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Demystifying Coherent Optics for Network Professionals

Practical Use Cases and configuration tips for 100G, 400G and 800G coherent plugs

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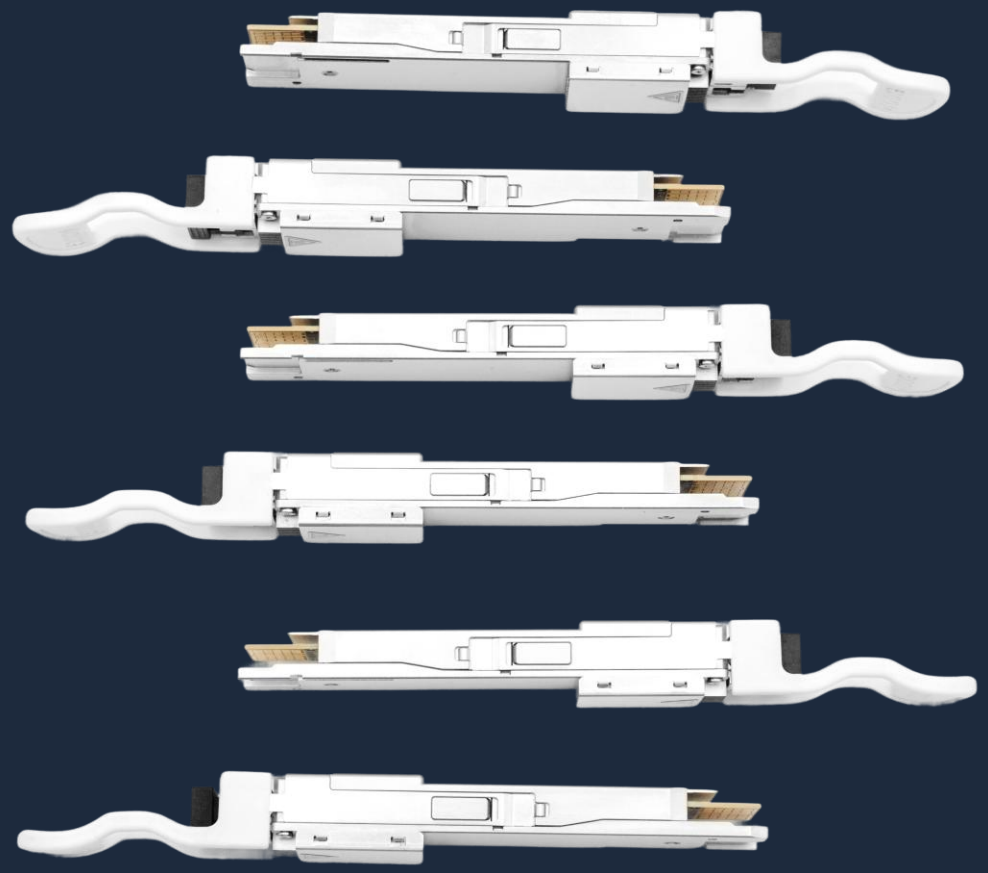
Salumanus



TNC26, Helsinki, 2026

What is a Coherent Transceiver?

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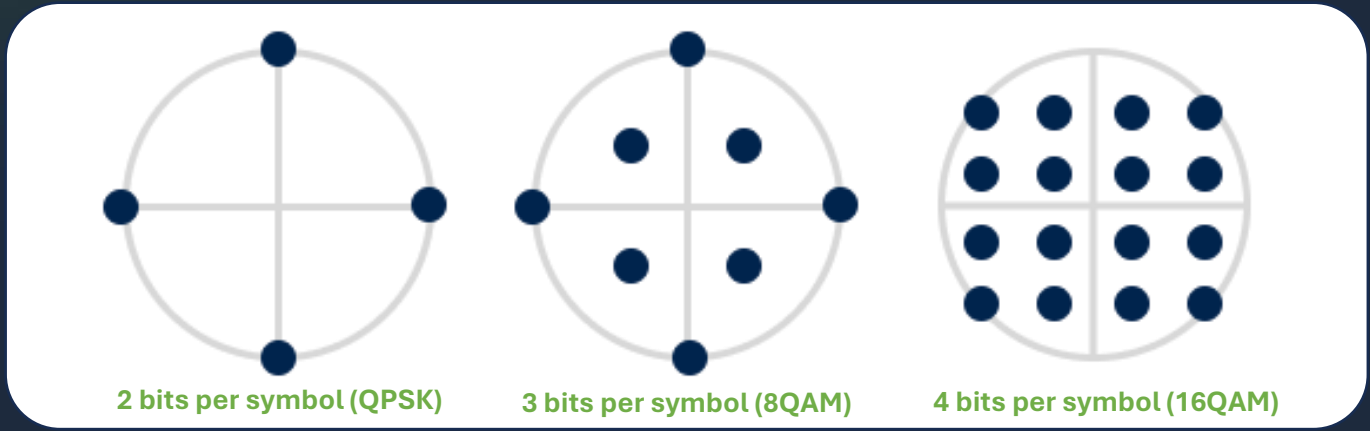
- **Brief introduction to coherent technology**

  *Coherent technology is an advanced method for transmitting data over fiber using **amplitude, phase and polarization of light**. Coherent plugs combines a **tunable laser, coherent receiver, digital signal processor (DSP), and FEC engine** in a single compact form factor like QSFP-DD or even QSF28.*



Bit rate =
Baud rate x Bit per symbol x Polarisation

- **How it differs from traditional (IMDD) optics?**

  ***IMDD (Intensity Modulation Direct Detection) uses only the light's amplitude** to transmit data, making it simple, cost-effective, and suitable for short distances.*

- **What standards are behind coherent transceivers?**

  OIF 400ZR, OIF 800ZR, OpenZR+, OpenROADM, CMIS / C-CMIS

What types are available on the market today?

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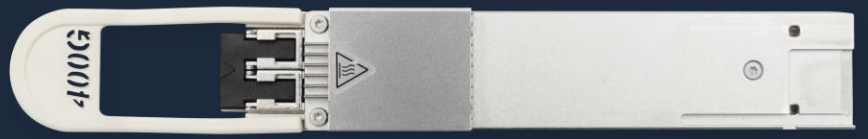
- **QSFP28 100G** with support for 100GbE or/and OTU4
  - 0dBm output power
  - -8dBm output power

- **QSFP-DD 400G**
  - OIF 400ZR with support for 400GbE, TX power -10dBm
  - OpenZR+ with support for 400GbE, 300GbE, 200GbE, 100GbE, TX power -10dBm/0dBm
  - ZR++ with support for 400GbE, TX power 0dBm



- **QSFP-DD 800G**
  - OIF 800ZR supporting 800GbE, TX power -8dBm
  - OpenZR+ supporting 800GbE, 600GbE, 400GbE, TX power -7dBm/0dBm

What should I know about host & media side applications?

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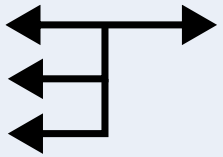
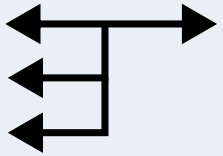
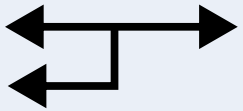
Host Side	Datapath					Media Side
Host Interface	Host Map/Demap	MUX/DMUX	Media Framing	FEC Encode/Decode	Modulation	Media Interface
1 x 400GBASE-R	1 x 400ZR.ts		400ZR	OFEC	16QAM	ZR400-OFEC-16QAM
2 x 200GBASE-R	2 x 200ZR.ts					
4 x 100GBASE-R	4 x 100ZR.ts					
1 x 400GBASE-R	1 x 400ZR.ts		400ZR	OFEC	8QAM	ZR400-OFEC-8QAM
2 x 200GBASE-R	2 x 200ZR.ts					
4 x 100GBASE-R	4 x 100ZR.ts					
3 x 100GBASE-R	3 x 100ZR.ts		ZR300	OFEC	8QAM	ZR300-OFEC-8QAM
1 x 200GBASE-R	1 x 200ZR.ts		ZR200	OFEC	QPSK	ZR200-OFEC-QPSK
2 x 100GBASE-R	2 x 100ZR.ts					
1 x 100GBASE-R	1 x 100ZR.ts		ZR100	OFEC	QPSK	ZR100-OFEC-QPSK

Source: https://openzrplus.org/

What shoud I know about host & media side applications?

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		Instances by Operational Mode Data Rate		
Client Type	**Chip-to-Module interface**	**800G**	**600G**	**400G**
100GBASE-R	100GAUI-1	8x	6x	4x
200GBASE-R	200GAUI-2	4x	3x	2x
400GBASE-R	400GAUI-4	2x	N/A	1x
800GBASE-R	800GAUI-8	1x	N/A	N/A

Description	Modulation	FEC	Symbol Rate (GBd)
OIF 800ZR, DWDM, amplified	16QAM	O-FEC	118.2
OpenZR+ ZR800-OFEC-16QAM	16QAM	O-FEC	118.2
OpenZR+ ZR600-OFEC-8QAM	8QAM	O-FEC	118.2
OpenZR+ ZR400-OFEC-QPSK	QPSK	O-FEC	118.2

Source: https://openzrplus.org/ & https://www.oiforum.com/

What shoud I know about host & media side applications?

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- **Step 1 -** gather your link requirements
  Link length? Dark fiber or DWDM? What is your channel spacing? OSNR level? Throughput?

- **Step 2** - select the right transceivers
  Example outcome of Step 1: 200km, DWDM, 50GHz, 19dB OSNR, 100GbE
  Option 1 -> QSFP28 100ZR
  Option 2 -> QSFP-DD OpenZR+ in 100GbE mode

- **Step 3** - match transmision mode to link budget
  Option 1 -> for QSFP28 it could work with 100GbE on 50GHz grid
  Option 2 -> for QSFP-DD OpenZR+ we could select ZR100-OFEC-QPSK, and 1x100GbE on host side*
  *some vendors support on 50GHz grid 200G, OFEC, 16QAM and 2x100GbE or 1x200GbE on host side

- **Step 4** - configure your transceivers
  Detailed guide on next slides ☺

Understanding basic optical parameters

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TX Power

- **What is it?**
  The amount of optical power emitted by the transceiver into the fiber
- **Why is it important?**
  It determines whether the signal can travel the required distance and remain detectable on the receiver side.
- **Unit:** *dBm (decibel-milliwatts)*
- **Typical range:** *-10 dBm to +1 dBm*
  depending on the module type and mode
- **Note:** *Insufficient TX power may result in poor signal quality*

Understanding basic optical parameters

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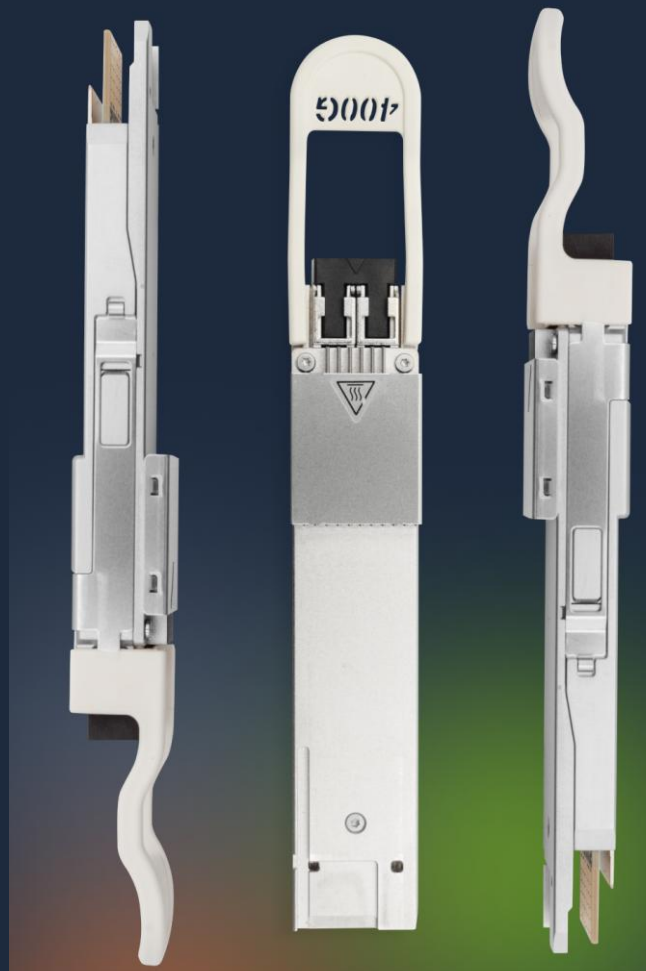
RX Power

- **What is it?**
  The amount of optical power received by the transceiver
- **Why is it important?**
  It shows if the incoming signal is strong enough for successful decoding
- **Unit:** *dBm*
- **Typical value:** *0 dBm to -30 dBm*
- **Note:** *If RX power is too low → errors or link down*
  If RX power is too high → receiver saturation



Understanding basic optical parameters

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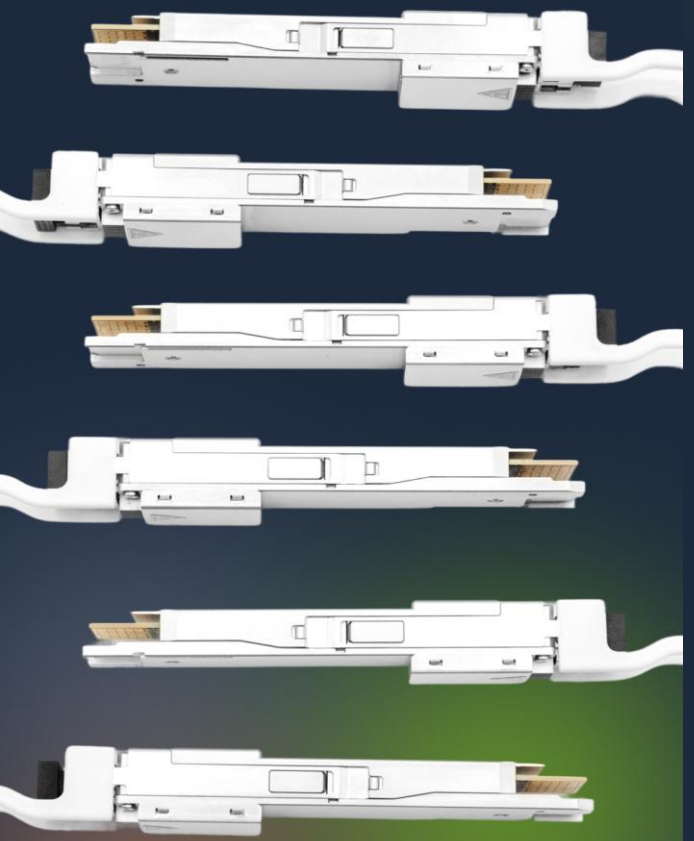


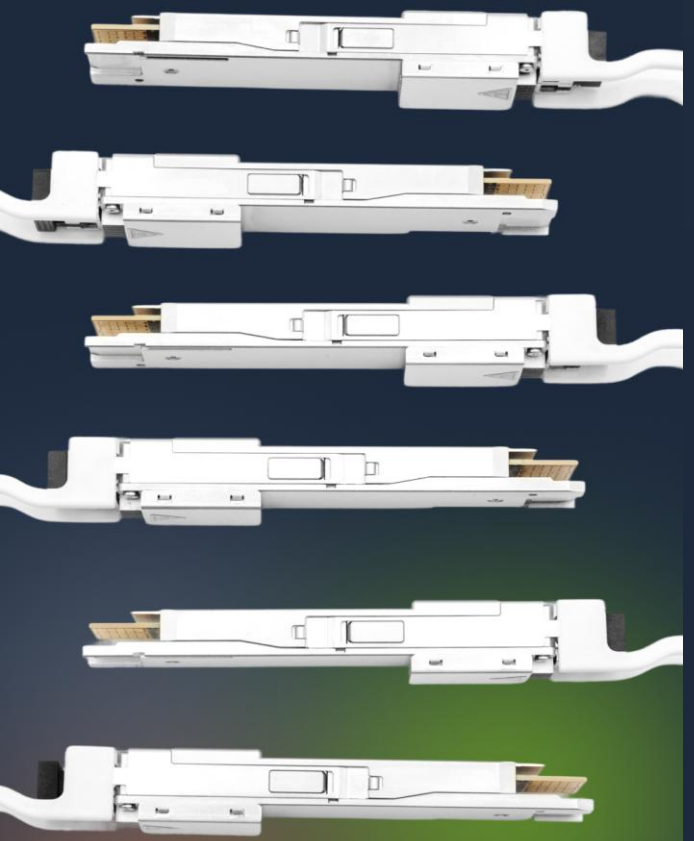
OSNR

- **What is it?**
  The ratio of the signal power to the noise power in the optical channel
- **Why is it important?**
  OSNR is a critical metric for coherent optics, as it directly impacts the bit error rate (BER)
- **Unit:** *dB*
- **Typical value:** *400G 16QAM: ~24 dB*
  200G QPSK: ~16 dB

Understanding basic optical parameters

Q-factor

- What is it?
  A measure of how distinguishable the optical signal is from noise and distortion. Simply Pre-FEC BER expressed using logarithmic scale.
- Why is it important?
  Higher Q-factor = cleaner signal, lower BER.
- Unit: *dB*
- Interpretation: *> 8 dB = Good*
  6.5 - 8 dB = Monitor
  < 6.5 dB = Risk of link failure



Q-margin

- **What is it?**
  The difference between measured Q-factor and the minimum required Q-factor represented by the efficiency limit of the FEC algorithm used.
- **Why is it important?**
  It reflects how much "headroom" you have before errors start appearing.
- **Example:**

Required Q = 6.5 dB
Measured Q = 9.0 dB
→ Q-margin = 2.5 dB

Understanding basic optical parameters

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```
Juniper@re0> show interfaces transport pm optics current et-0/0/4
…
    PM                              CURRENT   MIN       MAX       AVG       THRESHOLD
                                                                            (MIN)    (MAX)
  …
  Pre-FEC BER                       1.64e-3   1.62e-3   1.68e-3   1.64e-3   0        9.00e-3
  …
  Tx power(dBm)                     0.00      -0.01     0.01      0.00      -10.00   4.00
  Rx total power(dBm)               -6.34     -6.34     -6.22     -6.30     -21.00   4.00
  Rx signal power(dBm)              -6.53     -6.59     -6.53     -6.56     -17.50   2.00
  Tx bias current(mA)               100.00    100.00    100.00    100.00    0        0
  …
  OSNR(dB)                          31.2      31.2      31.2      31.2      0        0
  …
  Q value(dB)                       9.3       9.3       9.3       9.3       0        0
  Q margin(dB)                      2.1       2.1       2.1       2.1       0        0
```

My first Juniper link

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Basic commands:

show interfaces diagnostics optics-applications et-0/0/4

This command provides detailed optical module information, including supported modes

JUNIPER NETWORKS

```
Physical interface: et-0/0/4
  ...
```

Ap Sel	Host Intf Code	Host Id	Apsel Supported	Media Intf Code	Media Id
1	400GAUI-8 C2M (Annex 120E)	17	Y	400ZR, DWDM, amplified	62
2	400GAUI-8 C2M (Annex 120E)	17	Y	400ZR, Single Wavelength, Unamplified	63
3	100GAUI-2 C2M (Annex 135G)	13	Y	400ZR, DWDM, amplified	62
4	400GAUI-8 C2M (Annex 120E)	17	Y	ZR-400-OFEC-16QAM	70
5	100GAUI-2 C2M (Annex 135G)	13	Y	ZR-400-OFEC-16QAM	70
6	100GAUI-2 C2M (Annex 135G)	13	Y	ZR-300-OFEC-8QAM	71
7	100GAUI-2 C2M (Annex 135G)	13	Y	ZR-200-OFEC-QPSK	72
8	100GAUI-2 C2M (Annex 135G)	13	Y	ZR-100-OFEC-QPSK	73

My first Juniper link

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Basic commands:

```
show interfaces diagnostics optics-applications et-0/0/4
```
This command provides detailed optical module information, including supported modes

```
set interface et-0/0/0:0 optics-options application mediaid 70 hostid 17
```
This command set both line and host side transmission modes

```
set interfaces et-0/0/0:0 optics-options tx-power -6
```
This command set TX output power

```
set interfaces et-0/0/0:0 optics-options wavelength 1552.52
```
This command set wavelength

Additional commands:

```
set interface et-0/0/0 number-of-sub-ports 4 speed 100g
run show interfaces et-0/0/0
run show interfaces diagnostics optics et-0/0/0
run show interfaces transport pm et-0/0/0
```

JUNIPER NETWORKS

My first Nokia link

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Basic commands:

```
configure port 1/1/1 ethernet mode 400G
configure port 1/1/1 transceiver digital-coherent-optics true

configure port 1/1/1 optics-profile 400ZR
configure port 1/1/1 dwdm coherent compatibility long-haul
```

This command sets both line and host side application

```
configure port 1/1/1 dwdm coherent target-power 0
```

This command sets TX output power

```
configure port 1/1/1 dwdm frequency 194400000
```

This command sets wavelength

Additional commands:

```
configure port 1/1/1 connector breakout c1-400g
show port 1/1/c1 detail
info flat | match [port number]
```

NOKIA

My first Cisco link

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Basic commands:

```
configure terminal
interface ethernet 1/1

zrp-optics fec oFEC muxponder 1x400 modulation 16QAM dac-rate 1x1
```

This command sets both line and host side transmission mode

```
configure port 1/1/1 tx-power 0
```

This command sets TX output power

```
zrp-optics dwdm-carrier wavelength 1552.52
```

This command sets wavelength

Additional commands:

```
interface breakout module 1 port 1 map 100g-4x-pam4
show port 1/1/1 optics detail
show port 1/1/1 statistics
show port 1/1/1 performance
```

CISCO

My first OcNOS link

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Basic commands:

show qsfp-dd [port number] advertisement applications

This command provides detailed optical module information, including supported applications

qsfp-dd [port number]

application 8

This command sets both line and host side application

laser channel 20

laser fine-tune-freq 2.000

laser grid 50

laser output-power -1.00

This command sets TX output power & set wavelength

Additional commands:

show qsfp-dd [port number] eeprom

show interface brief

show running-config interface

show qsfp-dd [port number] state

show qsfp-dd [port number] laser status

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What do I need to know about the optical path?

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- **Example 1, my path OSNR is 21dB, grid 100GHz**
  - Option 1 - I can use 400ZR+, but need to set it up to ZR300-oFEC-8QAM and 3x100GbE (switch needs to be set to 3 sub-interfaces)
  - Option 2 - I can use 400ZR++ transceivers, which support also ZR400-oFEC-8QAM, this will allow me to use 400GbE mode on the host side

400G ZR+

Transmission mode	400ZR OIF	400ZR+	300ZR+	200ZR+	200G EX	100ZR+
Baud rate	60Gbaud	60Gbaud	**60Gbaud**	60Gbaud	30Gbaud	30Gbaud
Modulation	16QAM	16QA	8QAM	QPSK	16QAM	QPSK
Tx power	-10dBm - +1dBm	-10dBm - +1dBm	-10dBm - +1dBm	-10dBm - +1dBm	-10dBm - +1dBm	-10dBm - +1dBm
Rx sensitivity	-20dBm	-22dBm	-22dBm	-22dBm	-22dBm	-22dBm
DWDM reach	120km	450km	600km	1000km	450km	2000km
OSNR tolerance	26dB	24dB	**21dB**	16dB	19dB	12dB

400G ZR++/ULH

Transmission mode	400ZR++	400ZR+ ULH
Baud rate	**80Gbaud**	118Gbaud
Modulation	8QAM	QPSK
Tx power	-10dBm - +1dBm	-10dBm - +1dBm
Rx sensitivity	-22dBm	-22dBm
DWDM reach	2000km	2400km
OSNR tolerance	**20.5dB**	17.5dB

What do I need to know about the optical path?

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- **Example 2, my path OSNR is 18dB, flex-grid**
  - Option 1 - I can use 400ZR+, but need to set it up to ZR200-oFEC-QPSK and 2x100GbE (switch need to be set to 2 sub-interfaces)
  - Option 2 - I can use 800ZR+ transceivers, which support ZR400-oFEC-QPSK, this will allow me to use on host side 400GbE mode (it will require passband 150GHz)

400G ZR+

Transmission mode	400ZR OIF	400ZR+	300ZR+	200ZR+	200G EX	100ZR+
Baud rate	60Gbaud	60Gbaud	60Gbaud	**60Gbaud**	30Gbaud	30Gbaud
Modulation	16QAM	16QA	8QAM	QPSK	16QAM	QPSK
Tx power	0dBm	0dBm	0dBm	0dBm	0dBm	0dBm
Rx sensitivity	-20dBm	-22dBm	-22dBm	-22dBm	-22dBm	-22dBm
DWDM reach	120km	450km	600km	1000km	450km	2000km
OSNR tolerance	26dB	24dB	21dB	**16dB**	19dB	12dB

800G ZR+

	800G		400G		High Performance	
Transmission mode	OIF 800ZR	OpenZR+	ZR400-OFEC-8QAM	OR-400G	800-SDFEC-QAM16-PS	600-SDFEC-QAM16-PS
Baudrate	118Gbaud	118Gbaud	80Gbaud	**118Gbaud**	124Gbaud	119Gbaud
Bitrate	800G	800G	400G	400G	800G	600G
Modulation	16QAM	16QAM	8QAM	QPSK	16QAM	16QAM
Tx power	-2dBm	0dBm	0dBm	0dBm	0dBm	0dBm
DWDM reach	120km	500km	1500km	2000km	1000km	2000km
OSNR tolerance	25.5dB	25.5dB	22dB	**17.5dB**	23.5dB	20.5dB

My deployment/troubleshooting checklist

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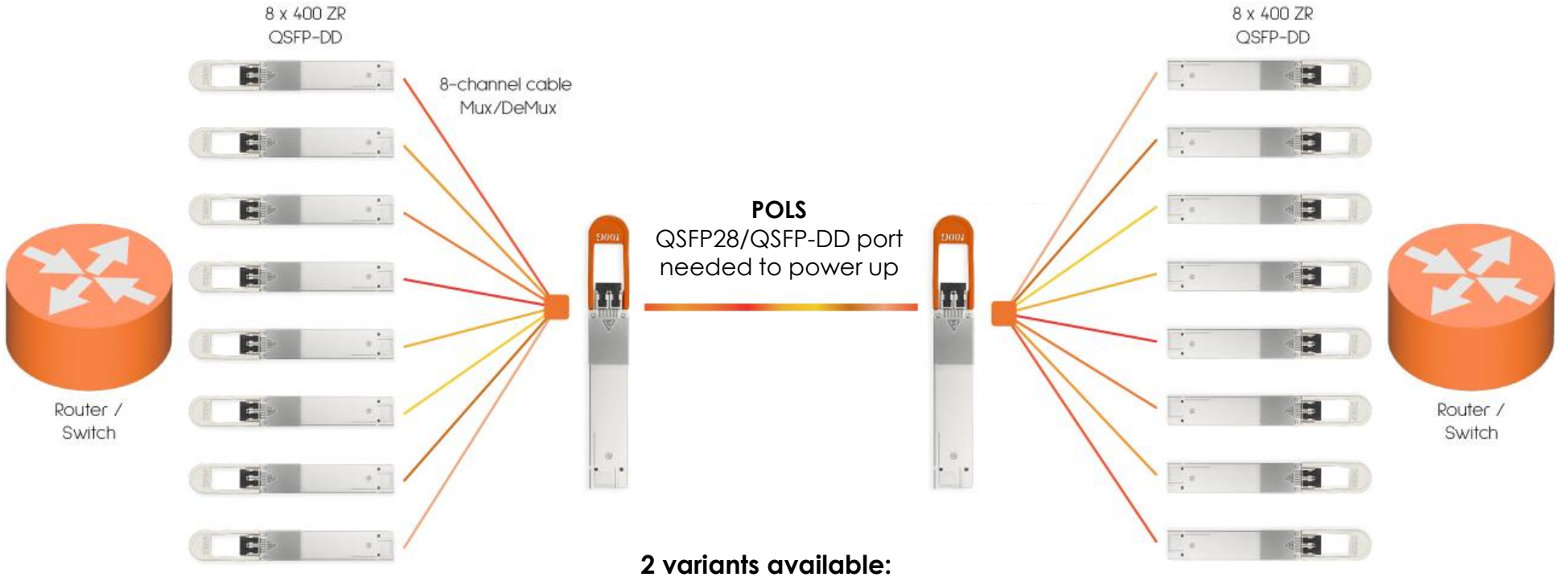
- **Step 1** - RX power
  Is the optical path continuous?
- **Step 2** - Channel
  Coherent receiver is reading only one wavelength set up for Tx
- **Step 3** - OSNR/Q-factor/Q-margin
  To establish stable link, we need to be within a range
- **Step 4** - Host side application
  Both end host side transmission mode need to be same
- **Step 5** - …
  LINK UP ☺

How to use this knowledge?



2 variants available:
8-channel for 120km
16-channel for 40km

How to use this knowledge?

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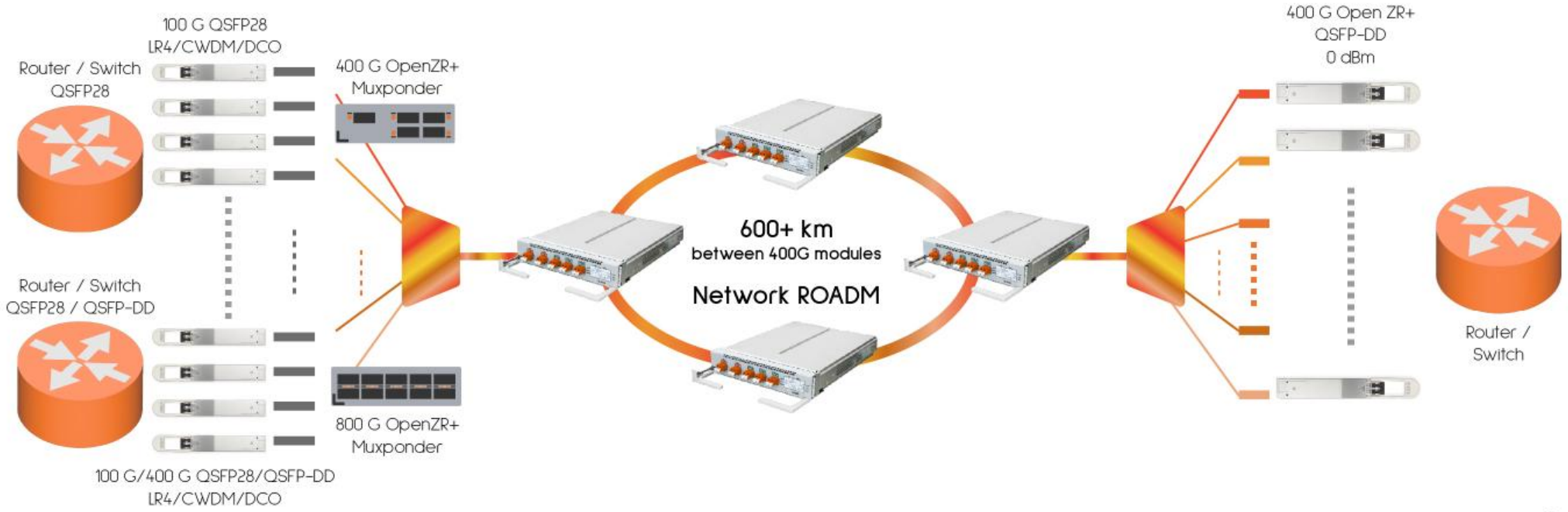
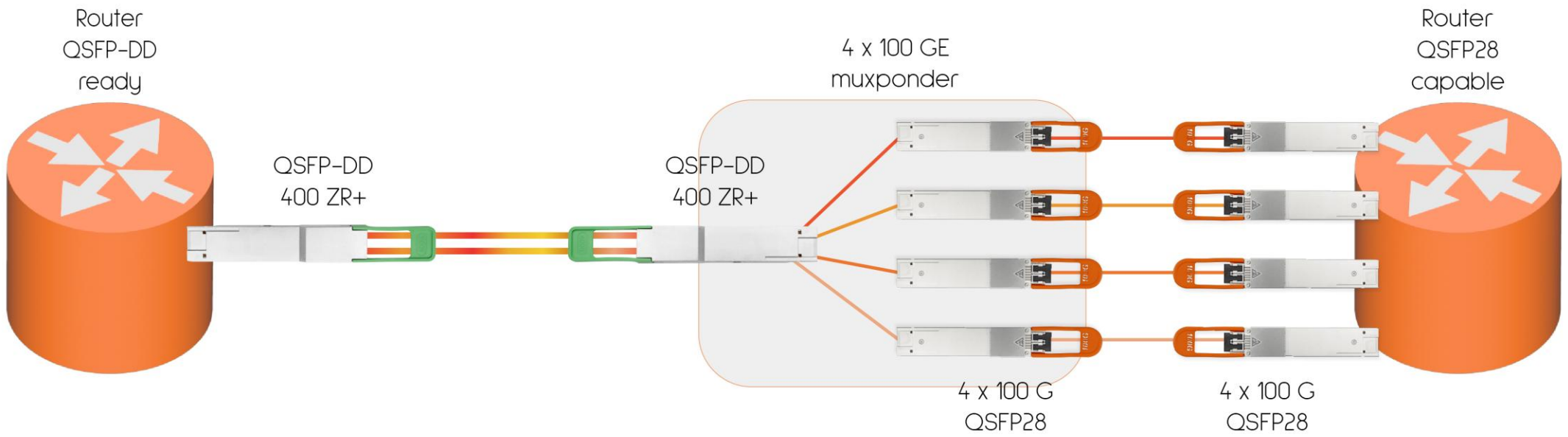


What if...

I need to connect 400G to 100G?



Source: https://openzrplus.org/

What if...

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I need to connect 400G to 100G?

```
port 14 {
        number-of-sub-ports 4;
        speed 100g;
}
et-0/0/14:X {
        optics-options {
                wavelength 1561.42;
                laser-enable;
                application {
                        hostid 13;
                        mediaid 70;
                        }
                high-power-mode;
                }
        }
}
```

What if...

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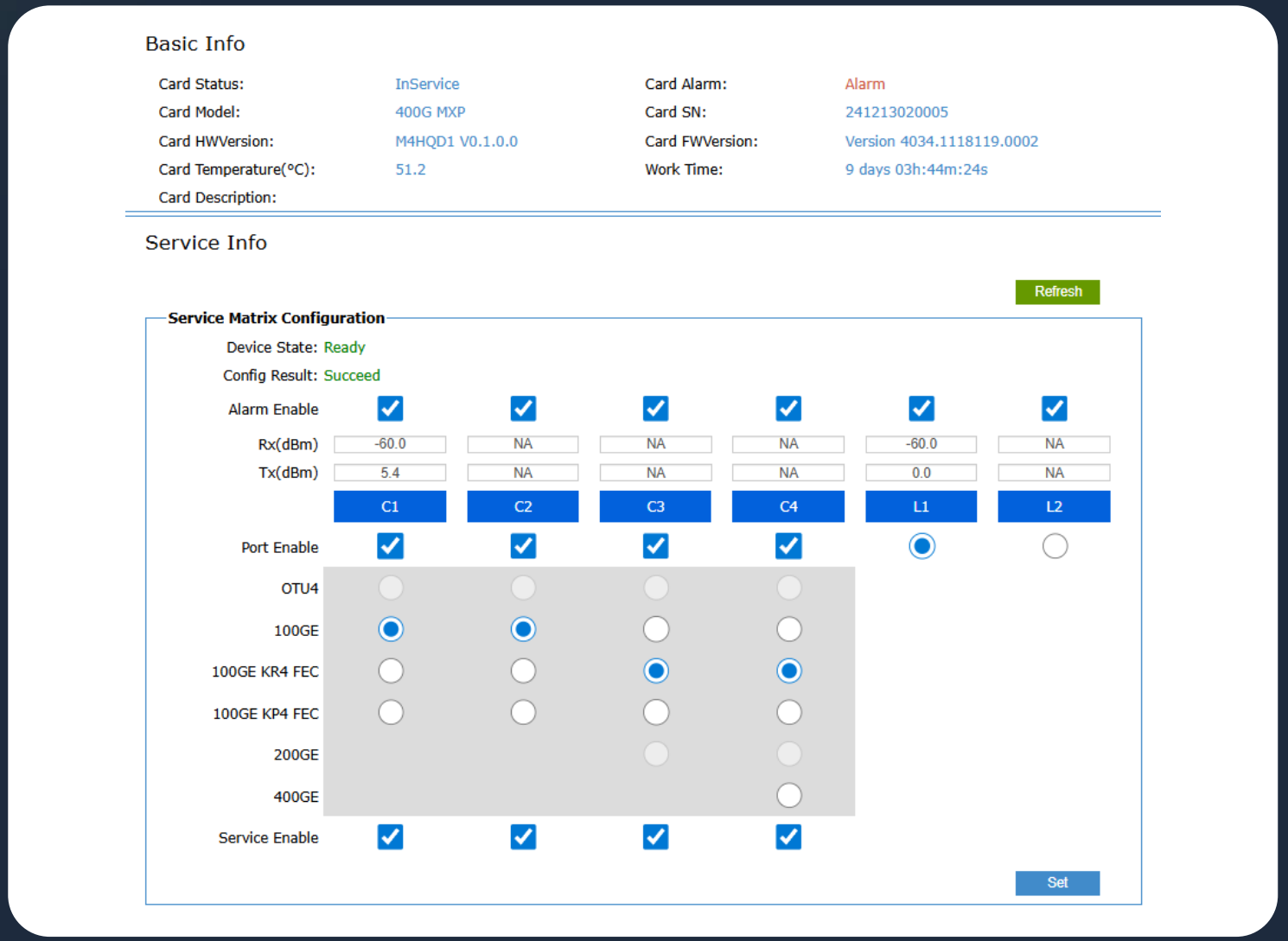
I need to connect 400G to 100G?



What if...

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I need to connect 400G to 100G?

Line Side 1(QSFP-DD-ZR)

Real Wavelength(nm):	1545.32		
Wavelength:	100GHz(48CH)	1545.32nm(194000.00GHz)	Set
Output Power(-6.0 ~ 1.0dBm):	0.0		Set
Rx Pre-FEC BER:	1.00e+00		
Rx Post-FEC BER:	0.00e+00		
Dispersion(ps/nm):	0		
OSNR Level(dB):	0.0		
QSFP-DD-ZR Module State:	Normal		

Port Description Information

C1:	
C2:	
C3:	
C4:	
L1:	
L2:	

Set

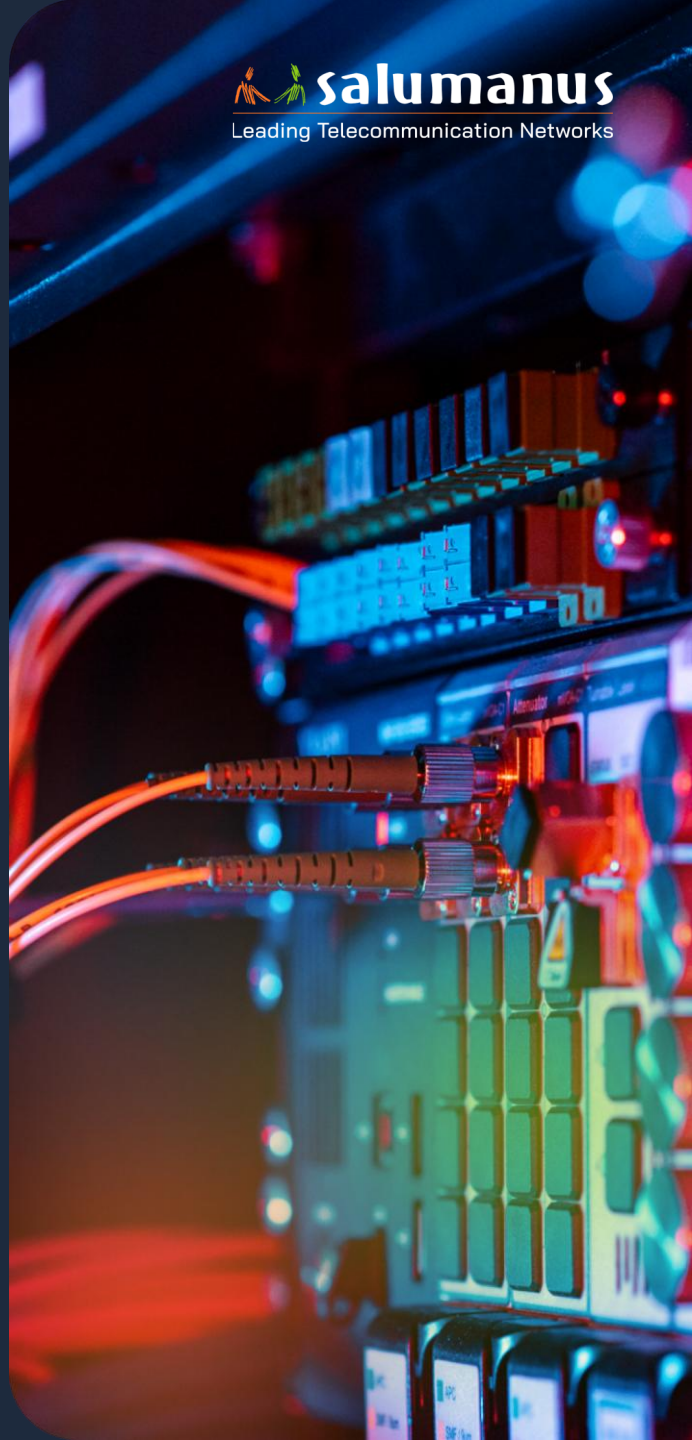
DDM Information

Port	Interface Type	VendorName	PN	SN	Lane	WL(nm)	Rx(dBm)	Tx(dBm)	Bias(mA)	Temp(°C)	Service Rate	Port State	Admin State
C1	QSFP28_LR4	GBC PHOTONICS	Q28DSLOLQE010CGP	GPH241029091	1	1295.56	-60.0	-0.4	44.3	31.1	100GE	Alarm	Up
					2	1300.05	-60.0	-0.5	38.3				
					3	1304.58	-60.0	-0.8	34.8				
					4	1309.14	-60.0	-0.4	35.8				
C2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Absent	NA
C3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Absent	NA
C4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Absent	NA
L1	QSFP_DD_ZR	GBC PHOTONICS	740-0__ZR+	GPI231211020	1	1545.32	-60.0	0.0	20.0	51.6	OTUC4	Normal	Up
L2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Absent	NA

What if...

I need to connect 400G to 100G?

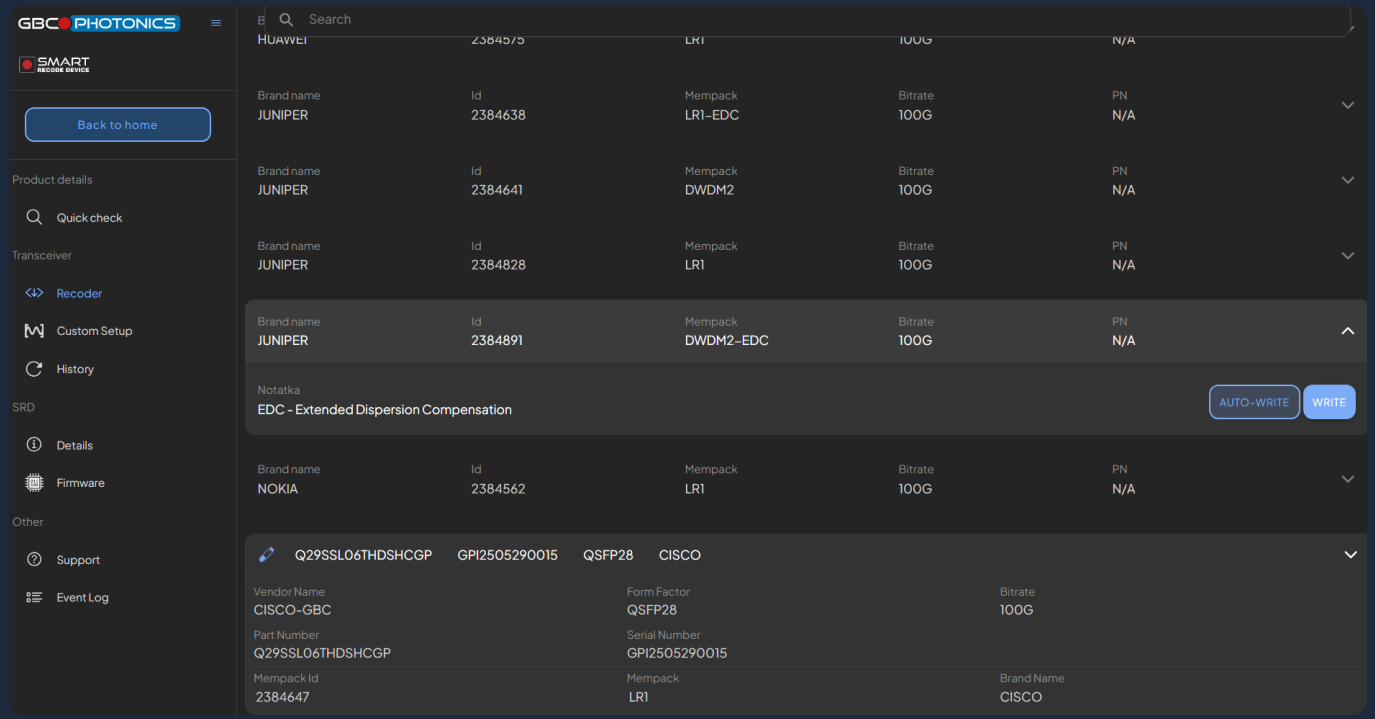
- **Why?**
  - Because we could deploy 400G coherent optics today, even if only one side of the link supports 400G transceivers
  - More efficient use of DWDM spectrum - 75GHz instead of 200GHz (4x50GHz)
  - Future-ready design - once both ends are upgraded to support 400G interfaces, you can remove the muxponder and connect the same optics directly
- **Cost**
  Less than 2x 100G
- **Flexibility**
  Client side of muxponder could be equipped with different transceivers



What if…

My device doesn’t support CMIS?

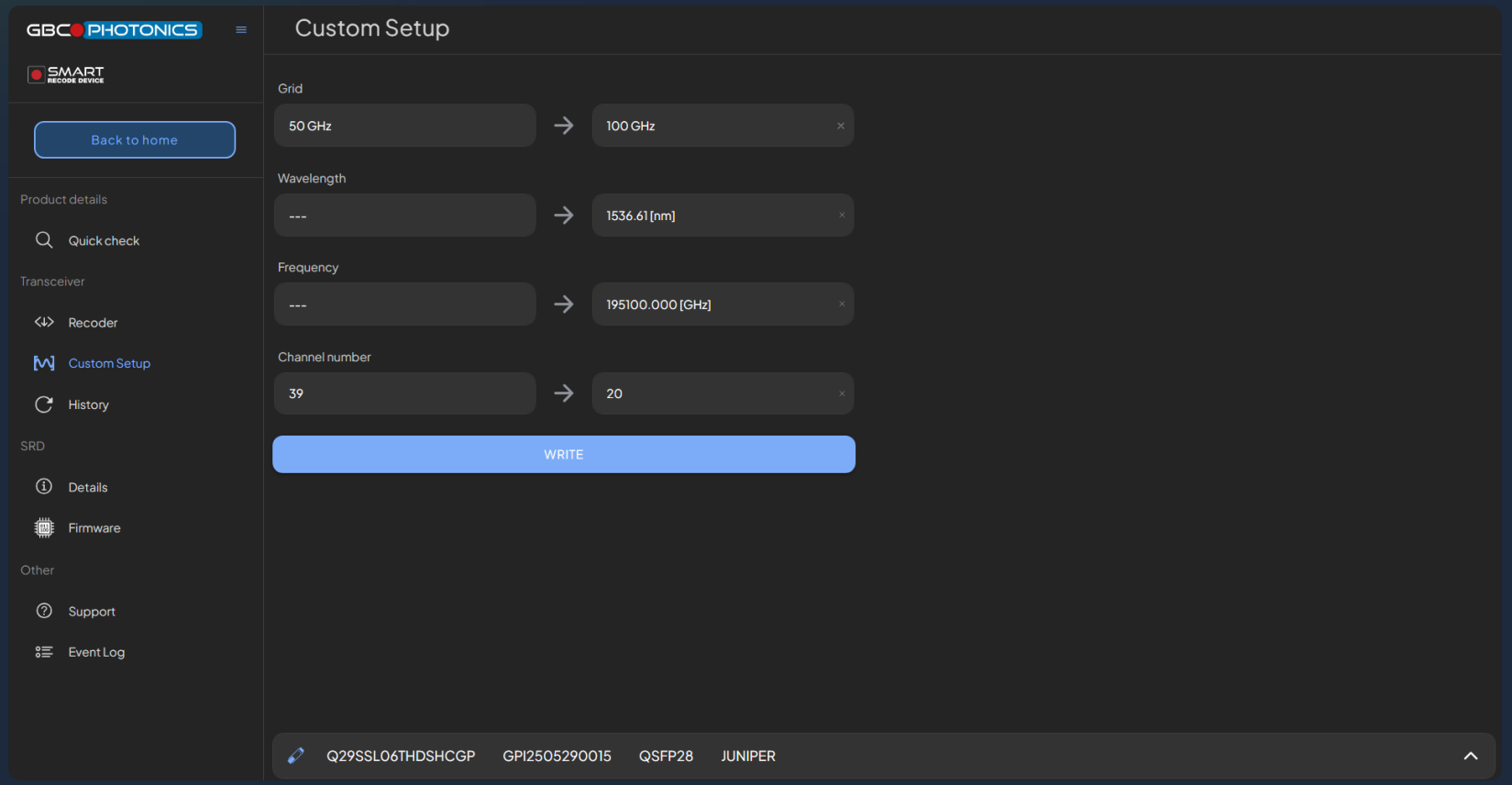
- How I could benefit from 100G Coherent transceivers if my device does not support CMIS?
  - SFF version - Simulating QSFP28 LR4
  - SFF version - Simulating QSFP28 LR1
  - SFF version - Simulating QSFP28 DWDM2



What if...

My device doesn’t support CMIS?

- How to run it on legacy devices? - Wavelength Tuning



What if...

My device doesn’t support CMIS?

- **How to run it on legacy devices? – Link Testing**

Pre-FEC BER 0.10	Q-factor 13.70 | dB
Q-margin 5.40 | dB	OSNR 28.10 | dB
Tx Power 1.4526 | dBm	Rx Total Power -18.62 | dBm
Module Temperature 49.6250 | C	Laser Temperature 48.5625 | C
eSNR 13.90 | dB	Residual ISI/Dispersion, line ingress 1691.00 | ps/nm
PDL 0.30 | dB	DGD 2.24 | Ps
Laser Bias Current 80.000 | mA	Module Voltage 3.2860 | V

Q29SSL06THDSHCGP GPI2601120014 QSFP28 EXTREME

Summary

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Key Takeaways

- Coherent transceivers simplify High-Speed, Long-Distance Networking
- Proper configuration is critical for success
- Coherent transceivers support flexible internetworking with legacy infrastructure

Common deployment mistakes to avoid

- Mismatched applications, host & media side on both ends
- Mismatched channel numbers
- Ignoring optical budget & OSNR requirements

Checklist for successful coherent deployment

- Confirm platform compatibility
- Select and apply correct application mode
- Verify optical path parameters
- Monitor link health after turn-up

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Thank you for your attention

Our name comes from the Latin words "salus" (helpful) and "manus" (hand), **reflecting our mission to support you**

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