Universität Bielefeld **Fakultät für Physik**

Physikalisches Kolloquium

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Towards the all-optical transistor – Fabrication, characterization and application of plasmonic nanostructures

They are ubiquitous and indispensable in our daily life: Electronic transistors are the key elements and the smallest processing units in our smartphones and computers - basically in every electronic device. Even though the miniaturization and optimization seems to be an ongoing and never ending process, the physical limit of the clock frequency of electronic transistors is about to be reached.

Within my talk I will present the idea of an all-optical transistor, for which the limitation of the conventional, electronic switching speed might not be valid. This optical switch is based on the interaction of propagating, metal-bound Surface-Plasmon Polariton (SPP) waves in confined metallic nanoantennas with single or few excitonic molecules.

These metallic nanoantennas are able to localize far-field electromagnetic waves in volumes of a fraction of the wavelength [1]. Hence the interaction of light with organic or inorganic molecules can be enhanced by several orders of magnitude. Standard tools for fabricating plasmonic antenna structures with sub-20 nm feature sizes are Electron Beam Lithography or Ga-based Focused Ion Beam (FIB) Milling. These structures however show limited electric field localization.

Within my talk, I will present new ideas to overcome this limitation and to fabricate plasmonic nanostructures with feature sizes of 6 nm and less by a combination of He and Ga ion beam milling. The superior ability to concentrate electric fields within these structures is demonstrated using linear and nonlinear confocal optical microscopy [2].

In a second step, two-dimensional tapered metallic wires with Ga-ion beam written gratings are fabricated to efficiently guide light into the transistor core. Here, our emphasis is placed on an efficient coupling process from far-field propagating light to metal-bound SPPs and on a dispersion-reduced propagation of the SPP waves [3]. A future idea for the interaction of the fabricated plasmonic nanostructures with dye molecules is finally discussed. Within this proposed scheme, the switching speed and hence the clock rate of the optical transistor is only limited by the switching speed of the involved excitonic molecules, which can be on the order of less than 100 fs.

[1] P. Bharadwaj, P. Deutsch, and L. Novotny, Optical Antennas. Adv. Opt. Photon., 1, 438 (2009)

[2] H. Kollmann, M. Silies, et al., Nano Letters 14, 4778 (2014)

[3] J. Yi, M. Silies, M. Silies et al., ACS Nano 4, 347 (2017)

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