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Design of Photonic Crystal with Defect Layer to Eliminate Interface Corrugations for Obtaining Unidirectional and Bidirectional Beam Splitting under Normal Incidence

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Abstract : Working with a dielectric photonic crystal (PC) structure which does not include surface corrugations, unidirectional transmission and dual-beam splitting are observed under normal incidence as a result of the strong diffractions caused by the embedded defect layer. The defect layer has twice the period of the regular PC segments which sandwich the defect layer. Although the PC has even number of rows, the structural symmetry is broken due to the asymmetric placement of the defect layer with respect to the symmetry axis of the regular PC. The simulations verify that efficient splitting and occurrence of strong diffractions are related to the dispersion properties of the Floquet-Bloch modes of the photonic crystal. Unidirectional and bi-directional splitting, which are associated with asymmetric transmission, arise due to the dominant contribution of the first positive and first negative diffraction orders. The effect of the depth of the defect layer is examined by placing single defect layer in varying rows, preserving the asymmetry of PC. Even for deeply buried defect layer, asymmetric transmission is still valid even if the zeroth order is not coupled. This transmission is due to evanescent waves which reach to the deeply embedded defect layer and couple to higher order modes. In an additional selected performance, whichever surface is illuminated, i.e., in both upper and lower surface illumination cases, incident beam is split into two beams of equal intensity at the output surface where the intensity of the out-going beams are equal for both illumination cases. That is, although the structure is asymmetric, symmetric bidirectional transmission with equal transmission values is demonstrated and the structure mimics the behavior of symmetric structures. Finally, simulation studies including the examination of a coupled-cavity defect for two different permittivity values (close to the permittivity values of GaAs or Si and alumina) reveal unidirectional splitting for a wider band of operation in comparison to the bandwidth obtained in the case of a single embedded defect layer. Since the dielectric materials that are utilized are low-loss and weakly dispersive in a wide frequency range including microwave and optical frequencies, the studied structures should be scalable to the mentioned ranges.

Keywords : asymmetric transmission, beam deflection, blazing, bi-directional splitting, defect layer, dual beam splitting, Floquet-Bloch modes, isofrequency contours, line defect, oblique incidence, photonic crystal, unidirectionality
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