Subwavelength Localization of Light on Double-periodic Nanowire Metamaterials

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Abstract: We relate localization of light to resonant transmission of planar metamaterial nano-wire array and show that due to plasmon resonance optical near-field distributions show a strong dependence on the wavelength and polarization.

Here for the first time we report simultaneous experimental spectral investigation of far-field transmission and near-field optical distributions at a double-periodic metamaterial at optical frequencies. We studied an aluminum-on-silica nanowire “fish scale” structure with a square unit cell of 440nm × 440nm (green square, Fig.1 (a)). The width of strips is 50nm. A frequency selective surface of its own rights, when sitting on metallic substrates, such kind of fish-scale metamaterial acts as an optical frequency “superconductor” and reverses the magnetic field of the incident wave upon reflection thus resembling a reflection from a hypothetical zero refractive index material, or “magnetic mirror” [1, 2].

Using a microspectrometer, we measured the far-field transmission spectra of the metamaterial sample, which is strong polarization dependent. For x-polarization incident light, the transmission resonance peak is at about 700 nm (Fig.1), while for y-polarization it is at about 1150 nm (not shown). Optical near-field distributions were measured using a scanning near-field optical microscope (SNOM) under transmission mode. Fig.1 (b-d) show fragments of the optical field distributions measured at the surface of the metamaterial sample at different wavelengths of excitation (550, 660 and 850nm, respectively). They show drastically different field distributions corresponding to different plasmon modes as shown in the transmission spectrum. Subwavelength hot spots harvesting optical energies are shown in Fig.1(b-d), which may be exploited as local enhancers for molecular Raman and fluorescence signal, therefore will have potential applications in areas like surface enhanced Raman scattering (SERS) and biosensors.

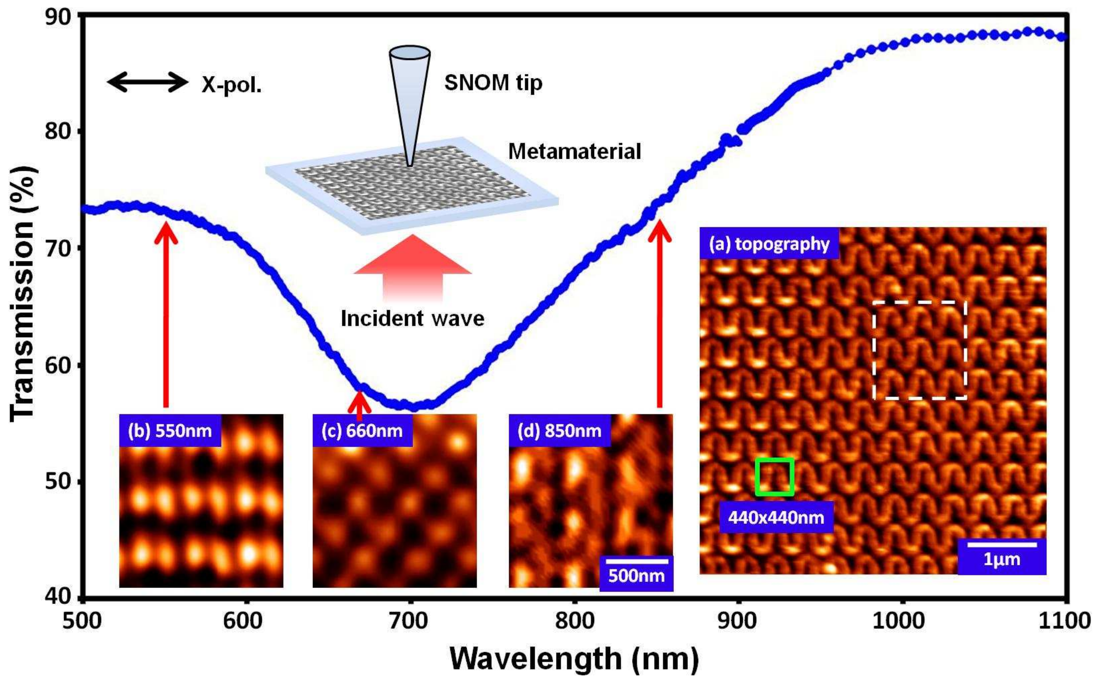

Fig. 1 The transmission spectrum (blue line) and optical near-field distributions (b-d) of a double-periodic nanowire metamaterial. (a) topography image of the sample. (b-d) fragments (dashed square area in (a)) of optical near-field distributions on the surface of the double-periodic nanowire metamaterial under different incident wavelengths. The polarization of incident light is along the x-axis, as indicated by the double arrow at the top-left corner. Insert: schematic diagram of SNOM measurement.

1. V. A. Fedotov, et. al., *Appl. Phys. Lett.* **88,** 091119 (2006).
2. A. S. Schwanecke, et. al., *J. Opt. A: Pure Appl. Opt.* **9**, L1-L2 (2007).