Juniper Coherent Optical Transceivers and Cables Guide

Published

2026-03-31

Juniper Networks, Inc.
1133 Innovation Way
Sunnyvale, California 94089
USA
408-745-2000
www.juniper.net

YEAR 2000 NOTICE

Juniper Networks hardware and software products are Year 2000 compliant. Junos OS has no known time-related limitations through the year 2038. However, the NTP application is known to have some difficulty in the year 2036.

END USER LICENSE AGREEMENT

Table of Contents

About This Guide

Use this guide to learn about the Juniper Networks® coherent optical transceivers and cables, their specifications, and how to install, remove, and maintain these transceivers.

1

CHAPTER

Introduction to Coherent Optical Technology

IN THIS CHAPTER

Overview

IN THIS SECTION

For decades, optical networks relied on Intensity Modulation Direct Detection (IMDD) where signaled bits were transmitted by pulsing a laser on and off. This signaling method eventually hit a ceiling as data demands exploded. To maximize network capacity and reach, optical networking evolved from simple direct-detection methods to coherent optics. This evolution makes it possible to manipulate light as an electromagnetic wave, using phase and amplitude to overcome the physical limitations of traditional on-off signaling.

Unlike traditional direct detection receivers that only measure the intensity of light, coherent detection introduces a Local Oscillator (LO) to mix with the incoming signal. This enables the receiver to capture a wave's amplitude, phase, and polarization rather than just its brightness. The detailed wave state enables coherent systems to achieve high data rates and extended reach required for modern network backbones.

Foundations of Coherent Transmission

IN THIS SECTION

The performance of a coherent link depends on three core components: the Digital Signal Processor (DSP), advanced modulation formats, and Forward Error Correction (FEC). While modulation defines how data is encoded onto the light wave, the DSP and FEC act as the system’s computational engine, mathematically reconstructing the signal and correcting errors caused by physical optical fiber impairments.

Digital Signal Processor

The Digital Signal Processor (DSP) is the core of a coherent transceiver. It enhances transmission distance, efficiency, and power consumption. In modern coherent modules (Juniper Coherent Optics [JCO] series), the DSP performs massive computational tasks in real time, including:

- **Dispersion compensation:** As light travels through optical fiber, different wavelengths travel at different speeds (chromatic dispersion) causing pulses to spread and overlap. The DSP applies inverse mathematical filters to reverse this distortion and eliminate the need for physical Dispersion Compensation Modules (DCMs) on the optical fiber line.
- **Carrier recovery:** The DSP tracks and corrects for frequency offsets between the transmitter and the local oscillator.
- **Forward Error Correction (FEC):** The DSP analyzes the statistical probability of bit values to correct errors that would otherwise result in data loss. This provides a significant coding gain, extending the reach of the signal.

Modulation Techniques

Modern coherent optics provide flexibility by using software to change modulation formats, allowing operators to trade capacity for reach.

Dual Polarization Quadrature Phase Shift Keying

Dual Polarization Phase Shift Keying (DP-QPSK) is a modulation technique that encodes 2 bits per symbol. It is extremely robust against noise and is used for ultra-long-haul links (thousands of kilometers).

Quadrature Amplitude Modulation

Quadrature Amplitude Modulation (QAM) adds amplitude variation to phase states, allowing higher data rates. It doubles the data rate compared to QPSK but requires a higher Optical Signal-to-Noise Ratio (OSNR).

Table 1: QAM Guidance

Modulation	Bits per symbol	Symbol rate
4QAM	2	1/2 x bit rate
8QAM	3	1/3 x bit rate

Table 1: QAM Guidance *(Continued)*

Modulation	Bits per symbol	Symbol rate
16QAM	4	1/4 x bit rate

Probabilistic Constellation Shaping

Probabilistic Constellation Shaping (PCS) is an advanced signal processing technique that optimizes high baud-rate transmission in 400G and 800G optical systems using probabilistic or geometric shaping.

- Probabilistic shaping adjusts the frequency of symbol use on a standard QAM grid to favor noise-resilient, low-energy points.
- Geometric shaping reconfigures the physical location of the constellation points to maximize the distance between symbols.

By favoring these noise-resilient symbols, the optical engine lowers the average signal power and minimizes the distortion caused by fiber non-linearities. This approach enhances OSNR tolerance and facilitates long-distance transmission across regional and long-haul spans that would otherwise require lower-capacity modulation. Consequently, PCS enables granular rate adaptation, allowing the hardware to maximize data throughput by tuning the information rate in small increments to match the specific link budget of a fiber span.

Forward Error Correction

In coherent networking, coherent signals use complex modulation to pack more bits into every pulse and are more susceptible to noise. Forward Error Correction (FEC) ensures that these high-speed signals remain reliable.

FEC is a digital signal processing method used to detect and correct bit errors without the need for retransmission. The transmitter adds redundant data (overhead) to the signal before it is sent. The receiver then uses this extra information to mathematically reconstruct any bits that were corrupted during transit.

FEC Algorithms

FECs are implemented through FEC algorithms. FEC algorithms are specific mathematical techniques or coding schemes. FEC algorithms detect and correct errors in transmitted data without requiring retransmission. The FEC process involves two steps:

- **Encoding** (at the Tx or Transmitter)—The FEC algorithm processes the original data and adds redundant bits or parity bits based on a specific mathematical rule. The encoded data is then transmitted over the communication channel.
- **Decoding** (at the Rx or Receiver)—The receiver uses the FEC algorithm to analyze the received data, including the redundant bits. If errors are detected, the algorithm attempts to correct them based on the redundancy.

The error correction capability of FEC depends on the specific algorithm used and the amount of redundancy added. Some of the commonly used FEC algorithms include:

- Reed-Solomon (RS) FEC
- Soft-Decision FEC (SD-FEC)
- Low-Density Parity-Check (LDPC) Codes
- Bose-Chaudhuri-Hocquenghem (BCH) Codes
- Concatenated FEC (CFEC)

The choice of FEC algorithm depends on the specific requirements of the communication system:

- **Data rate**—High-speed systems require more efficient algorithms. This could be LDPC or turbo codes.
- **Error characteristics**—Burst errors are better handled by block codes such as Reed-Solomon.
- **Latency**—Real-time applications such as video streaming require low-latency algorithms.
- **Power and complexity**—Systems with limited computational resources may use simpler codes like Hamming or BCH.

Optical Signal-to-Noise Ratio Tolerance

Optical Signal-to-Noise Ratio (OSNR) is the ratio between the power of the light signal and the noise floor of the optical link. OSNR tolerance is the minimum OSNR a receiver can handle before it can no longer correct errors. A stronger FEC (like OFEC) has a low OSNR threshold and can retrieve a clean signal out of a much noisier environment. The improvement in OSNR achieved using FEC is measured as Net Coding Gain (NCG).

FEC Types

The pluggable coherent optics support two types of FEC methods:

- **Concatenated forward error correction (CFEC)**: The CFEC is an FEC method used in ZR optics. CFEC concatenates two FEC codes with each other, an inner soft-decision Hamming (128,119) code and an outer Staircase BCH (255, 239) hard-decision outer code. The concatenation helps to obtain the optical performance as specified in the OIF ZR implementation agreement. CFEC uses hard-decision decoding, which is fast and results in sub-microsecond latency.

- **Open forward error correction (OFEC)**: The OFEC is an FEC method used in OpenZR+ optics. OFEC consists of a Turbo Product Code (TPC) using an Extended BCH (256, 239) code with 3-iteration soft-decision decoding. The improved performance of OFEC compared to CFEC is critical to achieve the higher optical performance as specified in the OpenZR+ MSA. OFEC uses soft-decision iterative decoding, where the DSP checks the data multiple times to ensure accuracy. This significantly increases the processing time (latency).

Dense Wavelength Division Multiplexing

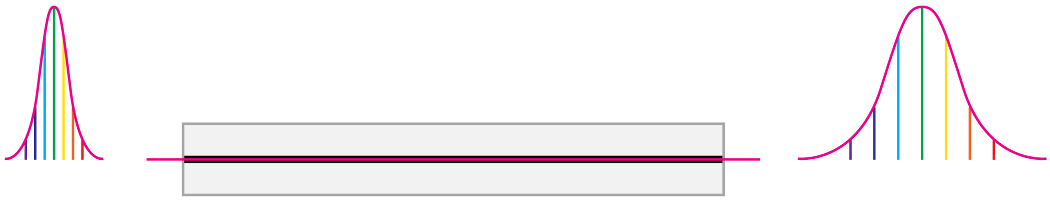
Coherent optics uses Dense Wavelength Division Multiplexing (DWDM). This technology increases the amount of data that can be transmitted over a single optical fiber. DWDM achieves this by using multiple light wavelengths or channels. The two types of DWDM connections used by Juniper's coherent DWDM optics are:

- **Unamplified link** (limited optical power)—In an unamplified link, the optical signal is sent through the optical fiber without any amplification. In this type of coherent DWDM optics, the maximum transmission distance is limited by the natural loss of optical power as the signal travels through the optical fiber. Without amplification, the light signal gradually weakens, restricting the distance it can travel. An unamplified link is more suitable for shorter distances and is often referred to as a power-limited optical signal.

- **Amplified link** (limited optical signal-to-noise ratio and chromatic dispersion)—In an amplified link, the optical signal strength is boosted using optical amplifiers. As you boost the signal strength in amplified link, the signal can travel long distances. However, it can also introduce noise or loss in signal quality. The noise is more prominent if you are using Erbium-Doped Fiber Amplifier (EDFAs). A high OSNR value ensures that the noise is low and the signal quality is acceptable.

Chromatic dispersion occurs because different wavelengths of light travel at different speeds through the optical fiber. This can cause signal distortion, especially over long distances. During optical transmission, short-duration input optical signals composed of multiple wavelengths or colors are incident on the optic fiber. The colored lines within the optical signal correspond to different wavelengths. These varied wavelengths in the optic signal enter the optical fiber simultaneously but propagate at different velocities due to their unique refractive indices. After traveling through the optical fiber, the output optical signal broadens and the different colors or wavelengths spread apart. This indicates that longer wavelengths have traveled at a different speed than shorter wavelengths.

Figure 1: Chromatic Dispersion



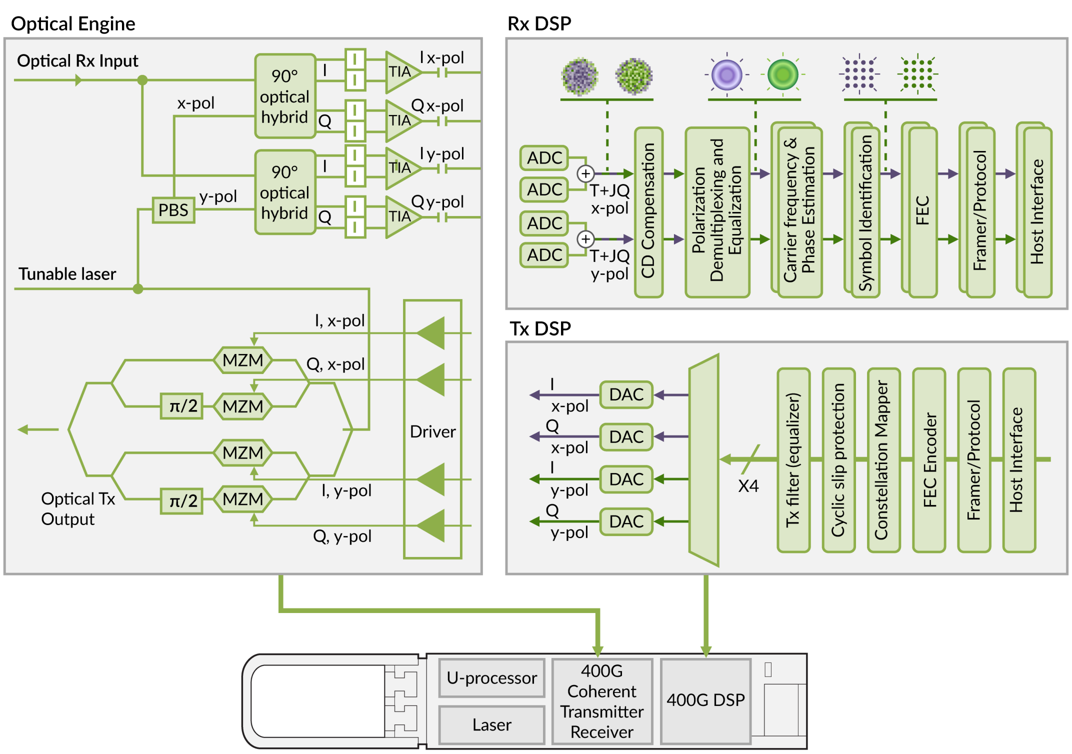
Chromatic dispersion in fiber caused by longer wavelengths traveling faster.

g103216

> **NOTE**: To overcome the OSNR limitation, a RAMAN amplifier can be used. RAMAN amplifiers have lower effective noise figure as they amplify the signal along the fiber.

For more information about the maximum chromatic dispersion and minimum ROSNR values of individual transceivers, see Hardware Compatibility Tool.

Figure 2: Coherent DWDM Optics Architecture (400G)



Coherent Standards and Interoperability

IN THIS SECTION

As optical networks transition to disaggregated architectures, interoperability ensures that coherent pluggable optics function across diverse platforms and optical infrastructures, regardless of speed.

OIF ZR compliance (100G, 400G, 800G)

The Optical Internetworking Forum (OIF) defines the ZR specifications to optimize high-density, point-to-point Data Center Interconnect (DCI) up to 120 km.

- **100G ZR**: Brings coherent benefits to the QSFP28 form factor with typical use cases in edge and access backhauls.
- **400ZR**: The foundational standard for interoperable 400G. It uses DP-16QAM modulation and Concatenated FEC (CFEC) to ensure a common baseline for all hardware vendors.
- **800ZR**: Enables 800G per wavelength for massive scale. It uses more advanced modulation to fit double the capacity into a similar spectral footprint.

OpenZR+ MSA Support

The OpenZR+ Multi-Source Agreement (MSA) was formed to enhance the 120 km limit of OIF ZR. It combines the Ethernet-friendly aspects of ZR with the high-performance OFEC used in carrier-grade systems to provide the following benefits:

- **Extended reach**—With OFEC, OpenZR+ modules can reach regional and metro distances (450km to 1000km+).
- **Multi-rate flexibility**—A single OpenZR+ module is often configurable. An 800G-capable module can be configured to run at 400G or 200G to achieve significantly longer distances or to operate over older, noisier optical fiber.

- **Interoperability**—OpenZR+ allows routers to communicate over brownfield networks by matching the modulation and FEC settings across different hardware vendors.

Interoperability with Open Line Systems

Modern coherent optics (JCO series) are designed to operate within disaggregated optical architectures. Through grid compliance, standardized signaling, and Common Management Interface Specification (CMIS), a Juniper Networks router equipped with a JCO series optic can transmit directly into a third-party optical line system consisting of amplifiers and Reconfigurable Optical Add-Drop Multiplexers (ROADMs) from other manufacturers.

Power Classes

IN THIS SECTION

One of the most critical decisions in deploying modern coherent optics is selecting the correct transmit output power. This generally splits into Standard Power (-10 dBm) and High Power (or "Bright", 0 dBm) variants.

In modern deployments (Greenfield), a new DCI link from scratch, operators often use simple point-to-point systems. These systems are designed to accept the lower power standard of OIF ZR (-10 dBm). Because the entire link is new, the line system amplifiers are engineered to handle this lower input signal.

Most telecom service providers have existing ROADM networks (Brownfield or legacy networks) that were built for older transponders. These legacy networks typically expect input signals at 0 dBm.

Standard Power Optics (-10 dBm)

These modules focus on power efficiency and cost. By omitting a high-power booster amplifier, they keep the module's power consumption lower (typically <20W for 400G). If you plug a -10 dBm module into a legacy ROADM expecting 0 dBm, the signal will be too weak. The ROADM's amplifiers may introduce excessive noise (ASE) when trying to boost this weak signal, resulting in a severe OSNR penalty. In many cases, the link simply won't come up.

Using these in brownfield networks requires external amplification (e.g., an external EDFA chassis) before the signal enters the ROADM. This adds rack space, cost, and complexity thereby negating the benefits of IPoDWDM.

Use standard power optics if you're building a short point-to-point link (DCI) or have a modern open line system explicitly designed for ZR optics.

High Power (Bright) Optics (0 dBm)

These modules integrate a miniaturized EDFA or Semiconductor Optical Amplifier (SOA) directly inside the pluggable transceiver. They output signal at 0 dBm to +1 dBm that allows them to match the power levels of existing 10G and 100G wavelengths on the optical fiber.

You can plug a high power optical transceiver directly into a router port and patch it into an existing ROADM add/drop port. The ROADM sees it as just another valid 0 dBm signal enabling operators to upgrade capacity without overhauling their optical line systems.

Use high power optics if you are traversing a ROADM network, integrating with legacy telecom infrastructure, or need the extra optical budget to span longer distances without amplification.

2
CHAPTER

Coherent Optical Technology in Juniper Networks

IN THIS CHAPTER

Converged Optical Routing Architecture

IN THIS SECTION

In traditional architectures, the IP layer (routers) and the Optical Layer (transponders and ROADMs) were managed as two separate entities. The Converged Optical Routing Architecture (CORA) combines these layers into a unified, packet-centric architecture by integrating the high-performance coherent optics (JCO series) directly into the router.

IP over Dense Wavelength Division Multiplexing

IN THIS SECTION

IP over Dense Wavelength Division Multiplexing (IPoDWDM) is the technological foundation of CORA. It eliminates the need for a standalone transponder shelf by integrating the DWDM interface into the router's line card. Instead of handing off a short-reach signal to an external transport system, the router generates the colored DWDM signal itself.

Benefits

- **Direct visibility**—Because the optic lives inside the router, Junos OS sees the optical layer directly. Operators can monitor OSNR, CD, and Polarization Dependent Loss (PDL) straight from the router CLI or using telemetry.
- **Reduced overhead**—Managing only the router instead of both a router and a transponder reduces operational complexity. Using Netconf/YANG models further automates optical parameter provisioning.

- **Power efficiency**—Router-based coherent optics consume significantly less power than shelf-based transponders. This efficiency maintains high port density without exceeding thermal limits in data centers or central offices.

Figure 3: Traditional and CORA Architectures

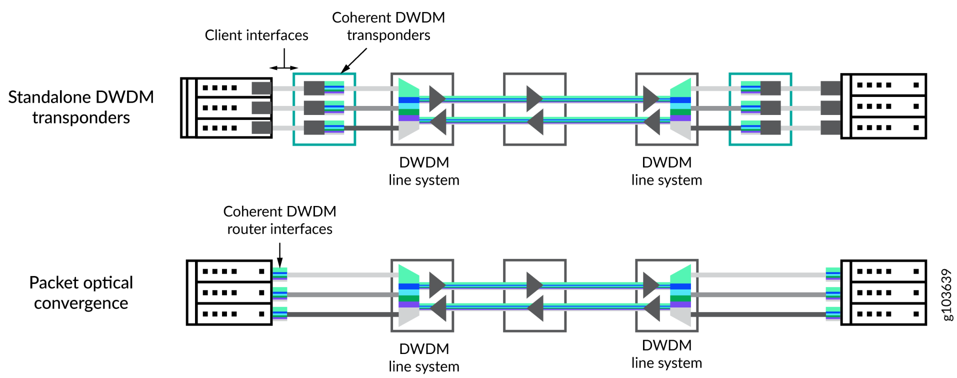


Table 2: Traditional Transport vs. CORA Architecture

Feature	Traditional Transport	CORA (IPoDWDM)
Hardware	Router and transponder shelf	Router with coherent optical transceivers
Footprint	High (multiple racks)	Low (router only)
Power	~50 W-100 W per 100G	~15 W-25 W per 400G/800G
Management	Two separate NMS platform	Unified IP/Optical management
Interconnect	Short-reach gray optics	No intermediate gray optics needed

Form Factors

IN THIS SECTION

Form factor refers to the physical dimensions and shape of a transceiver. The properties of a transceiver's form factor include size, shape, connector type, and other physical characteristics. It determines how the transceiver fits into networking equipments like switches, routers, or servers.

QSFP-DD

IN THIS SECTION

Juniper Networks supports the Quad Small Form Factor Pluggable Double Density QSFP-DD) form factor for 400G (QSFP56-DD) and 800G (QSFP-DD800) transceivers. The QSFP-DD form-factor is defined by the QSFP-DD MSA industry consortium. Juniper Networks is a founding member of the consortium. QSFP-DD can accommodate more ports per unit area than other form factors.

The QSFP-DD host cage design supports backward compatibility with QSFP28 and QSFP. You do not need any external mechanical adapter to support legacy transceivers. QSFP-DD is both forward and backward compatible.

Table 3: Features of QSFP-DD Form Factor

Feature	QSFP-DD	Notes
Size	Small	—
Heat sink	Standard heat sink limited by size constraints. Supports a riding heat sink	—
Host/electrical connector style	Small connector with 76 connector pins (16 differential pairs, the remaining pins being power, ground, status and control pins.)	—
Power consumption	Up to 30 W	For more information about the specific power consumption of individual transceivers, see Hardware Compatibility Tool.
Thermal requirements	Standard: 0 through 70 °C High power modules: 75 °C through 80 °C	Transceiver modules with QSFP-DD form factors are designed to operate within the case temperature ranges provided.
Backward compatibility	Compatible with some of the other QSFP transceiver module ports such as QSFP56, QSFP28, and QSFP+.	Backward compatibility with the existing hardware ensures smooth transition, upgrade, operational flexibility, and cost savings.

The following are the performance requirements of a QSFP-DD transceiver module:

Table 4: Performance Requirements of a QSFP-DD Transceiver Module

Performance Parameters	Description	Requirements
Mechanical or physical tests		
Plating type	Plating type on connector contacts	Precious

Table 4: Performance Requirements of a QSFP-DD Transceiver Module *(Continued)*

Performance Parameters	Description	Requirements
Surface treatment	Surface treatment on connector contacts	Manufacturer to specify
Wipe length	Designed distance a contact traverses over a mating contact surface during mating and resting at a final position. If less than 0.127 mm, test group 6 is required	Manufacturer to specify
Rated durability cycles	The number of durability cycles that a component encounters over the course of its life	Connector cage: 100 cycles Module: 50 cycles
Mating force[1]	Amount of force needed to mate a module with a connector when latches are deactivated	QSFP module: 60 N QSFP-DD module: 90 N
Unmating force[1]	Amount of force needed to separate a module from a connector when latches are deactivated	QSFP module: 30 N QSFP-DD module: 50 N
Latch retention[1]	Amount of force the latching mechanism can withstand without unmating	QSFP module: 90 N QSFP-DD module: 90 N
Cage latch strength[1]	The amount of force that the cage latches can hold without being damaged	125 N
Cage retention to host board[1]	Amount of force a cage can withstand without separating from the host board	114 N
Environmental requirements		
Field life	The expected service life for a component	10 years

Table 4: Performance Requirements of a QSFP-DD Transceiver Module *(Continued)*

Performance Parameters	Description	Requirements
Field temperature[2]	The expected service temperature for a component	65°C
Electrical requirements		
Current	Maximum current to which a contact is exposed in use	0.5 A per signal contact MAX 1.5 A per power contact MAX 2.0 A (Single port QSFP-DD 1600) per contact MAX
Operating rating voltage	Maximum voltage to which a contact is exposed in use	30 V DC per contact MAX

1—These performance criteria are not validated by EIA-364-1000 testing.

2—Field temperature is the ambient air temperature around the component.

The following are some of the key features of the QSFP-DD form factors:

Color Codes

The QSFP-DD transceiver modules adhere to a color code by application of color to its ejector tab or other appropriate method.

Table 5: QSFP-DD Color Codes

Product Type	Color	Pantone Code
QSFP-DD copper cables	Black	Not applicable
QSFP-DD AOC Cables	Gray	422U
QSFP-DD 850 nm solutions	Beige	475U

Table 5: QSFP-DD Color Codes *(Continued)*

Product Type	Color	Pantone Code
QSFP-DD 1310 nm solutions for up to 500 m	Yellow	107U
QSFP-DD 1310 nm solutions for up to 2 km	Green	354C
QSFP-DD 1310 nm solutions for up to 10 km	Blue	300U
QSFP-DD 1310 nm solutions for up to 30 km	Red	1797U
QSFP-DD 1310 nm solutions for up to 40 km	Tangerine	1575U
QSFP-DD 1550 nm solutions for up to 80 km	White	Not applicable

Thermal Requirements

The QSFP-DD transceiver module is required to meet the following thermal requirements while sustaining maximum power:

Table 6: QSFP-DD Transceiver Module Thermal Requirements

Parameter	Value
Maximum temperature rise (when all signal and power contacts are simultaneously energized)	Vendor specific

Power Requirements

Transceiver modules have varying power consumption levels and thermal output. It depends on the overall platforms design, airflow, size, height, and quality of the heat sinks on top of the ports. The power consumption for the ZR/ZR+ optics clients is up to 30 W.

QSFP28

Juniper Networks supports the QSFP28 form factor for 100G transceivers.

Table 7: Features of QSFP28 Form Factor

Feature	QSFP28	Notes
Physical dimensions	18.35 mm x 8.5 mm x 89.4 mm	—
Relative size	Small	—
Power consumption	Standard Optics: typically < 3.5 W Coherent DWDM: up to 6.5 W	For more information about the specific power consumption of individual transceivers, see Hardware Compatibility Tool.
Signal processing	Relies on host card	—
Electrical interface	1x100G	—
Host/electrical connector configuration	High-density connector with 38 pins	—
Heat sink requirements	Minimal heat sink due to low power consumption	Heat sink design is evaluated based on system configuration
Thermal requirements	Operating: 0 °C through 70 °C Industrial: -40 °C through 85 °C	—
Port density	High	—

Table 7: Features of QSFP28 Form Factor *(Continued)*

Feature	QSFP28	Notes
Breakout capability	No (single 100G port only)	—

Connector Types

Optical connectors ensure efficient and reliable connections between fiber-optic patch cables. Connectors are designed to minimize insertion loss and back reflection, ensuring high-quality signal transmission.

Juniper coherent optical transceivers support the following connector type:

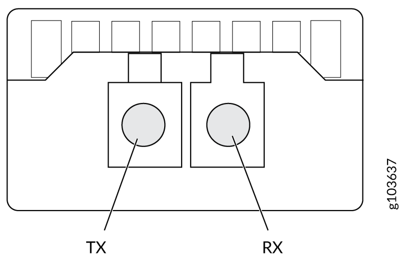
- **Duplex Lucent Connector (LC)**—A duplex LC connector is a type of connector that has small form factor and high-density design. The term duplex indicates that the connector houses two separate fiber-optic channels or lanes within a single unit. One channel is for transmission (Tx) and the other is for reception (Rx). The Tx and Rx channels enable full-duplex, bidirectional communication over a single connector. The typical LC interface is half the size of the traditional standard connector. The smaller size allows greater port density in patch panels and transceivers.

  Duplex LC/UPC is a duplex LC connector where each optical fiber end-face is polished using the ultra physical contact (UPC) method. For example, JCO400-QDD-ZR uses duplex LC/UPC connectors.

  > **NOTE**: Coherent DWDM optical transceivers such as JCO400-QDD-ZR, JCO400-QDD-ZR-M, JCO400-QDD-ZR-M-HP, and JCO800-QDD-ZR-M-HP use Duplex LC connectors for their optical connections.

  Figure 4 on page 21 represents the channel or lane allocation for an optical transceiver using duplex LC connector.

Figure 4: Duplex LC Connector Lanes



Patch Cable and Length

IN THIS SECTION

Cables are the physical medium that transmit optical and electrical signals. Juniper offers a wide variety of high-performance and cost-effective cables. These optical and electrical cables are available in various dimensions, distance ranges, and speeds. For more information, see Optical and Electrical Cables.

Juniper coherent optics support Single-Mode Fiber (SMF) patch cables. The length of the patch cable is determined by the link's optical budget and whether the link is amplified. SMFs have a core diameter of 9 microns and supports higher data rates and longer distances with minimal dispersion. The applications include long-distance communication and high-bandwidth transmission.

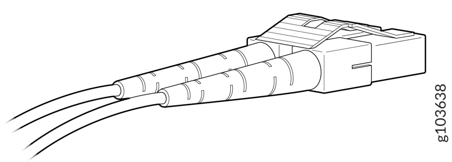
Table 8: Supported Cables and Connectors

Component	Specification
Fiber Type	OS2 Single-mode fiber (G.652.D or G.657.A)
Connector Type	LC Duplex
Fiber Core	9 µm

Table 8: Supported Cables and Connectors *(Continued)*

Component	Specification
Fiber Cladding	125 µm

Figure 5: LC Duplex Connector with SMF Cable



Patch Cable Length and Transmission Reach

Coherent optics use complex digital signal processing to transmit data over hundreds or thousands of kilometers. The maximum patch cable length for coherent optics is determined by the following factors:

- **Optical power budget**—In unamplified point-to-point links, the primary limiting factor is signal strength.
    - **Transmitter launch patch power**—The strength of the signal leaving the module (e.g., –10 dBm to 0 dBm).
    - **Receiver sensitivity**—Minimum power level the receiver needs to distinguish "1s" from "0s" (e.g., –20 dBm).
    - **Fiber attenuation**—A standard OS2 fiber loses roughly 0.25 dB per km at 1550nm.
    - **Passive loss**—Includes connector losses (typically 0.3 dB to 0.5 dB per pair) and splice losses (0.1 dB).
- **OSNR**—For longer, amplified links the bottleneck is signal integrity (instead of power).
    - **Amplifier noise**—Add a noise floor (Amplified Spontaneous Emission or ASE) every time you amplify the signal for distance.

  - **Required OSNR**—Higher data rates (800G) require a much higher OSNR (cleaner signal) than 100G. If the noise floor rises too high relative to the signal, the DSP cannot recover the data, even if the power level is high.

- **Dispersion**—While DSPs can fix signal distortion, they have limits.

  - **Chromatic dispersion (CD)**—Light of different wavelengths travels at different speeds, causing pulses to spread out. While Juniper coherent optics can compensate for thousands of kilometers of CD, every module has a specific tolerance (e.g., 2,400 ps/nm for a 400ZR).

  - **Polarization mode dispersion (PMD)**—Physical imperfections in the fiber can cause light to arrive at different times based on its polarization. A high PMD in older fibers can significantly shorten the usable cable length.

- **Signal regeneration**—The physical boundary where an optical signal must be reconstructed to continue.

  - **Regeneration threshold**—When accumulated noise or dispersion exceeds the DSP's compensation limit, you must perform an Optical-Electrical-Optical (OEO) conversion. This acts as a hard reset by removing any accumulated errors and retransmitting a clean signal.

  - **Capex and Opex impact:**—OEO requires a full set of transceivers and active chassis, making it significantly more expensive than an amplifier. The number of OEO sites on a path is a primary driver of the total cost-per-bit.

  - **Latency budget**—Each OEO hop adds microsecond-level processing latency for FEC decoding/encoding. For latency-sensitive applications (like high-frequency trading), the reach is often limited to avoid these regeneration points.

- **Modulation format and Baud rate**—The speed you choose directly changes how far you can go.

  - **Spectral efficiency**—A module running 16QAM (800G/400G) is fast but fragile. The signal can only travel shorter distances (metro reach).

  - **Downspeeding**—For long-haul, a coherent module might drop from 16QAM to QPSK (from 400G to 100G). A simpler signal can survive the noise and dispersion of a 1,000 km+ cable.

- **Fiber type and quality**

  - **Standard SMF (G.652)**—The most common OS2 fiber used for most calculations.

  - **NZDSF (G.655)**—Older fiber that can sometimes cause non-linear effects (like signal interference) when used with high-power coherent signals.

  - **Bend radius**—Micro-bends in patch panels or tight turns in cable trays increase attenuation. This effectively shortens your maximum distance by degrading your power budget.

- **Aging**—A margin (example 3 dB) must be subtracted from the total budget to factor:

- Fiber aging
- Future repairs (new splices)
- Environmental temperature changes that affect laser stability

For more information about the specific distance range of individual transceivers, see Hardware Compatibility Tool.

Juniper Optical Product Numbers

Juniper's optical components such as transceivers, cables, and connectors follow a naming convention. Each element in the product name corresponds to a specification. It helps you to better understand and select the appropriate optical component.

The standard format for Juniper Coherent Optics (JCO) is represented by:

```
[Brand][Speed]—[Form Factor]—[Protocol/Reach]—[Power Class]
```

For example:

- JCO400-QDD-ZR-M-HP
  - JCO—Juniper Coherent Optics. All modern Juniper Networks coherent transceivers use this prefix.
  - 400—The data rate (100, 400, or 800 Gbps).
  - QDD—QSFP-DD (QSFP28 for 100G coherent). Identifies the form-factor of the transceiver.
  - ZR—Follows the OIF 400ZR standard (typically using CFEC).
  - M—Metro or Multi-haul. Indicates OpenZR+ support and the use of OFEC for longer distances.
  - HP—High Power (often called *Bright* optics). These have an integrated micro-amplifier.

3

CHAPTER

Juniper Coherent Optical Transceivers

IN THIS CHAPTER

800ZR and 800G OpenZR+

IN THIS SECTION

Overview

The 800ZR is an Optical Interworking Forum (OIF) standard for transporting 800GbE over long distances through fiber-optic patch cables. The standard defines the solution to transport 800GbE optical signals using a single wavelength.

The primary application of 800ZR optics is to interconnect data centers within a distance of up to 450 km. Data centers require high bandwidth, high speed, and low latency networks. The 800ZR optical module meets these requirements.

800G OpenZR+ is an extension of 800ZR specifications to improve performance and adheres to OpenZR+ MSA standard.

Some characteristics of the 800ZR and 800G OpenZR+ optics are:

- Configuration of different speeds and negotiation between capacity and reach. For example, 800 Gbps can support a nominal reach of 450 kms, 600 Gbps up to 900 kms, and 400 Gbps up to 1800 kms.
- Capacity to carry the signals across long distances through fiber-optic patch cables with periodic optical amplification.
- Fully C-band tunable and dense wavelength-division multiplexing. We support 6.25/12.5/50/75/100 GHz channel spacings.
- Ability to operate in amplified and unamplified modes.

Transceiver Specifications

IN THIS SECTION

Form Factor

Juniper's coherent 800G transceivers make use of the QSFP-DD800 form factor (commonly referred as QSFP-DD). For more information on the QSFP-DD form factor, see "QSFP-DD" on page 14.

Juniper 800ZR and 800G OpenZR+ Transceivers

Juniper's coherent 800G transceivers cater to data center and AI-ML cluster applications for routing and switching solutions. To support the multi-vendor network environment, Juniper 800G transceivers adhere to key industry standards.

For a list of all 800G optics and their supported platforms for 800ZR and 800 OpenZR+, see Hardware Compatibility Tool.

Connector Types

Juniper’s coherent 800G transceivers support duplex LC PC/UPC connector type. For more information, see "Connector Types" on page 20.

Patch Cable Type and Length

Juniper’s 800G coherent optics utilize SMF to achieve extended reach across high-density optical links. For information on fiber media and patch cable lengths, see "Patch Cable and Length" on page 21.

Breakout Capabilities

Juniper's coherent 800G transceivers operate over single-mode fiber (SMF) using duplex optical connectors (commonly LC). Unlike conventional Ethernet optics that rely on multiple parallel optical lanes and support physical breakout cables, coherent modules transmit traffic on a single modulated optical wavelength.

These optics provide muxponder-like functionality by mapping client traffic into a single coherent carrier and support software-selectable operating rates (such as 100 GbE, 200 GbE, or 400 GbE). The selected mode adjusts parameters such as modulation format and forward error correction to optimize link reach and meet optical signal-to-noise ratio (OSNR) requirements.

Because the transmission uses a single coherent wavelength, the optical signal cannot be physically split into multiple interfaces using breakout cables. Any separation of transported Ethernet traffic occurs only after coherent demodulation at the receiving system. The receiving platform may then map the received client traffic to logical interfaces or, depending on platform capabilities, to separate physical Ethernet interfaces.

The 800G OpenZR+ coherent transceivers support the following rate selections:

- 1 x 800GbE
- 2 x 400GbE
- 4 x 200GbE
- 8 x 100GbE
- 3 x 200GbE
- 6 x 100GbE
- 1 x 400GbE
- 2 x 200GbE

Licensing

You need a Juniper Coherent Optics or Third-party Coherent Optics Software License to use the 800ZR and 800G OpenZR+ coherent DWDM transceivers on Juniper devices. For information about the licensing model for the coherent 800ZR and 800G OpenZR+ optics, see Software Licenses for Juniper Coherent Optics. For additional information about License management, see Licensing Guide. You can also contact your Juniper Account Team or Juniper Partner.

400ZR and 400G OpenZR+

IN THIS SECTION

Overview

The 400ZR is an Optical Interworking Forum (OIF) standard for transporting 400GbE over long distances through fiber-optic patch cables. The standard defines the solution to transport 400GbE optical signals using a single wavelength.

The primary application of 400ZR optics is to interconnect data centers within a distance of up to 120 km. Data centers require high bandwidth, high speed, and low latency networks. The 400ZR optical module meets these requirements.

400G OpenZR+ (model numbers: QDD-400-ZR-M, JCO400-QDD-ZR-M, QDD-400G-ZR-M-HP, and JCO400-QDD-ZR-M-HP) is an extension of 400ZR specifications to improve performance and adheres to OpenZR+ MSA standard.

Some characteristics of the 400ZR and 400G OpenZR+ optics are:

- Configuration of different speeds and negotiation between capacity and reach. For example, on the QDD-400G-ZR-M and JCO400-QDD-ZR-M transceivers, 400 Gbps can support a nominal reach of 500 km, 300 Gbps up to 900 km, and 200 Gbps up to 2000 km. Exact reach depends on an optical line system that is in use (400G OpenZR+ optics only).

- Capacity to carry the signals across long distances through fiber-optic patch cables with periodic optical amplification.

- Fully C-band tunable and dense wavelength-division multiplexing. We support 75-GHz and 100-GHz channel spacings.

- Ability to operate in amplified and unamplified modes.

- Support for 400 Gbps speed. You can use the port as one 400GbE interface or channelize it to operate from one up to four 100GbE interfaces.

Transceiver Specifications

IN THIS SECTION

Form Factor

Juniper's coherent 400G transceivers make use of the QSFP56-DD form factor (commonly referred as QSFP-DD). For more information on the QSFP-DD form factor, see "QSFP-DD" on page 14.

Juniper 400ZR and 400G OpenZR+ Transceivers

For a list of all 400G optics and their supported platforms for 400ZR and 400G OpenZR+, see Hardware Compatibility Tool.

Connector Types

Juniper's coherent 400G transceivers support Duplex LC PC/UPC connector type. For more information, see "Connector Types" on page 20.

Patch Cable Type and Length

Juniper's 400G coherent optics utilize SMF to achieve extended reach across high-density optical links. For information on compatible fiber media and patch cable lengths, see "Patch Cable and Length" on page 21.

Breakout Capabilities

Juniper's coherent 400G transceivers operate over single-mode fiber (SMF) using duplex optical connectors (commonly LC). Unlike conventional Ethernet optics that rely on multiple parallel optical lanes and support physical breakout cables, coherent modules transmit traffic on a single modulated optical wavelength.

These optics provide muxponder-like functionality by mapping client traffic into a single coherent carrier and support software-selectable operating rates (such as 100 GbE, 200 GbE, or 400 GbE). The selected mode adjusts parameters such as modulation format and forward error correction to optimize link reach and meet optical signal-to-noise ratio (OSNR) requirements.

Because the transmission uses a single coherent wavelength, the optical signal cannot be physically split into multiple interfaces using breakout cables. Any separation of transported Ethernet traffic occurs only after coherent demodulation at the receiving system. The receiving platform may then map the received client traffic to logical interfaces or, depending on platform capabilities, to separate physical Ethernet interfaces.

The 400G OpenZR+ coherent transceivers support the following rate selections:

- 1 x 100GbE
- 2 x 100GbE
- 3 x 100GbE
- 4 x 100GbE
- 1 x 400GbE

Licensing

You need a Juniper Coherent Optics or Third-party Coherent Optics Software License to use the 400ZR and 400G OpenZR+ coherent DWDM transceivers on Juniper devices. For information about the licensing model for the coherent 400ZR and 400G OpenZR+ optics, see Software Licenses for Juniper Coherent Optics. For additional information about License management, see Licensing Guide. You can also contact your Juniper Account Team or Juniper Partner.

100G ZR

IN THIS SECTION

Overview

The 100G ZR is a coherent optical solution designed for transporting 100GbE over long distances through fiber-optic patch cables. This standard defines the technology required to transport 100GbE optical signals using a single wavelength.

The primary application of 100G ZR optics is to provide high-bandwidth connectivity for edge routing, metro aggregation, and data center interconnects (DCI) within a distance of up to 80 km in unamplified links and significantly further in amplified systems. The 100G ZR optical module provides a cost-effective path for operators to scale bandwidth without requiring complex transponder shelves.

Some characteristics of the 100G ZR optics are:

- Configuration of different modulation formats (such as DP-QPSK) to balance capacity and reach. While optimized for 100 Gbps, these optics can support a nominal reach of 80 km in point-to-point unamplified scenarios and up to 300 km or more with periodic optical amplification.
- Capacity to carry signals across long distances through fiber-optic patch cables by utilizing DSP to mitigate fiber impairments like chromatic dispersion (CD).
- Fully C-band tunable and supports dense wavelength-division multiplexing. These modules typically support standard 50 GHz or 100 GHz channel spacings, allowing for high spectral efficiency in existing optical fibers.
- Ability to operate in both amplified and unamplified modes, making them suitable for simple passive filter deployments or complex integrated optical line systems.

Transceiver Specifications

IN THIS SECTION

Form Factor

Juniper coherent 100G transceivers make use of the QSFP28 form factor. For more information on the QSFP28 form factor, see "QSFP28" on page 19.

Juniper 100G ZR Transceivers

For a list of all 100G optics and their supported platforms for 100G ZR, see Hardware Compatibility Tool.

Connector Types

Juniper's coherent 100G transceivers support Duplex LC PC/UPC connector type. For more information, see "Connector Types" on page 20.

Patch Cable Type and Length

Juniper's 100G coherent optics utilize SMF to achieve extended reach across high-density optical links. For information on compatible fiber media and patch cable lengths, see "Patch Cable and Length" on page 21.

Breakout Capabilities

Juniper's coherent 100G transceivers operate exclusively over SMF using LC duplex connectors. Unlike standard optics that use physical breakout cables to split port speeds, coherent modules utilize Software-Defined Rate Selection (logical channelization). As the signal is delivered over a single wavelength, physical breakout to multiple downstream devices is not supported. All rate-based channelization occurs within the logical configuration of the single fiber pair.

The 100G coherent transceivers support the 1 x 100GbE rate selection.

4

CHAPTER

Install or Remove Coherent Optical Transceivers and Fiber-Optic Cables

IN THIS CHAPTER

Install an QSFP-DD or QSFP28 Transceiver

SUMMARY

Use the information in this topic to install QSFP-DD or QSFP28 optical transceivers and fiber-optic patch cables. Juniper Networks transceivers are hot-removable and hot-insertable field-replaceable units (FRUs). You can remove and replace them without powering off your device or disrupting device functions. To understand how to install or remove a transceiver and fiber-optic patch cables of your device, read the following sections.

Before you install a transceiver in a device, ensure that you have taken the necessary precautions for safe handling of lasers (see Laser and LED Safety Guidelines and Warnings).

NOTE: We recommend that you use only optical transceivers purchased from Juniper Networks with your Juniper Networks device.

CAUTION: The Juniper Networks Technical Assistance Center (JTAC) provides complete support for Juniper-supplied optical modules. However, JTAC does not provide support for third-party optical modules that are not qualified or supplied by Juniper Networks. If you face a problem running a Juniper device that uses third-party optical modules, JTAC may help you diagnose host-related issues if the observed issue is not, in the opinion of JTAC, related to the use of the third-party optical modules. Your JTAC engineer will likely request that you check the third-party optical module and, if required, replace it with an equivalent Juniper-qualified component.

Use of third-party optical modules with high-power consumption (for example, coherent ZR or ZR+) can potentially cause thermal damage to or reduce the lifespan of the host equipment. Any damage to the host equipment due to the use of third-party optical modules is the users' responsibility. Juniper Networks will accept no liability for any damage caused due to such use.

To install an QSFP-DD or QSFP28 transceiver:

1. Wrap and fasten one end of the ESD wrist strap around your bare wrist, and connect the other end of the strap to a site ESD point or to the ESD point on the device.
2. Remove the transceiver from its bag.

CAUTION: To avoid electrostatic discharge (ESD) damage to the transceiver, do not touch the electrical connector pins at the end of the transceiver.

3. Check to see whether the transceiver is covered by a rubber safety cap. If it is not, cover the transceiver with a rubber safety cap.

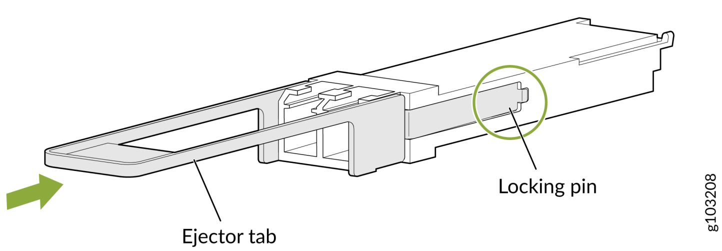
LASER WARNING: Do not leave a fiber-optic transceiver uncovered except when inserting or removing a cable. The rubber safety cap keeps the port clean and prevents accidental exposure to laser light.

4. If the port in which you want to install the transceiver is covered with a dust cover, remove the dust cover and save it in case you need to cover the port later. If you are hot-swapping a transceiver, wait for at least 10 seconds after removing the transceiver from the port before installing a new transceiver.

NOTE: Make sure to use a dust cap to cover ports that are unused.

5. Orient the transceiver over the port so that the transceiver connector faces the appropriate direction.
6. Slide the transceiver into the slot until the locking pins lock in place. If there is resistance, remove the transceiver and flip it so that the connector faces the other direction.

Figure 6: Install an QSFP-DD or QSFP28 Transceiver



7. Remove the rubber safety cap from the transceiver when you are ready to connect the patch cable to the transceiver.

LASER WARNING: Do not look directly into a fiber-optic transceiver or into the ends of fiber-optic cables. Fiber-optic transceivers and fiber-optic cables connected to transceivers emit laser light that can damage your eyes.

NOTE: After you insert a transceiver or after you change the media-type configuration, wait for 6 seconds for the interface to display operational commands.

Remove an QSFP-DD or QSFP28 Transceiver

SUMMARY

Use the information in this topic to remove QSFP-DD or QSFP28 optical transceivers and fiber-optic cables. Juniper Networks transceivers are hot-removable and hot-insertable field-replaceable units (FRUs). You can remove and replace them without powering off your device or disrupting device functions. To understand how to install or remove a transceiver and fiber-optic patch cables of your device, read the following sections.

Before you remove a transceiver from a device, take the necessary precautions for safe handling of lasers (see Laser and LED Safety Guidelines and Warnings).

CAUTION: The Juniper Networks Technical Assistance Center (JTAC) provides complete support for Juniper-supplied optical modules. However, JTAC does not provide support for third-party optical modules that are not qualified or supplied by Juniper Networks. If you face a problem running a Juniper device that uses third-party optical modules, JTAC may help you diagnose host-related issues if the observed issue is not, in the opinion of JTAC, related to the use of the third-party optical modules. Your JTAC engineer will likely request that you check the third-party optical module and, if required, replace it with an equivalent Juniper-qualified component.

Use of third-party optical modules with high-power consumption (for example, coherent ZR or ZR+) can potentially cause thermal damage to or reduce the lifespan of the host equipment. Any damage to the host equipment due to the use of third-party optical modules is the users' responsibility. Juniper Networks will accept no liability for any damage caused due to such use.

Ensure that you have the following parts and tools available:

- An antistatic bag or an antistatic mat
- Rubber safety caps to cover the transceiver and fiber-optic patch cable connector

- A dust cover to cover the port or a replacement transceiver

To remove an QSFP-DD or QSFP28 transceiver:

1. Place the antistatic bag or antistatic mat on a flat, stable surface.
2. Wrap and fasten one end of the ESD wrist strap around your bare wrist, and connect the other end of the strap to a site ESD point or to the ESD point on the device.
3. Label the patch cable connected to the transceiver so that you can reconnect it correctly.
4. Remove the patch cable connected to the transceiver (see Disconnect a Fiber-Optic Cable). Cover the transceiver and the end of each fiber-optic patch cable connector with a rubber safety cap immediately after disconnecting the fiber-optic patch cables.

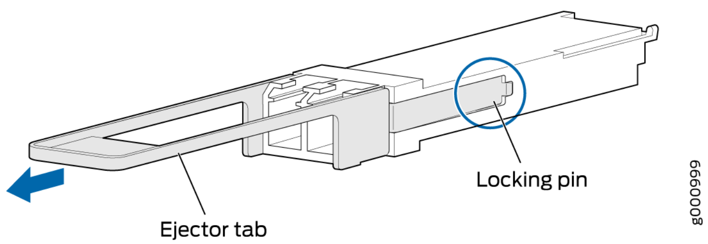
   LASER WARNING: Do not look directly into a fiber-optic transceiver or into the ends of fiber-optic patch cables. Fiber-optic transceivers and fiber-optic patch cables connected to transceivers emit laser light that can damage your eyes.

   LASER WARNING: Do not leave a fiber-optic transceiver uncovered except when inserting or removing a cable. The rubber safety cap keeps the port clean and protects your eyes from accidental exposure to laser light.

   CAUTION: Do not bend fiber-optic patch cables beyond their minimum bend radius. An arc smaller than a few inches in diameter can damage the cables and cause problems that are difficult to diagnose.

5. If there is a cable management system, arrange the cable in the cable management system to prevent it from dislodging or developing stress points. Secure the cable so that it does not support its own weight as it hangs to the floor. Place excess cable out of the way in a neatly coiled loop in the cable management system. Placing fasteners on the loop helps to maintain its shape.
6. Pull the transceiver's ejector tab straight back. The locking pins on the transceiver release automatically.
7. Gently slide the transceiver straight out of the port and place the transceiver on the antistatic mat or in the electrostatic bag.

Figure 7: Remove an QSFP-DD or QSFP28 Transceiver



CAUTION: To avoid ESD damage to the transceiver, do not touch the electrical connector pins at the end of the transceiver.

NOTE: After you remove a transceiver or after you change the media-type configuration, wait for 6 seconds for the interface to display operational commands.

8. Insert a dust cover in the empty port.

Maintain Fiber-Optic Patch Cables

IN THIS SECTION

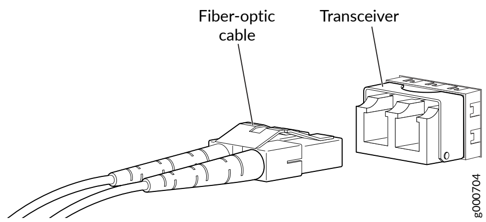
Connect a Fiber-Optic Patch Cable

Before you connect a fiber-optic patch cable to an optical transceiver installed in a device, take the necessary precautions for safe handling of lasers (see Laser and LED Safety Guidelines and Warnings).

To connect a fiber-optic patch cable to an optical transceiver installed in a device:

LASER WARNING: Do not look directly into a fiber-optic transceiver or into the ends of fiber-optic patch cables. Fiber-optic transceivers and fiber-optic patch cables connected to transceivers emit laser light that can damage your eyes.

1. If the fiber-optic patch cable connector is covered with a rubber safety cap, remove the cap. Save the cap.
2. Remove the rubber safety cap from the optical transceiver. Save the cap.
3. Insert the cable connector into the optical transceiver.



4. Secure the cables so that they do not support their own weight. Place excess cable out of the way in a neatly coiled loop. Placing fasteners on a loop helps cables maintain their shape.

CAUTION: Do not bend fiber-optic patch cables beyond their minimum bend radius. An arc smaller than a few inches in diameter can damage the cables and cause problems that are difficult to diagnose.

Do not let fiber-optic patch cables hang free from the connector. Do not allow fastened loops of cables to dangle, which stresses the cables at the fastening point.

Disconnect a Fiber-Optic Patch Cable

Before you disconnect a fiber-optic patch cable from an optical transceiver, ensure that you have taken the necessary precautions for safe handling of lasers. See Laser and LED Safety Guidelines and Warnings.

Ensure that you have the following parts and tools available:

- A rubber safety cap to cover the transceiver
- A rubber safety cap to cover the fiber-optic patch cable connector

Juniper Networks devices have optical transceivers to which you can connect fiber-optic patch cables.

To disconnect a fiber-optic patch cable from an optical transceiver installed in the device:

1. Disable the port in which the transceiver is installed by issuing the following command:

```
[edit interfaces]
user@device# set interface-name disable
```

> **LASER WARNING**: Do not look directly into a fiber-optic transceiver or into the ends of fiber-optic patch cables. Fiber-optic transceivers and fiber-optic patch cables connected to transceivers emit laser light that can damage your eyes.

2. Carefully unplug the fiber-optic patch cable connector from the transceiver.
3. Cover the transceiver with a rubber safety cap.

> **LASER WARNING**: Do not leave a fiber-optic transceiver uncovered except when inserting or removing a cable. The rubber safety cap keeps the port clean and protects your eyes from accidental exposure to laser light.

4. Cover the fiber-optic patch cable connector with the rubber safety cap.

How to Handle Fiber-Optic Patch Cables

Fiber-optic patch cables connect to optical transceivers that are installed in Juniper Networks devices.

Follow these guidelines when handling fiber-optic patch cables:

- When you unplug a fiber-optic patch cable from a transceiver, place rubber safety caps over the transceiver and on the end of the cable.
- Anchor fiber-optic patch cables to prevent stress on the connectors. When attaching a fiber-optic patch cable to a transceiver, secure the fiber-optic patch cable so that it does not support its own weight as it hangs to the floor. Never let a fiber-optic patch cable hang free from the connector.
- Avoid bending the fiber-optic patch cables beyond their minimum bend radius. Bending fiber-optic patch cables into arcs smaller than a few inches in diameter can damage the cables and cause problems that are difficult to diagnose.
- Frequent plugging and unplugging of fiber-optic patch cables in and out of optical instruments can damage the instruments, which are expensive to repair. To prevent damage from overuse, attach a short fiber extension to the optical equipment. The short fiber extension absorbs wear and tear due

to frequent plugging and unplugging. It is easier and more cost-efficient to replace the short fiber extension than to replace the instruments.

- Keep fiber-optic patch cable connections clean. Microdeposits of oil and dust in the canal of the transceiver or cable connector can cause loss of light, reduction in signal power, and possibly intermittent problems with the optical connection.
    - To clean the transceiver canal, use an appropriate fiber-cleaning device such as RIFOCS Fiber Optic Adaptor Cleaning Wands (part number 946). Follow the instructions in the cleaning kit you use.
    - After cleaning the transceiver, make sure that the connector tip of the fiber-optic patch cable is clean. Use only an approved alcohol-free fiber-optic cable cleaning kit such as the Opptex Cletop-S® Fiber Cleaner. Follow the instructions in the cleaning kit you use.

5

CHAPTER

Coherent Optical Transceivers FAQs

IN THIS CHAPTER

Frequently Asked Questions

IN THIS SECTION

What is coherent optical technology?

Coherent optical technology allows for the manipulation of light as an electromagnetic wave, utilizing phase and amplitude to overcome the physical limitations of traditional on-off signaling methods used in optical networks. Unlike traditional direct detection receivers that measure only the intensity of light, coherent detection introduces a Local Oscillator (LO) to mix with the incoming signal. This process allows the receiver to capture the wave’s complete information (amplitude, phase, and polarization) rather than just its brightness.

What are the core components that determine the performance of a coherent link?

The components of a coherent link are the Digital Signal Processor (DSP), advanced modulation formats, and Forward Error Correction (FEC). These components work together to encode data onto light waves, reconstruct the signal, and correct errors caused by physical impairments in optical fibers.

What modulation techniques are used in coherent optics?

Coherent optics use modulation techniques such as Dual Polarization Quadrature Phase Shift Keying (DP-QPSK), Quadrature Amplitude Modulation (QAM), and Probabilistic Constellation Shaping (PCS) to encode data onto light waves. DP-QPSK is commonly used for long-haul links due to its robustness and efficiency. QAM supports higher data rates but requires a higher optical signal-to-noise ratio, making it more suitable for shorter distances or high-quality links. PCS optimizes symbol placement to improve noise resilience, offering a balance between performance and efficiency.

What is Forward Error Correction (FEC) and why is it important in coherent networking?

FEC is a digital signal processing method used to detect and correct bit errors without the need for retransmission, ensuring that high-speed signals remain reliable. It adds redundant data to the signal before transmission, allowing the receiver to reconstruct corrupted bits, ensuring reliable transmission.

What role does the Digital Signal Processor (DSP) play in coherent optics?

The DSP enhances transmission distance, efficiency, and power consumption. It performs tasks like dispersion compensation, carrier recovery, and forward error correction in real-time.

What is Converged Optical Routing Architecture (CORA)?

CORA integrates IP and optical layers into a unified architecture, eliminating the need for standalone transponders through IP-over-DWDM (IPoDWDM). This reduces the network's physical footprint, power consumption, and operational complexity. By combining layers, CORA streamlines network management and enhances scalability.

What are the differences between Standard Power and High Power Optics?

Standard Power Optics (-10 dBm) are designed for power efficiency and cost, suitable for short point-to-point links and new deployments with low-power systems. High Power Optics (0 dBm) integrate amplifiers for longer distances, suitable for legacy networks expecting higher input signals.

If you are plugging into an existing Reconfigurable Optical Add-Drop Multiplexer (ROADM) network that expects 0 dBm input, a standard -10 dBm module will be too weak and likely fail. High Power modules have a built-in amplifier to match the legacy power levels.

What is the difference between ZR and ZR+?

ZR is a fixed standard optimized for point-to-point data center interconnect (DCI) up to 120 km. ZR+ (OpenZR+) is a flexible standard allowing higher performance (better FEC, variable modulation) to reach hundreds or thousands of kilometers across ROADM networks.

What form factors are supported by Juniper Networks for coherent optics?

Juniper Networks supports QSFP-DD for 400G and 800G transceivers, and QSFP28 for 100G transceivers.

Can Juniper coherent optics interoperate with other vendors?

Juniper coherent optics are standards-based. They comply with OIF ZR, OpenZR+ MSA specifications, and supports standardised OpenConfig models for vendor-agnostic management providing easy integration and deployments in multivendor environments.

What are the typical cable types and lengths used in coherent optical systems?

Coherent optics typically use Single-Mode Fiber (SMF) cables, with duplex LC connectors. The length is determined by the optical power budget, signal-to-noise ratio, dispersion, and other factors affecting signal integrity.

What are the breakout capabilities of coherent optics?

Coherent optics do not support physical breakout. Coherent modules transmit traffic over a single wavelength. They support software-defined rate selection, multiple modulation formats, and forward error correction to deliver different transmission rates.

How does Juniper manage coherent optics through software?

Juniper integrates coherent optics directly into Junos OS and Junos OS Evolved, treating the optical layer as a native extension of the router. You can manage the optics by using the following methods:

- A unified CLI to configure optical parameters such as center frequency, target TX power, and modulation directly within the router. This eliminates the need for a separate optical management console.
- Full support for OpenConfig YANG models and gNMI to stream real-time telemetry (like Pre-FEC BER and Chromatic Dispersion) to any vendor-agnostic monitoring tool.
- Juniper Paragon Automation correlates real-time optical telemetry with IP traffic health. By monitoring metrics like Pre-FEC BER, it can trigger proactive rerouting before signal degradation leads to a hard traffic outage.