5. Conclusion

In conclusion, the frequency dependence and temperature dependence of the optical constants of 5CB have been reported in 0.2 – 1 THz by using THz time-domain-spectroscopy. In this frequency range, 5CB doesn't show any sharp resonant absorption and clear dispersion. The ordinary and extraordinary indices of 5CB are 1.577 – 1.597 and 1.762 – 1.786, respectively. The extinction coefficient is smaller than 0.02 without anisotropy. The temperature dependence of 5CB has also reported, which the behavior is quite similar to it in visible range. The temperature dependent birefringence, which relates to the order parameter has also been reported. The order parameter is the character of materials, which should be fixed no matter measured in any frequency range. This is confirmed by fitting the results of temperature dependent birefringence. The studies of the optical constants of 5CB in THz range show the attractive potential of the applications in this range, such as phase shifter or filter…etc., due to the comparable large birefringence (~0.2) and relative small extinction coefficient (<0.02).

For the tunable phase shifter, we have demonstrated the electrically controlled and magnetically controlled tunable LC THz phase shifters. The phase shift of electrically controlled one is achieved by electrical control of the effective refractive index of LC 5CB layer. A maximum phase shift of 4.07° was observed at 1.07 THz when the device was driven at 589.3 V/cm. In principle, the phase shift can be increased with a thicker LC cell and/or optimization of the electrode geometry. In magnetically controlled phase shifter, the phase shift is achieved by magnetically controlling of the effective refractive index of LC layer. The magnetic field also helps to align the LC for cell as thick as 1.5 mm. Three cells, which are the 1-mm-thickness cell, 1.5-mm-thickness cell and the sandwich cell are employed in this work. The measured results are all in agreements with the theoretical predictions, which assume that all the molecules of LC are re-orientated parallel to the strong magnetic field. The maximum phase shifts of 108º, 141° and 368° was obtained at ~1.0 THz by using the 1-mm-thick, 1.5-mm-thickness and the sandwich LC cells. A phase shift over 2π is achieved by employing the sandwich cell, which is a milestone of the tunable THz phase shifter. In principle, the phase shift/retardation can keep being increased by employing a LC cell with larger optical thickness and/or larger magnetic inclination angle. Alternatively, this can be also realized with a thinner LC cell with higher Δn.

We have also demonstrated for the first time a tunable room-temperature THz tunable Lyot filter. The key elements are fixed and variable liquid crystal phase retarders. The central passband frequency of the filter can be continuously tuned from 0.388 THz to 0.564 THz (a fractional tuning range of 40%) using magnetically controlled birefringence in nematic liquid crystals. The insertion loss of ~8 dB is attributed to scattering of the LC molecules in the thick LC cells. The bandwidth of the present device is 0.1 THz . Still narrower bandwidth is possible by adding more elements. This filter can be operated at room temperature. The experimental results are in agreement with theoretical predictions. Extension of the LC-based Lyot filter to the higher THz frequency range (10~30 THz) or mid-infrared is straight forward, with additional benefits of still larger tunable range because of the shorter wavelength.

The studies of LCs in THz range or the LC-based THz devices are not done but just a beginning. The measured optical constants of the LCs, 5CB and E7, all show the potential of further applications. In the future work, there are two directions to go: The exploration of other LCs, which might be with larger birefringence or lower absorption and the development or design of the new LC-based THz quasi-optical devices.