Near-field imaging and tuning of plasmonic particle modes: weak and strong interacting regimes

Aitzol Garcia-Etxarri[1,2], Martin Schnell[4], Isabel Romero[1], F. Javier García de Abajo[3], Rainer Hillenbrand[4], Javier Aizpurua[1,2]
[1]*Donostia International Physics Center -DIPC-,20018 Donostia-San Sebastián, Spain,*
[2]*Centro Mixto de Física de Materiales CSIC-UPV/EHU, 20018 Donostia-San Sebastián, Spain*
[3]*Institute of Optics CSIC, 28006 Madrid, Spain*
[4]*CIC NanoGUNE Consolider, 20009 Donostia-San Sebastián, Spain*

Surface plasmons in metallic nanoparticles have become a powerful driving force in the scientific and technological development of nanooptics. Since a surface plasmon mode is extremely sensitive to environmental changes, the process of measuring, controlling and extracting information on the near-field of a plasmon pattern needs a fundamental understanding of the role of the interacting-probe in the process of measurement.

Here we establish a basis for the interpretation and control of the electromagnetic near-field in plasmonic nanoantennas probed by a tip in scattering-type scanning near-field optical microscopy (s-SNOM) [1-3].

We experimentally demonstrate weak and strong probe-antenna coupling regimes in gold nanodisks with use of two different atomic force microscope tips: a tip formed by a nanotube showing a weak dielectric response (schematics on the left-hand side of Fig.1a) and a Pt tip showing the typical optical response of a metal (Fig.1b). The experimental images of the nanodisk plasmon patterns obtained for the same sample are shown on the right-hand side of Fig.1 for each case respectively (top CNT tip and bottom Pt tip). A clear asymmetric dipolar pattern, associated with an undistorted disk plasmon is obtained for the carbon nanotube (left-bottom), whereas a distorted pattern is clearly observed when the Pt tip is used (right-bottom).

By means of full electrodynamical calculations based on the Boundary Element Method (BEM) [5-6] (middle images) we address the interaction of the disk with a strongly-interacting point-dipole probe (right) and provide an understanding of the influence of the AFM tip in s-SNOM, allowing for mapping and mechanical tuning of the antenna response of the gold disk. A simple model based on a dipolar interaction between the probe and the sample explains the asymmetric image obtained in the strongly interacting regime.
Moreover, Near-field spectral analysis of the optical antenna [6] shows that a control of the plasmon response can be achieved by varying the dielectric properties of the tip, the interaction distance or by modifications of the characteristics of the incoming radiation. Both image interpretation and tuning capability are aspects of utmost importance in nanophotonics due to the prospects of ultrahigh-resolution amplitude and phase mapping of antenna modes.

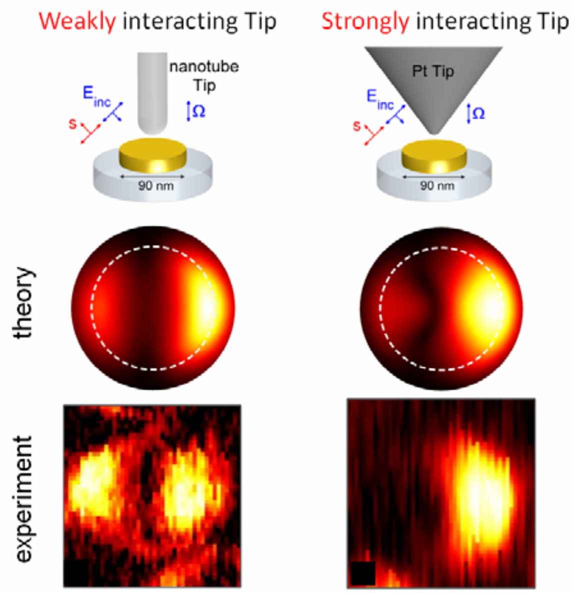

Fig.1: Top: Schematics showing the experimental configuration for a weak probe-sample interacting regime with use of a carbon nanotube tip (a) and a strongly interacting regime given by a Pt tip (b). Middle: Calculations of s-SNOM images of a gold nanodisk with use of a weakly interacting dipole probe (left) and with a strongly interacting dipole probe (right). Bottom: Experimental images of the near-field amplitude are shown in the two different coupling regimes.

[1] R. Hillenbrand, F. Keilmann, P. Hanarp, D.S. Sutherland and J. Aizpurua, APL 83, 368 (2003)
[2] R. Esteban, R. Vogelgesang, J. Dorfmüller, A. Dmitriev, C. Rockstuhl, C. Etrich, and K. Kern. Nano Letters 8, 3155 (2008).
[3] M. Rang, A. C. Jones, F. Zhou, Z.-Y. Li, B. J. Wiley, Y. Xia, and M. B. Raschke, Nanoletters 8, 3357 (2008)
[4] F. J. Garcia de Abajo and A. Howie, Phys. Rev. Lett. 80, 5180 (1998);
[5] F. J. Garcia de Abajo and A. Howie, Phys. Rev. B. 65, 115418 (2002).
[6] Ghenuche P, Cherukulappurath S, Taminiau TH, van Hulst NF, Quidant R, PRL 101, 116805 (2008)