Quantum Plasmonics and Single-Electron Detection for Ultrafast Picotransport

S. Großenbach[1], M. Gedamke[1], M. Falk[1], J. Fiedler[1], M. Ludwig[1], R. Tenne[1] and A. Leitenstorfer[1]

[1] *Department of Physics and Center of Applied Photonics, University of Konstanz, D-78457 Konstanz*

Plasmonics is based on collective oscillations of electronic charges in metallic systems forming giant dipoles. Nanostructures spatially constrict surface plasmons, leading to enhanced light-matter coupling. Together with excitation by single-cycle laser pulses, this fact enables confinement and control of currents at atomic spatio-temporal scales [1,2]. On these fundamental dimensions, quantum effects like electronic correlations and vacuum noise might strongly influence the electronic transport properties.

Current experiments on quantum plasmonics focus on the investigation of 100 nm spheres manipulated by atomic force microscopes or supramolecular interactions [3,4]. With few-nanometer gaps between the spheres, the physics can be described by an effective parallel plate model and many atoms contribute to the coupling.

Here, we present first results for the plasmonic resonance of gold nanoantennas with a single-atomic tunneling gap. It is embedded into the center of the antenna by a controlled thinning of the bridge connecting both arms via electromigration. We characterize the scattering spectrum of a single nanoantenna in the near infrared using dark-field spectroscopy. Simulations of the antenna response are in qualitative agreement with the measured spectra. They also show that reducing the gap results in a redshift of the resonance frequency (see Fig. 1), diverging at sub-nanometer distances. Thinning of the bridge also gives rise to a redshift. Quantum effects will need to be considered in the transition regime.

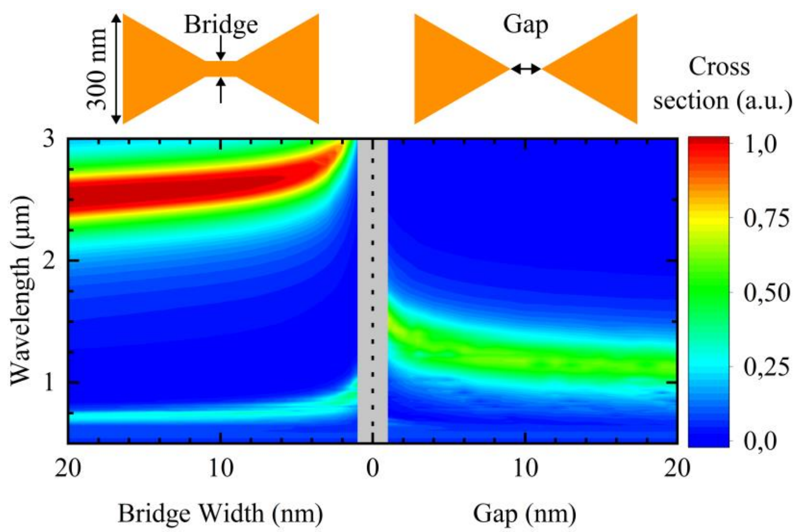

Fig. 1: *Plasmonic resonance of a 300-nm bow-tie antenna calculated by solving Maxwell's equations. In the point contact region (grey area), the resonance frequencies diverge, indicating a breakdown of the classical picture.*

Besides the photons emitted by the antenna, also electric currents induced by single-cycle laser pulses carry information on the quantum state of the contact. Currently, the picoampere average currents are detected in a time-integrated way and information on the charge statistics of individual tunneling events is lost. We will also present first results on a current measurement scheme based on radio-frequency single-electron transistors [5] capable of single-pulse detection of such light-induced atomic-scale currents.

References:

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