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Sideband generation in moving photonic crystals

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The idea of using photonic crystals (PCs) to alter the dispersion relation of photons has received widespread interest. However, most of the existing research focused on the stationary PCs, while moving PCs were somewhat overlooked. In this abstract, we explore the guidance properties of moving hollow-core (HC) PCs. We find that the interaction between light and a moving HC-PC can lead to generation of frequency combs. Besides, amplitude of the sidebands in the frequency combs is dependent on the modal distribution of the PC guided modes, and could be considerably enhanced by introducing periodical point defects to the innermost rows of the HC-PC.

Consider two reference frames - a stationary frame S with coordinates (x, y, z, t) and a moving frame S' with coordinates (x', y', z', t'). The corresponding axes of the two frames are mutually parallel, and the frame S' moves at a constant velocity v with respect to the frame S along its x-axis. The spacetime in the frame S' could be related to the spacetime in the frame S via Lorentz transformation (LT). A HC-PC is moving along the x-axis in the frame S, so it is stationary in the frame S'. The hollow core of the PC is a defect introduced into the infinite PC by removing one row of lattice rods. For such a PC waveguide, one could readily find the modal solution of the core-guide modes at a certain frequency in the moving frame S'. Then, by applying LT to this modal solution, the corresponding solution of the guided mode in the frame S could be obtained. Therefore, the dispersion relation of the guided mode could be also obtained by performing modal analysis at a continuous range of frequencies. From the dispersion relation, we could find that two frequency combs are generated inside of the hollow core of a moving PC in the frame S. By analyzing the modal solution of the guided mode in the frame S, we also find that amplitude of the sidebands in the generated frequency combs is dependent on the modal distribution of the PC guide mode, which could be varied by introducing periodic point defects to the innermost rows of the hollow-core PC. Based on the results of our Comsol simulation, we conclude that the amplitude of the sidebands generated by regular moving PC is generally one to three order smaller than those of the sidebands generated by the moving PCs with periodic point defects.

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