Wavefront regulation of terahertz frequency based on all-silicon medium coded metasurface

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Abstract

➢ By designing geometric or electromagnetic parameters on a small size, it can achieve flexible and effective regulation of electromagnetic characteristics. The ohmic loss caused by metal materials will seriously affect the coding efficiency of the metasurface.

➢We propose an all-silicon medium metasurface. The coded metasurface is constructed by designing different basic coding sequences to control the terahertz frequency wavefront.

Metasurface Design

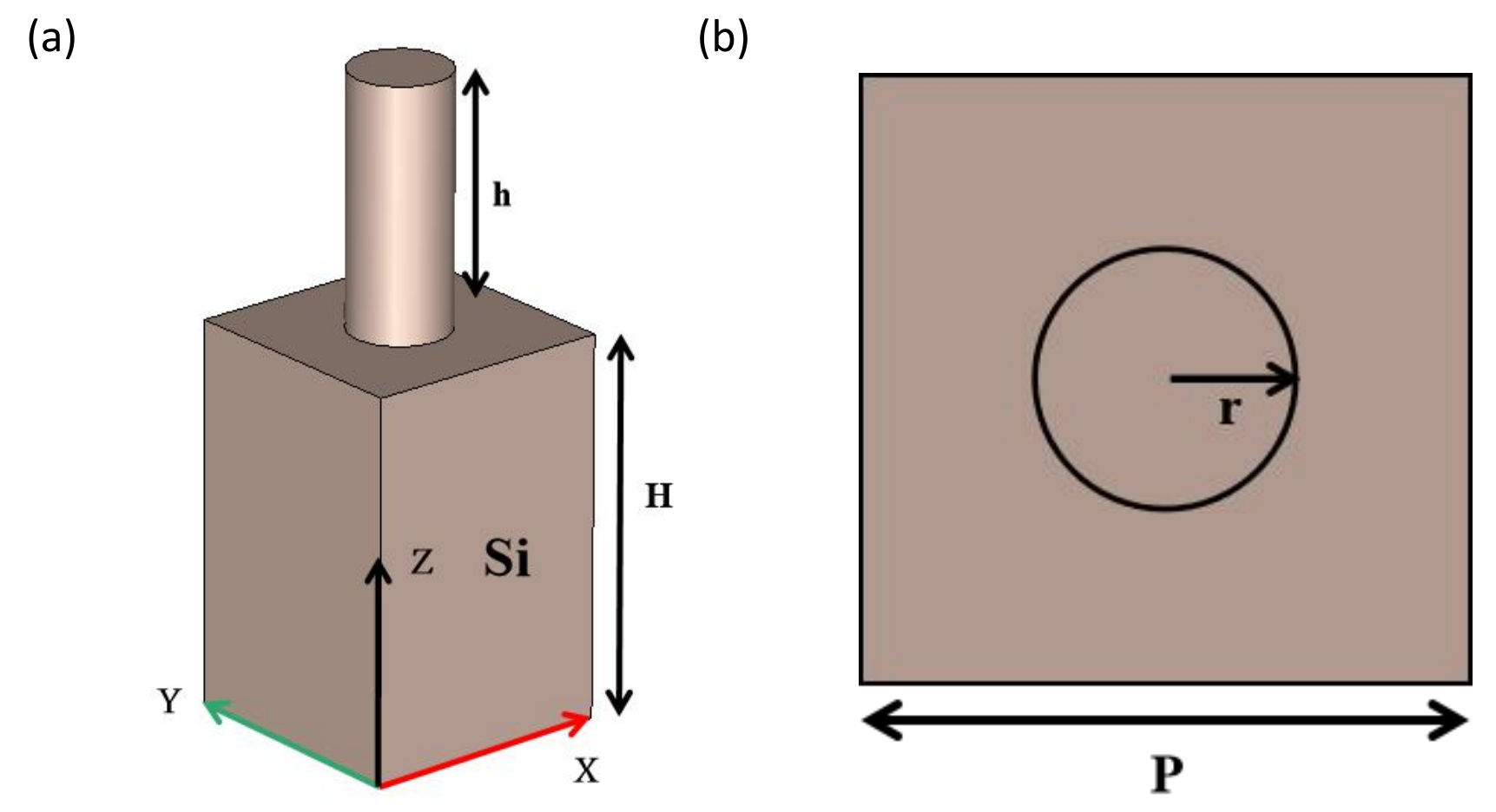


Fig.1 Schematic diagram of all-silicon metasurface unit structure. (a) Front view. (b) Vertical view.

As shown in Fig.1, the upper columnar structure and the lower square structure are made of silicon material. The complete transmission phase shift is obtained by changing the size of the radius.

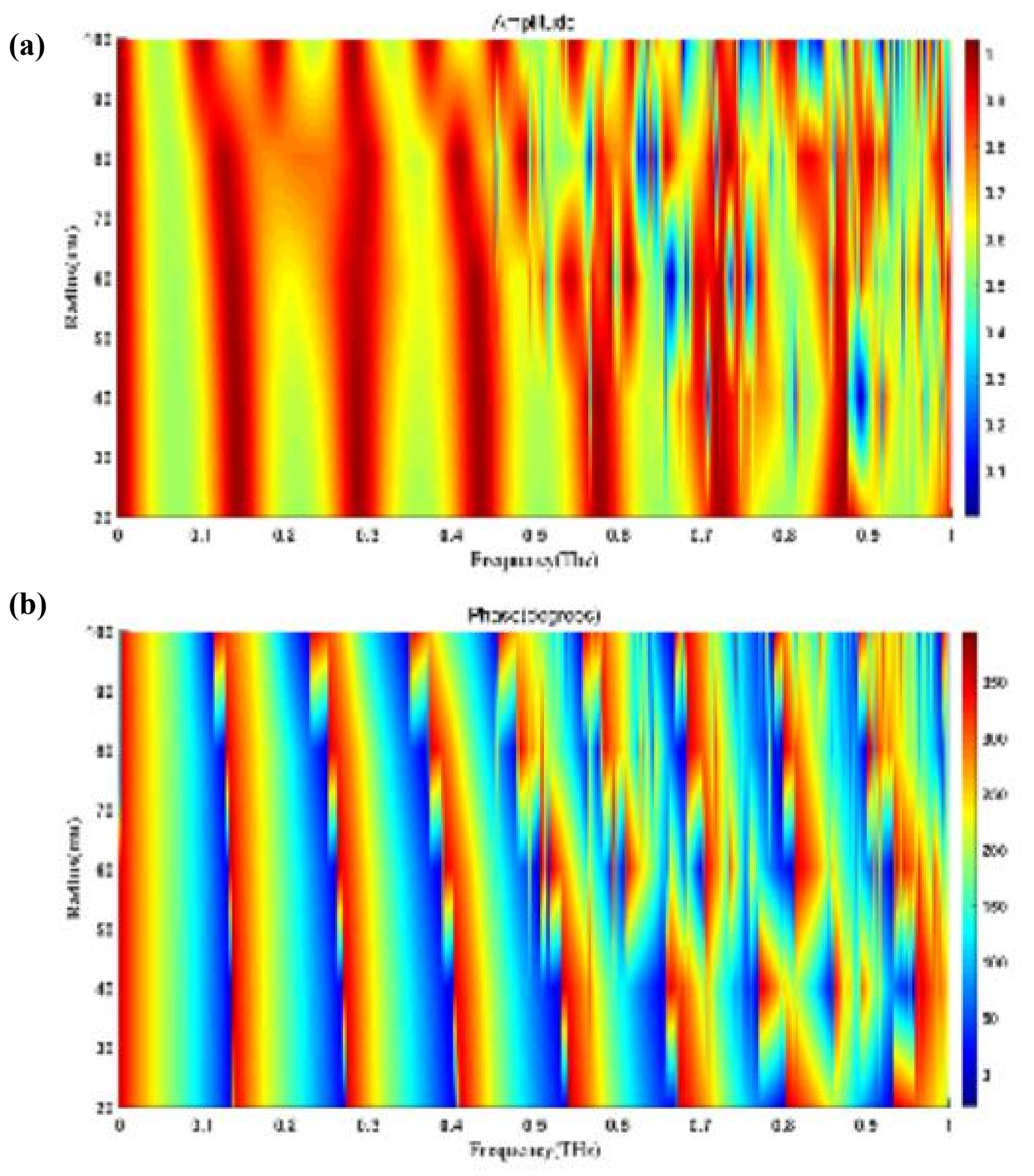


Fig.2 The corresponding (a) analog transmission amplitude and (b) analog transmission phase at 0.2-0.8THz frequency.

According to the simulation results of electromagnetic simulation software CST, the transmission efficiency and phase response within the frequency range of 0-1THz are obtained, as shown in Fig. 2 (a) and (b). The height of the columnar structure is 200μm and the radius is *r*. The length of the lattice is 200 μm. In the CST software, the frequency is set to 0-1THz, and the boundary conditions are unit cell in the X and Y directions, and open in the Z direction. The air layer is set to 500 in the z direction. The transmission amplitude and transmission phase of the unit structure are monitored respectively. It can be seen from the figure that the designed unit structure has a higher transmission coefficient at 0.4THz. Through the optimization algorithm, when the radius r=40μm, r=96μm, r=80μm and r=50μm, the phase difference is about, which satisfies the condition. They are coded as 0, 1, 2 and 3.

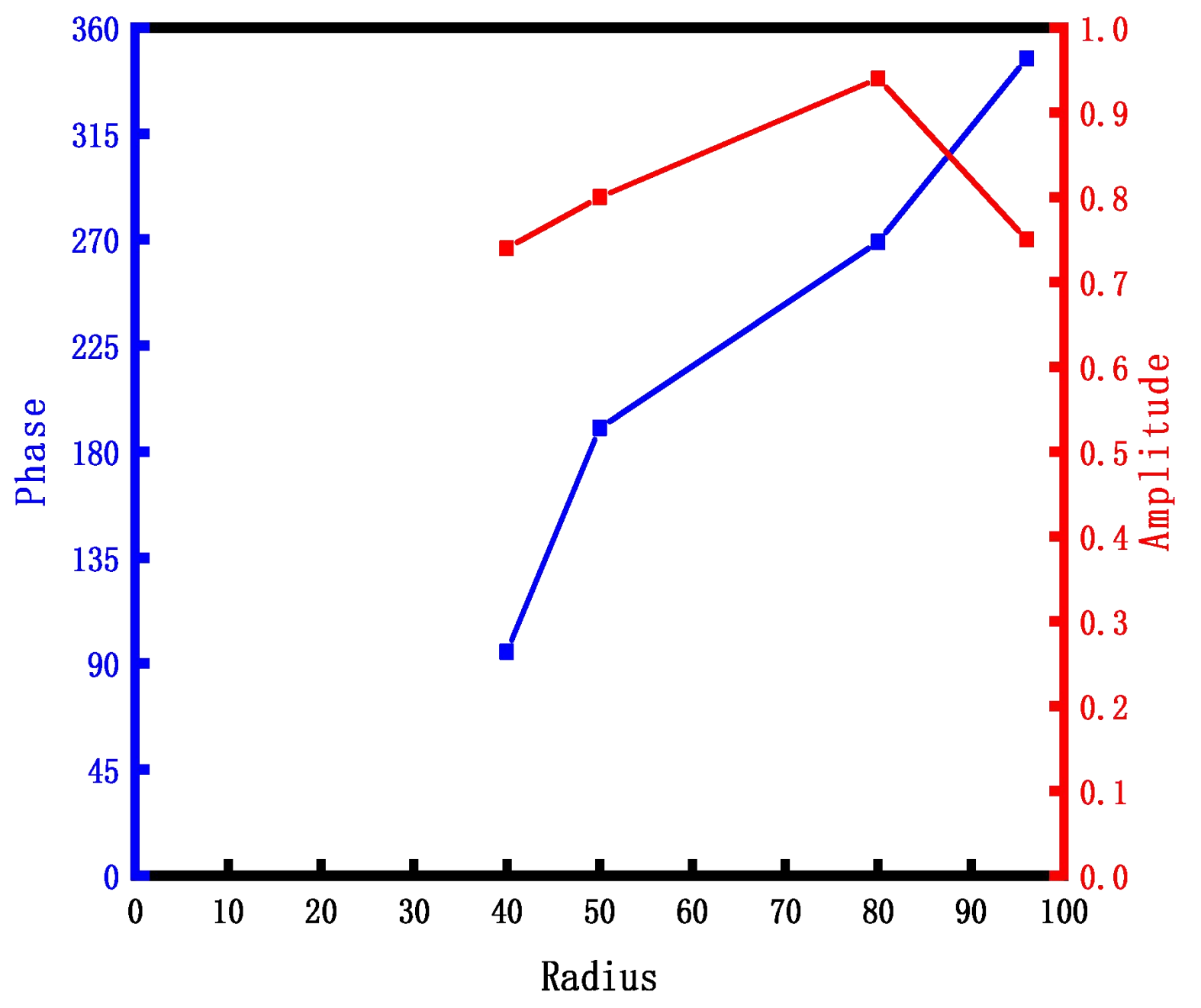
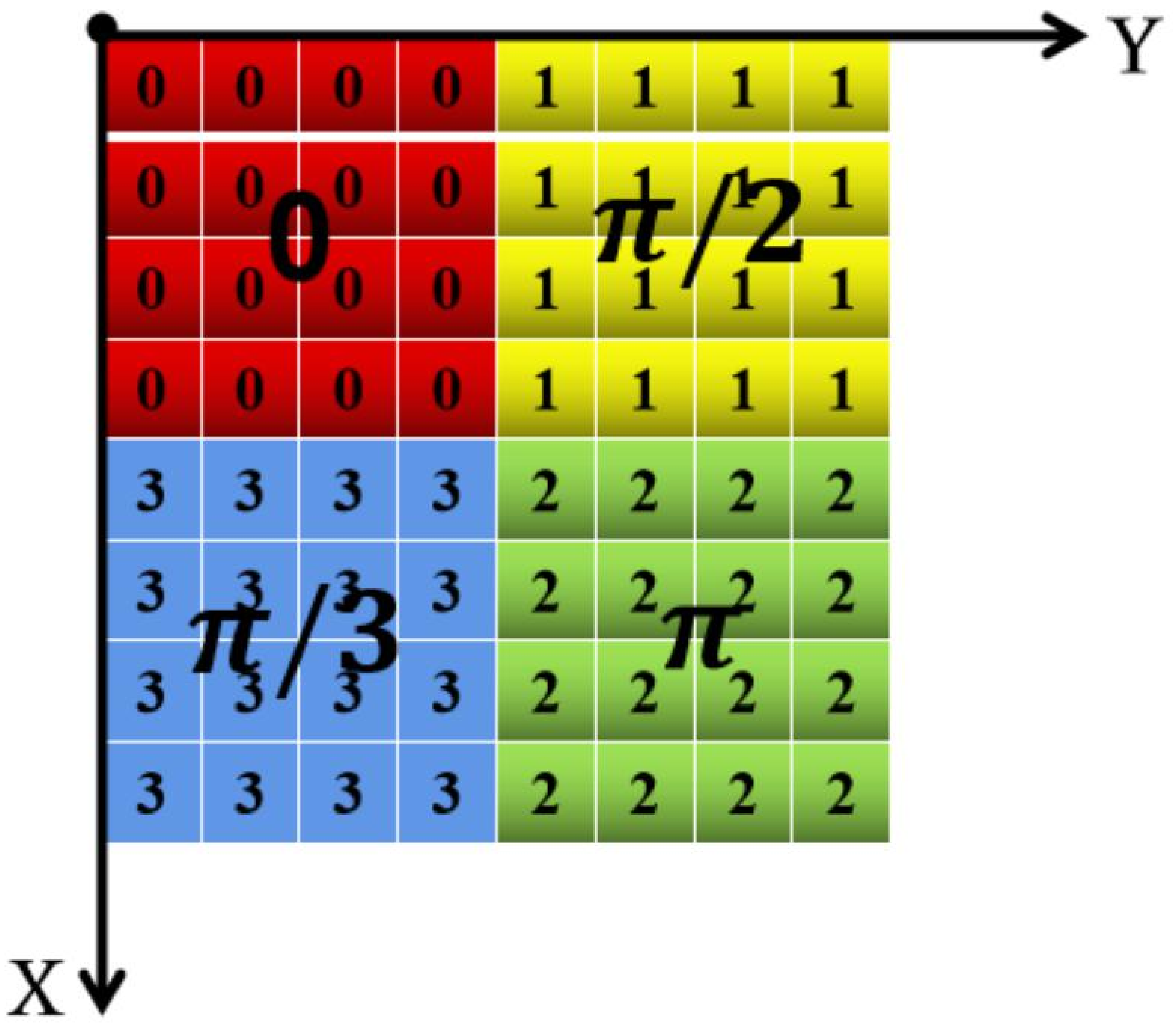


Fig.3 The transmission amplitude and transmission phase of four cell structures with different circular hole sizes at *f*=0.43THz.

The transmission amplitudes and transmission phases of the four selected unit structures are shown in Fig.3. Using the generalized Snell's law, the Fourier operation on the surface provides a larger experimental basis for the free and flexible operation of visible light. Compared with metal-plate metamaterials, the transmission efficiency of this design is greatly improved.

Results and discussion



0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
0	0	0	0	1	1	1	1
3	3	3	3	2	2	2	2
3	3	3	3	2	2	2	2
3	3	3	3	2	2	2	2
3	3	3	3	2	2	2	2

Fig.4 Schematic diagram of the hypersurface generated by the vortex beam when the topological charge number l=1.

Vortex beam is a rotating beam that carries orbital angular momentum and has a spiral phase wavefront that brings a central phase singularity to produce a hollow intensity distribution. Next we need to do, is through the basic structure of the above research, coding, and through CST simulation, to obtain the vortex light. We design the vortex phase plate to generate the vortex beam by using the above four metasurface units.

Fig. 4 designs a vortex beam phase plate with topological charge number of 1 in an 8×8 unit structure. Each color represents a unit structure. Red, yellow, green, and blue represent transmission phases 0, π/2, π, and 3π/2, respectively. 2π is divided into 4 phase differences, and the phase difference between the two adjacent quadrants is π/2, which is arranged clockwise as 0, π/2, π, and 3π/2.

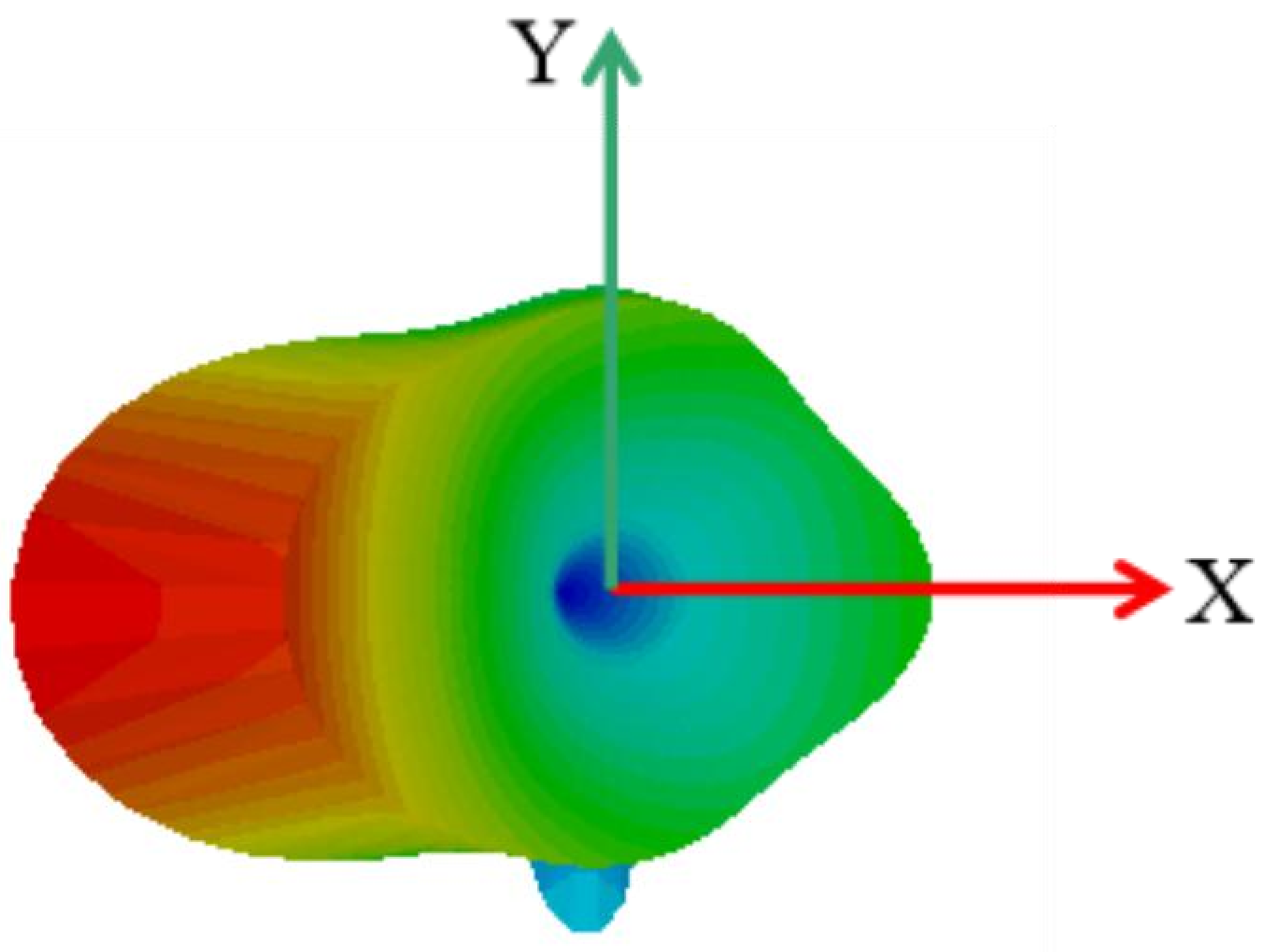


Fig.5 Three-dimensional far-field scattering diagram of the vortex beam generated when the topological charge number l=1

Fig. 5 is a 3D far-field scattering diagram of vortex beam. We can see that the 3D image of vortices is distributed in a donut style, and they all have phase singularities, which is a common feature of vortices. Vortices prepared in this band can be used as optical tweezers to control particles, and also has a wide range of applications in optical communication and other fields. In conclusion, our metasurface can produce vortices, and vortices with different topological charge numbers can be obtained through different arrangements. The formation of the spiral beam wavefront will provide a broad prospect for the future research in the fields of large capacity and high speed communication. With the limitation of traditional material design thought exposed day by day, the research and development of new functional materials becomes more and more important. In recent years, with the deepening of research work, many breakthroughs have been achieved by using coded metasurfaceThese coded metasurfaces have a promising future in information communication, signal processing, electromagnetic imaging and other fields.

Conclusion

In this paper, an all-silicon metasurface with cylindrical structure on the top and square structure on the bottom is designed. Compared with the metal plate, the transmission efficiency is greatly improved. At the same time, a vortex coded metasurface with topological charge number l=1 is designed to generate the corresponding vortex beam.

The coded metasurface designed in this paper proves that the all- silicon medium metasurface can achieve multifunctional wavefront regulation of terahertz waves.

Terahertz vorticity has great potential in many fields. The penetration and security of terahertz wave gradually show its broad application prospect in many fields. It is beneficial to the practical application of terahertz technology in holographic imaging, terahertz switch, vortex generator and other fields.

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