A new paradigm for highly collimated beaming from sub-wavelength apertures in photonic crystals

James Bauer and Sajeev John,
Department of Physics, University of Toronto, 60 St. George St., Toronto, Ontario, Canada.

Light exiting an aperture smaller than its wavelength normally diffracts sharply over all angles. This diffraction has been previously mitigated by introducing a surface corrugation surrounding the aperture, yielding a small angular divergence of the emerging beam [1]. This method was applied to light exiting small-aperture photonic crystal (PC) waveguides in [2]. However, it is limited by its narrow operational bandwidth. Here we present a method to reduce the beam divergence from small-aperture PC waveguides based on an entirely different physical principle. When the frequency of the light is above some tunable structural resonance, the phase change provided by the resonance modifies the far-field radiation pattern into a highly collimated beam. As this effect depends not on being near resonance, but rather being above resonance, a much broader working bandwidth is possible than in the corrugated surface case.

We employ the introduced collimator when coupling to single-mode index-guiding waveguides and find that high coupling efficiency of more than 94% can be achieved for a large bandwidth of 260 nm when centered at 1550 nm. We also study coupling to low-index Bragg stack waveguides and find that efficiencies of 94% over a large bandwidth of 380 nm are attainable.

[1] H.J. Lezec *et. al*., *Science* ***297***, 820-822 (2002).
[2] E. Moreno *et. al*., Phys. Rev. B **69**, 121402(R) (2004).