All-optical mapping of the position of single quantum dots embedded in a nanowire antenna

Romain FONS[a*], Andreas D. OSTERKRYGER,[b], Petr STEPANOV[a], Eric GAUTIER[c], Joël BLEUSE[a], Jean-Michel GERARD[a], Niels GREGERSEN[b] et Julien CLAUDON[a]

a. : Univ. Grenoble Alpes, CEA, INAC, PHELIQS, joint group 'Nanophysique et semiconducteurs', F-38000, Grenoble, France

b. : DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Ørsteds Plads Building 343, DK-2800 Kongens Lyngby, Denmark

c. Univ. Grenoble Alpes, CEA-CNRS, INAC, SPINTEC, F-38000, Grenoble, France

∗ : romain.fons@cea.fr

In the last years, nanowire antennas embedding isolated quantum dots (QDs) have appeared as a powerful platform for solid-state quantum optics. They have enabled the realization of bright sources of quantum light [1,2]. Such devices can be obtained by etching a planar semiconductor structure which contains a single sheet of self-assembled QDs. This top-down fabrication strategy leads to a random position of the QDs in the waveguide section. The QD position influences the device performance (optical brightness and likely QD spectral coherence).

In this context, mapping precisely the QD position inside the photonic structure is highly desirable. However, conventional optical imaging is here not applicable, because the antenna supports only one, or few optical guided modes. In this work, we introduce an all-optical mapping technique based on Fourier-space microscopy, and determine the position of individual QDs with an accuracy better than 10 nm [3].

The technique exploits two guided modes which feature very different transverse spatial profiles: (i) the fundamental guided mode with a Gaussian profile and (ii) the second-order guided mode with a ring profile. The fraction of spontaneous emission funneled into each mode strongly depends on the QD position. Consequently, the far-field emission pattern contains information on the radial and azimuthal position of the QD in the waveguide section. We have developed a Fourier microscopy setup which allows mapping the far-field emission of individual QDs, isolated by spectral filtering [4]. We investigate the far-field emission of distinct QDs embedded in the same structure. We obtain very different far-field maps, which highlights the large sensitivity of this quantity to the QD position. The results are in excellent agreement with numerical simulations based on the device geometry. Comparison with the experimental data yields the QD position with an accuracy on the order of 10 nm. As a first application, we also correlate the QD position with their measured photoluminescence lifetime. Our results open interesting perspectives for the fine characterization and optimization of single-QD nanowire devices.

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