Sideband generation in moving photonic crystals

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Abstract—We theoretically demonstrate the generation of sidebands within the hollow core of moving photonic crystals. Amplitude of the generated sideband could be enhanced by introducing periodic point defects to the photonic crystal.

Keywords—photonic crystal; moving photonic crystal; sideband generation;

In recent years, the idea of using PCs to alter the dispersion relation of photons has received widespread interest and consideration due to numerous potential applications [1]. Most of the existing research however focused on the stationary PC, while moving PCs were somewhat overlooked. In our previous study, we reported that the interaction between light and a moving photonic crystal can lead to the generation of frequency combs [2]. In this paper, we further explore the guidance properties of moving PCs, and we note that amplitude of the sidebands in the frequency combs generated in the hollow core of a moving PC is dependent on the modal distribution and the Fourier coefficients of a core guided mode in a regular PC [3]. We therefore conclude that two frequency combs are generated inside of the hollow core of a moving 2D PC. From Eq. (2), we find that the Fourier coefficients \( A'_{\phi,\gamma}(y) \) represent the amplitude of the generated harmonics. Also note that these Fourier coefficients could be calculated by applying a Fast Fourier Transform (FFT) to the periodic function \( U'_{\phi,\gamma}(x',y) \). We use Comsol to numerically calculate the electric field \( E'_{\phi} \) of the core-guided mode of a hollow-core PC in the moving reference frame (Fig. 1(b)). In our simulation, the lattice constant \( a \) of the hollow core PC is 1 \( \mu \)m, and the radius \( R \) of an individual lattice rod is 0.38 \( \mu \)m. Thus, according to Eq. (1), the periodic function \( U'_{\phi,\gamma}(x',y) \) could be obtained. Applying FFT to \( U'_{\phi,\gamma}(x',y) \), we then have the Fourier coefficients \( A'_{\phi,\gamma}(y) \) (see Fig. 1(c)). From the result in Fig. 1(c), we note that amplitude of the sidebands in the harmonics are generally three orders smaller than that of the fundamental band. Introducing periodic point defects in the innermost row of the PC could modify the electric field of the guided mode, and thus increase amplitude of the harmonic sidebands. As an example, consider a hollow core PC that has periodic defect rod in its innermost rows. The defect rods feature a smaller radius \( R_d = 0.4*R \) and have a spatial periodicity of 8\( \pi \). The electric field of the core-guided mode in such a waveguide is numerically calculated using Comsol (Fig. 1(d)), and the corresponding Fourier coefficients \( A'_{\phi,\gamma}(y) \) are also calculated and plotted in Fig. 1(e). Compared to the regular moving PC, the moving PC with periodic defect points could generate sidebands with much higher amplitudes. Particularly, we note that the first several low-order sidebands have the coefficients one-order smaller than that of the fundamental band, which indicates a significant enhancement in the sideband amplitude.

Fig. 1. (a) Schematic of a 2D hollow core photonic crystal. (b-e) Electric field distribution and the Fourier coefficients of a core guided mode in a regular PC (b,c) and a PC with point defects (d,e).

REFERENCE