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Compact 10 Gb/s Avalanche Photodiode Receiver Module with a Variable Optical Attenuator for Transmission System

FAN Hong[1], ZHA Yi[2]

(1 *Department of Electric Power and Automation Engineering, Shanghai University of Electric Power, Shanghai* 200090, *China*)

(2 *Oclaro Technology (Shenzhen) Co., Ltd, Shenzhen, Guangdong* 518038, *China*)

Abstract: A compact 10 Gb/s avalanche photodiode (APD) module is developed that employs an integrated micro-electro-mechanic system (MEMS) variable optical attenuator (VOA). The structure and basic characteristics of the 10 Gb/s APD-TIA subassembly are introduced. The performances of integrated MEMS VOA are tested, its attenuation varies with the applied voltage, dynamic range of discrete APD is increased by VOA at least 50% (13 dB), which is an ideal result for the application of Metro dense wavelength division multiplexing (DWDM), and is also an effective way to compensate signal change in high speed optical communication system. The test results of the optical receiver and the eye pattern of 10 Gb/s APD subassembly are reported, a sensitivity of -26.5 dBm and a clear eye diagram of receiver are achieved.

Key words: Avalanche Photodiode (APD); Variable Optical Attenuator (VOA); Sensitivity; Micro-Electro-Mechanic System (MEMS)

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0 Introduction

With the development of 10 Gb/s high capacity synchronous digital hierarchy (SDH) and wavelength division multiplexing (WDM) optical communication system, 10 Gb/s transmitter and receiver modules make a rapid progress in applications. High sensitivity receiver is a key part of high speed optical communication system[1]. Erbium doped fiber amplifiers (EDFAs) are widely used in current optical networks to extend the communication research. Signal levels vary with the distance between nodes, and the optical receiver will have a high overload if the received optical signal level at a node becomes so high. And, very short optical surges caused by a sudden input level change in the EDFA will do harm to receiver without VOA attenuation when part of system is shut down or restarted. An effective way to compensate signal change is to use an APD receiver module integrated with a VOA at the receiver front-end. Both sufficient attenuation and compactness are achieved by reducing the size of VOA and employing lens alignment optics[2-5].

1 Module configuration

This type of receiver consists of a MEMS VOA which improves dynamic range of receiver, an optical detector (APD) which converts the optical signal to an electrical signal, a low-noise preamplifier and a precision thermistor in a hermetic coplanar package with a connectorized single-mode fiber pigtail. It has been optimized for 10 Gb/s metro or long-haul applications, either as a discrete device or within a transponder, using NRZ modulation, with or without FEC, at data rates up to 10.709 Gb/s. The signal generated by a detector is generally too weak to be used, so the detector is followed by the next stage of further amplification and signal conditioning which typically include a trans-impedance amplifier. Module configuration can show the major parts of components as follows.

Our module includes focusing optics, a magneto-optic VOA, an avalanche photodiode (APD) and a trans-impedance amplifier (TIA). For the optical design, we employ single-lens focusing optics, where the optical system itself is

First author: FAN Hong (1978—), female, lecturer, Ph. D. degree, mainly focuses on electronic communication transmission planning and smart electric grids. Email: hong_fh@163.com

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compact rather than a collimating system. In addition, VOA can be small, which is another factor that makes the module more compact. All the components are integrated, which is shown in Fig. 1. To focus a 9-μm-diameter fiber core and a 25-μm-diameter APD aperture, the lens magnification

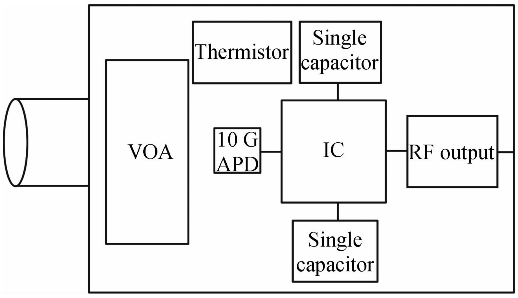

Fig. 1　Module configuration

was about 1 : 2.5. A single-lens configuration is also advantageous as regards cost. The incident light passes through a transparent VOA and the light angle is controlled by a magnetic field that is proportional to the voltage applied to the VOA. All the components are fixed in position by passive alignment except for fiber collar where active alignment is employed. This optical setup exhibits an excess loss of about 0.3 dB and is confirmed to function effectively. The packaged device is developed as shown in Fig. 2. The device size is only 10.7×8.0×4 mm^3.

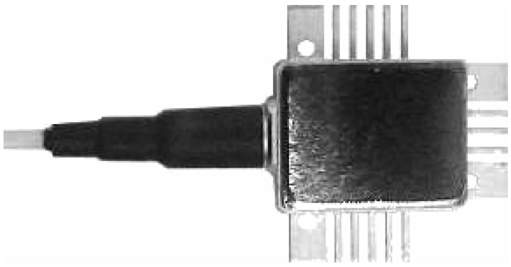

Fig. 2　Photograph of the module

2　Characteristics and reliability

The attenuation dependences on V (VOA) in the C band have shown in Fig. 3 and Fig. 4.

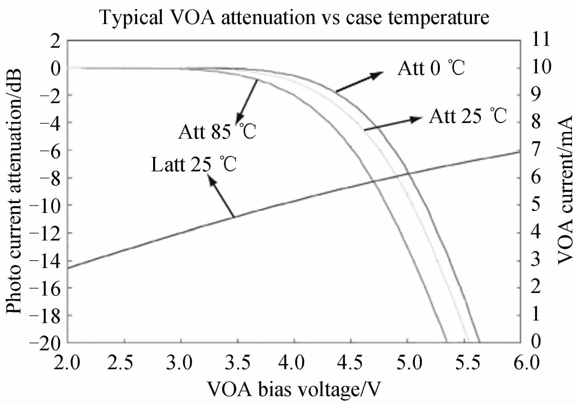

Fig. 3　Typical VOA attenuation

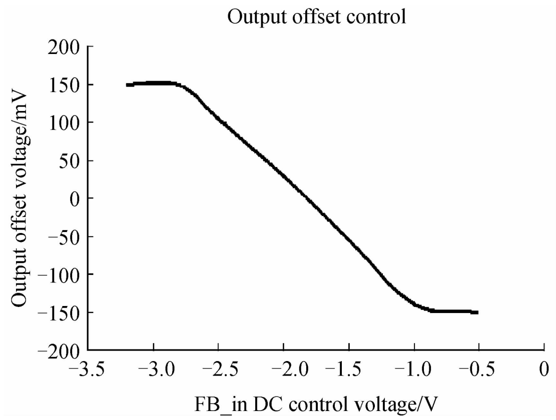

Fig. 4　FB in transfer function

3　Bit error rate and Sensitivity

The voltage at the output of the TIA or PA can be considered as a superposition of the wanted signal voltage and the unwanted noise voltage. Occasionally, the instantaneous noise voltage may become so large that it corrupts the received signal, leading to a decision error or bit error. The bit error rate (BER) is defined as the probability that a zero is misinterpreted as a one or a one is misinterpreted as a zero. An expression curve for the BER can be obtained as follows (Fig. 5 and Fig. 6).

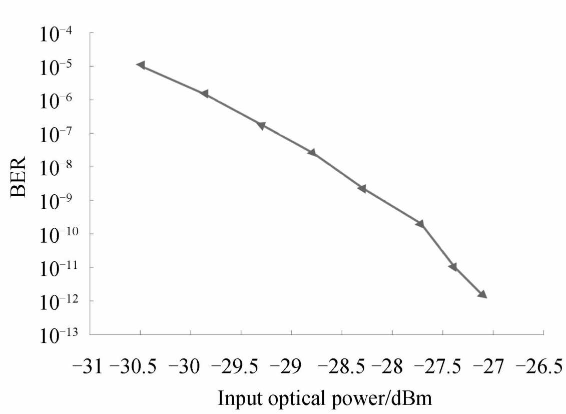

Fig. 5　Typical BER performance, M=10, 10 Gb/s 231-1 PRBS, optical extinction ratio=12 dB

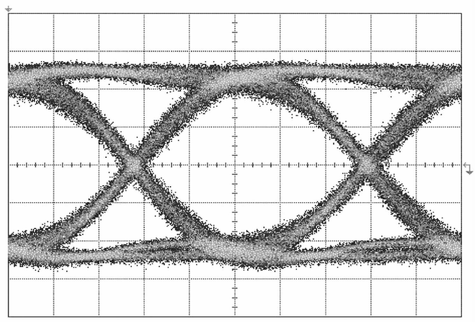

Fig. 6　Electrical output data eye, M=10, 10 Gb/s 231-1 PRBS, -20 dBm optical input

3.1 Sensitivity

The sensitivity of a receiver is the minimum signal needed at the input to achieve a certain BER. It reflects to what level the transmitted signal can become attenuated and still be detected reliable by the receiver. Sensitivity can be defined in the electrical as well as in the optical domain.

3.2 Overload

A receiver can work properly within a limited range of optical power. Sensitivity specifies the lower side of this limit. From a theoretical point of view, sensitivity represents a point where SNR falls below the level that corresponds to the target BER. On the other hand, as the received power increases, eventually we get to a point where the receiver begins to saturate. For instance, the current output from the photo-detector may get so large that the trans-impedance amplifier can no longer handle the signal. Saturation of the input stage of the amplifier will then lead to excessive distortion and cause the receiver to not function properly. The maximum optical power that a receiver can receive while still working properly is known as the overload. Due to the integration of a MEMS VOA in this kind of receiver, integrated MEMS VOA extends overload beyond +10 dBm.

3.3 Reliability

To clarify the influence of the stress, a temperature-cycling test was performed at temperatures ranging from −40 ℃ to 85 ℃. The results for 500 cycles are shown in Fig. 7 and Fig. 8. A sample of 11 devices was submitted to this test. The key parameter changes of all devices were within the required specification after 500TC.

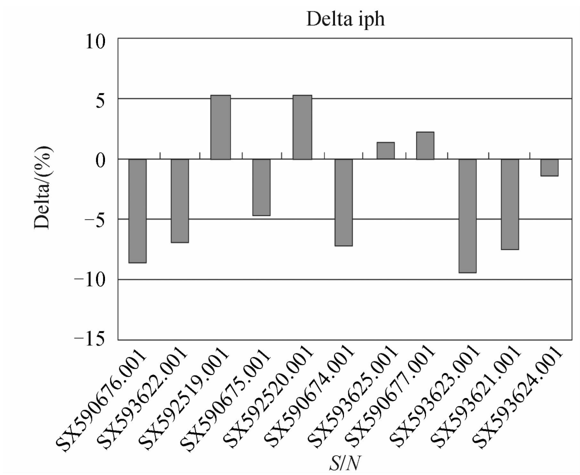

Fig. 7 The results of temperature cycling test for deviation in dark current

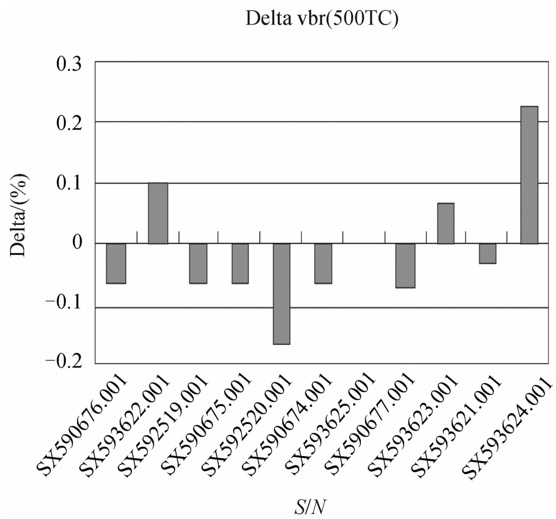

Fig. 8 The results of temperature cycling test for deviation in APD breakdown voltage

Receiver modules submitted to this qualification exercise have successfully met the requirements of qualification to GR-468-CORE.

4 Conclusion

A compact 10 Gb/s APD receiver employs a VOA using single-lens focusing optics. The typical attenuation is 20 dB when a voltage (VOA) of 5.5 V was applied. The power consumption of VOA is 350 mW. The breakdown voltage of less than 40 V and the dark current of less than 10 nA are confirmed for APD receiver module. The developed module has the potential to protect itself from optical surges from the EDFA because of its fast response characteristics. Temperature-cycling tests are performed for modules covered with resin.

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10 Gb/s 带可变光衰减器的雪崩光电二极管接收器

范宏[1],查毅[2]
(1 上海电力学院,上海 200090)
(2 奥兰若科技(深圳)有限公司,广东 深圳 518038)

摘　要:报导了一种集成 MEMS 的光接收器件的 10 Gb/s 雪崩光电二极管,并介绍了 10 Gb/s APD-TIA 的结构和基本特点. 对衰减器进行了性能测试,所得到的特性曲线表明其衰减随所加电压变化而变化. 集成 MEMS VOA 接收器的动态范围至少增加了 50%达到 13 dB,这个结果对密集波分复用系统中的应用非常理想,同时对高速通信系统中的信号改变是一种有效的补偿方式. 本文报导了传输速率 10 Gb/s 带衰减器的雪崩光电二极管光接收器的眼图和测试结果,能够获得−26.5 dBm 的灵敏度和清晰的眼图.

关键词:雪崩光电二极管;衰减器;灵敏度;微机电系统