SGDBR tunable laser on gallium arsenide for 1030 nm lidar applications

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Abstract – A sampled grating distributed Bragg reflector tunable laser with a center wavelength of 1032 nm is demonstrated on a gallium arsenide photonic integrated circuit platform. The laser demonstrates a 32 nm tuning range, 37 dB side-mode suppression ratio, and 20 mW of output power.

I. Introduction

Tunable semiconductor lasers are of interest for a variety of applications ranging from fiber optic telecommunications to light detection and ranging (Lidar) and free space optical communications [1-4]. Monolithic integration of tunable lasers with other optical devices (e.g., semiconductor optical amplifiers (SOAs), modulators, photodetectors) on photonic integrated circuit (PIC) platforms is highly desirable for reduction of overall system size, weight, and power (SWaP). This is particularly advantageous for air and space-borne systems where low SWaP is critical. Widely tunable lasers with sampled grating distributed Bragg reflector (SGDBR) mirrors have been demonstrated on indium phosphide (InP) PIC platforms for operation near 1550 nm [2-6]. However, there are applications outside this spectral range that could benefit from similar PIC technology. For example, airborne Lidar systems utilizing wavelengths near 1000 nm have applications in topographical measurements [7] and can take advantage of highly sensitive detectors at this wavelength [8]. In this work, we demonstrate an extended tuning range SGDBR laser on a gallium arsenide (GaAs) PIC platform for operation near 1030 nm.

II. Design and Fabrication

The SGDBR laser presented in this work is a four section laser with gain, phase, and front and back mirror sections. A sideview schematic is shown in Fig. 1(a), and a micrograph image of a fabricated device is shown in Fig. 1(b). The gain section consists of three layers of 5 nm thick indium gallium arsenide ($In_xGa_{1-x}As$) quantum wells (QWs) with x = 0.271, surrounded by gallium arsenide phosphide ($Ga_{1-x}AsP_x$) barriers with x = 0.1. GaAs waveguide layers are placed above and below the multi-quantum well (MQW) layers and surrounded by aluminum gallium arsenide ($Al_xGa_{1-x}As$) separate confinement heterostructure (SCH) layers, with low aluminum content (graded from x = 0.1-0.2). The lower n-type cladding is $Al_{0.75}GaAs$ and the upper p-type cladding is $Al_{0.6}GaAs$. Active-passive integration is accomplished with an offset quantum well (OQW) structure whereby the MQW is selectively removed with etching. This is followed by formation of the gratings and regrowth of the upper SCH and p-cladding layers by metalorganic chemical vapor deposition (MOCVD). This OQW structure creates gain regions integrated with passive waveguide sections for the phase section and grating mirrors, and the platform could be leveraged to realize more complex PICs as well.

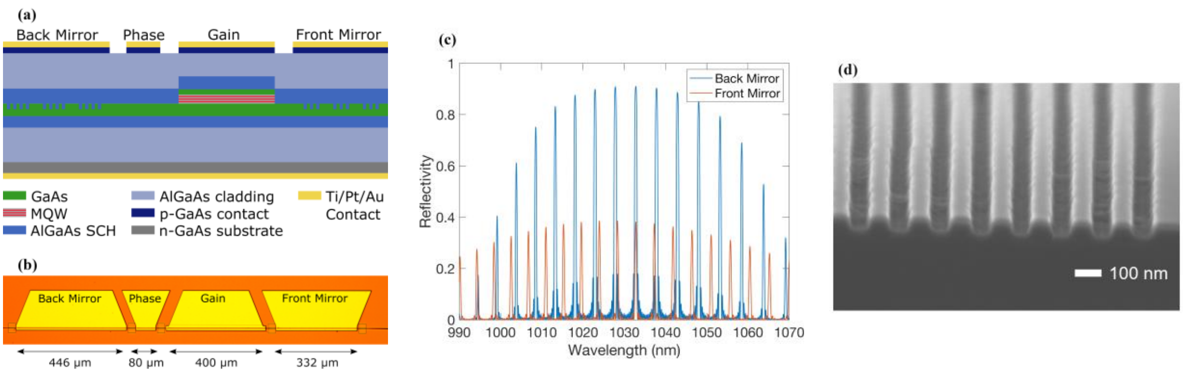

Fig. 1. (a) Schematic diagram of a four-section SGDBR laser and (b) top-view micrograph image of fabricated SGDBR laser. (c) Simulated reflectivity spectrum for front and back mirrors and (d) cross section SEM image of etched gratings.

Wavelength tuning is accomplished by injecting current into the front and back SGDBR mirrors [9]. Prior to regrowth, the gratings are patterned in the GaAs waveguide layer using electron beam lithography (EBL), and etched using inductively coupled plasma reactive ion etching (ICP-RIE) with chlorine (Cl_2) and nitrogen (N_2) chemistry. The grating pitch is 156 nm with 50% duty cycle and the etch depth is 35 nm, resulting in a calculated

2021 27th International Semiconductor Laser Conference (ISLC) | 978-1-6654-4133-9/21/$31.00 ©2021 IEEE | DOI: 10.1109/ISLC51662.2021.9615662

coupling coefficient for the un-sampled grating of $\kappa = 490\ cm^{-1}$ and designed Bragg wavelength of 1032.8 nm. Figure 1(d) shows a cross section scanning electron microscope (SEM) image of the fabricated gratings prior to upper cladding regrowth. The total front mirror length is 332 µm with a sampling period of 33.163 µm and 10 grating periods per burst. Similarly, the back mirror is 446 µm long with a sampling period of 29.728 µm and 20 grating periods per burst. These mirrors result in the simulated reflectivity spectra shown in Fig. 1(c). Direct current injection in the mirror sections changes the refractive index and shifts the mirror spectra in Fig. 1(c) to select different modes, effectively tuning the laser's output wavelength.

III. Measurement Results

Figure 2(a) shows the light current voltage (LIV) characteristic of the SGDBR laser from Fig. 1(b). This laser demonstrates a threshold current of 22 mA and up to 20 mW output power from the front mirror (measured by coupling output to an integrating sphere) at 100 mA continuous wave (CW) current injection, without mirror tuning. Power output from the front mirror was then coupled to a lensed fiber and connected to an optical spectrum analyzer (OSA) to observe the laser's spectral output. Figure 2(c) shows a zoomed in view of the free running laser output spectrum with 100 mA applied to the gain section and no mirror or phase section current, demonstrating 37.17 dB side mode suppression ratio (SMSR) and a center wavelength of 1032.63 nm. Current applied to the front and back mirrors was then swept between 0 and 100 mA, while the gain section current was held constant at 100 mA. Figure 2(b) shows the output spectra at 8 different tuning current levels superimposed on one another, demonstrating a tuning range of 32 nm. The peaks above 1032 nm in Fig. 2(b) represent the output with only front mirror tuning, as the front mirror spectrum from Fig. 1(c) is shifted to longer wavelengths with applied current, while the back mirror spectrum remains constant. Similarly, the peaks below 1032 nm represent the laser output with only back mirror tuning. All of the spectra shown here were generated without phase section tuning.

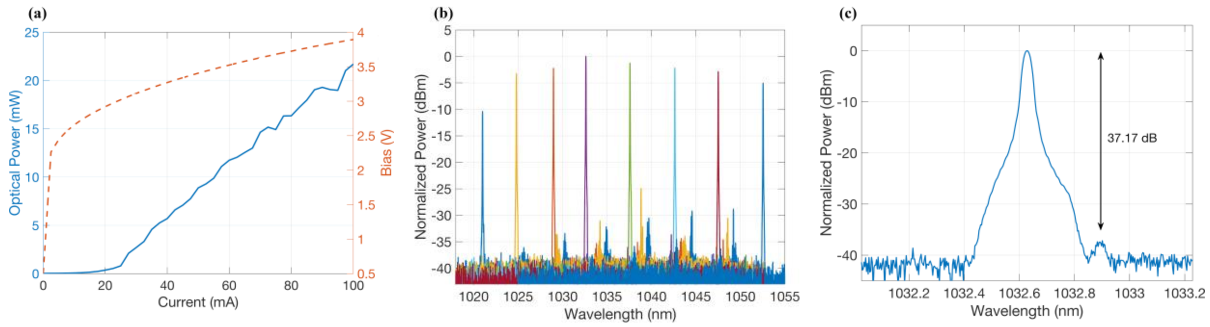

Fig. 2. (a) SGDBR laser LIV curve. (b) Tuning spectra at 8 different tuning mirror current levels and (c) close-up of free running laser spectrum showing 37.17 dB of SMSR and center wavelength 1032.63 nm.

IV. Conclusion

An extended tuning range SGDBR laser on GaAs was demonstrated with operation near 1030 nm, with a 32 nm tuning range, 37.17 dB SMSR, and up to 20 mW CW output power. To the best of the authors' knowledge, this is the first demonstration of a monolithically integrated, in-plane, extended tuning range laser for operation in this wavelength region on a GaAs PIC platform.

V. Acknowledgements

The authors acknowledge funding support from the NASA ESTO Advance Component Technology program. A portion of this work was carried out in the UC Santa Barbara Nanofabrication Facility.

VI. References

[1] L. A. Coldren *et al., J. Light. Technol.*, vol. 22, no. 1, pp. 193–202, 2004
[2] H. Zhao *et al.*, *IEEE J. Sel. Top. Quantum Electron.*, vol. 24, no. 6, pp. 1–6, 2018
[3] B. J. Isaac *et al.*, *IEEE J. Sel. Top. Quantum Electron.*, vol. 25, no. 6, pp. 1–7, 2019
[4] S. Arafin and L. A. Coldren, *IEEE J. Sel. Top. Quantum Electron.*, vol. 24, no. 1, 2018
[5] J. Fridlander, *et al,* Conference on Lasers and Electro-Optics (CLEO) 2020.
[6] V. Lal *et al.*, *J. Light. Technol.*, vol. 35, no. 7, pp. 1320–1327, 2017
[7] A. W. Yu *et al.*, Proc. SPIE 8599, 85990P (2013)
[8] M. A. Krainak *et al.*, *in Proc. SPIE Defense, Security, and Sensing,* Orlando, FL, USA, 2010
[9] V. Jayaraman *et al.*, *IEEE J. Quantum Electron.*, vol. 29, no. 6, pp. 1824–1834, 1993