Near IR Quantum Dot Lasers for Ultrashort Pulse Generation

CNF Project # 1190-04
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Abstract:
In recent years quantum dot (QD) lasers have become an active field of research. They offer a number of advantages over their quantum well laser counterparts, exhibiting lower threshold currents and improved temperature stability. Furthermore, a gain medium which comprises of self assembled quantum dots grown by MBE exhibits a broader gain spectrum along with a lower line-width enhancement factor compared to a quantum well based gain medium. These two factors make the prospects for producing pulses with widths approaching 100 fs via mode-locking quite lucrative.

Summary:
Our group is actively investigating QD lasers for generating ultra-short pulses via mode-locking. Recently, passively mode-locked quantum dot lasers have successfully produced pulses with pulse widths approaching 400 fs and peak powers of 500 mW [1,2].

A monolithic passively mode-locked semiconductor laser is comprised of a ridge waveguide etched into the semiconductor. On this ridge, two sections are defined of which the longer one is forward biased and acts as the gain section. Electrically isolated from the gain section is the saturable absorber section whose length is usually kept much shorter than the gain section. This segment is reverse biased, and for a suitable reverse bias voltage and forward bias current, the laser begins to emit a train of pulses at a repetition rate which depends on the length of the ridge waveguide. Feedback in the laser is provided by the cleaved facets which can be coated with various dielectric films to increase or decrease reflectivity.

One of the most promising samples consisted of three stacks of self-assembled InAs QDs sandwiched between AlGaAs cladding layers grown on a GaAs substrate. Waveguides with widths ranging from 2-5 µm were patterned using standard lithography techniques. Etching of the waveguides was performed on the newly installed III-V PlasmaTherm-770 ICP etcher. A combination of BCl₃/Ar with the right RF parameters was able to provide a smooth, vertical waveguide profile. The waveguides were then planarized using a thermally curable polyimide before the top metal contact was evaporated. The samples were then thinned to 110 µm and after evaporating the back contact, the laser bars were cleaved with lengths varying between 250 µm and 3 mm. Unfortunately only laser bars whose lengths were below 1 mm demonstrated lasing at wavelengths just below 1200 nm. Several tens of mW of power was collected from one side of the device. The shorter waveguide lasers exhibited threshold currents around 100 mA. So far we have been unable to confirm mode-locking in these devices. Their short lengths would lead to repetition rates exceeding 50 GHz and would be a step forward towards high repetition rate devices. Facet coating by evaporating dielectric layers resulted in the reduction of the threshold currents as well as more output power.

References:
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Figure 1, top left: A schematic representation of a modelocked semiconductor laser. The waveguide is surrounded by low index polyimide. The gain and the saturable absorber section are electrically isolated. Light is extracted from one of the facets.

Figure 2, bottom left: A SEM showing the cleaved facet of a fabricated laser diode.

Figure 3, above: Coating one of the facets with a high reflector leads to an increase in the output power as well as reduction in the threshold current.