Plasmon field tomography of coupled metallic nanoparticles

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Plasmonic modes in metal nanostructures induce field localization, strong coupling effects and high sensor sensitivity, properties that can be expressed by the photonic local density of states (LDOS). Coupling of metallic nanoparticles is recognized as a method for maximizing the photonic LDOS in the gap region between separate nanoparticles, but until recently no tool was available for the direct 3D nanoscale measurement of the photonic LDOS. However, to exploit the full potential of plasmonics, full 3D characterization becomes mandatory. Here EELS tomography-is used for understanding complex plasmonic nanoparticles created by electron beam lithography and by imaging local near-fields around nanoparticles and in gap regions in three dimensions.

We reconstruct particle plasmon fields from a tomographic tilt series of EELS spectrum images. While first approaches and demonstrations of plasmon field tomography were limited to very small particles [1] - small enough to neglect retardation - we lift this limitation with our approach making plasmon field tomography generally applicable to nanoparticles of all sizes. Formulation EELS tomography as an inverse problem allows reconstructing the complete dyadic Green tensor for plasmonic particles, from which the photonic LDOS can be calculated [2].

First, we use this approach for reconstructing the full 3D LDOS around a single cuboid silver nanoparticle, where we can observe the field distributions of a dipolar and a quadrupolar resonance (Fig. 1) [3]. Next we investigate nanoparticle dimers both in a lateral and in a vertical configuration, where coupling between the nanoparticles takes place (Fig. 2). In both these geometries we can reconstruct the near-fields of bonding and antibonding plasmonic modes. While for the lateral configuration a good idea about the near-fields can be already obtained from 2D, for the vertical configuration no distinction is possible from 2D maps, while in a 3D investigation the bonding and antibonding mode come out clearly [4]. Plasmon field tomography clearly reveals the strong near-fields in the gap regions of nanoparticle dimers, both in lateral and vertical arrangements.

This work generalizes plasmon field tomography to particles of all sizes and proves its general applicability, paving the way for detailed investigations of realistic and complex plasmonic nanostructures.

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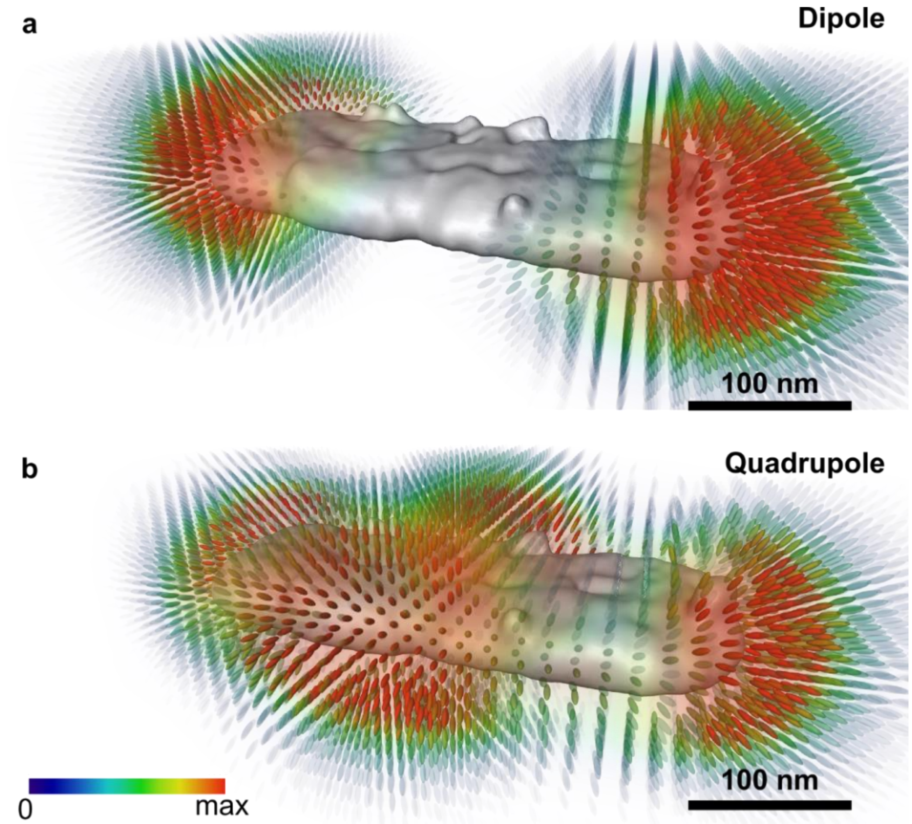

Figure 1: Reconstruction of the photonic LDOS around a silver nanoparticle for (a) a dipolar resonant mode, (b) a quadrupolar resonant mode [3]

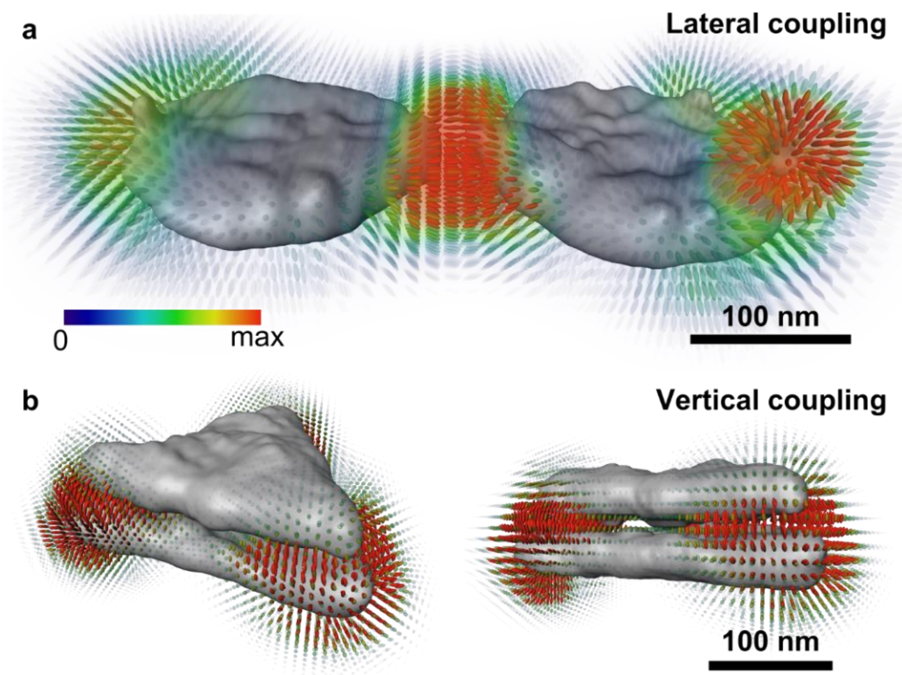

Figure 2: Coupling between metallic nanoparticles Reconstruction of the photonic LDOS for the bonding mode (a) around laterally coupled sliver nanodisks [3] (b) around vertically coupled silver triangles [4]