Electromagnetically Induced Transparency in Au:VO_2 Nanoparticles

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Plasmonic nanostructures exhibiting electromagnetically induced transparency (EIT) have been proposed as ultracompact sensors [1]. We increase detector sensitivity below that of purely plasmonic EIT structures by incorporating a switchable, phase-changing component to enable detection with a lock-in.

The plasmonic component of the nanoarrays is a geometry in which strong coupling between radiant dipole and subradient quadrupole antennas produces EIT.[1] The phase-changing component is vanadium dioxide (VO_2), a transition metal oxide whose dielectric function changes as it undergoes an insulator-to-metal transition (IMT). Thermally inducing the IMT in VO_2 at 340K[2] modulates the dielectric environment of the plasmonic nanoarrays, shifting the wavelength of the plasmonic resonance of the EIT structures.[3] This change in wavelength can be measured using white light spectroscopy.

Three-dimensional full-field finite-difference time-domain simulations using Lumerical Solutions® were carried out to determine nanostructure dimensions which maximize the EIT transmission window and signal. The simulated response gold EIT structures before and after optimization are shown in Figure 1.

To fabricate the structures, VO_2 film was deposited on an ITO-coated glass substrate using electron beam deposition and annealed to form polycrystalline, switchable VO_2. Electron beam lithography and thermal evaporation were used to fabricate arrays of 40 nm thick of gold EIT structures. The dipole-quadrupole interaction was varied by changing the antenna-antenna spacing on the VO_2 substrate. Figure 2 shows a scanning electron micrographs (SEM) of the sample.

Spectroscopic indicate that (1) the thermally induced phase transition in VO_2 modulates the surface plasmon resonance of the EIT structures, blue shifting the resonance as the VO_2 becomes metallic and (2) changing the antenna-antenna distance modulates the transmission depth and alters the symmetry of the dips of the EIT curve, as predictued by FDTD simulations.

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[1] N. Liu *et al.*, Nature Materials 8(9), 758-762 (2009).
[2] H.W.Verleur, *et al.*, Phys. Rev. 172 (3), 788-798 (1968).
[3] J. Y. Suh *et al*., J. Opt. A: Pure Appl. Opt. 10 055202 (2008).

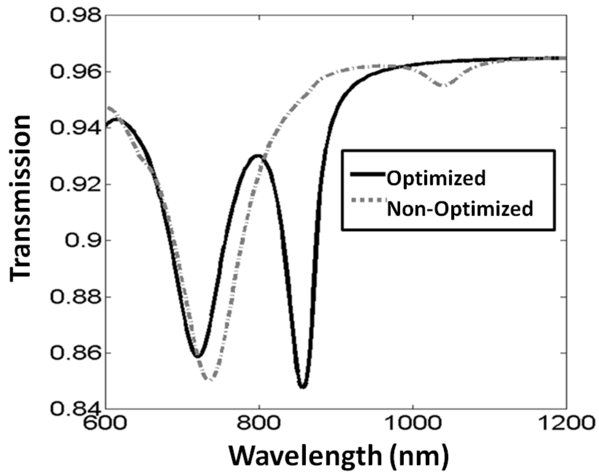

Figure 1: Effect of Optimization on EIT Structures: Simulated spectral response of optimized and non-optimized 40nm gold EIT structures on a glass substrate.

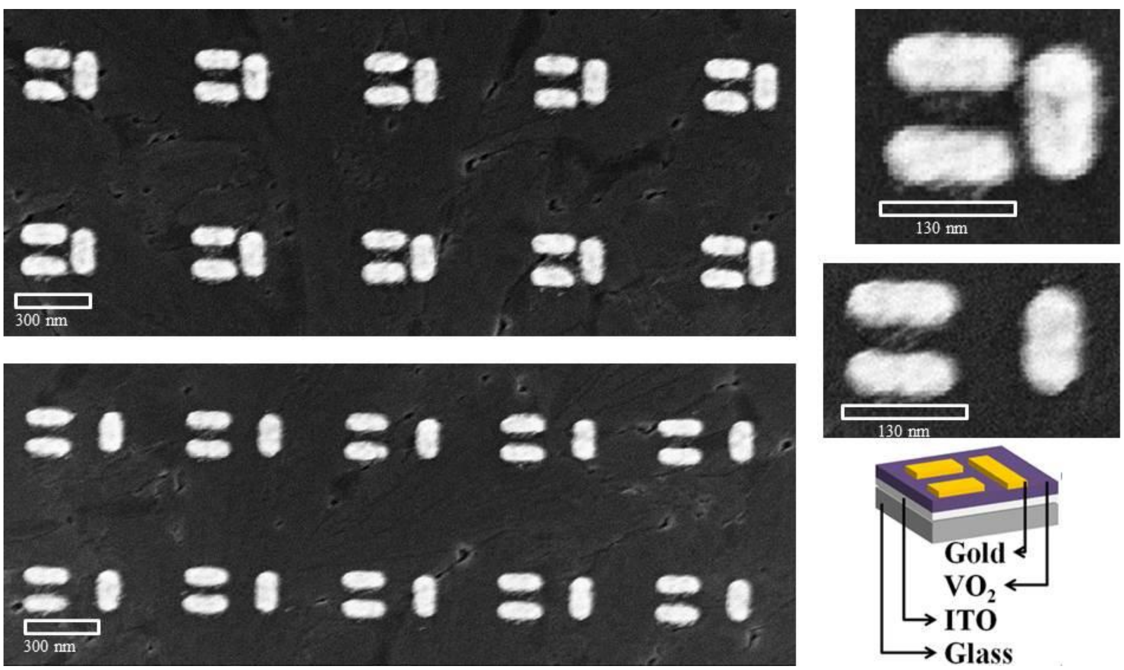

Figure 2: EIT Plasmonic Structure: Left - SEM images of arrays of gold on VO2 EIT structures with 20 nm and 90 nm antenna-antenna distances respectively. Right - SEM images of single nanostructures with 20 nm and 90 nm antenna-antenna distances respectively, and schematic showing gold on VO2 on ITO on glass.