Photoconductively loaded plasmonic nanoantennas as a building block for ultracompact optical switches

Nicolas Large[1,2], Martina Abb[3], Javier Aizpurua[1] and Otto L. Muskens[3]

[1]Centro de Física de Materiales CSIC-UPV/EHU and Donostia International Physics Center DIPC, Paseo Manuel de Lardizabal 4, Donostia-San Sebastian 20018, Spain
[2]CEMES-CNRS / Université de Toulouse, France
[3]School of Physics and Astronomy, University of Southampton, Highfield, Southampton SO17, 1BJ, United Kingdom
O.Muskens@soton.ac.uk ; aizpurua@ehu.es

Plasmonics has emerged recently as an extremely promising technological research area. Active control over subwavelength optical fields is important in several application fields (sensing, optical communication and quantum information technology). In the terahertz (THz) range, the conductivity of semidonductor has been used to control the transport of THz waves through the coupling to the surface plasmon modes of nanostructures [1]. Recent works have shown control over progressive loading of a nanoantenna, which could be understood in the framework of circuit theory [2].

Here we explore a plasmonic nanoantenna switch as a novel building block for ultracompact nonlinear photonic devices. We propose that the large light-matter interaction strength and fast dynamics of a single nanoantenna can be used to control both far- and near-fields. Tunability of the nanoantenna by impedance loading of its nanogap using a dielectric medium has been studied both experimentally and theoretically [3,4]. Our nanoantenna switch i based on a similar but conceptually very distinct approach using photoconductive loading of the nanoantenna gap. Figure 1 represents the principle of the photoconductively loaded nanoantenna built by two gold nanorods separated by a gap filled with amorphous silicon. The photoconductive gap loading results in a transition from a capacitively coupled ("OFF") to conductively coupled ("ON") state.

To investigate theoretically this concept we use the Boundary Elements Method (BEM) in a full electromagnetic calculation including retardation [5,6]. This method consists in solving Maxwell's equations by means of a distribution of surface charge densities and currents at the surfaces of the objects that interact selfconsistently with the incoming field. Figure 2 shows the extinction spectra of the nanoantenna for two free carrier densities (N_{eh}) resulting in the two switching "OFF" and "ON" states. The transition from the unswitched to the switched state results in a large red shift of the antenna resonance, an increase of the radiation efficiency (insets) and a strong modification of the near-field distribution (not shown here). The theoretical concept is generally applicable to a wide range of experimental designs and will be of importance for applications involving nonlinear optics and SERS, quantum emitters and coherent control.

References

[1] H.-T. Chen et al, Nature Phot. **3**, 148 (2009).
[2] M. Schnell, A. Garcia-Etxarri, A. J. Huber, K. Crozier, J. Aizpurua, R. Hillenbrand, Nature Phot. **3**, 287 (2009).
[3] A. Alù and N. Engheta, Nature Phot. **2**, 307 (2008).
[4] J. Berthelot et al, Nano Lett. 9, 3914 (2009).
[5] F. J. García de Abajo and A. Howie, Phys. Rev. Lett. **80**, 5180 (1998).
[6] J. Aizpurua et al, Phys. Rev. B **71**, 235420 (2005).

Figures

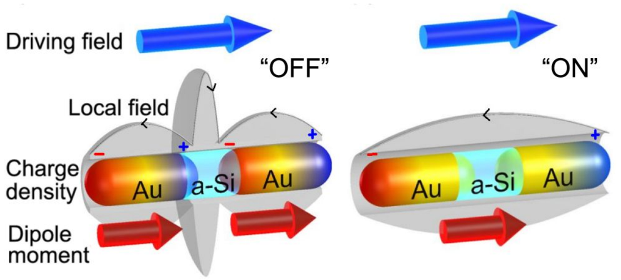

Figure 1- Principle of operation of the antenna switch, showing transition from capacitively coupled gap ("OFF") to conductively coupled gap ("ON").

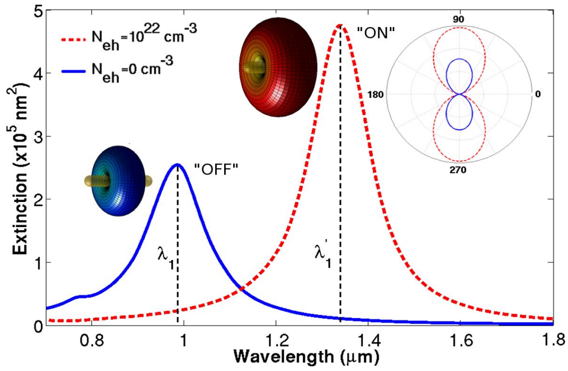

Figure 2- Calculated extinction spectra of nanoantenna switch, with radiation patterns (insets).