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Coherent transmission and reflection of imperfect photonic crystals: Spectra of multilayers of alumina and silica spherical particles

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Technique to calculate coherent transmission and reflection coefficients of imperfect two-dimensional (2D) planar photonic crystal (PC) at normal illumination is proposed. It is based on the quasi-crystalline approximation (QCA) of the theory of multiple scattering of waves. At this approximation spatial particle correlations are characterized by the radial distribution function. We propose the method of the 2D imperfect planar PC radial distribution function simulation. It consists in the calculation of coordination circles of ideal crystal lattice and following blurring them into the “rings” with fuzzy edges to describe the crystal lattice of an actual crystal. The width of the “rings” depends on the distance from coordinate origin [1,2]. The method allows simulation of the PCs lattices with various ordering degrees by the QCA. The phase of the transmitted and the reflected waves is investigated in the conditions of the quenching effect. It is shown that in such a case small changes in the refractive index of particles can cause dramatic phase changes.

The results of numerical calculations of coherent transmittance and reflectance of monolayers with different orderings of spherical monodisperse particles are displayed. They applied to consider coherent transmittance and reflectance of multilayers consisting of one-dimensional Fibonacci, Thue-Morse, and periodic sequences of plane-parallel ordered monolayers of spherical alumina and silica particles in the 0.3 μm to 2 μm spectral range. Consideration is based on the quasi-crystalline approximation for individual monolayers and the transfer matrix method for multilayers. Comparison with sequences of the homogeneous plane-parallel layers is made. It is shown that the Fibonacci and Thue-Morse structures provide more possibilities to control light in comparison with the regular ones.

The outcomes of the work have potential for design and fabrication of the optical and electro-optical devices with enhanced properties on the base of photonic crystals, for example, highlight-emitting diodes and antireflection layers, optical filters, solar cells, displays. The results can be used to solve the problem of quality of the photonic crystal lattices by measurement of coherent transmittance and reflectance.

[1] Miskevich A. A., Loiko V. A. Two-dimensional planar photonic crystals: Calculation of coherent transmittance and reflectance at normal illumination under the quasicrystalline approximation. J. Quant. Spectr. & Rad. Transfer. 2011;112:1082–1089.
[2] Miskevich A.A., Loiko V.A. Coherent transmission and reflection of a two-dimensional planar photonic crystal. JETP. 2011;113(1):1–13.