Compact Tunable DBR/Ring Laser Module Integrated with Extremely-high-Δ PLC Wavelength Locker

Masayoshi Nishita[1], Yasutaka Higa[1], Noritaka Matsubara[1], Junichi Hasegawa[1], Kazuki Yamaoka[1], Maiko Ariga[1], Yusuke Inaba[1], Masayoshi Kimura[1], Masaki Wakaba[1], Masahiro Yoshida[1], Kazuomi Maruyama[1], Shunsuke Okuyama[1], Toshihito Suzuki[1], Hiroyuki Ishii[1], Vitaly Mikhailov[2], Richard Sefel[3], and Yasumasa Kawakita[1]

[1]Telecommunications & Energy Laboratories, Furukawa Electric Corporation, 6 Yawata-kaigandori, Ichihara, Chiba 290-8555, Japan
[2]OFS Laboratories, 19 Schoolhouse Rd, Somerset, New-Jersey 08873, USA
[3]FETI, 28A Kesmark u., Budapest H-1158, Hungary
masayoshi.nishita@furukawaelectric.com

Abstract: A compact tunable laser module integrating a newly developed DBR/Ring laser and an extremely-high-Δ PLC wavelength locker is demonstrated with narrow spectral linewidth of <100 kHz across the full C-band.
OCIS codes: (130.3120) Integrated optics devices; (140.3600) Lasers, tunable

1. Introduction

Wavelength tunable laser is a key device as a light source for high-capacity optical communications systems using wavelength division multiplexing [1]. Digital coherent technology has been introduced into a long-distance system to accommodate the demand on capacity increase. Digital coherent technology is also expanded into the short reach applications such as metro area network and the inter-datacenter communications. In such applications, both compact and low power consumption are required for optical transceivers. Therefore, miniaturization of light sources is also expected at the same time.

We have developed a distributed feedback (DFB) laser array and a distributed reflector (DR) laser array as a narrow linewidth tunable laser [2-4], and narrow linewidth operations less than 100 kHz have been obtained in the full C-band tuning range. However, miniaturization of a module was limited because a wavelength locker based on spatial optical subsystem using bulk optical elements was used. In this work, we developed a smaller wavelength tunable laser module with introducing two new elements. One is the wavelength tunable DBR/Ring laser, which is the monolithically integrated device on InP substrate. The other is newly designed wavelength locker using extremely-high-Δ planar lightwave circuit (PLC) technology. By using the PLC instead of the spatial optical subsystem, very compact tunable laser module can be obtained. We demonstrate narrow linewidth of <100 kHz in full C-band with the laser module.

2. Design

2.1. Tunable Laser Chip

The schematic structure of the newly developed laser chip is shown in Fig. 1. The laser chip has two different types of wavelength-selective reflectors besides the gain section. An SOA is integrated at the output port to boost and to control the output power. The rear side reflector consist of a ring resonator and a 1x2 MMI coupler. And, the front side reflector is distribute Bragg reflector (DBR). Local micro heating elements are formed on each reflectors to enable the wavelength spectra tunable arbitrary.

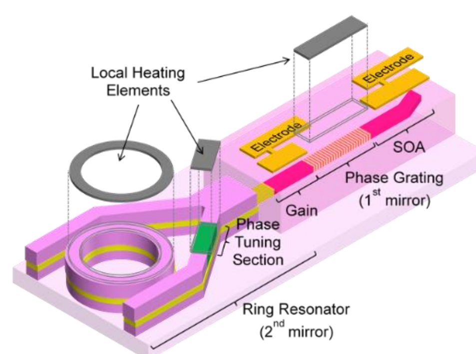


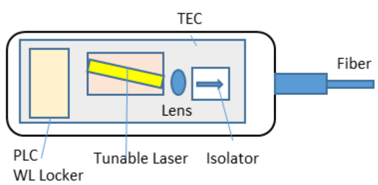
Fig. 1. Schematic structure of DBR/Ring laser

The ring reflector causes the periodic reflective comb determined by length of the ring waveguide. Due to the relatively small size of the ring reflector, the electric power of the heater for tuning is small [5]. On the other hand, the DBR also has multiple reflective peaks, because the phase of DBR is modulated periodically, such as the super-structure grating (SSG) [6]. Its phase modulation function is optimized numerically, and 8 equal reflective peaks are generated in the C-band. The wavelength tuning range can be designed at desired range because the number of peaks is limited. The wavelength tuning range is expanded based on principle of the Vernier scale such as S(S)G-DBR-LDs [5-8]. This DBR/Ring laser chip is monolithically integrated on the InP substrate, and the sizes is 3 mm x 0.35 mm. The optical tap circuit is inserted between the DBR and the SOA, and a part of the laser output light is led to the rear monitor port. This rear monitor port is used for a wavelength locker.

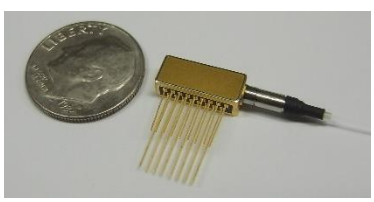
2.2. Laser Module with PLC Wavelength Locker

The schematic diagram of the laser module structure together with a photograph is indicated in Fig 2. The size of the module is 12mm(L) x 5mm(W) x 3.6mm(H). It consists of a DBR/Ring laser chip, a thermo-electric-cooler, a beam splitter, an isolator, lenses, photo-diodes (PD) and a PLC wavelength locker. The extremely-high-Δ PLC we have developed so far [9] was used for a wavelength locker instead of spatial optical subsystem including a bulk etalon filter in order to reduce the module size. This PLC consists of SiO_2-ZrO_2 core. The refractive index difference (Δ) is about 5% and it enables us to make a wavelength locker as small as 1.7 mm x 2.5 mm. A laser rear output from the monitor port is led to PLC and the PLC outputs are monitored by PDs.

Figure 3 shows a light circuit diagram of the PLC wavelength locker. After the input light is divided into 3 waveguides, the one is led to power monitor output and the others are led to ring resonators. The length of the ring resonator is 2565.0 um and 2565.3 um respectively, and those resonant frequencies are different from only 20 GHz. Figure 4 shows output characteristic of the PLC. It is possible to specify the oscillating frequency of the laser from the optical output received in PD because the optical output intensities are dependent on optical frequency of input light. The laser wavelength can be locked at arbitrary wavelength by selecting the appropriate ring resonator.



(a)



(b)

Fig. 2. (a) Schematic structure and (b) photograph of module

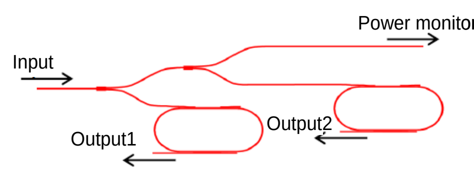


Fig. 3. Optical circuit diagram

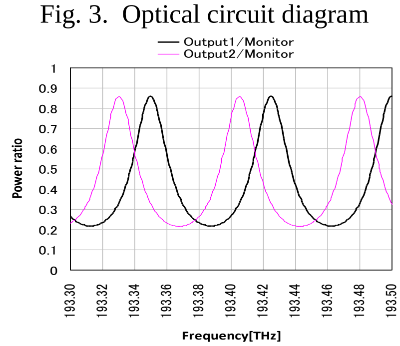


Fig. 4. Transmitting characteristics

3. Performance

An example of the lasing spectra of the fabricated module is shown in Fig. 5. A tuning range of more than 41 nm was achieved for this device. The fiber optical output of 17dBm was obtained in entire C-band by adjusting the current of SOA. The maximum power dissipation for heaters necessary to cover C-band fully is 220 mW. Figure 6 shows the spectral linewidth. The frequency noise spectrum was measured using a coherent receiver, and the linewidth was calculated from the white noise component of the measured noise spectrum. Narrow spectral linewidths lower than 100 kHz were obtained at all measured channels.

Figure 7 shows the lasing frequency accuracy when the wavelength was stabilized using a wavelength locker. The accuracy was within +/- 0.5 GHz when the case temperature was changed from -5 ℃ to 80 ℃. Thus, the wavelength was well stabilized using a PLC wavelength locker.

Figure 8 shows constellation diagrams obtained using the laser module. The total bit rate was set to 400 Gbit/s while the baud rate for QAM-16, -32, -64 were 66.5, 55.3 and 44.4 Gbaud, respectively. The results have been achieved using real-time digital signal processing with same complexity transmitter and receiver equalizers for all three modulation formats. On the diagrams at the top-row the laser module was used as a signal carrier while other commercial external cavity laser was used as a local oscillator, while on the diagrams at the bottom row it was used as a local oscillator while another laser has been used as a signal. The presented results demonstrate that the laser module can be successfully used as both signal and local oscillator laser at 400 Gbit/s modules.

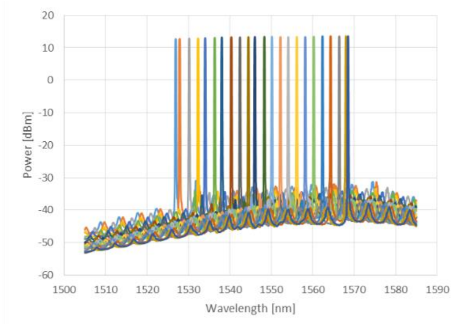


Fig. 5. Lasing spectra

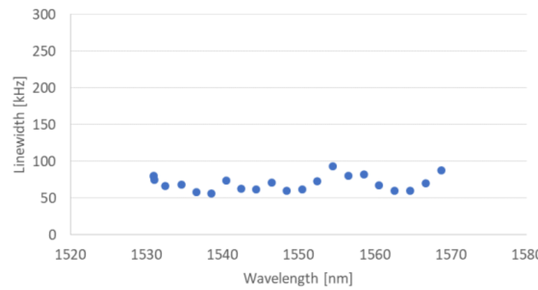


Fig. 6. Linewidth characteristics

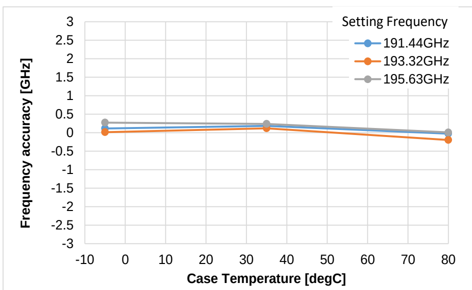


Fig. 7. Wavelength locking characteristics

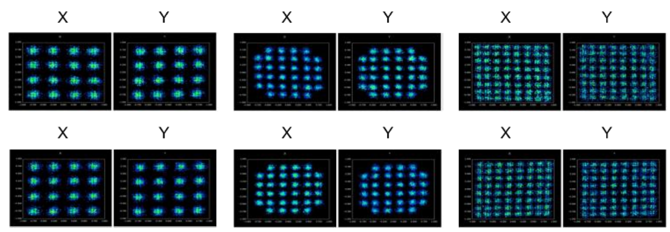


Fig. 8. Constellation diagrams

4. Summary

A compact tunable laser module, that size is 12mm x 5mm x 3.6mm, was demonstrated. The module has newly developed DBR/Ring monolithic laser chip and an extremely-high-Δ PLC wavelength locker. The laser module covers a full C-band with narrow linewidth less than 100 kHz, and fiber output power of 17dBm. This compact laser module is useful as a light source for small digital coherent transceivers.

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