Compact widely-tunable laser on an InP membrane on silicon

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***Abstract*— Compact broadband tunable laser source with a footprint of 0.82 mm^2 and a 50-nm wide tuning range is experimentally demonstrated on the InP membrane on silicon (IMOS) platform. This high-density integration technology allowed the reduction of the laser footprint by a factor of four, when compared to its equivalent realized in traditional InP technology.**

Keywords——Photonic integrated circuit, InP membrane, semiconductor tunable laser

I. INTRODUCTION

Optical beam steering is a fundamental and important technology for light-based detection and ranging (LiDAR) and optical wireless communications (OWC). Optical beam steering using photonic integrated circuits (PICs) has been actively researched in recent years, as advances in silicon photonics have enabled high-density integration of optical components such as optical phased arrays [1-2]. However, to implement all components for beam steering on a single chip, dense integration of III-V gain with other functional components remains under active research. In contrast, the InP platform has all the components such as laser, semiconductor optical amplifier (SOA), phase modulator and photodetector to build a high-performance beam steerer on a single chip. InP membrane on silicon (IMOS) technology has shown high potential in realizing high-density photonic circuits with speed and energy-efficiency benefits due to complete circuit integration [3-4]. In this paper, we experimentally demonstrate a compact widely-tunable ring laser operating near 1550 nm wavelength on the IMOS platform. This tunable laser footprint is 4 times smaller compared to its equivalent circuit on a bulk InP platform [5] due to the reduced bend radius on the InP membrane. By tuning the cascaded Mach-Zehnder interferometers in the laser cavity, a 50-nm wide tuning range with a minimum side mode suppression ratio (SMSR) of more than 25dB is achieved. This highly integrated widely-tunable laser is a promising technology for optical beam steering.

II. LASER DESIGN AND TUNING PRINCIPLE

The design of the extended ring cavity widely tunable laser discussed in this work is presented in Fig. 1 (a). A 1-mm-long 4 quantum well (QW) semiconductor optical amplifier (SOA) was used as the C-band gain medium for the laser. Lasing wavelength was selected by tuning three asymmetric Mach-Zehnder interferometers (AMZI) and in-line phase modulator. The high optical confinement of the membrane structure allows for a smaller bending radius in the arms of the AMZI, and therefore a small footprint of 1.27 × 0.65 mm^2 is achieved as shown Fig. 1 (b). Each AMZI has a different arm length asymmetry, allowing for coarse, medium, and fine tuning of the combined transmission. The filters were controlled by varying the power applied to the thermo-optic (TO) phase modulators in the filter. The in-line phase modulator is used for mode selection from the longitudinal modes in the ring. To achieve a linear frequency sweep, the peak transmission points

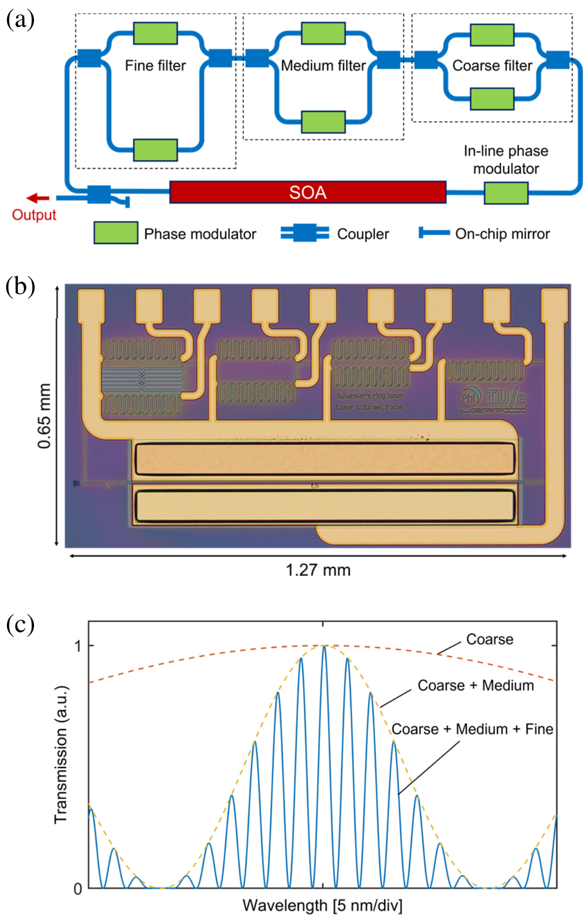

Fig. 1 (a) Schematic of the laser structure consisting of three cascaded asymmetric Mach-Zehnder filters and an intra-cavity phase shifter (not-to-scale). (b) Microscope image of a fabricated tunable laser. (c) The transmission spectra of a combination of a coarse, medium and fine filter.

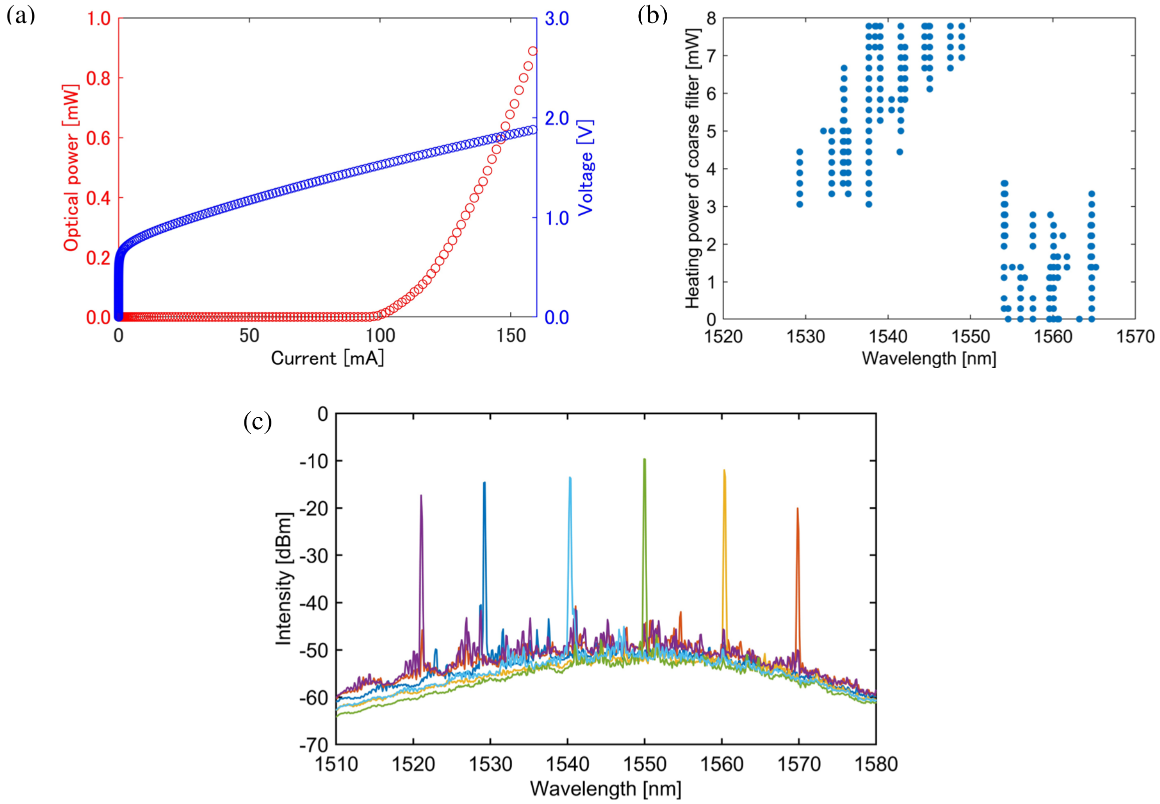

Fig. 2 (a) I-L and I-V characteristics of the laser. The optical power is measured in a fiber with a typical coupling loss of ~10dB. (b) Tuning maps for the coarse and medium filters. This map was obtained from a subset of 784 operating points, with the two filters tuned independently at 28 points. (c) Laser spectra for different control settings for all phase modulators at a bias current of 140 mA in the SOA section.

of the three filters must be aligned and tuned synchronously to achieve a selected peak in the transmission spectrum, as seen in Fig. 1 (c). The detailed performance of the AMZIs-based laser can be found in a previous publication [5].

III. Experimental Results

Fig. 2 (a) shows the LIV characteristics of the tunable laser without bias to the AMZIs. The substrate was thermally stabilized at 10°C by a temperature controller. The measurement was performed in pulse mode with a pulse width and a duty cycle of 1 μs and 50%, respectively. The threshold current was 105 mA and the differential resistance was 5.2 Ω. Only pulsed operation is obtained, which is likely due to problems in metalization. Fig. 2 (b) shows the first calibration step involving coarse and medium filters. A heating power of 0 mW to 7.6 mW (the resistance was measured to be about 70 Ω for each TO modulator) is applied to each TO phase modulators with a resolution of 28 points, and tuning maps were formed from 784 different heating power combinations. The tuning map obtained in this step allows us to define a linear function that fits the data of applied power with respect to wavelength, the response for the coarse filter was determined to be 4.0 nm/mW. Similar steps were performed for the medium and fine filters, and responses were determined to be 0.72 nm/mW and 0.051 nm/mW, respectively. Based on the obtained characteristics of each filter, the optical spectra when all AMZIs and the in-line phase modulator are tuned simultaneously are shown in Fig. 2 (c). The SOA section bias current was kept constant at I_{SOA} = 140 mA. Single-mode operation with SMSR > 25dB was obtained in the 1520 nm to 1570 nm range by tuning all filters appropriately so that their peaks coincide at a particular wavelength. Note that this 50 nm tuning range is only limited by the available gain, and a larger tuning range may be obtained with an extended bandwidth active layer design and improved thermal design [6].

IV. Conclusion

A compact widely-tunable laser on InP membrane on silicon (IMOS) platform was demonstrated. A wide tuning range of 50 nm with a 4-times smaller footprint (0.82 mm^2) was achieved. This technology is promising for beam steering, which requires high-density integration of wide tunable laser with beam steering components.

Acknowledgment

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