Enhanced Frequency Response in Buried Ridge Quantum Well Intermixed SGDBR Laser Modulators

James W. Raring, Erik J. Skogen, Leif A. Johansson, and Larry A. Coldren
Materials Dept. University of California, Santa Barbara, CA 93106
Phone: 805.893.8465, Fax: 805.893.4500, Email: jraring@engineering.ucsb.edu

Abstract: We have studied the effects of various proton implant profiles on the performance of buried-ridge-stripe electro-absorption modulators monolithically integrated with SG-DBR lasers. Two implant profiles were performed adjacent to the buried ridge, enhancing the bandwidth.

OCIS codes: (140.5960) Semiconductor lasers; (140.3600) Lasers, tunable; (250.5300) Photonic Integrated Circuits

Enhanced Frequency Response in Buried Ridge Quantum Well Intermixed SGDBR Laser Modulators

James W. Raring, Erik J. Skogen, Leif A. Johansson, and Larry A. Coldren
Materials Dept. University of California, Santa Barbara, CA 93106
Phone: 805.893.8465, Fax: 805.893.4500, Email: jraring@engineering.ucsb.edu

Abstract: We have studied the effects of various proton implant profiles on the performance of buried-ridge-stripe electro-absorption modulators monolithically integrated with SG-DBR lasers. Two implant profiles were performed adjacent to the buried ridge, enhancing the bandwidth.

OCIS codes: (140.5960) Semiconductor lasers; (140.3600) Lasers, tunable; (250.5300) Photonic Integrated Circuits

1. Introduction

We present an investigation into the effects of proton implantation on the performance of monolithically integrated buried ridge stripe (BRS) sampled grating (SG) DBR lasers with electro-absorption modulators (EAM). Two different proton implant profiles were performed, demonstrating a reduction in parasitic capacitance associated with the BRS structure. The modulation bandwidth, DC extinction, and optical loss of the modulators were characterized. It is shown that by using a proton implant profile that is in close proximity to the buried ridge and penetrates the homojunction, a 2X improvement in modulation bandwidth and a decreased optical loss can be achieved.

2. Experiment

A complete description of the device fabrication process and epilayer structure can be found in [1]. A schematic of the device is shown in Figure 1. In order to create a non-absorbing waveguide and an efficient EAM, QWI has been applied to two different extents, yielding a total of three unique band-edges on chip [2].

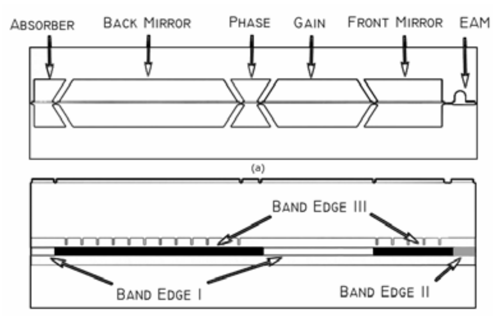
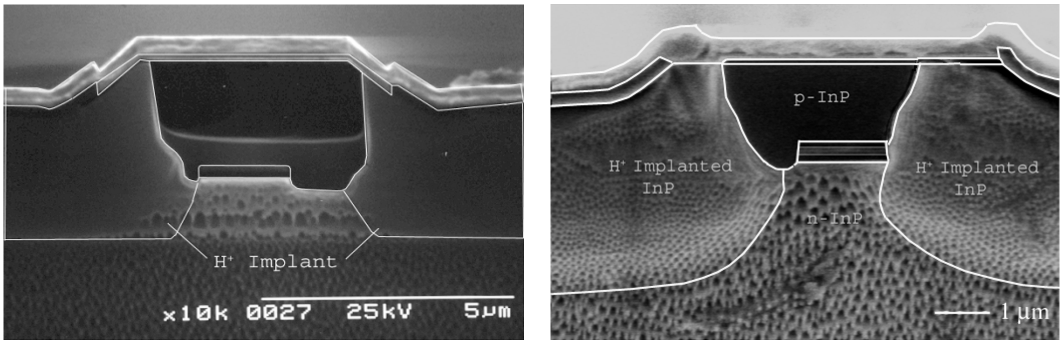


Figure 1: (a) Top view and (b) side view SG-DBR laser schematic illustrating the various sections and band-edges.

The fabrication process calls for two proton implants, the first is used for electrical isolation between laser sections and has a width of 10 µm over the buried ridge. The second, the BRS implant studied here, is a higher energy implant used to decrease leakage current in the laser and to lower parasitic capacitance in the EAM. In order to study the effects of proton implantation, two different BRS implant profiles were used. As a control, one sample was not BRS implanted. The second sample used a straight implant profile with a 4 µm wide implant mask over the EAM section, and a 10 µm wide implant mask was used over all other sections of the device. The third sample used a 28° angle implant with a 6 µm wide implant mask over the EAM section, and again used a 10 µm implant mask over all other sections. Figure 2 illustrates the implant profile for both samples with a BRS implant.



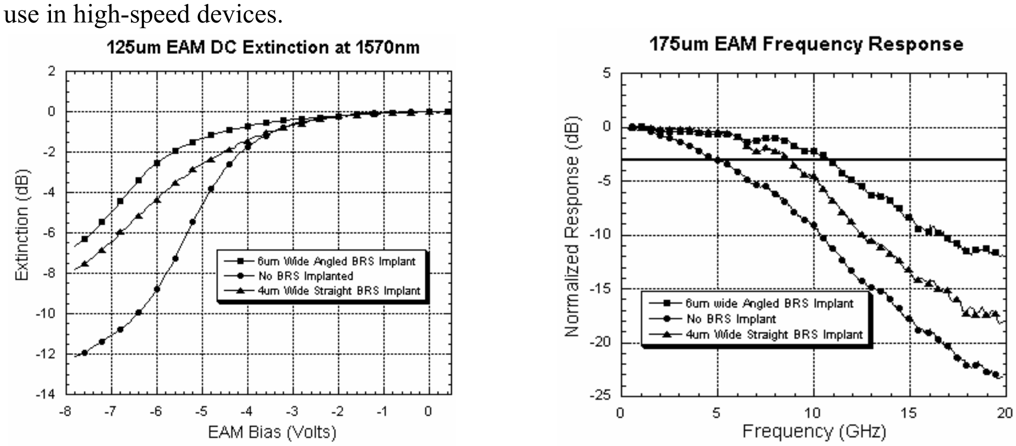
(a) (b)

Figure 2: Electron micrograph of (a) 4 µm wide straight implant profile, (b) 6 µm wide angled implant profile.

3. Results and Conclusions

The injection efficiency of the SG-DBR laser was shown to increase as the proton implant approached the buried ridge. The injection efficiencies were extracted to be 76%, 82%, and 85% for the non BRS implanted, 4um wide straight implant, and 6um wide angled implant, respectively. This can be explained by the reduction in the InP total homojunction area reducing the leakage current. The optical loss in the regions containing the passive band-edge and 10 µm wide BRS implant was found to be between 2.3 and 3.5 cm^{-1}. A significant reduction in optical loss, from 6.0 cm^{-1} to 1.8 cm^{-1}, was observed in the sample with the 6 µm wide angled implant compared to the sample without the BRS implant in the regions with the EAM band-edge. This can be attributed to less free carrier absorption associated with p-type doping [3].

The modulator characteristics for all implant profiles are shown in Figure 3. The decreased extinction for the implanted samples is likely due to proton straggle causing lattice damage within the quantum wells. The 6 µm wide angle implanted EAM demonstrates 11.5 GHz 3dB bandwidth, a greater than 2X improvement over the non BRS implanted sample, while the 4 µm wide straight implant demonstrated a 3dB bandwidth of 8.5 GHZ. Although the DC extinction was observed to suffer as the implant approached the ridge, with further optimization of the active region design and implant profile, proton implantation holds promise as a technique that could make the BRS more viable for use in high-speed devices.



(a) (b)

Figure 3: (a) DC Extinction for 125 µm EAMs of all implant profiles, (b) Frequency response for 175 µm EAMs of all implant profiles.

3. References

[1] E. Skogen, J. Barton, S. DenBaars, and L. Coldren, “A Quantum-Well-Intermixing Process for Wavelength-Agile Photonic Integrated Circuits,” *IEEE J. Sel. Topics in Q*uantum Electron., vol.8, pp. 863-869, 2002.

[2] E. Skogen, J. Raring, J. Barton, S. DenBaars, and L. Coldren, “Post-Growth Control of the Quantum-Well Band Edge for the Monolithic Integration of Widely-Tunable Lasers and Electroabsorption Modulators,” *IEEE J. Sel. Topics Quantum Electron. To be published 2004*.

[3] E.V. Rao, Y. Gottsman, M. Allovon, E. Vergnol, D. Sigogne, A. Talneau, H. Sik, S. Slempkes, B. Theys, and J. Chevallier, “CA Significant Reduction in Propagation Losses in InGaAsP-InP Buried-Stripe Waveguides by Hydrogenation,” *IEEE Photon. Technol. Lett.,* vol. 10, no. 3, pp. 370-372, (1998).