An Active Terahertz Magneto-plasmonic Device Based on a Cobalt Aperture Array

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***Abstract*—We demonstrate the ability to control the transmission of freely propagating terahertz radiation using a magnetic field. This is accomplished using a periodic array of subwavelength apertures fabricated in a free-standing metal foil coated in cobalt. Using a transverse magnetic field that corresponds to the Voigt geometry, we observe a quadratic change in the terahertz amplitude as a function of the applied magnetic field and dramatically larger than the response observed in any equivalent structure at optical frequencies.**

I. INTRODUCTION

WITHIN THE field of plasmonics, there has been significant work in demonstrating that the structure imparted to an otherwise planar metal film can give rise to a broad range of different responses. However, once such a structure has been fabricated, the response is typically fixed. One approach to allowing for allowing control over the response after the structure has been fabricated involves the use of ferromagnetic materials in the structure, which correspond to the excitation of magneto-plasmons. Until now, the bulk of the experimental work in this area has focused on developing devices that have been interrogated at optical frequencies [1]. In the presence of the external applied magnetic field, the propagation properties of the surface plasmons are altered such that an isotropic response, for example, becomes anisotropic. In the presence of a longitudinal magnetic field, this response is typically linear in the applied magnetic field. However, when the magnetic field is transverse to the propagation direction of the interrogating radiation, the response is typically quadratic. In this submission, we demonstrate that although we use a transverse magnetic field, the variation in transmission using a periodic aperture array is dramatically larger than equivalent studies at optical frequencies in any geometry.

II. RESULTS

To demonstrate this, we fabricated a periodic aperture array in a free-standing stainless steel metal foil. We then uniformly coat the structure with a ~1µm thick gold film on all sides. The array consists of 750 µm diameter apertures periodically spaced by 1.5 mm on a square lattice fabricated in a 75 µm thick metal foil. Since the skin depth of gold is ~150 nm, the gold film is much thicker than two skin depths, such that surface plasmons do not see the underlying medium (stainless steel). We use a commercial cw THz spectroscopy system that can scan from 0.05 – 1.5 THz. Given that the lowest order transmission resonance has a peak at 0.174 THz, independent of the metal coating, we only scan in a $\pm$ 20 GHz range about that peak as a function of the applied magnetic field. The observed transmission properties are shown in Figure 1 below. In both sets of data, the percent amplitude change is given by $(E_{magnetic} - E_0)/E_0$, where $E_{magnetic}$ is the transmitted THz radiation in the presence of the magnetic field and E_0 is the transmitted THz radiation in the absence of magnetic field. In the case of the gold array, we observed a maximum change of ~0.21 %, but there was no clear trend and no observed no hysteresis. However, we observed a large (~5%) change when the array was coated with cobalt. We discuss the variation in the response and potential applications that may arise from such structures.

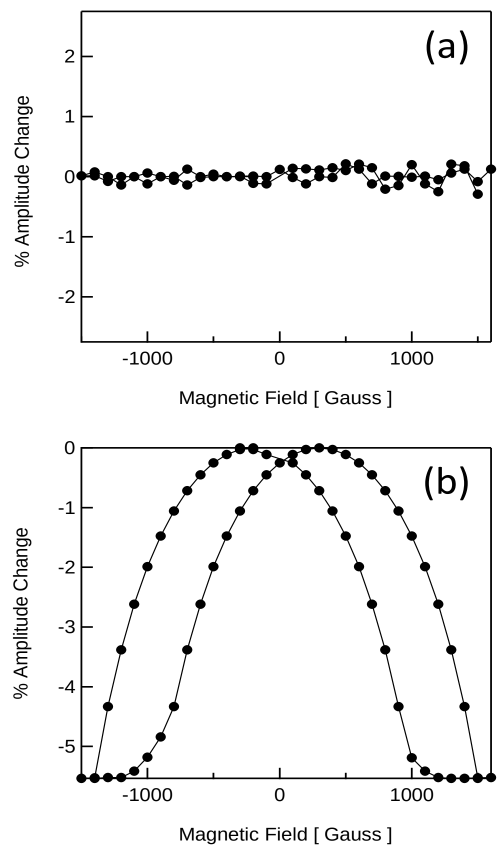

Fig. 1. (a) The percentage amplitude change of the transmitted THz radiation through subwavelength hole array. No hysteresis pattern is observed in the case of gold aperture array in the Voigt configuration. The maximum percentage amplitude change observed is ~0.21%. (b) The percentage amplitude change of the transmitted THz radiation through the subwavelength hole array. The change is measures at the peak of the resonance. The peak of the resonance changes slightly with the magnetic field. The variation of the percentage amplitude is quadratic for each cycle which is expected in the Voigt configuration. The maximum percentage amplitude change which occurs at the saturation magnetic field is ~5.2 %.

References

[1]. Strelniker, Y. M. & Bergman, D. J.. Phys. Rev. B **89**, 125312 (2014).