The Influence of Structure Parameters on Terahertz Wave Filter based on Photonic Crystal Ring Cavity

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Keywords: THz Communication, Filter, the Finite Difference Time Domain Method, Photonic Crystal Ring Cavity, WDM.

Abstract: Terahertz (THz) communication has important applications in high-speed and ultra-broadband wireless access networks. THz filter is one of the key device of WDM communications. THz filter based on ring cavity photonic crystal (TFRCPC) has many advantages such as simple structure, high integration and high flexibility. According to the coupling characteristics of waveguide and ring cavity, a novel structure of TFRCPC was proposed in this paper, the TFRCPC consists of 4×3 internal dielectric cylinder with four scattering dielectric cylinder. The influence of structure parameters of TFRCPC is mainly studied. The simulation results show that, on the basis of basal material of Si and lattice constant of 30μm, when the radius of dielectric cylinder is 5.7368μm, the radius of 4×3 internal dielectric cylinder is 3.5μm, the radius of scattering dielectric cylinder is 5μm, the wave at 83.535μm wavelength can go through the structure with the transmittance of 0.97674.

1 INTRODUCTION

Terahertz (THz) wave refers to the electromagnetic wave whose frequency is between 0.1~10THz (30μm~3mm), which is located between millimeter wave and infrared wave (Hu and Chen, 2008). It is the transition area between electronics and photonics. Terahertz communication devices have become the study hotspot in recent years. Banmali S.Rawat* et al. put forward 5G mobile communication should be realized in THz wave band in 2013 (Banmali et al., 2013). In 2014, G. Ducournau et al. (Ducournau, Yoshimizu et al., 2014) put forward the high performance of coherent THz wave in receiver data rate and sensitivity, so that terahertz communication could provide with high data rate services. The plane coupling structure composed of waveguide and resonant cavity has become a common THz filter structure (Su and Chen, 2010). Ring cavity has many advantages such as simple structure high integration and strong flexibility. It can achieve many functions such as filtering, splitting, WDM and so on (Guo, Fang, Wu et al., 2010).In 2009, Yaw- Dong Wu et al. has proposed a filter with high Q value which was based on photonic crystal ring cavity (Wu, Shih et al., 2009). The Q value was 3800, and the transmittance was 92%, but the structure was complex. It could filter the wave of 1550 nm.

This paper proposes a TFRCPC which consists of 4×3 internal dielectric cylinder with four scattering dielectric cylinder. By changing the radius of internal dielectric cylinder and its refractive index, the radius of scattering dielectric cylinder, the coupling intensity of the light in the ring cavity can change. Then it can filter the waves of different wavelengths according to different structures. Finally, the Q value of the filter is up to 3977.86, the transmittance of 83.535μm is 0.97674.

2 STRUCTURE DESIGN

The parameters of the TFRCPC proposed in this paper are set as follows: refractive index of silicon dielectric cylinder material n=3.4, radius of dielectric cylinder r=5.7368μm, lattice constant a=30μm. Because tetragonal crystal lattice has high symmetry, a ring cavity structure can get better transmission performance. The bandgap of photonic crystal structure can be acquired by the plane wave

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expansion method (Yang, Xu, Ye et al., 2011). The range of the normalized frequency a/λ is 0.29334~0.43124. The range of corresponding band gap of photonic crystal is about 69.57μm ~102.27μm. Removing part of the dielectric cylinder from the complete photonic crystal to form a straight waveguide as an input waveguide, there are two rows of columns between the photonic crystal waveguide and a ring cavity. Output waveguide is vertical to the input waveguide, as shown in Figure 1.

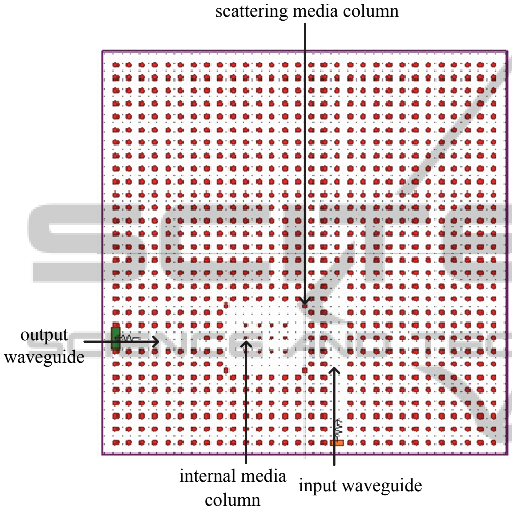

Figure 1: The structure of TFRCPC.

3 THE INFLUENCE OF STRUCTURE PARAMETERS ON THZ FILTER PERFORMANCE

3.1 The Influence of Internal Dielectric Cylinder Radius

By changing the radius of internal dielectric cylinder, the resonance wavelength can be changed. Then different wavelengths of THz waves can go through the output waveguide. On the basis of 4×3 internal dielectric cylinder, we study the influence of transmission spectrum when the radius of internal dielectric cylinder changes from 3.49μm to 3.52μm, as shown in Figure 2. The radius of internal dielectric cylinder from left to right is 3.49μm, 3.5μm, 3.51μm, 3.52μm respectively.

As can be seen from Figure 2, when the radius of dielectric cylinder increases, the transmission spectrum moves to long wavelength direction. When the radius of internal dielectric cylinder is 3.5μm,

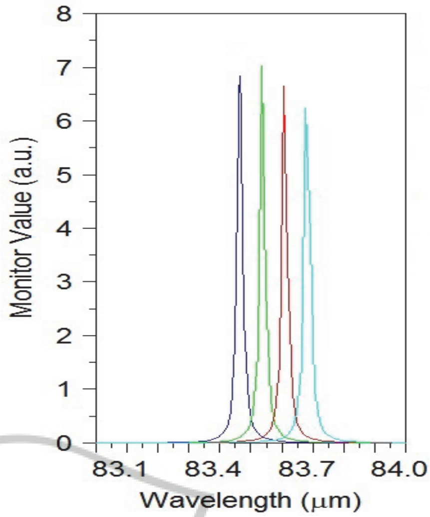

Figure 2: The influence of internal dielectric cylinder radius on the transmission spectrum.

the transmission spectrum peak of the THz wave at 83.535μm wavelength is the highest.

3.2 The Influence of Scattering Dielectric Cylinder Radius

By changing the radius of the scattering dielectric cylinder in the ring cavity, the output wavelength will change. On the basis of 4×3 internal dielectric cylinder, by introducing four scattering dielectric cylinder, we study when the radius of internal dielectric cylinder is 3.5μm, the impact on the transmission spectrum when the radius of scattering dielectric cylinder changes from 4.5μm to 6μm, as

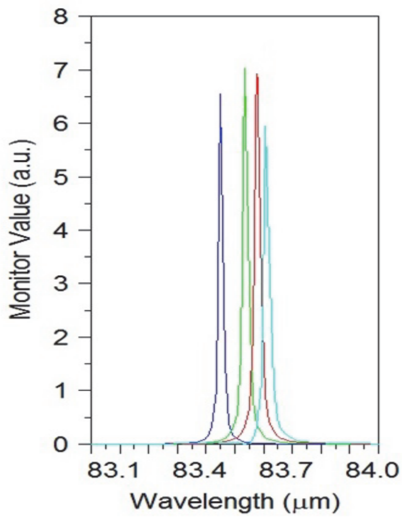

Figure 3: The influence of internal scattering dielectric cylinder radius on the transmission spectrum.

shown in Figure 3. The radius of scattering dielectric cylinder from high to low is 5μm, 5.5μm, 4.5μm, 6μm respectively.

Figure 3 shows that when the radius of internal dielectric cylinder is 3.5μm, transmission spectrum moves to long wavelength direction when the radius of scattering dielectric cylinder increases; when the radius of scattering dielectric cylinder is 5μm, the transmission spectrum peak of the THz wave which wavelength is 83.535μm is the highest.

3.3 The Influence of Internal Dielectric Cylinder Material

By changing the internal dielectric cylinder material in the ring cavity, the output wavelength will also change. When the radius of internal dielectric cylinder is 3.5μm, internal dielectric cylinder uses GaAs whose refractive index is 3.55. When the radius of scattering dielectric cylinder is 5μm, the wave which can go through the structure is different from the one whose internal dielectric cylinder is made of Si, as shown in Figure 4.

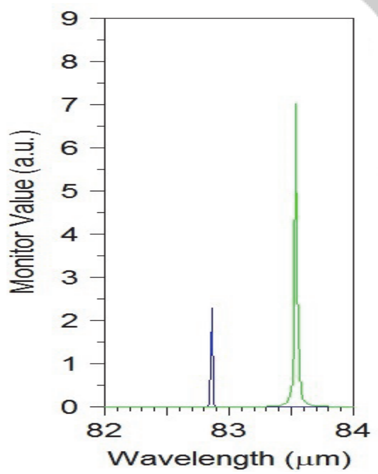

Figure 4: The influence of internal dielectric cylinder material on the transmission spectrum.

Figure 4 shows that when the radius of internal dielectric cylinder is 3.5μm, the radius of scattering dielectric cylinder is 5μm, internal dielectric cylinder uses GaAs whose refractive index is 3.55, the THz wave which wavelength is 82.866μm can penetrate. If internal dielectric cylinder uses Si, the wavelength of 83.535μm can penetrate.

4 THE TRANSMITTANCE OF FILTER

Based on FDTD of Rsoft software simulation, the results show that the basal material adopts silicon, lattice constant is 30μm, the radius of dielectric cylinder is 5.7368μm, the radius of internal column is 3.5μm, the radius of scattering dielectric cylinder is 5μm, the wave which wavelength is 83.535μm can penetrate. The Q value is as high as 3977.86, the transmittance is as high as 0.97674, the time domain steady state response and corresponding steady state mode field distribution are shown in Figure 5 and Figure 6.

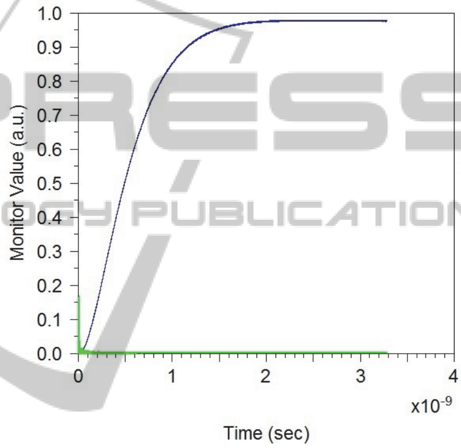

Figure 5: The figure of time domain steady state response when the incident wavelength is 83.535μm.

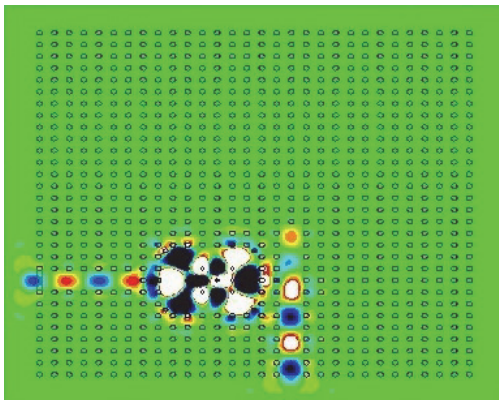

Figure 6: The steady mode field distribution when the incident wavelength is 83.535μm.

5 CONCLUSIONS

A novel TFRCPC which has 4×3 internal dielectric cylinder and four scattering dielectric cylinder is proposed in this paper. By changing the radius and refractive index of internal dielectric cylinder, the waves of different wavelengths can go through the filter. The radius of the scattering dielectric cylinder has an impact on the transmittance of the wavelength (Yang, Xu, 2010). The Q value of the final filter is as high as 3977.86, the transmittance of the wave which wavelength is 83.535μm is 0.97674. Compared with the TFRCPC in the literature (Wu, Shih et al., 2009), this filter's transmittance is higher. This terahertz wave filter with ring cavity has important significance for the future THz wave division multiplexing communication system (Chen and Wei, 2013).

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