Research statement – Dr. Yonatan Sivan

My research involves a variety of subjects in nano-photonics including linear and nonlinear optical effects in plasmonic and semiconductor nanostructures, metamaterials and photonic crystals. The research relies on a combination of analytical, asymptotical and numerical techniques, but always involves collaboration with an experimental group.

Some of the specific projects that occupy me are:

1. **The use of metallic nanoparticles for performance improvement in super-resolution microscopy**. This project is based on my recent prediction that metallic nanoparticles can be used to improve the resolution and signal brightness in Stimulated-emission-depletion microscopy (Y. Sivan et al., ACS Nano 2012; Y. Sivan, Appl. Phys. Lett. 2012). The project involves analytical work, heavy computations, nanofabrication and optical characterization (spectroscopy, imaging, lifetime imaging etc.). The work is done in collaboration with 3 groups at Imperial College London, and 2 groups in France (Lyon and Grenoble).

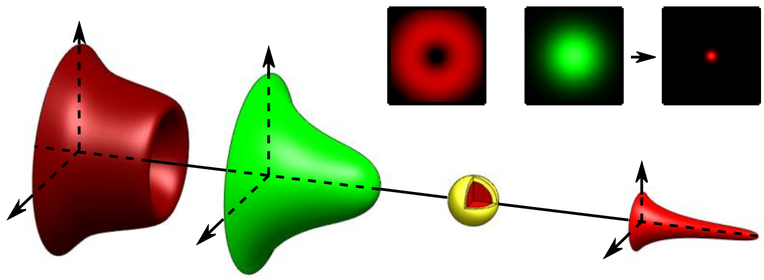

Fig. 1. A schematic illustration of a (NP-) STED nanoscope with excitation beam shape (green), depletion doughnut-shaped beam (dark red), hybrid plasmonic-fluorescent emitter (yellow-red metal shell nanoparticle) and overall sub-diffraction fluorescence signal (light red). Insets show the transverse cross sections of the field distributions and signal.

2. **Theory of loss compensation in plasmonic metamaterials**, and negative refractive index in particular. This involves development of both classical and quantum models for the interaction of quantum emitters (dye molecules, quantum dots etc.) with nano-plasmonic systems. The work is done in collaboration with groups at the Tel Aviv University and the Hebrew university.

3. **Novel designs of magnetic and negative refractive index metamaterials.** This work is based on a modal analysis of metal wire clusters. The work is done in collaboration with a group at Tel Aviv University.

4. **Nonlinear optical metamaterials.** This work involves incorporating complex models for the nonlinear response of metal nanostructures in the design of nonlinear metamaterials. It is done in collaboration with a group at Duke University.

5. **Ultrashort optical pulse reversal in semiconductor nano-photonic structures**. This project is based on a series of joint publications with Prof. Sir J. Pendry (Sivan and Pendry, Phys. Rev. Lett. 2010; Sivan and Pendry, Opt. Express 2010; Sivan and Pendry, Phys. Rev. A 2010) whereby we showed how to employ dynamically tuned photonic crystals for extreme manipulations of ultrashort pulses such as time-reversal, storage and stopping. The current theoretical work on light and charge carrier dynamics in semiconductor waveguides accompanies the experimental effort done in the University of Twente, The Netherlands. Some other aspects of the theoretical work are done in collaboration with a group at Imperial College London.

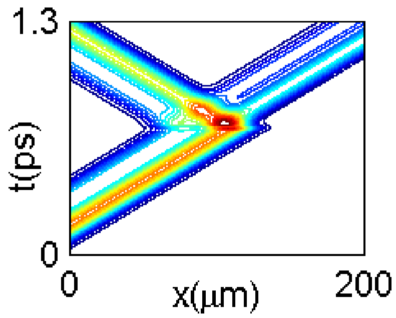

Fig. 2. A spatiotemporal contour map of wave evolution in the switchable mirror time-reversal scheme developed by Sivan and Pendry. The illustration shows the splitting of the incident wave to a forward and a backward (time-reversed) wave.

6. **Nonlinear nanofocusing in plasmonic waveguides**. In this project we are studying the prospects of focusing intense beams into nanometric light spots. We study the interplay between linear focusing provided by the plasmonic environment, nonlinear focusing and losses in the metal. This work is done in collaboration with groups at Tel Aviv University and North Carolina State University, USA.