Bandwidth Compression in Triangular Lattice Based Dynamic Photonic Crystals Structures

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***Abstract*– Triangular lattice photonic crystals model was proposed for optical storage [1]. The transmission characteristics and band structure of this model are calculated here. The obtained results verify both the qualitative and quantitative analyses previously done.**

***Index Terms*–Dynamic structures, temporal coupled mode theory, optical storage, refractive index modulation.**

I. INTRODUCTION

Photonic crystals have been a subject of interest for more than 20 years. Photonic crystals show new capabilities for the control of light. One of the important advances in the theory of photonic crystals is the development of the dynamic photonic crystal structures. They are basically coupled resonator array systems. By modulating the refractive index of the system, it behaves as both a tunable bandwidth filter and a tunable delay element [2]. These properties allow for high capabilities to store and process optical information. The original model for the dynamic process was based on a two dimensional square lattice of dielectric rods [3].

In a previous work [1], a dynamic model based on triangular lattice geometry and GaAs was proposed. This model shows an increase in the compressible bandwidth of the propagating pulse. In this work, both the qualitative and quantitative analyses previously discussed are verified. This is done by calculating the transmission characteristics and band structure for this model.

II. CONSTRUCTING THE MODEL

The unit cell of the basic system used to manipulate light pulses consists of a waveguide side coupled to two cavities [4]. Figure 1 shows a triangular lattice structure of dielectric rods with refractive index of 3.5 and a radius of 0.2*a*, embedded in air ($n=1$), where 'a' is the lattice constant [4]. In a previous work [1], this model was proved to obey the necessary conditions for pulse compression in dynamic structures. This system is adjusted to have the same center frequency ω_o=0.357($2\pi c/a$) [4] [5]. By modulating the refractive index of this system, the resonance frequencies of the unit cell cavities can be varied creating two cavities with resonance frequencies of $\omega_{1,2}=\omega_o\pm\delta\omega/2$ [6], $\delta\omega$ is the signal bandwidth. In this case of a triangular lattice, both cavities have the same symmetry and the system supports nonorthogonal modes [7]. This system exhibits electromagnetic induced transparency.

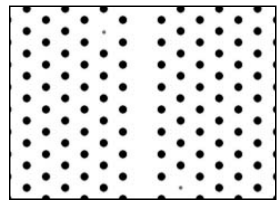

Fig. 1. Schematic of a two-dimensional triangular lattice photonic crystal structure with dielectric rods of radius 0.2a. Removing one row of dielectric rods creates a waveguide. In each unit cell, two single-mode cavities are created on opposite sides of the waveguide with a separation l_1=7a [1]

III. MODEL ANALYSIS

The qualitative analysis of this system [1] is verified by the results obtained from simulations. First, at ε=12.25, two systems are constructed one with a square lattice and the other with a triangular lattice. The transmission characteristics are calculated using the parameters obtained from simulating these systems and using the transmission coefficient obtained using the temporal coupled mode theory [4]. In either Fig. 2(a) or 2(b), both the square lattice system and triangular lattice system have the same refractive index modulation of the cavities. $\Delta \equiv |\omega_1-\omega_2|\tau$ is the frequency separation of the middle band for the system [5].

The band structure calculated using transmission matrix approach [8] is shown in Fig. 3 of the original model with a square lattice along with the newly constructed one for the case of a triangular lattice at the same parameters as those of the system used to calculate the transmission characteristics. Both systems exhibit three photonic bands. The width of the middle band depends strongly on the cavities resonant frequencies. By modulating the cavities frequency spacing, the system bandwidth can be compressed. Fig. 3(b) shows the possibility of nearly flat band in the entire Brillouin zone of a structure of a triangular lattice as it was previously obtained for a square lattice structure. In this way, by cascading the bandwidth filters shown in Fig. 2, it becomes possible to reduce the group velocity of the propagating pulse to zero.

Fig. 4 shows the effect of using GaAs on the bandwidth for both the square and triangular lattice structures.

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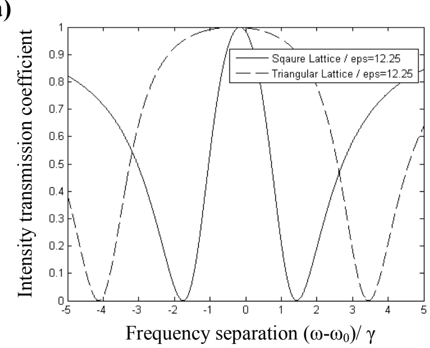
(a)



(b)

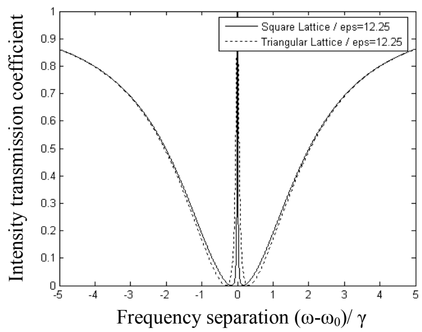
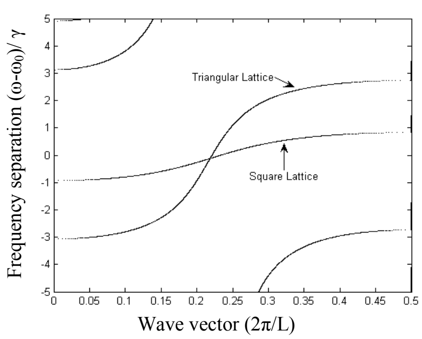


Fig. 2. Transmission spectra through the coupled resonator unit cell for two cases: a structure with square lattice, and a structure with a triangular lattice, γ is the decay rate of a given resonator.

(a)



(b)

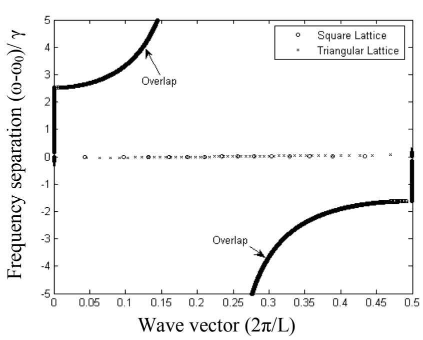


Fig. 3. The band structures for the system shown in Fig. 1
(a) Before modulation. (b) After modulation.

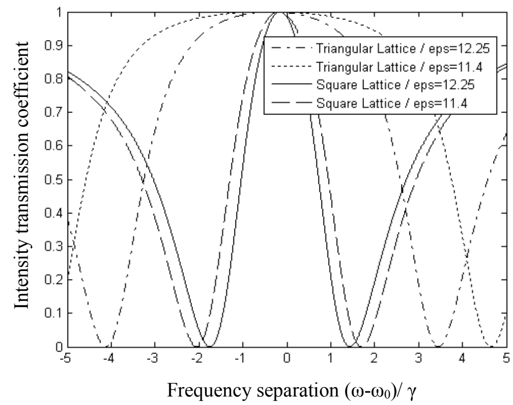


Fig.4. Intensity transmission through different combinations of lattice geometry and dielectric constant investigated.

IV. CONCLUSION

In a previous work, triangular lattice geometry and GaAs were proved to give higher compression capabilities for optical pulse compression. This represents an optimization step over the original square lattice model. The qualitative and quantitative analyses previously done are verified here. This is done by calculating the transmission characteristics and band structure. These systems show an increase in the compressible bandwidth Δ by ≈137% when triangular lattice is used and to ≈218% when GaAs is used with triangular lattice. In this way, using triangular lattice and GaAs represents a two steps optimization of the dynamic model.

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