Photonic bandgap materials:
On-chip optical information processing with trapped light

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Photonic band gap (PBG) materials are artificial periodic dielectric microstructures capable of trapping light on sub-wavelength scales, without absorption loss, in three dimensions (3D) [1–3]. A complete set of design rules now exists for guiding light, without scattering losses and heat dissipation issues, through air-waveguide circuit paths, over a bandwidth of 200 nanometers, centered at 1.5 μm wavelength, in a 3D optical microchip [4–6]. I will discuss possibilities for all-optical switching and "control of light with light" in this 3D optical microchip on the picosecond time scale with mW or less power. This occurs through exceptionally strong coupling of tightly confined light to quantum dots within the PBG circuit path [7]. By engineering the vacuum electromagnetic density of states [8, 9] in the vicinity of quantum dots, it is possible to achieve rapid population inversion, switching, and unusual control of the nonlinear dynamics of quantum dot optical Bloch vectors [10]. This offers a theoretical foundation for multi-wavelength-channel all-optical transistor action in a 3D chip. I will discuss the challenges and requirements of materials fabrication to realize these remarkable effects.

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