Development of Bipolar Cascade Laser with an Emission Wavelength of 1.57 µm

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Bipolar Cascade Laser (BCL) consists of several single stage lasers coupled by tunnel junctions. BCLs can achieve high quantum efficiencies (the ratio of the number of emitted photons to the number of injected electrons) because an injected electron can participate in more than one recombination event by tunneling from one laser stage to the next. This project aims to develop, fabricate, and characterize an InGaAsP/InP BCL structure with an emission wavelength λ=1.57 µm, catering to a λ=1.55 µm lightwave communication system.

The two main elements of the project are the development of a single stage semiconductor laser and the building of a tunnel junction. The chosen material system, (InGa)(AsP), offers a range of bandgap energies compatible with all-optical fiber networks and can be grown by gas source molecular beam epitaxy (GSMBE) on InP substrates. GSMBE growth is effectively used to achieve atomically abrupt doping and refractive index profiles.

A single stage laser structure has been designed and grown by GSMBE. The band structure is designed to confine carriers in the active region, which is much shorter than the carriers' diffusion length. In addition, the active layer is designed to have a larger index of refraction than the cladding layers, leading to the confinement of light to the active region. Thus, the active region essentially represents an optical waveguide. In the current design, dopant-graded InP layers surround an active $In_{0.56}Ga_{0.44}As_{0.93}P_{0.07}$ layer and $In_{0.91}Ga_{0.09}As_{0.2}P_{0.8}$ cladding layers. In order to make the device polarization insensitive, the quaternary layers are closely lattice matched to InP. The active layer has a bandgap that corresponds to a wavelength of 1.57 µm.

A tunnel junction is a crucial element of a BCL. In a BCL, a tunnel junction is operated in reverse bias, allowing electrons to tunnel from the p-doped side of the junction to the n-doped side, and hence cascading between the single stage lasers. Desirable properties of tunnel junction material include narrow bandgap, high doping, and abrupt doping profile. Current work focuses on design, growth, and characterization of a series of tunnel junctions. Tunnel junction materials under investigation include Si- and Be-doped InP and $In_{1-x}Ga_xAs_yP_{1-y}$ epilayers with bandgaps corresponding to wavelengths from 0.92 µm to 1.2 µm.