Directional emission and plasmon-exciton coupling in plasmonic nanostructures.

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We discuss several examples of coupled plasmonic nanostructures that are able to perform useful functions such as directing and spectral shaping of light. These abilities are governed by interactions between nanostructural elements. The first class of interactions that will be considered is a far-field type of interaction, specifically designed here to result in highly directional emission. We show several examples of such kind of behavior in materially asymmetric Ag-Au and Pd-Au dimers as well as asymmetric Au-Au pairs and its applications for color-routing and various kinds of sensing (Fig. 1a-c). The second class of interactions that will be considered is a near-field type of interaction, in this case between plasmons and excitons. Here, we report experimental observation of exciton-induced transparency on individual silver nanorods covered by J-aggregates (Fig. 1d).

In the first part of the talk, we will discuss plasmonic interactions leading to directional emission. A pair of detuned dipolar emitters positioned at a proper distance with respect to each other is well-known to generate directional emission pattern. To detune plasmonic resonances in such nanostructure pairs one could either vary sizes and shapes of the objects (see e.g. Fig. 1c) or, alternatively, break the compositional symmetry of the dimer (Fig. 1a, b). Using these simple and compact antenna designs, we have recently demonstrated directional color-routing in bimetallic Ag-Au nanoantennas and utilized similar arguments for single-wavelength and self-referenced hydrogen sensing in bimetallic Pd-Au dimers [1]. In the case of the color-router, we demonstrate spatial sorting of normally incident white light in accordance with its color (Fig. 1a). We also show that the effect of color-routing is polarization- and angle-dependent and that routing was only possible in heterometallic, but not in homometallic dimers. We have further utilized such material asymmetry concept for hydrogen sensing in the surrounding gas atmosphere by bimetallic Pd-Au dimers (Fig. 1b).

In the second part of the talk, we will discuss interaction between excitons and plasmons in the case of individual Ag nanorods covered by J-aggregates [2]. These hybrid systems were studied on an individual nanoparticle level by dark-field scattering and extinction as a function of particle dimensions. Particle spectra were shown to exhibit significantly suppressed scattering and extinction rates (see Fig. 1d) at the J-aggregate absorption band, signaling strong interaction between the localized plasmon in the metal core and the exciton of the surrounding molecular layer. The observed “transparency dips” correspond to an average vacuum Rabi splitting of the order of 100 meV, which approaches the plasmon dephasing rate and, thereby, the strong coupling limit for the smallest investigated particles. These findings could pave the way towards ultra-strong light-matter interaction on the nanoscale and active plasmonic devices operating at room temperature.
