Interaction between dipole emitters and 2D plasmonic nanoparticle arrays

Sean Rodrigues, Wei Zhou & Teri W. Odom

Northwestern University, 2145 Sheridan Road, Evanston, IL. USA
srodrig8@u.rochester.edu

Nanoparticle arrays have shown potential in creating feedback for lasing devices when immersed in organic dyes. The amplified stimulated emission from a gain medium between a periodic array of reflective surfaces results in distributed feedback lasing, when the amplification of the dye outweighs the loss due to absorption and leaking. Nanoscale DFB lasers have the potential to be used in photonic circuits and optical communications.[1]

Previously it was believed that the metal nanoparticles would quench the excitons formed within the organic dye, however as Forster et al. has shown, the addition of metallic nanoparticles will not quench the dye.[2] We believe these plasmonic effects can be used to tune or enhance the lasing that occurs within a nanoparticle array immersed in a polymer-dye gain medium. The effective cross section of incident radiation on the nanoparticle is increased by the local surface plasmon resonance of the nanoparticle. This increased electric field of the localized surface plasmon, can couple to the gain medium to produce more emission at a wavelength related to that of the leaking diffracted mode and enhance lasing. In this sense, the nanoparticle array has a second function as an optical antenna. Optical antennas improve the transition of local electromagnetic fields to propagating electromagnetic radiation in free space.[3]

The device is easily tuned by design or continuous modification. The absorption spectra of LSP's can be modified by the shape, dimension and composition of the nanoparticle, as well as the material of the dielectric. Thus the emission of the surface plasmons can be tuned to vary bandwidth outputs. Continuous tuning can be achieved by controlling the angle of incidence on the plasmonic material, thereby causing different diffraction modes. By varying these parameters, the stimulated emission within the device can be easily manipulated and tuned if the process is mediated by plasmonic factors.

The nanohole arrays were prepared using a combination of soft interference (phase shifting) lithography and PEEL, techniques created by the Odom Group of Northwestern. Soft interference lithography uses poly(dimethylsiloxane) (PDMS) stamps, created from a master mask that can be repeatedly adhered to photoresist surfaces and easily removed after UV exposure. The remaining surfaces have remarkable throughput.[4]

Gold nanohole array films were generated using soft interference lithography as seen on the left side of figure 1. Plasmonic metals were electron beam deposited through the nanohole array to generate nanoparticle arrays. A second layer of refractively indexed polymer is spin coated onto the nanoparticle array.

Initial results demonstrate potential for stimulated emission.[1] The gold nanoparticle array has a relatively narrow linewidth when pumped with increasing energies as seen in figure 2a. In figure 2b, our gold nanoparticle array demonstrates the linear relationship characteristic of lasing that begins at roughly 60uJ, the lasing threshold.

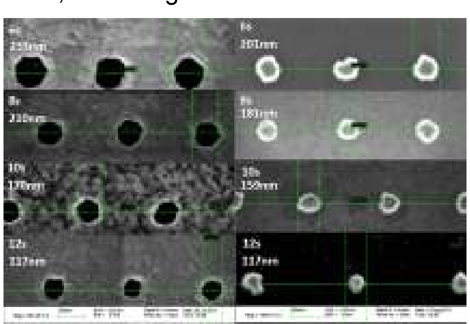

Figure 1

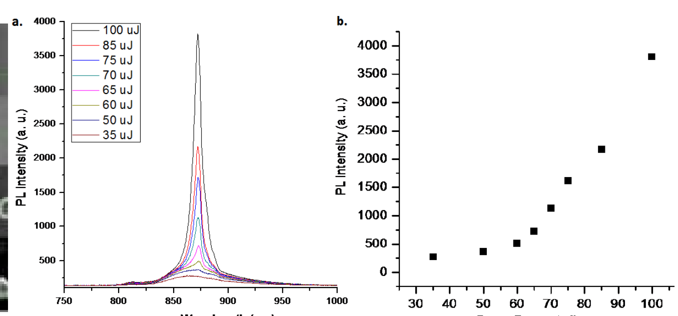

Figure 2

References

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