Liquid Crystal Based Tunable Terahertz Metamaterial Absorbers

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Introduction

Metamaterial-based absorbers play a significant role in applications ranging from energy harvesting and thermal emitters to sensors and imaging devices. Here, we use anisotropic liquid crystal(LC) as the dielectric layer to realize electrically tunable terahertz metamaterial absorbers(TMA). We use the COMSOL Multiphysics® software to simulate the tunable range of the far field resonant characteristic and the near field enhancement inside TMA.

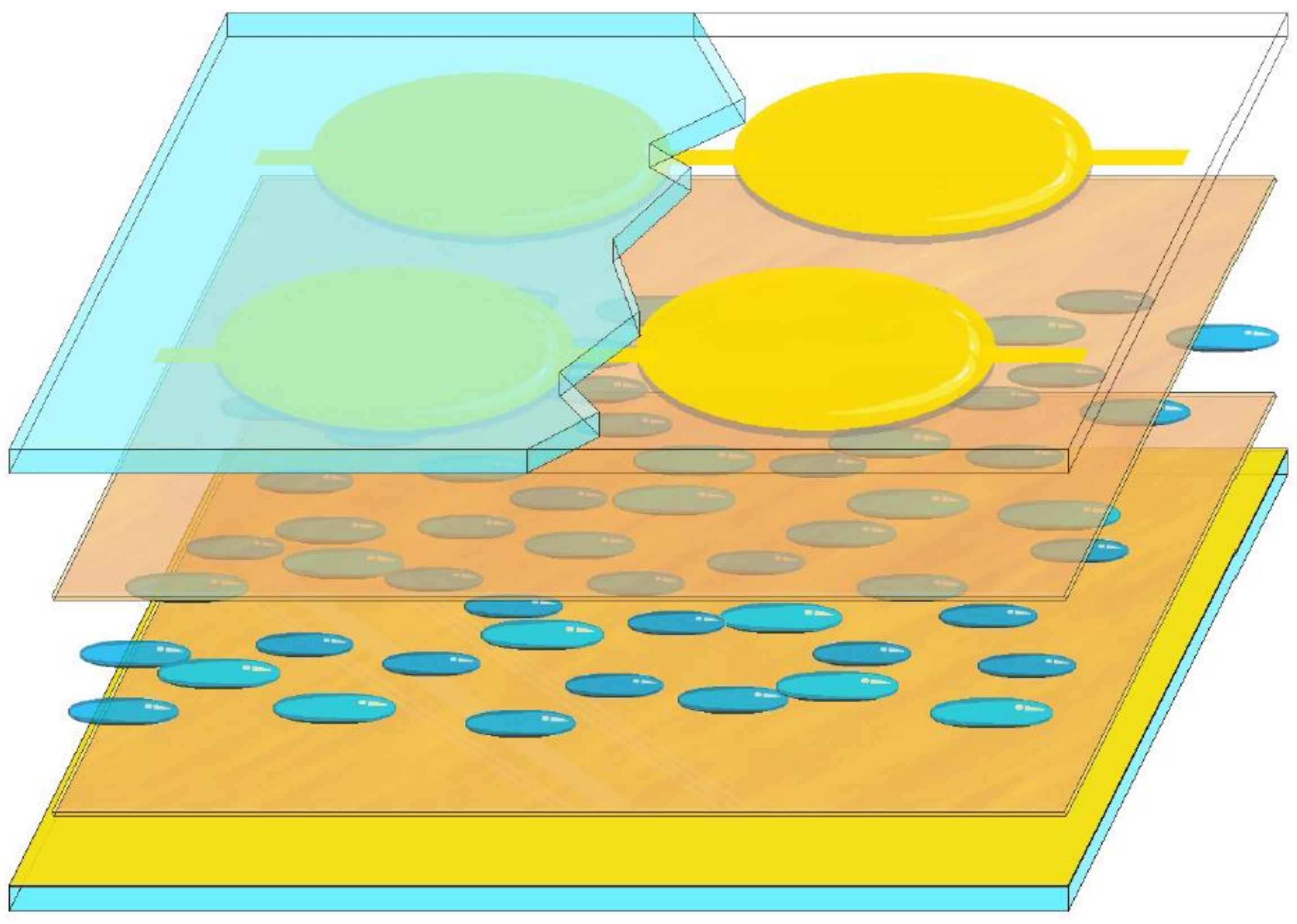

Fig. 1. Schematic of an LC-based tunable TMA.

Simulations

The frequency domain solver with periodic boundary conditions is performed. The Au is modeled as a Drude metal with a plasma frequency of 2π*2181 THz and a collision frequency of 2π*6.5 THz. The LC is an anisotropic material with $n_o = 1.5 + j0.05$ and $n_e = 1.8 + j0.03$.

We choose two cases to simulate. One case is for the initial LC director (the optical axis) parallel to the x axis, i.e., the unbiased state (0 V), with $n_x = n_e$, $n_y = n_o$, $n_z = n_o$; the other is the extreme situation where all the LC directors are in a vertical orientation with $n_x = n_o$, $n_y = n_o$, $n_z = n_e$. The linearly polarized THz wave is normally incident into the TMA with the electric field E_0 in the x direction.

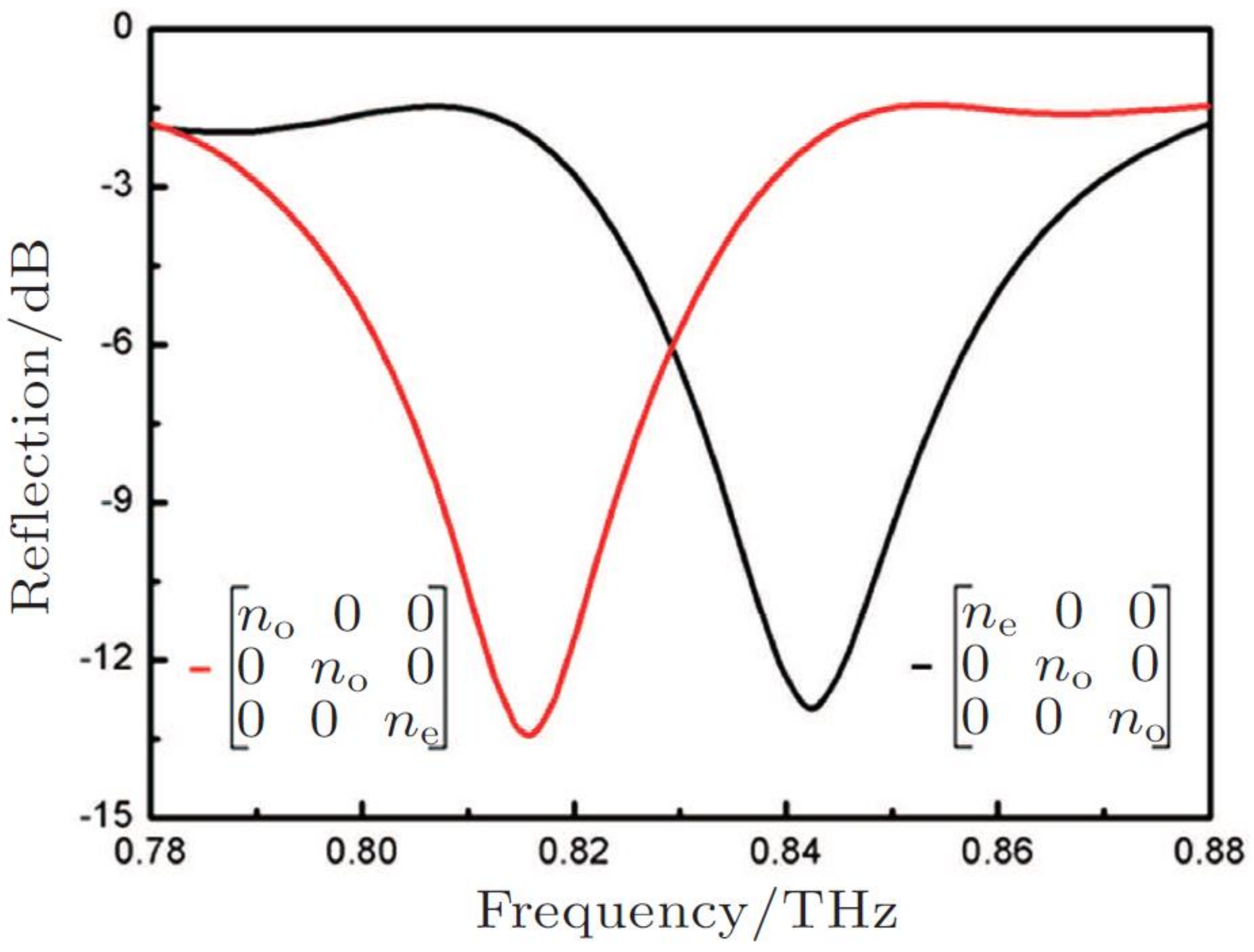

Fig. 2. Simulations of far field reflection spectra for the cases of the LC director parallel to the connecting wires (black curve) in the x–y plane and perpendicular to the electrode (red curve) in the z direction.

Results

Figure 2 shows that the resonance frequency shifts to lower frequencies when the LC director rotates out of the x–y plane by the applied voltages, and the maximum tunable range could be from 0.842 THz to 0.817 THz.

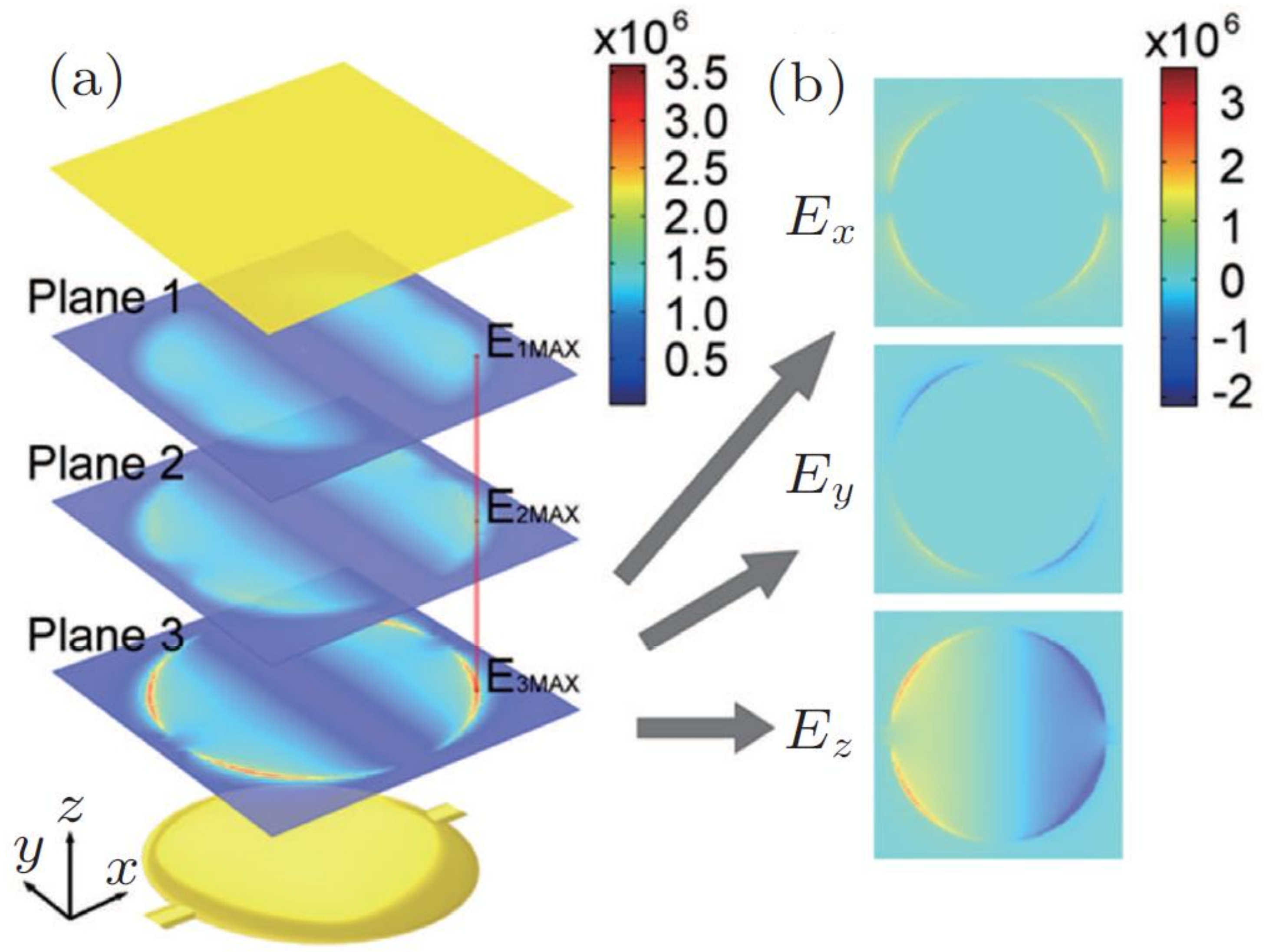

Fig. 3. Near field distribution of the unit cell inside the TMA. (a) Electric field cross sections of the LC layer from top to bottom at resonance frequency 0.842 THz (unbiased). (b) Each THz electric field component is shown at the plane 3 nearby metasurface.

Figure 3(a) exhibits the inhomogeneous internal electric field. E_{2max}/E_0 is about 10^4. We choose the plane nearest to the metasurface to explore the electric field distribution in the x–y plane, as shown in Fig. 3(b). The E field in the x–y plane is also inhomogeneous. The E_x, E_y focus on the edge of the disk, and E_z from the edge to the center of the disk exhibits a considerable position dependence, from a maximum to zero in only the length of one radius.

Conclusion

Liquid crystal based terahertz tunable devices usually have very slow response time induced by a thick cell. We use metamaterial which can compress the cell gap to just about 10μm to realize a fast tunable THz metamaterial absorber. It also has the performance of near-field enhancement and subwavelength resolution which will play important roles in THz biological imaging and sensing applications.

References

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