

# Development of 10Gb/s TOSA/ROSA that Operates over Wide Temperature Range

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The authors have successfully developed new TOSA (transmitter optical sub-assembly) and ROSA (receiver optical sub-assembly) with a wide operating temperature range of -5 to 90 deg. C. These devices meet the requirements for XFP (10 Gigabit small form factor pluggable) modules for DWDM (dense wavelength division multiplexing) networks. The TOSA features low power dissipation thanks to a newly designed EML (electro-absorption modulator integrated laser diode) chip, stable wavelength and good transmission characteristics at 1600 ps/nm. The ROSA, on the other hand, contains a high performance APD (avalanche photo diode) chip and a linear TIA (trans-impedance amplifier) with integrated an AGC (automatic gain control) circuit in a coaxial type package. The ROSA provides a high gain and good linearity for a robust OSNR (optical signal to noise ratio) performance throughout a wide range of input power.

Keywords: TOSA, ROSA, DWDM, XFP, low power dissipation

## 1. Introduction

The increase of data traffic in recent years has led to the deployment of DWDM (dense wavelength division multiplexing) technology, which multiplexes multiple different optical wavelength signals in a single transmission line.

XFP (10Gbit/s small form factor pluggable) is a 10Gbit/s optical module that features small form-factor and low power dissipation. To increase total data traffic capacity in 10Gbit/s transmission equipment, the number of host boards or XFPs installed on a board is increased. For such high density installation, the XFP needs to be power saving and capable of operating at a high temperature.

We have successfully developed a new TOSA (transmitter optical sub-assembly) and ROSA (receiver optical sub-assembly) with a wide operating temperature range of -5 to 90 deg.C for the high density XFP operation. The TOSA features low power dissipation by using a newly designed EML (electro-absorption modulator integrated laser diode) chip. The ROSA, on the other hand, consists of a high performance APD (avalanche photo diode) chip and a linear TIA (trans-impedance amplifier) with an integrated AGC (automatic gain control) circuit in a coaxial type package.

In this paper, we report the designs of these optical components.

## 2. Specifications

**Table 1** shows the specifications of the TOSA/ROSA.

As the operating temperature of XFP ranges from -5 to 85 deg. C, a target operating temperature range (case temperature) of TOSA/ROSA is specified from -5 to 90 deg.C. Dimensions of TOSA/ROSA are fully compliant with XMD-MSA (10Gbit/s Miniature Device Multi-Source Agreement) and we designed a box-type package for the TOSA and a coaxial type package for the ROSA. The average op-

tical power of TOSA is 0 to 4 dBm, and the power consumption of a TEC (thermoelectric cooler) in the TOSA is less than 2.0 W. the ROSA consists of an APD chip with high sensitivity and a TIA with an AGC circuit integrated for good linearity and long distance data transmission. APD responsivity is better than 0.7 A/W, trans-impedance gain of TIA is higher than 4 k $\Omega$  (single-ended) and minimum sensitivity of the ROSA is better than -27 dBm.

In transmission characteristic measurements with TOSA/ROSA, we achieved less than 2.0 dB of dispersion penalty with an 80km single mode fiber (1600 ps/nm of chromatic dispersion).

**Table 1.** Specifications of TOSA/ROSA

Operation Case Temperature	-5 to +90 deg. C
Mechanical Dimension	XMD-MSA Compliant
Optical Interface	LC Receptacle
Electrical Interface	8-PIN FPC
Operating Bit Rate	9.95 to 11.3 Gbit/s
<b>TOSA</b>	
Wavelength	1528.77 to 1563.05 nm
Optical Output Power	0 to 4 dBm
Operating Current	120 mA Max.
Extinction Ratio	9 dB Min.
Optical Cross Point	45% to 55%
Dispersion Penalty (1600ps/nm)	2.0 dB Max.
TEC Power Consumption	2.0 W Max.
<b>ROSA</b>	
APD Responsivity	0.7 A/W Min.
Transimpedance	4 k $\Omega$ (Single-ended) Min.
Minimum Sensitivity	-27 dBm Max.
Maximum Overload	-3 dBm Min.

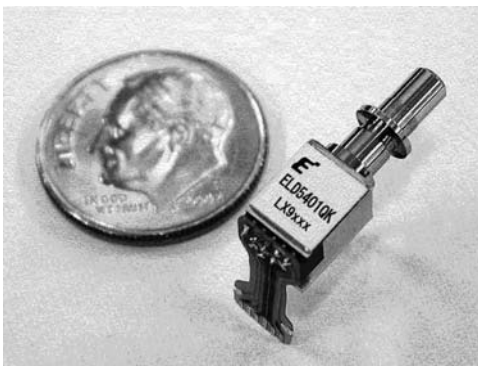
### 3. TOSA Characteristics

#### 3-1 Structure and interface

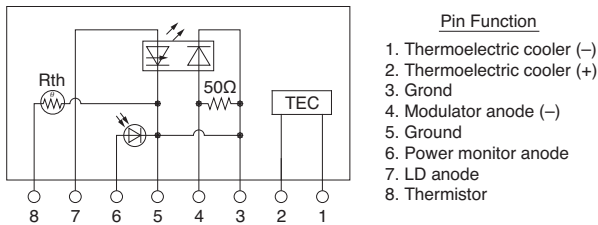
**Photo 1** shows the appearance of the TOSA. Dimensions of this product are fully compliant with XMD-MSA and an FPC (flexible printed circuit) is attached as an electrical signal interface. Function of each pad of the TOSA is shown in **Fig. 1**.

The light from a laser chip which is assembled on the top of a TEC is focused by lens and coupled to the fiber stub of the receptacle. A back-facet monitor PD (photodiode) is also built in the package for the APC (automatic power control) of the laser.

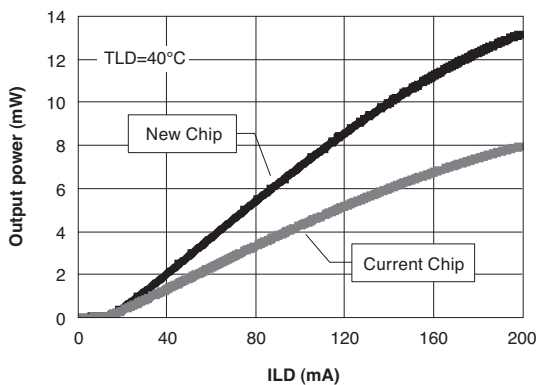
A newly designed high power EML chip is built in the TOSA, which has less power dissipation for 80 km trans-



**Photo 1.** Appearance of TOSA



**Fig. 1.** Block diagram



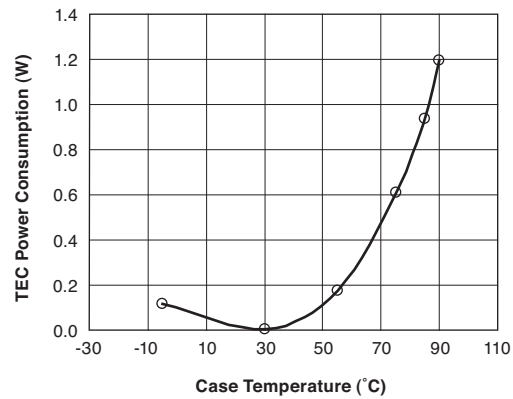
**Fig. 2.** Chip characteristic

mission and, as a result, it provides 2 dB more of optical power than the conventional product with the same condition of driving current (**Fig. 2**).

#### 3-2 Power consumption

**Figure 3** shows power consumption of the TEC in the TOSA. In the situation when the case temperature of the XFP rises or falls, the TEC serves to cool down or heat up the laser chip of the device, so as to keep its temperature constant.

In the case of an optical interface module, such as the DWDM XFP, the power consumption of the TEC in the TOSA greatly affects the total power consumption of the module. As the XFP requires a wide operating temperature range, such as -5 to +85 deg. C., the TOSA is required to operate up to 90 deg. C. LD current is set to 100 mA. The power consumption of the TEC tends to increase at a higher temperature to keep the LD chip cool. However, even at the highest temperature of 90 deg. C., power consumption of the TEC is well below 2.0 W.



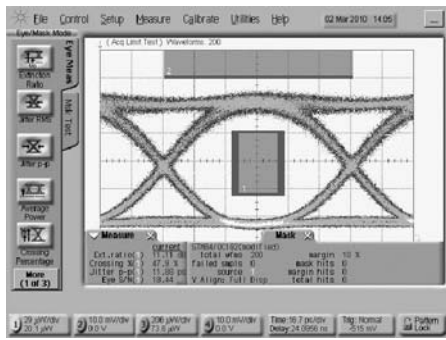
**Fig. 3.** Power consumption (TLD = 35 deg.C, Iop = 100 mA)

#### 3-3 Optical output waveform

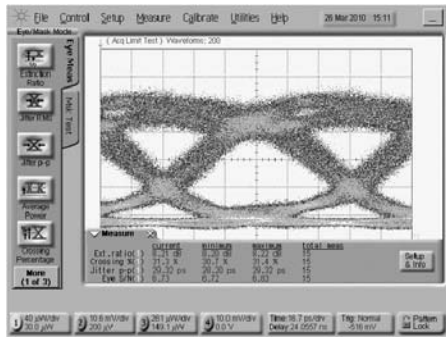
**Figure 4** shows optical output waveforms. **Figure (a)** shows the waveform before the transmission (back to back) and **(b)** shows after 80 km transmission (dispersion of 1600 ps/nm). A driving condition of the TOSA is optimized to obtain the specified output power. In this particular case, we set the LD temperature to 41 deg. C. and operating current to 90 mA. Offset voltage  $V_o$  is set to -0.5 V so as to ensure good transmission characteristics, while keeping a good eye diagram at back-to-back. Waveforms are measured by the optical plug-in module of an oscilloscope with Bassel-Thompson filter. The waveform of before-transmission satisfies the mask standard of STM64/OC-192 and has more than 20% mask margin. The optical extinction ratio is greater than 10 dB.

#### 3-4 Stability of wavelength

In DWDM applications, the stability of wavelength is a matter of the utmost importance. The main factors of wavelength change are temperature shift of the TOSA case and wavelength drift in a long term operation.



(a) Before transmission



(b) After transmission

Fig. 4. Optical output waveform

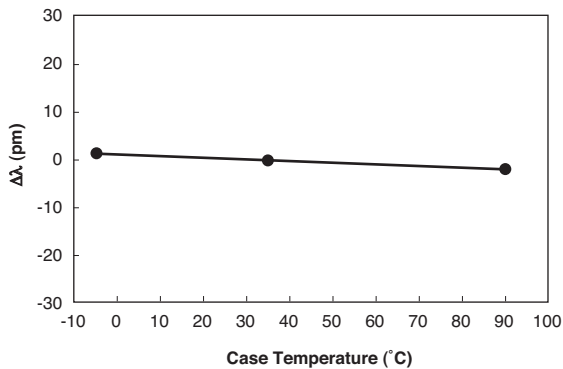


Fig. 5. Case temperature dependence of wavelength

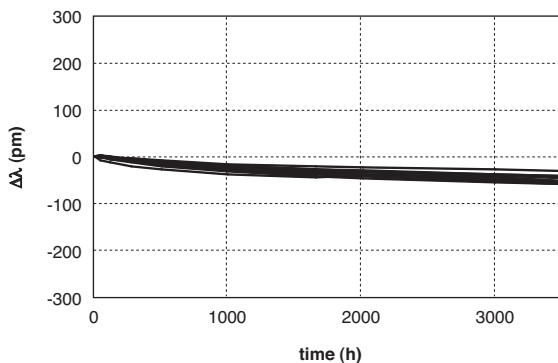


Fig. 6. Long-term stability of wavelength

Figure 5 shows case temperature dependence of wavelength. It shows good stability in the whole temperature range from -5 to 90 deg. C.

Figure 6 shows the aging test results of high temperature storage at 85 deg. C. The values of wavelength drift up to 3000 hours are within +/-60 pm and have enough margins compared to the target specification of +/-100 pm after 20 years.

## 4. ROSA Characteristics

### 4-1 ROSA

Photo 2 and Fig. 7 show the ROSA and its block diagram.

In-house developed APD and TIA chips, thermistor and noise filter circuit are assembled in a coaxial package. An FPC and LC-receptacle are connected as an electrical interface and an optical interface, respectively.

The back-illuminated APD with a wide sensitive area and integrated monolithic lens allows the high coupling efficiency.

The TIA consists of sub-blocks of a transimpedance amplifier with low-noise and wideband, a differential AGC amplifier and an output buffer loaded with 50 Ω.



Photo 2. ROSA

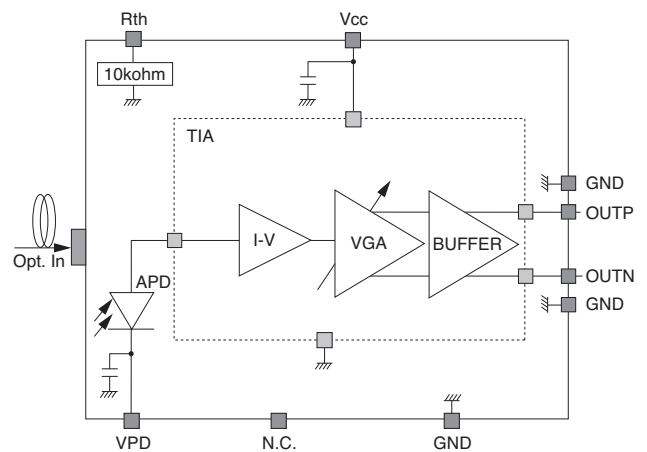


Fig. 7. Block diagram

#### 4-2 Transfer function

The transimpedance gain is 6 kΩ, and the output voltage swing is over 100 mVp-p at low optical input power.

The AGC amplifier attenuates the transimpedance gain at high optical input power effectively, and controls the output voltage swing properly throughout the optical input power range in use (Fig. 8).

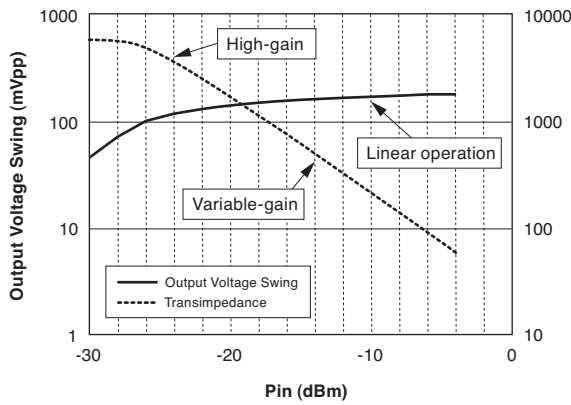


Fig. 8. ROSA transfer function

#### 4-3 ROSA eye diagram

Figure 9 shows electrical eye diagrams at back-to-back condition, bit rate of 9.95 Gb/s and 25 deg. C.

Good eye diagrams with small distortion were observed in the optical input range from -25 to -5 dBm.

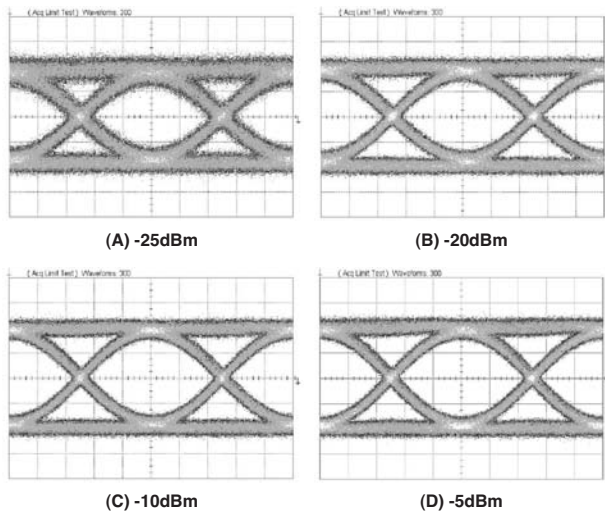


Fig. 9. ROSA eye diagram

### 5. Transmission Performance

#### 5-1 Dispersion penalty

The transmission test results of TOSA/ROSA are described as follows.

Figure 10 shows a measurement set up.

Electrical output from a PPG (pulse pattern generator) is set to 2 Vpp at 9.95 Gb/s with PRBS = 2<sup>31</sup>-1. Transmission tests are carried out using single mode fiber of +1600 ps/nm chromatic dispersion.

The APD multiplication factor is set to M = 9 and the threshold voltage is fixed at an optimal value in balance of before and after transmission.

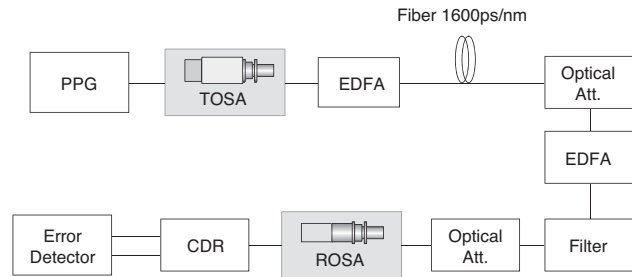


Fig. 10. Measurement set up for transmission

Figure 11 shows sensitivity of before and after transmission.

Minimum sensitivities of before and after transmission are -26.4 dBm and -25.6 dBm, respectively.

These results have enough margins compared with the general target specification of dispersion penalty, which is 2.0 dB (maximum).

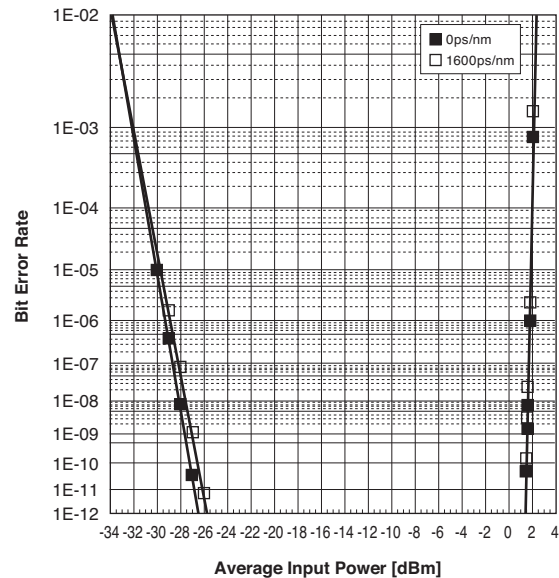


Fig. 11. Transmission performance

#### 5-2 OSNR tolerance

The ASE (amplified spontaneous emission) light from the multi-EDFA (erbium-doped fiber amplifier) is

accumulated in the fiber, which interferes with the main signal and causes beat noise. Thus OSNR (optical signal to noise ratio) is deteriorated. Good tolerance is required against the deteriorated OSNR for the ROSA in DWDM applications.

Figure 12 shows OSNR tolerance at 11.1 Gbit/s, 0 ps/mm dispersion, and temperature range from -5 to 90 deg. C.

The bit error rate of 1E-3 is obtained when the OSNR is 12 dB or less. At the wide temperature range from -5 to 90 deg. C. favorable tolerance to the OSNR is confirmed in the wide optical input power range from -20 to -5 dBm due to the good linearity of TIA.

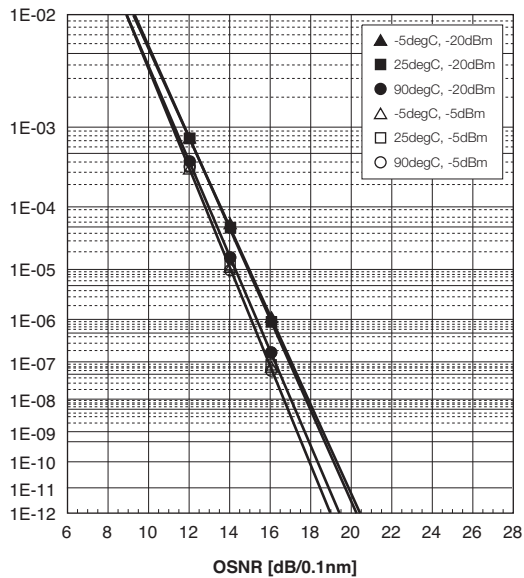


Fig. 12. OSNR tolerance

## 6. Conclusions

We have successfully developed 10Gb/s TOSA/ROSA that can operate at the wide temperature range for the use in pluggable optical modules. The TOSA features low power dissipation thanks to a newly designed EML chip, a good stability of wavelength, and a good transmission characteristic. The ROSA has a robust OSNR performance throughout wide ranges of input power and temperature owing to a high performance APD chip and a good linear TIA.

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