A Broadband THz Cutline Metamaterial Absorber

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Abstract: We demonstrate a broadband metamaterial (MM) absorber for THz frequencies. The MM was characterized in the spectral region of 0.3 - 3 THz with THz Time domain spectroscopy (TDS) using 1 mm ZnTe crystal for Electro-optic detection. A strong broadband resonance is observed, centered around 1.8 THz when the cut lines are aligned along the polarization of the THz electric field (0 degree). The Full width at half maximum (FWHM) of the resonance is ~ 1 THz. No such resonance is observed when the cut lines are aligned perpendicular to the THz electric field (90 degree).

Keywords: Metamaterials, THz Time domain spectroscopy.

1. Introduction

Frequencies between 0.1 - 10 THz constitute to the so called 'THz gap' which lies in between the microwave and optical regime. Extensive research is going on in this band of the spectrum due to its promising applications in the fields of security, pharmaceutical and imaging amongst many others [1-3].

Metamaterials are artificially engineered to exhibit properties not inherently seen in nature [4]. They could be seen as a very good candidate to manipulate THz frequencies as compared to natural materials due to their weak response and limited tunability. Here, we show the working of a broadband MM absorber in the THz frequency range. The MM was characterized in the spectral region of 0.3 – 3 THz with THz TDS using Electro-optic detection with 1mm ZnTe crystal. The measurement was gone with a frequency resolution of ~40 GHz, which is sufficient for our application. The MM was fabricated using E-beam lithography on a quartz substrate which was 500 µm thick, each unit cell consisting of a cutline 67.5 µm long, 2 µm width and 2D periodicity of the unit cell in the plane of the substrate was 50 µm as shown in Fig. 1.

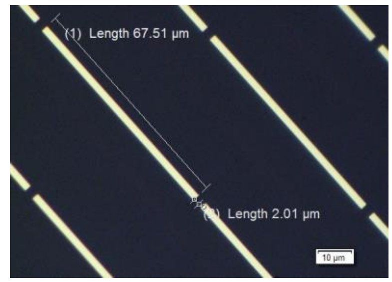

Figure 1. Microscopic image of MM with 100 nm gold.

2. Use of COMSOL Multiphysics

We used the RF module of COMSOL Multiphysics for designing and optimizing various parameters of the MM. We incident THz radiation perpendicular to the quartz substrate using Port excitation conditions. The electric field corresponding to their wave vectors are:

$$E_x = cos\theta e^{-iK_{az}Z}$$
$$E_y = sin\theta e^{-iK_{az}Z}$$

Periodic Boundary conditions were applied along the two orthogonal directions in the plane of the substrate. We computed S-parameters for the spectral range of 0 to 3 THz for two different orientations: when the cutlines were aligned along the incoming THz polarization and when they were orthogonal to the THz polarization. The Electric current density was also calculated at resonance which can be seen in Fig. 2.

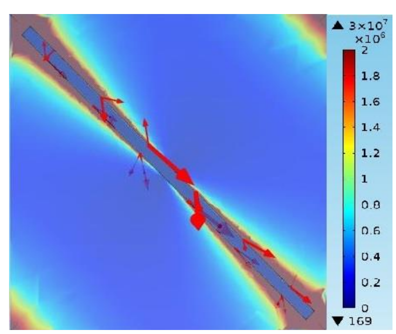

Figure 2. Electric current density with resonance at 1.8 THz.

3. Results

A strong resonance is observed at ~1.8 THz when the cutlines are aligned along the polarization on the incoming THz radiation as observed in Fig. 3 (0 degree). The resonance occurs due to the interaction of the cutlines with the incident THz field. Tuning of the central resonant frequency is possible by changing the length of the cutline, which effectively changes it inductance and capacitance if the MM is studied by LC circuit theory [5]. The full width at half maximum (FWHM) of the resonance was ~1 THz. No such resonance is observed when the lines are aligned perpendicular to the incoming THz polarization. (90 degree).

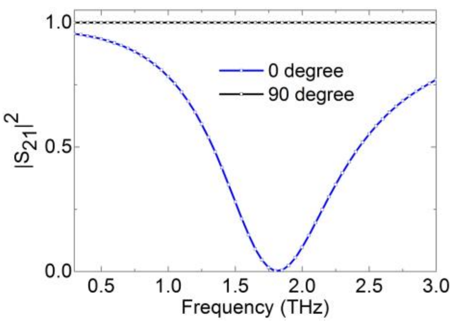

Figure 3. Simulated results of the MM exhibiting a broadband resonance at 1.8 THz.

It was observed experimentally that the resonance is shifted to ~1.4 THz and is narrower as compared to the simulated results which could be attributed to fabrication defects, see Fig. 4. The extinction ratio can be defined in terms of power transmission as:

$$ER\ (dB) = 10 log \frac{T_0}{T_{90}}$$

The experimentally observed ER was ~3.1 dB.

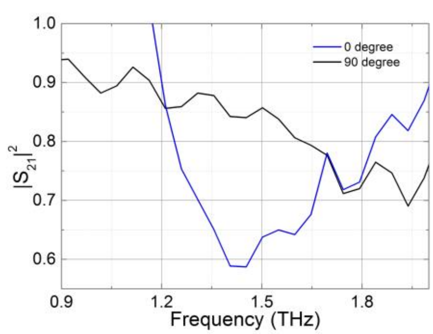

Figure 4. Experimental results of the MM exhibiting a broadband resonance at ~1.4 THz.

7. Conclusions

A cutline Metamaterial was simulated using the RF module of COMSOL Multiphysics which strongly resonated at 1.8 THz with the FWHM being ~1 THz. The MM was then fabricated using E-beam lithography and characterized using THz TDS. The experimentally observed value of extinction ratio was ~3.1 dB.

8. References

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