PREFACE

The worldwide increasing demands of optical devices whose bandwidth and speed of execution leads the curiosity among the researchers to perform the research in the field of the harnessing, generating, detecting and manipulating light. Since light has enabled to carry a large amount of information per second and wide-bandwidth data handling beyond the limitations of the electron as the information carrier. In addition, light waves are not strongly interacting as electrons, which promote to reduce the energy losses. A new class of optical materials known as photonic crystals or photonic band gap materials can respond to light-matter interactions which selectively regulate the propagation of light with a specific wavelength based on its intrinsic periodic structures. Photonic crystals constituted of minimum two different materials with refractive indices that change periodically on a length scale comparable to the wavelength of light. As a result, the formations of photonic band gaps take place that effectively prohibits the propagation of light in the certain direction and at certain wavelength. The photonic band gap properties provide unprecedented possibilities in classical and quantum information processing technologies, and also in life sciences. They are also leading to newer applications including efficient radiation sources, sensors, filters and optical computer chips and other future products with high-speed and wide-bandwidth data handling beyond the limitations of electronic technology.

Deviations from periodicity may result in higher complexity and give rise to a number of surprising results. One such deviation can be found in the field of optics in the realization of quasi-periodic photonic crystals, a class of structures created from building blocks which can be arranged using well-designed patterns with the lack of translational symmetry. Quasi-periodic systems are a well-defined and long-range ordered structure lie between periodic and disordered structures, which show sharp diffraction patterns, light scattering, and wave localization phenomena. These are one of the most interesting arrangements to obtain the suitable photonic band gaps considering of several structural parameters accessible to tune as compared to the periodic and disordered systems. This opens a new field of research in photonics in perspective of their vast technical applications.

Several efforts have been performed to achieve better confining, manipulating, guiding and coupling light in photonic crystals by considering different systems and materials. However, the ability to confine and manipulate the flow of light in photonic crystal structures can be further improved by introducing the concept of graded index optics. A conventional graded index medium is characterized by a gradual variation in refractive index and lattice parameters along the directions transverse to light propagation. Photonic crystals with gradual variations of refractive index and lattice parameters known as graded photonic crystals. The gradual modification of structural parameters in graded photonic crystals opens a new way to control electromagnetic wave propagation in photonic crystals. Graded photonic crystals play an important role in designing spectral filters, high efficiency bending waveguides, couplers, self-focusing media and antireflection coating, etc.

Due to the distinctive optical response and possibility to control, tune, confine and manipulate of light by different types of photonic crystals, in this Thesis, the influences of graded and dispersive materials on optical transmission, photonic and omnidirectional band gaps, localization modes and phase shift in one-dimensional photonic crystals with periodic and quasi-periodic systems have been described. This work can facilitate the design of filters, mirrors, detectors, and sensors, and provide the basic understanding of the influence of graded and dispersive materials on the photonic band gap properties. This thesis has been compiled into six chapters.

The first chapter contains the general introduction and the importance of photonic crystals with periodic and quasi-periodic systems and theoretical analysis of multi-layered systems. Main attentions paid to the types of photonic crystals and their applications, and the existence of the photonic crystals in nature and influence of quasi-periodic systems on photonic band gap, light scattering and wave localization phenomena and the general concept of design and applications of the graded photonic crystals. Theoretical techniques that were employed for the theoretical study of light scattering, interference, or diffraction caused by one-dimensional photonic crystal structures have also presented in this chapter. The mathematical expression of the distribution of electromagnetic waves in homogeneous and inhomogeneous (graded index) media have also been described. A brief description of the design of photonic crystal structures with the help of numerical modeling technique (Transfer matrix technique) used is presented and performed the transmission, reflection, dispersion relation and photonic band structure, respectively. The chapter also concludes with an overview of the current research trends on one-dimensional photonic crystals. Towards the end of this chapter, the aim of the thesis has been presented.

The second and third chapters deal to understand the influence of linear and exponential graded index materials on the photonic and omnidirectional band gap, and defect mode phenomena in one-dimensional photonic crystals. Refractive indices of the graded materials layer gradually change with the depth of layer. Observed results show that the structural and material parameters of graded index materials can change the photonic and omnidirectional band gap properties remarkably. The formation and position of photonic band gaps and defect modes can be modulated by structural parameters, gradation profile, grading parameters, incident angle, and polarization.

The fourth chapter presents the study of photonic and Omni-directional band gap in one-dimensional photonic crystal composed of graded and dispersive materials. Main attention is paid to the effect of structural and material parameters, and temperature on the photonic and Omni-directional band gaps. Results show that the parameters of graded index material and dispersive material can change the photonic and omnidirectional band structures significantly.

The fifth chapter demonstrates the effect of graded materials and semiconductor on the photonic band gaps in one-dimensional quasi-periodic photonic crystals constituted with graded materials and semiconductor. The influences of geometrical parameters, grading profile, temperature and different quasi-periodic sequences and generations on the photonic band gaps and localization modes have been demonstrated. Results show that the photonic and omnidirectional band gaps and generation of localization modes can be tuned by changing the temperature, lattice parameters, grading parameters and generation of quasi-periodic sequences and different types of quasi-periodic system.

In the last sixth chapter, conclusions of overall studies have been summarized. This chapter also comprises further future plans on this field of research.

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