BEGINNING OF “PHOTONICS” IN MESO- AND MACRO-SCALES: BEGINNING OF GRANULAR PHOTONICS

M. M. Khudyntsev

Odesa State Environmental University, Odesa, Ukraine
nh@te.net.ua

We observe the results of studying of electromagnetic wave transmission(reflection) through the systems with manipulated dielectric constant(refractive index). The possibility of generation of the s.c. ”photonics” by means of those phenomena is outlined due to eappearence of the band gape structure.

Key words: *photonics, band-gapes, electromagnetic waves, periodic structures*
PACS 78.67.Pt

During the past decade, there has been a growing interest in the determination of the dispersion curves for electromagnetic waves propagating in periodic dielectric structures, due mainly to the possibility of devising novel photonic devices. Electromagnetic-band-structure extraction and electromagnetic-wave-propagation formulation have been the major objectives for which different methods have been introduced.

Concerning the special case of one-dimensional structures composed of a layered stack of dielectrics, in [1,2] have been employed an easy matrix approach for investigating light propagation in which particular attention was paid to the special case of two alternating isotropic dielectrics. Similar results have also been reported for studying the dispersion of electromagnetic waves, although the results are limited to the special case of only two alternating dielectric layers, each having a uniform refractive index profile [3,4].Authors of [5,6] have discussed the extension of this matrix formalism for anisotropic and magneto-optic stratified layers. The same approach has also been applied in analysis of periodic and quasi-periodic structures [7,8]. All of these matrix approaches are usually referred to as transfer-matrix methods, where the cosine of the Bloch wavenumber is equal to the half of the trace of the transfer matrix corresponding to one unit cell of the whole structure [9]. In another report, it is shown that infinite and semiinfinite one-dimensional photonic crystals have the same band structure, whereas surface states exist only in semiinfinite photonic crystals [10]. A one-dimensional photonic crystal of finite dimensions has also been studied by using the finite-difference time-domain method [11,12].

The more general case of photonic crystals with an arbitrary number of homogeneous layers and refractive indices in one period has also been considered, and the universal curve for the location of their corresponding bandgaps has been found [10]. Lately, Kronig–Penney photonic crystals composed of conducting interfaces have been studied [13] and the dual properties of these electronic crystals have been shown [14]; consequently, new types of band structures supported by these photonic crystals have been found [15]. Moreover, the phase-shift method originated for the analysis of potential-scattering problems in atomic and nuclear physics has been applied to analysis of wave propagation in one-dimensional inhomogeneous media [16]. Such structures are also analyzed by expanding electromagnetic fields in terms of Legndre polynomials [17].

More recently, another one modification for the exact calculation of band structure in one-dimensional periodic media based on the differential-transfer-matrix method has been proposed [18–20] although the places of reported frequency gaps have not corresponded with the well-known Bragg condition at the edge of each Brillouin zone. Here, the already-employed mentioned vide supra method has been modified, and the extracted band structures of one-dimensional photonic crystals have been corrected to be in harmony with the Bragg condition. Furthermore, the most recently modified differential-transfer matrix is improved by reshaping the formulation in terms of which the electromagnetic fields are expanded and closed-form formulas, giving the allowed values of Bloch wavenumbers, which were not available before, are now given. It has been also shown that the presented approach has the benefit of greater accuracy, especially in group-velocity calculations. Because this approach can be extended to higher dimensions, it may also find some applications in diffractive optics [21,22].

The conventional method has been modified in this paper to find the governing dispersion equation of one dimensional photonic crystals having an arbitrary refractive index profile. This modification has been committed on both the phase and the amplitude of functions in terms of which tangential electromagnetic fields are expanded.

It should be noticed that the due phase and amplitude variations of electromagnetic fields were already overlooked in the conventional formulation. Different test cases corresponding to high contrast, low contrast, gradual, and steep refractive index profiles were considered and discussed. The final results were justified either by employing conventional transfer matrix method or by comparing with an exact analytical solution wherever such an exact solution was available. It should be noticed that even thought the transfer-matrix method can yield accurate results at the expense of heavy calculations and lower speed, especially at shorter wavelengths, the fast and analytical approach which surpasses the transfer-matrix method and other numerical methods in optimization and inverse problems looks as good alternative. The effective index method can be employed to double check the forbidden normalized frequencies in agreement with the well-known Bragg condition. The superiority of those conventional method can be also proved by considering the refractive index profile of harsher variations and by analysis of band structures at shorter wavelengths. Finally, the group velocities of Bloch waves can be displyed.

Author would like to express a large gratitude to Professor O.I.Gerasymov who outline the main constructions for given work.

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