Light-matter interactions at the nanoscale: challenges and opportunities

Kenneth B. Crozier

School of Physics and Department of Electrical and Electronic Engineering
University of Melbourne
Victoria 3010, Australia
kcrozier@unimelb.edu.au

Abstract—Optical methods are challenging to apply at the nanoscale, due to the large mismatch between the wavelength and the sizes of nanoscale objects. I will describe projects that have addressed this challenge for various applications.

Keywords—*photodetectors, nanostructure fabrication, subwavelength structure, optical resonator*

I. SEMICONDUCTOR NANOWIRE PHOTODETECTORS FOR MULTISPECTRAL IMAGING

We present recent studies in which engineering the interaction between light and nanoscale materials has been pursued for applications in image sensors and in spectroscopy. In the first, we present recent work by the author and colleagues on the use of silicon [1-5] and germanium [6] nanowires for multispectral imaging. We show that their ability to support waveguide modes leads to spectrally-selective absorption properties [1]. We show that this in turn enables the nanowires to be used as filters or photodetectors for color and multispectral imaging [2-6].

II. OPTICAL TRAPPING WITH PLASMONIC AND PHOTONIC NANOSTRUCTURES

A second theme of this presentation concerns optical nanotweezers.

The development of integrated approaches for optical trapping, based on photonic or plasmonic structures fabricated on a chip, offers several compelling advantages. First, chip-based optical traps enable the trapping platform to be miniaturized. Second, the chip-based configuration lends itself naturally to the incorporation of sensing modalities. Third, optical nanostructures can generate strong near-fields, boosting the trapping performance.

In this presentation, works by the author and his team in the field of optical trapping with silicon photonics and with plasmonics are described. We have pursued various approaches to optical trapping. A selection of these works will be presented at the conference, based on the available time.

We have demonstrated the use of silicon microring resonators for trapping [7] and sensing [8] particles. We have furthermore demonstrated silicon photonics for sorting particles [9], as well as for sensing proteins [10]. We have performed experiments in which a silicon photonic crystal cavity trapped a silver nanoparticle on whose surface molecules had been formed. We carried out Raman spectroscopy of these molecules, with the silver nanoparticle held in position via the photonic crystal cavity [11].

Plasmonic nanostructures are compelling for optical trapping due to the large gradient forces they can generate, a consequence of their ability to generate highly confined optical fields. Yet deleterious thermal effects can also occur. We have demonstrated the use of a plasmonic nanotweezer with an integrated heat-sink [12]. In our recent work, fluorescence microscopy was used to track the position of a nanoparticle trapped by a double nanohole aperture [13].

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Author/s:

Crozier, KB

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