Secondment report at UTT

Duration: 03-09-2018 to 23-09-2018

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Goals

As part of the ESRs project “Double photonic structure with a quantum-dot-in-nanowire” at EPFL, this secondment was undertaken for a period of 3 weeks in Light, Nanomaterials and Nanotechnologies (L2n) lab at UTT aimed at identifying points for collaboration between EPFL and UTT:

- Advanced optical characterization of quantum-dot-in-nanowire structures
- Identifying configurations suitable for coupling of nanowire emitters to waveguides

Personal Impact for the ESR

- Identified potential collaborative experiments between EPFL and UTT
- Completed training on various optical spectroscopy setups available at UTT
- Experiments on nanowire quantum dot samples grown at EPFL
- Strong interaction and collaboration established with researchers at UTT

Results

The samples used for characterization consisted of Ga-rich AlGaAs quantum dots (QDs) in the shell of GaAs/AlGaAs core-shell nanowires. These samples were fabricated at EPFL using molecular beam epitaxy (MBE) on Si substrates. The as-grown samples were mechanically transferred onto a bare Si wafer to measure the micro-photoluminescence (µ-PL) emission spectra. The samples were mounted on a probe in a closed-cycle He-cooled cryostat attoDRY1000 from Attocube. Superconducting magnets (9T) on the cryostat can be used to perform magnetic field-dependent PL measurements. A 405nm pulsed laser is used as an excitation source. Other excitation sources such as 405nm CW laser and 632.8nm CW and pulsed lasers are also available. The laser spot is focused using a microscope objective and directed into single or multi-mode optical fibers. An objective mounted inside the cryostat further focuses the incident beam onto the sample. The power density incident on the sample is controlled using various neutral density (ND) filters. The PL signal is collected using the cryostat objective through an optical fiber and dispersed onto a 1200l/mm grating and detected using a PIXIS eXcelon thermoelectrically cooled charge-coupled device (CCD). Using a CMOS camera, the laser beam is focused on a single NW lying on the Si wafer. Figure 1 shows an image of the cryostat used to perform the measurements described here.

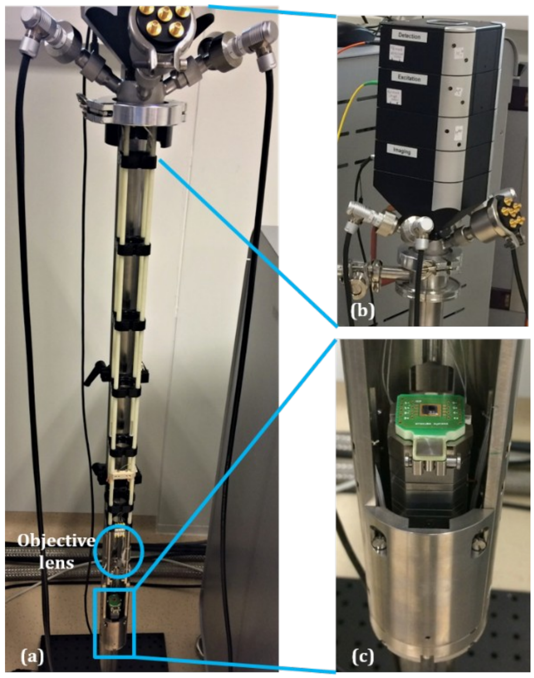

Figure 1 Schematics of the µ-PL measurement setup, a) Arm of the cryostat mounted with sample objective lens and sample probe, b) The setup unit with fiber in and out-coupling for laser excitation and detection of the PL signal. c) A magnified image of the sample mount.

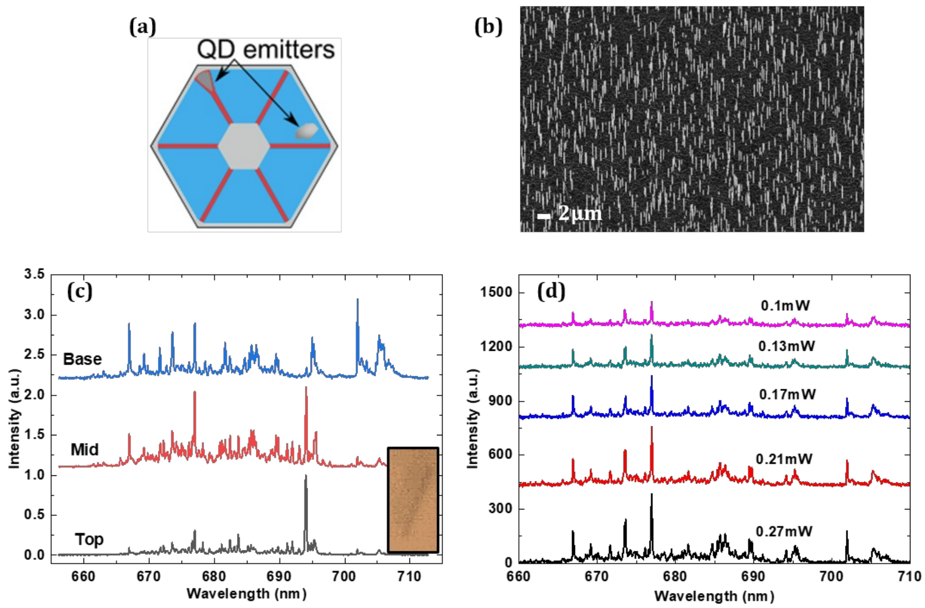

Figure 2 a) Cross-sectional schematic of a core-shell GaAs/AlGaAs NW (L. Francaviglia et al. APL 2015). b) SEM image of the as-grown sample used for PL measurements. c) μ-PL mapping of emission spectra along the length of the NW (inset: false-colored image of the NW used in the mapping). d) Power-dependent μ-PL spectra from the top part of the NW shown in c).

Figure 2a shows a cross-section of the NWs with QDs in the shell used in our experiments. These self-assembled QDs are present at random positions along the whole length of the NW. An SEM image of the as-grown NWs is shown in figure 2b which were transferred onto a Si wafer. By scanning across the sample, a single isolated NW is selected for PL mapping along its length. Once such NW is shown in the inset of figure 2c. Multiple sharp emission peaks are visible in the low temperature (4K) μ-PL spectra of figure 2c. These peaks can be attributed to emission from numerous QDs present in the NW shell. Since the QDs are formed by a self-assembly process, their shape and composition is random. Thus, the peak positions are different along the NW length. Figure 2d shows power-dependent μ-PL spectra acquired from the top part of NW. By isolating and studying their power dependence, such peaks can be resolved into exciton and biexciton emission lines in a single QD. In addition, various other single NWs were characterized, including with magnetic-field dependent PL measurements.

Outlook

The ultimate goal of this project is the growth of axial quantum dots in nanowires. During the aforementioned period of the secondment, the ESR completed training on various optical characterization setups using quantum-dots-in-nanowire samples. These will be useful in emitter characterization once the samples are available at EPFL. Future plans include integration with external waveguides along with advanced characterization such as second-order auto-correlation measurements and efficiency of coupling to waveguides.