DTU Library

Design of Slow and Fast Light Photonic Crystal Waveguides for Single-photon Emission Using a Bloch Mode Expansion Technique

de Lasson, Jakob Rosenkrantz; Rigal, B.; Kapon, E.; Mørk, Jesper; Gregersen, Niels

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
de Lasson, J. R., Rigal, B., Kapon, E., Mørk, J., & Gregersen, N. (2015). *Design of Slow and Fast Light Photonic Crystal Waveguides for Single-photon Emission Using a Bloch Mode Expansion Technique*. Abstract from 2015 Progress In Electromagnetics Research Symposium , Prag, Czech Republic.

Design of Slow and Fast Light Photonic Crystal Waveguides for Single-photon Emission Using a Bloch Mode Expansion Technique

J. R. de Lasson[1, 2], **B. Rigal**[2], **E. Kapon**[2], **J. Mørk**[1], **and N. Gregersen**[1]

[1]DTU Fotonik, Department of Photonics Engineering, Technical University of Denmark, Denmark
[2]Laboratory of Physics of Nanostructures, École Polytechnique Fédérale de Lausanne, Switzerland

Abstract— We design slow and fast light photonic crystal waveguides for single-photon emission using a Bloch mode expansion and scattering matrix technique. We propose slow light designs that increase the group index-waveguide mode volume ratio for larger Purcell enhancement, and address efficient slow-to-fast-light waveguide coupling.

Introduction: In the quest to realize quantum information technology and quantum computers, development of efficient and deterministic single-photon sources is an important step on the way. Single-photon emission occurs from quantum emitters, like atoms or quantum dots, via spontaneous emission that inherently is a non-deterministic process. To obtain a deterministic single-photon source, the spontaneous emission must be controlled, which is typically achieved by placing the quantum emitter in a suitably designed photonic environment; both resonant systems (cavities) and broadband structures (waveguides) have been proposed [1]. In cavity systems, matching of the spectrally narrow emitter and cavity is required, while waveguides relax this requirement due to their broadband nature. For on-chip emission and detection of single-photons, planar integration is necessary, and for this purpose semiconductor photonic crystal (PhC) membranes constitute a flexible and versatile platform. Theoretical efforts [2] and experimental demonstration [3] of single-photon emission in PhC waveguides have been reported.

In this contribution, we employ the Bloch mode expansion technique [4] for engineering of PhC waveguide modes as well as of quantum dot light emission. With this technique, one spatial direction is treated analytically, which makes it highly suitable for long structures like waveguide based single-photon sources, in contrast to spatial discretization methods as FDTD and FEM. In addition, direct access to scattering matrices [5] makes the optimization of multi-section structures particularly transparent, for example when interfacing slow and fast light waveguides in a PhC waveguide based single-photon source.

Specifically, we address the designs of slow and fast light PhC waveguides that serve the purposes of enhancing light-matter interactions and photon transport, respectively. In the former, much attention has been paid to increasing the Purcell factor via large group indices, while little has been said about designs that minimize the waveguide mode volume [2]. We propose designs that simultaneously provide large group indices and small mode volumes, and furthermore propose efficient transmission from slow to fast light PhC waveguides, needed for efficient routing of singly emitted photons to collection optics.

REFERENCES

1. Gregersen, N., P. Kaer, and J. Mørk, "Modeling and design of high-efficiency single-photon sources," *IEEE J. Sel. Top. Quantum Electron.*, Vol. 19, 9000516–9000516, 2013.
2. Manga Rao, V. S. C. and S. Hughes, "Single quantum-dot purcell factor and β factor in a photonic crystal waveguide," *Phys. Rev. B*, Vol. 75, 205437, 2007.
3. Arcari, M., I. Söllner, A. Javadi, S. Lindskov Hansen, S. Mahmoodian, J. Liu, H. Thyrrestrup, E. H. Lee, J. D. Song, S. Stobbe, and P. Lodahl, "Near-unity coupling efficiency of a quantum emitter to a photonic crystal waveguide," *Phys. Rev. Lett.*, Vol. 113, 093603, 2014.
4. Lecamp, G., J. P. Hugonin, and P. Lalanne, "Theoretical and computational concepts for periodic optical waveguides," *Opt. Express*, Vol. 15, 11042–11060, 2007.
5. Li, L., "Formulation and comparison of two recursive matrix algorithms for modeling layered diffraction gratings," *J. Opt. Soc. Am. A*, Vol. 13, 1024–1035, 1996.