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# Electromagnetically Induced Transparency by Tuning of Dark Mode Resonators for Active Terahertz Metamaterials

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Electromagnetically induced transparency (EIT) is a quantum phenomenon which shows a narrow transparent window over a wide absorption spectrum. In recent years, however, EIT-like spectrum has been realized by using of metamaterials with the dark mode resonator [1,2,3]. These EIT-like spectra by metamterials can be explained by interactions between two metamaterials with different Q factors. As a response frequency of metamaterials depends on its structure size, EIT metamaterials offer unique prospects for future applications in wide range frequency from visible to terahertz region.

In this presentation, we propose and demonstrate novel EIT-like phenomena for active terahertz metamaterials. The unit cell of the metamaterials consists of a pair of ring resonators (split ring resonators: SRRs or closed ring resonators: CRRs) as a dark mode resonator and a rod as a bright mode resonator. The dark mode resonance is excited by bright mode resonator when the ring resonator pair is split, resulting in a giant amplitude modulation of the EIT resonance. Consequently, excitation of dark mode resonance can be controlled without changing relative potisions between dark and bright mode resonators.

Figure 1 shows scanning ion microscopy (SIM) images of the fabricated metamaterials. Two types of metamaterial: a rod resonator with SRRs (fig. 1a) and a rod resonator with CRRs (fig. 1b) were fabricated by using maskless UV lithography technique. The bright and dark mode resonators are designed to show same resonance frequency.

For the measurement of optical properties of the fabricated metamaterials, Fourier Transform-Infrared (FT-IR) was used. Figure 2 shows transmission spectra of the metamaterials with $E_y$ polarized incident light. The transmission spectra change drastically whether the resonator has gap or not. In the case of the structure with SRRs, a narrow transparent window occurs at around 6.3 THz. On the other hand, no transparent window appears in the structure with CRRs. Such distinctive change of the transmission spectra is attributed to interactions between a rod and ring resonators. Only SRRs can couple to a rod due to their resonance mode for $E_x$ polarized input, in contrast to CRRs.

The theoretical electric field at the resonance frequency will also be discussed.

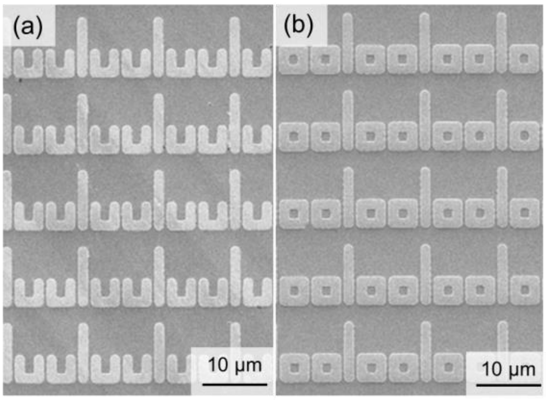


Fig. 1: SIM images of fabricated metamaterials. (a) Rod with SRRs. (b) Rod with CRRs. The micro-structure (110 nm thick silver, pattern area: 2.0 cm×1.5 cm) is patterned on a silicon substrate.

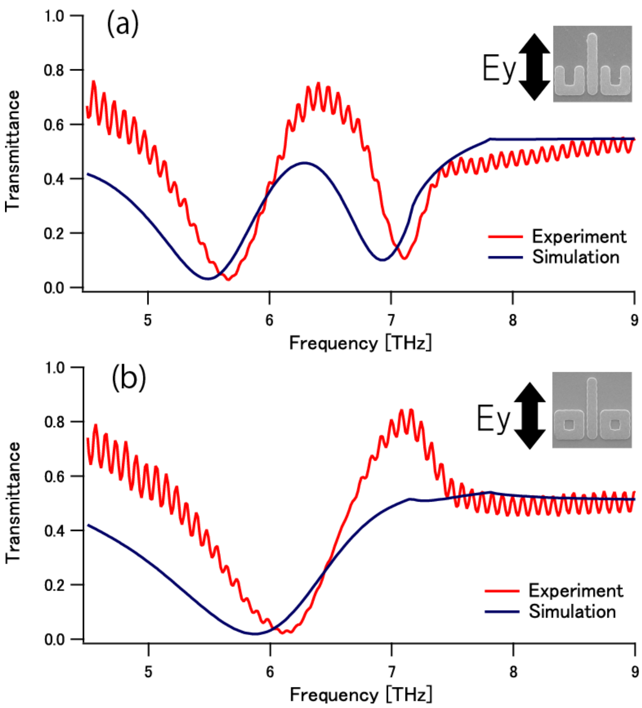


Fig. 2: Transmission spectra of EIT-like metamaterials with Ey polarized incident light. (a) Rod with SRRs (b) Rod with CRRs. Red and blue solid line presented experiment and simulation result respectively. Simulation spectra were measured by rigorous coupled wave analysis (RCWA) method. Inset: SIM image of unit cell of each metamaterial.

## References

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