Parallel Collective Resonances in Arrays of Gold Nanorods

Alan Vitrey[1], Lionel Aigouy[2], Patricia Prieto[1], José Miguel García-Martín[1], María U. González[1]

[1]IMM-Instituto de Microelectrónica de Madrid (CNM-CSIC), Isaac Newton 8, 28760 Tres Cantos, Madrid, Spain
[2]Laboratoire de Physique et d'Etude des Matériaux (LPEM), UMR CNRS 8213, Ecole Supérieure de Physique et de Chimie Industrielles (E.S.P.C.I.), 10 Rue Vauquelin, 75231 Paris Cedex 05, France
alan.vitrey@imm.cnm.csic.es

Localized surface plasmon resonances (LSPRs) sustained by metallic nanostructures have been shown to be suitable for various applications such as sensors and SERS because of the sensitivity of their extinction peak to environment modifications and their capability of enhancing the near-field intensity. Several works have pointed out that these properties are improved when the LSPRs couple with diffraction orders in periodic arrays of nanostructures [1-3]. Indeed, this coupling can induce a sharp peak of extinction which is associated to an intense enhancement and delocalization of the near-field. Recent studies have successfully demonstrated the benefit of these resonances −named lattice, geometric, or collective resonances− to a large range of applications, from the above mentioned SERS and sensing to the enhancement and control of spontaneous and stimulated emission [4-7]. However, these resonances undergo a damping in presence of a difference of optical index between substrate and superstrate, which could lead to their disappearance at glass-air interfaces.

The canonical configuration of these collective resonances consists in coupling the LSPRs with the evanescent diffraction orders travelling orthogonally to the dipolar moment of the nanostructures [1-3].
Recently, we have focused our attention on what we call the parallel coupling configuration, which involves diffraction orders propagating in the direction parallel to the dipole axis. In this work [8], we have analyzed the far- and near-field properties of arrays of gold nanorods (shown schematically in Fig. 1) with different coupling conditions between the LSPRs and the collective resonances depending on their geometrical characteristics. To carry out this investigation, we have performed extinction measurements and Scanning Near-field Optical Microscopy (SNOM). Figure 1 shows the scheme of principle of the SNOM technique we have used. Extinction spectra and SNOM images are compared to FDTD calculations, and a good agreement between experimental and numerical results has been achieved (see Fig. 2a and b for the far- and near-field results respectively). We show that parallel collective resonances can be excited even for a system with a glass-air interface while no major orthogonal coupling is observed, which could indicate a difference of robustness to index heterogeneity between both kinds of lattice resonances. Moreover, it is also shown that parallel resonances give rise to a sharp extinction peak (Fig. 2a) and a delocalization of the near-field (Fig. 2b). The near-field distribution of the parallel resonances differs from that of the orthogonal configuration, since in the first case the field is delocalized vertically whereas in the case of the canonical coupling it occurs between the nanostructures.

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Figures

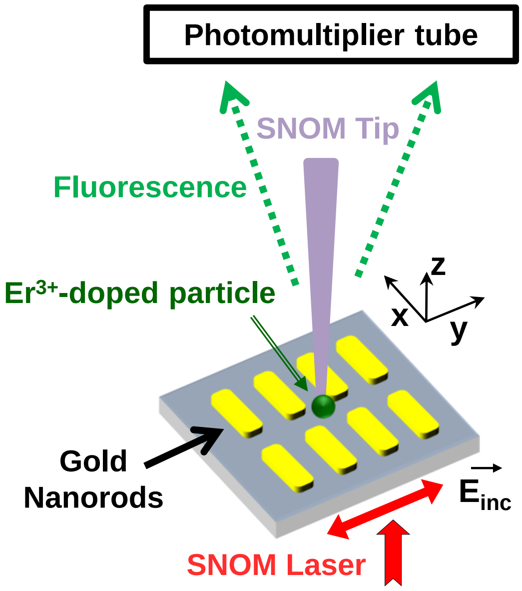

Figure 1. Schematic drawing showing the analyzed system of arrays of Au nanorods on glass and the SNOM configuration employed for the near-field measurements.

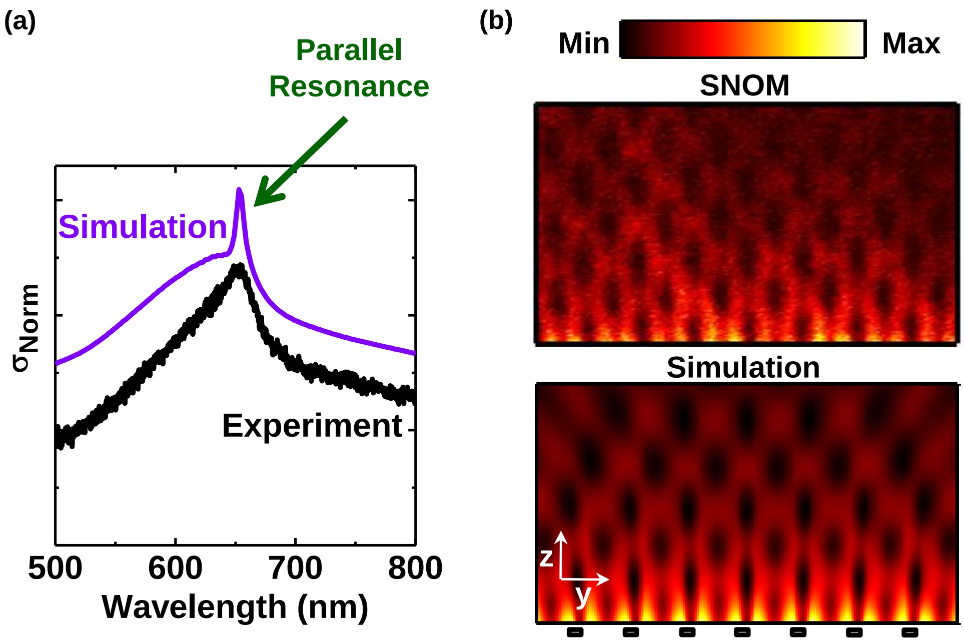

Figure 2. (a) Extinction cross-section spectrum of a Au nanorod array where the parallel diffraction order in air and the LSPR are strongly coupled, showing the presence of a parallel collective resonance. (b) Near-field distribution of this parallel collective resonance, obtained when only 16 periods within the array are illuminated.