Recent Progress in Optical Module and Transceiver Technology

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Abstract

Optical components that convert electrical signals to optical signals and vice versa are indispensable to optical communication networks (core, metro, and access networks). This paper reviews the fundamental technologies of optical modules and transceivers that use optical semiconductor devices and electronic devices and describes their recent progress.

1. Background

The increases in speed of core and metro network systems and the increased capacity achieved by wavelength division multiplexing (WDM) have led to the expansion of Internet services. Moreover, access network systems that send information to customers' homes via optical fiber are rapidly spreading throughout Japan. These systems require compact optical devices that provide high performance at a reduced cost.

In an optical communication system, electrical signals are converted to optical signals and vice versa by optical transmitter and optical receiver modules, respectively. The development of an optical transceiver, which integrates an optical transmitter module with an optical receiver module, has contributed greatly to both miniaturization and cost reduction because those modules were previously mounted discretely on a printed circuit board. Despite their simple functions, optical transceivers combine several diverse technologies: optical device and module technology, electronic circuit technology, and mounting and assembly technology. The optical transceiver is one of the key components in the optical communication network.

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2. Characteristics of optical modules

Most optical transmitter modules use a semiconductor laser diode (LD) as the light source. The optical receiver module uses a PIN-photodiode (positive-intrinsic-negative photodiode (PIN-PD)) or avalanche photodiode (APD). The integrated circuit (IC) that drives the LD is usually placed outside the optical transmitter module while the optical receiver and low-noise amplifier IC are usually built into the optical receiver module. Optical transmitter modules and their features are shown in **Table 1**. These modules are classified into four types: can, coaxial, transmitter optical sub-assembly (TOSA), and butterfly.

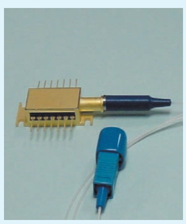
The can type was adapted from the widely used TO (transistor-outlined) package developed for IC packaging by giving it a window for outputting light. It is widely used for the LD package for DVDs (digital versatile disks) and CDs (compact discs).

The coaxial module, which has a coaxial shape, is designed to use a can as a basic component and connect with a pigtail fiber.

The TOSA module can be connected directly to an optical connector without using a pigtail fiber. In other words, optical connection can be achieved by inserting an optical connector directly from the outside into this optical module. The TOSA is composed of an LD and a fiber receptacle component with a lens.

The butterfly type achieves the most efficient and reliable characteristics among optical modules. The name comes from the arrangement of electrodes on the two sides. This module can easily include a ther-

Table 1. Characteristics of optical modules.

Type	Features		Components	Performance	Cost
Can		• Improved TO packages with window for optical devices	• Without fiber • No or one lens	Low	Low
Coaxial		• Coaxial shape to allow cans to be used as basic components and to connect to a pigtail fiber	• With fiber • One lens		
TOSA		• Directly connected to optical connector without fiber • With or without temperature controller	• Without fiber • One or two lenses		
Butterfly		• Most efficient, reliable characteristics in optical modules • Electrode terminals on both sides of module frame • With temperature controller	• With fiber • Two lenses • Integrated with LD driver IC	High	High

mo-electric cooler (TEC), which can regulate the temperature of the LD by acting as either a heater or cooler as required. Moreover, an LD driver IC can also be incorporated.

For any particular application, the module structure, the application of optical modules, and the demands related to performance and cost are judged overall, and the most appropriate type of optical module is selected. Table 1 shows the general tendency as regards performance and cost. The TOSA type is often used for optical transceivers to meet the demand for compactness and direct connection to an optical connector.

3. Characteristics of optical transceivers

Various multisource agreements (MSAs) have been made among manufacturers to specify component characteristics such as the external size and pin layout. MSA-based optical transceivers have recently been developed. The MSAs for optical transceivers designed for 10-Gbit/s operation are shown in **Fig. 1**. The MSA for optical transceivers with a 300-pin electrical connector [1] uses a pigtail fiber for the optical interface and has a large overall size because it houses various functional components. The 300-pin SFF (small form factor) MSA aims at a miniaturized 300-pin transceiver. XENPAK (10 Gigabit Ethernet transceiver package) transceivers conform to the 10 Gigabit Ethernet (10 GbE) standard and feature a compact package with a volume about half that of the 300-pin MSA. An optical connector is placed at the front of this transceiver and a card-edge-type electrical connector is affixed to the opposite side. One feature of this approach is that it enables the transceiver to be removed via the front panel. Another miniaturized type is the XFP (10 Gigabit small-form-factor pluggable) [3], which is a faster version of the SFP (small-form-factor pluggable) transceiver, which was a pluggable gigabit-per-second transceiver [4]. The MSA for SFP transceivers started with 1 × 9 devices and progressed via the Gigabit interface converter (GBIC), SFF [5], and SFP. The XFP will be widely used in the 10-Gbit/s optical transceivers of the future.

4. Trends of optical module and transceiver technologies

Research and development of optical modules and transceivers has advanced greatly with a view to achieving the three closely related goals of high performance, miniaturization, and cost reduction.

(1) High performance

High performance includes high-speed and long-distance transmission, WDM, and reduced power consumption.

(2) Miniaturization

The aim here is to reduce the packaging density in equipment that uses them. Miniaturization also helps

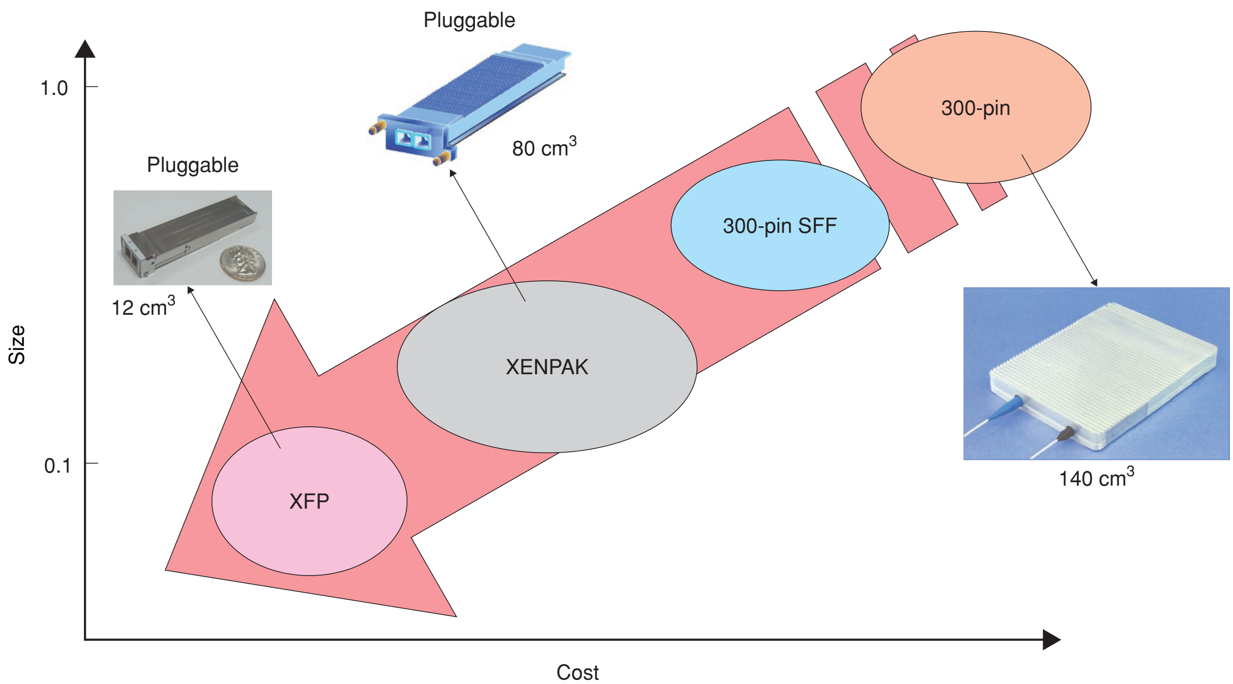


Fig. 1. MSAs of 10-Gbit/s optical transceivers.

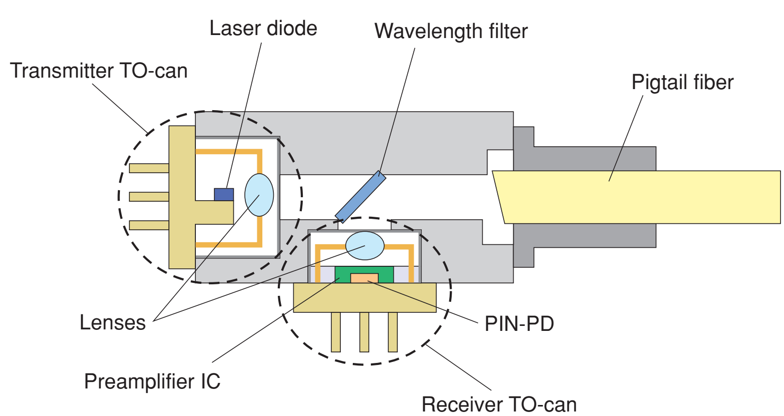


Fig. 2. Bi-directional optical transceiver.

to reduce costs, but it must be accomplished without any serious deterioration in performance.

(3) Cost reduction

Reducing the number of components and the material cost and developing innovative technology should lead to low-cost devices.

The aim of MSAs is to reduce costs by allowing mass production and to provide the market with a stable supply and common specifications. The advantage of this approach is that optical modules and transceivers with the same specifications can be bought from two or more different suppliers. Since the MSA is advantageous for both the demand and supply sides, this approach is likely to continue to be used in the future.

There is an urgent need to reduce the cost of optical transceivers for optical access systems. A bi-directional optical transceiver that integrates components such as a transmitter TO-can equipped with an LD, a receiver TO-can equipped with a PIN-PD, a preamplifier IC, a wavelength filter, and a pigtail fiber has been developed (**Fig. 2**). This transceiver shows that cost can be greatly reduced by compactly integrating the functions of optical transmission and reception. Moreover, the material cost is reduced by using a TO-can with a diameter of 5.6 mm, which is widely used for optical modules for DVDs and CDs.

5. Future plans

Our next target is a compact optical transceiver that provides, for example, electronic dispersion compensation, wavelength tunability, and 40-Gbit/s operation.

References

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[2] http://www.xenpak.org
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