Development of High Speed DFB and DBR Semiconductor Lasers

Personnel

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Sponsorship

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High-speed semiconductor DFB and DBR lasers are crucial for high-speed optical communication links. These lasers can be directly modulated at frequencies reaching 10 to 20 GHz, and have important applications in WDM (Wavelength Division Multiplexed) optical netwroks. Direct laser modulation schemes are much simpler to implement and integrate than modulation schemes based upon external modulators. However, modulation bandwidth of external modulators can easily go beyond 60 GHz. It is technologically important to have DFB/DBR lasers whose modulation bandwidths compete with those of external modulators. The goal of this project is to develop DFB and DBR lasers capable of being modulated at high speeds with low distortion and chirp.

High performance DFB and DBR lasers demand that careful attention be paid to the design of the grating, which provides the optical feedback. Spatial-hole burning, side-mode suppression, radiation loss, laser linewidth, spontaneous emission in non-lasing modes, lasing wavelength selection and tunability, laser relaxation oscillation frequency etc. are all features that are very sensitive to the grating design. In the last few years various techniques have been developed in the NanoStructures Laboratory that allow fabrication of gratings with spatially varying characteristics and with long-range spatial-phase coherence. Chirped optical gratings with spatially varying coupling parameter can be made using a combination of Interferometric lithography, spatially-phase-locked electron-beam lithography and X-ray lithography. This provides us a unique opportunity for exploring a wide variety of grating designs for semiconductor DFB and DBR lasers. We plan to explore laser devices suited for high-speed as well as for low-noise operation.

We have developed techniques for fabricating high-speed polyimide-planarized ridge waveguide laser structures that have low capacitance and are therefore ideally suited for high-frequency operation. Figure 18 shows a cross section of a polyimide planarized InP DFB laser. The active region consists of strain-compensated InGaAsP multiple quantum wells. The grating and the ridge are dry etched in RIE using a mixture of hydrogen and methane. Planarization is achieved by spinning multiple coatings of polyimide followed by a high temperature cure. Cured polyimide is dry etched in RIE using a mixture of oxygen and CF4 until the top of the ridge gets exposed. Ohmic contact to the ridge is made by lift-off on top of the polyimide layer. The thick layer of polyimide significantly reduces the capacitance between the top metal contact and the substrate. A large value of this capacitance can short out the active region at high frequencies. Figure 19 shows an SEM micrograph of a laser structure fabricated using this process. Figure 20 shows the measured output power from a DFB laser fabricated using the polyimide process. Figure 21 shows the measured spectrum of the DFB laser. Laser characteristics show reasonably high single mode output power with a side-mode-suppression ratio of 40 dB.

We have also developed techniques to fabricate high speed DFB cascade-laser structures. Cascade lasers offer improved performance in analog optical networks. In cascade lasers multiple PN junctions are connected electrically in series. Each electron injected into the laser is recycled from one PN junction to the next and can therefore emit multiple photons. Directly modulated cascade lasers offer better RF gain and signal-to-noise ratio in analog optical links. Figure 22 shows a polyimide based cascade laser structure in which different optical waveguides are connected electrically in series. Fabrication of this structure requires etching polyimide such that the sidewalls do not become too steep so that metal interconnects can be run over them. We have successfully developed etching techniques for polyimide that allows us to control the sidewall angle. Figure 23 shows an SEM micrograph of a metal interconnect running over the sidewall of a 2 µm thick polyimide layer

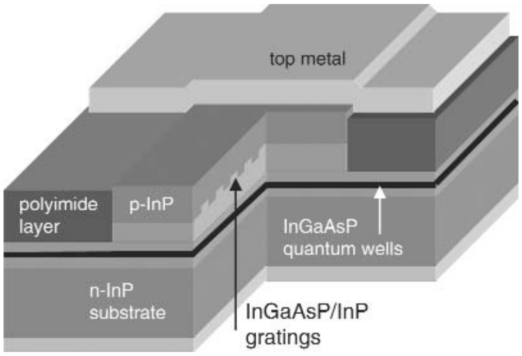

Fig. 18: Polymide planarized DFB ridge waveguide.

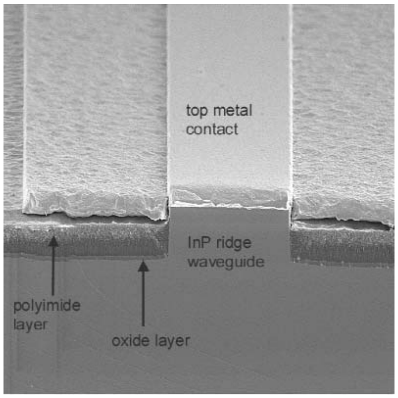

Fig. 19: SEM of a polyimide planarized DFB laser

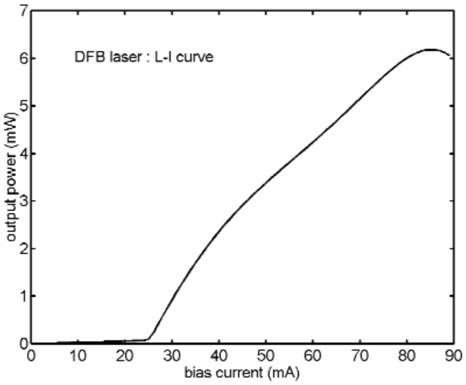

Fig. 20: Measured output power from a DFB laser. Maximum single mode output power is more than 6 mW.

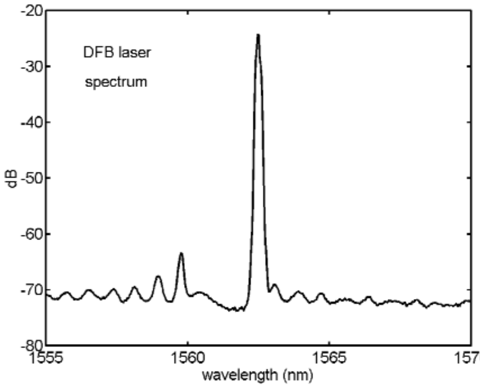

Fig. 21: Measured spectrum of a DFB laser. Side mode

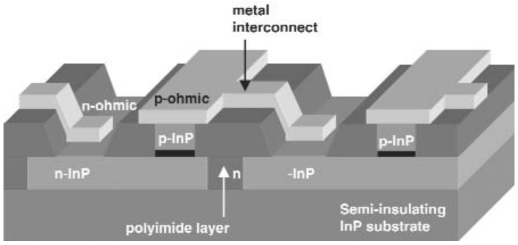

Fig. 22: DFB cascade laser in which optical

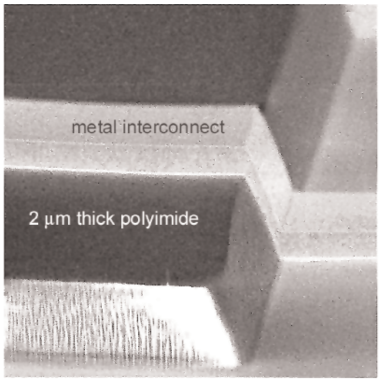

Fig. 23: Metal interconnect running over a 2 µm thick polyimide layer