T-MATRIX APPROACH FOR FINITE PLASMONIC LATTICES: EXPLAINING THE FAR-FIELD EMISSION FROM DARK-MODE LASING

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The multiple-scattering T-matrix method [1] is a direct generalisation of the coupled dipole (CD) approach for computing the electromagnetic response of ensembles of compact scatterers (particles), which takes into account also the higher-order electromagnetic multipole polarisations of the individual particles. It applies to much broader set of problems than the CD approximation, while still retaining relatively low demands on computational resources. Therefore, it is suitable for problems involving finite lattices, where periodic boundary conditions cannot be used and some lower-level methods (such as the more popular FDTD method) would not be computationally feasible.

We use the method to explain experimentally observed far-field radiation from lasing in assumed dark and bright modes of a finite-sized plasmonic lattice [2] (Figure 1) at the visible wavelength. The system includes a finite square array of silver cylindrical nanoparticles in a dye gain medium. In the bright mode, electric dipole oscillations dominate in the nanoparticles, and the mode is coupled to the far field for both infinite (as in the FDTD simulations) and finite-sized lattices. On the other hand, the assumed dark mode is a high-Q mode, dominated by electric quadrupoles of the nanoparticles; for an infinite lattice, it would not be coupled to the far field, being indeed dark. We show that in a finite array, electric dipoles get induced with maxima along the edges of the array, coupling out to the far field in correspondence with the experimental observations. The results open a route to exploit the finite size of the lattice in order to utilize the high-Q modes of plasmonic lattices for studies of strong light-matter interactions, condensation and photon fluids.

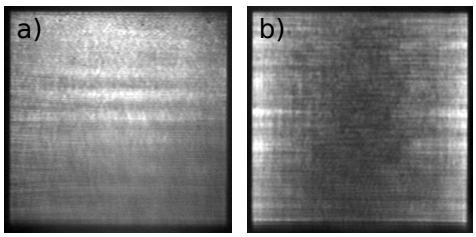

Figure 1: Experimentally observed real space images of bright (a) and dark (b) mode lasing in a finite-sized plasmonic lattice. The gain medium is pumped with light pulses polarised in the vertical direction.

[1] Yu-lin Xu, Phys. Rev. E 67, 046620 (2003).
[2] T. K. Hakala, H. T. Rekola, A. I. Väkeväinen, J.-P. Martikainen, M. Nečada, A. J. Moilanen and P. Törmä, Nature Communications 13687 (2017).