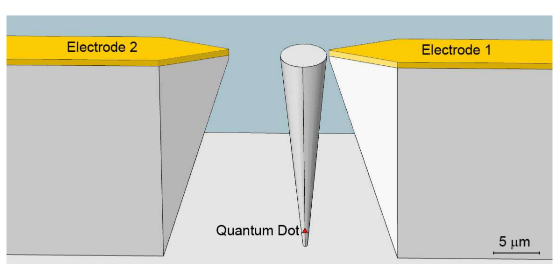

Figure 1 : Geometry of integrated electrodes used to bend the nanowire by means of a controlled electrostatic force