PL Mapping and Optimized Optical Trapping of Nanowires SLM beam shaping

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Abstract: We report a novel method for using spatial light modulator (SLM) to spatially map the luminescent properties of single trapped semiconductor nanowires by dynamic optical tweezers. Being able to control the axial position of the trapping focus with respect to the excitation source and collection view point, the composition along the long axis of the nanowire can be probed. We also explore the feasibility of tailoring trapping beam shape to enhance the axial trap stiffness for long nanowires (> 5 µm). This technology can be used to tailor the beam to suit the dimensions of extended objects to enhance the trapping properties.

1 Introduction: Nanowires are of considerable interest as basic building blocks for nanoelectronics and nanophotonics. InP nanowires are a strong candidate for high-density photonic integration due to its low surface recombination velocity and its excellent control over physical shape. Distinct from its bulk counterpart, InP nanowires can form both wurtzite (WZ) and zinc blende (ZB) crystal phase[1], which provides type II homojunctions in single nanowires. More recently, the emergence of optical tweezers [2], which is suited to manipulate microscopic objects, provides a precise method to manipulate individual nanowires and assemble nanowires. The nanowires usually have diameter of tens of nanometres and length of 5 to 15 micrometres.

Spatial light modulators (SLM) provide a versatile technique in the fields of laser microscopy and optical tweezers by shaping the optical beam [3]. In this paper, we present a method for using an SLM to study the axial composition of single InP nanowires. We also explore the feasibility of shaping a focused laser beam into a shape that closely resembles a nanowire in three dimensions with the SLM. We show the possibility of using standard Zernike modes to elongate the axial intensity distribution without losing the lateral confinement, thus creating the ideal optical trap for the large aspect ratio nanowires.

2 Results and discussion: Employing SLM to calibrate all trapping system aberration by control Zernike mode, the trap stiffness of nanowires can be greatly increased [4, 5], which allow us to move the nanowire to longer range than its length. By placing a 100 µm pinhole in a conjugate image plane, the axial resolution can be enhanced to 2 µm when probed by 1 µm red dyed polymer sphere.

Fig 1(a) shows the microscope image of a typical long nanowire (NW1), which is 14 µm in length. By addressing different Fresnel lens on SLM, the nanowire is shifted with respect to the excitation laser. The PL spectrum for different position is shown at Fig 1(c), and the peak wavelength change is plotted as a function of position in fig 1(b), where it is noted that the peak wavelength shift from ZB phase (907nm) to WZ (867nm) then back to ZB. It indicates that the density of the higher band gap WZ phase is in-

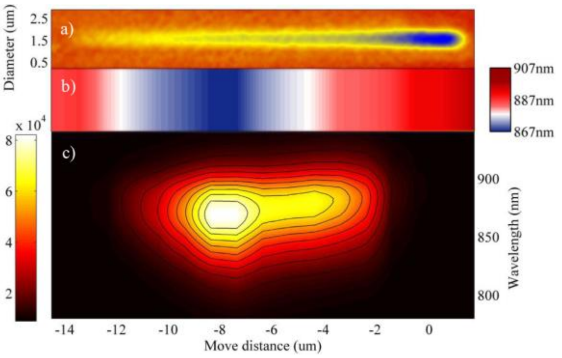

Fig. 1. Long nanowire mapping results.

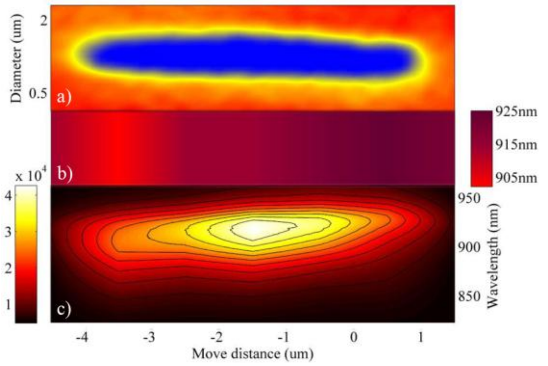

Fig. 2. Short nanowire mapping results.

creased in the middle. It is also noted that WZ phase in general gives stronger PL, as shown at fig 1(b). For a typical short nanowire (5 µm), which is shown at fig. 2(a), most of them present a pure ZB phase. This indicates that most of the short nanowires may be the bottom section of long nanowire. It is also interesting to know that for both short and long nanowires, the balance trapping position is above the central position of nanowire, since position 0 in the abscissa in Figs. 1(c) and 2(c) is the trapping focus position.

Based on vector diffraction integration modelling [6], the optimal focus (with best correction) for the trapping laser has a central intensity 3 MW/cm^2 for 10 mW incident power, with a depth of focus (DOF) of 0.64µm and a spot size of 0.33µm. When we introduce primary spherical aberration (-0.69λ) and secondary spherical aberration (-0.24λ), the DOF can be elongated to 2.1 µm without losing lateral confinement (spot size 0.36 µm) but with decrease of the central intensity (0.5 MW/cm^2). Similarly, by means of changing the filling factor to 0.635, the same DOF can be achieved, however the spot size is approximately doubled (0.553 µm), which results in a smaller lateral gradient force. The propagation intensity distribution of y-z (beam is x linear polarized) for optimal focus, Zernike shaped beam and under filling case are shown at figs. 3(a), 3(b) and 3(c), respectively.

3 Conclusion: By using dynamic optical tweezers based on an SLM, the composition along the trapped nanowire is investigated. By addressing the SLM with different phase pattern, the axial position of nanowire can be well controlled. The observation that trapping position is higher than middle point is also described. Based on applying Zernike modes, the beam shape in focus can theoretically be tailored to suit the geometry of long nanowires.

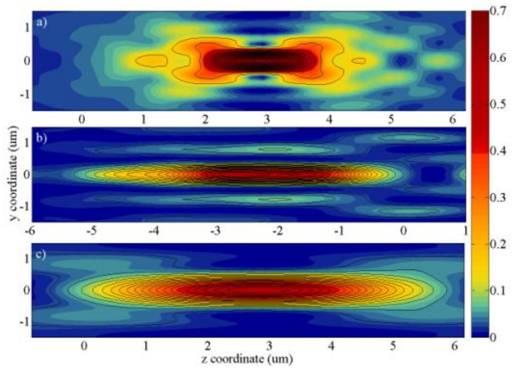

Fig. 3. Zernike shaped beam and under filling case.

Acknowledgements

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