Multi Fano Resonances in Optical Metamaterial

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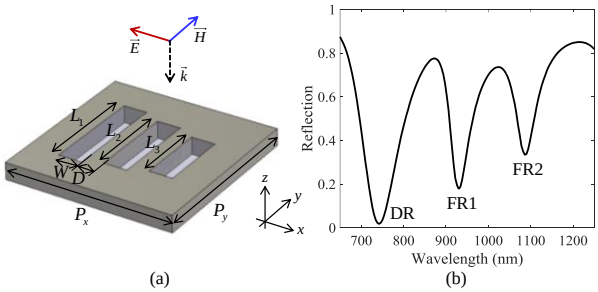
1. Introduction

Metamaterials are artificial electromagnetic materials composed of subwavelength metal structures, which have attracted a great attention due to a capability of controlling of electromagnetic waves in ultra-thin size. Fano resonance (FR) generation in metamaterials has the large number of potential applications in the development of sensors, filters, lasing and electro-optics [1], [2]. An asymmetric double bar (ADB) structure which is a pair of metal bars with slightly difference lengths has been studied for obtaining high quality factor (Q-factor) resonances in the optical spectral range [3]. In this study, we expand it to demonstrate FR in the schematic of not only metallic rods but also metallic slits using Babinet principle. In addition, we analyze multi FR in asymmetric triple bars and slits to achieve high sensitivity in optical region.

2. Simulation Results and Discussion

We analyze FR characteristics for an asymmetric double nanoslit structure which is complementary for ADB structure. Based on Babinet principle, FR occurs in the asymmetric nanoslit when electric field of the incidence wave is polarized perpendicular to long axis of the nanoslit. The asymmetric double slit has in-phase and out-of-phase magnetic field distributions in each slits, and that shows the same FR peak compared to ADB structure.

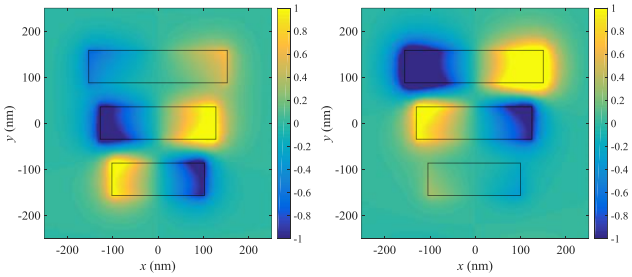


(a) (b)

Figure 1. (a) The unit cell scheme of asymmetric triple slit. The unit cell consists of triple nanoslit with lengths L1 = 300 nm, L2 = 300 nm, and L3 = 300 nm. The width W = 70 nm and the thickness T = 70 nm are same and each nanoslit is separated with the gap D = 50 nm. (b) Reflection spectrum of asymmetric triple slit structure.

To expand the aforementioned result, we demonstrate asymmetric triple nanoslit having multi FR in optical region as shown in Fig. 1(a). The proposed metamaterial is periodically arranged in *x*-*y* coordinates with the fixed period, $P_x = P_y = 500$ nm. Since the triple slits have slightly different lengths, the proposed structure shows different plasmonic resonances when compared with the conventional FR. It makes dipole resonance, the first FR, and the second FR which is indicated as DR, FR1, and FR2, respectively, in the Fig. 1(b).

In-phase resonance in all triple slits is present in the peak of the DR. Due to the selective resonance coupling, multi FR occur in two long slits and two short slits, respectively, as shown in Fig. 2. In addition, the DR and each FR have different values of sensitivity for sensor in optical region.



(a) (b)

Figure 2. Real parts of H_z component for (a) the FR1 and (b) the FR2. Real values of magnetic field are normalized for input light.

3. Conclusions

We expand FR in metamaterial structures of metallic nanorod to metallic nanoslit. The metamaterial of the asymmetric triple nanoslits having multi FR characteristic is proposed. The structure shows multi FR based on the selective FR coupling. Also, the DR and each FR in the proposed scheme have different sensitivities in optical region. The structure has advantage of plasmonic sensor having high sensitivity in optical metamaterial.

Acknowledgments

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