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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, computers - basically in every electronic device. Even though the miniaturization and optimization is 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, i.e. 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 their 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.
As a first step towards this all-optical switch, we have therefore used Ga- and He-ion based milling (HIM) for the fabrication of gold dimer nanoantennas with gap sizes of less than 6 nm combined with a high aspect ratio. These structures will later be the core of the optical transistor. Using polarization-sensitive linear and nonlinear Third-Harmonic (TH) optical spectroscopy, the ability of these structures to efficiently concentrate electric fields in nanometer dimensions is probed [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 a dispersion-reduced propagation of the SPP waves [3].
By now loading few or single dye molecules in the few-nanometer gap region of the plasmonic structure, the propagation of SPPs across the narrow gap region can be changed by manipulating the electronic density of state of the molecule with femtosecond temporal precision by means of a time-delayed optical pump pulse [4].
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 molecule, 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 et al., under review at ACS Photonics
[4] P. Vasa et al. ACS Nano, **4**, 7759 (2010)