Abstract:

We investigate light propagation in periodic nanoscale structures known as photonic crystals. The goal is to gain insight into how the propagation of light can be modified and exploited for uses in telecommunication, regenerative energy, quantum information processing and optical computing. To this end, we dope photonic crystals with optically resonant systems: systems which strongly modify light propagation.

We probe a Si woodpile photonic band gap crystal on both picosecond and femtosecond timescales with ultrafast, frequency-tunable pump-probe spectroscopy. Free carrier induced changes of both the width and the position of the stopband are observed, and are shown to depend strongly on the pump and probe frequency. At femtosecond timescales, we observe spectral features agreeing to a combination of the optical Kerr effect and non-degenerate two-photon absorption. Both effects have implications on density of states switching.

Cavities are especially suitable for switching because of their narrow resonances, or high quality (Q) factors. Using pump-probe spectroscopy, we are able to measure both the dynamic cavity resonance and the lineshape, which we find to broaden considerably. Since broadening might limit
the performance of next-generation optical networks, we delineate conditions for which this degradation can be minimized.

The behavior of the switched cavity resonance is used to control the release of light from the cavity. Therefore, the pulse's dwell time in the cavity can be controlled.

We can also control the propagation of continuous light. The extremely narrowband dispersion of atomic resonances can strongly modify the optical properties of photonic crystals. To this end, we have diffused resonant alkali atoms (Cs) into a photonic crystal, whose stopband frequency is
varied. We show both experimentally and theoretically how the lineshape of the atomic transition changes drastically for different relative positions of the stopband to the atomic resonance.