Coupling of Atomically Thin Semiconductors to Plasmonic Nanoantennas

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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 $MoSe_2$ monolayer. Fabricated bowtie nanoantennas show quality factors of Q = 5 and sub-10nm feed-gaps with estimated mode volumes as small as V_m = 2000nm^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 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.

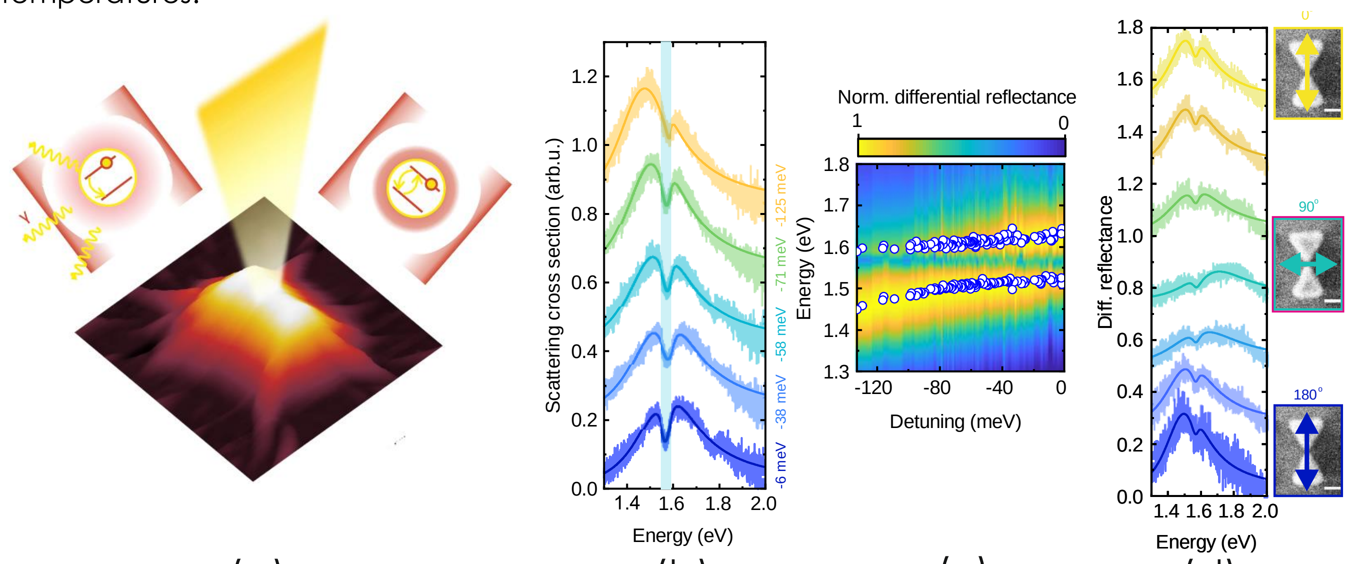

Figure 1: (a) Schematic representation of a TMD-bowtie hybrid nanostructure. (b)(c) Differential reflectance spectra recorded from single nanoantennas ordered by detuning to the exciton transition. Data reveals an anti-crossing-like behaviour. (d) Control of the optical response by tuning the polarization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

[1] Baranov et al. ACS Photonics 5(1), 2017, pp 24-42
[2] Wu, Gray, Pelton, Optics Express 18(23), 2010, pp 23633-23645