Juniper 100G Optical Transceivers and Cables Guide

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The information in this document is current as of the date on the title page.

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.

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About This Guide

Use this guide to learn about the Juniper Networks® 100G optical transceivers and cables, their specifications, and how to install, remove, and maintain these transceivers.

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CHAPTER

100G Optical Transceivers Overview

IN THIS CHAPTER

Know Your 100G Transceiver

IN THIS SECTION

100 Gigabit Ethernet (100G) transceivers are optical modules that handle data rates of 100 Gbps. With a transmission rate of up to 100 Gbps, 100G transceivers serve as essential components for transceiver requirements in many networks. Juniper Networks' 100G transceivers use the C Form-Factor Pluggable (CFP), C Form-Factor Pluggable 2 (CFP2), Quad Small Form-Factor Pluggable 28 (QSFP-28), Small Form-Factor Pluggable 56 Double Density (SFP56-DD), Small Form-Factor Pluggable 112 (SFP112), and Small Form-Factor Pluggable Double Density (SFP-DD) form factors. 100G transceivers are suitable for:

- Host platforms with 100G ports
- Networks with 100 Gbps data transmission
- Data center deployments

100G transceivers use multiple lanes of optical signals and advanced modulation techniques for higher capacity. These transceivers can employ multiplexing techniques—such as parallel optics or wavelength multiplexing—to transmit signals efficiently, with many implementations favoring wavelength multiplexing.

100G transceivers commonly feature a four-lane architecture, with each lane operating at 25 Gbps. SFP-DD and SFP56-DD transceivers use a two-lane architecture with each lane operating at 50 Gbps. The 100G transceivers use Non-Return to Zero (NRZ-OOK) or Pulse Amplitude Modulation 4-level (PAM4) modulation schemes. The PAM4 modulation scheme enables doubling the data rate per lane compared to traditional NRZ, which supports 100G transmissions with fewer lanes and fibers.

100G transceivers support multiple transmission rates and breakout modes to ensure compatibility with various network transport requirements. Design flexibility allows a single physical transceiver to be logically divided into multiple lower-speed Ethernet ports, adapting to different deployment scenarios:

- 1x100G—The transceiver operates as a single 100G port without breakout. This configuration is supported by SFP56-DD, SFP-DD, and QSFP28 form factors.

- 4x25G—The transceiver can break out into four separate 25G ports. The transceiver uses QSFP28 form factor that supports division of 100G transmission into four lower-speed lanes or ports of 25G each.
- 10x10G—The transceiver can break out into ten separate 10G ports. The transceiver module uses the form factor CFP (C represents the Roman numeral for 100) that supports division of the 100G transmission into ten lower-speed lanes or ports of 10G each.

NOTE: SFP-DD and SFP56-DD modules provide 100G in a single-port configuration and don't support breakout modes. They only have two lanes (2×50G).

NOTE: 2x50G breakout is possible with certain Direct Attach Copper (DAC) and Active Optical Cable (AOC) assemblies. Standard 100G optical transceivers don't support 2x50G breakout. Exceptions include 100G SR1P2 and 100G BXSR.

100G Optical Transceiver Flavors

You can have various 100G optical transceiver flavors, depending on their electrical interface and optical interface configurations.

Electrical Interfaces

- One-Lane Electrical Interface (100GAUI-1)
  - The 100GAUI-1 electrical interface uses a single high-speed lane operating at 100G.
  - These ASICs use 100G Serializer/Deserializer (SerDes) for native 100G support (PAM4 modulation).
  - The 100GAUI-1 interface is used with SFP112 modules (when available). It's also used in single-lane 100G QSFP28 modules (DR1, FR1, LR1), and the host provides a single 100G electrical lane.
- Two-Lane Electrical Interface (100GAUI-2)
  - The 100GAUI-2 electrical interface uses two high-speed lanes.
  - These ASICs use 50G SerDes for native 100G support. The 2x50G electrical interface between the host and the pluggable optic is necessary.
  - The two-lane interface is used with SFP56-DD and SFP-DD optics.
- Four-Lane Electrical Interface (100GAUI-4 and CAUI-4)
  - The electrical interface uses four high-speed lanes.

- These ASICs use 25G SerDes for native 100G support. The 4x25G electrical interface between the host and the pluggable optic is necessary.
- The four-lane interface is used with QSFP28 optics.
- Four-lane electrical interface has two variants:
  - 100GAUI-4—A newer standard that uses KR4 Forward Error Correction (KR4 FEC). Optics such as 100G SR4, ER4L, and 4WDM-40 use 100GAUI-4.
  - CAUI-4—A legacy standard that does not use FEC. Optics such as 100G LR4 use CAUI-4.

- Ten-Lane Electrical Interface (CAUI-10)
  - The CAUI-10 interface incorporates ten electrical lanes for data transmission.
  - It's supported by legacy PFE ASICs and early 100G implementations.
  - These ASICs employ 10G SerDes for native 100G support. The 10x10G electrical interface between the host and the pluggable optic is necessary.
  - Ten-lane electrical interface is used with CFP or CFP2 optics.

Table 1: 100G Electrical Interfaces

Electrical Interface	Number of Lanes	Lane Speed	FEC Support	Form Factors	Example Optics
100GAUI-1 (1x100G)	1	100G (PAM4)	Yes	QSFP28 (single-lane), SFP112 (when available)	Single-lane 100G optics
100GAUI-2 (2x50G)	2	50G (PAM4)	Yes	SFP56-DD, SFP-DD	100G-DR1, 100G-FR1, 100G-LR1
100GAUI-4 (4x25G)	4	25G (NRZ)	Yes (KR4 FEC)	QSFP28	100G-SR4, 100G-ER4L, 100G-CWDM4, 100G-4WDM-40
CAUI-4 (4x25G)	4	25G (NRZ)	No	QSFP28	100G-LR4 (legacy)

Table 1: 100G Electrical Interfaces *(Continued)*

Electrical Interface	Number of Lanes	Lane Speed	FEC Support	Form Factors	Example Optics
CAUI-10 (10x10G)	10	10G (NRZ)	No	CFP, CFP2	100G-LR10, 100G-ER10 (legacy)

Optical Interfaces

- Single-Lane Optical Interface (1x100G)
  - The single-lane optical interface uses a single optical lane operating at 100 Gbps with PAM4 modulation.
  - This interface requires only duplex fiber (one transmit, one receive) using duplex LC connectors.
  - This interface is available in multiple distance ranges—DR1, FR1, LR1, ER1 (500 m to 40 km over single-mode fiber).
  - It is supported by SFP56-DD, SFP-DD and QSFP28 form factors.
  - It is interoperable with 400G optics by using breakout cables.
  - Juniper commonly supports the following single-wavelength 100G optical interfaces:
    - SDD-100G-DR (100G-DR1)—Single wavelength, 500 meters reach over single-mode fiber using SFP56-DD or SFP-DD form factor.
    - QSFP-100G-DR (100G-DR1)—Single wavelength, 500 m reach over single-mode fiber.
    - QSFP-100G-FR (100G-FR1)—Single wavelength, 2 km reach over single-mode fiber.
    - QSFP-100G-LR (100G-LR1)—Single wavelength, 10 km reach over single-mode fiber.
- Two-Lane Optical Interface (2x50G)
  - Two-lane optical interface uses two optical lanes, each operating at 50 Gbps.
  - The design is optimized for multimode fiber deployments.
  - The fiber count is lower in comparison to four-lane solutions.
  - Juniper commonly supports the following two-lane 100G optical interfaces:
    - JNP-QSFP-100G-BXSR (QSFP28 form factor)—Bidirectional transmission using two wavelengths over multimode fiber, 100 m reach (OM4), uses 2 fibers (duplex LC PC/UPC connector).

- QSFP-100G-SR1P2 (QSFP28 form factor)—Two wavelengths over multimode fiber, 100 m reach (OM3, OM4. OM5), uses 2 fibers (duplex LC PC/UPC connector).

- Four-Lane Optical Interface (4x25G)
  - SR4—Parallel multimode cables with 8 fibers with a maximum reach of up to 70 m (OM3) or 100 m (OM4). SR4 is used within data center environments.
  - LR4—Duplex single-mode fiber with a maximum reach of up to 10 km.
  - ER4—Duplex single-mode fiber with a maximum reach of up to 40 km.
  - CWDM4—Uses duplex single-mode fiber with coarse wavelength spacing and has a maximum reach of up to 2 km.

- Ten-Lane Optical Interface (10x10G)

  SR10—Primarily focused on short-reach applications using multimode fibers with 20 fibers (10 transmit, 10 receive). As the technology for 100G SR4 matured, SR10 became legacy technology.

NOTE: We recommend transitioning to 100G SR4 or LR4 optics, which provide better performance and remain relevant.

Table 2: 100G Optical Interfaces

Optical Interface	Number of Lanes	Lane Speed	Fiber Type	Connector	Max Reach	Optics (Example)
1x100G (Single-lane)	1	100G (PAM4)	Single-mode	Duplex LC	500 m through 10 km	DR1, FR1, LR1
2x50G (Dual-lane)	2	50G	Multimode	Duplex LC	100 m	SR1.2, BXSR
4x25G (Quad-lane)	4	25G (NRZ)	Multimode or Single-mode	MPO-12 (SR4) or Duplex LC (LR4, CWDM4)	70 m through 100 m (SR4), 2 km through 10 km (LR4, CWDM4), 40 km (ER4) text.	SR4, LR4, CWDM4, ER4

Table 2: 100G Optical Interfaces *(Continued)*

Optical Interface	Number of Lanes	Lane Speed	Fiber Type	Connector	Max Reach	Optics (Example)
10x10G (Ten-lane)	10	10G (NRZ)	Multimode	MPO-24	100 m through 150 m	SR10 (legacy)

NOTE:

- Fiber count—Single-lane and two-lane use 2 fibers (duplex). Four-lane SR4 uses 8 fibers (parallel). Four-lane LR4/CWDM4 use 2 fibers (WDM). Ten-lane uses 20 fibers.
- Modulation—PAM4 for single-lane, NRZ for two-lane, four-lane, and ten-lane.
- Wavelength type—Single wavelength (DR1, SR4), WDM multiplexing (LR4, CWDM4), bidirectional (BXSR, SR1.2).

Table 3: Comparison of 100G Optical Transceiver Specifications

Property	Single-Lane (DR1/FR1/LR1)	Two-Lane (SR1.2/BXSR)	Four-Lane (SR4)	Four-Lane (LR4/CWDM4/ER4)	Ten-Lane (SR10)
Optical Lanes	1	2	4	4	10
Optical Lane Speed	100 Gbps (PAM4)	50 Gbps each	25 Gbps each (NRZ)	25 Gbps each (NRZ)	10 Gbps each (NRZ)
Symbol Rate (Baud)	~53.125 GBd	~26.5625 GBd per lane	~25.78125 GBd per lane	~25.78125 GBd per lane	~10.3125 GBd per lane
Electrical Interface	100GAUI-2 (2x50G) for SFP-DD	100GAUI-2 (2x50G)	100GAUI-4 (4x25G) with KR4 FEC	CAUI-4 (4x25G) without FEC (LR4) 100GAUI-4 (4x25G) with KR4 FEC (CWDM4, ER4L)	CAUI-10 (10x10G) without FEC

Table 3: Comparison of 100G Optical Transceiver Specifications *(Continued)*

Property	Single-Lane (DR1/FR1/LR1)	Two-Lane (SR1.2/BXSR)	Four-Lane (SR4)	Four-Lane (LR4/ CWDM4/ER4)	Ten-Lane (SR10)
Fiber Type	Single-mode	Multimode (OM3/OM4/ OM5)	Multimode (OM3/OM4)	Single-mode	Multimode
Fiber Count	2 (duplex)	2 (duplex)	8 (4 Tx + 4 Rx)	2 (duplex)	20 (10 Tx + 10 Rx)
Connector Type	Duplex LC	Duplex LC	MPO-12 (8 fibers used, 4 unused)	Duplex LC	MPO-24
Wavelength Technology	Single wavelength	Bidirectional	Parallel optics	LAN WDM	Parallel optics
Reach	DR1—500 m FR1—2 km LR1—10 km	SR1.2—70 m (OM3), 100 m (OM4), 150 m (OM5) BXSR—100 m (OM4)	70 m (OM3) 100 m (OM4)	LR4—10 km ER4—40 km ER4L—40 km (with FEC) or 30 km (without FEC)	100 m (OM3) 150 m (OM4)
Form Factor	SFP56-DD, SFP-DD, QSFP28	QSFP28	QSFP28	QSFP28	CFP, CFP2
FEC Support	Yes (RS-FEC)	Yes (RS-FEC)	Yes (KR4 FEC on electrical, RS-FEC on optical)	LR4—No ER4L—Yes (KR4 FEC)	No
Breakout Support	Yes (interoperable with 400G using breakout cables)	No	Yes (4x25G breakout)	Yes (4x25G breakout)	No
Modulation	PAM4	PAM4 (optical lanes)	NRZ	NRZ	NRZ

Table 3: Comparison of 100G Optical Transceiver Specifications *(Continued)*

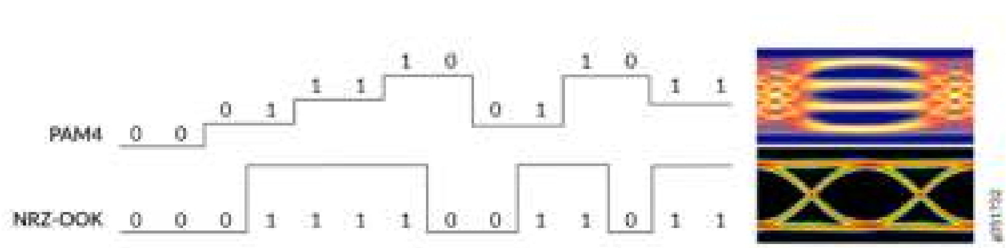
Property	Single-Lane (DR1/FR1/LR1)	Two-Lane (SR1.2/BXSR)	Four-Lane (SR4)	Four-Lane (LR4/ CWDM4/ER4)	Ten-Lane (SR10)
IEEE Standard	IEEE 802.3cd-2018 IEEE 802.3-2022	IEEE 802.3cd-2018	IEEE 802.3ba-2010 IEEE 802.3bm-2015	IEEE 802.3ba-2010 IEEE 802.3bm-2015	IEEE 802.3ba-2010

Modulation Methods

Pulse Amplitude Modulation 4-level (PAM4)—PAM4 is a four-level modulation format increasingly used in 100G optical transceivers, especially in shorter-reach, cost-sensitive scenarios such as data center interconnects. Each of the four amplitude levels represents two bits of data. This approach effectively doubles the data rate per lane compared to NRZ without requiring faster optical components. However, PAM4 reduces the distance between adjacent signal levels to one-third that of NRZ. This approach results in a theoretical Signal-to-Noise Ratio (SNR) penalty of approximately 9.5 dB (20 × log(1/3)). This reduction in SNR necessitates advanced Digital Signal Processing (DSP) and robust FEC to maintain link performance.

Non-Return-to-Zero On-Off Keying (NRZ-OOK) Modulation—NRZ is a fundamental binary modulation format used in many 100G optical transceivers, especially in implementations with multiple lanes at 25 Gbps or 10 Gbps per lane. In NRZ modulation, binary data is represented by two distinct signal levels—high and low—where each level corresponds to one bit (0 or 1). The signal doesn't return to zero between consecutive bits of the same value, so it's call "non-return-to-zero." NRZ provides good SNR performance due to the maximum separation between two signal levels, which is suitable for longer reaches or lower-complexity 100G systems.

Figure 1: Comparison of PAM4 and NRZ-OOK Modulation



FEC is a channel-coding technique that supports signal integrity. FEC transmits data with redundancies. FEC is necessary for ensuring signal integrity in 100G optical communications, particularly when using

PAM4 modulation. FEC encodes data with redundancy. This redundancy allows the receiver to detect and correct errors without retransmission.

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 includes 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 system then transmits the encoded data 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 the receiver detects errors, the algorithm corrects them based on redundancy.

The error correction capability of FEC depends on the specific algorithm used and the amount of redundancy added. For 100G optical transceivers, the industry standardized FEC codes are:

- RS(528,514)—RS(528,514) is standardized in 100GBASE-KR4 for 100G over copper backplanes using NRZ-OOK modulation. RS(528,514) is often called KR4 FEC.

- RS(544, 514) or FEC119—RS(544, 514) is standardized in 100GBASE-KP4 for 100G over copper backplanes using PAM4 modulation. RS(528,514) is often called KP4 FEC.

Figure 2: KP4 FEC in 100G Optics

100G optics also use the following technologies:

- DSP techniques—Not all 100G transceivers use advanced DSP techniques. Many standard 100G transceivers, especially shorter-reach variants like SR4, rely on simpler analog processing. DSP enhances signal integrity and extends the reach of certain 100G transceivers over optical fiber. Basic 100G optical transceivers (such as CFP-100GBASE-SR10, CFP2-100GBASE-LR4, and CFP2-100GBASE-ER4) typically use simpler analog processing. Functions such as Feed-Forward Equalization (FFE), Decision Feedback Equalization (DFE), and Clock Data Recovery (CDR) are used in

100G optics to ensure signal integrity in both electrical and optical signaling. DSP involves several components such as:

- SerDes—SerDes converts data between serial and parallel forms, enabling efficient and high-speed data transfer within the optic. The SerDes device works closely with the DSP to manage data flow and conversion.

- FFE and DFE—FFE and DFE mitigate inter-symbol interference (ISI) and enhance signal clarity. FFE addresses linear distortions before a decision is made. DFE helps correct errors based on previously received symbols, working dynamically to improve overall signal quality.

- CDR—CDR extracts timing information from a data signal and ensures accurate data retrieval and transmission in an optic network.

See the Hardware Compatibility Tool for the list of transceivers, their specifications, and the list of devices supported by the transceivers.

Key Characteristics

The following are the key design considerations for a 100G transceiver:

- Form factor—Juniper's 100G optical transceivers incorporate multiple form factors to meet different power, thermal, and port density requirements for 100 Gbps data transmission. The primary form factors include:

  - CFP (C Form-factor Pluggable)

  - CFP2 (C Form-factor Pluggable 2)

  - QSFP-28 (Quad Small Form-factor Pluggable 28)

  - SFP56-DD (Small Form-factor Pluggable 56 Double Density)

  - SFP-DD (Small Form-factor Pluggable Double Density)

- Fiber type and reach—The fiber type specifies the type of optical fiber (single-mode or multimode) compatible with 100G transceivers. The reach provides the maximum supported distance or range for an optical transceiver. It helps you to select the appropriate optical transceiver for different applications, such as inter-data center, intra-data center, long-haul networks, and so on.

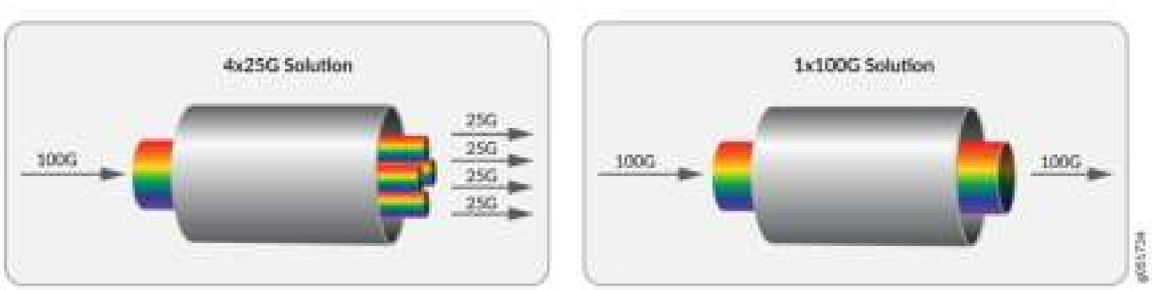
- Lane distribution—IEEE 802.3ba defines lane distribution. Lane distribution happens in the PCS, and lanes are then multiplexed to 4 or 10 lanes in the PMD depending on the exact optics type. The types of lane distribution include:

- Single lane—In a single-lane configuration, the entire Ethernet signal is conveyed through one optical lane or channel.

- Multiple lanes—Multiple lane distribution leverages parallel optical transmission by stripping Ethernet signals into multiple low rate lanes. The low rate lanes map into optical lanes or channels. This results in a more optimal cost per bit, fewer points of failure and interfaces, and lower power and heating.

100G optics operate with lane rates of 10G or 25G per lane depending on the transceiver type. However, with breakout capabilities, Juniper's 100G optics can offer 2x50G configuration, ensuring that the total bandwidth utilization is 100G. The breakout ports of lower speeds are fully independent and can run on separate time domains, enabling higher density applications.

Figure 3: 4x25G Solution Using Four Wavelengths



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 optical component that you need. For example:

QSFP-100G-SR4-C

- QSFP—In context of 100G optics, QSFP denotes QSFP-28 and is short for quad small form-factor pluggable-28. The prefix of Juniper's optical transceivers identifies the form-factor of the transceiver or cable.

- 100G—Indicates that the transceiver is capable of data transfer rates of 100 Gbps.

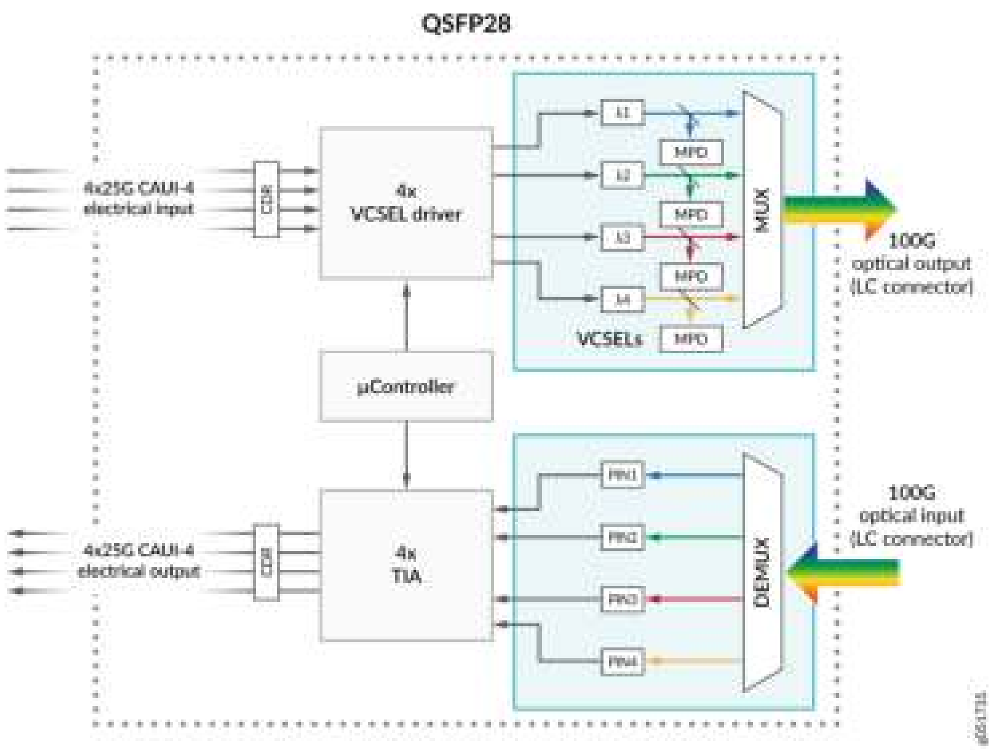
- SR4—Stands for 100GBASE-SR4. It is a specific standard that uses four parallel lanes of 25 Gbps to deliver 100 Gbps over multimode fiber for short-reach applications (up to 70 meters on OM3 fiber or 100 meters on OM4 fiber).

- C—The symbol C indicates that the SKU belongs to Juniper's common optics portfolio.

> **NOTE**: You can distinguish the Juniper optical cables from transceivers using the product numbers. For example, QSFP-100G-DAC-50CM and SDD-100G-1M (Juniper cables) specify the cable type (DAC) and distance range (50 centimeters or 1 meter) in their product names.

100G (X4) Transceiver Architecture

Figure 4: 100G (X4) Transceiver Architecture



The industry-standard and most widely deployed design for 100G transceivers uses a four-lane 4x25G NRZ electrical interface (100GAUI-4) on the host side. X4 denotes the four-lane electrical interface. The host side represents the part of the transceiver that connects to the switch, router, or any other host device. On the line side, the 100G transceivers uses a four-lane 4x25G NRZ optical interface (100G-

SR4). The line side represents the part of the transceiver that transmits and receives data over fiber cables to the network.

This architecture is used in 100G transceiver form factors like QSFP28. The following are the different components of a 100G transceiver architecture:

- 100G platform—The Juniper device (switch or router) that supports the 100G architecture.
- 4x25 Gbps electrical—The electrical interface between the switch and the transceiver components. It can transmit data over four separate 25 Gbps electrical lanes.
- 4x25 Gbps optical—The optical interface between the transceiver and the network. It can transmit data over four separate 25 Gbps optical lanes.
- DSP—The 100G DSP performs signal conditioning and conversion between the 4x25G electrical lanes and the 4x25G optical lanes. NRZ effectively provides reliable data transmission at 25G per lane. The CDR is responsible for re-timing incoming data to reduce jitter. The DSP handles functions like equalization, error correction, and other signal processing tasks.
- Driver—Drivers are electronic components that amplify the electrical signal. The x4 transceiver architecture has four drivers. Each driver corresponds to a 25G lane.
- Directly modulated laser (DML)—Modulated lasers convert the amplified electrical signals into optical signals. It includes Vertical-Cavity Surface-Emitting Lasers (VCSELs) for multimode applications and DMLs for single-mode applications.
- Transimpedance Amplifiers (TIA)—TIA is the receiving end of an optical transmission. It converts the electrical current output of a photodiode to a specific voltage level. It can operate with very low signal levels that are typical for long-distance optical communication.
- Photo-Detector— It works in tandem with the TIA to convert the optical information back into electrical form. For detailed information on photodiode technologies used in 100G transceivers, See "Photodiode Types in 100G Optical Transceivers" on page 15.

Some 100G optical transceivers, such as SR4 modules, use four parallel lanes each running at 25G NRZ, directly converting electrical to optical signals. Some 100G optical transceivers use wavelength division multiplexing to convert 4×25G electrical lanes into multiplexed optical signals. For example, LR4 modules use wavelength division multiplexing, where the four electrical lanes at 25G NRZ are converted into four optical wavelengths (1295.56 nm, 1300.05 nm, 1304.58 nm, 1309.14 nm) multiplexed onto a single fiber pair. This reduces the number of optical fibers required, simplifying cabling and connectors. For example, a 4×25G architecture requires eight fibers for its four lanes, often using MPO connectors or multiple duplex LC connectors. However, a 100G module such as LR4 that uses wavelength division multiplexing requires only two fibers (one duplex LC connector) to transmit and receive signals. Some 100G optical transceivers use bidirectional transmission with gearbox conversion to optimize fiber utilization. For example, BiDi 100G-SR1.2 modules use a 4:2 gearbox, where the four electrical lanes at

25G NRZ are converted into two optical lanes at 50G PAM4 using bidirectional 850 nm or 910 nm wavelengths on duplex LC connectors.

Photodiode Types in 100G Optical Transceivers

100G optical transceivers use two types of photodiodes for converting optical signals back to electrical signals:

- Positive-intrinsic-negative photodiodes (PIN)—PIN photodiodes are used in short-reach and medium-reach 100G transceivers where optical input power levels are relatively high. PIN photodiodes have a higher damage threshold and are suitable for high input optical power levels. Hence, optics with PIN photodiodes such as LR4, CWDM4, DR, FR1, and LR1 can be connected back-to-back without risk of damage.
- Avalanche photodiodes (APD)—APDs provide are designed to detect very weak optical signals. They are used in long-reach 100G transceivers where maximum optical sensitivity is critical. Since APDs have a low damage threshold, they can be easily damaged by excessive optical input power. This is particularly applicable on short, low-loss fiber links. Optics with APD photodiodes, such as ER4L, 4WDM40, ZR4, and ER1-40, require external optical attenuators on short links. Attenuators ensure that the optical input power stays below the damage threshold and prevent damage.

The choice of photodiode technology has significant operational implications, particularly regarding optical power handling and link design. Always verify optical power levels before deploying transceivers. Excessive input power can damage photodiodes, especially those using APD. Transceivers used in short distance transmissions receive higher optical power. This power can exceed the damage threshold of your APD transceiver, if not properly attenuated.

NOTE: For short-reach transmission, we recommend PIN-based transceivers. However, if you are using APD-based transceivers, ensure that you employ appropriate optical attenuators.

100G Optical Transceiver Technologies

IN THIS SECTION

100G optical transceivers can be organized by their wavelength technologies and reach capabilities. Understanding these options helps you select the appropriate transceiver for your specific deployment scenario.

Single-wavelength Optics

100G single-wavelength optics (FR, LR, DR, ER1) are pluggable transceivers that leverage PAM4 modulation technology to transmit the full 100G data using a single laser. These optics conform to IEEE 802.3cd-2018 and IEEE 802.3-2022 standards for 50 Gbps and 100 Gbps per lane operation using PAM4 modulation.

NOTE: QSFP-100G-SR1P2 and SDD-100G-SR1P2 transceivers use two parallel fibers (one for TX, one for RX) with a single wavelength on each fiber. They operate at 50 Gbps per lane (bidirectional 850 nm and 910 nm wavelengths) and conform to IEEE 802.3cd-2018 standards.

Single-wavelength optics are different from legacy 100G modules such as LR4, PSM4, CWDM4, and so on. Also, due to the adoption of PAM4 optical modulation, single-wavelength optics are not interoperable with legacy 100G modules. However, they are interoperable with 400G optics using breakout cables. 400G break-out optics are thus backwards compatible with legacy 100G line cards and optics:

The following are Juniper's current 100G single-wavelength optical transceivers:

Table 4: 100G Single-wavelength Optical Transceivers

Product Number	Long Description	IEEE Standard
SDD-100G-DR	SFP56-DD or SFP-DD form-factor, 100G-DR/DR1, 500 m reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-DR)

Table 4: 100G Single-wavelength Optical Transceivers *(Continued)*

Product Number	Long Description	IEEE Standard
SDD-100G-FR1	SFP-DD form-factor, 100G-FR/FR1, 2 km reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-FR1)
SDD-100G-LR1	SFP-DD form-factor, 100G-LR/LR1, 10 km reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cu (100GBASE-LR1)
SDD-100G-ER1-40	SFP-DD form-factor, 100G-ER/ER1, 40 km reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	MSA specification (BiDi technology with complementary wavelengths)
SDD-100G-SR1P2	SFP-DD form-factor, 100G-SR, 100 m reach over MMF (OM4), Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-SR1, 2-lane BiDi)
QSFP-100G-FR	QSFP form-factor, 100G-FR/FR1, 2 km reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-FR1)
QSFP-100G-LR	QSFP form-factor, 100G-LR/LR1, 10 km reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cu (100GBASE-LR1)

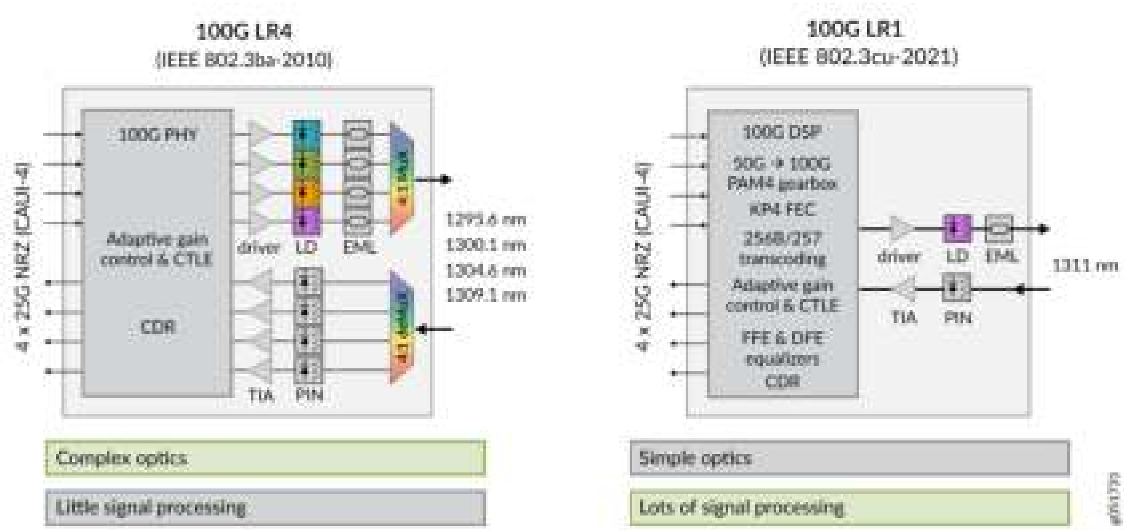
Table 4: 100G Single-wavelength Optical Transceivers *(Continued)*

Product Number	Long Description	IEEE Standard
QSFP-100G-DR	QSFP, 100G-DR/DR1, 500 m reach over SMF, Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-DR)
QSFP-100G-SR1P2	QSFP28 form-factor, 100G-SR, 100 m reach over MMF (OM4), Standard Temperature (0 °C through 70 °C), Duplex LC connector	IEEE 802.3cd (100GBASE-SR1, 2-lane BiDi)

NOTE: Optical transceivers with SFP112 form-factor (when available) are expected to support single-wavelength 100G optics.

NOTE: The SFP56-DD and SFP-DD modules (SDD-prefix) use a 2×50G electrical interface with PAM4 modulation. QSFP28 modules (QSFP-prefix) use a 4×25G electrical interface. However, both support single-wavelength optical transmission.

Figure 5: Single-wavelength and Four-wavelength Optical Interfaces



Bidirectional (BiDi) 100G Optical Transceivers

Bidirectional (BiDi) optical transceivers use wavelength division multiplexing to transmit and receive data simultaneously over the same fiber strand. BiDi reduces fiber infrastructure requirements. 100G BiDi transceivers come in two main categories:

- Duplex LC multimode BiDi optics (SR1P2, BXSR)
- Simplex LC single-mode BiDi optics (LRBD, ERBD)

Duplex LC Multimode BiDi Optics (SR1P2, BXSR)

Multimode BiDi transceivers use two fiber strands (duplex configuration) with bidirectional transmission on each fiber. Each fiber carries bidirectional traffic using different wavelengths. The two wavelengths that duplex LC multimode BiDi employs are 850 nm and 910 nm. That is, when one fiber transmits at 850 nm and receives at 910 nm, the other transmits at 910 nm and receives at 850 nm. Thereby, it creates two independent 50 Gbps bidirectional optical lanes (2x50G). Some of the Juniper optical transceivers that use duplex LC multimode BiDi technology are:

- JNP-QSFP-100G-BXSR—100 m reach on OM4 fiber
- QSFP-100G-SR1P2—70 m (OM3), 100 m (OM4), 150 m (OM5)

Simplex LC single-mode BiDi optics (LRBD, ERBD)

Single-mode BiDi transceivers use a single fiber strand (simplex configuration) with bidirectional transmission. The simplex optic transmits and receives on the same fiber using different wavelengths. It has a single optical lane that operates at 100 Gbps and a 100GAUI-2 (2x50G PAM4) electrical interface. The common simplex LC single-mode BiDi wavelength pairs are LRBD (1270 nm Tx and 1330 nm Rx or reversed) and ERBD (1270 nm Tx and 1330 nm Rx or reversed). Some of the Juniper optical transceivers that use simplex LC single-mode BiDi technology are:

- QSFP-100G-LRBD-D—QSFP28 100G LR BiDi downstream transceiver
- QSFP-100G-ERBD-D—QSFP28 100G ER BiDi upstream transceiver

Extended Reach and ZR 100G Optical Transceivers

Extended reach (ER) 100G transceivers are designed for long-distance transmission ranging from 40 km to 80 km, serving metro, regional, and inter-data center applications. These transceivers use advanced technologies including APD photodiodes, higher-power lasers, and sophisticated DSP to achieve extended reach over single-mode fiber.

ZR 100G transceivers represent coherent optical technology designed for ultra-long-distance transmission up to 80 km and beyond. Unlike traditional ER transceivers that use direct detection with intensity modulation, ZR transceivers employ coherent detection with advanced modulation schemes (DP-QPSK), tunable DWDM lasers, and sophisticated digital signal processing. This enables ZR transceivers to achieve significantly greater reach, integrate seamlessly with DWDM transport systems, and provide built-in performance monitoring capabilities, making them ideal for long-haul metro, regional networks, and data center interconnect applications.

Table 5: Comparison of ER and ZR Optics

Characteristic	ER (Extended Reach)	ZR (Long Haul)
Transceiver Types	ER4 (legacy), ER4L 4WDM-40 ER1-40 BiDi	ZR4
Technology Type	Direct detection, intensity modulation	Coherent detection, phase modulation
Optical Lanes	4 lanes (ER4, ER4L, 4WDM-40) 1 lane (ER1-40)	4 lanes
Lane Speed	25 Gbps NRZ (ER4, ER4L, 4WDM-40) 100 Gbps PAM4 (ER1-40)	25 Gbps DP-QPSK
Modulation	NRZ-OOK (ER4, ER4L, 4WDM-40) PAM4 (ER1-40)	DP-QPSK (coherent)
Wavelength Technology	LAN WDM - 4 wavelengths (ER4, ER4L, 4WDM-40) Single wavelength BiDi with complementary pairs (ER1-40)	Tunable DWDM (ITU grid, C-band, 50 GHz spacing)
Wavelengths	1295.56, 1300.05, 1304.58, 1309.14 nm (ER4, ER4L, 4WDM-40) Complementary pairs - vendor specific (ER1-40)	Tunable across ITU grid

Table 5: Comparison of ER and ZR Optics *(Continued)*

Characteristic	ER (Extended Reach)	ZR (Long Haul)
Maximum Reach	40 km (ER4, ER4L with FEC, 4WDM-40, ER1-40) 30 km (ER4L without FEC)	80 km (up to hundreds of km with DWDM amplification)
Fiber Type	Single-mode	Single-mode
Fiber Count	2 (duplex)	2 (duplex)
Connector Type	Duplex LC	Duplex LC
Electrical Interface	CAUI-4 or 100GAUI-4 (ER4) 100GAUI-4 (ER4L, 4WDM-40) 100GAUI-2 / 2x50G PAM4 (ER1-40)	100GAUI-4
FEC Type	Optional (ER4) Mandatory KR4 FEC (ER4L, 4WDM-40, ER1-40)	Internal coherent FEC (RS-FEC)
Form Factor	QSFP28 (ER4, ER4L, 4WDM-40) SFP-DD (ER1-40)	QSFP28
Photodiode Type	APD (Avalanche PhotoDiode)	APD (Avalanche PhotoDiode)
Power Consumption	~3.5W (ER4) ~2.5W (ER4L, 4WDM-40) ~2.0W (ER1-40)	~4-5W
Technology Generation	Legacy (ER4) Modern (ER4L, 4WDM-40, ER1-40)	Modern (coherent)

Table 5: Comparison of ER and ZR Optics *(Continued)*

Characteristic	ER (Extended Reach)	ZR (Long Haul)
Platform Compatibility	Older platforms without FEC or modern with FEC (ER4) Modern platforms with KR4 FEC (ER4L, 4WDM-40) Modern platforms with 2x50G SerDes (ER1-40)	Modern platforms with DWDM support
Relative Cost	Higher (ER4) Lower (ER4L, 4WDM-40) Medium (ER1-40)	Significantly higher
Status	Legacy, being phased out (ER4) Current standard (ER4L, 4WDM-40, ER1-40)	Current standard
DWDM Integration	No	Yes (tunable wavelength)
Wavelength Tunability	No - fixed wavelengths (ER4, ER4L, 4WDM-40) No - fixed complementary pairs (ER1-40)	Yes (tunable ITU grid)
Performance Monitoring	Basic DDM (Digital Diagnostics Monitoring)	Advanced (coherent DSP with comprehensive diagnostics)
DSP Complexity	Low (ER4, ER4L, 4WDM-40) Medium (ER1-40)	Very High (coherent)
Matched Pair Requirement	No (ER4, ER4L, 4WDM-40) Yes - complementary wavelengths (ER1-40)	No
APD Protection Required	Yes - optical attenuators required on short links or back-to-back connections	Yes - optical attenuators required on short links or back-to-back connections

Table 5: Comparison of ER and ZR Optics *(Continued)*

Characteristic	ER (Extended Reach)	ZR (Long Haul)
Breakout Support	Yes - 4x25G (ER4, ER4L, 4WDM-40) No (ER1-40)	Yes - 4x25G
Interoperability	ER4, ER4L, 4WDM-40 are interoperable with each other ER1-40 not interoperable with ER4 variants (different modulation/lanes)	Not interoperable with direct detection ER optics
Standards	IEEE 802.3ba (ER4) MSA based on 802.3ba (ER4L, 4WDM-40) MSA BiDi specification (ER1-40)	OIF 100G-ZR Implementation Agreement
Use Cases	Metro networks, inter-building (ER4 - legacy) Metro networks, cost-sensitive deployments (ER4L, 4WDM-40) Modern metro, high-density deployments (ER1-40)	Long-haul metro (60-80 km), regional networks, DCI, DWDM integration
Advantages	Established technology, broad compatibility (ER4) Lower power/cost, modern standard (ER4L, 4WDM-40) High port density (SFP-DD), lower power (ER1-40)	Maximum reach (80 km), DWDM compatible, tunable wavelength, advanced performance monitoring
Limitations	Higher power, being phased out (ER4) 4-lane requires more host resources (ER4, ER4L, 4WDM-40) Requires matched pairs, BiDi technology (ER1-40)	High cost, high power consumption, complex technology

2

CHAPTER

100G Optical Transceivers Specifications

IN THIS CHAPTER

Form Factors

SUMMARY

Juniper's 100G transceivers cater to the growing demand for bandwidth in metro, edge, core, and data center networks. To support the multivendor network environment, Juniper 100G transceivers adhere to key industry standards.

Form factor refers to the physical dimensions and shape of a transceiver. Form factor includes aspects like the size, shape, connector type, and other physical characteristics. It determines how the transceiver fits into networking equipment like switches, routers, or servers.

Juniper supports the following form factors:

- CFP (centum form-factor pluggable or C form-factor pluggable)
- CFP2 (centum form-factor pluggable or C form-factor pluggable 2)
- SFP56-DD (small form-factor pluggable 56 double density)
- QSFP-28 (quad small form-factor pluggable 28)
- SFP-DD (small form-factor pluggable double density)
- SFP112 (small form-factor pluggable 112) - When available from Juniper

Figure 6: 100G Form Factors CFP and CFP2

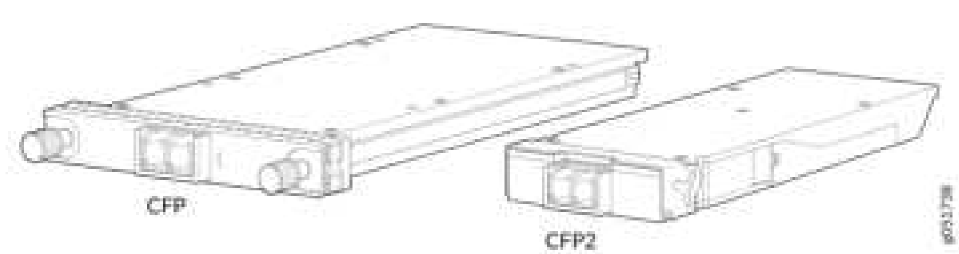
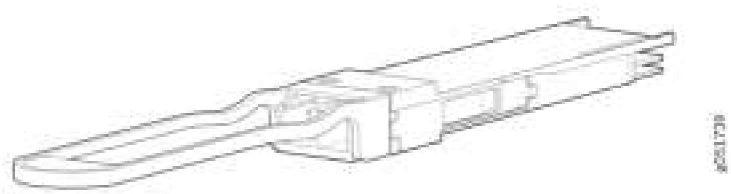


Figure 7: 100G Form Factor QSFP28



The CFP, CFP2, SFP56-DD, SFP-DD, SFP112, and QSFP-28 form factors are defined by the standards CFP MSA, CFP2 MSA, SFF-8402 (SFP56-DD MSA), SFF-8402 (SFP-DD MSA), SFP112 MSA, and SFF-8665 respectively.

CFP, CFP2, SFP56-DD, SFP112, SFP-DD, and QSFP-28 are all physically distinct form-factors:

- CFP represents the first generation of 100G optics. CFP has the largest physical dimension.
- CFP2 offers a balanced approach with reduced size.
- SFP56-DD provides a compact, single-port solution with two electrical lanes operating at 56 Gbps each (2x50G PAM4).
- SFP-DD provides a compact, single-port solution with two electrical lanes operating at 50 Gbps each (2x50G PAM4). SFP-DD is backward compatible with SFP28, SFP+, and SFP modules.
- SFP112 provides compact, single-port solution with a single electrical lane operating at 112 Gbps (1x100G PAM4).

> **NOTE**: Support for SFP112 optical transceivers will be available soon from Juniper Networks.

- QSFP-28 provides a compact, four-port, breakout-capable solution with optimal power efficiency.

Each form factor utilizes different electrical interfaces and signal processing approaches to achieve 100 Gbps total bandwidth:

- CFP and CFP2 use a 10x10G or 4x25G electrical interface to achieve a total bandwidth of 100 Gbps.
- SFP56-DD uses a 2x56G (~2x50G) electrical interface to achieve a total bandwidth of 100 Gbps.
- SFP-DD uses a 2x50G electrical interface to achieve a total bandwidth of 100 Gbps.
- SFP112 (when available) uses a 1x112G (~1x100G) electrical interface to achieve a total bandwidth of 100 Gbps.

- QSFP-28 uses a 4x25G electrical interface to achieve a total bandwidth of 100 Gbps.

Here are some major differences between the 100G form factors:

Table 6: Key Differences Between 100G Form Factors

Feature	CFP	CFP2	QSFP-28	SFP56-DD	SFP-DD	SFP112	Notes
Physical Dimensions	82 mm × 13.6 mm × 144.8 mm	41.5 mm × 12.4 mm × 107.5 mm	18.35 mm × 8.5 mm × 89.4 mm	13.5 mm × 8.5 mm × 56.6 mm	13.5 mm × 8.5 mm × 56.6 mm	13.5 mm × 8.5 mm × 56.6 mm	
Relative Size	Large	Medium	Small	Very Small	Very Small	Very Small	
Power Consumption	Gray Optics: < 24 W Coherent (tunable DWDM): up to 32 W	Gray Optics: < 12 W Coherent (tunable DWDM): up to 24 W	Gray Optics: typically < 3.5 W Coherent (tunable DWDM): up to 6.5 W	Gray Optics: typically < 2.5 W	Gray Optics: typically < 2.5 W Coherent (tunable DWDM): up to 6.5 W	Gray Optics: typically < 2 W	
Signal Processing	Integrated, within package	Relies on host card	Relies on host card	Relies on host card	Relies on host card	Relies on host card	
Electrical Interface	10x10G or 4x25G	4x25G	4x25G	2x56G (2x50G PAM4)	2x50G	1x112G (1x100G PAM4)	SFP112 uses single-lane architecture for lowest complexity
Connector Configuration	High-density connector with comprehensive pin configuration	Compact connector optimized for 4x25G	High-density connector with 38 pins	High-density connector with 38 pins	High-density connector with 38 pins	High-density connector with 38 pins	

Table 6: Key Differences Between 100G Form Factors *(Continued)*

Feature	CFP	CFP2	QSFP-28	SFP56-DD	SFP-DD	SFP112	Notes
Heat Sink Requirements	Large heat sink for substantial cooling	Optimized heat sink for medium power consumption	Minimal heat sink due to low power consumption	Minimal heat sink due to very low power consumption	Minimal heat sink due to very low power consumption	Minimal heat sink due to lowest power consumption	Heat sink design is evaluated based on system configuration
Thermal Requirements	Operating: 0°C to 70°C Storage: -40°C to 85°C	Operating: 0°C to 70°C Storage: -40°C to 85°C	Operating: 0°C to 70°C Industrial: -40°C to 85°C	Operating: 0°C to 70°C Industrial: -40°C to 85°C	Operating: 0°C to 70°C Industrial: -40°C to 85°C	Operating: 0°C to 70°C Industrial: -40°C to 85°C	
Backward Compatibility	Not compatible with smaller form factors	Not backward compatible with CFP	Compatible with QSFP+ (40G) in some configurations	Limited	Compatible with SFP28, SFP+, and SFP modules	Expected compatibility with SFP-DD and SFP28 (when available)	SFP-DD offers excellent backward compatibility with other SFP transceivers
Port Density	Low	Medium	High	High	High	High	Critical consideration for data center deployments
Breakout Capability	Yes (10×10G or 4×25G)	Yes (4×25G)	Yes (4×25G or 2×50G)	Yes (4×25G or 2×50G)	No (single 100G port only)	No (single 100G port only)	SFP-DD operates as single port, QSFP28 and CFP modules support breakout

Juniper 100G Transceivers

Juniper's 100G transceivers cater to data center and enterprise network applications for routing and switching solutions. The 100G optical transceivers from Juniper are essential for metro and long-haul network deployments. To support the multi-vendor network environment, Juniper 100G transceivers adhere to key industry standards.

Juniper's 100G transceivers use the CFP, CFP2, and QSFP28 form factors. For a list of all 100G optics and their supported platforms, see Hardware Compatibility Tool.

Platform Support for 100G Transceivers

Juniper's 100G transceivers support multiple Juniper platforms. For information about the Juniper platforms or devices that support 100G transceivers and cables, see the Product Matrix tab in Hardware Compatibility Tool.

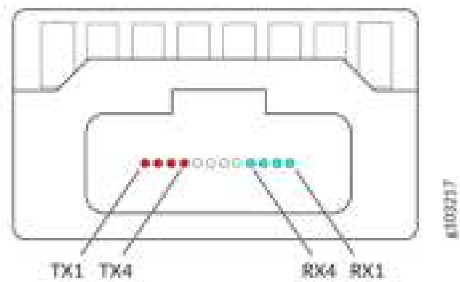
Connector Types

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

100G transceivers support the following connector types:

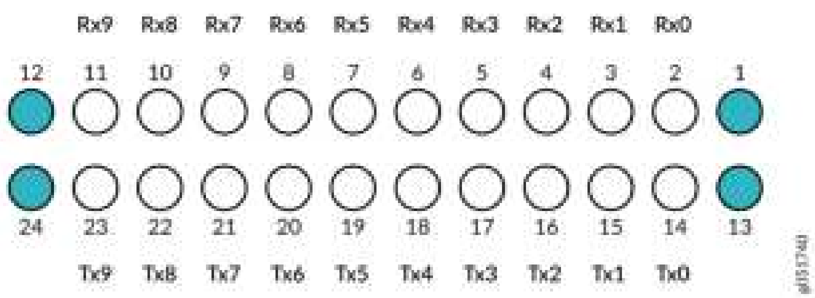
- MPO-12 APC and MPO-12 PC/UPC—A multifiber push-on (MPO-12) has a single row of connectors with 12 optical fiber channels or lanes. An MPO-12 connector contains four transmission (TX) channels and four reception (RX) channels that are used to transmit and receive signals. Four optic fiber channels are unused or reserved in MPO-12 connectors used with 100G optical transceivers. In a standard deployment, the four unused channels or lanes are those located in the center of the row. MPO-12 PC/UPC is used for parallel multimode optics such as 100G-SR4. MPO-12 APC is used for parallel single-mode optics such as 100G-PSM4.
  - APC—Angled physical contact (APC) denotes an optical fiber endface that is polished at an eight-degree angle. APC reduces back reflection by directing reflected light into the fiber cladding rather than back toward the source.
  - PC/UPC—Physical contact (PC) or ultra physical contact (UPC) denotes a rounded optical fiber endface that is polished to maintain a very smooth, slightly curved surface (nearly zero degrees). PC/UPC helps to improve contact quality and reduce back reflection compared to other physical contact connectors.

Figure 8: MPO-12 Connector



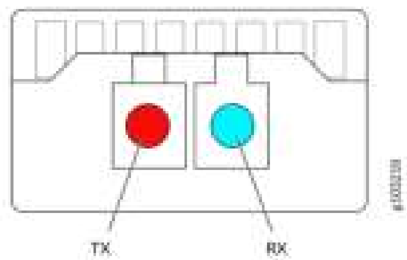
- MPO-24 PC/UPC—A multi-fiber push-on 24 (MPO-24) connector has 24 optical fibers in a single connector. For example, the 100G-SR10 transceiver uses 20 fibers of the MPO-24 connector. Ten fibers are used as TX (transmit) channels and ten fibers are used as RX (receipt) channels. Each fiber carries a 10G NRZ channel, totaling ten parallel channels per direction for 100G aggregate bandwidth. With physical contact (PC) or ultra physical contact (UPC), the connector minimizes back reflection and ensures better signal integrity. MPO connectors offer high-density connections and support multiple fibers in a single connector. MPO connectors are often used in data centers.

Figure 9: MPO-24 Connector



- Duplex LC PC/UPC—A duplex LC connector is a type of lucent connector (LC) 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 (SC). The smaller size allows greater port density in patch panels and transceivers. Duplex LC connectors use PC/UPC polish for both multimode and single-mode applications. Like other optical connectors, the duplex LC connector is color-coded. This helps maintain correct polarity and simplifies installation and troubleshooting.

Figure 10: Duplex LC Connector



The image represents the channel or lane allocation for a 100G optical transceiver using duplex LC connector:

- Red (TX)
- Blue (RX)

- Simplex LC PC/UPC—A simplex LC connector is a single-fiber lucent connector (LC) with the same small form factor and high-density design as duplex LC. The term simplex indicates that the connector houses a single fiber optic channel within the connector. Simplex LC connectors are used exclusively with bidirectional (BiDi) optical transceivers that transmit and receive on the same fiber using different wavelengths. Simplex LC connectors use PC/UPC polish. They are typically used with single-mode BiDi transceivers such as 100G LRBD and 100G ERBD. LRBD and ERBD require only one fiber strand for full-duplex bidirectional communication.

Cable Types and Length

IN THIS SECTION

Cables are the physical medium that transmit optical and electrical signals. Juniper offers a broad variety of high-performance and cost-effective cables. These optical and electrical cables are available in various dimensions, distance ranges, and speeds. Cables offer a wide selection of breakout configurations that enable you to operate at lower Ethernet speeds. Cables help you effectively interconnect devices and increase port density. For more information, see Optical and Electrical Cables.

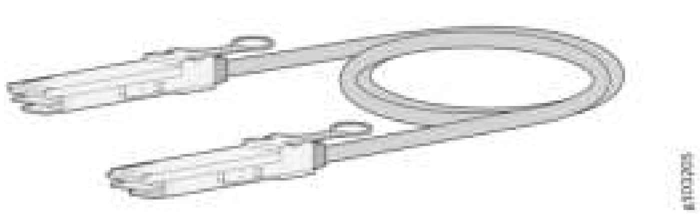
The two broad types of cables are:

- Direct attach copper cables (DAC)
- Active optical cables (AOC)

Direct Attach Copper Cables

Made of twinax copper, the primary type of Direct Attach Copper (DAC) cable is known as twinax cable. It is ideal for ultra short-range connections. DAC supports high-speed connections between servers, switches, and storage devices. DAC cables cost less and are more durable than optical fibers. Also, they are less susceptible to dust and environmental disturbances.

Figure 11: 100G DAC Cable



DAC cables can be of two types:

- Passive DAC cables—Passive DAC cables transmit signals without the use of electrical components to boost or regenerate the signal. The network equipment's host handles signal amplification and conditioning. Typically, passive DAC cables are limited to a maximum length of two and a half meters, as their performance diminishes over longer distances.

- Active DAC cables—Active DAC cables, in contrast, include an additional driving chip that conditions the signal, enhancing transmission quality over longer distances. These cables share the same setup as passive DAC cables but provide signal boosting through built-in electronics. Active DAC cables can typically extend up to 10 meters or more, offering a longer reach in comparison with passive DAC cables. By offering both passive and active options, DAC cables provide flexible solutions for various network environments, balancing signal integrity with distance requirements.

The 100G Juniper DAC cables that you can use include:

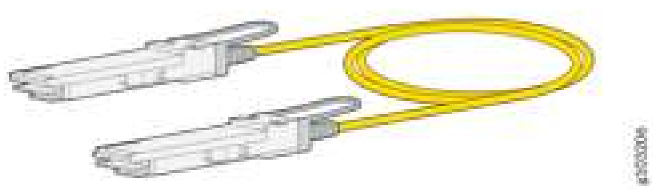
- 1x100G DAC cables
- 2x50G DAC cables
- 4x25 DAC cables

For more information, see Hardware Compatibility Tool.

Active Optical Cables

Active Optical Cables (AOC) consists of duplex optical fibers with connectors on both ends. AOC utilizes fiber optic transceivers within the connectors, making it more complex and costly in comparison with DAC cables. The external interface of an AOC is always electrical, not optical. Therefore, unlike passive cables, AOCs require external power to convert electrical signals to optical signals and vice versa. The use of fiber optics in AOC allows for extended reach, supporting longer distances. It makes AOC an ideal choice for high-performance networking where longer cable runs are necessary.

Figure 12: 100G AOC Cable



AOC is lightweight in design in comparison with DAC cables. AOCs are immune to electromagnetic interference. They have a higher throughput at longer distances in comparison with DACs. With AOCs, you can select your cabling solution considering a variety of form factors, breakout cables and speed options.

AOC cables can be of two types:

- Single-Mode fiber (SMF)—It has 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.

  NOTE: Active Optical Cables (AOCs) typically use multi-mode fiber and optics due to cost considerations. Using single-mode fiber in AOCs is generally much more expensive.

- Multimode fiber (MMF)—It has a core diameter of 62.5 microns. It is easier to install and align but has higher attenuation and dispersion than SMF, making it suitable for shorter distances. The applications include short to medium-distance communication, typically within buildings or campuses.

The 100G Juniper AOC cables that you can use include:

- 1x100G AOC cables
- 4x25G AOC cables

For more information, see Hardware Compatibility Tool.

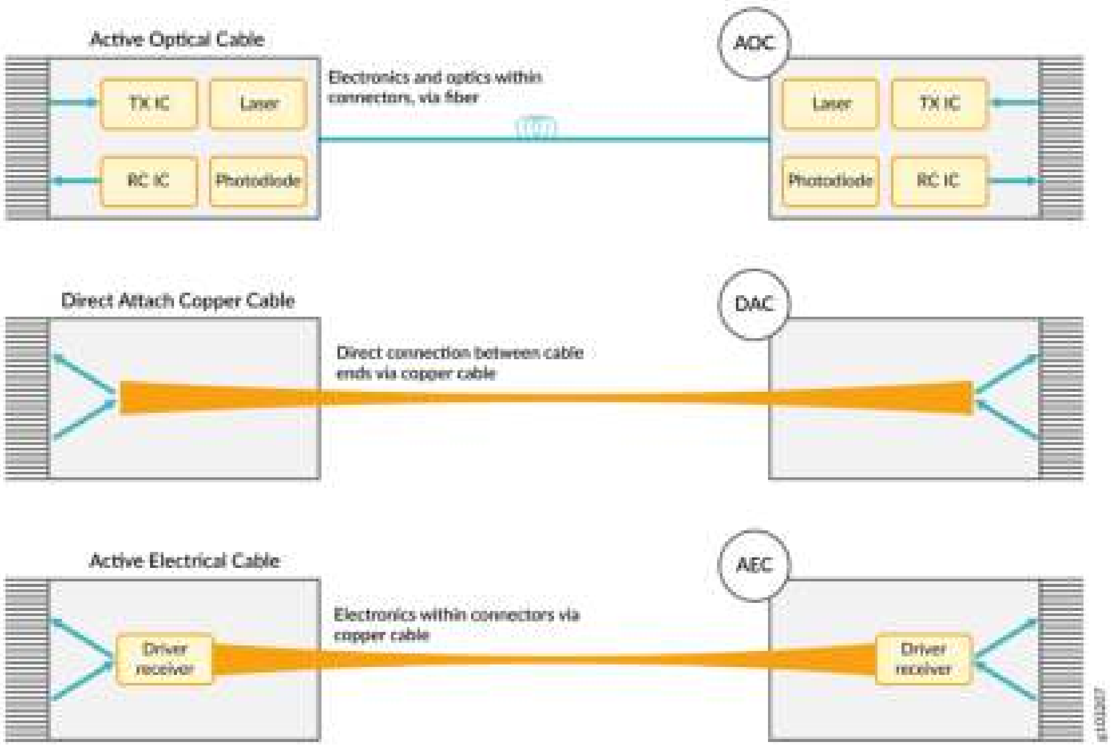
NOTE: Most of the DAC and AOC cables used along with 100G optical transceivers do not have connectors. The optical transceivers are permanently attached to the cables.

Architecture of AOC and DAC Cables

AOC and DAC each use distinct architectures, resulting in different operational characteristics. DAC cables, both active and passive, use copper wires to transmit electrical signals. Passive DAC cables directly transmit signals without any conditioning. Active DAC cables incorporate a driving chip within the transceivers to enhance and condition the signals.

In contrast, AOC cables transform electrical signals into optical signals using fiber optics, requiring external power for this conversion. The optical signals are then converted back to electrical signals at the receiving end. This architecture enables AOC cables to maintain high signal integrity over longer distances.

Figure 13: Architecture of AOC and DAC Cables



Cable Length or Range

Juniper 100G transceivers support varying cable lengths to meet specific needs. For more information about the specific distance range of individual transceivers, see Hardware Compatibility Tool.

Breakout Capability

IN THIS SECTION

Due to the rise of flat data center architecture models, breaking out high-speed ports has become a critical requirement. A flat data center architecture is a network and storage design that minimizes or eliminates traditional hierarchical layers. This approach creates a simplified, scalable, and high-performance infrastructure, which leverages breakout capability to optimize network resources.

Breakout capability is the ability to split one high-capacity optical link into multiple lower-capacity links. This is typically done using breakout cables with suitable connectors that divide a single high-speed port into multiple lower-speed connections. Breakout capability is crucial for optimizing available bandwidth and physical infrastructure. For example, it allows a single 100G transceiver port to be split into multiple lower-speed ports.

Breakout relies on the concept of channelization to accomplish the split. Channelization involves splitting a high-speed physical port into multiple lower-speed lanes at the hardware level, using Serializer/Deserializer (SerDes) technology. In other words, breakout is the practical application of channelization, creating multiple lower-speed ports from one high-speed port. Channelization can be configured at the level of an individual port, a block of ports, or a quad of ports. A block of ports is a group of ports that share hardware resources within a Juniper switch or router. For blocks that support breakout capability, SerDes technology enables the flexible allocation and operation of these lanes.

Channelization occurs at the physical layer, splitting a high-speed port into multiple lanes. It differs from Ethernet port channels or link aggregation (LAG). LAG combines multiple physical links into a single logical link at Layer 2 or Layer 3.

You can perform port speed configuration at either the chassis level or the interface level. At the chassis level, you have three main options for port speed configuration:

- Channelize individual port—Configure an individual port to operate at a specific channel speed. You must specify a port number and channel speed.
- Channelize block of ports—Configure a range of ports (a block) to operate at the same channel speed. You must specify the port range and the channel speed.
- Configure speed per quad—Configure port speeds in groups of four ports (quads), not individually. You must specify the speed for the first port in the quad. All four ports operate at the speed that you specified for the first port.

At the interface level, you must configure the speed for individual logical interfaces derived from the physical ports. This helps you in managing breakout interfaces after chassis-level speed settings are applied. For information about interface-level configuration, see Configure Speed at Interfaces Level.

Juniper supports the following breakout speed or mode options for its 100 Gbps ports:

- 4x25G
- 2x50G
- 1x100G (no breakout)

Breakout capability enables a network architect to configure a single port to support standardized 25 Gbps, 50 Gbps, or 100 Gbps data, depending on the network requirement. For more information about the breakout configuration that you can use in your Juniper device, use Port Checker.

100G optical transceivers with QSFP-28 form factor support breakout capability. 100G QSFP28 transceivers use 4x25G lanes (NRZ modulation), making them compatible with 25G optics via breakout cables. Breakout capability enables 100G optical transceivers to provide flexible connectivity with 25G and 50G line cards and platforms deployed in your network.

NOTE: CFP and CFP2 form factors do not support breakout capability. These form factors implement integrated signal processing within the module.

Breakout Cables

Breakout cables have a single transceiver at one end and multiple transceivers at the other end. You can use breakout cables to channelize a port and increase the number of interfaces. To channelize the network ports on your Juniper device, connect breakout cables and configure the recommended CLI commands. For more information, see Port Settings.

Breakout cables have one transceiver preattached to one end and more than one transceiver preattached to the other end. For information on how to maintain a breakout cable, see Maintain Breakout Cables.

The inclusion of APC or UPC connectors helps minimize reflection loss and ensure high precision. To connect two transceivers of the same type, you can use a variety of cables with the suitable connector. Breakout cables are use-specific. Depending on port channelization and the type of connectors, some of the breakout cables include:

- 12-Fiber Ribbon Patch Cables with MPO-12/APC Connectors.
- 12-Fiber Ribbon Breakout Cables with MPO-12/APC-to-LC Duplex Connectors.
- Patch cables with LC duplex connectors.

Table 7: 12-Ribbon Patch and Breakout Cables Available from Juniper Networks

Juniper Model Number	Cable Type	Connector Type	Fiber Type	Cable Length
MTP-4LC-S10M	12-ribbon breakout cable	MTP to 4xLC pairs	SMF	10 m

Table 7: 12-Ribbon Patch and Breakout Cables Available from Juniper Networks *(Continued)*

Juniper Model Number	Cable Type	Connector Type	Fiber Type	Cable Length
MTP-4LC-S1M	12-ribbon breakout cable	MTP to 4xLC pairs	SMF	1 m
MTP-4LC-S3M	12-ribbon breakout cable	MTP to 4xLC pairs	SMF	3 m
MTP-4LC-S5M	12-ribbon breakout cable	MTP to 4xLC pairs	SMF	5 m
MTP12-FF-S10M	12-ribbon patch cable	MTP 12 fiber	SMF	10 m
MTP12-FF-S1M	12-ribbon patch cable	MTP 12 fiber	SMF	1 m
MTP12-FF-S3M	12-ribbon patch cable	MTP 12 fiber	SMF	3 m
MTP12-FF-S5M	12-ribbon patch cable	MTP 12 fiber	SMF	5 m

NOTE: The terms MPO and MTP describe the same connector type, though MTP is a brand name for a mechanically superior MPO connector.

3

CHAPTER

Install or Remove 100G Optical Transceivers and Fiber-Optic Cables

IN THIS CHAPTER

Install a QSFP28 Transceiver

SUMMARY

Use the information in this topic to install 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 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 and optical connectors 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 and cables. However, JTAC does not provide support for third-party optical modules and cables that are not qualified or supplied by Juniper Networks. If you face a problem running a Juniper device that uses third-party optical modules or cables, 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 or cables. Your JTAC engineer will likely request that you check the third-party optical module or cable 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 or cables is the users' responsibility. Juniper Networks will accept no liability for any damage caused due to such use.

To install a 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 connector pins at the end of the transceiver.

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

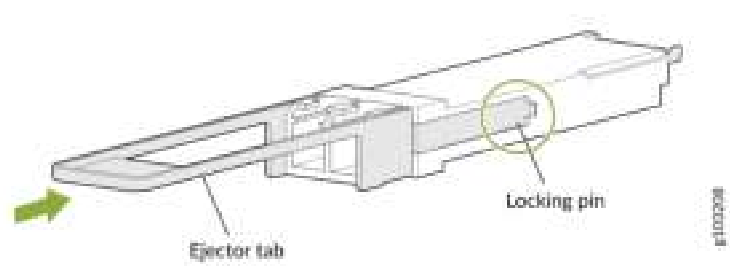
LASER WARNING: Do not leave a fiber-optic transceiver uncovered except when inserting or removing a cable. The rubber safety cap keeps the port clean and prevents accidental exposure to laser light.

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 14: Install a QSFP28 Transceiver



7. Remove the rubber safety cap from the transceiver when you are ready to connect the 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 a QSFP28 Transceiver

SUMMARY

Use the information in this topic to remove 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 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 and cables. However, JTAC does not provide support for third-party optical modules and cables that are not qualified or supplied by Juniper Networks. If you face a problem running a Juniper device that uses third-party optical modules or cables, 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 or cables. Your JTAC engineer will likely request that you check the third-party optical module or cable 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 or cables 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 cable connector
- A dust cover to cover the port or a replacement transceiver

To remove a 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 cable connected to the transceiver so that you can reconnect it correctly.
4. Remove the cable connected to the transceiver (see Disconnect a Fiber-Optic Cable). Cover the transceiver and the end of each fiber-optic cable connector with a rubber safety cap immediately after disconnecting the fiber-optic cables.

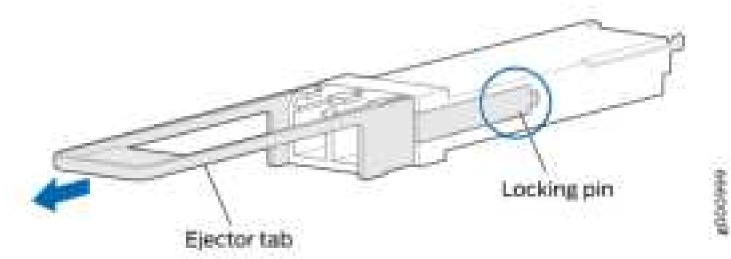
   LASER WARNING: Do not look directly into a fiber-optic transceiver or into the ends of fiber-optic cables. Fiber-optic transceivers and fiber-optic cables connected to transceivers emit laser light that can damage your eyes.

   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 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 15: Remove a QSFP28 Transceiver



> **CAUTION**: To avoid ESD damage to the transceiver, do not touch the 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 Cables

IN THIS SECTION

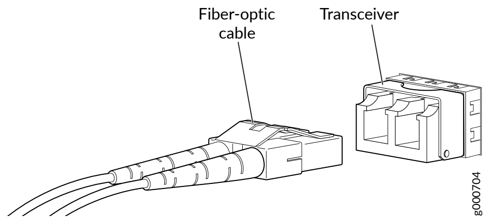
Connect a Fiber-Optic Cable

Before you connect a fiber-optic 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 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 cables. Fiber-optic transceivers and fiber-optic cables connected to transceivers emit laser light that can damage your eyes.

1. If the fiber-optic 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 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 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 Cable

Before you disconnect a fiber-optic 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 cable connector

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

To disconnect a fiber-optic 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 cables. Fiber-optic transceivers and fiber-optic cables connected to transceivers emit laser light that can damage your eyes.

2. Carefully unplug the fiber-optic 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 cable connector with the rubber safety cap.

How to Handle Fiber-Optic Cables

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

Follow these guidelines when handling fiber-optic cables:

- When you unplug a fiber-optic cable from a transceiver, place rubber safety caps over the transceiver and on the end of the cable.
- Anchor fiber-optic cables to prevent stress on the connectors. When attaching a fiber-optic cable to a transceiver, secure the fiber-optic cable so that it does not support its own weight as it hangs to the floor. Never let a fiber-optic cable hang free from the connector.
- Avoid bending the fiber-optic cables beyond their minimum bend radius. Bending fiber-optic 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 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 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 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.

4

CHAPTER

100G Optical Transceivers FAQs

IN THIS CHAPTER

Frequently Asked Questions

IN THIS SECTION

Which 100G transceivers does Juniper offer?

See Hardware Compatibility Tool for a list of all the 100G transceivers offered by Juniper, along with their detailed specifications.

Which 100G transceivers does my device support?

See Hardware Compatibility Tool for a list of the supported transceivers for your device.

Can I use a third-party transceiver with my device?

We recommend that you use only optical transceivers and optical connectors 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 and cables. However, JTAC does not provide support for third-party optical modules and cables that are not qualified or supplied by Juniper Networks. If you face a problem running a Juniper device that uses third-party optical modules or cables, 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 or cables. Your JTAC engineer will likely request that you check the third-party optical module or cable 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 or cables is the users' responsibility. Juniper Networks will accept no liability for any damage caused due to such use.

What form factors do 100G transceivers support?

Juniper supports CFP, CFP2, SFP-DD, and QSFP28 transceivers. See "Form Factors" on page 25 for a comparison of the various form factors and for more details.

What speeds do 100G transceivers support?

100G transceivers can support a range of speeds, depending upon their type. They can support:

- A single port of 100 Gbps
- Two ports of 50 Gbps
- Four ports of 25 Gbps

What are the different types of 100G transceivers?

100G transceivers can be classified based on their electrical and optical interface configurations.

- Electrical Interfaces
  - 2-Lane Electrical Interface (100GAUI-2)
  - 4-Lane Electrical Interface (400GAUI-4)
  - 10-Lane Electrical Interface (10x10G)
- Optical interfaces
  - Single-Lane Optical Interface
  - 4-Lane Optical Interface
  - 10-Lane Optical Interface

See "100G Optical Transceiver Flavors" on page 3 for details.

What standards do 100G transceivers follow?

100G transceivers and modules adhere to the IEEE 802.3ba-2010 standards, followed by 802.3bg-2011, 802.3bj-2014, 802.3bm-2015, and 802.3cd-2018 for 100G signaling. They also follow the IEEE 802.3-2022 standards for single-wavelength and FEC119.

The CFP, CFP2, SFP-DD, and QSFP28 form factors are defined by the CFP MSA, CFP2 MSA, SFP-DD MSA, and SFF-8665 standards respectively.

What does the name of the optic mean?

Optics and transceivers follow a naming convention where the product name contains the form factor, data rates, and lane distribution of the optic. See "Juniper Optical Product Numbers" on page 12 for a detailed example.

What is the optical lane distribution on 100G transceivers?

100G optics generally use 4 parallel lanes, each of which support 25 Gbps. Multiplexing occurs over multiple fibers, parallel optics, or optical or wavelength multiplexing techniques.

What modulation techniques do 100G transceivers support?

100G optics use Pulse Amplitude Modulation 4-level (PAM4) and Non-return to Zero (NRZ) or PAM2 modulation.

PAM4 combines two bits into a single symbol with four amplitude levels, enabling you to transmit twice as much data. It has a higher required signal-to-noise ratio which requires shorter transmission distances. It requires Forward Error Correction (FEC) to handle the loss of signal integrity. FEC is enabled by default on Juniper's transceivers.

NRZ is a binary modulation format with two distinct amplitude levels within a data channel. NRZ provides a good signal-to-noise ratio, giving it longer transmission reach.

See "Modulation Methods" on page 9 for more details.

What is Forward Error Correction?

Forward Error Correction (FEC) is a channel coding technique to ensure signal integrity in optical communication. FEC transmits the data with redundancies, allowing the receiver to detect and correct errors without requiring retransmission. FEC involves encoding the data at the transmitter end using FEC algorithms and decoding, analysing, and correcting the data at the receiver end. The error correction capability of FEC depends on the specific algorithm used and the amount of redundancy added.

What is Digital Signal Processing?

Digital Signal Processing (DSP) techniques are used to enhance the signal integrity on optical connections and to extend the reach of optical transceivers. DSP involves components such as Serializer/Deserializer (SerDes), Feed-forward Equalization (FFE), and Decision Feedback Equalization (DFE).

What is Clock Data Recovery?

Clock Data Recovery (CDR) is the process of extracting timing information from a data signal. The receiver uses the timing information embeddded in the data signal to determine the frequency of the transmitter's clock. The receiver then uses this information to re-time the signal to ensure accurate data retrieval and transmission. CDR helps to reduce jitter and improve signal integrity and reach.

What are the components of a 100G transceiver architecture?

100G (x4) optics are composed of the following:

- 100G host platform
- 4x25 Gbps electrical interfaces
- Digital Signal Processor/Clock Data Recovery (DSP/CDR)
- Drivers (4)
- Directly modulated lasers
- 4x25G optical interfaces
- Transimpedance Amplifiers (TIA)
- Photo-detectors

See "100G (X4) Transceiver Architecture" on page 13 for a detailed explanation of each component.

What is Dense Wavelength Division Multiplexing?

Dense Wavelength Division Multiplexing (DWDM) uses multiple light wavelengths or channels to increase the amount of data that can be transmitted over a single optical fiber.

What are tunable DWDM transceivers?

Tunable DWDM optical transceivers use advanced modulation and equalization techniques to encode more data onto light waves and overcome transmission impairments. Tunable DWDM optics use both amplitude and phase modulation for data encoding.

Juniper's tunable DWDM optics use two types of DWDM connections:

- Unamplified link (limited optical power)
- Amplified link (limited optical signal-to-noise ratio and chromatic dispersion)

See No Link Title for more details on tunable DWDM optics.

What are breakout capability and breakout cables?

Breakout capability is the ability to split a high-speed link into multiple smaller, lower-speed links. This is also called channelization. Breakout capability is crucial for optimizing the use of available bandwidth and physical infrastructure in various networking scenarios.

You can configure port speeds at the chassis level or the interface level. You can channelize an individual port, a block of ports, or a quad of ports.

Breakout cables have a single transceiver at one end and multiple transceivers at the other end. You can use breakout cables to physically split a single high-speed port to multiple lower-speed ports.

For more details, see "Breakout Capability" on page 35.

How does my device support breakout/channelization?

See Port Checker for details on channelization support for your device.

What are single-mode and multi-mode fibers?

Single-mode fibers (SMF) are designed to trasmit only one mode of an optical signal at a time. They have a core diameter of 9 microns. They have low attenuation and can support higher data rates and longer transmission distances.

Multi-mode fibers (MMF) can transmit multiple optical signals at the same time. They have a core diameter of 62.5 microns. They are easier to handle and manufacture as compared to SMF. They have higher attenuation and are used to transmit data over shorter distances.

What are the different types of cables used in 100G transceivers?

100G transceivers use direct attach cables (DAC) and active optical cables (AOC). See "Cable Types and Length" on page 31 for details.

For a list of AOC and DAC cables supported by Juniper, see Hardware Compatibility Tool.

What are the different types of connectors used in 100G transceivers?

100G optical cables use duplex LC, MPO-12/APC, MPO-12/BiDi/UPC, and MPO-24 connectors. See "Connector Types" on page 29 for more details.

What is the power requirement for 100G optics?

Different form factors have different power requirements:

- CFP transceivers require up to 24 W of power. DWDM coherent optics require up to 32 W.
- CFP2 transceivers require up to 12 W of power. Tunable DWDM optics require up to 24 W.
- SFP-DD transceivers require up to 2.5 W of power. Tunable DWDM optics require up to 6.5 W.
- QSFP28 transceivers require up to 3.5 W of power. ZR coherent optics require up to 6.5 W.

Can I plug a 40G QSFP+ module into a QSFP28 port?

Yes. The QSFP28 ports are backward compatible with the QSFP+ ports in some configurations. You must configure the QSFP28 port for a data rate of 40G instead of 100G.

Can I plug a CFP/CFP2 module into a QSFP28 port and vice versa?

No. CFP, CFP2, and QSFP28 refer to optics with different physical form factors. You can plug only CFP modules into CFP ports, CFP2 modules into CFP2 ports, and QSFP28 modules into QSFP28 ports.