Single Wavelength Laser TO-CAN Integrated with One-Chip Wavelength Locker

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Abstract: A φ5.6-mm TO-CAN packaged light source module integrated with a Si photonics-based wavelength locker chip has been fabricated with a frequency shift of less than ±1.1 GHz, small enough to achieve wavelength locking operation with a compact TO-CAN package for short-reach coherent communication. © 2024 The Author(s)

1. Introduction

Over the past few years, the network traffic handled by data centers has dramatically increased due to the proliferation of smart devices and machine learning application. To meet the demand for increased transmission capacity, the communication schemes for 800Gb/s and 1.6Tb/s have been actively discussed [1,2]. Although the IMDD method is mainly adopted for short-range communications, the transmission distance has been limited as communication capacity increases, estimated to have an upper limit of around 10 km in the 800 Gb/s generation [3-5]. As an alternative, digital coherent communication, which performs in long-distance communication, is being considered for use in shorter distances. However, since it has been used for high-quality communications the cost and power consumption are sub-optimal compared to IMDD. In recent years, simpler coherent methods have been proposed, such as the use of zero-dispersion wavelengths and polarization dividing functions in the optical domain, but further improvement is still essential when it comes to practical situations [6,7].

Introducing another approach, this paper focuses on the development of a light source module that is applicable for the short-reach coherent communication. So far, these kinds of light source modules have been required to have a wide wavelength tunability within the entire C-band spectrum. However, since a peer-to-peer system called gray link is applied, unlike long-haul applications, the requirement for light sources is only to match the wavelengths of both the transmitter and receiver. In other words, the requirement can be satisfied when the source emits light with a single wavelength and capable of fine wavelength tuning for synchronization. A single wavelength light source module could be realized with a laser chip and a wavelength locker. A DFB laser could be considered suitable for the simplest light source, should cost reduction be considered, while a conventional etalon-based wavelength locker has a highly complex configuration [8,9]. Although there has been a report of waveguide-integrated filters using a PLC which allows size reduction [10], additional lens and PDs are required and room for assembling simplicity and footprint suppression has been considered.

In order to realize a smaller form factor light source module and a simpler wavelength locker, we had proposed a Si photonics-based wavelength locker, with characteristic performance shown in [11,12], but the wavelength locking function still needs to be evaluated. In this paper, a fabricated TO-CAN module packaging with a DFB laser and our compact wavelength locker chip has been presented and measurement results of the wavelength stability of the DFB laser by using the wavelength locker has been reported.

2. Fabricated TO-CAN

Fig. 1 shows the fabricated TO-CAN package. This module has a diameter of 5.6 mm and a height of 8 mm, whose size is the smallest category among the widely distributed light source modules for digital coherent communication. The output light is emitted from the lens cap, and the electrical signal is exchanged through the pins of the TO header.

Fig. 2 shows the schematic diagram of a laser chip together with the proposed wavelength locker chip integrated into the package. To simplify the module configuration, the DFB laser was selected as the single wavelength light source. The Si photonics chip behaves as a wavelength locker, which consists of a grating coupler, a power divider, a ring resonator filter, and two PDs for power monitor (output current: I_{p}) and wavelength monitor (output current: I_{λ}). The front light of the DFB laser is emitted from the lens of the TO-CAN package, coupled to a fiber, while the rear light goes to the Si photonics chip. As the light is connected to the grating coupler without any lenses, the assembling procedure was finished with a single bonding step, allowing a compact and simple configuration. Both

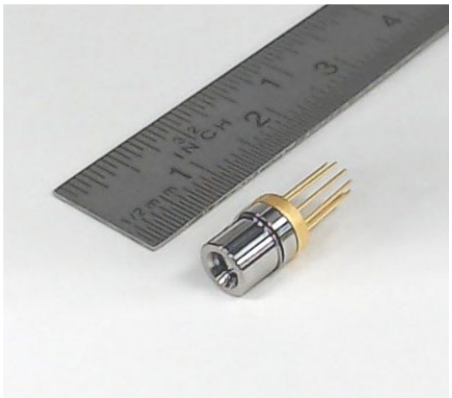

Fig. 1. Fabricated TO-CAN.

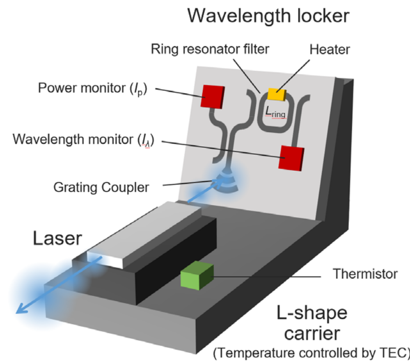

Fig. 2. Schematic diagram of wavelength locker configuration

the laser and the wavelength locker chip were mounted on an L-shaped carrier. To enhance the coupling efficiency between the laser and the grating coupler and to reduce the back reflection to the laser, the two chips were mounted at a 10° angle. Although we packaged a DFB laser and a wavelength locker chip for the O-band this time, it is also possible to operate in other bands like C-band or L-band by replacing both chips with the corresponding frequency characteristics.

3. Output from wavelength locker

It is necessary to have precise wavelength control in coherent communication applications. Since the DFB laser was adopted as the light source, temperature control is also needed to tune the lasing wavelength. However, as both the laser and the Si photonics chip are mounted on the identical L-shape carrier, as shown in Fig. 2, the two chips' temperatures vary simultaneously. A fixed filter characteristic is generally used to estimate lasing wavelength change, but the filter spectrum also shifts with the lasing wavelength change in this configuration. Then, the wavelength estimation method in [11,12] was applied to this module. Before evaluating the wavelength stability, the outputs of the wavelength locker chip were measured. Fig. 3 shows a block diagram of the measurement setup. The TO-CAN was electrically controlled by a current source together with a TEC controller to drive the laser, and to change the laser temperature, respectively. Additionally, the photocurrents from the integrated PDs were monitored by current monitors. Fig. 4 shows the result of laser outputs and the wavelength locker chip packaged in the module, where the lasing wavelength was swept by varying the temperature of the TEC from 40 to 75 °C, and the power monitor current I_p and wavelength monitor current I_λ were plotted, respectively. The graph shows that a lasing wavelength from 1270.0 to 1272.5 nm was observed. Also, I_p has a small wavelength dependence as a power monitor, and I_λ has the characteristics of a ring resonator filter but has a wider FRS than on a fixed temperature condition. This feature comes from the synchronized temperature control of the laser and Si photonics chip, which is the expected result as described in [11,12]. By using these wavelength characteristics, wavelength locking operation was conducted and wavelength stability was discussed in the following section. A locking wavelength was set to 1272.1 nm because the filter slope is the largest around the wavelength.

4. Wavelength locking operation

The wavelength stability was evaluated using the integrated wavelength locker chip in the TO-CAN package. To confirm its performance, the measurement system shown in Fig. 3 was used. The wavelength stability was validated using two different methods: (a) thermistor control and (b) wavelength locker control. In (a), the temperature was observed using a thermistor mounted on the carrier, and the TEC current was varied so that the temperature remained constant. In (b), a normalized output I_λ/I_p of the wavelength locker is kept constant by changing the injection current to the TEC. In this evaluation, the target value of I_λ/I_p was set to 0.4.

Fig. 5 shows the evaluated results of wavelength stability with the condition that the case temperature is varied from 20 to 70 °C. The black plot shows the measurement results of the thermistor control, and the red plot shows the results of the proposed wavelength locker control. The measurement results show that both have almost linear characteristics. The thermistor-controlled case exhibits a dependence of 0.18 GHz/K, while the wavelength locker has that of -0.03 GHz/K. As a result of monitoring the output of the wavelength locker, the temperature dependence becomes six times smaller than that of the thermistor control condition. When considering the case temperature range from -5 to 75 °C, while the frequency shift is estimated to be within ±7.1 GHz with the thermistor control, a

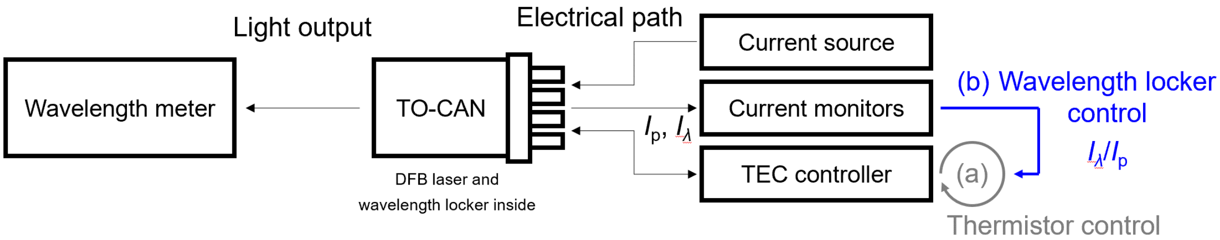

Fig. 3. Measurement setup, (a) thermistor control, (b) wavelength locker control.

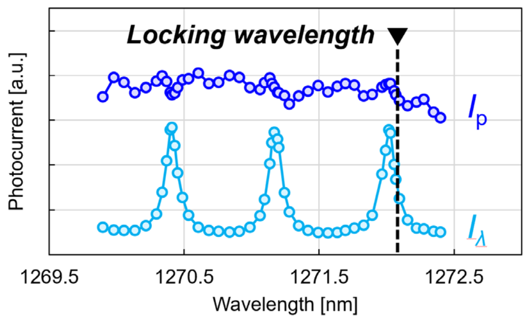

Fig. 4. Measured characteristics of wavelength locker.

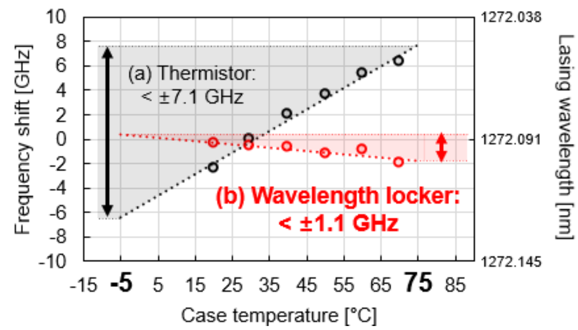

Fig. 5. Comparison of frequency stability

±1.1 GHz variation was obtained by the wavelength locker control. This number is less than the standardized value of ±1.25 GHz in OIF-ITLA-MSA-01.3, which infers that the fabricated device has good wavelength stability and has the potential to be applied to digital coherent communication. Based on the result, the proposed TO-CAN encased, one-chip wavelength locker together with a DFB laser has been successfully fabricated, which could be one of the promising devices for future short-reach coherent communication systems.

5. Conclusion

A single wavelength φ5.6mm TO-CAN module integrated with Si-photonics based wavelength locker and measurement results of its frequency stability has been reported, wherein a Si chip and laser chip were mounted on an L-shape carrier and were optically coupled by a grating coupler. The measurement results of the module showed frequency stability of less than ±1.1 GHz, which is optimal for digital coherent communication, which could be used for constructing a compact laser source module for the digital coherent transceivers used in future data center networks.

6. References

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