Characterization of slow light regime in 2D photonic crystal waveguides

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We present a comprehensive study of the slow light behavior in photonic crystal waveguides as key elements in optical buffer devices.

Photonic band gap materials are now recognized as excellent candidates for novel applications in the area of all-optical telecommunication networks. Systems based on these novel materials could outperform current generation optoelectronic devices in applications related to optical buffering [1,4,5,8,9], low-threshold lasing [10], or interferometry [7], just to cite a few examples.

In photonic crystal structures, where the dielectric permittivity varies periodically, a complete photonic band gap (CPBG) can appear. This gives rise to a frequency range where no light can propagate into the crystal structure independently of its propagation direction. If the periodicity is broken in certain ways (such as introducing point or line defects), localized light modes are formed around the defect region [3]. In this way, a photonic crystal waveguide can be tailored in such a way that light is guided from one point in the photonic crystal to another, no matter the geometrical complexity of the defect pathway. Moreover, in certain cases, light propagating through this waveguide can exhibit extremely low group velocity, which yields to considerable delays over the light pulse [11].

This work presents an exhaustive study of CPBG maps for two-dimensional photonic crystals based on the square and triangular lattices. These maps have been obtained by gradually sweeping rods/holes radii and dielectric contrasts. To perform the corresponding simulations, the finite element method (FEM) [2] and the plane wave expansion method [6] were used. FEM has also been applied to the study of PCWs, where harmonic propagation and eigenvalue analysis simulations have been done, showing that localized modes tend to present an extremely low group velocity. Finally, defect mode group velocity, group velocity dispersion (GVD), resulting bandwidth, and power loss are reported for different defect line widths in standard PCWGs. Taking into account these criteria, an optimum PCW is proposed, implementing the best combination of hole/rod radii, index contrast, waveguide width, and operational frequency bandwidth. The so obtained structures possess a great potential for the development of low-power consuming on-chip photonic buffers, whose impact on future telecommunication networks and optical computing will be of decisive importance.

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