Extraordinary Optical Transmission in Copper-Based Devices at Terahertz Frequencies

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Abstract

While low frequency light is poorly transmitted through an aperture in a conductive thin film, in the phenomenon known as extraordinary optical transmission (EOT), a narrow band of selected frequencies are transmitted when incident on an array of subwavelength periodic apertures where the resonant frequency is determined by the geometry of the aperture array and the metal-dielectric interface [1]. This takes place due to the excitation of surface plasmon polaritons (SPPs) at the metal and dielectric interface. After SPPs are initiated at the apertures' edges when light is incident on the metal surface, they propagate along the surface of the metal and then decouple into free space and recouple at the apertures' edges [2].

Using the COMSOL Multiphysics® software RF Module, a three dimensional model is constructed in which a linearly polarized terahertz (THz) frequency electromagnetic plane wave propagates through an air-filled waveguide. A unit cell section of a copper-based EOT device (Figure 1) is modeled in order to verify theoretical calculations of the resonant frequency using S-parameter calculations. The simulation of the interaction of the THz light with the copper-based EOT device exhibits a resonant transmission at 0.86 THz (Figure 2), that is slightly red-shifted from the predicted 0.96 THz utilized in the device design. Such deviation of the predicted resonance has been seen experimentally as well for copper-based EOT devices with similar aperture dimensions [2]. The coupling of the SPP wave on the surface of the copper-based EOT can be seen in Figure 3(a). Future simulation work will study the effect(s) of a conductive thin film added to one surface of the device so as to evaluate the hypothesis that the thin-film's electromagnetic properties can be characterized using extraordinary optical transmission in order to advance characterization of novel thin film materials.

Reference

[1] H. F. Ghaemi et al. Surface plasmons enhance optical transmission through subwavelength holes, Phys. Rev. B, 58, 6779-6782(1998).

[2] A, Baragwanath et al. Time-of-Flight Model for the Extraordinary Transmission Through Periodic Arrays of Subwavelength Apertures at THz Frequencies, Plasmonics, 6, 625–636(2011).

Figures used in the abstract

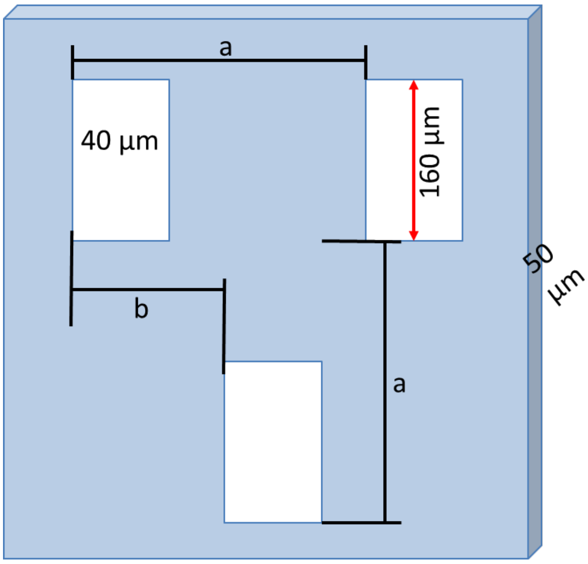

Figure 1: Dimensions of the copper-based EOT device. The resonant frequency is primarily dependent on the length “a."

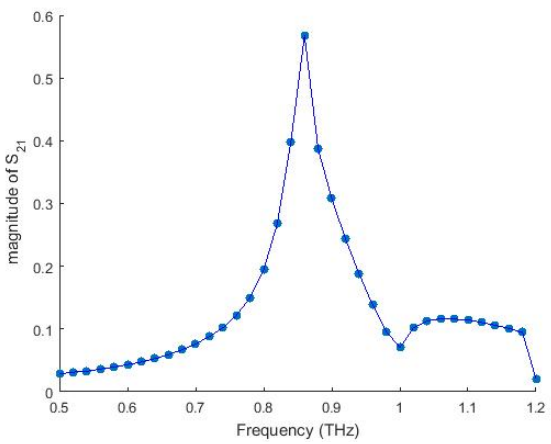

Figure 2: The magnitude of the S21-parameter of the copper-based EOT device, which exhibits a resonant frequency at 0.86 THz.

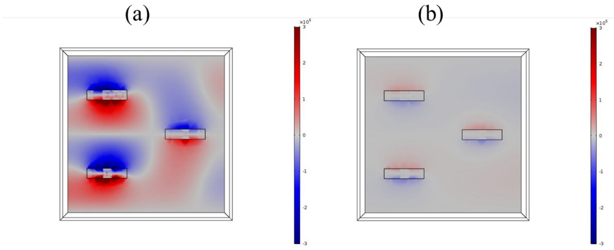

Figure 3: (a) The z-component of the electric field on the surface of the copper-based EOT device at 0.86 THz shows the coupling and propagating of the wave on the surface. (b) The propagation of the surface wave cannot be seen at a frequency lower than 0.60 THz. The intensity scale is the same for both images.