Ferromagnetic Plasmonic Nanoantennas

J. Chen[1,2], P.Albella[1,2], Z. Pizadeh[3], P. Alonso-González[1], F. Huth[1], P. Vavassori[1,4], A. Dmitriev[3], J. Aizpurua[2] and R. Hillenbrand[1,4]
1 CIC nanoGUNE Consolider, 20018 Donostia-San Sebastián, Spain
2 Centro de Fisica de Materiales (CSIC-UPV/EHU) and Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastián, Spain
3 Department of Applied Physics, Chalmers University of Technology, 41296 Göteborg, Sweden
4 IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain

Optical antennas are devices designed to efficiently convert optical radiation into localized energy and vice versa.[1] Currently, there is great interest in the development of magnetic optical nanoantennas that combine optical nanofocusing properties with magnetic functionality. Such antennas would be interesting for bioseparation, drug targeting and cell isolation.[2] However, plasmons in ferromagnetic materials are typically strongly damped. A common strategy to overcome this problem is to develop hybrid structures consisting of noble metals and ferromagnetic materials.[3] Plasmon properties of pure ferromagnetic nanostructures are a widely unexplored terrain, although pure ferromagnetic structures offer the advantage of stronger magnetic polarization and less demanding fabrication.

Here we report an experimental and theoretical study of the optical properties of ferromagnetic nanostructures fabricated purely of nickel. By far-field extinction spectroscopy (Fig. 1a) we provide direct experimental evidence of particle plasmon resonances in nickel disks and ellipsoids. In order to identify the mode associated with the resonance peak, we imaged amplitude (Fig. 1b) and phase (Fig. 1c) of the vertical near-field component using a scattering-type scanning near-field optical microsocpe (s-SNOM) operating at 633 nm wavelength. In the amplitude image we observe two bright spots aligned along the polarization direction, which are oscillating out of phase for 180°. Such a near-field pattern provides direct experimental evidence of a dipole mode, which has been observed earlier for plasmon-resonant gold disks.[4,5] We emphasize that we also clearly observe the transverse plasmon mode in the elliptical antenna.

Performing numerical calculations, we find significant differences between far- and near-field spectra of plasmonic nickel antennas, which are indicated experimentally by comparing single-wavelength near-field images and far-field spectra. We find that the near-field resonance is dramatically red shifted compared to the far-field resonance. This is a fundamental behavior already reported earlier for gold nanoantennas[6], but which is not fully understood yet. We will discuss these shifts theoretically. We also discuss a simple harmonic oscillator model revealing that a major contribution to the shift between near- and far-field resonances is a consequence of the plasmon damping.

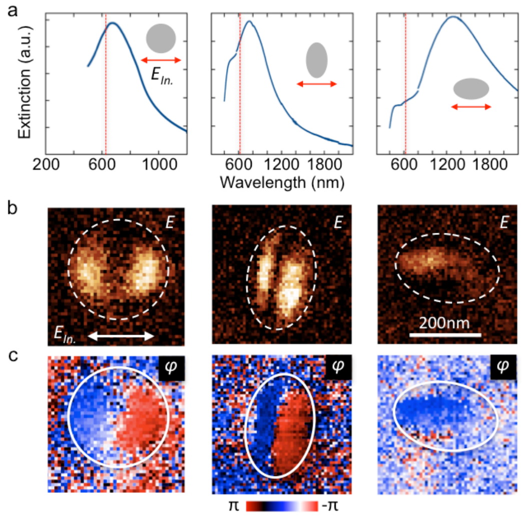

Fig. 1: Plasmonic nickel nanoantennas. (a) Extinction spectra of circular and elliptical nickel antennae. The red line in the spectra marks the wavelength λ=633 nm where near-field imaging was performed. The arrows indicate polarization of incident light. (b) Near-field optical amplitude images *E*. The arrow and bar denote the polarization of incident laser and scale of the images. (same for all three particles) (c) Near-field optical phase images *φ*.

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