Phase singularity in double-layer metamaterial

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Electromagnetic wave experiences phase changing both in propagation and resonance. Extreme phase changing is interesting and has its applications. Here we report a phase singularity phenomenon in double-layer metamaterial.

Metamaterial as an artificial material with an array of subwavelength metallic structures has demonstrated its ability to control electromagnetic wave on amplitude, phase and polarization, both in propagation and resonance [1]. Metamaterial resonance modes, such as the capacitor-inductor (LC) resonance, dipole resonance, quadrupole, etc., are usually seen. Owing to the resonance, metamaterial devices show transmission/reflection dips or peaks in the spectra, where the phase information experiences a phase reverse. Usually the phase changing of one resonance is within 180 degrees. However, extreme phase changing is interesting and useful. In specific conditions, extreme phase changing can lead to a phase singularity. Researchers have demonstrated that metasurfaces can show a phase singularity with light reflection when the reflection approaches minimum [2-3]. While a transmission type phase singularity is as significant as the reflection type, but not yet been well investigated. Here in this work, we report a phase singularity phenomenon in double-layer metamaterial. We account for the phenomenon from two type of metamaterial resonances, the anti-parallel dipole resonance from the double-layer metallic patterns and the lattice resonance from the metamaterial lattice size.

The schematic of the double-layer metamaterial design is shown in Fig. 1(a), where we map the lattice size from L=150 μm to 170 μm for the simulation. The amplitude and phase shift are presented in Fig. 1(b) and 1(c). The blue area of transmission dips indicates metamaterial resonances, and the singularity pole is shown when the lattice size is close to 163 μm. From physics view, this work might help to investigate the coupled resonators system, while from application view, this work might help to design tunable metamaterial devices and sensing techniques.

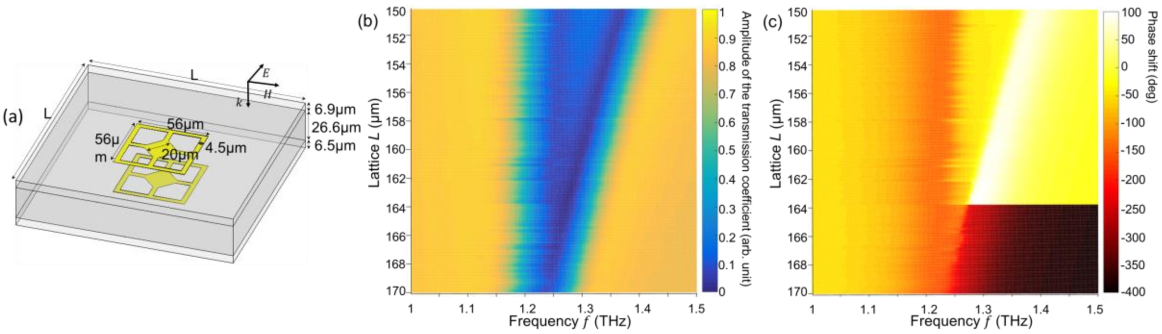

Fig.1 (a) schematic of the double-layer metamaterial. (b) Amplitude of the transmission coefficient from simulation. (c) Phase shift of the transmission coefficient from simulation. Around lattice L=163μm, a phase singularity pole is shown.

Acknowledgements: The authors would like to thank the micro system integration center (μSIC) of Tohoku Univ. for facility usage. This work was partly supported by JSPS Kakenhi (17K18368) and JSPS Kakenhi (17H01282).

Reference: [1] Optics Letters Vol. 43, Issue 12, pp. 2977-2980 (2018). [2] Nature Materials vol. 12, pp. 304–309, 2013. [3] 2D Mater. vol. 5, pp. 035018, 2018.