Lithographically defined plasmonic bowtie nanoantennas on GaAs and SiO_2 substrates with proximal quantum emitters

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The local-field enhancements around structured metallic nanoparticles can strongly influence the strength of light-matter interactions over extreme sub-wavelength dimensions. For example, they give rise to strong enhancements of the spontaneous emission yield in hybrid systems that combine metallic nanostructures with proximal emitters and fluorophores [1],[2] and have been predicted to enhance the efficiency of photovoltaic devices [3].

Here, we present the simulation, design and fabrication of gold bowtie nanoantennas on GaAs and SiO_2 using electron beam lithography. We measure the surface plasmon resonance frequency (λ_{SPR}), characterize the impact of geometrical parameters and test the influence of the antenna on the radiative properties of proximal quantum emitters. Two different samples were fabricated with plasmonic nanostructures; (i) on SiO_2 decorated with implanted CdSe nanocrystals and (ii) on GaAs with near surface self-assembled InGaAs quantum dots. As shown in fig 1 (inset), high quality nanostructures with feed-gaps and tip radii as small as $d = 10$ nm (see fig 1) were realized, with simulated field enhancement factors of 10^3-$10^4\times$. White light reflectivity was used to determine λ_{SPR} and demonstrate that it can be continuously tuned in the range $1\mu m \geq \lambda_{SPR} \geq 700\, nm$ by reducing the nano-triangle size from $s = 200$ nm to 100 nm. This directly shifts λ_{SPR} into the range of optical activity of colloidal CdSe nanocrystals (~640 nm). For nano-antennas on GaAs, the much higher refractive index of the substrate ($n_{GaAs} = 3.5$ c.f. $n_{SiO_2} = 1.5$) shifts λ_{SPR} by ~300 nm to longer wavelength for similar structure sizes. On GaAs substrates, λ_{SPR} could be tuned into the emission range of InGaAs quantum dots (900 nm to 950 nm) opening the way to probe coupling phenomena. First investigations of the influence of such plasmonic bowtie antennas on the linear and non-linear optical properties of CdSe and InGaAs proximal quantum emitters will be presented and characterized as a function of the feed-gap size and the surface plasmon resonance wavelength.

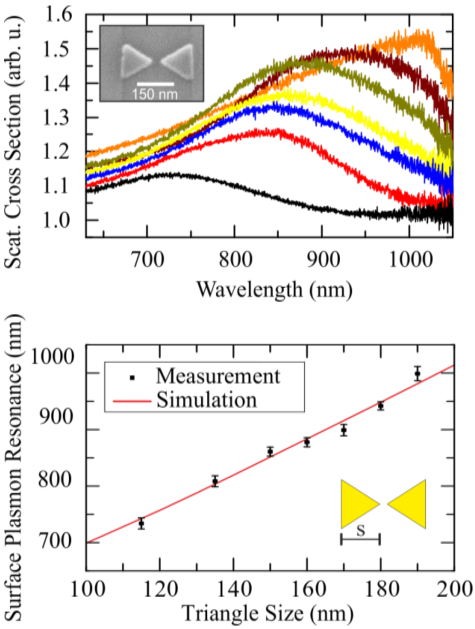

Fig. 1: Typical measurements and FDTD simulation of surface plasmon resonances for a 35nm thick gold bowtie nanoantennas on glass as a function of triangle size. The inset shows a SEM picture of a typical structure investigated.

[1] A. Kinkhabwala et al., Nature Photonics 3, 654-657 (2009)
[2] P.P. Pompa et al., Nature Nanotechnology 1, 126-130 (2006)
[3] H. A. Atwater & A. Polman, Nature Materials 9, 205-213 (2010)