Impact of resonator rotational symmetry on infrared metamaterial absorber

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Abstract

We investigate the impact of rotational symmetry of the metamaterial perfect absorber on its performance. The calculated results show that a absorption peak appears at the same wavelength in the absorption spectrum no matter the polarization of the incident light parallels to *x* axis or y axis when the absorber possesses four-fold rotational symmetry. However, in the case of two-fold rotational symmetry, the absorption peak splits into two peaks when the polarization of the incident light parallels to *x* axis. The results of the absorption peak properties with different rotational symmetry may be helpful to design novel polarization-insensitive absorbers.

I. INTRODUCTION

Since Landy *et al.* [1] present that the perfect absorption can be achieved by adjusting the equivalent permittivity and permeability of metamaterials, the absorbers based on the metamaterials have caused widespread attention [2-3]. Compared with conventional absorbers, these absorbers has two strengths: the first one is its absorption frequencies can be tailored by changing the geometry of metamaterial units, which is very helpful for designing the appropriate perfect absorber for specific electromagnetic band applications. The second one is the device miniaturization. Their structural unit size as well as the entire thickness of the material are very small, which is very helpful for system integration and reducing noise.

Now, the perfect absorbers over wide range of frequencies, including terahertz [4], microwave [5], infrared [6] and optical [7] band have been investigated. Many characteristic absorbers, for example, polarization insensitive absorption [8], wide angle absorption [9], multi-band absorption [10] and broadband absorption [11] have achieved with various structures. Moreover, multi-band [12] or broadband [13] absorbers possess polarization insensitive and wide angle absorption features simultaneously have also been confirmed experimentally. It is worthy to simplify the absorber structure while keep these existing advantages. Because the polarization insensitive absorber provides more efficient absorption for the nonpolarized incident light, so how to make the new structure insensitive with polarization is very important.

In this paper, by introducing air holes at the edges of the metal square particle along the *y* direction, we investigate the impact of rotational symmetry of the metamaterial perfect absorber on its performance. The results show that when the polarization of the incident light parallels to *x* axis or *y* axis, the same single absorption peak appears in the absorption spectrum of the four-fold rotational symmetrical absorber. However, for the two-fold case, the absorption peak splits into two peaks when the polarization of the incident light parallels to *x* axis.

II. Numerical model and simulations

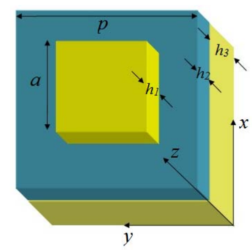

Figure 1. (Color online) Schematic structure of the perfect absorber cell structure. The top layer is square gold particle. The middle and bottom layer are MgF_2 and gold film, respectively.

Fig. 1 shows the schematic structure of the absorber. The absorber consists of three layers. The top layer consists of an array of square gold particle, the middle and bottom layer are MgF_2 and gold film, respectively. The dielectric function of gold (Au) obeys the Drude model as $\varepsilon(\omega)=\varepsilon_0\{1-\omega_p^2/(\omega^2+i\gamma\omega)\}$, where ε_0 is the permittivity of the vacuum, ω_p=1.37×10^{16} rad/s is the plasma frequency, ω is the angle frequency of the incident wave, and γ=4.08×10^{13} rad/s is the damping rate [14]. The parameters of the absorber are a=350 nm, h_1=20 nm, h_2=30 nm, h_3=200 nm, p=600 nm. The incident wave propagates along negative *z* axis and the boundary conditions in the metal plane are set as periodic boundary conditions. To investigate the absorption spectra, the finite-difference-time-domain (FDTD) method is employed. [15]

Fig. 2 presents the absorption spectrum of the four-fold rotational symmetrical structure when the polarization of the incident light parallels to *x* axis. The calculated results show a absorption peak of 0.99 locates at 1795 nm. Because this structure possesses four-fold rotational symmetry, it can be easily inferred that when polarization parallels to *y* axis, the spectrum has the same absorption feature.

By introducing air hole at the edge of the metal square particle along the *y* direction, the two-fold rotational symmetrical absorber is obtained. The width and height of the air hole are fixed at 200nm and 20nm, respectively. The length is set with different values in this paper. Fig. 3(a), (b) are the simulated absorption spectra of the twofold rotational symmetrical absorber with different length of air hole when the

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polarization of the incident light parallels to x axis (a) and y axis (b) , respectively.

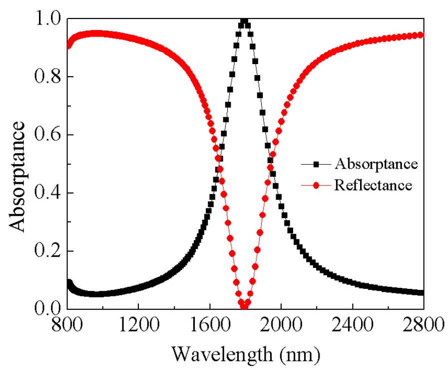
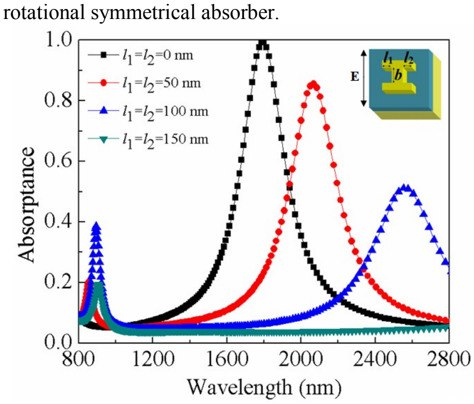
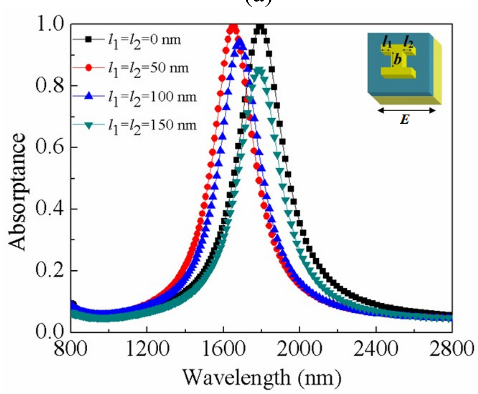


Figure 2. (Color online) Simulated absorption and reflection spectrum of the four-fold rotational symmetrical absorber.



(a)



(b)

Figure 3. (Color online) The simulated absorption spectra of the two-fold rotational symmetrical absorber with different length of air hole when the polarization of the incident light parallels to x axis (a) and y axis (b) , respectively.

As shown in Fig. 3(a), when the length of air hole is $l_1 = l_2$ = 50 nm, the original single absorption peak (1795 nm) splits into two separated absorption peaks (855 nm and 2065 nm), locating at the both sides of the 1795 nm peak. when the length increases from 50 nm to 100 nm, both two absorption peaks exhibit red shift, the 855 nm peak only has a 37 nm redshift, however, the 2065 nm peak possesses a 490 nm redshift.

As shown in Fig. 3(b), when the length of air hole is $l_1 = l_2$ = 50 nm, the absorption peak does not split. A new absorption appear in the spectrum at 1650 nm. when the length changes from 50 nm to 100 nm, the peak has a 40 nm redshift, locating at 1690 nm.

III. Conclusion

We investigate the impact of rotational symmetry of the metamaterial perfect absorber on its performance. The calculated results show that the absorption peak of four-fold rotational symmetrical absorber appears at the same wavelength with incident light polarization parallels to x axis or y axis. However, the absorption peak of two-fold rotational symmetric absorber splits into two peaks with incident light polarization parallels to x axis. The results of the absorption peak properties with different rotational symmetry may be helpful to design novel polarization-insensitive absorbers.

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