Ultrafast spectroscopy for single-nanowire optoelectronic devices

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Over the past two decades, semiconductor nanowires have emerged as a novel class of material for electronic and optoelectronic applications[1]. With diameters in the range of 10-1000nm and lengths in the range of microns, their geometry make them an exciting platform for quantum-confinement in one dimension, strong light-matter interaction, high anisotropy applications and heteromaterial growth. Developments in growth using MBE or MOVPE have led to demonstrations of new architectures such as dot-in-wire[2] (for single photon emission), axial superlattices[3] (for lasing applications), radial heterostructures[4] (for photovoltaics) and branched structures.

A key feature of semiconductor nanowires is the role of the surface in carrier dynamics. The large surface-to-volume ratio, can be beneficial for use in chemical sensing applications[5]; however, for optoelectronics surface recombination represents a major source of inefficiency in light harvesting or light emission. While understanding carrier dynamics in semiconductor materials is critical, in general, quantifying the recombination processes in nanowire systems is challenging given the small material volume and complex electrical contacting methods.

In this tutorial I will describe a number of all-optical methods to characterize carrier dynamics in nanoscale systems. In particular, I will describe photoluminescence spectroscopic approaches based on time-resolved detection, optical-pump terahertz-probe spectroscopy for electronic characterization on the picosecond timescale[6], and non-linear spectroscopy for lasing applications. These techniques have been used to determine fundamental material properties such as dopant densities[7], surface recombination velocities[8] and carrier mobility[9], as well as application specific features such as single-nanowire detector bandwidth[10] and nanolasers threshold[11].

Most recently, the role of inhomogeneity in nanoscale systems has emerged as a critical issue to industrial uptake of this material system. I will discuss recent developments in large-scale spectroscopic techniques to address this challenge[12,13].

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