# Optical spectroscopy of single nanowires

Application Note

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## Introduction

III-V semiconductor nanowires (NW) can be regarded as very promising candidates for future high-performance nanoelectronic and nanophotonic devices [1]. Thus, NWs enable the integration of the superior electronic and optical properties of direct bandgap III-V semiconductors onto the well-established silicon platform due to the effective strain relaxation mechanism at the silicon/nanowire interface. Here, we report on the effect of the crystal structure on the optical properties of GaAs-AlGaAs core-shell nanowires.

## Setup

For single nanowire photoluminescence (PL) spectroscopy, a homebuilt micro-photoluminescence setup is used as illustrated in Figure 1. For the measurements, NWs were first transferred onto the substrates from solution via drop-casting. Further on, the samples were mounted in a liquid helium flow cryostat which is cooled down to temperatures below 10K. Well-isolated individual NWs are excited by a picosecond pulsed laser diode at a wavelength of 660 nm while the laser is focused to a spot size of around 2 μm$^2$ by a 50x-objective. The objective is mounted at a high-precision closed-loop piezo-system (scan range: 80 μm x 80 μm) allowing us to record high-resolution intensity profiles over a large area by scanning the laser spot. The PL emission of the NWs is dispersed by an Andor Shamrock SR-500i-D1-SIL spectrograph. The spectrograph is equipped with a thermo-electrically cooled CCD-detector (Andor iDus DU416A-LDC-DD) for quick multichannel acquisition. The grating turret of the spectrograph is equipped with 300 lines/mm (blaze 760 nm), 600 lines/mm (blaze 800 nm) and 1200 lines/mm (blaze 750 nm). These gratings are silver coated to ensure for optimum performance in the target wavelength range. For PL-lifetime measurements, the second (side) output port of the spectrometer is equipped with a X-Y fiber coupler (with Slit Assembly) which allows us to couple light into a multi-mode optical fiber guiding the signal towards a single photon avalanche diode (SPAD).

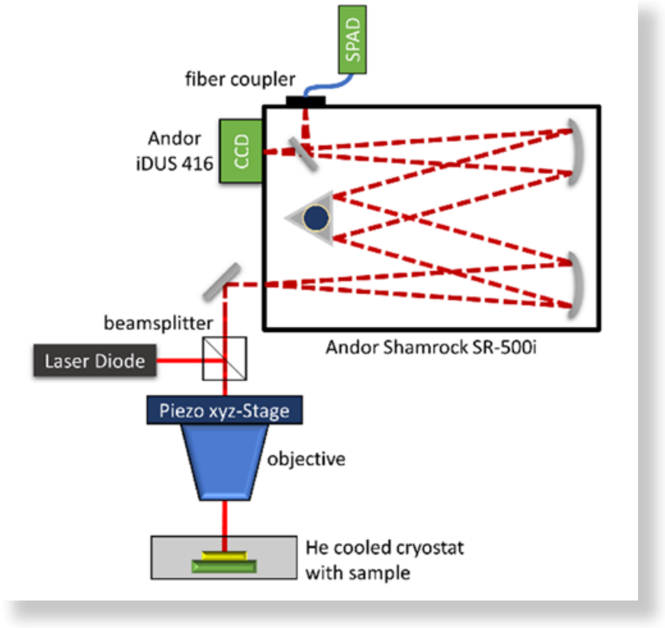

Figure 1: Schematic of the experimental setup.

## Results

Figure 2 shows a typical PL intensity mapping of a GaAs-AlGaAs core-shell NW at low temperatures of about 10 K. In this experiment, the laser is scanned across the sample and a spectrum is recorded at each position. In Figure 2a the integrated intensity map of the NW is shown. The NW is clearly visible with a maximum intensity at one end of the NW. In Figure 2b and Figure 3a, a low-temperature PL spectral map and single PL spectrum of the NW recorded at the center of the NW are shown, revealing a double peak structure. The two peaks separated by about ΔE=26 meV. Here, Peak 1 at 1.488 eV is attributed to emission from localized excitons at a single twin plane defect [2,3].

Twin defects commonly occur in these NWs due to the inclusion of wurtzite crystal phase segments within the otherwise zincblende crystal structure. This leads to the formation of so-called indirect excitons with holes confined in the twin wurtzite segment and electrons in the surrounding zincblende structure [2,3,4]. In order to identify the origin of the two emission peaks we performed time-resolved PL. At 1.514 eV, the time transient exhibits a clear mono-exponential decay with a characteristic lifetime of $\tau \sim 0.7$ ns, which is consistent with literature values for free excitons in GaAs nanowires. In contrast to the mono-exponential decay of emission peak 2, multi-exponential decay is observed at 1.488 eV. In addition to the fast decay, an increased exciton lifetime is characteristic for the spatial separation of electron free exciton.

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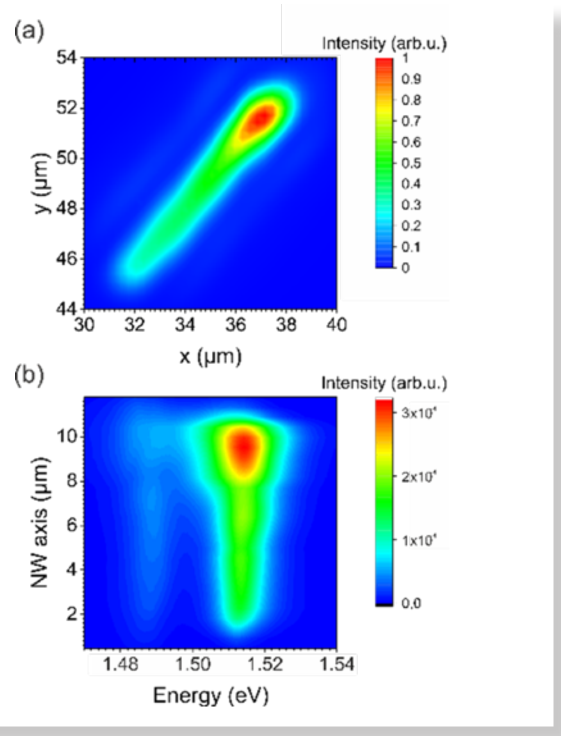

Figure 2: (a) Intensity mapping of a GaAs–AlGaAs core–shell nanowire. (b) Map of the PL spectrum recorded along the NW axis at 10 K.

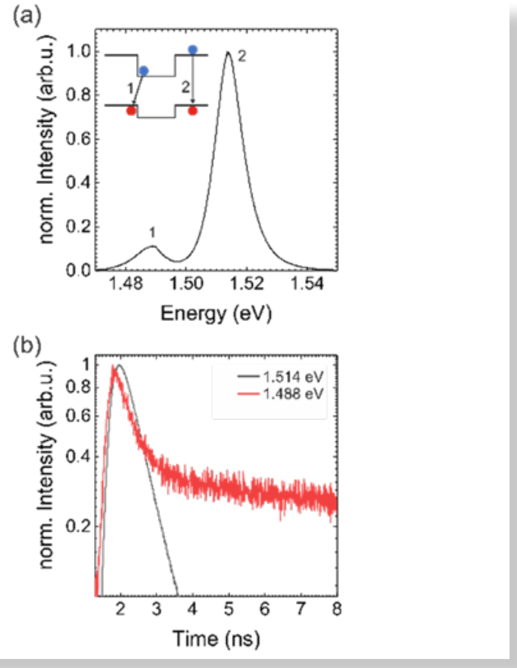

Figure 3: (a) PL spectrum recorded at T = 10 K of an individual GaAs–AlGaAs core–shell nanowire showing a double peak structure. (b) Time evolution of PL peaks recorded at E=1.514 eV (grey, 2) and E=1.488 eV (red, 1). The fast decay rate can be attributed to the recombination of free excitons (2) whereas the slow decay rate results due to the recombination of indirect excitons localized at single twin plane defects (1) as shown in inset (a).

## Conclusion

The Shamrock 500i spectrograph equipped with the Andor iDus 416 CCD camera and the X-Y Fiber Couplers enable us to examine the optical properties of semiconductor nanowires.

## References

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