

# LASING IN DARK AND BRIGHT MODES OF A FINITE-SIZED PLASMONIC LATTICE

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In the presentation, I will show our results on lasing in plasmonic nanoparticle arrays at visible wavelengths [1]. The most startling result is that the lasing action occurs simultaneously in two modes at different energies, namely the bright and dark modes of the plasmonic lattice. We have found an intriguing out-coupling mechanism through which the dark mode can radiate to the far field. The out-coupling mechanism is based on the finite size of the array and is explained with gradual built-up of dipole moments in nanoparticles towards the array edges.

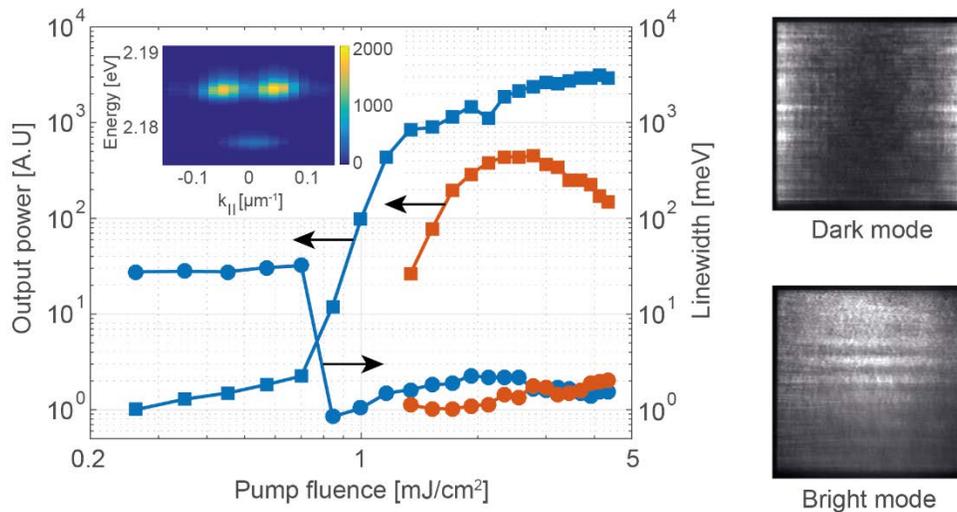


Figure 1. Left: Measured output power and linewidth of the dark mode (blue) and the bright mode (red) as a function of pump fluence. Inset: the momentum-energy distribution of the emission above threshold. Here,  $k_{||}$  refers to the in-plane momentum along one of the principal directions of the square lattice. Right: Real space distribution of the laser emission of the dark and bright mode, respectively.

We use an organic dye, Rhodamine 6G, as the gain material. The arrays consist of cylindrical silver nanoparticles with a diameter of 60 nm and a height of 30 nm, arranged in a square lattice. The periodicity is varied between 370 – 390 nm and the samples exhibit lasing in the wavelength range of 560 – 595 nm. We achieve a remarkably narrow linewidths of < 0.2 nm, beam divergence of 0.3° and a spatial coherence across the whole 100 x 100 μm<sup>2</sup> sized array. The results demonstrate a novel access to the dark mode and pave the way for studies of strong light-matter interaction and condensation phenomena in plasmonic lattices. In the presentation, I will also discuss recent advances related to this work.

[1] T. K. Hakala et al., *Nature Communications* **8**, 13687 (2017), [doi:10.1038/ncomms13687](https://doi.org/10.1038/ncomms13687).