Coupling of Atomically Thin Semiconductors to Plasmonic Nanoantennas

Marko Petrić, Anna Nolinder, Michael Kaniber, Andreas Stier, Kai Müller, Jonathan Finley
Walter Schottky Institute, Technical University of Munich, Am Coulombwall 4, 85748 Garching, Germany
marko.petric@wsi.tum.de

Combining nano-optical systems with optically active two-dimensional materials has recently emerged as a fascinating topic to achieve new optical functionalities at the nanoscale [1]. In this contribution, we present investigations of light-matter interactions between transition metal dichalcogenide (TMD) monolayers and lithographically defined gold bowtie nanoantennas. By performing 3D-FDTD calculations, we tuned the design of the bowtie nanoantennas to match the dipolar resonance with the fundamental exciton transitions in a proximal MoSe2 monolayer. Fabricated bowtie nanoantennas show quality factors of $Q \approx 5$ and sub-10nm feed-gaps with estimated mode volumes as small as $V_m = 2000 \text{nm}^3$. Typical differential reflectance spectra recorded from individual TMD-bowtie nanostructures at room temperature reveal low- and high-energy peaks separated by a dip at the energy of the uncoupled exciton. To elucidate the nature of characteristic spectral features, we use the coupled oscillator model [2], which result in coupling constants at zero detuning of $g = 55 \text{ meV}$. This places our hybrid system in the weak-coupling regime with spectra exhibiting Fano-like behavior. Furthermore, we demonstrate active control of the optical response by varying the polarization of the excitation light. The methods developed in our work contribute to on-demand realization of optimally coupled TMD-nanoantenna systems that can be site-selectively addressed. This type of nanostructure could pave the way for on-chip actively controlled hybrid devices operating at elevated temperatures.

Figure 1: (a) Schematic representation of a TMD-bowtie hybrid nanostructure. (b)(c) Differential reflectance spectra recorded from single nanoantennas ordered by detuning to the exciton transition. Data reveals an anti-crossing-like behaviour. (d) Control of the optical response by tuning the polarization of the excitation light.