Heterogeneously Integrated O-band SG-DBR Lasers for Short Reach Analog Coherent Links

Stephen Misak[1*], Aaron Maharry[1], Junqian Liu[1], Ranjeet Kumar[2], Duanni Huang[2], Giovanni Gilardi[2], Richard Jones[2], Ansheng Liu[2], Larry Coldren[1], Clint Schow[1]
[1]*Department of Electrical and Computer Engineering, University of California, Santa Barbara, CA 93106, United States*
[2]*Intel Corporation, 2200 Mission College Blvd, Santa Clara, CA 95054, United States*
**smisak@ucsb.edu*

Abstract: We report record performance for a heterogeneously integrated O-band SG-DBR laser, achieving a tuning range of 48 nm, 50 dB MSR, >20 mW output power, and ~0.67 MHz apparent linewidth.

1. Introduction

Tunable lasers have applications in multiple areas, but this paper focuses on short reach, intra-datacenter communications. Intra-datacenter link performance is key because it accounts for over 70% of datacenter traffic [1]. Analog coherent links are generating interest to improve speed and reduce power consumption. The lasers in this paper are designed to act as the local oscillator (LO) for analog coherent links. An optical phase-locked loop (OPLL) is used in analog coherent links to frequency- and phase-lock the LO to the transmitter laser. This is accomplished by modulating a diode in the laser cavity with an error signal generated by feeding part of the received data signal through a Costas loop phase/frequency detector and loop filter. A diode phase section with sufficient bandwidth and tuning efficiency is required to maintain phase locking [2,3]. For fabricating the laser, the silicon photonics platform is advantageous for its large-scale manufacturability, reduced cost, and integration capabilities [4,5]. While silicon does not have a native light source, wafer bonding of III-V on silicon has matured, enabling high performance lasers on silicon and a large variety of photonic integrated circuits (PICs) to be manufactured at scale [6,7].

2. Device Design

Using Intel's silicon photonics platform, several sampled grating distributed Bragg reflector (SG-DBR) laser variants were designed. Fig. 1 shows the fabricated lasers and a design schematic. The gratings were designed to maximize output power with a low threshold and high mode suppression ratio (MSR). For high front output power, the front gratings were designed with low reflectivity by reducing the number of periods (Λ) per grating burst ($Z_1 = n\Lambda$) and the number of bursts. A long, high reflectivity back mirror was used for high MSR and low threshold. The cavity length needs to be optimized such that the phase section provides several GHz of tuning for frequency locking using the OPLL. To examine the impact on MSR, threshold, tuning efficiency, and output power, multiple grating designs and phase section lengths were fabricated.

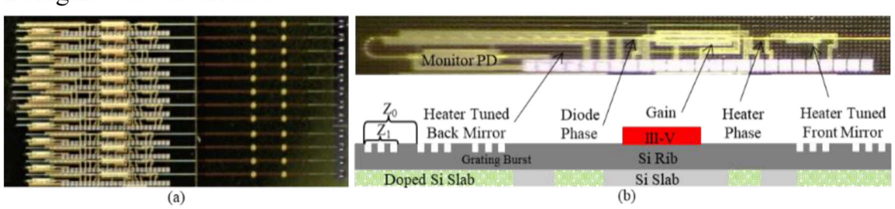

Fig. 1. (a) The full array of laser variants is shown. (b) A schematic view of the laser shows the details for the SG-DBR devices.

3. Measurement Results

For all measurements, a thermo-electric cooler is used for temperature stability, and a probe card is used for biasing. For one variant, labeled Design A, a tuning range of 48 nm (1273 to 1321 nm) and MSR of 50 dB, as shown in Fig 2, were measured by sweeping the voltage for the front and back mirror heaters while measuring a fraction of the output power with an optical spectrum analyzer (OSA). The low MSR band in Fig 2(b) is likely due to reduced gain, supported by the lower spontaneous emission at longer wavelengths in Fig. 2(c). Output power shown in Fig. 2(d) is measured using an integrating sphere with a power meter. The output power and threshold worsen as the wavelength increases, but >20 mW of power is achieved from 1280 to 1315 nm. To the author's best knowledge, this is a record for O-band SG-DBR lasers on silicon, and it is comparable to other O-band widely tunable lasers [8,9]. Although the laser has a large tuning range, Fig. 2 shows that continuous tuning is only achieved in a 1 to 3 nm range around each SG-DBR supermode, not across the entire tuning range. By sweeping the diode phase section current, tuning efficiency was

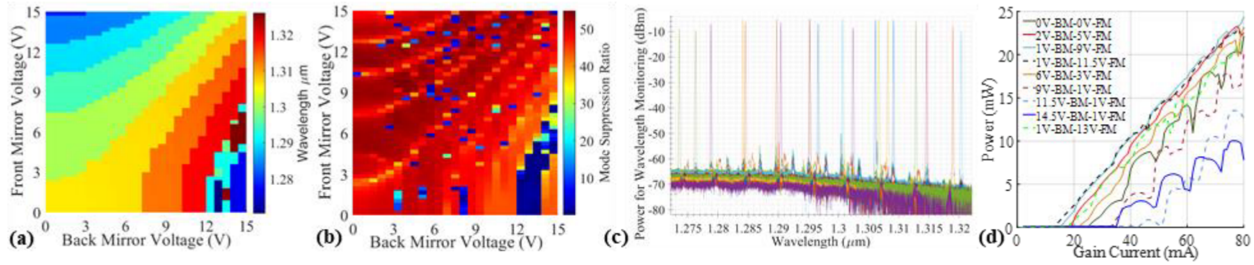

Fig. 2. For Design A, (a) wavelength map (b) MSR, (c) spectra, and (d) output power are measured at 20˚C

measured using an OSA as shown in Fig 3. The 400 μm length for Design A provides up to 0.75 GHz/mA tuning compared to 0.32 GHz/mA for the 200 μm length in Design B. The decrease in tuning efficiency at higher currents is likely caused by Joule heating. Using a delayed self-heterodyne (DSH) setup with a 25 km fiber delay and a 200 MHz acousto-optic modulator, a linewidth (LW) of ~ 0.67 MHz (broadened by flicker and other technical noise) was fitted for Design A. The frequency response of the diode phase tuner was measured by converting the optical frequency modulation to amplitude modulation (AM) using the edge of a bandpass optical filter. A photoreceiver connected to an electrical spectrum analyzer was used to measure the frequency response of the AM signal, yielding a ~100 MHz 3-dB BW, sufficient for operation in the analog coherent OPLL.

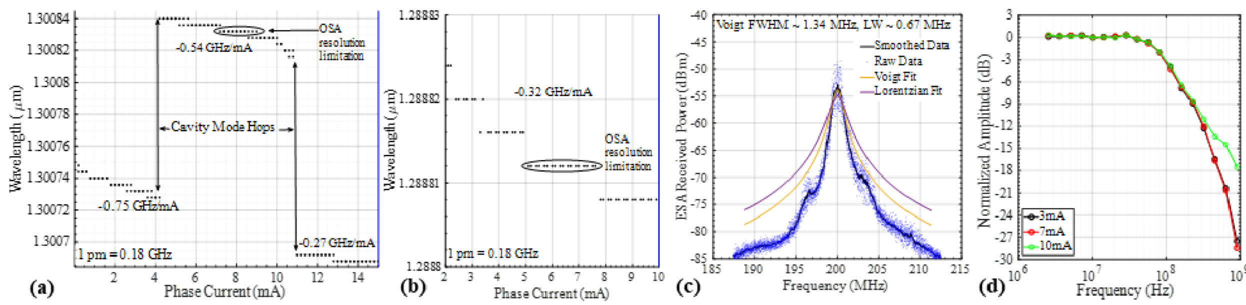

Fig. 3. Tuning efficiency is larger for (a) Design A compared to (b) Design B. Apparent LW (c) of Design A is ~0.67 MHz. (d) Diode phase tuner frequency response shows ~100 MHz 3-dB BW.

4. Conclusion

Record performance has been measured for heterogeneously integrated SG-DBR lasers with wavelengths from 1273 to 1321 nm and >20 mW of output power. A phase tuning efficiency of up to 0.75 GHz/mA is shown with ~100 MHz 3-dB BW. Spectral quality is demonstrated with 50 dB of MSR at most bias conditions and a DSH LW of ~0.67 MHz. This performance is adequate for integration into an analog coherent link with an OPLL.

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6. References

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