Light-Matter Interactions in Photonic Crystal Waveguides: From Disorder-Induced Localization to Single Photon Sources

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Abstract

Semiconductor-based planar photonic crystals are of great interest in nanophotonics due to their unique functionalities and their ease of fabrication using standard etching and lithography techniques. As is now well established, high-index-contrast photonic crystal structures can exhibit many interesting optical phenomena such as light trapping on sub-wavelength spatial dimensions or engineered waveguide band dispersions with a vanishing group velocity. Both of these effects give rise to novel regimes of light-matter interaction and have applications in nano- and quantum-technologies. Yet, there remains considerable challenges in modeling and understanding real device structures, where one must accurately describe light-matter interactions on nm-length scales. This challenge is exasperated for photonic crystal waveguide systems, where one must describe the light-matter processes over hundreds-to-thousands of unit cells.

In this work, we will focus on two timely aspects of light-matter interactions using photonic crystal waveguide systems. First, we will present a new theoretical formalism to quantitatively describe disorder-induced coherent scattering in photonic crystal waveguides. Importantly, this formalism necessarily extends previous approaches of weak scattering [1], by including multiple forward- and backward- scattering events. Using carefully designed light transmission measurements and frequency-delay reflectometry maps, obtained for GaAs photonic crystal membranes, we demonstrate the transition from propagation with a well defined group velocity to a regime completely dominated by disorder-induced coherent scattering. Second, we will discuss the exciting prospects of using open system waveguides for applications in chip-based quantum optics [2, 3]. Specifically, we will show that periodic waveguides can allow one to realize efficient single photon sources. Stand alone waveguides and coupled cavity-waveguide systems will be exampled.

References

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