

We thus see that by tuning the angle of the output polarizer, we not only can change the lineshape of the transmission spectrum, but also the phase change through the structure. The tunable phase change can be used to obtain a tunable group delay, calculated as $\Delta\tau = -d\phi/d\omega$. Fig. 6 (c), Fig. 6 (f) and Fig. 6 (i) show the dimensionless group delay, $(\Delta\tau)c/a$. For a fixed frequency (fixed $\varepsilon^R \approx -0.5$), the group delay can be tuned from negative to positive by changing θ_p .

The physical value of the delay can be obtained from the graph by multiplying by $a/c = 1.7 fs$. For the relatively low quality factor mode studied here, the delays are in the 1 to 2 fs range. The delay increases linearly with quality factor, Q . Recently, a photonic crystal lattice has been designed that supports a coupled, linearly-polarized guided resonance mode with theoretical quality factor as high as 10^5 [19]. Such a Q value would increase the delay to the picosecond range.

In this paper, we have demonstrated lineshape and time delay tuning by fixing the incident polarization and tuning the collection polarization. We could also have fixed the collection polarization and tuned the incident polarization. This can be inferred from Eq. (8). Substituting θ_i with $\theta'_p - \theta_p$, fixing θ'_p to be 45° , and tuning θ_p from 0° to 180° , the zero point of the system has the same trace as shown in Fig. 5, yielding a similar tuning mechanism for the lineshape.

6. Conclusion

In summary, we have proposed a method for tuning the transmission lineshape through a photonic crystal slab membrane using polarization control. The principle is to tune the transmission ratio between the direct, Fabry-Pérot path and the indirect, guided resonance path. We first presented an analytical model for the transmission spectrum. We then fabricated and characterized a Suzuki-phase lattice photonic crystal slab membrane to validate the model. There is excellent agreement between theoretical predictions and experimental results. We show that the lineshape can be tuned from a highly asymmetric shape to a highly symmetric one, while the corresponding group delay is tuned from negative to positive. The tuning is achieved simply by rotating an external output polarizer. More generally, the polarization angle dependence measurement and surface fitting technique shown in this work provide an accurate method to characterize guided resonance modes. We expect our results to be useful in a range of applications of photonic crystal guided-resonance modes, including filtering and sensing.

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