16. Electrically-Activated Nanocavity Laser using One-Dimensional Photonic Crystals

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In the future, optical networks may see an expanded role not only in telecommunications, but also in computers and other common electronic devices. These optical networks will require small, on-chip light sources. Photonic crystals have the ability to confine light much more effectively than any form of end-mirror used in standard semiconductor lasers, meaning that light experiences less loss upon reflection at the ends of the laser cavity. This allows photonic crystal lasers to be both very small and very efficient.

The laser described herein is made up of two crossing photonic crystal waveguides, one on top of the other, as depicted in Figure 1. The bottom waveguide, known as the 'active region', consists of an InGaAs quantum dot layer sandwiched between two GaAs and AlGaAs layers. When a voltage is applied to the two contact pads light is produced at a wavelength of about 1.3 µm. Once generated in the active region, the light will be confined above and below, as well as side to side, by index of refraction changes at material interfaces. At the two ends of the guide, however, a series of small holes are etched, forming the photonic crystal, which will confine the light lengthwise. Some of the light will leak into the upper InGaAlP waveguide, known as the 'guiding region'. The upper waveguide is less lossy than the lower. It also has fewer holes etched into one end than the other, which allows light to leak out, directing the laser emission. The laser nanocavity is located where the two guides cross, and is formed by leaving a roughly 1 µm gap between photonic crystal holes. The entire photonic crystal part of the laser is about 5 µm square.

This photonic crystal laser design has numerous advantages over existing lasers. First, the photonic crystal laser is only a few microns in length, making it ideal for small, densely packed chips. It is also edge-emitting and electrically-activated, meaning that by simply applying a voltage to the laser, light can be emitted in the plane of the chip. Another advantage is that the 'active region' and 'guiding region' are separated, allowing light to be created in one waveguide, and then leak up into a less lossy waveguide from which it will eventually be emitted. Having two separate waveguides increases the overall efficiency of the device. Also increasing efficiency is the small size of the microcavity and the quantum dot active material which it surrounds. The cavity size and quantum dots will lead to a very small threshold power. Finally, the laser is very flexible in that by simply changing the size of the quantum dots, causing them to emit light at a different frequency, and changing the size and spacing of the photonic crystal holes accordingly, the laser can easily be built to emit light at wavelengths other than 1300 nm. This novel laser will be more efficient than the current technology from both energy and chip design standpoints, and should represent a major improvement in on-chip light sources.

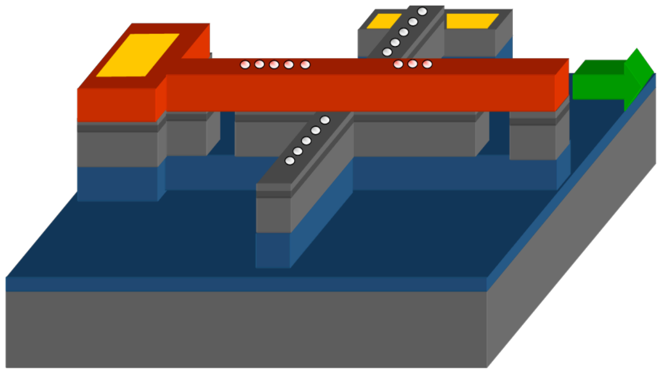

Figure 1: Depiction of the electrically-activated photonic crystal nanocavity laser. The green arrow represents the direction and location of the emitted light.