Detailed Analysis of Photonic Crystal Waveguides Near Mode-gap and its Applications for Dispersion Engineering

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W1 photonic crystal waveguides (PCWs) formed by removing one line of holes in the ΓK direction of a triangular lattice photonic crystal (PC) of air holes in a dielectric material have been widely investigated for guiding light within planar slab PC platforms. One of the unique features of the dispersion of these waveguides is the formation of the mode-gap as the result of the coupling of different orders of guided modes with the same parity. This property has inspired researchers to design slow-light devices based on the low group velocity portion of the PCW dispersion diagram above the mode-gap and PC cavities based on mode-gap light confinement. On the other hand, a major drawback of the existence of the mode-gap is that it limits the bandwidth of PCWs which is extremely crucial for communications applications.

Here, we present a detailed analysis of the dispersive properties of W1 PCW modes near the mode-gap based on a coupled-mode-theory treatment of the coupling of guided modes of different orders. In addition, recipes for engineering the dispersion properties of PCW modes based on design parameters are presented for different applications. It will be shown that the practical bandwidth of a W1 PCW can be increased by a factor of 2~3 by an appropriate tuning of the holes radii in the two PC layers above and below the guiding region. Also, through this dispersion engineering, a cavity architecture based on mode-gap light confinement is proposed and its performance is compared with previously reported high-Q cavities.