Near-Field Localization of Au Nano-objects: PEEM and Group Theory Description

Sarra Mitiche1*, Sylvie Marguet2, Fabrice Charra1, Ludovic Douillard1
(1) Service de Physique de l’État Condensé SPEC CEA CNRS Université Paris Saclay, Gif sur Yvette, France
(2) Nanosciences et Innovation pour les Matériaux, la Biomédecine et l’Énergie NIMBE CEA CNRS Université Paris Saclay, Gif sur Yvette, France

Localised surface plasmon resonances (LSPRs) are coherent and collective oscillations of the conduction electrons in metallic nanoparticles (NPs) under the influence of an external electromagnetic field. The resonance wavelength depends on the nanoparticle characteristics, the external environment and the illumination geometry.

In this work, the optical response of various metallic nano-objects of different geometries and sizes, taken individually: triangles [1], cubes [2], hexagons,... or in groups: dimers (bowties), chains... are studied by PhotoEmission Electron Microscopy (PEEM), a non-intrusive and high resolution (20nm) mapping technique allowing a selective addressing of plasmon modes. The LSPRs are excited by a femtosecond pulsed laser source operating in the visible and near IR wavelength ranges, and the polarisation is adjusted with a half-wave plate.

In addition to the experimental investigation, the search for a specific optical near-field distribution is also carried out using group theory, an original theoretical method allowing to predict the results in just a few minutes. Further theoretical support is obtained by boundary element method (BEM) numerical simulations.

To illustrate our investigation, figures (1.a) and (1.b) display the experimental and numerical dipolar signatures of a subwavelength sized nanocube under grazing incidence in p polarisation. These results show a good agreement between experiment and group theory. Taking into account the object symmetry, the near-field distribution can be interpreted as a combination of two dipolar modes, one excited by an electric field component normal to the cube upper face and a second one excited by the in-plane electric field component parallel to the same face (figure (1.c)). Any change in the light polarisation modifies the near-field optic distribution, so we can selectively address NP plasmon modes by changing the polarisation of the incident light.

Figure 1. Near optical field mapping (a) PEEM (b) BEM simulation (c) Interpretation within a group theory approach.

To sum up, the plasmonic response of nano-objects depends strongly to the polarisation of the incident light and the object symmetry. Near field distribution of NPs of subwavelength size can be predicted within a group theory approach.

References

Corresponding author email: sarra.mitiche@cea.fr