Photonic Band Gap Materials: Engineering the Fundamental Properties of Light

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Abstract

Photonic Band Gap (PBG) materials are engineered dielectrics that provide a versatile platform for tailoring fundamental properties of electromagnetic wave propagation. These include refraction, diffraction, spontaneous emission of light from atoms, and blackbody radiation. A particularly striking feature of PBG materials is their ability to localize light. This may be important for all-optical communications and information processing. Three dimensional (3D) PBG materials offer a unique opportunity for simultaneously (i) synthesizing micron-scale optical circuits that do not suffer from diffractive losses and (ii) engineering the electromagnetic vacuum on this optical micro-chip. This combined capability opens a new frontier in integrated optics as well as the basic science of radiation-matter interactions.

We review some recent approaches to micro-fabrication of photonic crystals with a large 3D PBG centered near 1.5 microns. These include photo-electrochemical approaches to synthesize lattices of pores in bulk semiconductors. Another approach relies on templating methods based on direct laser-writing and holographic lithography in polymer photo-resists. We introduce the concept of a hybrid 2D-3D PBG hetero-structure that enables both very low-loss wave-guiding of light and frequency selective control of spontaneous emission of light from atoms. This architecture facilitates broadband (180 nanometers), single-mode, wave-guides of light in air in an all-optical micro-chip. Unlike traditional wave-guides that confine light in a high refractive index medium using total internal reflection, these air-wave-guides operate using the principle of light localization.