Optical Device Technology Supporting NEC Open Networks – Optical Transmission Technology for 800G and Beyond

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Abstract

Communication traffic has been increasing rapidly in recent years and is expected to continue to grow exponentially in the future. While the capacity of backbone networks needs to be increased, there is also a growing trend toward openness where networks are constructed by flexibly selecting equipment without being bound to a specific vendor and another growing trend toward greenness where networks are designed to reduce power consumption to address concerns about environmental issues. This paper introduces NEC's optical device technologies and product lines that support openness and greenness.

Keywords

Optical device, coherent, transponder, optical transceiver, high capacity, openness, greenness

1. Introduction

NEC'S product line of digital coherent optical transceivers that combine digital signal processing (DSP) and coherent wave detection are being actively developed to achieve higher capacity in optical network equipment.

On the other hand, the market needs are not only for higher capacity but also for openness and greenness. Openness is wanted to enable flexible selection of equipment as well as flexible construction of networks without dependence on a specific vendor as in the past. Greenness is wanted to address environmental concerns and to reduce the overall power consumption of networks. Efforts are also being made to establish power consumption standards of network equipment to meet this need for openness and greenness.

This paper describes the technology used in NEC's transponders and digital coherent optical transceivers and also introduces NEC's product lines that support the increased capacity, openness, and greenness of optical networks.

2. Transponders

Transponders play an important role in optical networks by multiplexing signals at speeds such as 100 GbE or 400 GbE into multiple channels and converting them into optical signals suitable for high-capacity transmission. **Fig. 1** shows the configuration of a typical transponder. Here, three 400-GbE client signals are converted into a single 1.2-Tbps multilevel modulated signal for transmission and reception.

Pluggable optical transceivers that transmit and receive

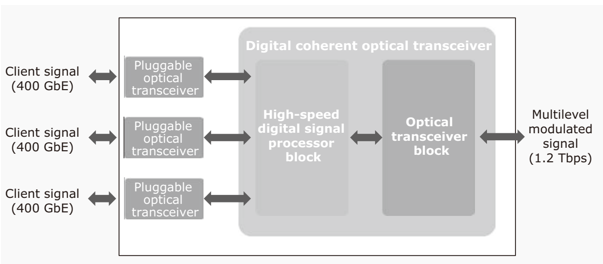

Fig. 1 Configuration of a transponder.

client signals exist in multiple form factors that are defined by the standards established to address environmental concerns, and transponders are designed to enable compliant devices to be connected. As a result, users have the freedom to select the pluggable optical transceivers that best suit their applications and to modify the configurations of the transponders.

The DSP block uses high-speed processing of the digital signals to convert the format of the transmitted and received signals and to add error correction codes and other necessary information. The optical transceivers transmit signals with multilevel modulation and demodulate received signals using coherent wave detection in real time.

Among the functional blocks of the transponders, the digital coherent optical transceiver is responsible for the optical interface and not only directly affects the transmission capacity and power consumption but also occupies an important role in making the technology more open and green. As a result, the form factors, specifications, and power consumption standards that ensure interoperability are being actively promoted in standardization activities.

3. Digital Coherent Optical Transceivers

Section 3 introduces NEC's efforts to develop high-capacity digital coherent optical transceivers, the trends toward open and green technology, and also miniaturization.

3.1 Technology for over-800 Gbps optical transmission

3.1.1 Digital coherent optical communication

Digital coherent communication is one of the technologies used to increase the capacity of optical transceivers. Coherent optical communication enables multilevel modulation using information on the frequency, phase, and polarization of the carrier wave and it can significantly improve frequency utilization efficiency compared to methods that use only the intensity information of the carrier wave, which was the method used before digital coherent optical communication.

The technology for digital coherent optical communication combines this coherent optical communication with high-speed digital signal processing. Digital signal processing compensates for wavelength dispersion, polarization dispersion, and other factors that degrade the quality of waveforms caused by optical fiber transmission, thereby enabling long-distance, large-capacity transmission.

3.1.2 Multilevel modulation

Multilevel modulation is made possible by the use of the phase and polarization information of the carrier wave. An example is dual polarization quadrature phase shift keying (DP-QPSK) that transfers four modulation patterns with different phases using two polarized waves. Compared to the conventional method of information transmission where one symbol transfers one bit of data, in DP-QPSK one symbol transfers two bits of data and two symbols at different polarizations are used for transmission, so the frequency usage efficiency improves by a factor of four and thereby contributes to higher capacity transmission lines. Further improvement of the frequency usage efficiency is also advanced by the 16 quadrature amplitude modulation (QAM) that increases the number of modulation patterns to 16 by varying the amplitude information in addition to the phase information and also by the 64QAM that increases the number of modulation patterns to 64. On the other hand, an increase in the number of modulation patterns results in modulation control accuracy and clarity of modulation patterns becoming issues. To ameliorate these issues, developments of modulator control methods that do not require pilot signals, improvement of the skew correction accuracy, and improvement of the signal-to-noise ratio after long-distance transmission by frequency correction are underway.

3.1.3 Utilization of wider bandwidths

Increasing the speed of the modulated signal increases the quantity of symbols transmittable per unit of time and thereby improves the transmission capacity. Therefore, optical components such as optical modulators and optical receivers actively work to support the wider bandwidths. Meanwhile, for optical transceivers, it is not enough to adopt optical devices that support broadband, so efforts are being made to support broadband in digital signal processors (DSP) that perform high-speed digital signal processing on demodulated signals and to

Table Standardization organizations and their standards for optical transceivers.

	Organization	Standard name
Form factor MSA	QSFP MSA CFP MSA OSFP MSA, etc.	QSFP-DD CFP2-DCO OSFP-XD, etc.
Functional specification MSA	OIF OpenZR+ MSA OpenROADM MSA, etc.	400ZR OpenZR+ (400G) OpenROADM (400G), etc.

design the wiring of boards to handle high-speed signals of 70 GHz or higher.

3.1.4 FlexGrid compatibility

While the setting interval of the wavelength used for the light source has traditionally been fixed, now flexible setting changes of light source wavelengths are supported to optimize the frequency usage efficiency of the transmission lines.

3.2 Trend of openness

Various standardization organizations are involved in the openness of optical transceivers, as shown in the following **table**, from multiple perspectives such as form factors and functional specifications. NEC is involved in activities to promote such openness in optical transmission by participating in these standardization organizations to create multi-source agreements (MSA).

3.3 Trend of greenness

To make optical transceivers more environmentally friendly or green, devices must not only consume less power but also meet ever-increasing traffic demands. Therefore, discussions should not consider only a simple reduction in power consumption but also consider transmission capacity versus power consumption as an index. **Fig. 2** shows the power consumption of digital coherent optical transceivers to date. Assuming that the power consumption of a 100G digital coherent optical transceiver in 2016 is 100%, the current quad small form factor pluggable double density (QSFP-DD) transceiver consumes 24% of the power and has four times the transmission capacity. This means that the power consumption per transmission capacity is reduced to 6%. The QSFP-DD800, which is scheduled for development, consumes slightly more power than the QSFP-DD but has twice the transmission capacity, resulting in a 4% reduction in power consumption per transmission capacity compared to the 100G digital coherent optical transceivers. This is expected to contribute greatly to the greening of the entire network.

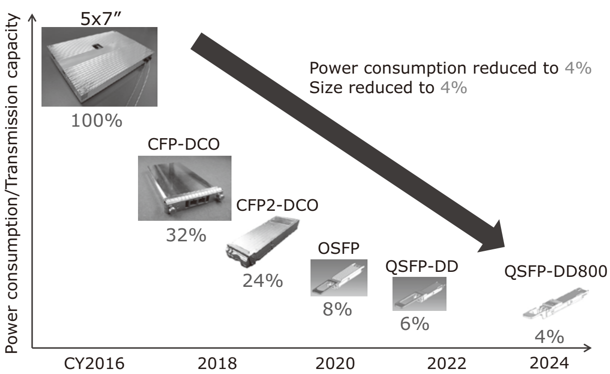

Fig. 2 Change in power consumption per transmission capacity.

3.4 Miniaturization

Compact and high density packaging technologies are indispensable to ensure transmission capacity while keeping the transceiver within the form specified in the common standards. This section introduces the technologies used in NEC's digital coherent optical transceivers to achieve these goals.

3.4.1 Miniaturization of optical components

The nano-integrable tunable laser assembly (nITLA) further miniaturizes the conventional wavelength tunable laser, and the high-bandwidth coherent driver modulator (HB-CDM) integrates the optical modulator and peripheral drivers. The nITLA and the HB-CDM are used to reduce the mounting area and to realize compact, high-quality optical transceivers.

3.4.2 High-density packaging of components

As the mounting area shrinks, there is a growing need for technology to efficiently arrange mounted components. NEC has realized high-density packaging by incorporating 3D mounting design and thermal design using 3D-CAD.

3.4.3 Miniaturization in the DSP chip process

By using a higher degree of miniaturization in the DSP chip process, an improved performance per unit area and lower power consumption can be attained. The DSP chip process has been scaled down from 40 nm about 10 years ago to 5 nm today, contributing to the significant miniaturization and low power consumption of optical transceivers.

4. Product Introduction

Finally, this section introduces the digital coherent optical transceiver products being developed at NEC as shown in **Fig. 3**.

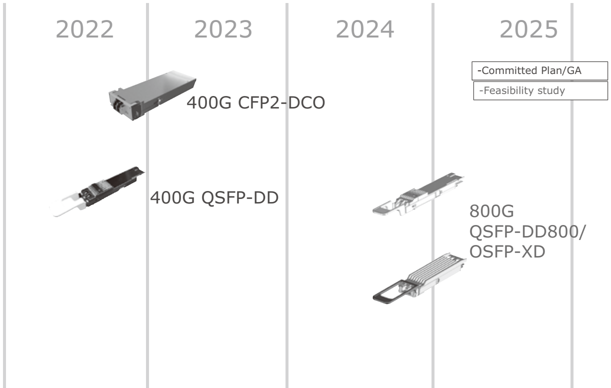

Fig. 3 NEC's roadmap of optical transceiver development.

Photo 2 400G CFP2-DCO optical transceiver.

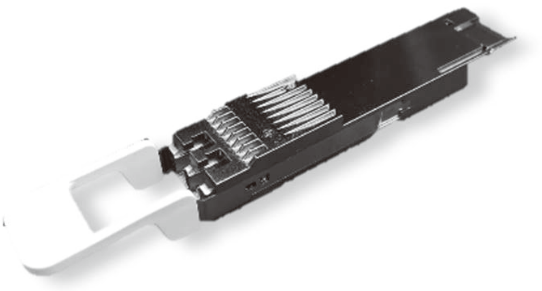

Photo 1 QSFP-DD optical transceiver that supports 400ZR and OpenZR+ specifications.

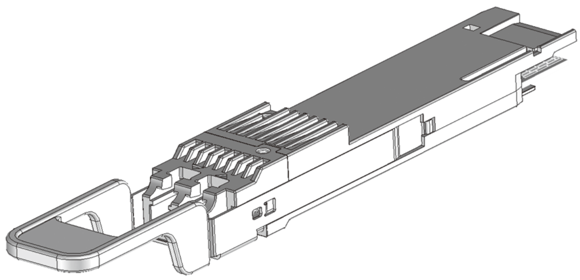

Fig. 4 QSFP-DD800 optical transceiver.

4.1 QSFP-DD that supports 400ZR and OpenZR+ specifications

The QSFP-DD shown in **Photo 1** is an optical transceiver for DCI (data center interconnect) and metro applications and supports the 400ZR and Open ZR+ specifications. This product is under production.

4.2 400G CFP2-DCO

The 400G CFP2-DCO (100-gigabit, form-factor pluggable bi-directional digital coherent optical module) shown in **Photo 2** is an optical transceiver for DCI and metro applications supporting 400ZR, OpenZR+, and OpenROADM specifications. Samples are now available.

4.3 Pluggable transceivers that support 800ZR and ZR+

The QSFP-DD800 (**Fig. 4**) and OSFP-XD (extra dense) optical transceivers will be developed for DCI and metro applications supporting 800ZR and 800ZR+. These products are under development with sample shipments targeted for 2024.

5. Conclusion

In this paper, we introduced the technologies used to increase the capacity of optical networks including digital coherent optical communication and multilevel modulation; broadband technologies; the trends toward the openness and greenness of optical transceivers; and NEC's optical transceiver products. The global trend toward higher capacity, openness, and greenness will continue to accelerate in the future. To lead these trends, NEC is determined to continue to develop and apply advanced optical device technologies to its products and participate in standardization organizations.

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