# Switchable EIT-like effect realized by MEMS based metamaterial

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**Abstract**

In this paper a switchable EIT-like metamaterial is designed and tested. The metamaterial unit cell is reshaped through micro-electro-mechanical systems (MEMS) technology. By MEMS switching, the electromagnetically induced transparency (EIT) effect is simulated in the design. The EIT-like effect in metamaterial can be applied in slow light, optical switch and tunable filter.

## 1. Introduction

Metamaterial attracted many attentions because of its wide applications in super-lens, cloaking and slow light. For practical use for different frequencies, switchable metamaterial is desired. However, the switching range is quite limited under traditional method [1]. A complementary approach is to re-configure the metamaterial unit cell through MEMS technology where switching frequency is up to GHz [2-3]. In this paper, rather than switch resonant frequency by blue or red shift, a MEMS switchable metamaterial is designed to switch on resonances from a non-resonant state and the special switch effect is achieved by inducing EIT-like effect in metamaterial [4]. Similar with light pumping inducing resonance in EIT material, this metamaterial induces strong resonance by MEMS tuning.

## 2. Metamaterial device realizing EIT-like effect

Fig. 1(a) shows the schematic of metamaterial realizing switchable EIT effect. The 60 µm × 60 µm unit cell consists of a 2-cut SRR structure with two 50-µm-long metal slabs along the cut of the SRR. The wavelength of incident light is several times larger than the unit cell scale; the polarization is perpendicular with metal slab as in Fig. 1(b). At target light frequency, the SRR is excited and the induced resonance is defined as bright mode similar with that in EIT. Oppositely, at the same frequency, the resonance on metal slabs can only be induced by the coupling between SRR and metal slabs instead of the direct light excitation. This resonance is defined as the dark mode of the metamaterial.

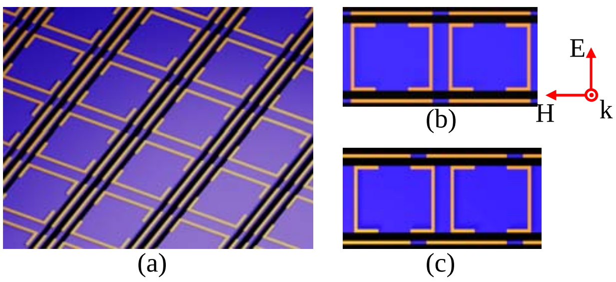


Fig. 1: (a) switchable EIT-like metamaterial; (b) symmetrical state and (c) asymmetrical state of two unit cells

To control the coupling between SRR and metal slabs, the metal slabs are released and suspended from substrate, which then connected with MEMS actuator. Under electrical pumping, the metal slabs can be shifted along its horizontal directions by MEMS actuator. The unit cell is defined as symmetrical state (Fig. 1(b)) before shift and asymmetrical state (Fig. 1(c)) after 15 µm shifting of metal slabs.

## 3. Numerical simulation and theoretical analysis

The transmission and reflection intensity of the metamaterial are numerically calculated using Finite Integration Technique (FIT) for both symmetrical and asymmetrical states of the metamaterial.

As shown in Fig. 2(a), the transmission resonant peak shifts from 1.04 THz at symmetrical state to 1.02 THz at asymmetrical state with a narrower FWHM. For symmetrical state, bright mode is induced by incident light on SRR structure. Both left and right half of SRR is coupled with metal slab, nonetheless, due to structure symmetric, the two couplings cancel each other and no dark mode is induced. As a result, only bright mode contributes to the resonance at 1.04 THz and surface current is strong on SRR while quite weak on metal slabs (Fig. 2(b)).

For asymmetrical state, the couplings of two parts of SRR with metal slabs are no longer the same, and the dark mode is excited with strong current induced on slabs at 1.02 THz (Fig. 2(c)). Due to the destructive interaction between left half SRR and metal slabs, the current drops on left SRR but remains the same on right SRR which couples with metal slabs weakly. Thus at asymmetric state, both bright and dark mode contribute to the resonance at 1.02 THz and narrow its FWHM.

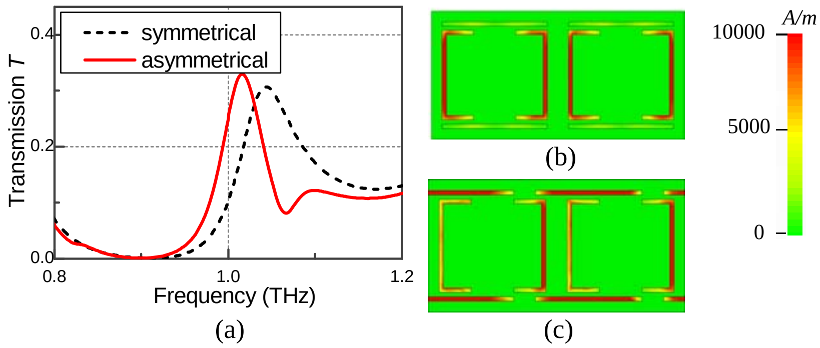


Fig. 2: simulated (a) transmission for symmetrical (black dash) and asymmetrical (red solid) states and surface current (b) at 1.04 THz for symmetrical state and (c) 1.02 THz for asymmetric state

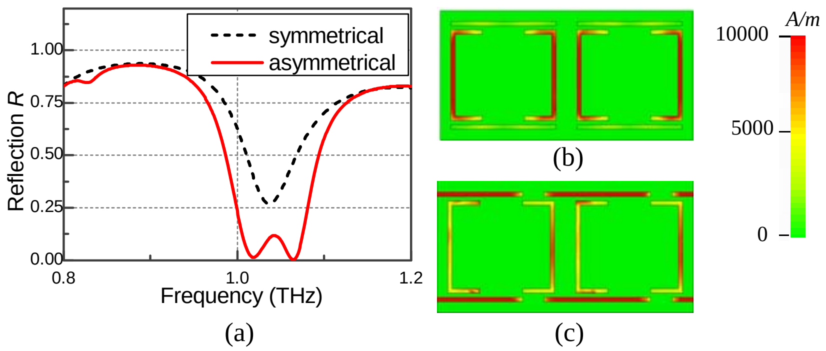


Fig. 3: simulated (a) reflection for symmetrical (black dash) and asymmetrical (red solid) states and surface current at 1.04 THz for (b) symmetrical state and (c) asymmetric state

The reflection spectra are also calculated (Fig. 3(a)). The resonant peak at 1.04 THz in asymmetrical state is due to destructive couplings of both half parts of SRR with metal slabs, resulting in current drop on the whole SRR and increase on metal slabs (Fig. 3(b) and (c)). So bright mode is suppressed and only dark mode contributes to the resonance, which induces an EIT-like peak.

## 4. Experimental results and discussions

The metamaterial of 160 × 160 unit cells is fabricated on silicon on insulator (SOI) wafer and the active area is 1 $cm^2$. The suspended slabs are connected with MEMS actuator through supporting beam. The SRR and slabs are patterned with aluminium thin films of 0.5-μm thickness and 2-μm width.

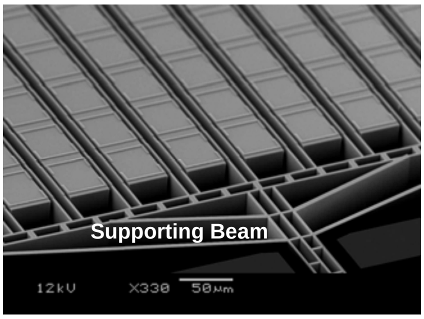


Fig. 4: SEM graph of switchable EIT-like metamaterial connected with the supporting beam

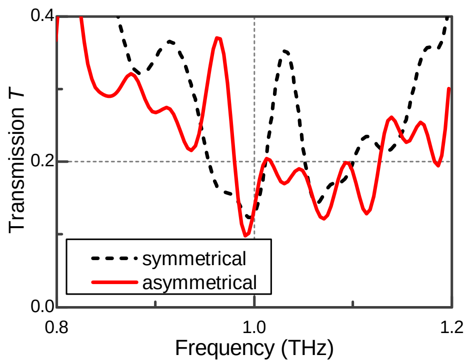


Fig. 5: measurement results of the transmission at symmetrical (black dash) and asymmetrical (red solid) state

The transmission spectra of symmetrical and asymmetrical state are measured using Fourier transform infrared spectroscopy (FTIR). The observed resonant peak shifts from 1.03 THz to 0.97 THz, indicating the EIT-like effect is induced. The resonant peak difference between simulation and experiment results may come from deviation of substrate thickness used in calculation and the actual sample, which affects the bright and dark mode peak to different extent. Due to the noise of substrate Fabry-Perot effect, the experimental transmission is higher than simulation at 0.8 THz to 0.9 THz range

## 5. Conclusions

A switchable EIT-like metamaterial was demonstrated. The triggering on of the EIT-like effect was theoretically analyzed and proved by numerical and experimental methods. Switchable EIT-like effect of the metamaterial in terahertz range enables it to be applied in THz switch and slow light.

## Reference

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