Study of Band Structure and Electromagnetic Density of States in a One-Dimensional Photonic Crystal

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Abstract

One-dimensional photonic crystals (1D PhCs), or Bragg gratings, are periodic dielectric structures that exhibit a unique property: the formation of photonic band gaps (PBGs). These are frequency ranges where the propagation of light is forbidden. This paper presents a detailed theoretical and computational analysis of the photonic band structure and the corresponding electromagnetic density of states (EM DOS) in a 1D PhC. The crystal is modeled as a stack of alternating dielectric layers with high and low refractive indices. The transfer matrix method (TMM) is employed to calculate the transmission spectrum and the photonic band structure. The EM DOS is then derived from the band structure using a k-space sampling technique. Our results confirm the existence of complete photonic band gaps where the EM DOS drops to zero. We demonstrate a direct correlation between the features of the band structure—such as flat bands and band edges—and the singularities in the EM DOS. Specifically, van Hove singularities are observed at the critical points of the band structure. This study underscores the profound ability of 1D PhCs to control the flow of light and engineer the photonic environment, which is crucial for applications in low-threshold lasers, optical filters, and enhanced light-matter interaction.

Keywords

Photonic Crystal, Band Structure, Density of States, Photonic Band Gap, Transfer Matrix Method, Van Hove Singularity.