Extended Abstracts of the 2017 International Conference on Solid State Devices and Materials, Sendai, 2017, pp415-416

H-7-02

1.7 μm Wavelength Tunable Laser Diode Using Silicon External Cavity

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Abstract

Wavelength tunable laser diode with silicon external cavity for 1.7 μm wavelength range was presented. The widely wavelength tuning with 104 nm wavelength range was demonstrated by the optimizing of the wavelength filter.

1. Introduction

Wavelength tunable laser diodes (LDs) are indispensable for wavelength division multiplexing (WDM) transmission system. In addition, wavelength tunable LDs operating at longer wavelength than 1.55 μm are promising as a light source for gas sensing and free space optics (FSO) system [1], therefore a compact and inexpensive wavelength tunable LDs are required. The wavelength tunable LDs constructed with a Si-wire waveguide ring resonator wavelength filter and a semiconductor optical amplifier (SOA) can be realized in compact size and be operated with low power consumption, because they have a sharp bend and high thermo-optic (TO) effect [2]. Here we present the results of wavelength tuning around 1.7 μm by optimizing structure of ring resonators.

2. Structure of Wavelength Tunable LD and Gain Spectrum in 1.7 μm SOA

Figure 1 shows the schematic structure of our wavelength tunable LD. The LD consists of an InGaAsP multi quantum-well (MQW) 1.7 μm SOA and a tunable filter with Si-wire waveguide (size of 500 × 220 nm) ring resonators. Although transmission characteristics of the ring resonator periodically change for wavelength, a single wavelength output is realized over wide wavelength range on the basis of the Vernier effect [3] by the free spectral ranges (FSRs) difference of the two ring resonators. The lasing wavelength can be controlled by electric heating the Ta thin film heater placed on each ring resonator because of changing the refractive index by the thermo-optic effect of Si. The important parameters of the tunable filter include a transmittance difference related to the stability of single-mode lasing and a wavelength tunable range that determines the bandwidth capable of single-mode lasing. These characteristics depend on parameters such as FSRs of ring resonators, coupling efficiency of the Si bus-waveguide and the ring resonator. As the coupling efficiency becomes smaller,

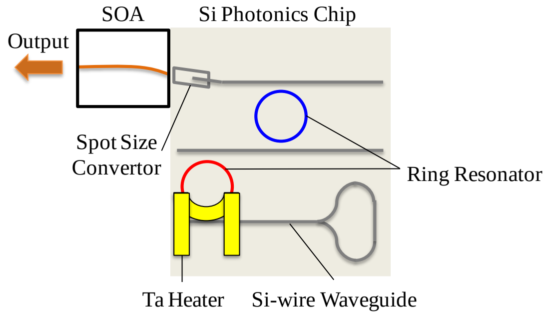

Fig. 1 Schematic structure of wavelength tunable LD.

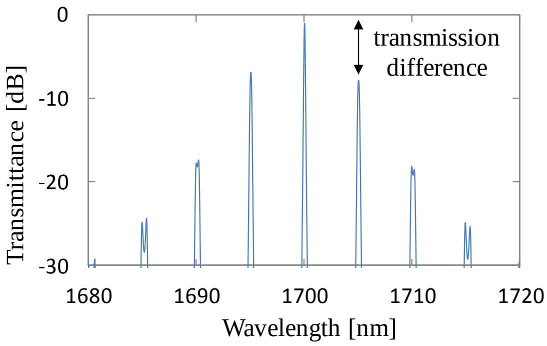

Fig. 2 Calculated Transmission spectrum of the designed wavelength filter.

the transmittance difference can be made larger, therefore it is possible to construct a filter with high wavelength selectivity, however on the other hand transmittance of the lasing wavelength decreases. Thus, it is necessary to design so that the transmittance difference can be made large while maintaining a high transmittance. The transmission spectrum of the wavelength filter designed in this research is shown in Fig. 2. The coupling efficiency was set to 0.15 at 1700 nm wavelength and the FSRs were set to 524 GHz and 507 GHz, respectively. Approximately 150 nm wavelength tuning range and 7 dB transmittance difference were obtained.

In evaluating the operating characteristics of the tunable lasers, we estimated the optical gain spectrum in the SOA by Hakki - Paoli method [4]. Figure 3 shows the gain spectrum of the 1.7 μm SOA and the calculation result of the filter loss. It was confirmed that the gain was the largest around 1.7 μm. Moreover, since the gain must exceed the cavity loss in order to

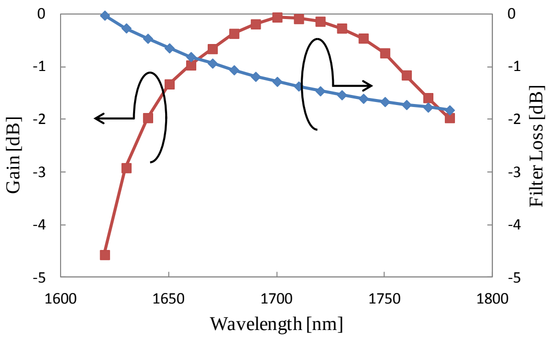

Fig. 3 Normalized gain spectrum of the 1.7 μm SOA and filter loss.

cause laser oscillation, when this filter is used as an external resonator of a laser, it was considered that the lasing appeared in the range of approximately 1670 ~ 1770 nm.

3. Laser Characterization

The 1.7 μm SOA and the tunable filter were coupled and the laser characterization was evaluated by using an optical spectrum analyzer (OSA, Yokogawa AQ6375). Figure 4 shows the relationship between SOA injection current and fiber-coupled power. An output power was 0.6 mW when the SOA current was 100 mA and threshold current was 41.5 mA. Figure 5 shows the superimposed optical spectra for different lasing wavelengths measured with the SOA current of 180 mA. Single mode laser oscillation was observed in either current, and a wavelength tunable range over 100 nm was obtained. The relationship between the power consumption of the heater and the lasing wavelength is shown in the Fig. 6. Since the oscillation wavelength varies substantially linearly with respect to the power consumption of the heater, it can be seen that the wavelength tuning operation can be performed correctly. The efficiency of wavelength tuning operation by the heater was approximately 0.73 mW/nm. Moreover, the wavelength tuning operation was obtained at 1675 ~ 1779 nm which almost coincided with the operation range estimated from Fig. 3, therefore the tunable LD with Si external cavity for 1.7 μm wavelength range have been successfully demonstrated.

4. Conclusion

The wavelength tunable LD for longer wavelength range constructed with Si-wire waveguide ring resonator tunable filter and the SOA was proposed. Widely wavelength tuning over 100 nm wavelength range around 1.7 μm was achieved by the optimizing structure of the ring resonators. The maximum output power and wavelength tuning range will be improved by the reduction of coupling loss between the SOA and the silicon photonic external cavity. Our tunable LD for longer wavelength will be effective light source for optical communication or sensing.

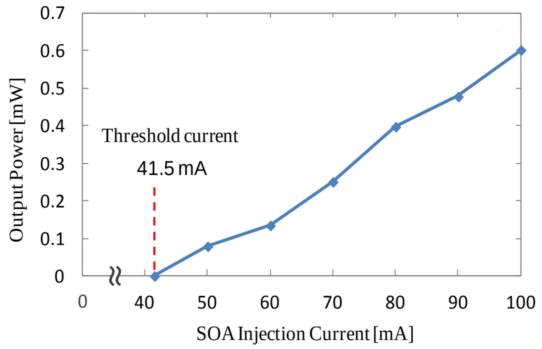

Fig. 4 Relationship between SOA injection current.

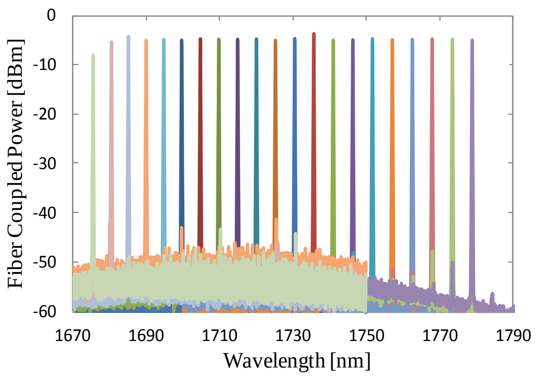

Fig. 5 Superimposed optical spectra for different lasing wavelengths.

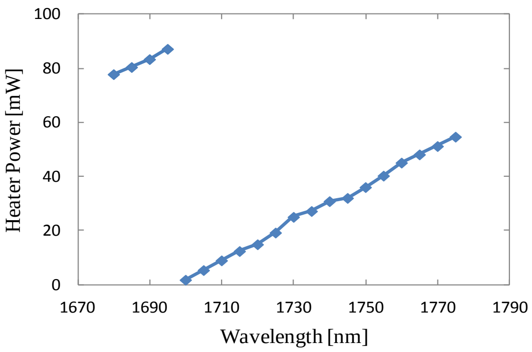

Fig. 6 The relationship between the power consumption of the heater and the lasing wavelength.

Acknowledgements

This research was partly supported by the R&D project on carrier-conversion technology with high environmental tolerance, National Institute of Information and Communication Technology, Japan.

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