Investigation of terahertz surface plasmonic resonance based on metallic wire woven meshes

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1. Introduction

Terahertz (THz) plasmonic structures with surface plasmon polaritons (SPPs) based on periodic metal holes or slits have been investigated in the decade. THz electromagnetic waves can thus be trapped at the structural apertures with characteristic surface field, resembling the SPPs of normal metal. Therefore, THz plasmonic devices based on the surface-confined field can be applied for the optical sensing or spectral filter because of the response beyond the performance in free-space condition. In recent years, Fano resonances have been introduced as one important effect due to its superior characteristics with asymmetric and sharp spectral response [1–3]. Woven steel meshes were studied for the microwaves and THz waves due to the flexibility and deformable functions [4, 5]. The THz spectroscopic analysis on the meshes is revealed, but Fano resonance induced from the mesh structure has not found yet [4, 5]. In this paper, the metal wire woven mesh (MWWM) is experimentally investigated in the transmission spectrum of 0.1–1 THz and presented as a THz plasmonic structure with localized resonance field. The investigation expresses that the spectral-dip feature comes from the asymmetry of the MWWM unit, like Fano resonance, and the resonance field longitudinally covers the input and output end faces due to the woven wires, thereby having the large field volume for the near-field sensing applications.

2. Configurations and modeling

In this presentation, a MWWM is considered as one kind of THz plasmonic structure with Fano-like resonance, resulted from the asymmetric metal hole structure. Figure 1 (a) schematically plots the 3D structure of MWWM with the rectangle holes, constructed by vertical across layers of periodic metal wires.

3. Results and conclusion

Numerical simulations based on the finite element method (FEM) were used to compare the transmittance spectra in 0.1–0.9 THz between the MWWM and planar hole array with the same metal width (D) and structural pitch (Λ) of 0.08 and 0.254 mm, respectively. The spectral dip at 0.63 THz is observed in the transmittance spectrum of MWWM due to the double-layered 3D structure, in contrast to that of the planar hole array. The inset of Fig. 1(b) illustrates the calculated THz fields at 0.56, 0.63 and 0.70 THz, representing the waves at the rejection band, spectral resonance dip and transmission band, respectively. The field patterns exhibit opposite dipolar plasmonic modes on the metal-air interfaces with the accumulated fields at the wire bending sections. The rejection- and transmission-band fields are located only at input and output end-faces, but 0.63 THz resonance field is located at the both end-faces, resulting in very high power-distinction ratio with the spectral peak about 1000.

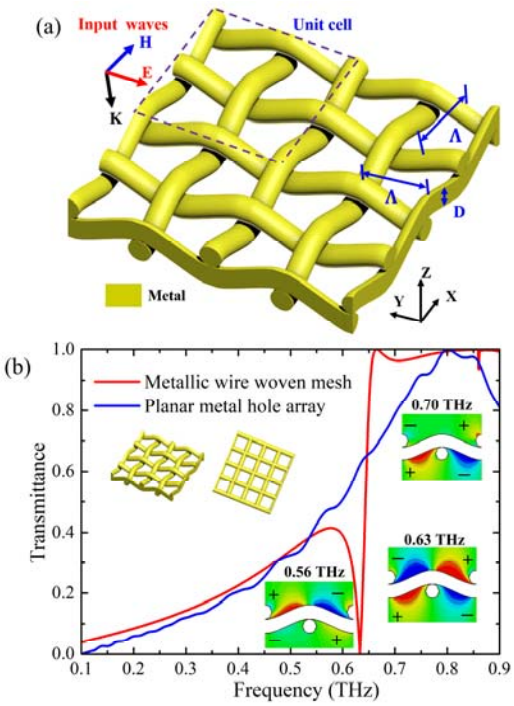

Fig. 1. 3D structure of MWWM. (b) Transmittance spectra of MWWM and planar metal hole array. (inset) THz field distributions in X-Z plane at 0.56, 0.63 and 0.7 THz.

References

[1] U. Fano, "Effects of configuration interaction on intensities and phase shifts," Phys. Rev. **124**, 1866 (1961).

[2] A. E. Miroshnichenko, S. Flach, Y. S. Kivshar, "Fano resonances in nanoscale structures," Rev. Mod. Phys. **82**, 2257 (2010).

[3] M. F. Limonov, M. V. Rybin, A. N. Poddubny, and Y. S. Kivshar, "Fano resonances in photonics," Nat. Photonics **11**, 543 (2017).

[4] C. Sabaha, M. D. Thomson, F. Meng, S. Tzanova, and H. G. Roskos, "Terahertz propagation properties of free-standing woven-steel-mesh metamaterials: Pass-bands and signatures of abnormal group velocities," J. Appl. Phys. **110**, 064902, (2011).

[5] M. Ghebrebrhan, F. J. Aranda, D. P. Ziegler, J. B. Carlson, J. Perry, D. M. Archambault, D. A. DiGiovanni, A. J. Gatesman, R. H. Giles, W. Zhang, E. R. Brown, and B. R. Kimball, "Tunable millimeter and sub-millimeter spectral response of textile metamaterial via resonant states," Opt. Express **22**, 2853–2859 (2014).