Student name: Sean Baur
Faculty mentor name: Dr. Mark Wistey
Project title: Direct Bandgap Dilute Carbides

Briefly describe any new skills you acquired during your summer research:

- Operation of many clean room processing machines, including Rapid Thermal Processing, Residual Ion Etch, Plasma-Enhanced Chemical Vapor Deposition, and others.
- Establishing and maintaining an ultra-high vacuum in a complex system.

Please briefly share a practical application/end use of your research:

My research tasks were a few in many steps to the realization of Ge and GeC lasers, which would allow integration of high-performance optoelectronics far more easily into existing material systems (mostly Si).

Project summary:

The goals of the research group that I joined this summer were the realization of Ge and GeC lasers through physical manipulation of the Ge crystal lattice and material composition, as well as the fabrication of high-efficiency solar cells on Ge, grown on Si substrates. Both of these initiatives are approached through Molecular Beam Epitaxy (MBE), a high-vacuum growth method that epitaxially grows materials onto substrates with extreme precision and material composition control. This is ideal for such applications because of the low defect tolerance in optoelectronic devices. The project that I was most closely involved with was the optimization of Ge oxide passivation, which would be key in the development of a Ge laser.

Unfortunately, there was a major equipment failure during my first few weeks in the clean room that required extensive cleaning on the MBE system. A failure in a purifying filter for a key N_2 line led to the contamination of almost all of our equipment, as well as much of the processing equipment around the lab. Due to the high-vacuum nature of MBE, this contamination could not be ignored, as it would cause a significant hike in pressure and subsequent decrease in the quality of materials grown. Therefore, over the course of several weeks, we disassembled large parts of this system, cleaned them, and reassembled them to their original condition. Although this incident was unfortunate, it provided an opportunity to really understand what each component of the MBE system did, and how everything worked together to achieve one common goal. Additionally, there was an emphasis on a wider set of skills (such as fixing pumps and plumbing) that I got to develop, that would certainly assist me in any future lab research that required somewhat custom machinery, such as the MBE system.

However, once the contamination issue was under control, there were opportunities to focus on the project of optimizing the GeO_2 passivation layer for a Ge substrate. Ge has a highly reactive surface, such that the native oxide can form in less than 30 minutes. This native oxide layer is far too disorganized to use in optical applications, requiring that we instead engineer a better solution. I had the opportunity to clean samples, prepare them for and actually grow the oxide using a Rapid Thermal Processing (RTP) system, and then analyze the resulting oxide quality using a Photoluminescence (PL) test. RTP is ideal for developing high-performance passivation layers, because it can heat samples quickly enough to ensure that only the best oxides passivate the crystal lattice (they can be heated to temperatures on the order of 400°C in a matter of seconds). After preparing these samples, we would analyze them using PL, where a laser excites electrons in the material, and the resulting emission spectrum is measured. Based on the magnitude of these spectra, we can determine the relative quality of the oxide, and refine our process accordingly.