LIST OF FIGURES AND TABLES

CHAPTER – 1

Figure 1.1 Some applications on the basis of different optical properties of the photonic crystals. **2**

Figure 1.2 Simple examples of one-, two- and three-dimensional PCs. **4**

Figure 1.3 Typical photonic nanostructures in natural creatures: (A) 1-D grating: Hibiscus trionum and Tulipa species; (B) 1-D periodicity in the form of multilayers existing in some insects, birds, fish, plant leaves, berries and so on; (C) some discrete 1-D periodicity: Morpho-butterflies and certain plant leaves; (D) natural surfaces with 2-D gratings in some nocturnal insects such as moth and some butterflies; (E) natural 2-D periodicity in the form of cylindrical voids found in iridescent hairs of certain marine worms-Aphrodite; (F) close-packed spheres of solid materials generate the iridescence of gem opals; (G) inverse opal analogous nanostructures generate the iridescence of several species of exotic butterflies such as Parides sesostris. **5**

Figure 1.4 One-dimensional photonic crystals and their some applications. **7**

Figure 1.5 1-D photonic crystal structure with d = 0.5a, the corresponding band gap diagrams are shown for: (a) GaAs bulk (ε = 13); (b) GaAs/GaAlAs multilayer (ε_1 = 13, ε_2 = 12); and (c) GaAs/air multilayer (ε_1 = 13, ε_2 = 1). **8**

Figure 1.6 Panels (a), (b) and (c) are real lattice, reciprocal lattice and Brillouin zones of square lattice in which $a_1 = a_2 = a$, and $\theta_{lattice} = a_1, a_2 = 90^o$; and panel (d), (e) and (f) are real lattice, reciprocal lattice and Brillouin zones of Triangular lattice in which $a1 = a_2 = a$, and $\theta_{lattice} = a_1, a_2 = 60^o$ made of air holes r = 0.3a , respectively. **9**

Figure 1.7 Band structure diagram of 2-D photonic crystal structures made of air hole (r = 0.3; n1 = √ε1 = 1) in silicon (Si) host material (n2 = √ε2 = 3.45) calculated by the Plane wave expansion method for the polarizations TE (line) and TM (dashed line) of (a) the square lattice and (b) the triangular lattice. **10**

Figure 1.8 (a) Schematic illustrations and SEM image of 3-D Yablonovite structure fabrication, (b) Photonic dispersion curve of Yablonovite. Inset is the schematic illustrations of Yablonovite and photonic band gap is indicated in yellow region. **11**

Figure 1.9 Schematic representations of the PCs with defects. (a) 1-D PC structure with defect layer, (b) line and point defects in 2-D PC structure and (c) 3-D PC structures with cavity and waveguide defects. **12**

Figure 1.10 (a) Picture of the graded photonic crystal lens, and (b) Profile of the electric field at several frequencies in the focal plane. **14**

Figure 1.11 (a) Schematic of a non-resonant multilayer Fibonacci structure composed of two dielectric layers (SiO2 and TiO2) of thicknesses LA and LB deposited using electron-beam evaporation on a glass substrate. (b) Optical transmission spectra for Fibonacci dielectric coating stacks F6 to F8, that show the evolution of the transmission spectrum with the number of layers as Fn increases. **18**

Figure 1.12 Reflection and refraction at an optical interface between two medium (n_1 and n_2). The wave vectors of the incident, transmitted and reflected waves are $\overrightarrow{k_1}$, $\overrightarrow{k_t}$ and $\overrightarrow{k_r}$. The electric fields are decomposed into their components parallel and perpendicular to the incidence plane, $\overrightarrow{E^{\parallel}}$ and $\overrightarrow{E^{\perp}}$. **27**

Figure 1.13 (a) Reflection of a single wave from the boundaries of a multi-layered medium. (b) In each layer, the forward waves are lumped into a forward collected wave A, and the backward waves are lumped into a backward collected wave B. **29**

Figure 1.14 The schematic representation of the stacking of two different dielectric materials (A and B) in the form of the periodicity. **30**

CHAPTER – 2

Figure 2.1 Schematic representation of one dimensional graded photonic crystal structures with linearly (a) increasing and (b) decreasing refractive index in a linear graded layer. **40**

Figure 2.2 (a) Schematic representation of the structure with a linear graded defect layer form of $(AB)^P ADA(BA)^P$ with period P and (b) relative refractive index variation in central unit cells. **44**

Figure 2.3 Reflectance spectra of the considered 1-D GPC structures for the refractive index (a) $n_B = 1.0$ and (b) $n_B = 1.5$ with various layer thickness coefficient D $(= q\lambda_0/4)$. Panel (c) shows the reflection spectra for the structure with uniform refractive index of layer A and B equal to 1.5 and 3.0, respectively. **46**

Figure 2.4 The distribution of bandwidth of photonic band gaps as a function of the layer thickness constant D for the structures with homogenous layers refractive index (a) $n_B = 1.0$, and (b) $n_B = 1.5$, and plot (d) shows the total band gap of the forbidden band regions against the layer thickness constant D $(= q\times\lambda_0/4)$. **48**

Figure 2.5 Panel (i) shows the dispersion spectra for both types of considered periodic arrangements for optical layer thickness with relative refractive index equal to (a) $\lambda_0/4$ and (b) $\lambda_0/2$, while panels (ii) and (iii) illustrate the reflection phase shift of the structures $(AB)^{10}$ and $(A'B)^{10}$, respectively and $n_B = 1.0$. **50**

Figure 2.6 Distributions of electric field intensity in the systems $(AB)^{10}$ and $(A'B)^{10}$, respectively show in the panels (i) and (ii) at three selected frequencies (a) 699.5 THz, (b) 729.7 THz, and (c) 735 THz impinging **51**

under ≈50%, ≈0% and ≈100% reflection.

Figure 2.7 Reflection (R) spectra for (a) TE-polarization, (b) TM-polarization and (c) projected reflection band structure as changing of the incident angle for the quarter-wave type layer stacking arrangement in the considered structure with n_B = 1.5. **53**

Figure 2.8 Reflection (R) spectra for (a) TE-polarization, (b) TM-polarization and (c) projected reflection band structure as changing of the incident angle for the quarter-wave type layer stacking arrangement in the considered structure with n_B = 2.0. **54**

Figure 2.9 Reflectance spectra for different values of the contrast between initial (n_i) and final (n_f) refractive index of linear graded index layer in the considered 1-D GPC structures with (a) quarter-wave layer stacking and (b) precise layer thickness; d_1 = 60 nm and d_2 = 90 nm arrangements, and parameters; $n_i = 1.5$ and $n_B = 1.0$. **56**

Figure 2.10 The variations of bandwidth of photonic band gaps as a function of the contrast value $(n_f \sim n_i)$ for different layer thickness arrangement in the considered 1-D GPC structures with homogenous layers refractive index equal to 1.0, here $n_i = 1.5$ and d = 150 nm. **57**

Figure 2.11 Transmission spectra of the structure (a) $(AB)^6AA(BA)^6$, (b) $(AB)^6ADA(BA)^6$ and (c) $(AB)^7ADA(BA)^7$. Here, refractive indices: $n_A = 1.5$, $n_B = 4.5$, $n_i = 1.5$ and $n_f = 4.5$, and thickness: $[n_A.a = n_B.b = n_m.d = \lambda_0/4]$, where λ_0 = 600 nm and $n_m = (n_i + n_f)/2$. **59**

Figure 2.12 The dependence of (a) defect mode frequency (f_D) and (b) defect mode intensity on the period (P) in the structure of the form $(AB)^PADA(BA)^P$ containing linear graded index material as defect layer D. **60**

Figure 2.13 Transmission spectra of the defect modes of $(AB)^5ADA(BA)^5$ at different thickness of defect layer D. The refractive indices: $n_A = 1.5$, $n_B = 4.5$, $n_i = 1.5$ and $n_f = 4.5$. Case of (a) thickness of defect layer D equal to thickness of layer B, (b) thickness of defect layer D = 25 nm, (c) thickness of defect layer D = 100 nm and (d) thickness of defect layer D = 200 nm. **60**

Figure 2.14 Transmission spectra at different values of contrast between initial (n_i) and final (n_f) refractive index of the graded index defect layer of the structure $(AB)^6ADA(BA)^6$. Refractive index, $n_i = 1.5$, and values of n_f are shown in the figure. **61**

Figure 2.15 The electric field distribution at the defect modes frequency (a) 336.9 THz and (b) 659.7 THz in the defect structure form of $(AB)^5ADA(BA)^5$ containing defect layer as D of a linear graded index material. **62**

Figure 2.16 Transmission spectra at different incident angle (a) $\theta = 0^{\circ}$, (b) $\theta = 15^{\circ}$, (c) $\theta = 30^{\circ}$, (d) $\theta = 45^{\circ}$ and (e) $\theta = 60^{\circ}$ for TE-wave in the structure $(AB)^6ADA(BA)^6$ containing linear graded index defect layer as D. **63**

Figure 2.17 Transmission spectra at different incident angle (a) $\theta = 0^{\circ}$, (b) $\theta = 15^{\circ}$, **64**

(c) θ = 30°, (d) θ = 45° and (e) θ = 60° for TM-wave of the structure $(AB)^6ADA(BA)^6$ containing linear graded index defect layer as D.

Figure 2.18 The dependence of defect mode frequency (f_D) on the incident angle (θ) for (a) TE-mode and (b) TM-mode in the structure form of $(AB)^6ADA(BA)^6$ containing linear graded index defect layer as D. **64**

Figure 2.19 The dependence of defect mode intensity on the incident angle (θ) for (a) TE-mode and (b) TM-mode in the structure form of $(AB)^6ADA(BA)^6$ containing exponential graded index defect layer as D. **65**

Table 2.1 Reflection band region and bandwidth of the considered 1-D GPC structures at different layer thickness under normal angle of incidence. **49**

Table 2.2 Omnidirectional band region and bandwidth for different values of refractive index n_B in the considered 1-D GPC structures with quarter wave layer stacking. **54**

Table 2.3 Reflection band region and bandwidth for different values of contrast $(n_f - n_i)$ of the considered 1-D GPC structures at normal incidence, and $n_i =$ 1.5 and d = 150 nm. **57**

CHAPTER – 3

Figure 3.1 The schematic representation of the considered 1-D GPC structures composed of graded index materials with exponentially (a) increasing and (b) decreasing refractive index along the thickness of layer. **69**

Figure 3.2 (a) Schematic representation of the 1-D PC structure with defect layer (D) as an exponential graded material of the form $(AB)^PADA(BA)^P$ with period P and panel (b) show the relative refractive index variation in central unit cells. **73**

Figure 3.3 Reflectance spectra of the structures for the refractive index (a) $n_B = 2.0$, (b) $n_B = 1.5$and (c) $n_B = 1.0$, with various layer thickness constant D. **76**

Figure 3.4 The distribution of photonic bandwidths as a function of the layer thickness constant D (= $q\lambda_0/4$, q = 1, 2, 3 …) for the structures with homogenous layer refractive index (a) n_B = 1.0 and (b) n_B = 1.5. **77**

Figure 3.5 The distribution of total band gap of the photonic band gaps against the layer thickness constant D (= $q\lambda_0/4$, q = 1, 2, 3 …). **78**

Figure 3.6 The distribution of photonic bandwidths as a function of the homogenous layer refractive index n_B for the structures with (a) quarter wave layer stacking arrangement and (b) precise layer thickness d_1 = 50 nm and d_2 = 75 nm arrangement. **79**

Figure 3.7 Panels (i) and (ii), respectively show the spatial distributions of the electric field intensity in the systems type1 $(AB)^{10}$ and type2 $(A'B)^{10}$ at three selected frequencies (a) 580 THz, (b) 628.4 THz and (c) 635 THz, impinging under ≈0%, ≈50% and ≈100%, respectively. **80**

Figure 3.8 Panels (i) and (ii), respectively show the dispersion spectra and phase shifts of the considered structures for optical layer thickness with relative refractive index equal to (a) $\lambda_0/4$ and (b) $\lambda_0/2$. **81**

Figure 3.9 Reflectance spectra for different precise layer thickness of graded layers (d_1) and normal layers (d_2) for the structures with fixed values of (a) d_2 = 75 nm and (b) d_1 = 50 nm, respectively. **83**

Figure 3.10 Reflection spectra for (a) TE-polarization, (b) TM-polarization and (c) projected band spectra as changing of the incident angle of the quarter-wave stacked structure with n_B= 2.0. **84**

Figure 3.11 Reflection spectra for (a) TE-polarization, (b) TM-polarization and (c) projected band spectra as changing of the incident angle of the quarter-wave stacked structure with n_B= 1.5. **85**

Figure 3.12 Projected band spectra as the changing of the incident angle of the latent type structures with refractive index (a) n_B = 2.0, and (b) n_B = 1.5. **86**

Figure 3.13 The distribution of Omni-directional band gap as a function of the refractive index n_B for the structure with quarter wave staking arrangements. **88**

Figure 3.14 Reflectance spectra for different values of grading parameter γ (or γ') for the structures with arrangement in (a) quarter wave stacking and (b) precise layer thickness d_1 = 64 nm and d_2 = 136 nm. **89**

Figure 3.15 Panel (a) shows the distribution of bandwidths as a function of the ratio n_f/n_i for the structures with quarter wave stacking arrangement and different n_B-values and (b) exhibits the distribution of bandwidths as a function of the ratio n_f/n_i for the structures with specific layer thickness, and n_B = 1.0 and d = 200 nm. **90**

Figure 3.16 Transmission spectra of the structure (a) $(AB)^6AA(BA)^6$, (b) $(AB)^6ADA(BA)^6$ and (c) $(AB)^7ADA(BA)^7$ with exponential graded index defect layer as D. Here, refractive indices; $n_A = 1.5$, $n_B = 4.5$, $n_i = 1.5$ and $n_f = 4.5$, and thickness: $[n_A.a = n_B.b = n_m.d = \lambda_0/4]$, where λ_0 = 600 nm and $n_m = (n_i + n_f)/2$. **92**

Figure 3.17 The dependence of (a) defect mode frequency (f_D) and (b) defect mode intensity on the period (P) in the structure of the form $(AB)^PADA(BA)^P$ containing exponential graded index material as defect layer D. **93**

Figure 3.18 Transmission spectra of the structure of the form $(AB)^5ADA(BA)^5$ at different thickness of exponential graded index defect layer D. The refractive indices: $n_A = 1.5$, $n_B = 4.5$, $n_i = 1.5$ and $n_f = 4.5$. Case of (a) thickness of defect layer D equal to thickness of layer B, (b) thickness of defect layer D = 25 nm, (c) thickness of defect layer D = 100 nm and (d) thickness of defect layer D = 200 nm. **93**

Figure 3.19 Transmission spectra at different values of contrast between initial (n_i) and final (n_f) refractive index of the exponential graded index defect layer of the structure $(AB)^6ADA(BA)^6$ with quarter-wave stacking **94**

arrangement. Refractive index, $n_i = 1.5$, and values of n_f are shown in the figure.

Figure 3.20 The electric field distribution at the defect modes frequency (a) 345.6 THz and (b) 662.4 THz in the structure of the form $(AB)^5ADA(BA)^5$ containing exponential graded index defect layer as D. **95**

Figure 3.21 Transmission spectra at different incident angle (a) θ = 0°, (b) θ = 15°, (c) θ = 30°, (d) θ = 45° and (e) θ = 60° for TE-wave of the structure $(AB)^6ADA(BA)^6$ containing exponential graded index defect layer as D. **96**

Figure 3.22 Transmission spectra at different incident angle (a) θ = 0°, (b) θ = 15°, (c) θ = 30°, (d) θ = 45° and (e) θ = 60° for TM-wave of the structure $(AB)^6ADA(BA)^6$ containing exponential graded index defect layer as D. **97**

Figure 3.23 The dependence of defect mode frequency (f_D) on the incident angle (θ) for (a) TE-mode and (b) TM-mode in the structure form of $(AB)^6ADA(BA)^6$ containing exponential graded index defect layer as D. **97**

Figure 3.24 The dependence of defect mode intensity on the incident angle (θ) for (a) TE-mode and (b) TM-mode in the structure form of $(AB)^6ADA(BA)^6$ containing exponential graded index defect layer as D. **98**

Table 3.1 Reflection bands region and bandwidths in the 1-D GPC structures at normal incidence for different layer thickness. **82**

Table 3.2 Omni-directional bands region and bandwidths in the considered 1-D GPC structures for various n_B-values. **87**

Table 3.3 Reflection bands region and bandwidths in the GPC structures at normal incidence for different (n_f/n_i) values. **90**

CHAPTER – 4

Figure 4.1 (a) Reflectance and (b) band structure of the structure with alternating layers of exponential graded index material (16 mm thick) and the negative index material (thickness d2) at normal incidence. Panels (i), (ii), (iii), (iv) and (v) are for the thicknesses d_2 equal to 24 mm, 20 mm, 16 mm, 12 mm and 8 mm, respectively. **107**

Figure 4.2 The dependence of photonic band gaps on the ratio of thickness of graded index and negative index materials layer under three different lattice constants (a) d_1 = 24 mm, (b) d_1 = 20 mm and (c) d_1 = 12 mm of the structures at normal incidence. **108**

Figure 4.3 Panels (a) d_1 = 24 mm, d_2 = 28 mm, (b) d_1 = 18 mm, d_2 = 28 mm and (c) d_1 = 24 mm, d_2 = 18 mm show the reflection spectra as a function of the ratio $\varepsilon_f / \varepsilon_i$. **109**

Figure 4.4 The dependence of the photonic band gaps on the ratio ($\varepsilon_f / \varepsilon_i$) under three different lattice constants (a) d_1 = 24 mm, d_2 = 28 mm, (b) d_1 = 18 mm, d_2 = 28 mm and (c) d_1 = 24 mm, d_2 = 18 mm for the structure. **109**

Figure 4.5	Reflection spectra for (a) TE-polarization, (b) TM-polarization and (c) projected reflection band structure as changing of the incident angle in the structure with lattice constant d_1 = 24 mm and d_2 = 28 mm.	**110**
Figure 4.6	The distribution of the Omni-directional bandwidths as a function of the ratio of the thicknesses of graded and negative index materials under three different lattice constants (a) d_1 = 24 mm, (b) d_1 = 16 mm and (c) d_1 = 8 mm for the considered structures.	**111**
Figure 4.7	Reflectance for the structure with alternating layers of exponential graded index material (24 mm thick) and the epsilon-negative material (thickness d_2) at normal incidence. Panels (a), (b), (c), (d) and (e) are for different values of thickness d_2 equal to 40 mm, 36 mm, 32 mm, 28 mm and 24 mm, respectively.	**112**
Figure 4.8	The dependence of PBGs on the ratio of the thickness of graded and epsilon-negative materials layers under three different lattice constants (a) d_1 = 24 mm, (b) d_1 = 20 mm and (c) d_1 = 16 mm for the considered structure at normal incidence.	**112**
Figure 4.9	The reflection spectra as a function of the ratio $(\varepsilon_f / \varepsilon_i)$ show in panels (a) d_1 = 24 mm, d_2 = 40 mm, (b) d_1 = 18 mm, d_2 = 40 mm and (c) d_1 = 24 mm, d_2 = 28 mm.	**113**
Figure 4.10	The dependence of the photonic band gaps on the ratio $(\varepsilon_f / \varepsilon_i)$ under three different lattice constants (a) d_1 = 24 mm, d_2 = 40 mm, (b) d_1 = 18 mm, d_2 = 40 mm and (c) d_1 = 24 mm, d_2 = 28 mm of the structure.	**114**
Figure 4.11	Reflection spectra for (a) TE-polarization, (b) TM-polarization and (c) projected reflection band structure as changing of the incident angle in the structure with lattice constant d_1 = 24 mm and d_2 = 40 mm.	**115**
Figure 4.12	The distribution of the Omni-directional bandwidths as a function of the ratio of the thickness of graded and epsilon-negative materials under three different lattice constants (a) d_1 = 24 mm, (b) d_1 = 20 mm and (c) d_1 = 16 mm for the structure.	**115**
Figure 4.13	Reflectance spectra of the structure with alternating layers of exponential graded index material (16 mm thick) and mu-negative material (thickness d_2) at normal incidence. Panels (a), (b), (c), (d) and (e) are the reflectance spectra for the thickness d_2 equal to 40 mm, 32 mm, 24 mm, 16 mm and 8 mm, respectively.	**116**
Figure 4.14	The dependence of the photonic band gaps on the ratio of the thickness of graded index and mu-negative materials under three different lattice constants (a) d_1 = 24 mm, (b) d_1 = 20 mm and (c) d_1 = 12 mm of the structure at normal incidence.	**117**
Figure 4.15	Reflection spectra as a function of the ratio $(\varepsilon_f / \varepsilon_i)$ show in panels (a) d_1 = 20 mm, d_2 = 24 mm, (b) d_1 = 16 mm, d_2 = 24 mm and (c) d_1 = 20 mm, d_2 = 16 mm.	**118**
Figure 4.16	The dependence of PBG on the ratio $(\varepsilon_f / \varepsilon_i)$ under three different	**118**

cases of the lattice parameter (a) d_1 = 20 mm, d_2 = 24 mm, (b) d_1 = 16 mm, d_2 = 24 mm and (c) d_1 = 20 mm, d_2 = 16 mm for the considered structure.

Figure 4.17 Reflection spectra for (a) TE-polarization, (b) TM-polarization and (c) projected reflection band structure as changing of the incident angle in the structure with lattice parameter d_1 = 24 mm and d_2 = 40 mm. **119**

Figure 4.18 The distribution of the Omni-directional bandwidths as a function of the ratio of the thickness of graded and mu-negative materials under three different lattice parameters (a) d_1 = 24 mm, (b) d_1 = 20 mm and (c) d_1 = 16 mm of the structures. **120**

Figure 4.19 (a) Schematic diagram of the considered structure constituted with graded index layers as A (linear and exponential graded index material) and semiconductor material layers as B, the background medium is air. (b) Refractive index variation in a graded layer as a function of layer thickness d_1 (here, d_1 = 10 μm). (c) and (d) are the real and imaginary part of the refractive index of the semiconductor (InSb) as a function of frequency with the varying temperature. The parameters are $\varepsilon_\infty = 15.68$, $m^* = 0.015m_e$, $m_e = 9 \times 10^{-31}$kg and $\gamma = 2\pi \times 0.05$ THz. **121**

Figure 4.20 The reflectance as a function of frequency with varying temperature and layers thickness d_1 = 5 μm and d_2 = 1 μm for the 1-D PC structure $(AB)^{10}$ with linear and exponential graded index materials. **127**

Figure 4.21 The distribution of the photonic band gaps (black region) as a function of the temperature for the PC structure $(AB)^{10}$ with (a) linear and (b) exponential graded index materials. Layers thickness are d_1 = 5 μm and d_2 = 1 μm. **127**

Figure 4.22 Panels (i) dispersion spectra and (ii) the reflection phase shifts for the periodic structure with (a) linear and (b) exponential graded index materials at different temperatures. **128**

Figure 4.23 Reflection spectra for the structure $(AB)^{10}$ with (a) linear and (b) exponential graded index materials as a function of frequency with the varying temperature and layers thickness d_1 = 10 μm and d_2 = 5 μm. **129**

Figure 4.24 The distributions of the electric field intensity in the system $(AB)^{10}$ with (a) linear and (b) exponential graded index materials at frequencies 8.59 THz and 9.15 THz, respectively with four selected temperature 200 K, 250 K, 300 K and 350 K, and layers thickness d_1 = 12 μm and d_2 = 5 μm. Reflection spectra around the frequency 8.59 THz and 9.15 Thz are shown in insets of the panels (a) and (b), respectively. **131**

Figure 4.25 Reflection spectra as a function of frequency with varying layers thickness d_1 and d_2 for the structure $(AB)^{10}$ with linear and exponential graded index materials at temperature T = 300 K. **132**

Figure 4.26 The distribution of the photonic band gaps (black region) as a function of the thickness ratio (d_1/d_2) for the periodic structure $(AB)^P$ with (a) linear and (b) exponential graded index materials, where d_2 = 1 μm and T **133**

= 300 K.

Figure 4.27 The distribution of the photonic band gaps (black region) as a function of the thickness d_2 for the periodic structure $(AB)^P$ with (a) linear and (b) exponential graded index materials, where d_1= 5 μm and T = 300 K. **133**

Figure 4.28 Reflection spectra at different values of n_f for the structure $(AB)^{10}$ with (a) linear and (b) exponential graded index materials at temperature T = 300 K, and layers thickness d_1 = 10 μm and d_2 = 5 μm, and refractive index n_i = 1.5. **134**

Figure 4.29 The distribution of forbidden band gaps (black region) as a function of the refractive index n_f of the graded layer for the structure $(AB)^P$ with (a) linear and (b) exponential graded index materials, here d_1 = 5 μm, d_2 = 1 μm, n_i = 1.5 and T = 300 K. **135**

Figure 4.30 The distribution of forbidden band gaps (black region) as a function of the refractive index n_i of the graded layer for the structure $(AB)^P$ with (a) linear and (b) exponential graded index materials, here d_1 = 5 μm, d_2 = 1 μm, n_f = 4.5 and T = 300 K. **135**

Figure 4.31 Reflection spectra at different values of damping factor γ for the structure $(AB)^{10}$ with linear and exponential graded index materials, here temperature T = 200 K, refractive index n_i = 1.5 and n_f = 4.5, layers thickness d_1 = 8 μm and d_2 = 3 μm. **136**

CHAPTER – 5

Figure 5.1 Reflection spectra calculated at different layer thickness constant (D) for the structures (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$ with linear graded index material as one of the layer. **144**

Figure 5.2 Reflection spectra calculated at different values of constant (D) for the structures (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$ with exponential graded index material as one of the layer. **145**

Figure 5.3 The distribution of the PBGs as a function of layer thickness for the structure $(F_2)^{10}$ with (a) linear and (b) exponential graded index materials as one of the layer. **145**

Figure 5.4 The distribution of the PBGs as a function of layer thickness for the structure $(F_3)^{10}$ with (a) linear and (b) exponential graded index materials as one of the layer. **146**

Figure 5.5 The variation of total bandwidth of as a function of the layer thickness for the structure $(F_2)^{10}$ and $(F_3)^{10}$ with (a) linear and (b) exponential graded index materials as one of the layer. **146**

Figure 5.6 Panels (a) and (b) show the reflectance spectra at different values of grading profile parameter 'α' of linearly graded index material in the structures $(F_2)^{10}$ and $(F_3)^{10}$, respectively. **147**

Figure 5.7 Panels (a) and (b) show the reflectance spectra at different values of **148**

grading profile parameter ‘γ’ of exponentially graded index layers in structures $(F_2)^{10}$ and $(F_3)^{10}$, respectively.

Figure 5.8 Reflectance (R) versus frequency (f) spectra of the structures (a) F_7, (b) F_8 and (c) F_9 for normal, linear and exponential graded index materials under normal incidence. **149**

Figure 5.9 Reflection coefficient (R) versus frequency for the quasi-periodic photonic crystal structures of (a) 5th, (b) 6th and (c) 7th generation Thue-Morse sequence with linear and exponential graded materials. **150**

Figure 5.10 Reflectance (R) versus frequency for the structures of (a) 5th, (b) 6th and (c) 7th generation Double-Periodic sequence with linear and exponential graded materials. **151**

Figure 5.11 The distribution of the photonic bandwidths as a function of the Thue-Morse generations for the photonic crystal structures with (a) linear and (b) exponential graded layers. **152**

Figure 5.12 The distribution of the photonic bandwidths as a function of the Double-Periodic generations for the photonic crystal structures with (a) linear and (b) exponential graded layers. **153**

Figure 5.13 The total band gap variation with the generations of the sequence (a) Thue-Morse and (b) Double-Periodic in photonic crystal structures with linear and exponential graded layers. **154**

Figure 5.14 Reflectance (R) of the structure (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$ as a function of frequency with varying temperature, and assuming $d_1 = 7$ μm and $d_2 = 3.5$ μm. **155**

Figure 5.15 The distribution of the photonic bands as a function of the thickness ratio (d_1/d_2) at normal incidence for the structure (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$, where $d_2 = 4$ μm and T = 300 K. **156**

Figure 5.16 The distribution of the photonic band gaps in the structure (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$ as a function of the thickness ratio (d_2/d_1) at normal incidence, where $d_1 = 5$ μm and T = 300 K. **156**

Figure 5.17 Reflectance (R) spectra of the structure $(F_2)^{10}$ at normal incidence under different fixed layer thickness ratio (a) $d_1{:}d_2 = 1{:}1$, (b) $d_1{:}d_2 = 1{:}2$ and (c) $d_1{:}d_2 = 2{:}1$, and T = 300 K. **157**

Figure 5.18 The distribution of the photonic bands as a function of the Fibonacci generation in the 1-D Fibonacci multilayer structures with lattice parameters $d_1 = 7$ μm, $d_2 = 3$ μm and temperature T = 300 K. **158**

Figure 5.19 Reflectance (R) spectra for (a) TE-polarization, (b) TM-polarization and (c) projected band gaps structure as a function of incident angle in the structure $(F_2)^{10}$ with lattice parameters $d_1 = 7$ μm, $d_2 = 3$ μm and temperature T = 300 K. **159**

Figure 5.20 Reflectance (R) spectra of the structure $(F_3)^{10}$ for (a) TE-polarization, (b) TM-polarization and (c) projected band gaps structure as a function of incident angle, and assuming lattice parameters $d_1 = 7$ μm, $d_2 = 3$ μm and **160**

temperature T = 300 K.

Figure 5.21 Distribution of the omnidirectional band gaps as a function of temperature for the structures (a) $(F_2)^{10}$ and (b) $(F_3)^{10}$, here lattice parameters d_1 = 7 μm and d_2 = 3 μm. **161**

Figure 5.22 The distribution of the omnidirectional bands as a function of Fibonacci generation of the structures with lattice parameters d_1 = 7 μm, d_2 = 3 μm and temperature T = 300 K. **161**

Figure 5.23 The distribution of the photonic bands as a function of (a) Thue-Morse generation and (b) Double-Periodic generation for 1-D quasi-periodic photonic crystal structures, where lattice parameters d_1 = 7 μm, d_2 = 3 μm and temperature T = 300 K. **162**

Figure 5.24 Reflectance (R) of the structure (a) $(T_3)^{10}$ and (b) $(T_4)^{10}$ as a function of frequency with varying temperature and assuming parameters d_1 = 7 μm and d_2 = 3 μm. **163**

Figure 5.25 Reflectance (R) of the structure (a) $(D_3)^{10}$ and (b) $(D_4)^{10}$ as a function of frequency with the varying temperature, and assuming d_1 = 7 μm and d_2 = 3 μm. **164**

Figure 5.26 The distribution of omnidirectional band gaps as a function of (a) Thue-Morse and (b) Double-Periodic generation for 1-D quasi-periodic PC structures, where lattice parameters d_1 = 7 μm, d_2 = 3 μm and temperature T = 300 K. **164**

Figure 5.27 The distribution of omnidirectional bands as a function of temperature for the structures (a) $(T_3)^{10}$ and (b) $(T_4)^{10}$, where lattice parameters d_1 = 7 μm and d_2 = 3 μm. **165**

Figure 5.28 The distribution of omnidirectional bands as a function of temperature for the structures (a) $(D_3)^{10}$ and (b) $(D_4)^{10}$, here lattice parameters d_1 = 7 μm and d_2 = 3 μm. **165**

Figure 5.29 The variation of the total photonic bandwidth as a function of the (a) quasi-periodic generation and (b) Temperature in 1-D quasi-periodic multilayer structures, where lattice parameters; d_1 = 7 μm and d_2 = 3 μm. **166**

Figure 5.30 The variation of the total omnidirectional bandwidth as a function of the (a) quasi-periodic generation and (b) Temperature in 1-D quasi-periodic multilayer structures, where d_1 = 7 μm and d_2 = 3 μm. **167**

Table 5.1 Generations of the quasi-periodic sequences. **141**

★★★★★★★