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Study of the effect of the presence of a homogeneous collisional plasma layer on the optical properties of a photonic crystal

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Abstract

Plasma photonic crystals are structures in which dielectric materials and plasma are arranged periodically. Owing to its characteristic plasma frequency and Debye length, plasma strongly influences the behavior of electromagnetic waves. In the analysis of wave propagation in plasma, the inclusion of collisions is essential, since real plasmas always involve electron–ion and electron–neutral interactions. These collisions are the primary source of the effective resistance of electrons against field oscillations and therefore determine how much of the wave energy is transmitted, absorbed, or reflected by the plasma. In this paper, wave transmission through one-dimensional photonic structures consisting of dielectric layers and a plasma defect layer is investigated using the transfer matrix method and detailed numerical simulations. The simulation results show that increasing the plasma density shifts the defect modes toward higher frequencies, whereas increasing the thickness of the plasma layer shifts them toward lower frequencies. Moreover, increasing the electron collision frequency leads to wave damping, a reduction in transmission intensity, and a broadening of the resonant peaks. Precise control of plasma parameters and photonic structure design provides a powerful tool for realizing filters and sensors with tunable resonant characteristics.

Keywords: Photonic Crystal, Plasma, Defect Layer, Transfer Matrix, Electron Plasma Frequency

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