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InP-based monolithic tunable laser with thermally tuned ring resonator

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Abstract

We report a thermally tuned DBR/ring laser with high wavelength selectivity for the applications into digital coherent systems. Microheaters are placed on narrow high-mesa waveguides at the front DBR mirror and the rear ring mirror. Low power consumption of 40 mW at the ring section is demonstrated for one free spectral range (FSR) tuning.

1. Introduction

Developing narrow linewidth wavelength tunable lasers is a key to increase capacity in digital coherent transmission system [1]. As the digital coherent technology is expanded into metro and inter-datacenter networks as well as long-haul communications, downsizing and reducing power consumption are required for optical transceivers comprising tunable lasers. In previous work, we fabricated narrow linewidth integrated tunable laser arrays [2-4]. However, the device sizes are limited by the numbers of the laser diodes, and the power consumption tends to become high for thermally tuning the laser wavelength by thermo-electric coolers (TECs). Therefore, we have developed an InP-based compact tunable DBR/ring laser with local micro heating elements. The lasing wavelength can be arbitrarily selected in the C-band by tuning the DBR and ring mirrors. In addition, the microheater on the high-mesa waveguide at the ring resonator enables power dissipation less than 40 mW for wavelength shifts of one FSR.

2. Device design

Figure 1 shows a device schematic of the compact tunable DBR/ring laser [5]. Our InP-based monolithically integrated laser chip consists of a rear mirror, a gain, a front distributed Bragg reflector (DBR) mirror, followed by a semiconductor optical amplifier (SOA). The rear mirror is composed of a ring resonator, a phase tuning section, and a 1×2 multimode interferometer (MMI) coupler. The active regions comprising the gain and the SOA have a buried heterostructure (BH) with high injection efficiency and high reliability. The front and rear mirrors have passive high-mesa waveguides connected to the active waveguides by a butt-joint process.

In principle, lasing wavelength is determined by tuning the periodic reflective combs of the DBR and the ring, which is based on the Vernier effect [6-9]. The DBR has 8 equal reflective peak wavelengths with ~660 GHz FSR in the C-band, which is owing to the numerically optimized phase modulation function of the DBR. In contrast, the FSR of the ring is designed to be around 600 GHz. Because such high FSRs allow to perform good wavelength selectivity, the short length of the ring with low optical loss is necessary. Thus, we use the high-mesa waveguide with width narrower than 2 µm, which allows for stronger optical confinement compared to a BH waveguide. Thermal wavelength tuning is performed through the local heating elements which are placed on the DBR, the phase tuning section, and the ring. Since thermal tuning avoids optical absorption induced by carrier injection, the narrow linewidth of the laser is realized, compared to

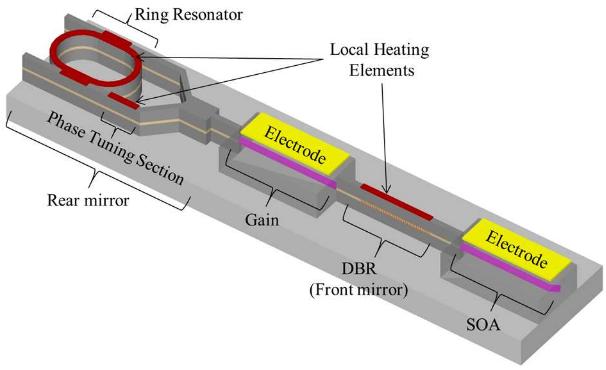

Fig. 1. A schematic of the DBR/ring laser.

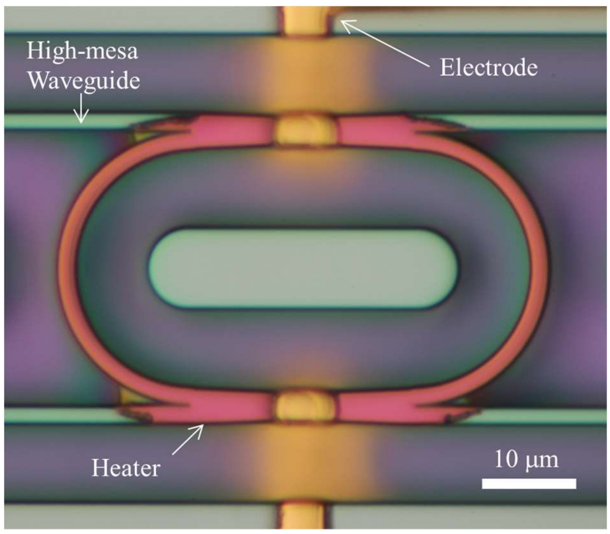

Fig. 2. An optical microscope image of a ring resonator.

current tuning [6]. An optical micrograph image of a typical ring resonator with the small radius of 14 µm is shown in Fig. 2. We have fabricated the DBR/ring tunable lasers with device sizes of 3 mm×0.35 mm.

3. Performance

The laser chips were characterized at a junction temperature of around 50 °C in the air, and injection currents for the gain and the SOA were fixed at 150 mA and 200 mA, respectively. The lasing wavelengths were measured by an optical wavelength meter coupled from a single-mode fiber, while the light output power was obtained by a calibrated photodiode. Figure 3 shows a wavelength map for the DBR/ring laser by sweeping the heater powers of the DBR and ring sections, while keeping the heater power of the phase section as zero. We confirm that the lasing wavelength is well tuned by adjusting reflective peaks of the DBR and the ring.

Furthermore, the wavelength dependence of the chip output power was evaluated with different heater powers taken at zero phase tuning as shown in Fig. 4. The lasing wavelength covers a tuning range of more than 40 nm. Output power within the wavelength range shows a uniformity of 17.5±0.5 dBm.

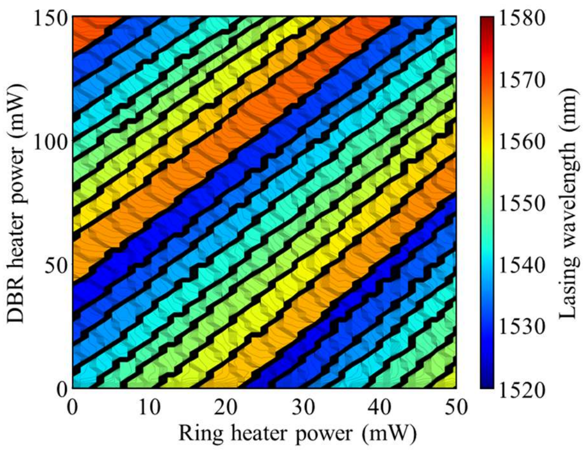

Fig. 3. A wavelength map as a function of DBR and ring heater powers taken at zero phase tuning.

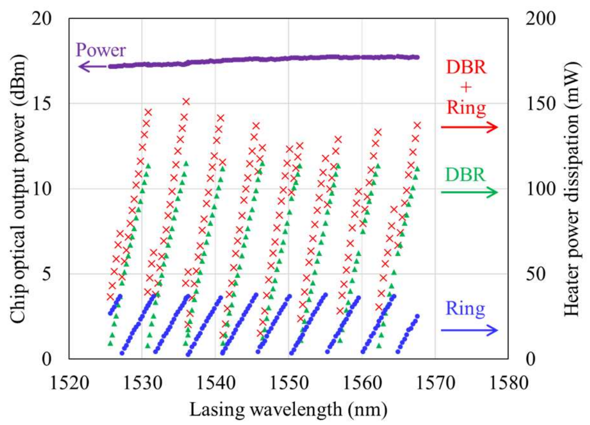

Fig. 4. Chip output powers (purple dots) and heater powers for DBR (green triangles) and ring (blue dots) mirrors across the tuning range. Red crosses correspond to the sum of the DBR and ring heater powers.

In Fig. 4, we plot the wavelength dependence of the heater powers. The wavelength is linearly redshifted as increasing the ring heater powers. This is because temperature increase at the heater causes the effective lengths of the DBR and the ring to be long linearly, resulting in redshifts on the resonant wavelength. From the interval between selected lasing wavelengths at a fixed heater power, 665 GHz FSR for the DBR and 591 GHz FSR for the ring are extracted.

We are also able to determine the heater power dissipation for one FSR tuning, and the values were 104 mW at the DBR and 34 mW at the ring. Assuming that the temperature coefficient of the wavelength shift is 0.1 nm/K, the thermal resistances at the DBR and the ring are 510 K/W and 1390 K/W, respectively.

Since high-mesa waveguides are used for the thermal tuning sections, the thermal resistances are larger compared to BH waveguides. In particular, efficient thermal tuning at the ring is demonstrated because the waveguide length is significantly shorter than that of the DBR. Therefore, the sum of the DBR and ring heater powers is well suppressed below 200 mW for covering the entire C-band.

4. Conclusions

We have developed, for the first time, an InP-based monolithic tunable laser with thermally tuned ring resonator for coherent applications. A wavelength map measurement confirms that the lasing wavelength is easily selected by controlling the heater powers of the DBR and the ring. Maximum power consumption at the ring heater is less than 40 mW for one FSR tuning. Our results demonstrate that the laser is suitable for applications into small digital coherent transceivers.

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References

[1] J. Buus, *et al.*, “Tunable laser diodes and related optical sources,” 2nd ed. Piscataway, NJ, USA: Wiley-IEEE, 2005.
[2] T. Kimoto, *et al.*, OptoEletron. Commun. Conf./ Photon. Switching, Kyoto, Japan, 2013, Paper MK2-6.
[3] G. Kobayashi, *et al.*, Optical Fiber Conf., 2014, Tu2H.2.
[4] T. Suzuki, *et al.*, Int. Semicond. Laser Conf., Kobe, 2016, TuC3.
[5] M. Nishita, *et al.*, Optical Fiber Conf., 2020, M2A.6.
[6] T. Segawa, *et al.*, IEEE J. Quantum Electron., vol. 45, No. 7, pp. 892-899, 2009.
[7] H. Ishii, *et al.*, IEEE J. Quantum Electron., vol. 32, no. 3, pp. 433-441, Mar. 1996.
[8] M. C. Larson, Int. Semicond. Laser Conf., Kobe, 2016, TuC2.
[9] Y. Matsui, *et al.*, Compound Semicond. Week, Toyama, 2016, MoC4-1.