Narrow-linewidth widely tunable hybrid external cavity laser using Si_3N_4/SiO_2 microring resonators

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***Abstract*—We report on the characteristics of a tunable hybrid external cavity laser using silicon nitride microring resonators. A wavelength tuning range covering from 1530nm to 1580nm is demonstrated with a side mode suppression ratio larger than 45dB. Typical linewidth values are 65kHz.**

***Keywords*—Tunable Laser, External Cavity Laser, Silicon Nitride.**

I. Introduction

Widely wavelength tunable lasers have found widespread applications in many fields, such as atomic clocks, interferometric sensors and coherent optical communications [1]-[3]. For use in coherent optical communications as transmitters and local oscillators, high output power and narrow linewidth characteristics are typical requirements. To date, several types of tunable laser have been demonstrated, such as distributed feedback (DFB) lasers [4], distributed Bragg reflector (DBR) lasers [5] and microring resonator based external cavity lasers (MRR-ECL) [6]-[9]. Typical linewidth values of DFB and DBR type lasers are a few MHz due to their short cavity lengths. On the other hand, MRR-ECL can provide narrow linewidth owing to its long passive cavity provided mainly by low-loss and high Q-factor microring resonators. In [6], a narrow linewidth laser is presented, however, utilizing triple-ring resonators to obtain stable single mode operation. In [8], Kobayashi et al. reported a silicon photonic hybrid external cavity laser based on microring resonators. To obtain low-loss silicon wire-waveguides, special attention has to be paid to the design and fabrication processes. In [9]-[11], based on the TriPleX™ platform, some of us have fabricated low-loss box-shape silicon nitride (Si_3N_4/SiO_2) waveguide microring resonators and reported tunable MRR-ECLs covering the whole C-band.

In this paper, we present a narrow linewidth widely tunable MRR-ECL based on the TriPleX™ double-stripe Si_3N_4/SiO_2 waveguide platform [12]. Owing to the advantage of low propagation loss (<0.1 dB/cm) of passive double-stripe Si_3N_4/SiO_2 waveguide, this laser exhibits a wavelength tuning range of approximately 50nm and output power of 16mW, which are improvements compared to [9]-[11]. Also a high side mode suppression ratio (SMSR) of larger than 45dB and a typical narrow linewidth value of 65kHz are obtained, which are comparable to [9]-[11].

II. Waveguide Design

Fig. 1 shows a schematic diagram of the designed MRR-ECL. It consists of a high power InP/InGaAsP semiconductor optical amplifier (SOA) gain chip provided by the Fraunhofer Heinrich Hertz Institute in Berlin (HHI), two microring resonators, one phase section and one power tuning section. Front and back facets of the SOA are high- and anti-reflection coated, respectively. Two MRRs with slightly different radii are used here to increase the wavelength tuning range by using the Vernier effect. Phase and power tuning sections are used for finely tuning the longitudinal mode and output power, respectively.

Fig. 2 illustrates the cross-section of the double-stripe Si_3N_4/SiO_2 waveguide of two MRRs. Two 170nm-thick Si_3N_4 layers are surrounded by outside SiO_2 cladding. The thickness of SiO_2 layer between two Si_3N_4 layers is 0.5μm. The buried Si_3N_4 width is 1.2μm. To achieve a low-loss coupling between gain chip and passive waveguide, the width and thickness of Si_3N_4 layers are tapered to 4.3μm and 35nm, respectively. Details of the waveguide structures can be found in [12] and [13].

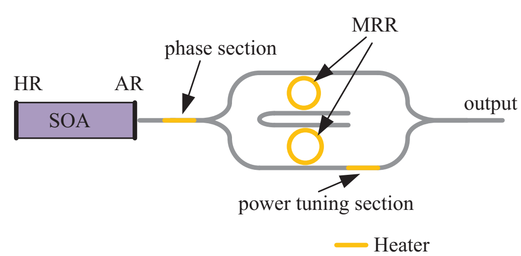

Fig. 1 Schematic diagram of the MRR-ECL.

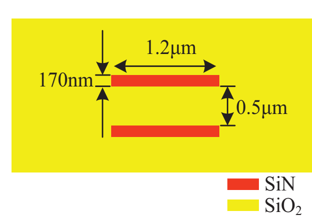

Fig. 2 Schematic cross-section of the double-stripe waveguide geometry.

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The gain chip has a 3dB gain bandwidth of about 30nm-35nm. To achieve a wide wavelength tuning range with high SMSR, free spectral ranges (FSRs) of the two rings are designed to be approximately 1.63nm and 1.58nm, respectively. The corresponding circumferences of the two rings are 857.4µm and 885.1µm, respectively. This leads to a theoretical wavelength tuning range of around 50.4nm.

III. Device Characteristics

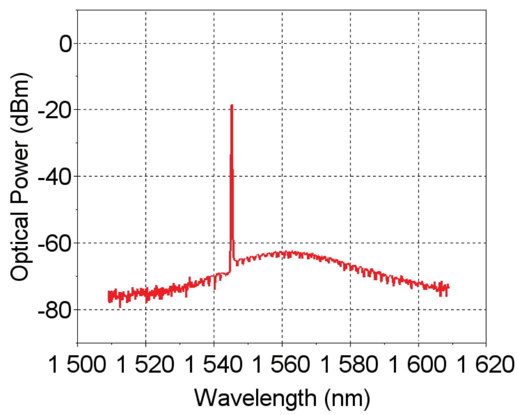

Fig. 3 Laser spectrum.

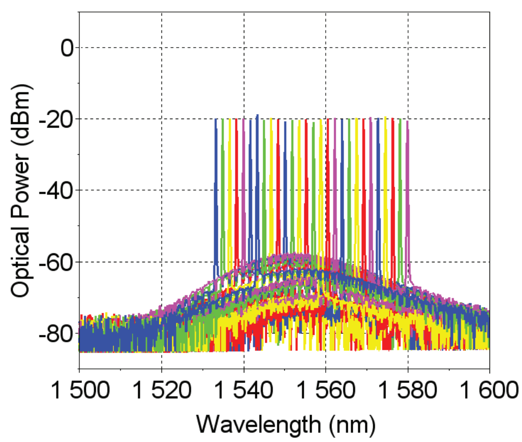

Fig. 4 Superimposed laser spectra.

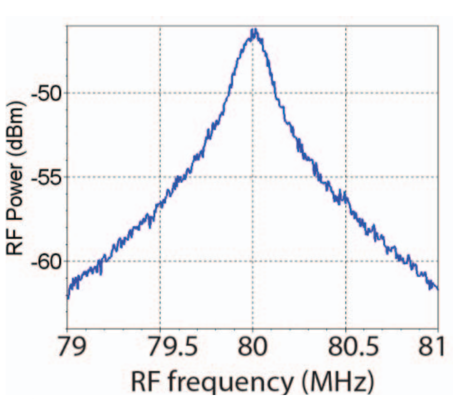

Fig. 5 Self-delayed heterodyne RF-beat spectrum indicating a laser linewidth of 65kHz.

Fig. 3 shows a spectrum of the laser. It is clear that good single mode characteristic is obtained with a SMSR larger than 45dB. The SOA is biased at 500mA and the corresponding laser output power is about 16mW. By varying the voltage applied on the heater electrode on one of the two rings, mode hops occur. Fig. 4 shows an example of the superimposed spectra of the laser tuned to 28 approximately equidistant wavelengths. To achieve a full (2π) tuning of the microrings, a maximum voltage of 14V was applied to the heater.

To measure the spectral linewidth, we used a self-delayed heterodyne interferometer structure [9] with a fiber delay line of ~20km. The measured power spectrum of the RF-beat signal is shown in Fig. 5. The 3dB RF-bandwidth is about 130kHz, which corresponds to a typical 65kHz laser linewidth. A best linewidth value of 35kHz is obtained for this laser.

IV. Conclusion

Based on the double-stripe Si_3N_4/SiO_2 waveguide, low-loss and high Q-factor microring resonators are fabricated and a widely wavelength tunable hybrid InP/SiN external cavity laser is demonstrated. The laser exhibits a wide wavelength tuning rage of around 50nm and has a typical narrow linewidth of 65kHz, which is promising for use in coherent transmission systems.

References

[1] Y. Y. Jiang et al., “Making optical atomic clocks more stable with 10^{-16}-level laser stabilization,” *Nat. Photon.*,vol. 5, pp. 158-161, Jan. 2011.

[2] J. Buss et al., *Tunable Laser Diodes and Related Optical Sources*. Hoboken, NJ, USA: Wiley, 2005.

[3] L. A. Coldren et al., “Single-chip integrated transmitters and receivers,” *Opt. Exp*., vol. 20, no. 26, pp. B377-B385, Dec. 2012.

[4] H. Ishii et al., “Spectral linewidth reduction in widely wavelength tunable DFB laser array,” *IEEE J. Sel. Topics Quantum Electron*., vol. 15, no. 3, pp. 514-520, May/Jun. 2009.

[5] V. Jayaraman et al., “Theory, design, and performance of extended tuning range semiconductor lasers with sampled gratings,” *IEEE J. Quantum Electron*., vol. 29, no. 6, pp. 1824-1834, Jun. 1993.

[6] M. Takahashi et al., “Tunable lasers based on silica waveguide ring resonators,”*Proc. OFC*, OWJ1, 2007.

[7] T. Kita et al., “Compact silicon photonic wavelength-tunable laser diode with ultra-wide wavelength tuning range,”*App. Phy. Lett.,* vol. 106, 2015.

[8] N. Kobayashi et al., “Silicon photonic hybrid ring-filter external cavity wavelength tunable lasers,” *IEEE J. Light. Technol.*, vol. 33, no. 6, pp. 1241-1246, 2015.

[9] R. M. Oldenbeuving et al., “25kHz narrow spectral bandwidth of a wavelength tunable diode laser with a short waveguide-based external cavity,” *LaserPhys. Lett.,* vol. 10, no. 1, pp. 015804-015812, Dec. 2012.

[10] Y. Fan et al., “A semiconductor-glass waveguide laser,” *Proc. SPIE* 9135, 91351B (2012).

[11] Y. Fan et al., “Q-factor measurements through injection locking of a semiconductor-glass hybrid laser with unknown intracavity loss,” *Opt. Lett.,* vol. 39, no. 7, pp. 1748-1751, Apr. 2014.

[12] F. Morichetti et al., “Box-shaped dielectric waveguides: a new concept in integrated optics?,” *IEEE J. Light. Technol.*, vol. 25, no. 9, pp. 2579-2589, 2007.

[13] K. Wörhoff et al., “TriPleX: a versatile dielectric photonic platform,” *Adv. Opt. Technol.*, vol. 4, no. 2, pp. 189-207, 2015.