# ND*nano* Undergraduate Research Fellowship (NURF)
# 2012 Project Summary

Student Name: Nicholas Castro
Faculty Mentor Name: Anthony Hoffman
Project Title: On-chip coherent beam combining with quantum cascade lasers

New Skills Acquired:

- Became acquainted with the EigenMode expansion program FIMMPROP. Used the simulations run on the program to design and model transmission of coherent light down a semiconductor waveguide.
- Developed design skills in the CAD program L-Edit for mask making.
- Training for mask writing, contact photolithography, plasma enhanced chemical vapor deposition, reactive-ion etching, and electron-beam evaporation in the University of Notre Dame Nanofabrication Facility.

Practical Applications:

- remote sensing; essentially, the product of our research will be useful detection of hazardous chemicals in unique situations due to feasibly higher power output.

Project Summary:

Quantum cascade (QC) lasers are semiconductor lasers that emit in the mid-infrared portion of the electromagnetic spectrum. These mid-infrared lasers are of particular interest for sensing applications because the emitted photons interact with the fundamental vibrational and rotational modes of many molecules of interest. The wavelength of QC lasers is determined by the quantum mechanical structure of the gain region and can be designed such that the devices emit in either of the two atmospheric windows in the mid-infrared. Lasers operating in these atmospheric windows are useful for remote detection of hazardous chemicals; however, the use of current generation QC lasers in such applications is limited by their output power. While work has been done to coherently combine the output of several QC lasers on-chip to make a high power mid-infrared source, to date, little benefit has been realized.

Here, we present a master oscillator power amplifier array (MOPAA) that circumvents previous device limitations. Our configuration utilizes the power from a single QC laser which is split and amplified in an array of on-chip amplifiers and then recombined, resulting in high optical power output. Using a commercial software package, FIMMPROP, we calculated transmission through S-Bend waveguides that are needed for the amplifier arrays. Based on these calculations, we selected a bend radius of 8 mm for the waveguides and designed several array configurations (Fig. 1). To fabricate these devices, photolithography masks were created using the Mann 3600F. We developed a fabrication recipe for processing a QC laser in the ND Nanofabrication facility. This included photolithography, dielectric deposition and etching, and metal deposition (Fig. 2). The next step of the project is to use the recipe we developed to fabricate a MOPAA device.

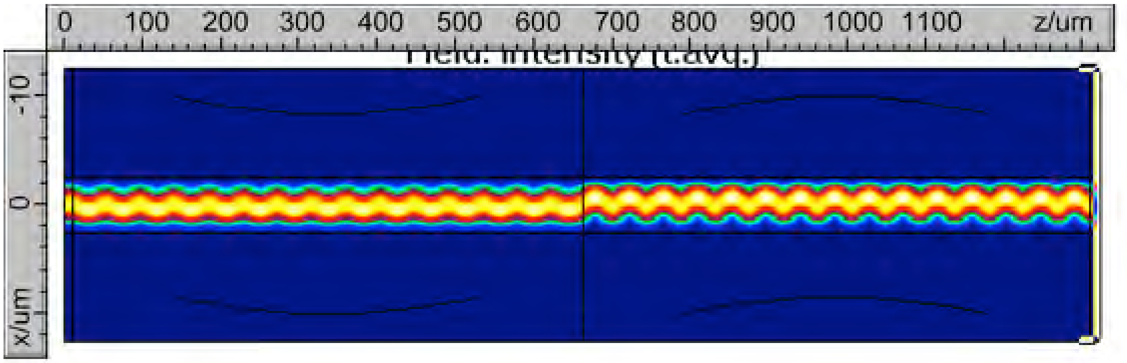


Figure 1: Image of waveguide transmission with 5 µm wavelength light in FIMMPROP.

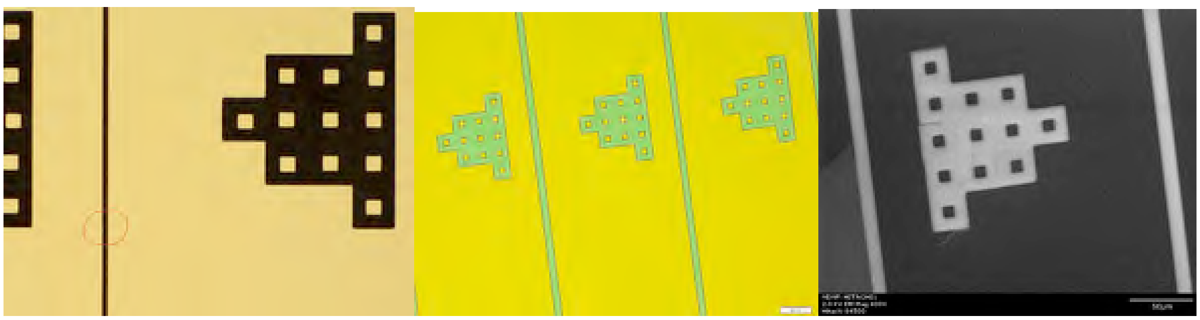

Figure 2: Various steps of the fabrication process. Microscopic images from the left: the photolithography mask (50x), a sample after dielectric deposition and photolithography (20x), and a SEM image of the same sample after 12 minutes of reactive-ion etching and removal of photoresist (50x).