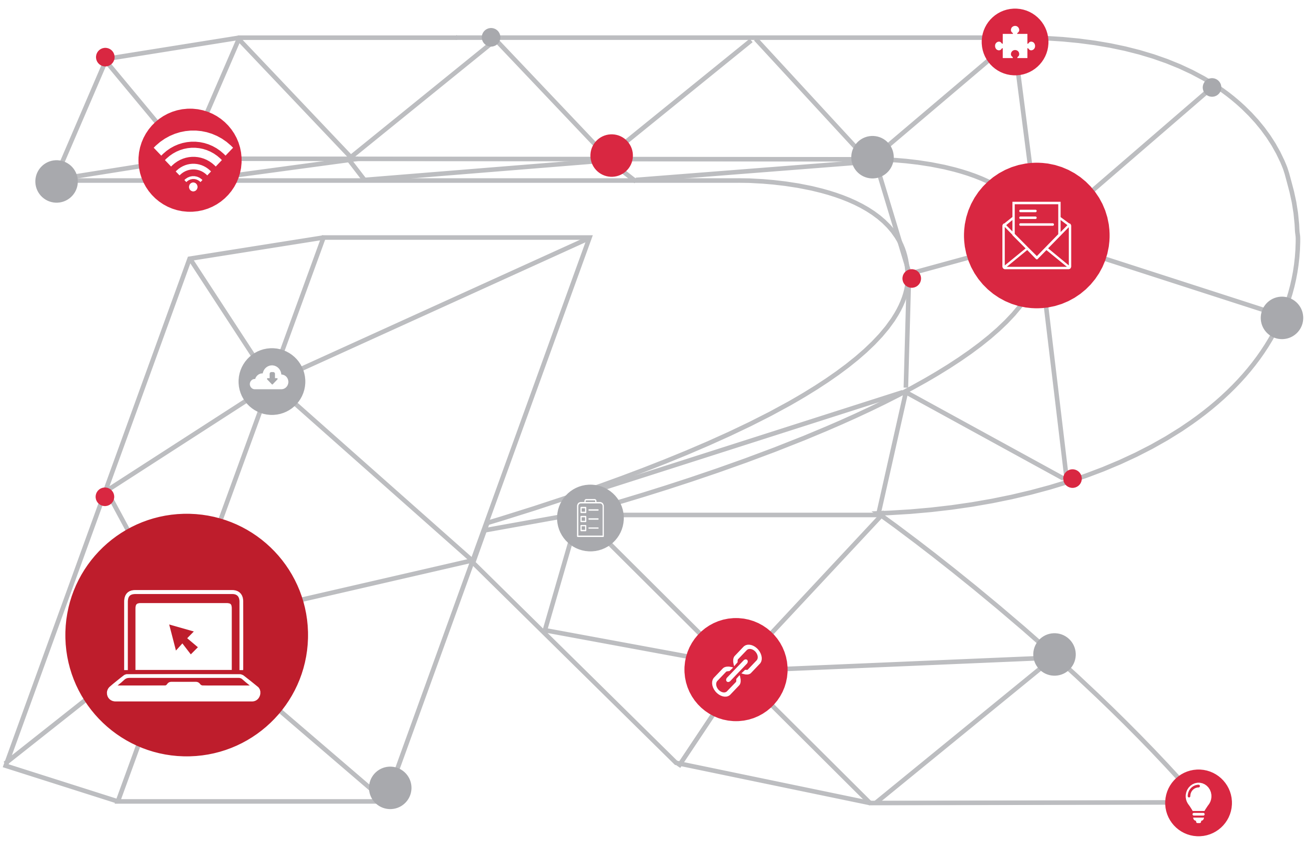
Ruijie BiDi Optical Technology

White Paper



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Introduction

This document describes the basics, principles, and applications of the bidirectional (BiDi) technology, as well as optical subassemblies, their principles, and BiDi products.

• Optical Fiber Communication

Optical fiber communication refers to the communication using optical fibers as a medium for optical signal transmission. Compared with cable and microwave communications, optical fiber communication features high frequency, wide band, large capacity, excellent security performance, low loss, long relay distance, and strong anti-interference capability. Optical communication networks have become the basic platform of the modern communication network because of these advantages. The optical communication system develops rapidly in recent years and optical fiber communication products such as optical switches, optical modules, and optical transceivers have been applied widely.

• Two-Fiber Bidirectional Technology, WDM, and BiDi

In the early optical fiber communication, one optical fiber transmits signals of only one wavelength, such as 850 nm, 1310 nm, or 1550 nm. Two optical fibers are required to implement the full-duplex communication, one optical fiber transmits Tx optical signals, and the other optical fiber transmits Rx optical signals. This is two-fiber bidirectional communication. In recent years, with the increase of fiber network users, existing network resources cannot meet increasing user requirements. The wavelength division multiplexing (WDM) and BiDi technologies emerge in order to increase the transmission capacity of optical fibers and improve the optical fiber usage. In WDM, a multiplexer is used at the Tx end to multiplex optical carrier signals (that carry various information) of two or more wavelengths and couple them onto the same optical fiber for transmission; a demultiplexer is used at the Rx end to demultiplex the signals into the optical carrier signals of different wavelengths, which are further processed by an optical receiver to restore the original signals. WDM requires special multiplexers and demultiplexers, resulting in complex structure and high cost.

By contrast, BiDi does not require special multiplexers and demultiplexers but uses a beam splitter to implement single-fiber bidirectional transmission. The costs of lasers and network devices are very low. In addition, BiDi uses one optical fiber to implement the transmitting and receiving of optical signals, saving optical fiber resources. Figure 1 shows a two-fiber bidirectional optical module with two LC connectors. The optical module needs to be connected to two optical fibers for bidirectional data transmission. Figure 2 shows a BiDi optical module with only one LC connector. The optical module needs to be connected to only one optical fiber for bidirectional data transmission. BiDi helps reduce the network building and operation costs, and therefore it is widely used in the fields, such as fiber to the x (FTTx), optical transmission network (OTN), wireless backhaul, dedicated transmission network and IP surveillance.

Figure 1 Two-Fiber BiDi SFP Optical Module

Figure 2 Single-Fiber BiDi SFP Optical Modules

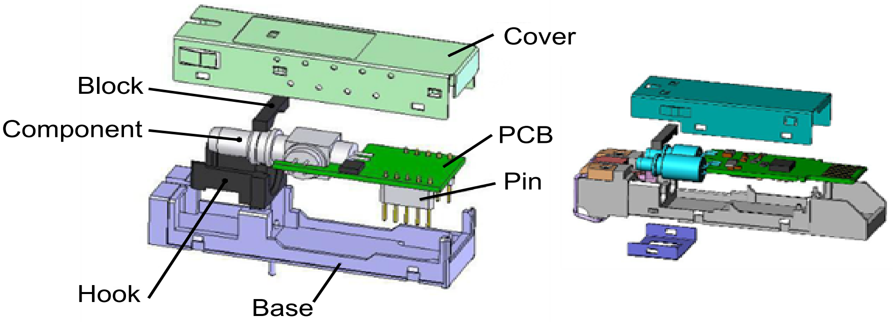
BiDi Principles

A large number of optical modules or optical transceivers are required to convert electrical signals into optical signals for transmission. An optical module or optical transceiver is composed of optoelectronic components, functional circuits, and optical interfaces.

• Two-Fiber Bidirectional Optical Subassemblies

Optoelectronic components of a two-fiber bidirectional optical module/optical transceiver include a transmitter optical subassembly (TOSA) and a receiver optical subassembly (ROSA). The TOSA is mainly composed of a light source (semiconductor light emitting diode (LED) or laser diode (LD)) and a monitoring diode (MD); while the ROSA is mainly composed of a photodetector (photodiode (PIN) or avalanche photodiode (APD)) and a head amplifier. In the sending part, the inputted electrical signals at a certain bit rate are processed by an internal driver chip, and then the driver semiconductor laser (LD) or LED emits modulating optical signals at a rate. The LD or LED has an internal automatic optical power control circuit to ensure that the power of the outputted optical signals is stable. In the receiving part, optical signals at a certain bit rate are converted by the photodetector into electrical signals. Then, the head amplifier outputs the electrical signals at a bit rate. The outputted signals are of the PECL level. In addition, the head amplifier outputs an alarm signal when the input optical power is smaller than a specified value. Figure 3 shows the function subassemblies of a two-fiber bidirectional small form-factor pluggable (SFP) optical module.

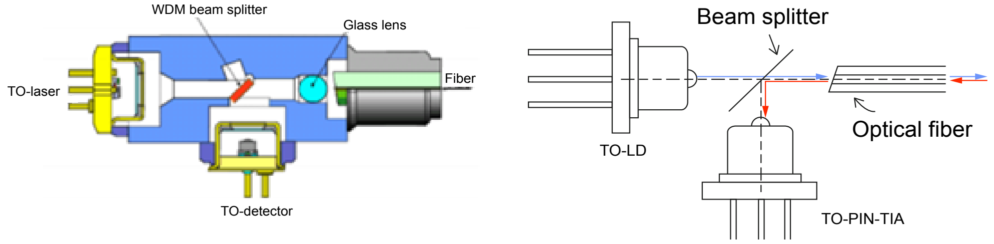
Figure 3 Function Subassemblies of a Two-Fiber SFP Optical Module



• BiDi Optical Subassemblies

Different from a two-fiber bidirectional optical module/transceiver, a BiDi optical module/transceiver uses a bidirectional optical subassembly (BOSA). The BOSA integrates the LD, PIN, and beam splitter by using the coaxial coupling technology. The optical power signals sent by the LD are focused by a self-focusing lens into parallel beams, which are then coupled by a beam splitter onto an optical fiber for transmission. External signals are projected on the beam splitter by the optical fiber, reflected onto the self-focusing lens for light concentration, and then coupled by the photodetector. The single-fiber bidirectional optical transceiver subassembly uses a BOSA to replace the TOSA and ROSA, implementing bidirectional transmission over one optical fiber.

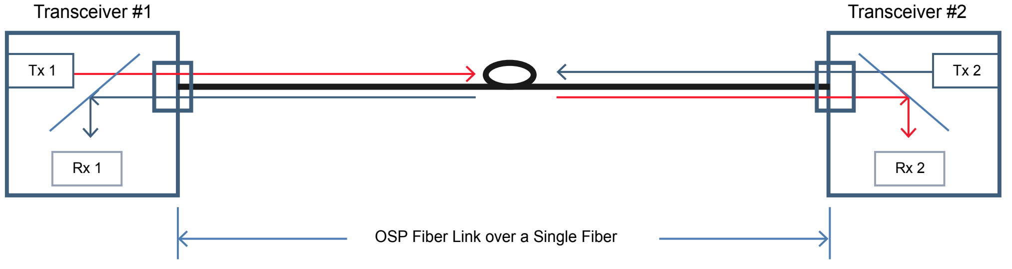
Figure 4 BOSA and Its Schematic Diagram



Currently, single-fiber bidirectional transceiver subassemblies include single-wavelength BOSAs and dual-wavelength BOSAs. A dual-wavelength BOSA uses a WDM beam splitter, which transmits the light from the LD at the Tx end and reflects Rx light, implementing optical splitting for the sending and receiving of different wavelengths, such as 1310 nm TX/1550 nm RX. A dual-wavelength BiDi module or device uses two different central wavelengths in the transmit and receive directions, such as 1310 nm/1550 nm, 1310 nm/1490 nm, and 1470 nm/1610 nm. Dual-wavelength BiDi modules or devices must be used in pairs. For example, if a BiDi module supporting 1310 nm TX/1550 nm RX is used at one end, a module supporting the same wavelengths must be used at the other end. The beam splitter used by a single-wavelength BOSA half transmits and reflects Tx/Rx wavelengths. The BOSA integrates the TO-LD and TO-PIN-TIA. Light is not transmitted along a straight line because there are light transmission, reflection, refraction, and diffuse reflection. WDM beam splitters cannot be used if the same wavelength is used for bidirectional signal transmission. The reason is that a large portion of the Tx light directly goes to the Rx end of the BOSA and a large portion of the Rx light directly goes to the Tx end, causing adverse impact on the signal-to-noise ratio (SNR) and reducing the transmission distance.

A single-wavelength BiDi product uses one wavelength for transmission. Though the same wavelength is not required at both ends and the building, operation, and maintenance are easy, single-wavelength BiDi products have immature and unstable performance and support a transmission distance of only about 40 km. Dual-wavelength BiDi products require the same wavelengths at both ends and the network building, operation, and maintenance are troublesome, but they are the mainstream BiDi solution in the market because of their mature and reliable performance, low cost, and long transmission distance. The BiDi optical modules and BiDi optical transceivers released by Ruijie Networks use the 1310 nm/1550 nm wavelengths.

Figure 5 Signal Transmission at the Same Wavelength over a Single Optical Fiber

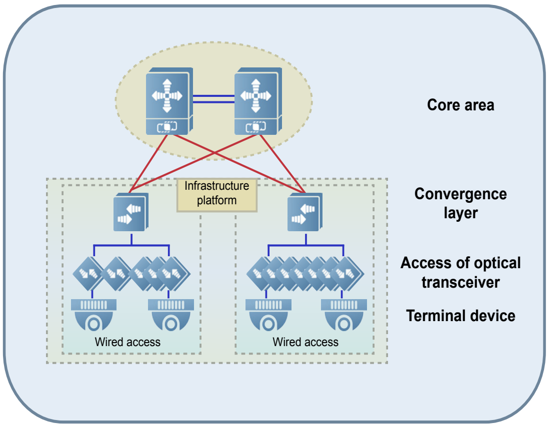


Technical Parameters of BiDi Products

Currently, BiDi products mainly include BiDi optical modules and BiDi optical transceivers. BiDi optical modules are mainly SFP and SFP+ optical modules. Optical transceivers, also called optical-to-electrical converters, are used for data communication between twisted pairs and optical cables and implement network expansion and extension through fiber links. BiDi optical transceivers support a maximum transmission distance of 120 km and therefore are widely applied in outdoor monitoring access and wireless access point (AP) access scenarios.

Pay attention to the following specifications for optical interfaces of the BiDi products.

Figure 6 Ethernet Ring Protection Switching in a Link Failure



• Rate

Transmission rate refers to the number of bits transmitted per second, with the unit of Mbit/s or Gbit/s. BiDi optical modules are mainly 155M, 622M, 1.25G, 2.5G, and 3G SFP optical modules. 10G BiDi optical modules are rarely used currently, but many optical module manufacturers have released 10G SFP+ BiDi optical modules successively. Optical transceivers mainly support the transmission rate of 100 Mbit/s and 1000 Mbit/s.

• Transmission Distance

The transmission distance is limited because optical signals experience certain loss and dispersion during the transmission over optical fibers. Loss refers to the light energy loss caused by the absorption of the medium, scattering, and leakage during the light transmission over optical fibers. Electromagnetic waves of different wavelengths are propagated at different speeds over the same medium and optical signals of different wavelengths arrive the Rx end at different time points because of long transmission distances. As a result, pulse broadening occurs and signal values cannot be distinguished. This is dispersion. BiDi SFP optical modules support a transmission distance of 120 km. 10G BiDi SFP+ optical modules support a maximum transmission distance of 60-80 km. The 10G BiDi SFP+ optical modules supporting a transmission distance of 80 km is immature and they need to be selected through testing. BiDi optical transceivers support a transmission distance of 120 km.

• Optical Interface Type

BiDi optical modules mainly use LC interfaces. BiDi optical transceivers mainly use SC interfaces.

• Transmit Optical Power

Transmit optical power refers to the output optical power of the light source at the Tx end, with the unit of dBm. The longer the transmission distance, the larger the required transmit power.

• Receiver Sensitivity

Receiver sensitivity refers to the minimum receive optical power of an optical module at a certain rate and bit error rate (BER), with the unit of dBm. In general, If the rate is higher, the receiver sensitivity is poorer, that is, the minimum receive optical power is larger, and higher requirements are posed for components at the Rx end of an optical module.

• Light Saturation

Light saturation, also called saturated optical power, refers to the maximum input optical power at a certain transmission rate and BER, with the unit of dBm. Note that a photodetector may experience the phenomenon of saturation of photoelectric current when exposed under strong light. When the phenomenon occurs, the photodetector needs a period of time for recovery. In this period, the receiver sensitivity is reduced, received signals may be incorrectly judged and bit errors are incurred, and the photodetector at the Rx end may be easily damaged. Therefore, it is not recommended that the optical power be beyond the saturated optical power during operations.

Comparative Analysis

• Analysis of Comparison Between BiDi and Two-Fiber Bidirectional Technology

BiDi products implement bidirectional transmission of optical signals over one optical fiber, utilizing existing optical fiber resources to a larger extent and reducing building and operation costs.

• Analysis of Comparison Between SFP BiDi and CWDM & DWDM

With regard to the coarse wavelength division multiplexing (CWDM), the wavelength interval is restricted to 20 nm, special filters are required for multiplexing and demultiplexing of different wavelengths, the filter coating thickness is as many as 50 layers compared with the 1310 nm, 1490 nm, and 1550 nm filters, and therefore the cost is high. With regard to the dense wavelength division multiplexing (DWDM), the wavelength interval is reduced to as small as 0.4 nm, special filters are also required for multiplexing and demultiplexing of different wavelengths, the filter coating thickness is as many as 150 layers, and therefore, the cost is much higher. In addition, lasers need the temperature control function, and the temperature control part needs to be added to the modules, sharply increasing the module cost.

The BiDi makes use of existing wavelength resources and low-cost beam splitters. It is applicable to access networks or local area networks (LANs) to be expanded where optical fiber resources are already deployed.

Application Precautions

1. BiDi modules use different wavelengths for bidirectional signal transmission over optical fibers. Therefore, BiDi modules need to be used in pairs. Pay attention to the color of pull taps on optical modules. An optical module with the yellow pull tap needs to be used with an optical module with the blue pull tap. Optical modules with pull taps of the same color cannot be used together.
2. No standard has been released for BiDi. The wavelengths supported by BiDi modules from other manufacturers may not be consistent with those supported by Ruijie BiDi modules (1310 nm/1550 nm). There are optical modules supporting 1490 nm/1500 nm wavelengths available in the market. Therefore, Ruijie BiDi modules may not interwork with optical modules from other manufacturers.
3. Before BiDi is used, it is recommended that unified planning be made, for example, the wavelength for upper layer devices and the wavelength for access devices be determined, so as to prevent interworking failures because of wavelength differences during implementation.

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For further information,please visit our website **http://www.ruijienetworks.com**