Current research efforts are focused on the interesting ways in which light propagates within microfabricated high-contrast periodic dielectric and metallic structures. The use of periodic structures to engineer electromagnetic wave propagation has a rich history dating back to some of the early work on microwave radar technologies during the Second World War and more recently to the design of Distributed Feedback Lasers and Fiber Bragg Gratings which have become integral components of the fiber-optic telecommunication industry. Today these ideas have been reborn in the form of photonic bandgap (PBG) materials or photonic crystals (PC), in which high-contrast periodic dielectric and metallic structures are used to create such strong dispersion as to open up frequency windows within which the propagation of light is entirely forbidden.

This new focus on optical PBG materials has spawned a great deal of interest in work on the control of light emission from materials placed within PBG structures. It has long been realized that the spontaneous emission of radiation from an excited state of matter depends critically upon the electromagnetic environment in which it is placed. One may thus imagine using PBG materials to significantly alter the way in which radiation is emitted from that in free space. Using a variety of micro and nano-fabrication techniques to create wavelength scale features in semiconductor materials we have been able to realize this goal. By forming optical cavities in which light is trapped within modal volumes approaching the theoretical limit of a cubic half-wavelength (some hundredths of a cubic micron), electrons and holes within the semiconductor material are forced, when they recombine, to emit light into a single resonant mode of the cavity. Ongoing projects involve the design, fabrication, and characterization of semiconductor laser sources based upon this technology, and more fundamental studies of the interactions of electrons and photons within these ultra-small volume single-mode optical cavities.

As with some of the earlier applications of periodic structures, our research group is also looking at utilizing the more fundamental aspects of photonic crystals, that being their dispersive properties. Present research involves the design and fabrication of different planar photonic crystal structures for wavelength division multiplexing (WDM) applications, non-linear optics, and high-density planar lightwave circuits.