Monolithic Integration of Widely-Tunable DBR and DFB Lasers with One-Step Grating Formation

Victoria Rosborough[1], Fengqiao Sang[1], Joseph Fridlander[1], Hongwei Zhao[1], Bowen Song[1], Simone Tommaso Šuran Brunelli[1], Jeffrey. R. Chen[2], Mark A. Stephen[2], Larry Coldren[1] and Jonathan Klamkin[1]
[1]Electrical and Computer Engineering Department, University of California, Santa Barbara, CA 93106, USA
[2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
rosborough@ucsb.edu

Abstract: We demonstrate the integration of widely-tunable sampled-grating DBR (SGDBR) and DFB lasers on indium phosphide. The SGDBR laser exhibits a 36-nm tuning range with ≥36-dB SMSR and the DFB laser an SMSR of 51.6 dB.
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1. Introduction

The complexity of indium phosphide (InP) based photonic integrated circuits (PICs) has increased in the past decade both in number of on-chip functions and functional complexity [1]. Multiple active and passive elements such as lasers, modulators, couplers, and photodetectors are fabricated in a single PIC for applications such as coherent transmitters and receivers, optical downconverters for microwave frequency generation, and LIDAR [1–3]. These PICs employ either sampled-grating distributed Bragg reflector (SGDBR) lasers for their wide tuning range or distributed feedback (DFB) lasers for their wavelength stability. In this work, we present a platform for integrating both SGDBR and DFB lasers on same substrate using a simplified fabrication process with a single grating lithography and etch step.

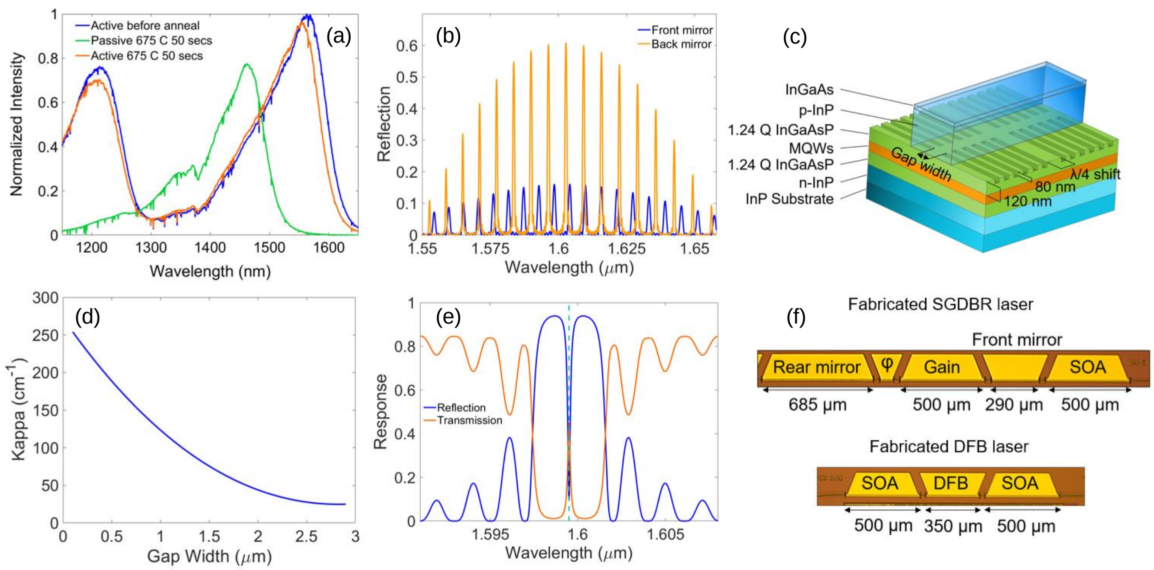

Fig. 1. (a) Photoluminescence intensity curves showing a 100 nm blueshift in the quantum well band edge after implantation and annealing. (b) Calculated rear and front mirror reflectivity for the SGDBR laser using an 80 nm etch depth into the top waveguide layer for the gratings. (c) Schematic of the DFB laser structure showing the vertically etched Bragg grating with a central gap. (d) Grating coupling coefficient (kappa) as a function of gap width. (e) Calculated grating response of a 350 μm-long quarter-wave-shifted DFB laser with a 1-μm gap width. (f) Optical micrographs of fabricated SGDBR and DFB lasers.

2. Design and Fabrication

Active/passive integration was achieved with a quantum well intermixing (QWI) process. Ion implantation into a sacrificial cap layer created vacancies that diffused into the quantum wells when annealed, resulting in a blueshift of the quantum well band edge [4]. Figure 1(a) shows a 100-nm shift in the band edge of implanted sections after annealing as measured by photoluminescence. The QWI approach was chosen for the ability to integrate DFB lasers without the specialized regrowth techniques required for butt-joint regrowth or selective area growth.

Figure 1(b) shows the calculated reflection of the rear and front SGDBR mirrors for an 80-nm grating etch depth. To achieve a lower coupling coefficient, kappa, for the DFB lasers, a central gap was introduced into the vertically etched gratings as illustrated in Fig. 1(c). This lower kappa design reduces fabrication time and improves process reliability by allowing the use of a single etch depth for both the SGDBR and DFB laser mirror gratings. The grating coupling coefficient as a function of the gap width is plotted in Fig. 1(d). Figure 1(e) shows the calculated response of a quarter-wave-shifted DFB grating with a 1 µm gap. Optical micrographs of fabricated SGDBR and DFB lasers are shown in Fig. 1(f).

3. Characterization

Figures 2(a) and (b) show the light-current-voltage (LIV) characteristics of the SGDBR and DFB laser, respectively. The optical power was measured by an on-chip detector following each laser. The SGBDR laser outputs 6 mW at 200 mA and has a threshold current of 30 mA. The jump in output power near 100 mA is due to a cavity mode hop. The DFB laser outputs 5 mW from a single end at 150 mA and has a threshold current of 30 mA. As shown in Fig. 2(c), the SGDBR laser exhibits a 36 nm tuning range. The side mode suppression ratio (SMSR) was greater than 36 dB over the entire tuning range with a maximum SMSR of 46.2 dB at 1580.5 nm. Figure 2(d) shows single-mode operation of the DFB laser at 1605 nm with an SMSR of 51.6 dB.

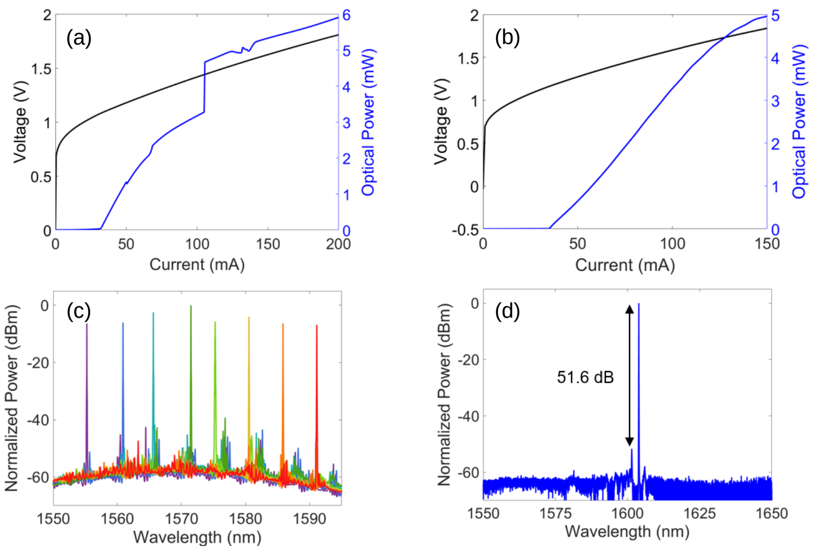

Fig. 2. LIV characteristic of (a) an SGDBR laser and (b) a DFB laser. (c) Superimposed output spectra of the SGDBR laser showing 36-nm tuning range. (d) DFB lasing spectrum with SMSR of 51.6 dB.

4. Conclusion

To the best of the authors' knowledge, we have presented the first monolithic integration of a widely-tunable SGDBR laser with a DFB laser on InP. Future PIC designs will take advantage of an SGDBR laser source for wide-tunability along with a DFB laser for wavelength stability.

5. Acknowledgements

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6. References

[1] S. Arafin and L. A. Coldren, "Advanced InP Photonic Integrated Circuits for Communication and Sensing," IEEE JSTQE **24**(1) (2018).
[2] F. Kish, et al., "System-on-Chip Photonic Integrated Circuits," IEEE JSTQE **24**(1) (2018).
[3] B. Isaac, et al., "Indium Phosphide Photonic Integrated Circuit Transmitter with Integrated Linewidth Narrowing for Laser Communications and Sensing," 2018 IEEE International Semiconductor Laser Conference (ISLC).
[4] E. J. Skogen, et al., "A Quantum-Well-Intermixing Process for Wavelength-Agile Photonic Integrated Circuits," IEEE JSTQE **8**(4) (2002).