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FDTD Simulation of One-Dimensional Photonic Band Structure

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Abstract : *The behavior of a Photonic crystal relies upon Photonic Band Gap (PBG). In the present work, band gap has been computed for a 1D Photonic Crystal. Both PWE and FDTD methods are widely used for band gap computation of Photonic Crystals. FDTD method is used for the simulation of band gap and PWE method as a band solver.*

Keywords: *1-D Photonic Crystals, FDTD, PWE, Photonic Band Gap (PBG).*

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Introduction :

The principle of Photonic Crystals (PhCs) is similar to how the properties of semiconductor enable the creation of electronic devices. A photonic crystal is called a crystal, because of its periodicity, and photonic because it acts on light. A Photonic Crystal is known as the special class of optical media with periodic modulation of the refractive index and permittivity. The defining feature of a photonic crystal is the periodicity of dielectric material along one or more directions. Based on its periodicity it can be classified into three major groups–One-Dimensional, Two-Dimensional and Three-Dimensional Photonic Crystals (Yablonovitch E., 1987 and Joannopoulos John D. et. al., 2008). If this periodic arrangement is of the order of the wavelength of light, then for some range of wavelengths light can not go through the crystal. This range of wavelength is called the Photonic Bandgap (John S., 1987).

This paper is subdivided into three major sections: Section-I gives a brief introduction about the work, Section-II gives a brief theoretical background of the computational methods which are used for simulation and analysis. Section-III gives the Results and outcomes of this study, including the corresponding tables and graphs. Section-IV is for the conclusions of the research work.

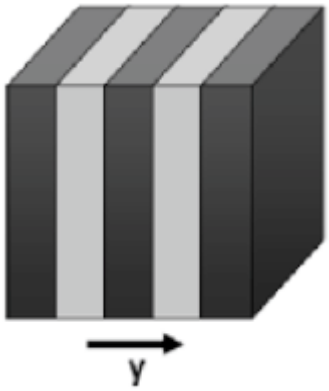


Fig. 1. Schematic view of One-Dimensional Photonic Crystal

Numerical Techniques : Two major techniques are involved for the computational simulation of the band gaps:

– Finite Difference Time Domain (FDTD) method

– Plane Wave Expansion (PWE) Method

The Plane Wave method is widely used for the computation of the band structures. It allows to solve the Eigenvalue problem formulated for the specific periodic structure and requires mathematical description of the PhCs lattice and the Bloch theorem (Johnson Steven G., 2001) is used for representation of the Eigen-functions in the general form. In contrast to PWE method, the FDTD provides possibility of the refractive index variation during the computation process, which allows to take into account losses and nonlinearity when computing the band structure. Because of strong diffraction and multiple scattering in periodic structures of photonic crystals, Maxwell's equation needs to be numerically solved. FDTD has been widely applied in simulating and modeling photonic band materials. This method linearly scales with the simulation dimension and can be implemented in parallel computing environment very efficiently.

For this purpose, we have used OptiFDTD software. After the designing of our desirable crystal structure, we have calculated the band gaps. The structure is made by arranging the dielectric materials of different dielectric constants (high and low) alternately.

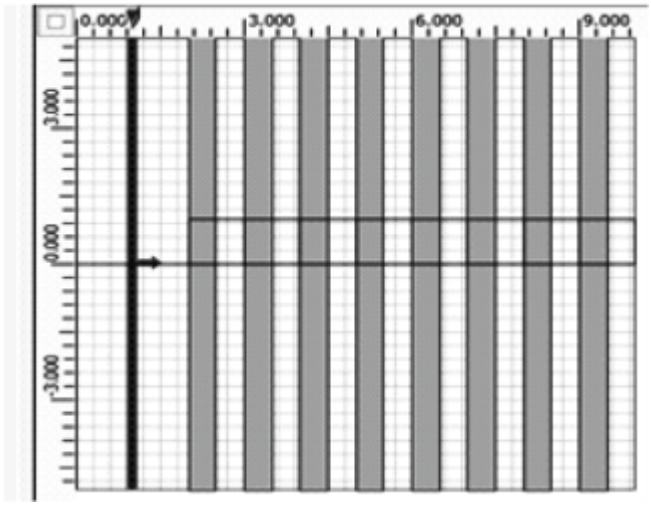


Fig. 2. Representation of dielectric layers in One-Dimensional Photonic Crystal

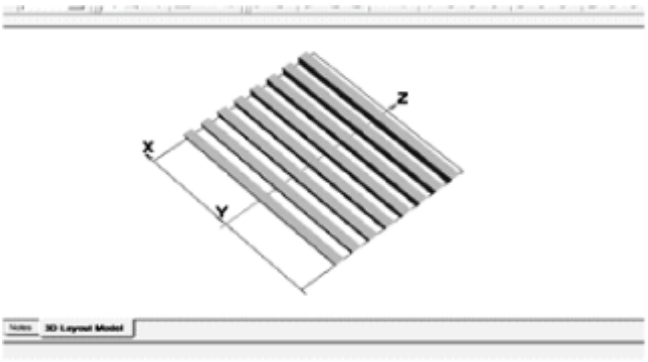


Fig. 3. Layout of the model designed

Results and Discussion :

The two dielectrics are assumed to be loss-less within the operational frequency range, so the light beam reaching the internal interfaces undergoes only reflection and transmission without any absorption and scattering. As light energy goes off with each reflection, the eventual light energy that goes out the whole crystal will attenuate to be zero after infinite layers. That means, the light could be totally reflected after infinite periodic units. Actually the total reflection can be realized within finite layers if the frequency of light is right in certain band-gap.

The band structure generated by each pair of the dielectric constants has been shown through images below. The images are screenshots of the output generated by the OptiFDTD software. The corresponding graph outlines, the behavior of the crystal when a light wave of certain frequency falls on it.

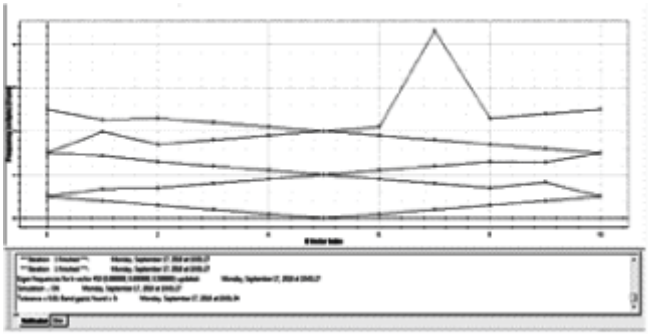


Fig. 4. Band structure computation of 1D for eps1=1; eps2=1

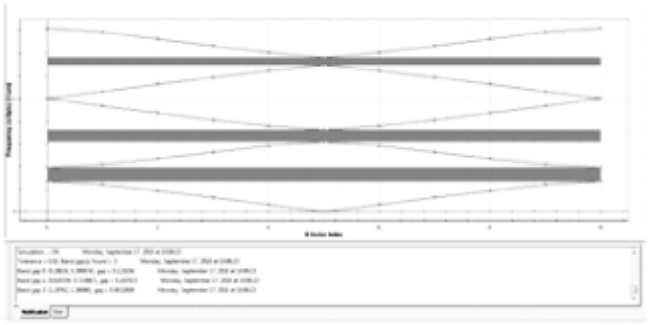


Fig. 5. Band structure computation of 1D for eps1=1; eps2=2

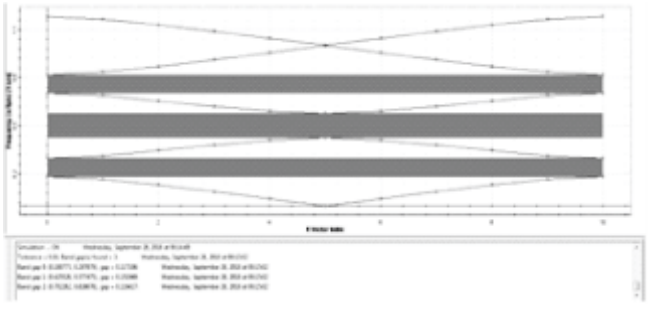


Fig. 6. Band structure computation of 1D for eps1=1; eps2=3

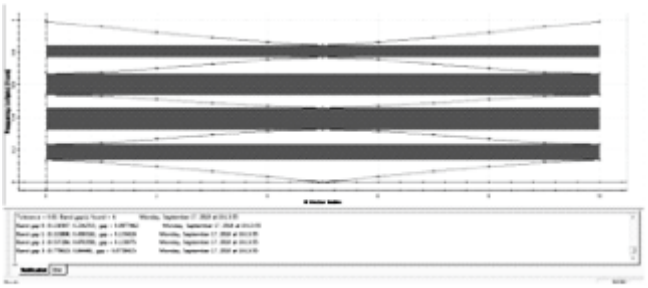


Fig. 7. Band structure computation of 1D for eps1=1; eps2=4

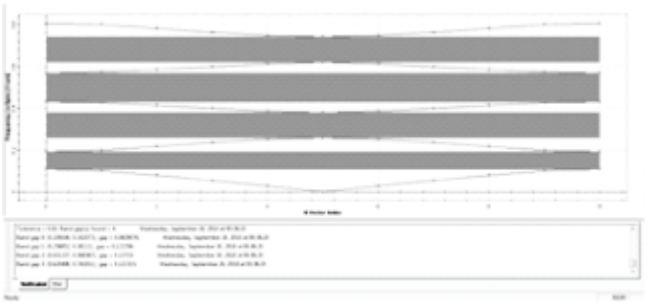


Fig. 8. Band structure computation of 1D for eps1=1; eps2=5

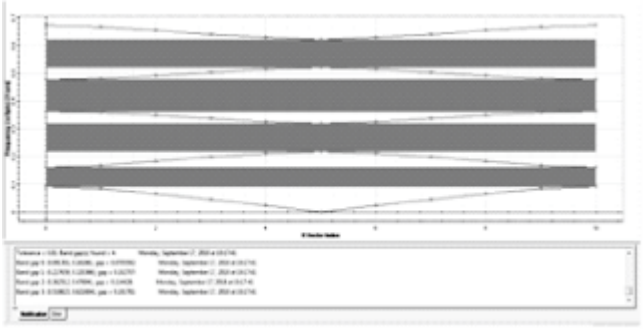


Fig. 9. Band structure computation of 1D for eps1=1; eps2=6

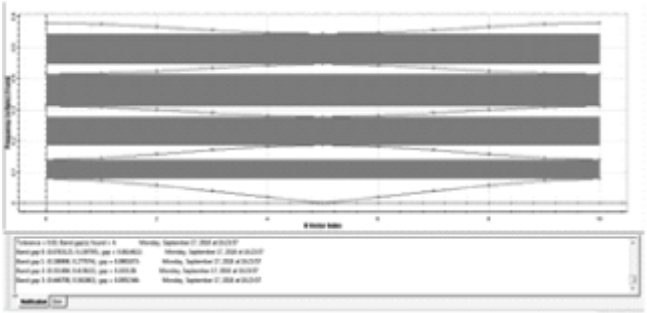


Fig. 10. Band structure computation of 1D for eps1=1; eps2=7

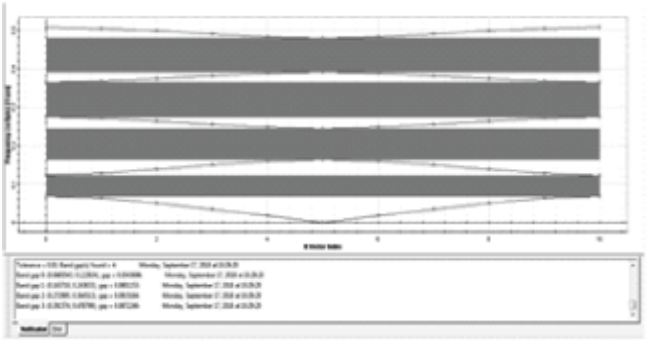


Fig. 11. Band structure computation of 1D for eps1=1; eps2=8

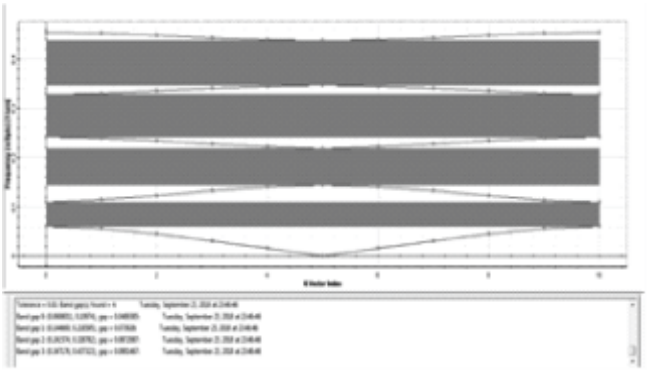
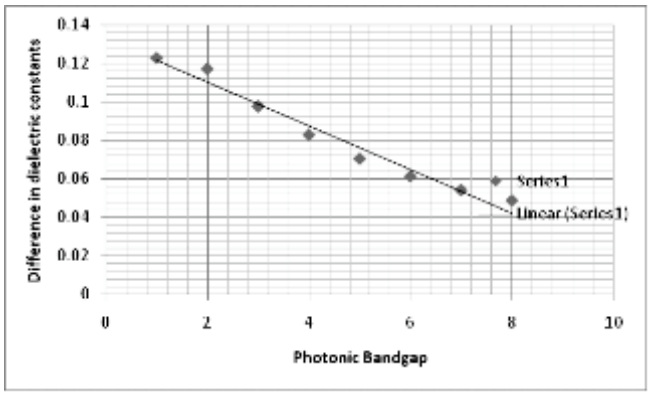


Fig. 12. Band structure computation of 1D for eps1=1; eps2=9

Table 1. Tabular representation of dielectric constants taken into consideration and their corresponding band gaps

Sl. No.	Eps1	Eps2	Difference	Band Gap
I	1	1	0	0.0
II	1	2	1	0.122634
III	1	3	2	0.117106
IV	1	4	3	0.0977462
V	1	5	4	0.0829076
VI	1	6	5	0.0705592
VII	1	7	6	0.0614822
VIII	1	8	7	0.0543696
IX	1	9	8	0.0489385



Graph 1. Depicting the graph of difference in dielectric constants vs photonic band gaps

Conclusions :

This work shows the value of Band-gap decreases as the difference between the values of alternately arranged dielectrics increases. This band gap allows some wavelengths of light to pass but not others, allowing unprecedented control over the behavior of light. The mechanism of photonic band-gap is illustrated by Bragg reflection and then the photonic band-gap is calculated through numerical modeling by the finite difference time domain (FDTD) method.

The quality of a Photonic Crystal depends upon its photonic bandgap.

To verify the results obtained above, numerical simulation of the band-gap of one dimensional photonic crystal based on the FDTD method is conducted. In the same band-gap structure defect can be introduced to simulate and design sensors for different medical and engineering purposes.

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References :

John S. (1987). Phys. Rev. Lett. 58, 2486.

Johnson Steven G. (2001). "Photonic crystal: From theory to practical", Massachhussets Institute of Technoloy.

Joannopoulos John D., Steven. G. Johnson,Winn Joshua N., MeadeRobert. D. (2008). "Photonic Crystal: Molding the flow of light", second edition. Princeton, Princeton University Press.

Yablonovitch E. (1987). Phys. Rev. Lett. 58, 2059.