Topics for summer jobs in the Optics and Photonics group in 2018

1. Control of light emission and absorption by nanostructuring

Theoretical and experimental research concerning metal and dielectric nanostructures that provide enhancement of light emission and absorption by semiconductor quantum dots and organic molecules. The enhancement is based on resonant interaction of the nanostructures with light. Several basic geometries, such as metal nanogrids, binary dielectric gratings and metal nanorod arrays, will be considered. The goals are to increase (1) brightness of fluorescent films (through increasing the rate and directivity of the emission by the particles), (2) coupling of light to absorbing films (through excitation of in-plane propagation modes), and (3) sensitivity of both emission and absorption to the incident-light polarization and propagation direction (through increasing the anisotropy and spatial dispersion of the material). Examples of nanostructures making spontaneous emission directive are shown in Fig. 1 (see also Ref. [1]). The results of the research on this topic can find applications in the future light-emitting diodes, solar cells, and integrated photonic components, such as microscopic light sources and detectors, as well as the input and output couplers for photonic microcircuits.

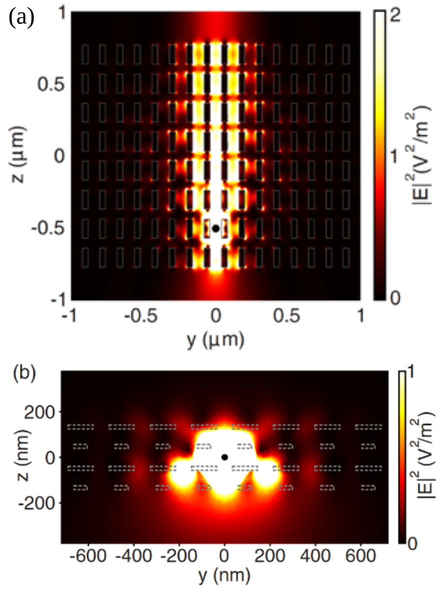

Fig. 1: Directive spontaneous emission from inside an array of (a) silver nanorods and (b) pairs of silver nanodisks [1].

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

2. Ghost imaging through turbid and distorting media

Optimization, construction and experimental testing of a novel optical imaging system that combines the principles of optical coherence tomography and classical ghost imaging. These two techniques are based on the field and intensity correlations. A spatially incoherent light beam is divided into two beams, of which one interacts with the object and the other plays the role of a reference beam. At the detector, the beams are combined with a time-varying delay of one beam with respect to the other, and only the AC component is detected. If a turbid or distorting medium is introduced in the object arm, the intensity image at the detector is destroyed, but not the interference (AC) image. Previously, we have used the two-photon absorption phenomenon to measure the intensity and polarization correlations between two beams with a Michelson interferometer (see Fig. 2 and Ref. [2]). A similar optical arrangement will be used to realize the ghost imaging, for which the object will replace one of the mirrors (M) and a fluorescent film will be used as a light source instead of an optical fiber (OF). We plan to test the idea and construct an interferometric microscope for biological and medical applications.

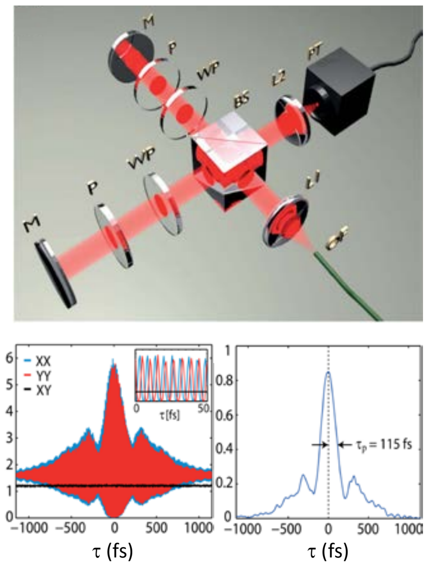

Fig. 2: The interferometer (top), the two-photon absorption signal (bottom left) and the polarization correlation function (bottom right) [2].

[2] A. Shevchenko, M. Roussey, A. T. Friberg, and T. Setälä, "Polarization time of unpolarized light," *Optica* **4**, 64 (2017).

3. Ultrafast imaging using femtosecond laser pulses

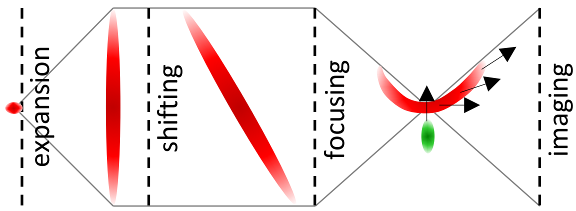

Fig. 3: Pulse transformations used for ultrafast imaging. The pulsed beam is expanded and focused with cylindrical lenses, shifted longitudinally with a diffraction grating, and imaged with a CCD array. A pulse to be detected is shown by the green spot.

Theoretical and experimental work on imaging of ultrafast (femtosecond-scale) optical phenomena. In the optical system to be constructed, a femtosecond pulsed laser beam is expanded in a transverse direction using a cylindrical lens. The expansion transversely enlarges the pulse (see Fig. 3). Then, a blazed diffraction grating is used to introduce a longitudinal shift of the pulse proportionally to the transverse coordinate. Finally, another cylindrical lens is used to focus the pulse. The technique maps the temporal distribution of the probe light in the focal plane into a spatial intensity distribution at the detector plane. If a nonlinear medium (e.g., exhibiting two-photon absorption) is introduced in the focal plane, the system can register optical pulses crossing the focal region simultaneously with the probe pulses; the green spot in Fig. 3 shows schematically the pulse to be registered. The technique should allow measuring laser pulse profiles with femtosecond resolution and provide a number of advantages over the existing methods [3, 4]. In the future, the method can be used to study ultrafast optical phenomena, such as excited-state absorption by organic molecules, to realize ultrafast all-optical modulation, and to create ultrafast devices for optical information processing.

[3] S. Hooker and C. Webb, *Laser Physics*, Chap. 17, Oxford University Press, 2010.
[4] B. E. A. Saleh and M. C. Teich, *Fundamentals of Photonics*, Chap. 22, John Wiley & Sons, 2007.