Topics for summer jobs in the Optics and Photonics group in 2024

1. Optical metamaterials and metasurfaces (simulations & experiments)

Development of metal-dielectric nanostructures based on the optical metamaterial concept. The goals are (1) to increase coupling of light to the structures and its trapping and enhancement on the surface, (2) to enhance the sensitivity of the phase shift imposed by a metasurface to the propagation direction of light, and (3) to efficiently control the angular spectrum of light with an ultrathin surface structure. An example of a metamaterial making spontaneous emission of a point source directive and providing unidirectional optical guidance is shown in Fig. 1.

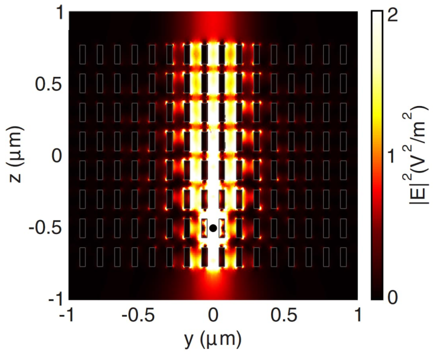

Fig. 1: Directive spontaneous emission from inside an array of silver nanorods [1].

The results of this research can find applications in superior plasmonic probes for Surface-Enhanced Raman Spectroscopy and in future compact and efficient integrated optical devices.

[1] M. Nyman, V. Kivijärvi, A. Shevchenko, and M. Kaivola, "Generation of light in spatially dispersive materials," *Phys. Rev. A* **95**, 043802 (2017).

2. Advanced optical imaging (simulations & experiments)

Development of novel methods for in aberration-insensitive optical imaging. A microscope exhibiting high resolution and insensitivity to the distance to the object will be constructed and tested. Using this device, objects extended along the optical axis will be observed sharp. This property will be achieved by composing the images of non-diverging Bessel beams instead of focused spherical waves, which can be done by means of spatial filtering. In the research, suitable spatial filters will be fabricated and tested experimentally in a systematic way. Figure 2 shows some images that have been recently obtained in our group with a microscope based on this principle.

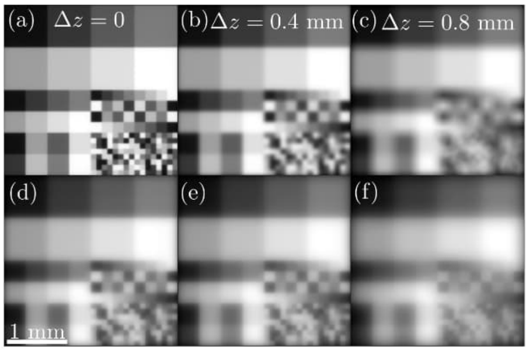

Fig. 2: Microscope images of a longitudinally displaced object (by Δz) taken without [(a)-(c)] and with [(d)-(c)] a ring-shaped spatial filter.

The results of this research can find applications in optical information processing and optical microscopy for biological and medical applications.

3. Optical nanochips (theory & experiments)

Theoretical and experimental work on optical nano-waveguides and on-chip optical modulators. We have previously developed a method to reduce the crosstalk between closely spaced nano-waveguides by using higher-order radially and azimuthally polarized modes [cases (e) and (f) in Fig. 3]. The goals are (1) to fit the design to on-chip waveguide arrays and (2) to test experimentally the first nanofabricated waveguide structures.

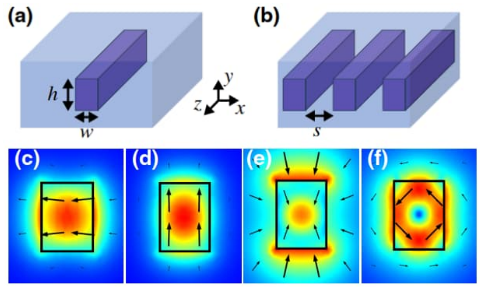

Fig. 3: Exciting higher-order modes [as in (e) and (f)] in a waveguide array can lead to crosstalk cancellation [2], even if $s \approx 100$ nm.

The techniques can be used in optical chips with a high information transfer capacity and LIDARs.

[2] S. Maurya, R. Kolkowski, M. Kaivola, and A. Shevchenko, "Crosstalk reduction between closely spaced optical waveguides by using higher-order modes," *Phys. Rev. Appl*. **18**, 044077 (2022).