Standing Wave Expansion Method: Calculation of a 2D Photonic Crystal Resonator

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The Standing Wave Expansion Method (SWE) [1-2] was developed especially to calculate the electromagnetic spectrum and field distribution inside a kind of ordered finite size objects – photonic crystal resonators (PCR). A PCR looks like a rectangular island deposited on the substrate. Due to the special ways of electromagnetic field exciting inside the total internal reflection (TIR) region of the resonator shown in Fig.1, the system traps irradiation which, in turn, can be processed and redirected out the system. The photonic crystal resonators are of interest for all-optical signal processing as elements of logic devices with extremely high quality factor which may be reached at modern state of technology. The starting basis of 2D eigenfunctions is formed on the ground of standing electromagnetic waves – solutions of the so-called intrinsic problem for field inside the TIR region. A general feature of the solutions corresponding to modes trapped inside the resonator is that all its energy are concentrate inside the resonator whereas outside the resonator we have only falling tails of states. A finite one dimensional problem serves as a generator of analytically determined functions describing X or Y part of the total 2D basis with close periods in both directions. The 2D basis generator works to cover the $N_1 \bullet N_2$ periodic resonator with 1D functions found for N_1-period resonator in X direction and N_2-period resonator for Y direction. It is easy to understand that the predominant density of field energy is concentrated inside the $N_1 \bullet N_2$ resonator unlike to other approaches based on plane waves. The set of basis' functions {|s,g>} found for p-polarised waves may be described with the help of magnetic field.

We calculated several types of PCR differing by intrinsic contrastivity beginning with weak contrastive SiO_2/SiO_2 PCR, intermediate Si/SiO_2 PCR and strongly contrastive Si/air resonators by the SWE method. In Fig.2, shown is the chosen standing mode $H(x,y,\mathbf{\Omega}_{36})$ coordinate dependence calculated in zero-approximation for the 2D SiO_2/SiO_2 PCR situated in air and containing *36* rectangular cells where $\varepsilon_1 = 3.24$, $\varepsilon_2 = 2.25$. The states numbering begins from 0, the lowest state with no node lines and maximal density in middle of the PCR. The lattice and also in the case of nonlinear external covering layers.

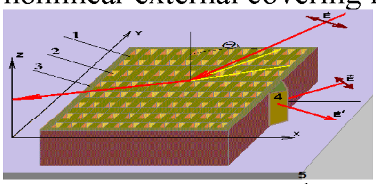

Fig. 1 The geometry of the problem. Two ways of intrinsic modes (standing waves inside the TIR region) excitation in a 2D 12x8 PCR. 1, 2, period forming layers of width d_1 (host material) and (wells); 3, external a-layer (in general case nonlinear) of width d_a, 4, input prism, 5 substrate, $\vec{E}$, $\vec{E}'$ are beams incident and reflected.

In summary, we have considered the SWE method to calculate electromagnetic eigenwaves in a finite 2D photonic resonator of rectangular external shape. The 2D basis of standing waves was generated and its properties were studied. The spectrum and field distribution inside the resonator were calculated for several types of PCRs and various shapes of wells. Several types of resonator states were discussed: band, waveguide, surface and pure local states, a classification of 2D modes based on 1D modes and 2D knot theorem was proposed.

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2. E. Ya. Glushko, Optics Communications, vol. 247, no. 4–6, pp. 275–280, 2005.