Heterogeneous silicon widely-tunable lasers with monolithically integrated high-Q ring

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Abstract: We present preliminary results on a widely-tunable laser with monolithically integrated high-Q ring based on heterogeneous silicon integration platform. The laser exhibits > 43 nm tuning range with side mode suppression ratio larger than 40 dB in the O-band.

OCIS codes: (140.3600) Tunable lasers; (140.3560) Lasers, ring; (250.5960) Semiconductor lasers.

1. Introduction

Monolithically integrated widely tunable semiconductor lasers are of great interest for a variety of applications ranging from dense wavelength division multiplexing communication systems to remote sensing [1]. They offer advantage over bulky mechanically tuned external-cavity lasers in terms of footprint, cost and energy efficiency. Different configurations have been demonstrated in two major semiconductor platforms: Indium Phosphide (InP) and heterogeneous InP on silicon, including sampled-grating distributed Bragg reflector (SGDBR) laser [2], distributed feedback (DFB) laser array [3], and ring resonator (RR) laser [4].

As for InP-based tunable lasers, their linewidth performance is typically around 1 MHz, which is limited by the propagation loss and low obtainable Q factor of the resonator unless external feedback is applied. This scenario can be improved with silicon as low waveguide propagation loss allows high-Q photon storage in the silicon cavity, which was shown to reduce spectral linewidth down to as low as 50 kHz in heterogeneously integrated lasers [4]. Previously we proposed and theoretically analyzed the incorporation of a fully integrated high-Q ring (HQR) ring (intrinsic Q ~ 1 million, assuming silicon waveguide propagation loss of 0.5 dB/cm) inside widely tunable heterogeneous silicon lasers to realize narrow linewidth lasers [1]. In this paper, we report our preliminary testing results of this novel high-Q ring laser (HQRL). A wide tuning range over 43 nm with side mode suppression ratio (SMSR) > 40 dB is realized.

2. Laser design and performance

A schematic diagram of the fabricated HQRL is shown in Fig. 1. The laser consists of a gain section, a phase section, two RRs and a HQR. Two loop-mirrors form the oscillating cavity. The widely-tunable single mode operation is realized by the combination of the two RRs and the HQR as outlined in [1]. The RRs inside the cavity form a Vernier filter, which is used to filter out a single resonance of the high-Q ring as well as provide wide-tunability. The HQR ring with FSR ~ 25 GHz filters out a single longitudinal mode of the cavity, and also helps to improve the linewidth due to cavity length enhancement at resonance and negative optical feedback. A semiconductor optical amplifier is integrated at the output waveguide to boost the output power. 7° degree angle and flare-out taper is employed to minimize reflections. The lasers were designed using a heterogeneous photonic integration process design kit (PDK) and fabricated under a DARPA EPHI multiproject wafer (MPW) program [5]. The total chip size is 3.6 mm × 0.5 mm.

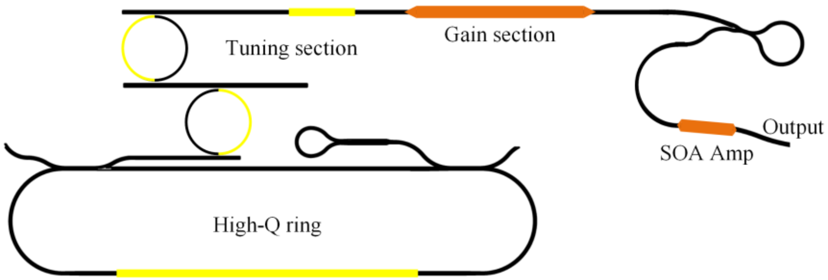

Fig. 1 A schematic view of a widely tunable high-Q ring laser design. Thermal tuners are yellow, gain section and SOA amplifier are orange.

The laser is tested on a copper heat sink with a fixed stage temperature of 23 ℃. Fig. 2 shows the light-current curve of the tested chip with different SOA amplifier currents. The lasing threshold current is around 38 mA. The output light is then coupled with a lensed single mode fiber to measure the spectrum. Fig. 3 shows the laser spectrum at a gain section current of 60 mA and SOA amplifier current of 40 mA. A SMSR larger than 50 dB indicates narrow bandwidth of the combined RRs and the HQR. The wavelength tuning map shown in Fig. 4 at the same bias condition is obtained by simultaneously heating the two RRs as well as adjusting phase section and HQR section current, indicating a tuning efficiency around 31.3 mW/pi. A wide tuning range over 43 nm with SMSR > 40 dB is realized as exhibited in Fig. 5. The dependence of linewidth on wavelength tuning will be reported at the conference.

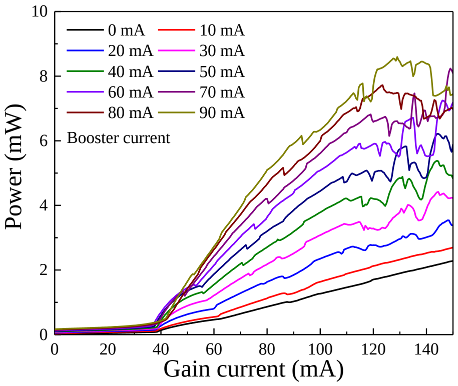

Fig. 2 L-I curve of the tested HQRL with different SOA amplifier current.

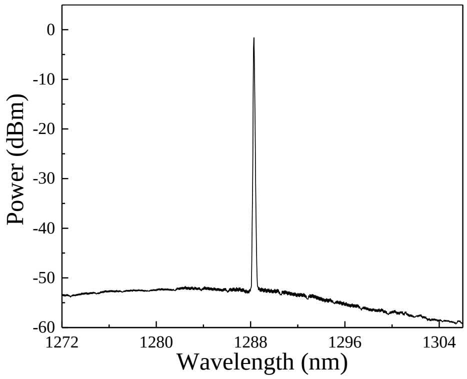

Fig. 3 Laser emission spectrum at gain current 60 mA and SOA amplifier current 40 mA.

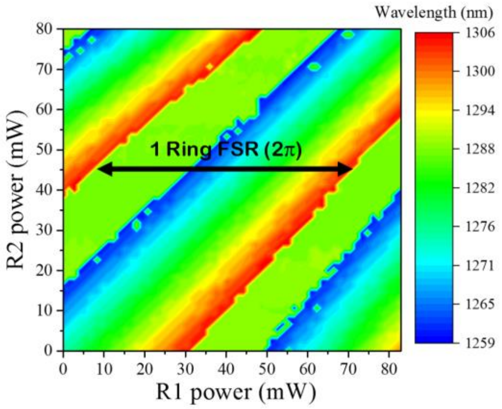

Fig. 4 Wavelength tuning map of the tested HQRL

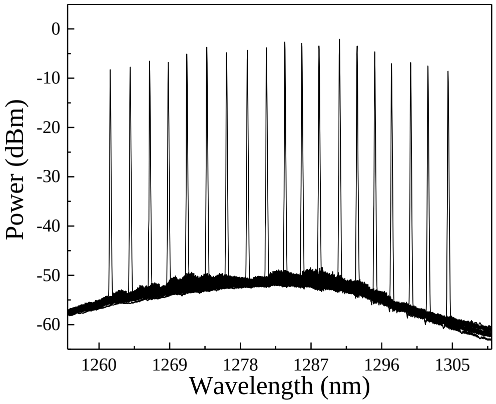

Fig. 5 Superimposed laser spectra.

3. Acknowledgment

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