High Optical Output Power and High-responsivity IC-TROSA for 800 Gbps applications

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Abstract *We developed an Integrated Coherent Transmit-Receive Optical Sub-Assembly (IC-TROSA) type-2 for 800 Gbps applications. The unmodulated optical output power of more than 6.0 dBm per polarization at maximum transmission condition and the minimum receiver responsivity for signal input of 60 mA/W at the center wavelength of 1550 nm are obtained by improving optical coupling efficiency between optical components. A 3-dB bandwidth of 57 GHz for modulator and 55 GHz for receiver are achieved.*

Introduction

Data traffic is expanding in line with the increase in social network services and video delivery services. To cope with this growth, digital coherent optical transmission technology which could drastically increase data capacity has been widely applied as a solution. These days, it is being deployed in not only long-haul and metro networks but also data center networks. Therefore higher-speed and smaller-sized devices will be required. Considering these demands, a small size coherent IC-TROSA type-2 module which integrates a modulator, a receiver and a tunable laser in a gold-box has been standardized by the OIF[1] in order to be incorporated in small optical tranceivers such as QSFP-DD[2].

In this paper, we present an IC-TROSA type-2 with high optical output power, high-responsivity and low power consumption for 800 Gbps applications such as 80 Gbaud polarization multiplexed (PM) 64 quadrature amplitude modulation (QAM) or 96 Gbaud PM-32QAM.

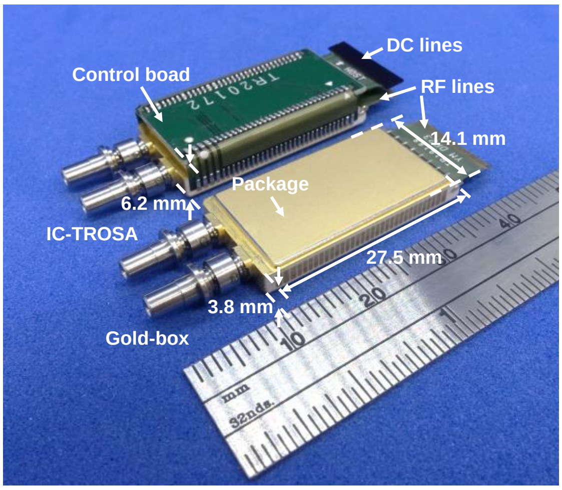

Fig. 1: Photograph of IC-TROSA and gold-box

Module structure

Figure 1 shows a photograph of the fully OIF implementation agreement compliant IC-TROSA type-2 we developed. The size of the gold-box is 14.1 mm x 27.5 mm x 3.8 mm, and this low-height package enables us to stack a control board on

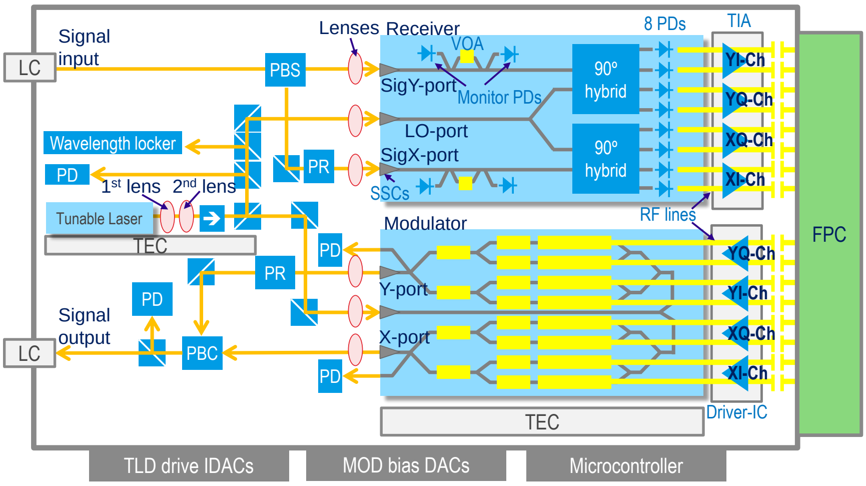

Fig. 2: Schematic diagram of optical couplings between optical components in gold-box

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top of the gold-box complying with the dimensions specified in OIF spec. The control board has functions of tunable laser control, modulator bias voltage control and coherent receiver control. Figure 2 shows a schematic diagram of the optical couplings between optical components in the gold-box. The IC-TROSA is composed of a newly developed InP-based modulator[3], an InP-based receiver[4] of 90° optical hybrid integrated PDs with variable optical attenuator (VOA) and monitor PDs for regulating input power, a high optical power tunable laser with semiconductor optical amplifier (SOA)[5], a quad transimpedance amplifier (TIA) and a quad Driver-IC. The thermal conditions of the modulator and the tunable laser, which has a wavelength locker mounted on the same substrate, are controlled individually by thermalelectric coolers (TECs).

Optical and Electrical design

Optical couplings inside the gold-box are constructed with micro optics as shown in Fig. 2. In order to realize high optical coupling efficiency, there are two main features for InP-based devices and micro optics. Spot-size converters (SSCs) are monolithically integrated into every optical input and output ports for both the receiver and the modulator for the purpose of making a circular mode field pattern with relatively large diameter. The other approach is usage of two lenses for collimating a beam from the tunable laser as shown in Fig. 2. The 2nd lens of which focal length is longer than that of the 1st lens acts as an alignment lens and contributes to broaden the tolerance of the fabrication process and improves the stability of optical coupling against temperature variation. From these approaches, we realized optical coupling loss of 2.0 dB from the tunable laser through an LC receptacle for signal output excluding the propagation loss of the modulator and the coupling loss of 1.4 dB between the tunable laser and the receiver.

We optimized the skews and impedances of the radio frequency (RF) lines considering connections between the TIA and the gold-box, the Driver-IC and the gold-box, the gold-box and a flexible printed circuit (FPC).

Optical characteristics

Figure 3 shows the wavelength dependence of the optical output power from the modulator and polarization dependence loss (PDL) with the laser current of 210 mA and the SOA current of 250 mA. The modulator was not modulated and Mach-Zehnder (MZ) biases of each MZ arms were set at maximum transmission condition. The total optical output power from the modulator was more than 9.2 dBm, and more than 6.0 dBm for both X-port (horizontal-polarization) and Y-port (vertical-polarization) were obtained without an extra optical amplifier after the modulator. In addition, the difference of optical output power between the X-port and Y-port, or PDL, was less than 0.3 dB. The optical output power with modulation was estimated to be more than -0.8 dBm when we assume a power back-off of 10 dB.

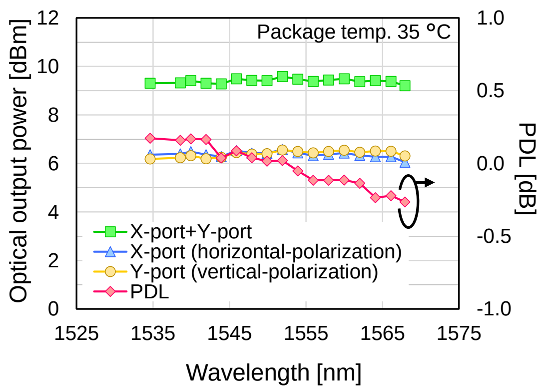

Fig. 3: Wavelength dependence of optical output power and PDL

The wavelength dependence of responsivities, with a PD bias voltage of 5 V and a TIA supply voltage of 3.3 V, for a signal input at three temperatures are shown in Fig. 4. The minimum responsivity of 60 mA/W was obtained at the wavelength of 1550 nm within the temperature range from -5 °C to 75 °C. The responsivities declined for longer wavelength and higher temperature, but it could be improved by optimizing the length of multi-mode interferometer (MMI) used as 90° optical hybrid in the receiver.

Frequency Response

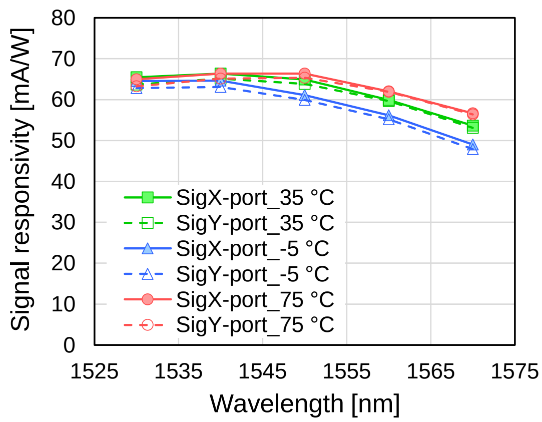

Fig. 4: Wavelength dependence of responsivities for SigX-port and SigY-port at 3-temperatures

We evaluated the electrical-to-optical (E/O) response of the modulator, and the measured results are shown in Fig. 5. A 3-dB bandwidth of

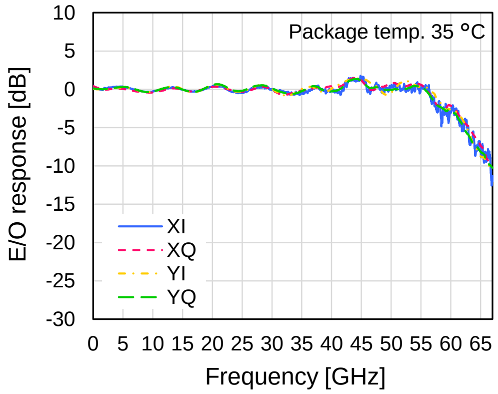

Fig. 5: E/O response for all channel

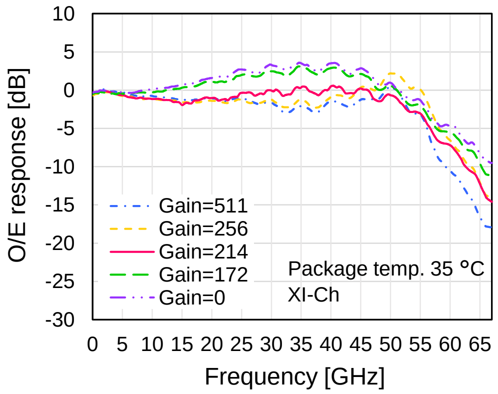

Fig. 6: Gain value dependence of O/E response

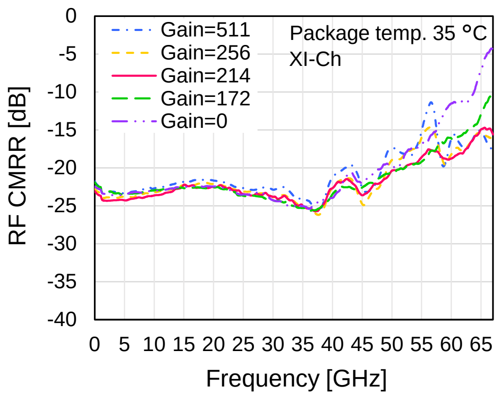

Fig. 7: Gain value dependence of RF CMRR

57 GHz and a flat frequency response over 50 GHz were obtained. The optical-to-electrical (O/E) response and an RF dependence of common mode rejection ratio (CMRR) were measured using the proposed method in the paper [6]. The measured O/E response for XI-channel as a function of TIA gain settings (from 0 to 511) are shown in Fig. 6. A 3-dB bandwidth of more than 55 GHz was obtained at a medium gain value (Gain = 214). Ripples that appeared in O/E responses were due to an impedance mismatch between the FPC and an RF test board used for the measurement. The RF CMRR for the XI-channel was less than -20 dB in a frequency range of up to 52 GHz as shown in Fig. 7.

These results show promise that our developed IC-TROSA has sufficient capability of transmitting and receiving modulated signals with a symbol rate over 96 Gbaud.

Conclusions

We developed an IC-TROSA type-2 composed of a newly developed InP-based modulator and a receiver with SSCs and low optical coupling loss micro optics. The unmodulated optical output power from the modulator was more than 6.0 dBm per polarization at maximum transmission condition, and the receiver responsivitiy for the signal input was more than 60 mA/W at the wavelength of 1550 nm within the temperature range from -5 °C to 75°C. We have also confirmed a 3-dB bandwidth of 57 GHz for the modulator and 55 GHz for the receiver resulting from optimization of skews and impedances of RF lines of the gold-box and the FPC. In addition, an operating power consumption for the gold-box of less than 5.2 W at a package temperature of 75 °C was obtained. We believe the developed IC-TROSA is suitable for 800 Gbps coherent transceivers with small form factors such as QSFP-DD.

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