

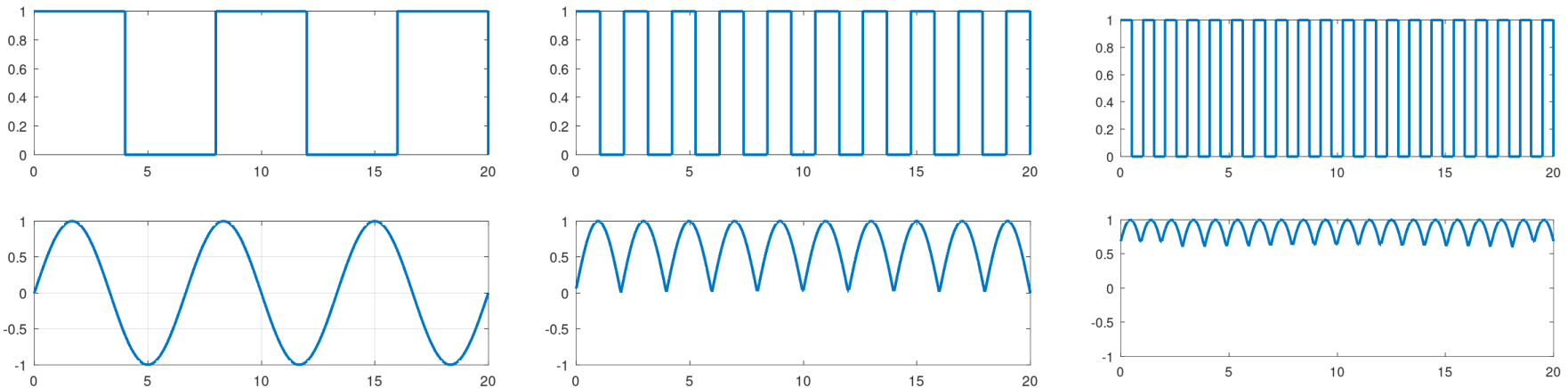
coherent optical transceivers



current capabilities and
future possibilities

Direct Detection Transceiver limits

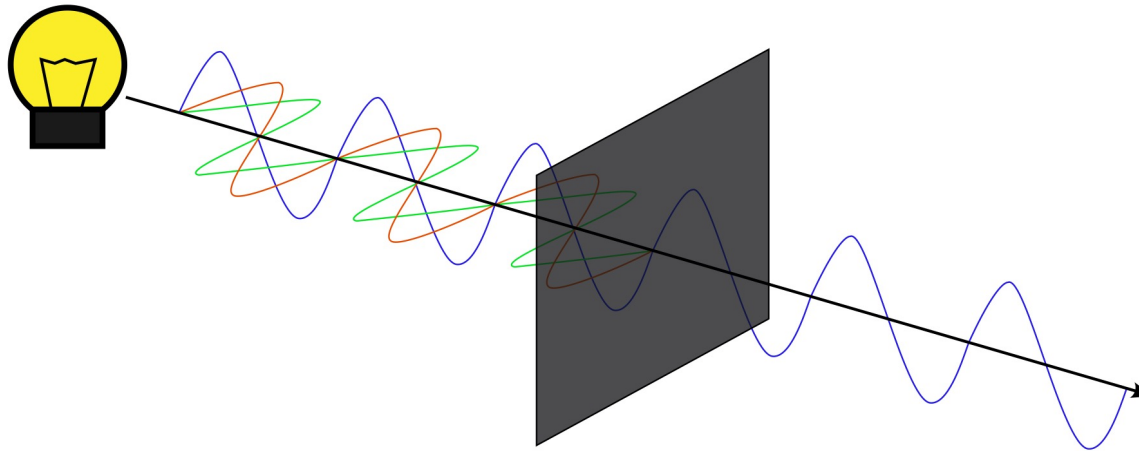
With **higher** frequencies -> harder for Photodiodes to detect



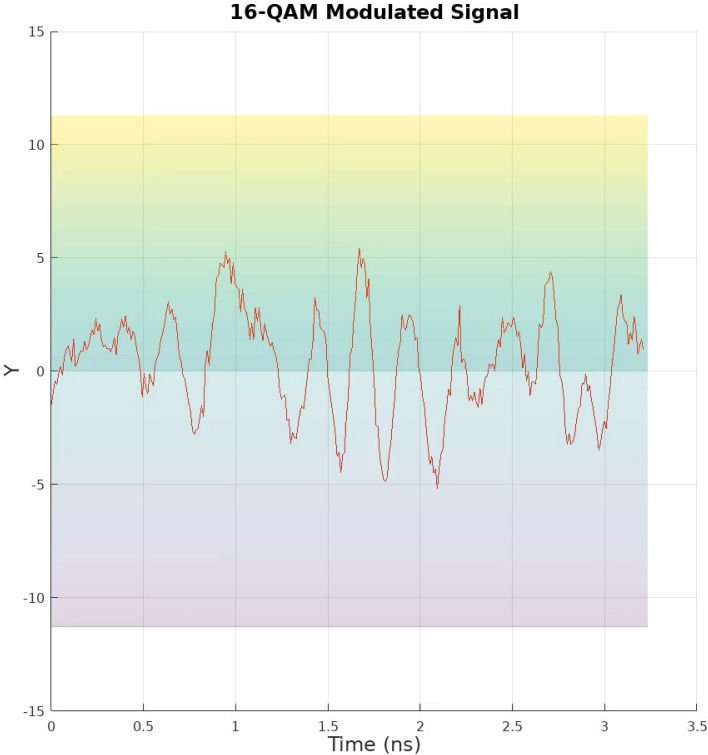
Missed Opportunity: **Light** has more **Properties**

Main Properties of Photonic Waves

- Besides **Amplitude**, also **Phase** and **Polarisation**
- More properties per Carrier = Higher Bandwidth

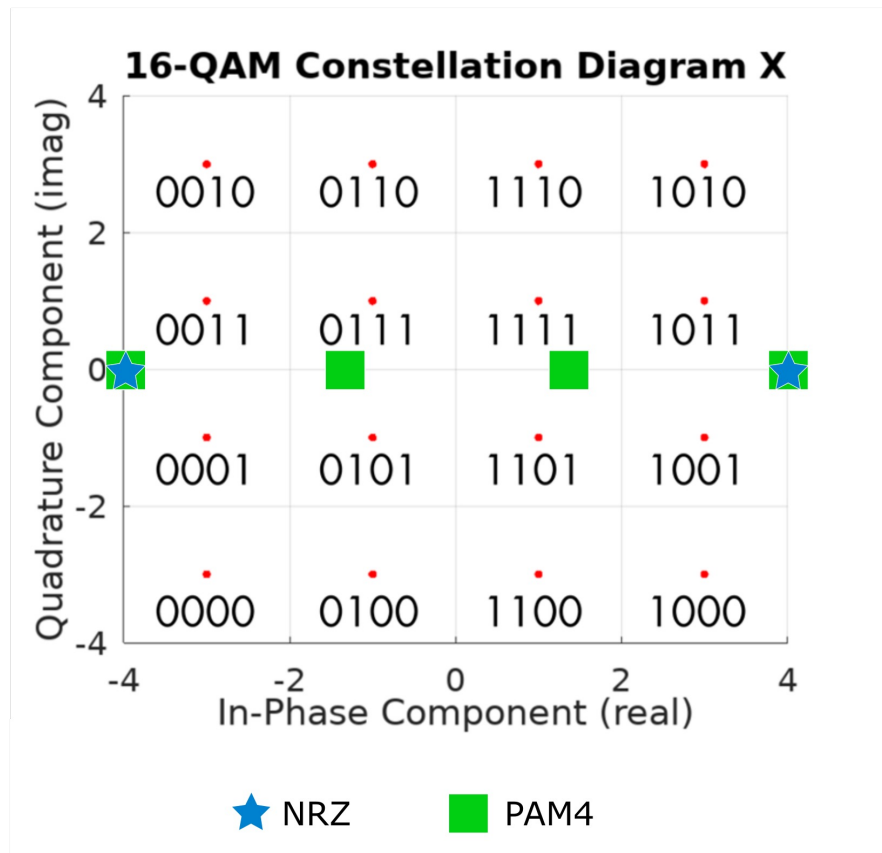


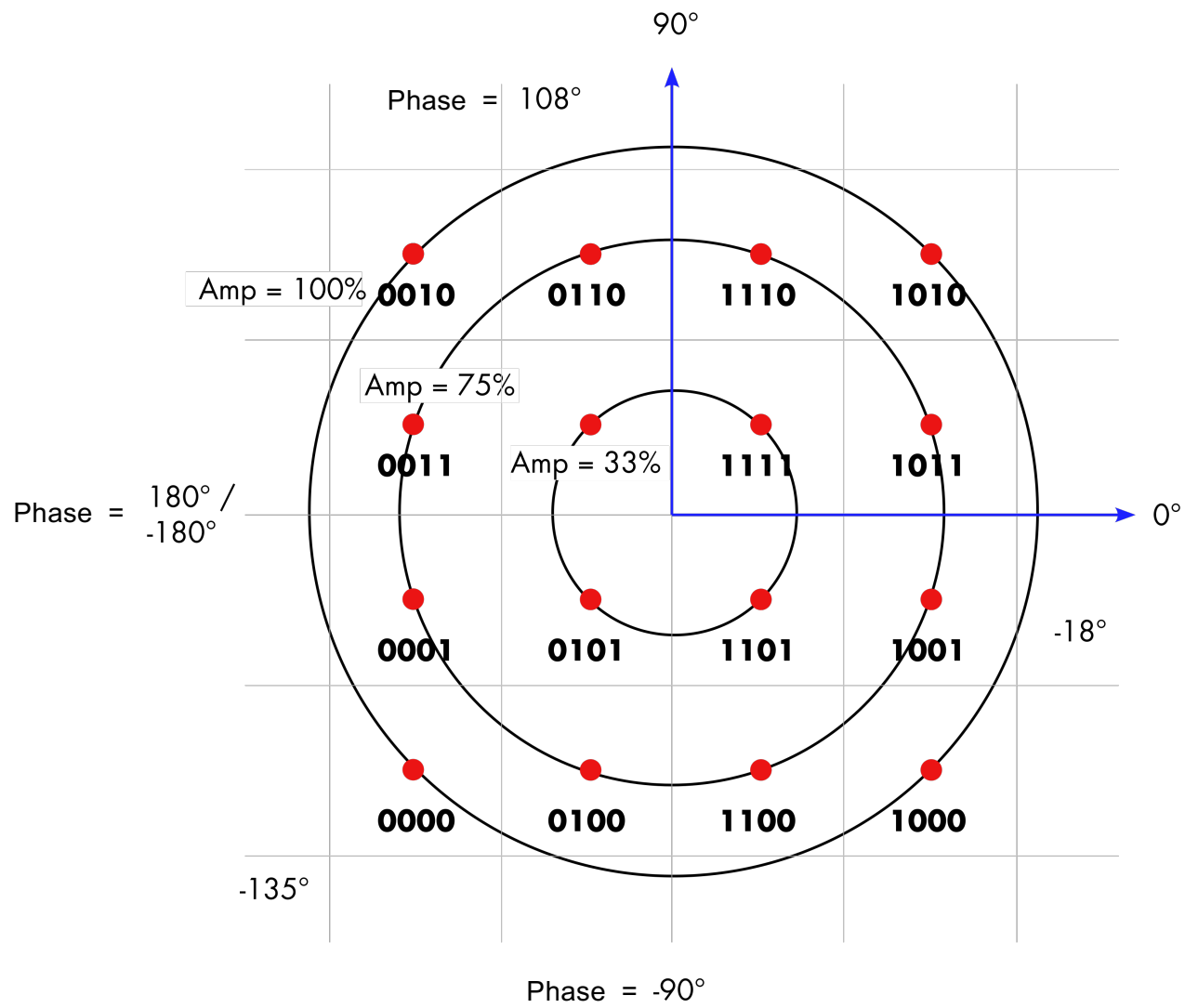
Polarisation Signal on X and Y Plane



Bit Sequence in 16QAM

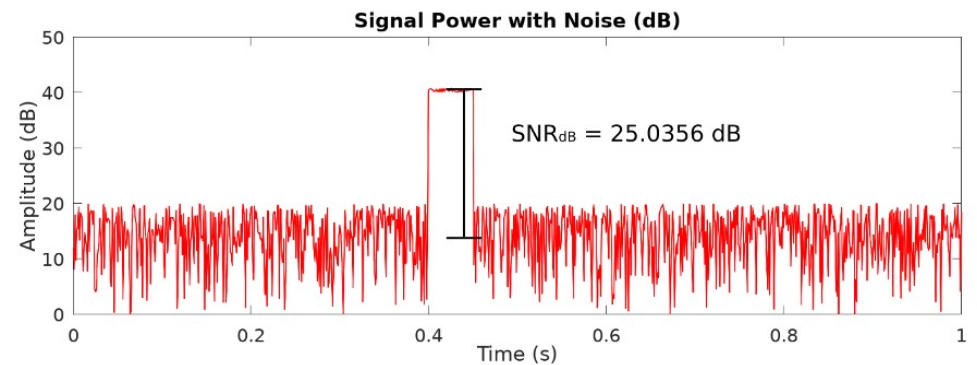
Amplitude and
Phase
together



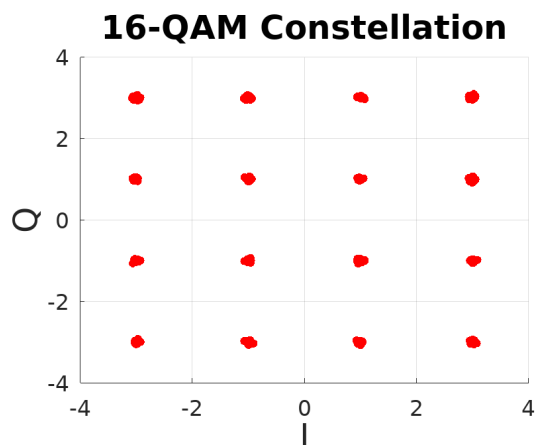


Measuring Signal Quality

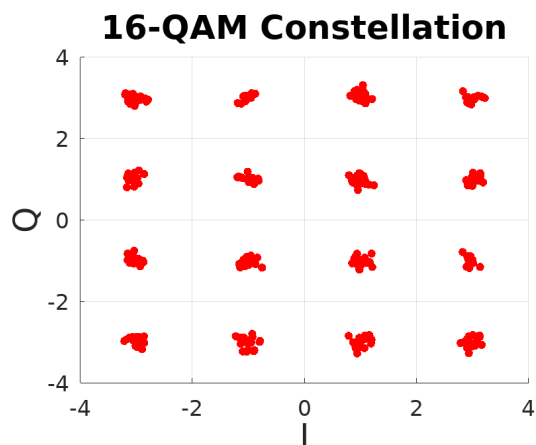
- **SNR** = Signal-to-Noise-Ratio
- Convenience of using decibels for **small** and **large** values
- (e)SNR vs OSNR:
electrical vs optical



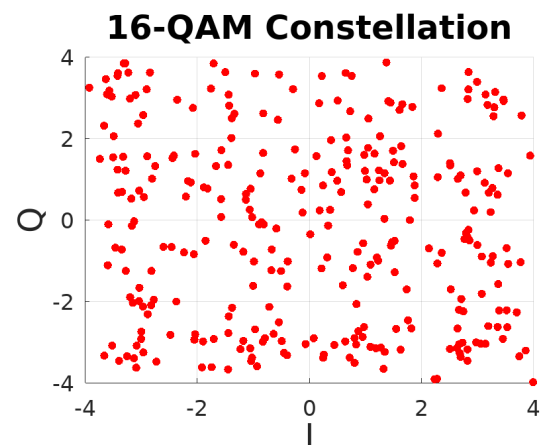
Phase and Amplitude Errors



SNR = 30 dB



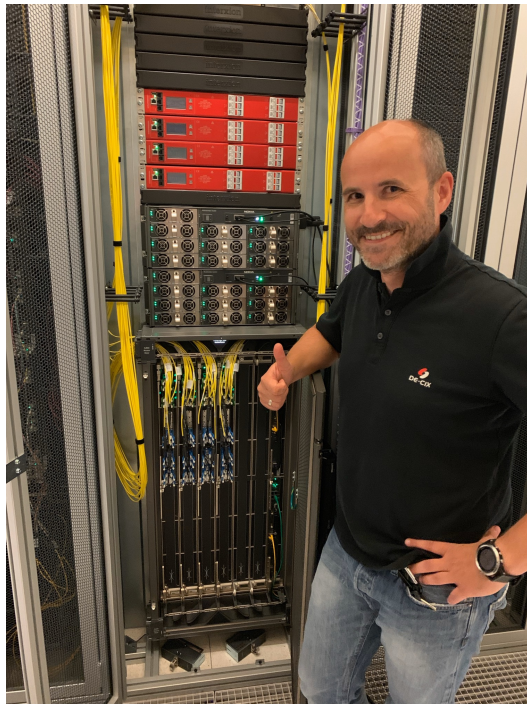
SNR = 20 dB



SNR = 5 dB

NOTE: Polarisation Error not considered

NOKIA SR-OS and 400G ZR Transceiver



source: Daniel Melzer; DE-CIX

+



=

terrific
coherent
workshop

source: <https://www.flexoptix.net/en/d-co164hg-2-yt.html>

config with the CLI

```
Nokia 7950 XRS# show port 8/1/c7

=====
QSFP-DD Connector
=====
Description      : -
Interface        : 8/1/c7
FP Number        : 2
MAC Chip Number  : 3
...
Breakout         : c1-400g
RS-FEC Config Mode : None

Transceiver Data

Transceiver Status : operational
Transceiver Type   : QSFP-DD
Model Number       : 3HE16564AARA01 NOK INUIAPHHAA
TX Laser Wavelength: 1558.983 nm
DCO                : Enabled
Present Channel    : 23
Configured Chann* : 23

Laser Tunability   : flex-tunable
Config Freq (MHz)  : 0
Oper Freq (MHz)    : 192300000
Min Freq (MHz)     : 191300000
Max Freq (MHz)     : 196100000
Fine Tune Range    : 6000 MHz
Fine Tune Resolu*  : 1 MHz
Supported Grids    : 100GHz 75GHz 50GHz 25GHz 12.5GHz 6.25GHz
Diag Capable       : yes
Number of Lanes    : 1
Connector Code     : LC
Vendor OUI         : 20:20:20
Manufacture date   : 2021/12/12
Media              : Ethernet
...
Optical Compliance : 400G-ZR-Amp 400G-ZR-Unamp
Link Length support: Unknown
...
```

analysis with the CLI

```
still show port 8/1/c7, DDM should be known by now

...

=====
Transceiver Digital Diagnostic Monitoring (DDM)
=====

```

	Value	High Alarm	High Warn	Low Warn	Low Alarm
Temperature (C)	+48.0	+80.0	+75.0	+15.0	-5.0
Supply Voltage (V)	3.26	3.46	3.43	3.17	3.13

```
=====
Transceiver Lane Digital Diagnostic Monitoring (DDM)
=====

```

	High Alarm	High Warn	Low Warn	Low Alarm
Lane Tx Output Power (dBm)	0.00	-2.00	-13.00	-14.00
Lane Rx Optical Pwr (avg dBm)	2.00	0.00	-21.02	-23.01

```
-----
Lane ID Temp (C) /Alm      Tx Bias (mA) /Alm      Tx Pwr (dBm) /Alm      Rx Pwr (dBm) /Alm
-----
1          -              -              -8.20              0.01/H-W
=====

...
```

```
still show port 8/1/c7, now it becomes tricky

...

=====
Coherent Optical Module
=====
Cfg Tx Target Power:  1.00 dBm          Present Rx Channel : 23
Cfg Rx LOS Thresh   : -23.00 dBm       Cfg Rx Channel    : 23

Disp Control Mode   : automatic        Sweep Start Disp  : -25500 ps/nm
Cfg Dispersion      : 0 ps/nm          Sweep End Disp    : 2000 ps/nm
CPR Window Size     : 32 symbols        Rx LOS Reaction   : squelch
Compatibility       : openZrpOfec1
Cfg Tx Power Min    : -22.90 dBm       Cfg Tx Power Max  : 4.00 dBm

Cfg Alarms          : modflt mod netrx nettx hosttx
Alarm Status       :
Defect Points       :

Rx Q Margin         : 2.4 dB            Chromatic Disp    : 220 ps/nm
SNR/OSNR X Polar   : 17.4 dB / 34.4 dB  Diff Group Delay  : 2 ps
SNR/OSNR Y Polar   : 17.4 dB / 34.4 dB  Pre-FEC BER      : 1.213E-03

Module State       : ready
Tx Turn-Up States  : init laserTurnUp laserReadyOff laserReady
                   : modulatorConverge outputPowerAdjust
Rx Turn-Up States  : init laserReady waitForInput adcSignal opticalLock
                   : demodLock

=====
```

```
still show port 8/1/c7, the receiver requires its own laser
```

```
...
```

```
=====  
Coherent Optical Module  
=====
```

```
Cfg Tx Target Power: 1.00 dBm          Present Rx Channel : 23  
Cfg Rx LOS Thresh  : -23.00 dBm       Cfg Rx Channel    : 23
```

required to establish the link, no sweeping

```
Rx Q Margin      : 2.4 dB          Chromatic Disp  : 220 ps/nm  
SNR/OSNR X Polar : 17.4 dB / 34.4 dB  Diff Group Delay : 2 ps  
SNR/OSNR Y Polar : 17.4 dB / 34.4 dB  Pre-FEC BER    : 1.213E-03
```

```
Module State      : ready  
Tx Turn-Up States : init laserTurnUp laserReadyOff laserReady  
                  modulatorConverge outputPowerAdjust  
Rx Turn-Up States : init laserReady waitForInput adcSignal opticalLock  
                  demodLock
```

```
=====
```

Chromatic Dispersion (CD)

```
still show port 8/1/c7, back in the past with 10G and CWDM this was a major issue
...
=====
Coherent Optical Module
=====
Cfg Tx Target Power:  1.00 dBm          Present Rx Channel : 23
Cfg Rx LOS Thresh  : -23.00 dBm       Cfg Rx Channel    : 23

Disp Control Mode   : automatic        Sweep Start Disp  : -25500 ps/nm
Cfg Dispersion      : 0 ps/nm          Sweep End Disp    : 2000 ps/nm
Rx LOS Reaction     : squelch

Cfg Tx Power Max    : 4.00 dBm

hosttx

Chromatic Disp      : 220 ps/nm
Diff Group Delay    : 2 ps
Pre-FEC BER         : 1.213E-03

ReadyOff laserReady
utPowerAdjust
rInput adcSignal opticalLock
=====
```

If **Disp Control Mode** is manual:
Configure a target dispersion, where the switch may decide whether to raise warnings or not.

Sweep: With **start** and **end** you indicate a range of allowed dispersion that can be handled by a compensator (DSP in this case)

Difference in propagation time for X and Y polarisation

```
still show port 8/1/c7, don't be to late
...
=====
Coherent Optical Module
=====
Cfg Tx Target Power: 1.00 dBm      Present Rx Channel : 23
Cfg Rx LOS Thresh  : -23.00 dBm   Cfg Rx Channel    : 23

Disp Control Mode  : automatic     Sweep Start Disp  : -25500 ps/nm
Cfg Dispersion     : 0 ps/nm       Sweep End Disp    : 2000 ps/nm
                                           Rx LOS Reaction   : squelch

                                           Cfg Tx Power Max  : 4.00 dBm

hosttx

Chromatic Disp    : 220 ps/nm
Diff Group Delay  : 2 ps
Pre-FBC BER       : 1.213E-03

ReadyOff laserReady
utPowerAdjust
rInput adcSignal opticalLock
=====
```

Signal-to-Noise Ratio (SNR)

```
still show port 8/1/c7, almost done
...
=====
Coherent Optical Module
=====
Cfg Tx Target Power:  1.00 dBm
Cfg Rx LOS Thresh  : -23.00 dBm

Disp Control Mode   : automatic
Cfg Dispersion      :      0 ps/nm
CPR Window Size     : 32 symbols
Compatibility       : openZrpOfec1
Cfg Tx Power Min    : -22.90 dBm

Cfg Alarms          : modflt mod netrx nettx h
Alarm Status        :
Defect Points       :

Rx Q Margin         :      2.4 dB
SNR/OSNR X Polar    :  17.4 dB / 34.4 dB
SNR/OSNR Y Polar    :  17.4 dB / 34.4 dB
Pre-FEC BER         : 1.213E-03

Module State        : ready
Tx Turn-Up States  : init laserTurnUp laserReadyOff laserReady
                   : modulatorConverge outputPowerAdjust
Rx Turn-Up States  : init laserReady waitForInput adcSignal opticalLock
                   : demodLock
=====
```

OSNR: check datasheet,
depends on application mode

Q Margin (Q Factor): gap
between the current pre-FEC
BER value and error-free
threshold in dB

Compatibility / Application Mode

```

still show port 8/1/c7, !??

...

=====
Coherent Optical Module
=====
Cfg Tx Target Power:  1.00 dBm          Present Rx Channel : 23
Cfg Rx LOS Thresh  : -23.00 dBm       Cfg Rx Channel    : 23

Disp Control Mode  : automatic         Sweep Start Disp  : -25500 ps/nm
Cfg Dispersion    :      0 ps/nm       Sweep End Disp   :  2000 ps/nm
CPR Window Size   : 32 symbols         Rx LOS Reaction   : squelch
Compatibility     : openZrpOfec1
Cfg Tx Power Min  : -22.90 dBm        Cfg Tx Power Max  :  4.00 dBm
  
```

Application Mode	MSA format	Nokia Compatibility	Host format	Nokia Config	Electrical interface	FEC	Modulation	Line Symbol Baud Rate
1	OIF 400ZR, amplified	oif-400g-zr	400GBASE-R	c1-400g	1x 400GAUI-8 (8x 50G)	CFEC	DP-16QAM	59.8GBd
2	OIF 400ZR, unamplified		400GBASE-R		1x 400GAUI-8 (8x 50G)	CFEC	DP-16QAM	59.8GBd
3	OpenZR+ MSA	openZrpOfec1	400GBASE-R	c1-400g	1x 400GAUI-8 (8x 50G)	oFEC	DP-16QAM	60.1GBd
4	OpenZR+ MSA		2x 200GBASE-R		2x 200GAUI-4 (4x 50G)	oFEC	DP-16QAM	60.1GBd
5	OpenZR+ MSA	openZrpOfec1	4x 100GBASE-R	c4-100g	4x 100GAUI-2 (2x 50G)	oFEC	DP-16QAM	60.1GBd
6	OpenZR+ MSA, Enhanced	openZrpOfec2	400GBASE-R	c1-400g	1x 400GAUI-8 (8x 50G)	oFEC	DP-16QAM	60.1GBd
7	OpenZR+ MSA, Enhanced		2x 200GBASE-R		2x 200GAUI-4 (4x 50G)	oFEC	DP-16QAM	60.1GBd
8	OpenZR+ MSA, Enhanced	openZrpOfec2	4x 100GBASE-R	c4-100g	4x 100GAUI-2 (2x 50G)	oFEC	DP-16QAM	60.1GBd
9	OpenZR+ MSA	openZrpOfec1	2x 100GBASE-R	c2-100g-aii2	2x 100GAUI-2 (2x 50G)	oFEC	DP-QPSK	60.1GBd
10	OpenZR+ MSA	openZrpOfec2	1x 100GBASE-R	c1-100g-aii2	1x 100GAUI-2 (2x 50G)	oFEC	DP-QPSK	30.1GBd
11	OpenZR+ MSA	openZrpOfec1	3x 100GBASE-R	c3-100g	3x 100GAUI-2 (2x 50G)	oFEC	DP-8QAM	60.1GBd
12	OpenZR+ MSA, Enhanced		3x 100GBASE-R		3x 100GAUI-2 (2x 50G)	oFEC	DP-8QAM	60.1GBd
13	OIF 400ZR, amplified	oif-400g-zr	4x 100GBASE-R	c4-100g	4x 100GAUI-2 (2x 50G)	CFEC	DP-16QAM	59.8GBd
14	OpenZR+ MSA, Enhanced	openZrpOfec2	2x 100GBASE-R	c2-100g-aii2	2x 100GAUI-2 (2x50G)	oFEC	DP-16QAM	30.1GBd
15	OpenZR+ MSA		100GBASE-R		1x CAUI-4 w/o FEC (4x25G)	oFEC	DP-QPSK	30.1GBd

Compatibility / Application Mode

```

still show port 8/1/c7, !??

...

=====
Coherent Optical Module
=====
Cfg Tx Target Power: 1.00 dBm          Present Rx Channel : 23
Cfg Rx LOS Thresh  : -23.00 dBm       Cfg Rx Channel     : 23

Disp Control Mode  : automatic
Cfg Dispersion     : 0 ps/nm
CPR Window Size    : 32 symbols
Compatibility      : openZrpOfec1
Cfg Tx Power Min   : -22.90 dBm
    
```

```

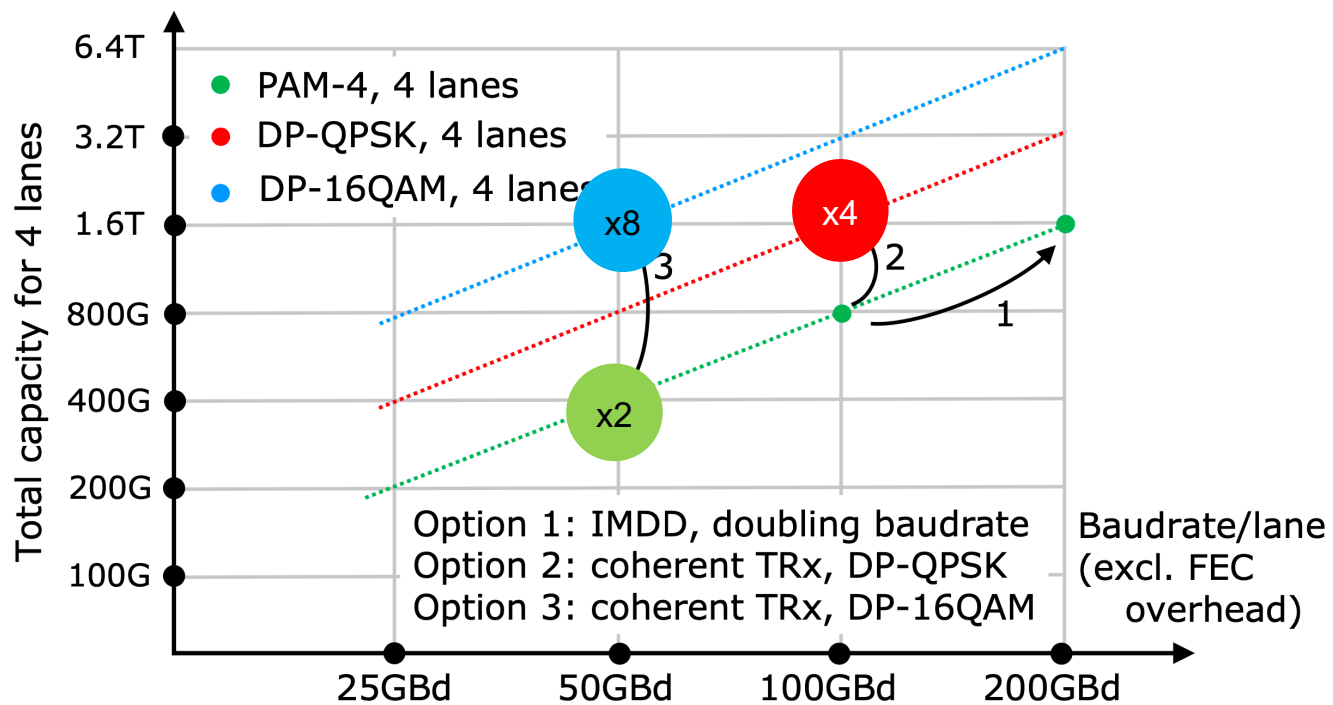
Nokia 7950 XRS# show port 8/1/c7

=====
QSFP-DD Connector
=====
Description       : -
Interface         : 8/1/c7
FP Number         : 2
...
Breakout          : c1-400g
RS-FEC Config Mode : None

Transceiver Data
...
Laser Tunability  : flex-tunable
Config Freq (MHz) : 0
Oper Freq (MHz)   : 192300000
Fine Tune Range   : 6000 MHz
Supported Grids   : 100GHz 75GHz 50GHz 25GHz
...
Optical Compliance : 400G-ZR-Amp 400G-ZR-Unamp
Link Length support: Unknown
    
```

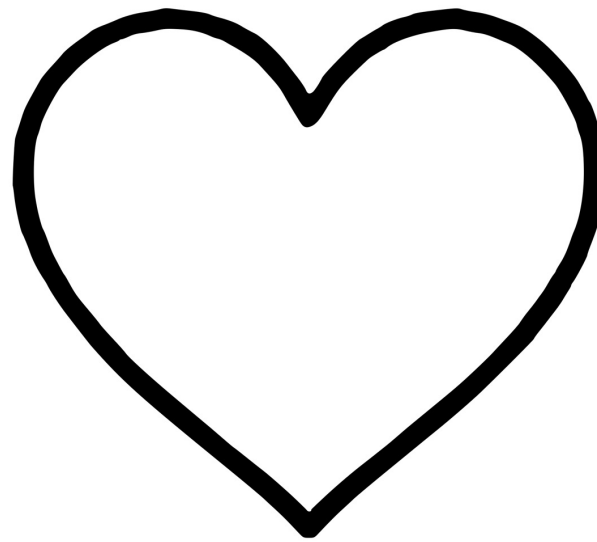
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1	OIF 400ZR, amplified	oif-400g-zr	CFEC	DP-16QAM	59.8GBd
2	OIF 400ZR, unamplified		CFEC	DP-16QAM	59.8GBd
3	OpenZR+ MSA	openZrpOfec1	oFEC	DP-16QAM	60.1GBd
4	OpenZR+ MSA		oFEC	DP-16QAM	60.1GBd
5	OpenZR+ MSA	openZrpOfec1	oFEC	DP-16QAM	60.1GBd
6	OpenZR+ MSA, Enhanced	openZrpOfec2	oFEC	DP-16QAM	60.1GBd
7	OpenZR+ MSA, Enhanced		oFEC	DP-16QAM	60.1GBd
8	OpenZR+ MSA, Enhanced	openZrpOfec2	oFEC	DP-16QAM	60.1GBd
9	OpenZR+ MSA	openZrpOfec1	oFEC	DP-QPSK	60.1GBd
10	OpenZR+ MSA	openZrpOfec1	oFEC	DP-QPSK	30.1GBd
11	OpenZR+ MSA	openZrpOfec1	oFEC	DP-8QAM	60.1GBd
12	OpenZR+ MSA, Enhanced		oFEC	DP-8QAM	60.1GBd
13	OIF 400ZR, amplified	oif-400g-zr	CFEC	DP-16QAM	59.8GBd
14	OpenZR+ MSA, Enhanced	openZrpOfec2	oFEC	DP-16QAM	30.1GBd
15	OpenZR+ MSA	100GBASE-R	oFEC	DP-QPSK	30.1GBd

Outlook: more Bandwidth for 800G, 1.6T or even 3.2T



source: [1]

Thank you!



thomas.weible@flexoptix.net
gerhard.stein@flexoptix.net

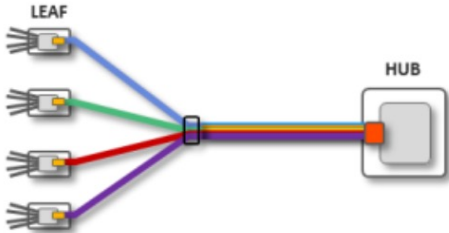
Outlook: OpenXR 16 x 25Gbit/s via DSCM

Point-to-Point



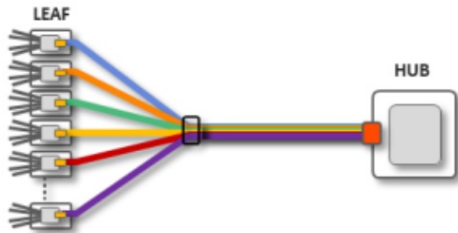
100G/200G/400G P2P

Break-out Mode



4 X 100G LEAFS TO 400G HUB

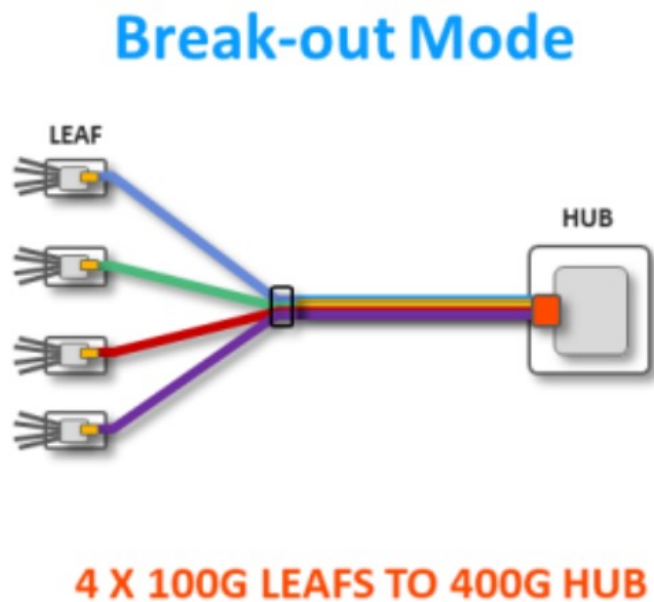
Flexible Point-to-Multipoint



UP TO 16 LEAFS TO 400G HUB

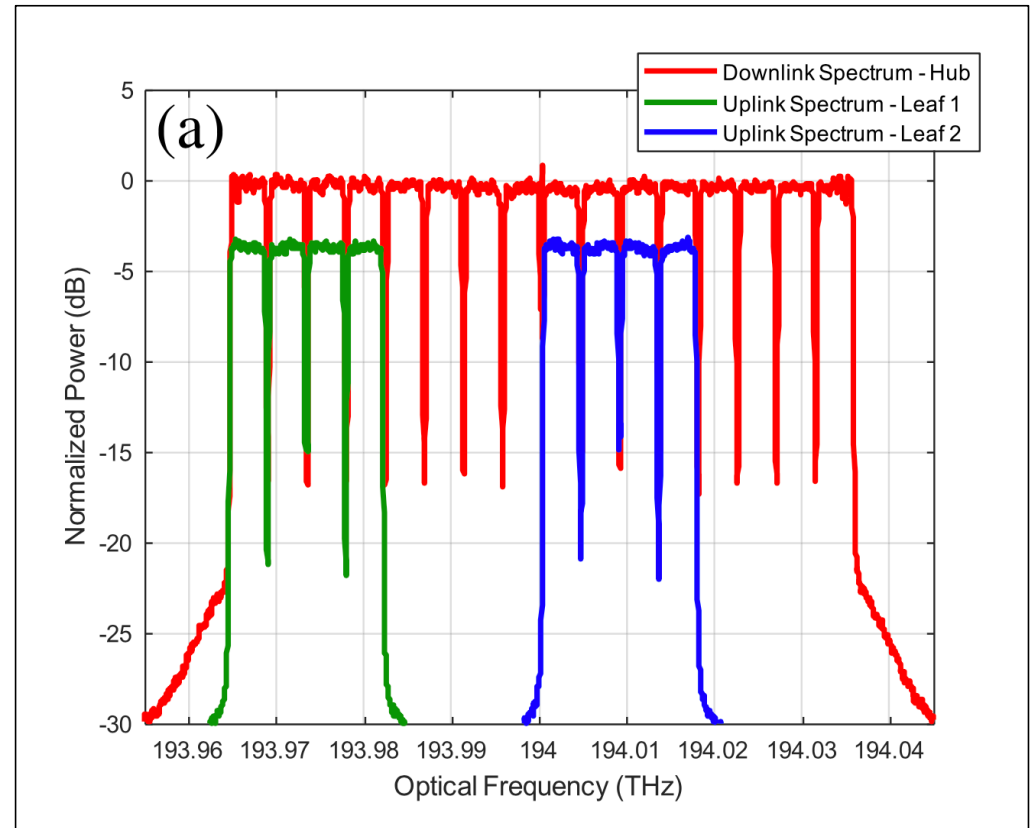
source: [7]

Outlook: DSCM (Digital SubCarrier Multiplexing)



source: [7]

13.02.24



source: [8]

References

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3. Lumentum Operations LLC, <https://www.lumentum.com/en/products/400g-zr-zr-qsfp-dd-dco> (accessed Nov. 2023)
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7. Digital Subcarrier Multiplexing: Enabling Software-Configurable Optical Networks, Dave Welch et. Al. February 15th of 2023, JOURNAL OF LIGHTWAVE TECHNOLOGY, VOL. 41, NO. 4
8. SFF-8024, SFF Module Management Reference Code Tables, Rev. 4.10, November 24th of 2022