Looking inside photonic nanowires with coherent X-ray imaging

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Abstract

The development of efficient single-photon sources is a key step required for the progress of efficient quantum communications. Such a device would allow to emit on-demand light pulses containing exactly one photon. Such a source was recently developed at INAC/CEA Grenoble (France), using InAs quantum dots (QDs) embedded in a GaAs nanowire. The InAs QDs act as single photon sources, for which the exact wavelength varies with the shape and size of the QDs. The GaAs nanowire (diameter ~600 nm) acts as an optical wave-guide [1] (figure 1).

The photo-emission properties are studied by micro-photoluminescence (μPL) measurements as shown in (figure 2). The spectral lines come from individual dots and it is possible to separate them as long as there are few dots (<10) in the wire. Each dot has a unique spectral line because they are all different in size, shape and position within the same nanowire. Therefore in order to improve these photonic devices, it is necessary to understand the relationship between the μPL measurements and the size, position and location of the QDs.

The structural properties are studied via the deformation field created by the QDs inside the nanowire. Coherent X-ray Diffraction Imaging (CDI) provides a 3D image of the density distribution and also the projection of the strain along the Bragg reflection. The scattering intensity around a Bragg reflection is sensitive to the deformation of the crystal, at a resolution smaller than the d-spacing of the considered reflection. Moreover with X-rays, it is possible to study buried objects without sample preparation that might change their strain state.[3] The final image of the studied sample is obtained by reconstructing the experimental results using interative algorithms based on Fourier Transformation.

Here we present CDI measurements on GaAs nanowires with embedded InAs QDs measured in two different ways: with Coherent 3D Bragg diffraction (figure 3) and with Ptychograpy (figure 4). For the first case the 3D images are obtained by scanning the reciprocal space with a 2D detector. With Ptychography the sample is scanned along the wire with overlapping illuminating areas. For the latter we also show reconstructed nanowire with the embedded QD (figure 5)[4].

References

[1] J. Claudon et al. Nature Photon, **4,** (2010) 174.
[2] Favre-Nicolin V. et al. New Journal of Physics **12** (2010), 35013.
[3] Robinson, Ian, & Ross Harder. Nature Materials **8** (2009),291-298.
[4] Mastropietro F., PhD Thesis, Univ. Grenoble (2011)

Figures

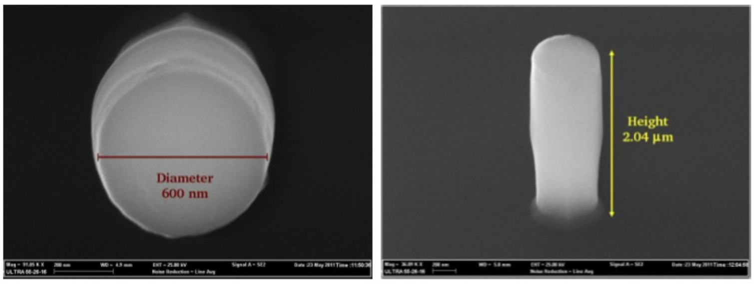

Figure 1: Scanning electron microscopy images of the investigated nanowire with InAs QDs.

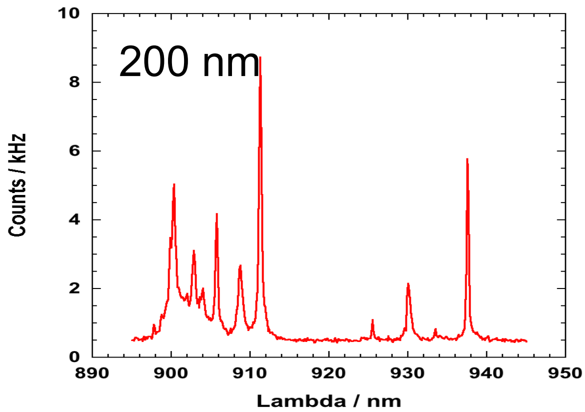

Figure 2: µPL measurements of 200 nm diameter nanowire. The multiple µPL lines come from single QDs inside the nanowire.

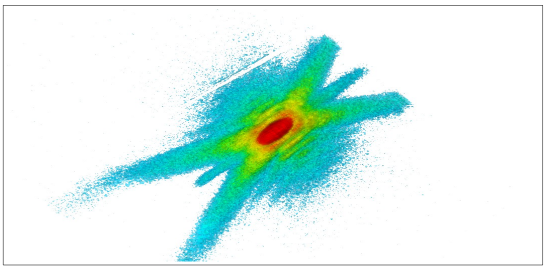

Figure 3: 3-dimensional diffraction pattern collected at the QDs position for the (115)GaAs Bragg reflection.

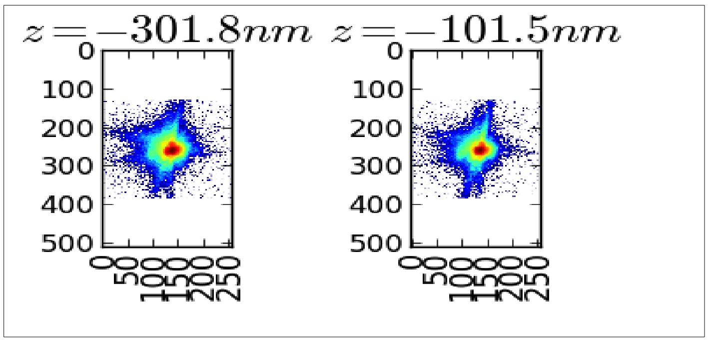

Figure 4: 2D scatterings from a vertical scan along the GaAs wire with for two values of the scan.

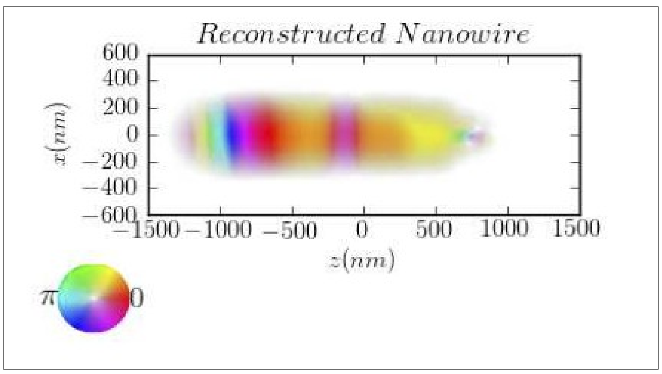

Figure 5: Reconstructed shape of the nanowire. The color difference at z=0 corresponds to the insertion of the QD.