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Short summary of the thesis:

Fundamental interest in photonic crystals is spurred by the possibility of a photonic band gap, a frequency range for which no optical modes exist at all. Tailoring the density of optical states allows one to control fundamental atom-radiation interactions in solid-state environments. Exciting prospects arise when photonic band gap crystals are switched on ultrafast timescales, allowing the switching-on or -off of light sources in the band gap. Semiconductors have favorable properties for optical switching, hence they are excellent constituents for switchable photonic materials. Therefore, this thesis describes the first ultrafast optical switching experiments in semiconductor photonic band gap crystals. Chapter 2 discusses four important experimental requirements on the switching timescale, -magnitude, the induced absorption, and spatial homogeneity. In Chapter 3 we describe a nonlinear absorption model to quantify the spatial homogeneity of optically excited free-carrier plasmas in semiconductors, and find optimum pump conditions near the two-photon absorption edge. Chapter 4 describes our time resolved spectroscopy setup, and presents a new data acquisition method that allows for sensitive pump probe measurements. Chapter 5 demonstrates switching of the photonic strength of GaAs-AlAs photonic structures. We observe both a narrowing of the stop band and a blue-shift of the center position of the band that compare well to exact transfer matrix theory. Chapter 6 presents the first ultrafast all-optical switching measurements in photonic band gap crystals. Si woodpile crystals are homogeneously excited, and the reflectivity is probed over an octave in frequency (including the telecom range) as a function of time. We observe competing refractive index changes due to an electronic Kerr nonlinearity and to optically excited free carriers. The measured spectra agree well with exact modal method calculations. Chapter 7 discusses switching experiments on Si inverse opals. We demonstrate large and ultrafast frequency shifts of the stop bands in the frequency range of the photonic band gap. From a comparison to band structure calculations we estimate the corresponding change of the optical density of states to be sufficiently large to allow experiments in which the emission rate of internal lights sources is switched. Chapter 8 discusses possible applications of this work.