Near-field Coupling between Double-layer Metallic Patterns

°Zhengli Han[1], Seigo Ohno[1, 2], Yu Tokizane[1], Kouji Nawata[1], Takashi Notake[1], Yuma Takida[1],
Hiroaki Minamide[1]
([1]RIKEN Center for Advanced Photonics, RAP [2]Tohoku University)
E-mail: zhengli.han@riken.jp

Near-field coupling plays an essential role in near-field optics, such as the near-field scanning optical microscope (NSOM). Optimized near-field coupling can efficiently improve the system or device performance. In the metamaterial with subwavelength metallic structures, the control of the near-field coupling in between metallic patterns, especially in between difference layers of metallic patterns, can bring novel functionalities to metamaterial devices for optics. In this paper, we analyze the near-field coupling within a unit of double-layer metallic patterns to show a new strategy for metamaterial devices in terahertz (THz) optics.

Metamaterials with single layer metallic patterns [1], such as the very popular split ring resonator (SRR), have demonstrated their ability to form several different types of meta-devices among the spectra from microwave, THz, infrared, to visible. While the in-plane near-field coupling in between the metallic patterns of single layer usually limits the engineering capability on the near-field coupling, which results in the limitation of the metamaterial functionality. The out of plane near-field coupling with multilayers of metallic patterns provides additional freedom for the device design [2]. Figure 1 presents a metamaterial unit of double-layer SRRs and its numerical simulations on the surface currents under THz wave incidence with different polarizations. With particular distance designed between the double-layer SRRs to control the near-field coupling, it shows different behaviors under TE and TM modes of polarizations. Specifically, for TE mode, the loop currents associated with LC (inductor-capacitor) resonance on the top and bottom are in phase, while for TM modes, the dipole currents associated with dipole resonance are out of phase. On the other hand, the incident THz wave shows high transmittance with both the two modes, from which, a high performance THz-wave quarter wave plate is expected.

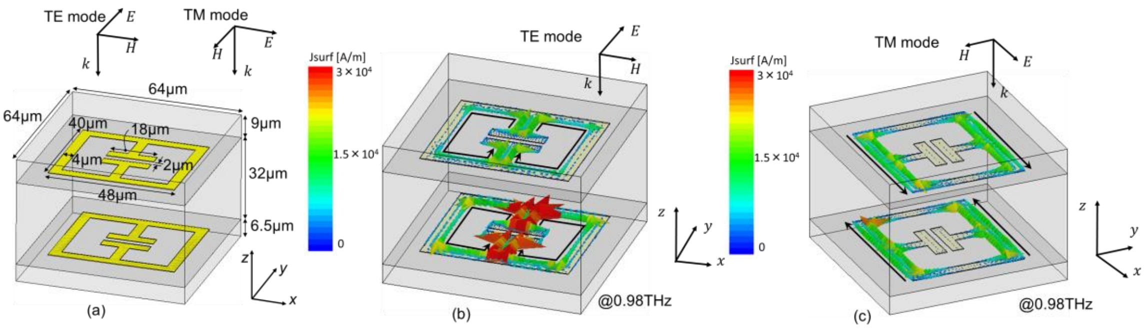

Fig.1 (a) Metamaterial unit of double-layer SRRs. (b) Surface currents distribution with TE mode at 0.98THz. (c) Surface currents distribution with TM mode at 0.98THz.

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

[1] Hou-Tong Chen, John F. O'Hara, Antoinette J. Taylor, Richard D. Averitt, C. Highstrete, Mark Lee, and Willie J. Padilla, "Complementary planar terahertz metamaterials," Optics Express Vol. 15, Issue 3, pp. 1084-1095 (2007).
[2] Z. Han, S. Ohno, Y. Tokizane, K. Nawata, T. Notake, Y. Takida and H. Minamide, "Thin terahertz-wave phase shifter by flexible film metamaterial with high transmission," Optics Express Vol. 25, Issue 25, pp. 31186-31196 (2017).