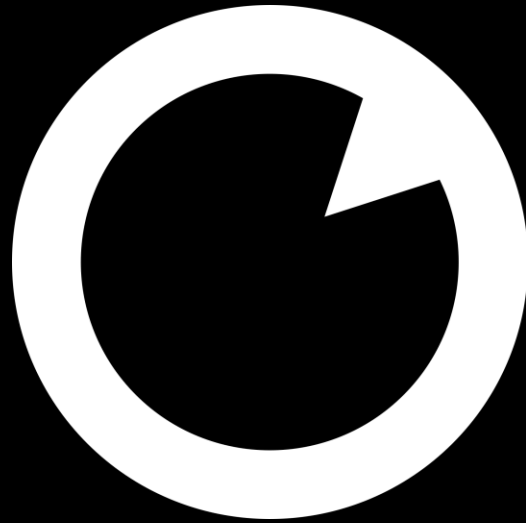


# coherent optical transceivers



current capabilities and  
future possibilities

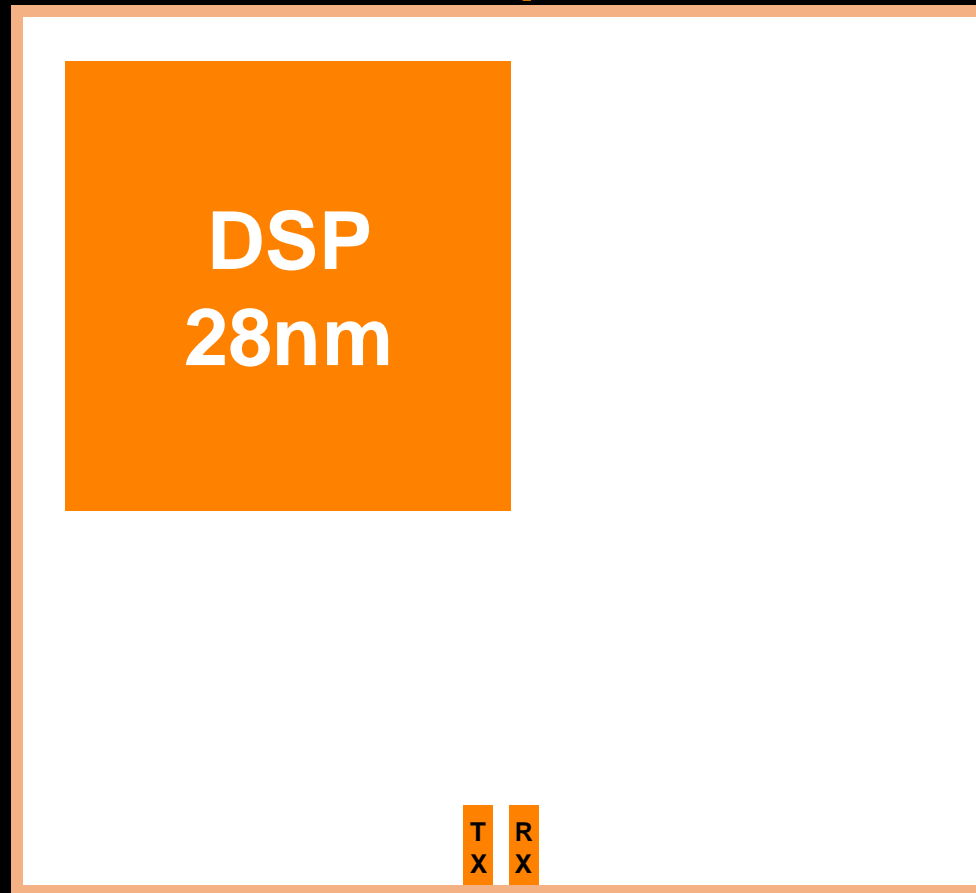
# 100G ecosystem limits ...



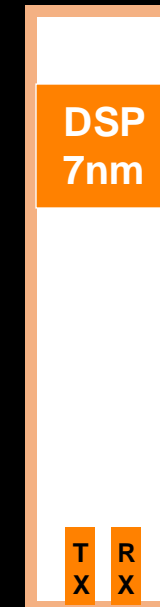
- ratio of **power consumption** to formfactor
  - focus on **inner datacenter links**
- **variation of diverse hardware**

# ... sorted now with 400G

## DWDM transponder card

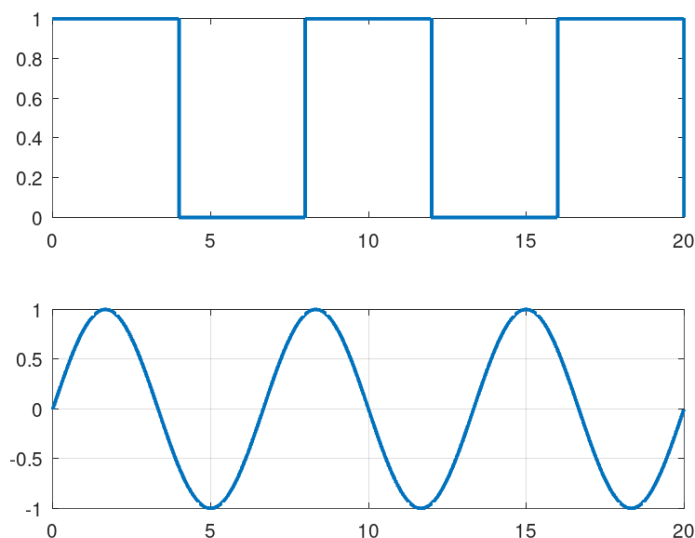


## pluggable QSFP-DD



# Direct Detection Transceiver limits

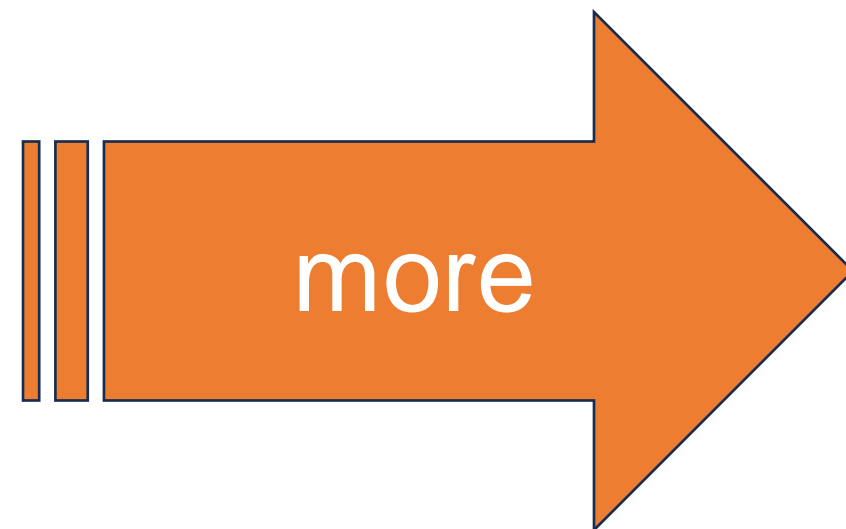
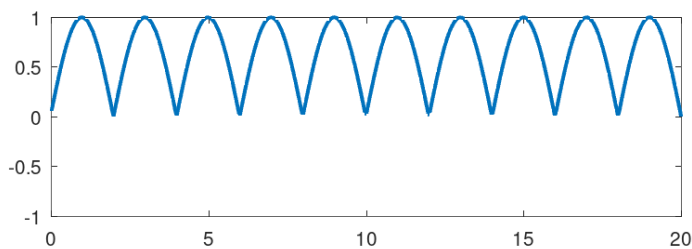
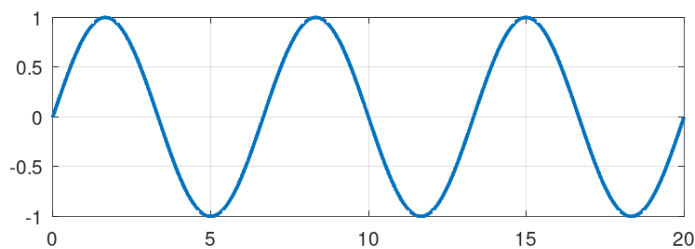
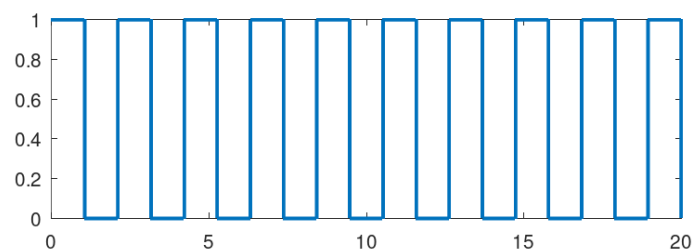
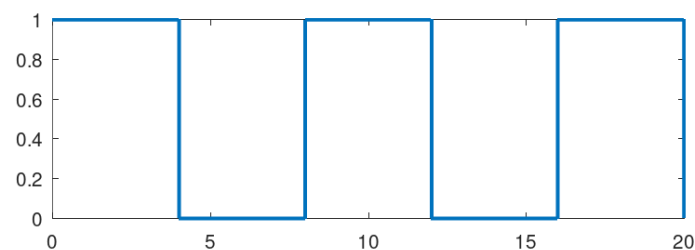
With **higher** frequencies -> harder for Photodiodes to detect



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

# Direct Detection Transceiver limits

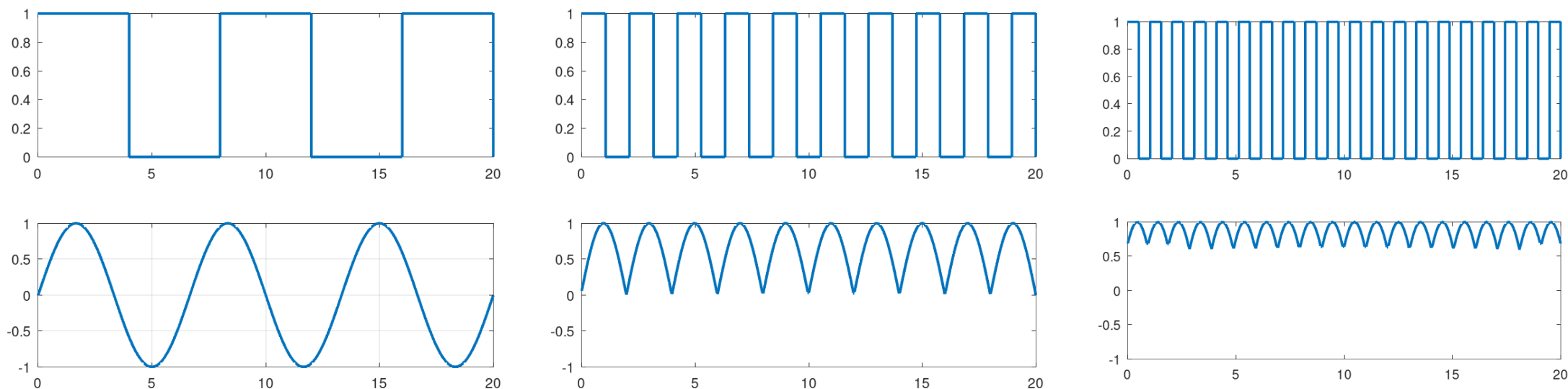
With **higher** frequencies -> harder for Photodiodes to detect



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

# Direct Detection Transceiver limits

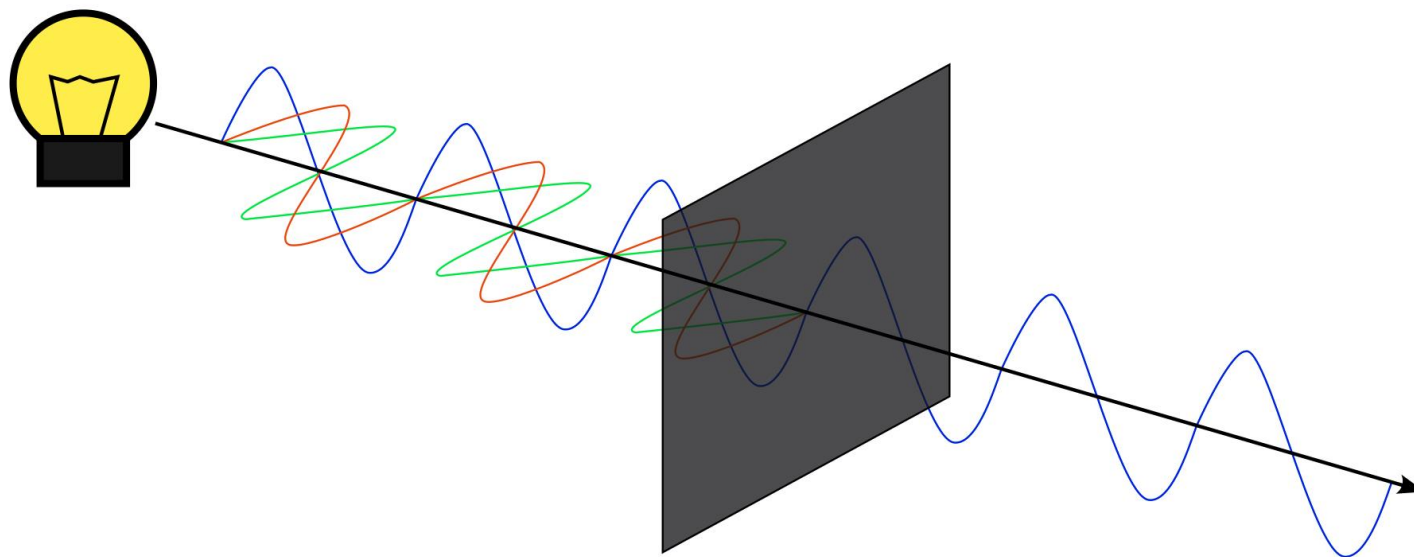
With **higher** frequencies -> harder for Photodiodes to detect



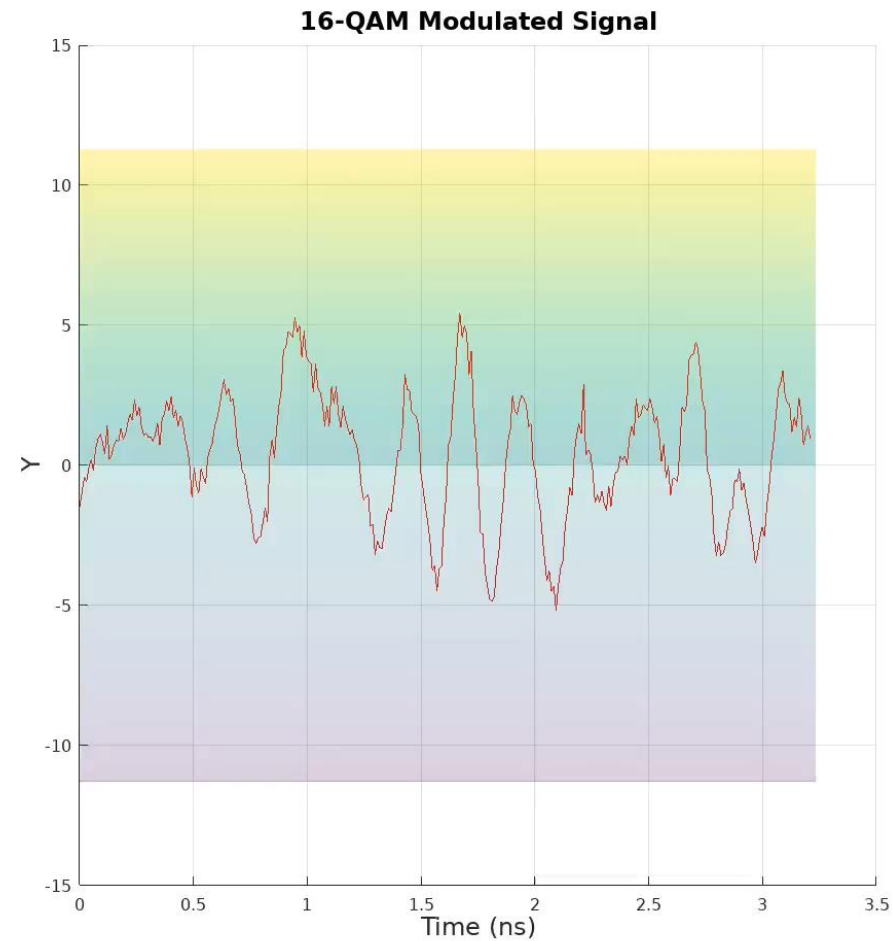
Missed Opportunity: **Light** has more **Properties**

# Main Properties of Photonic Waves

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

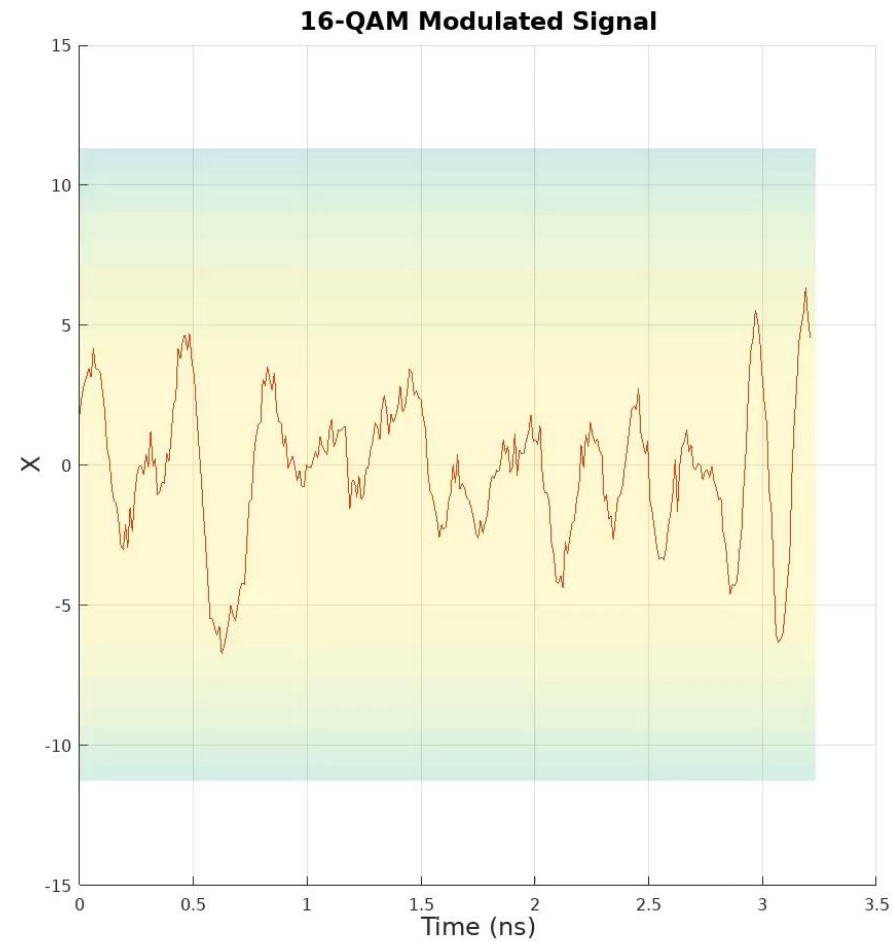


# Polarisation Signal on X and Y Plane

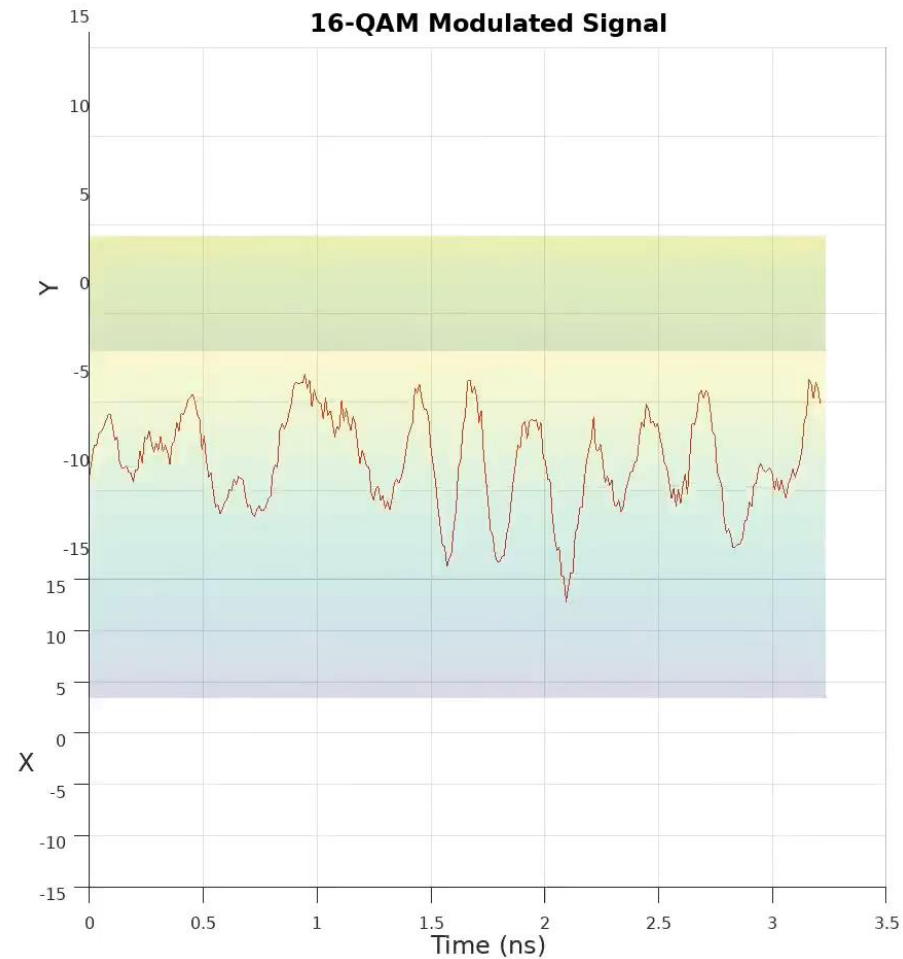




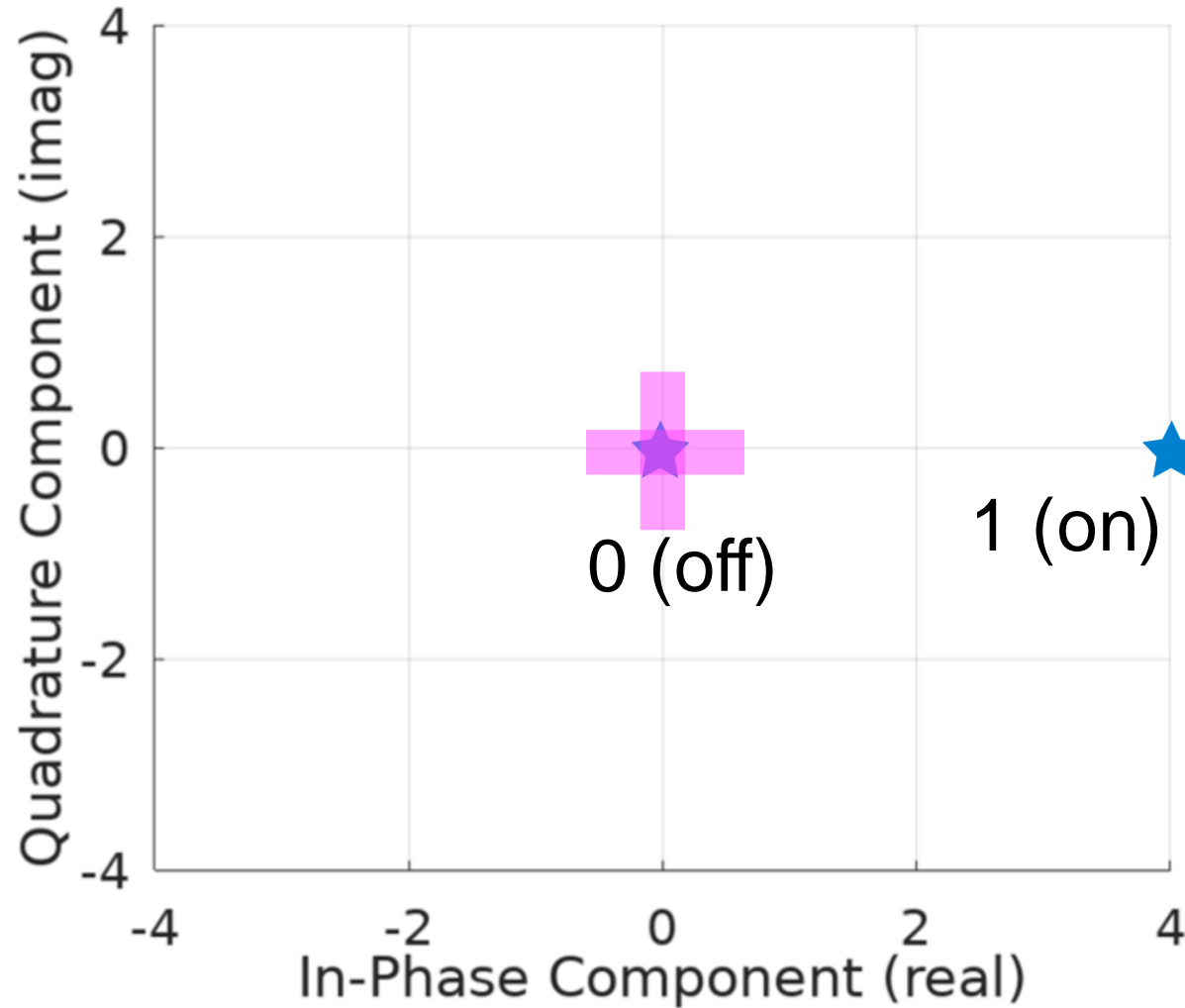
# Polarisation Signal on X and Y Plane



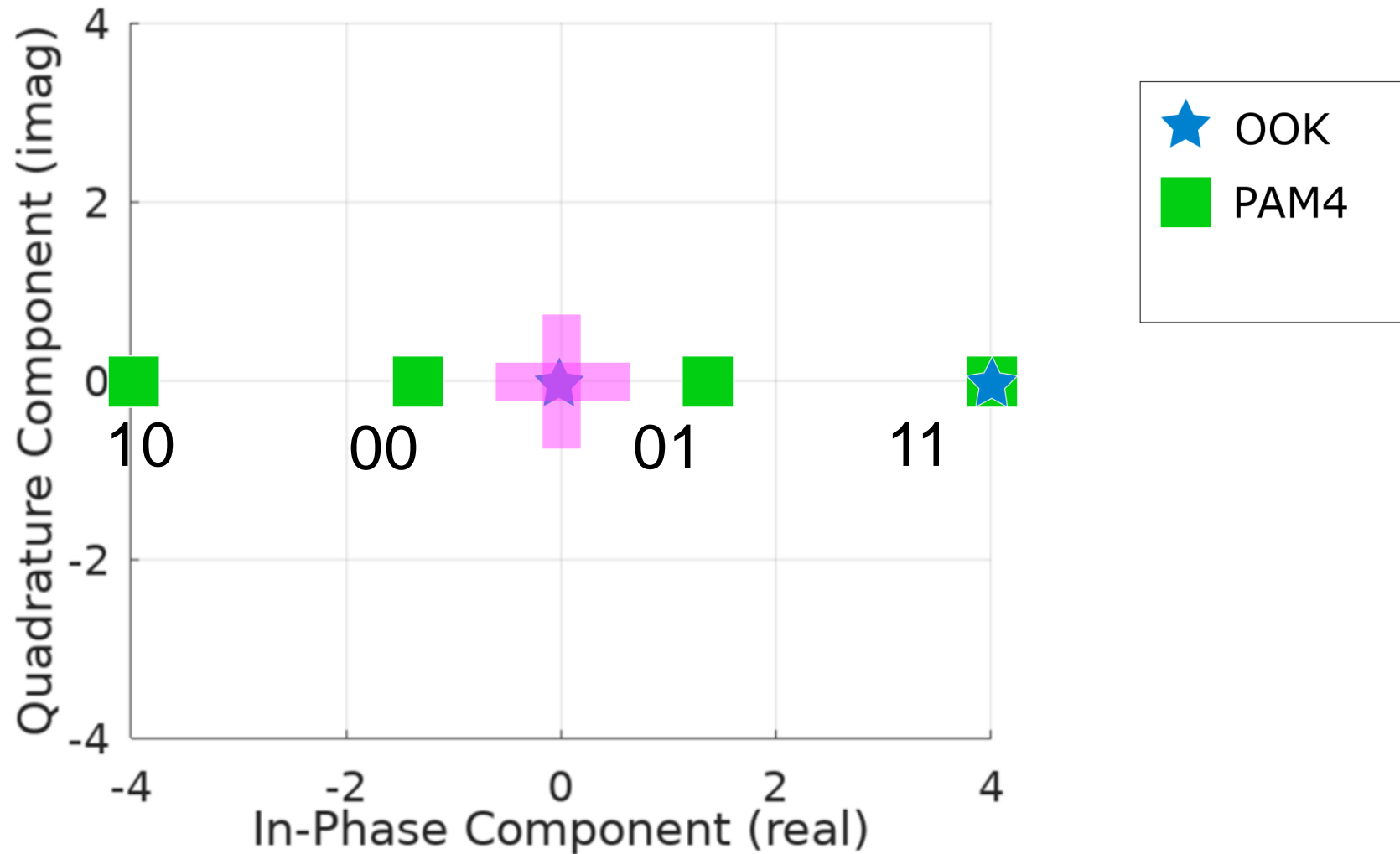
# Polarisation Signal on X and Y Plane



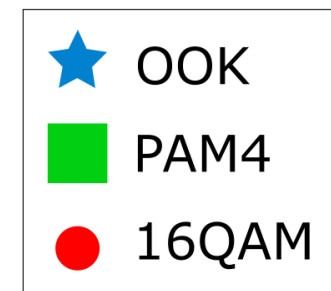
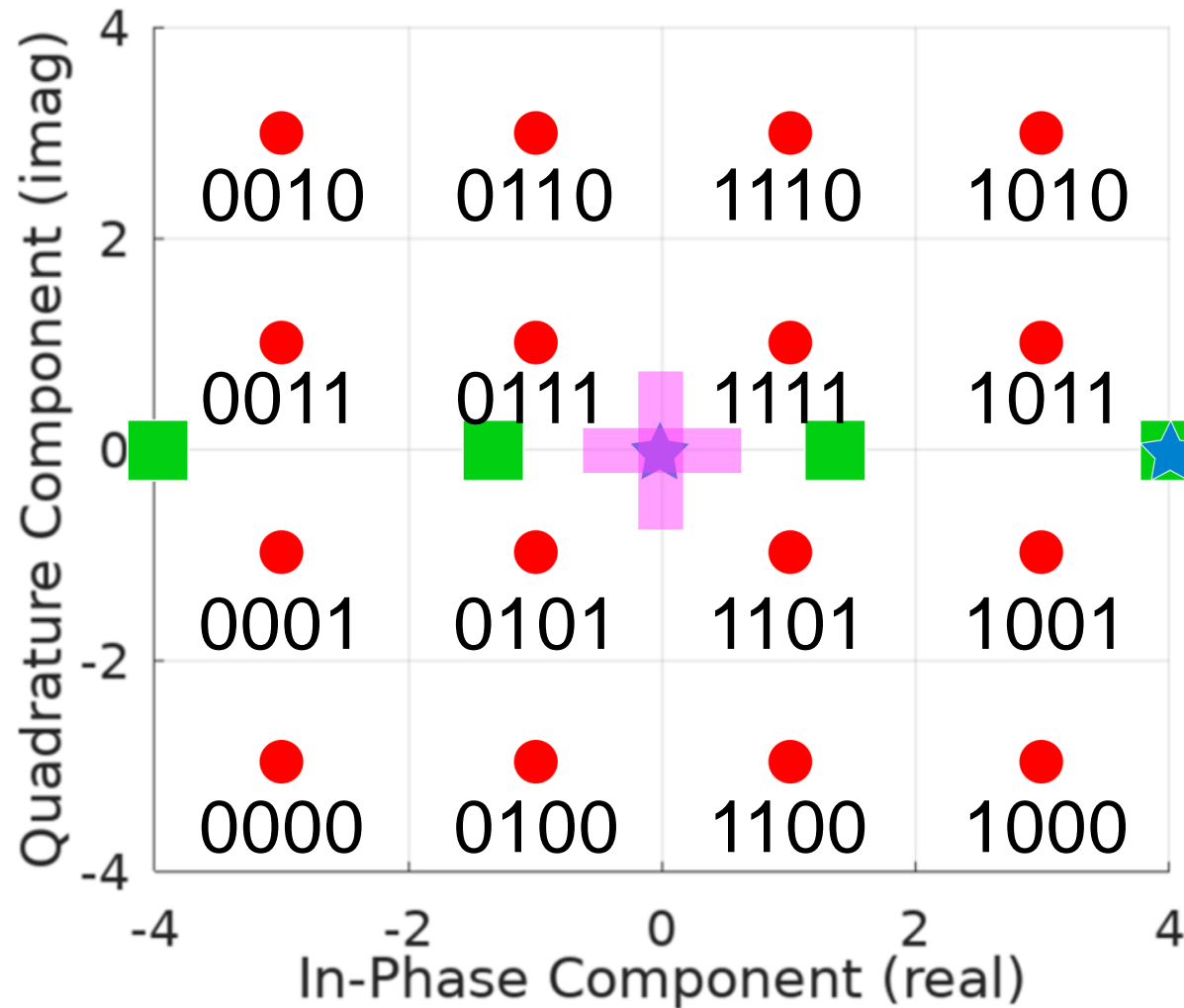
# Constellation Diagram



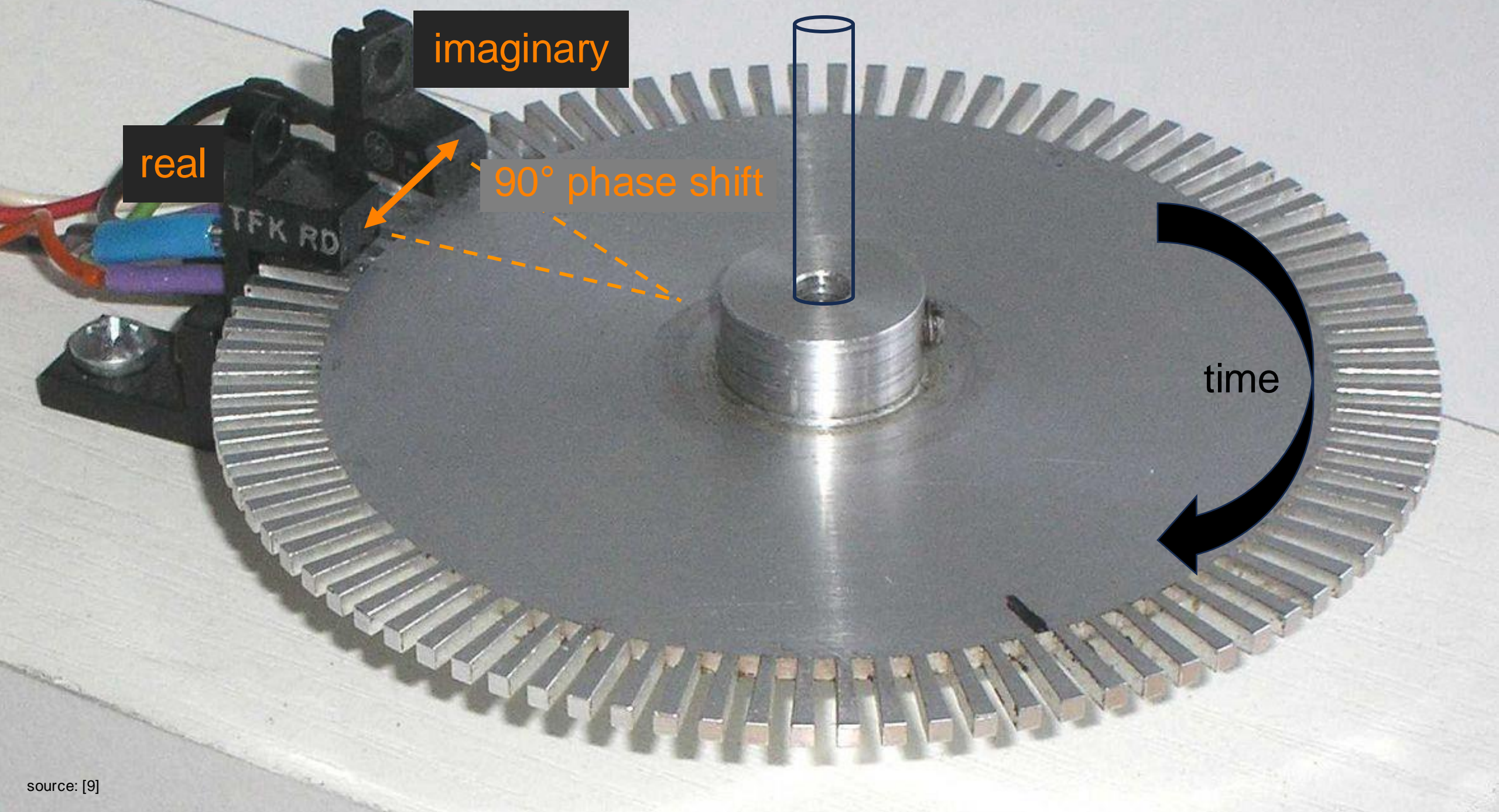
# Constellation Diagram



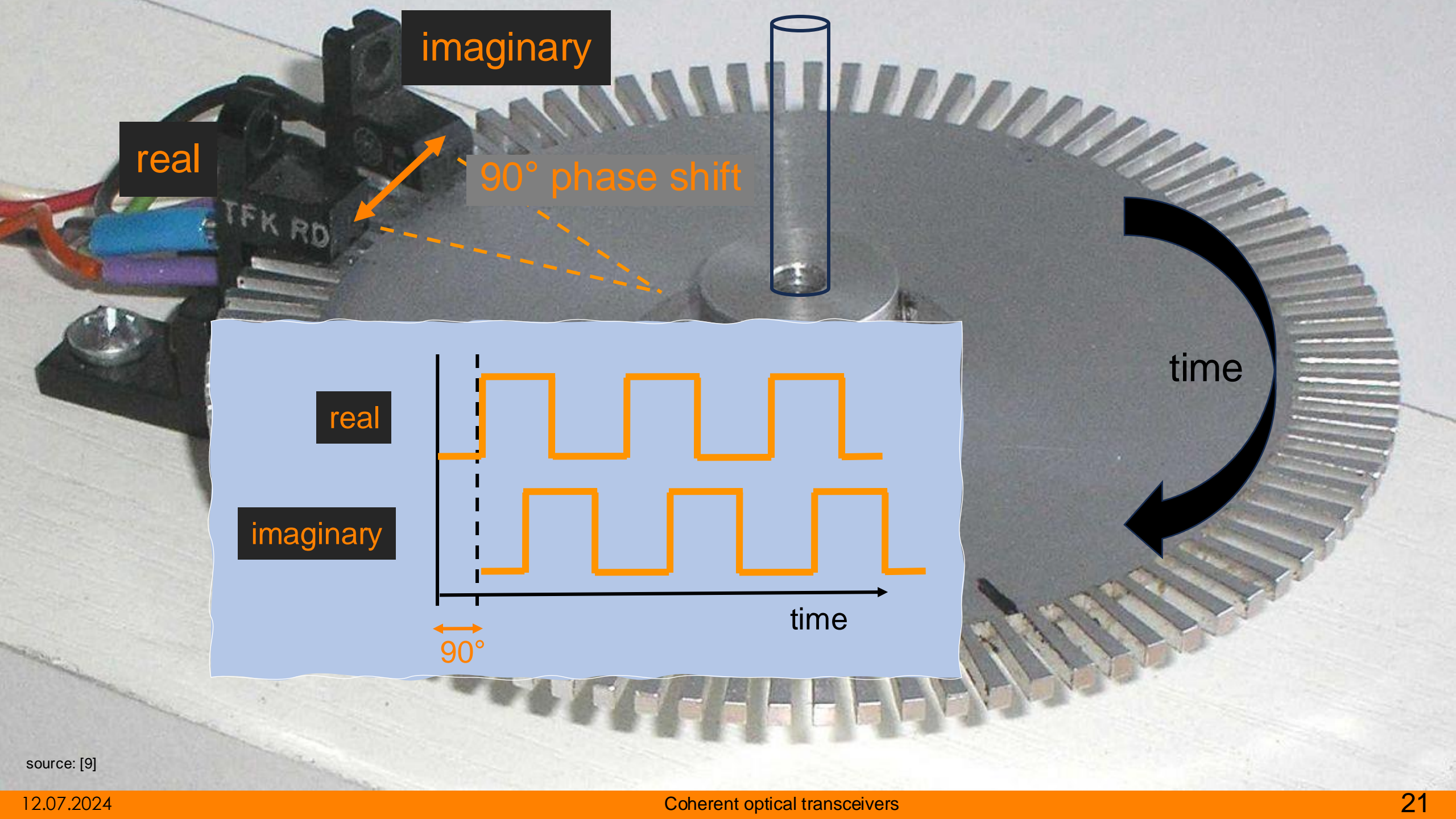
# Constellation Diagramm



90°  
phase  
shifted  
amplitude



source: [9]



imaginary

real

90° phase shift

time

real

imaginary

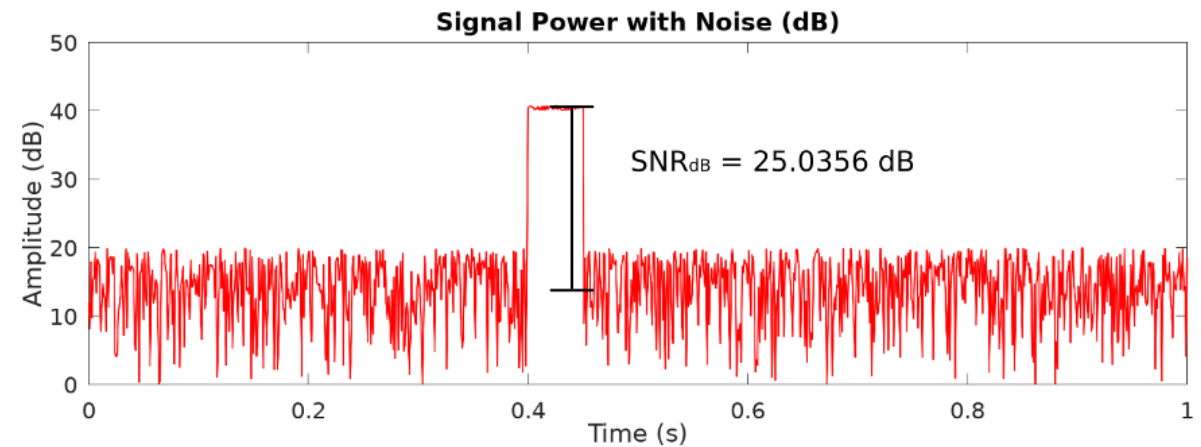
time

90°

source: [9]

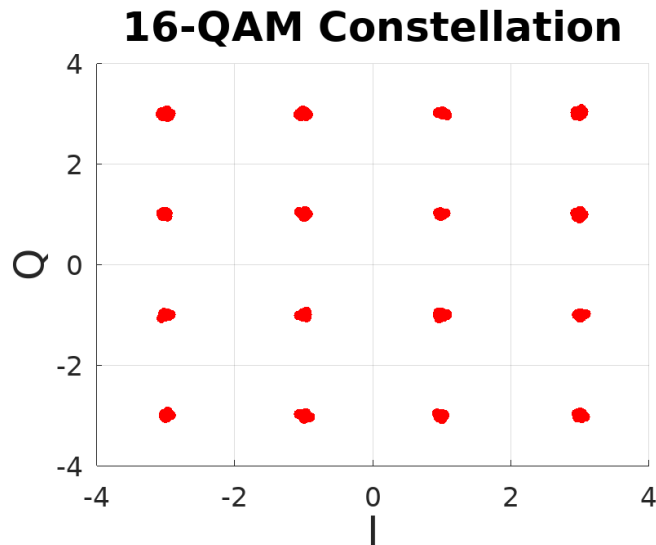
# Measuring Signal Quality

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

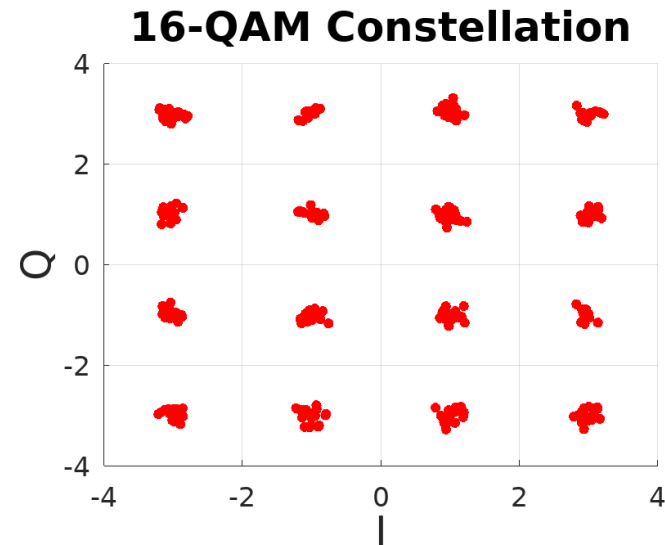




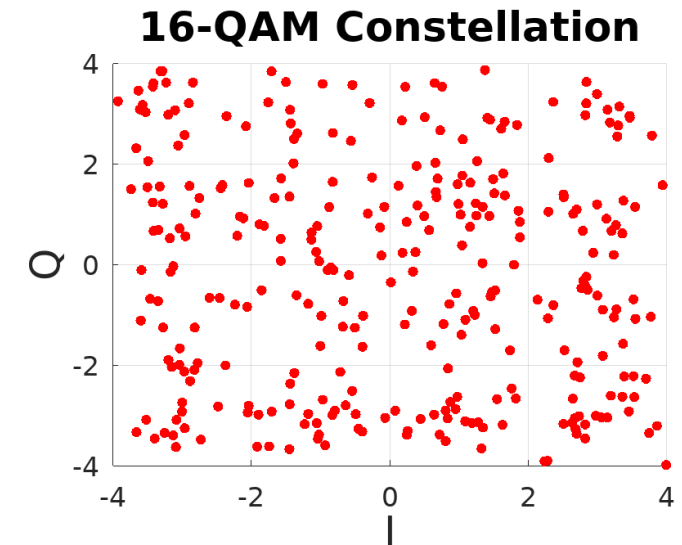
# Phase and Amplitude Errors



SNR = 30 dB



SNR = 20 dB



SNR = 5 dB

**NOTE:** Polarisation Error not considered

# NOKIA SR-OS and 400G ZR Transceiver



+



=

terrific  
coherent  
workshop  
with



DE CIX

source: Daniel Melzer; DE-CIX

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                               DCO                : Enabled
Model Number       : 3HE16564AARA01 NOK INUIAPHHAA
TX Laser Wavelength: 1558.983 nm                          Present Channel    : 23
                                                           Configured Chann* : 23
Laser Tunability   : flex-tunable
```

```
Config Freq (MHz) : 0
```

```
Min Freq(MHz) : 191300000
```

```
Oper Freq(MHz) : 192300000
```

```
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
...
```

# 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
=====

...
```

# analysis with the CLI

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

...

=====  
Transceiver Digital Diagnostic Monitori  
=====

Value High

**Temperature (C) +48.0**

Supply Voltage (V) 3.26

=====  
Transceiver Lane Digital Diagnostic Mon  
=====

High A

Lane Tx Output Power (dBm)

Lane Rx Optical Pwr (avg dBm)

=====  
Lane ID Temp (C) /Alm Tx Bias (mA) /A  
=====

1

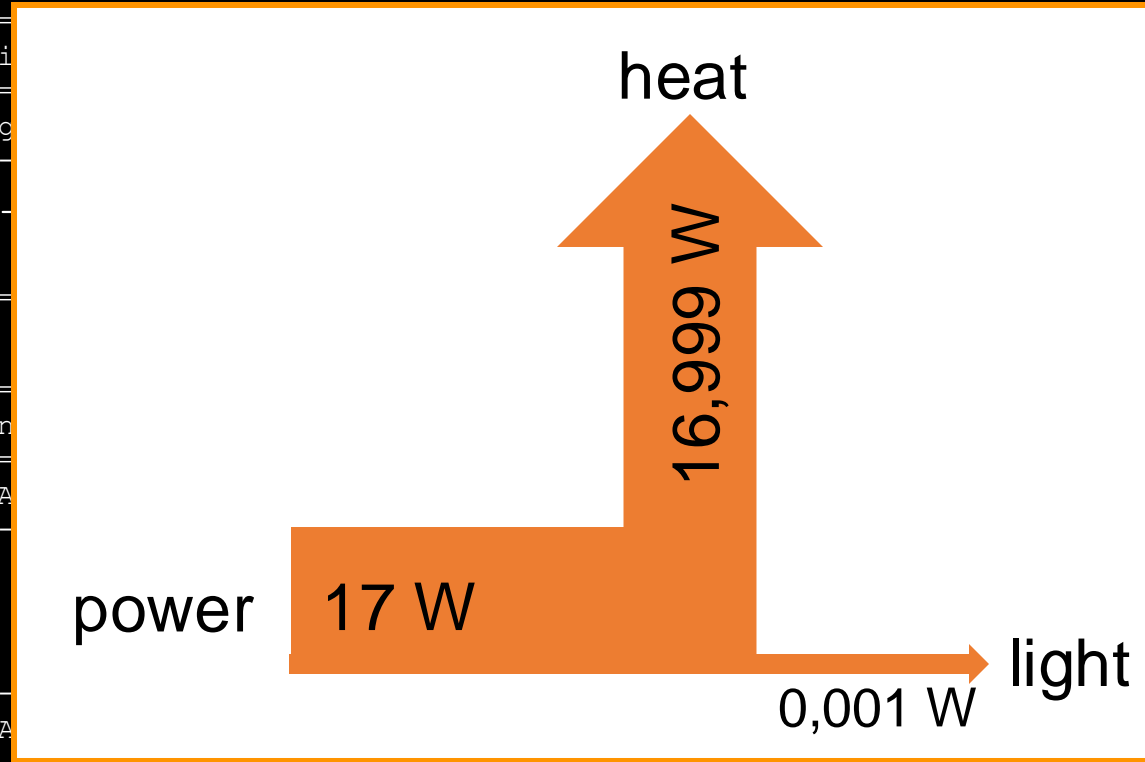
-

-

-8.20

0.01/H-W

...



# the interesting part

```
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

=====
```

# RX Channel

```
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 IOS Thresh  : -23.00 dBm       Cfg Rx Channel    : 23

Disp Control Mode  : automatic
```

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)

```
Sweep Start Disp: -25500 ps/nm
```

```
Sweep End Disp  : 2000 ps/nm
```

```
Rx IOS 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
outPowerAdjust
rInput adcSignal opticalLock
```



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  
Cfg Rx LOS Thresh : -23.00 dBm
```

```
Present Rx Channel : 23  
Cfg Rx Channel : 23
```

```
Disp Control Mode : automatic  
Cfg Dispersion : 0 ps/nm
```

```
Sweep Start Disp : -25500 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  
outPowerAdjust  
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           Pres
Cfg Rx LOS Thresh   : -23.00 dBm         Cfg

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

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

Rx Q Margin : 2.4 dB
OSNR X Polar: 34.4 dB
OSNR Y Polar: 34.4 dB

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

**Pre-FEC BER: 1.213E-03**

# 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-ai2	2x 100GAUI-2 (2x 50G)	oFEC	DP-QPSK	60.1GBd
10	OpenZR+ MSA	openZrpOfec2	1x 100GBASE-R	c1-100g-ai2	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-ai2	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  
Cfg Rx LOS Thresh : -23.00 dBm
```

```
Present Rx Channel : 23  
Cfg Rx Channel : 23
```

```
Disp Control Mode : automatic  
Cfg Dispersion : 0 ps/nm  
CPR Window Size : 32 symbols
```

```
Compatibility: openZ
```

```
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  
...
```

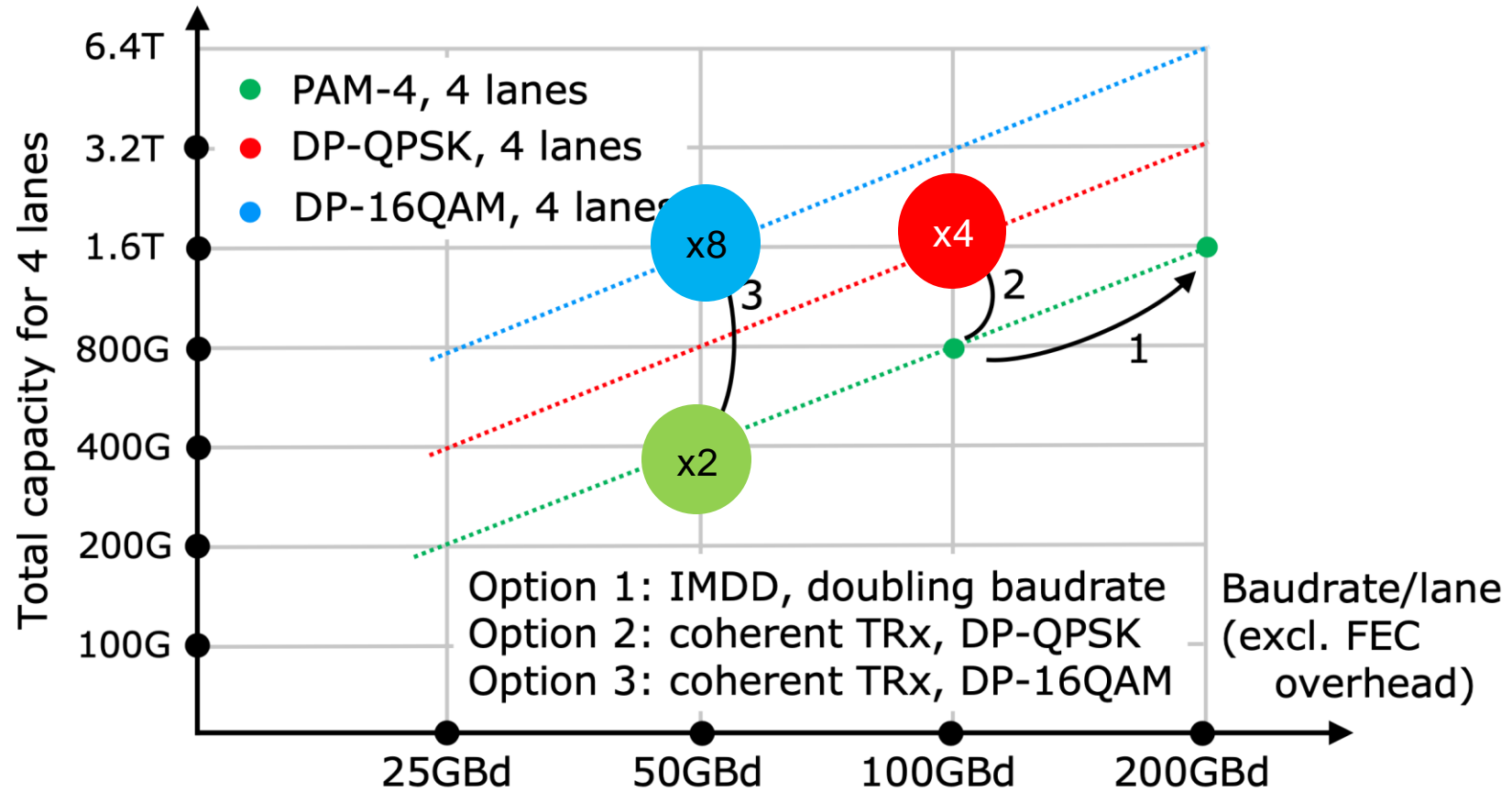
Application Mode	MSA format	Nokia Compatibility
1	OIF 400ZR, amplified	oif-400g-zr
2	OIF 400ZR, unamplified	
3	OpenZR+ MSA	openZrpOfec1
4	OpenZR+ MSA	
5	OpenZR+ MSA	openZrpOfec1
6	OpenZR+ MSA, Enhanced	openZrpOfec2
7	OpenZR+ MSA, Enhanced	
8	OpenZR+ MSA, Enhanced	openZrpOfec2
9	OpenZR+ MSA	openZrpOfec1
10	OpenZR+ MSA	openZrpOfec1
11	OpenZR+ MSA	openZrpOfec1
12	OpenZR+ MSA, Enhanced	
13	OIF 400ZR, amplified	oif-400g-zr
14	OpenZR+ MSA, Enhanced	openZrpOfec2
15	OpenZR+ MSA	

```
100GBASE-R 1x CAUI-4 w/o FEC (4x25G) oFEC DP-QPSK 30.1GBd
```

# OIF 400ZR vs. OpenZR+ MSA optical parameters

	<b>OIF 400ZR</b>	<b>OpenZR+ MSA</b>	
		<b>60LA</b>	<b>60HA</b>
<b><i>max. TX power</i></b>	-6 dBm	-10 dbm	0 dBm
<b><i>min. RX power</i></b>	-12 dBm	-12 dBm	-12 dBm
<b><i>CD Tolerance</i></b>	2,400 ps/nm	20,000 ps/nm	
<b><i>PMD Tolerance</i></b>	10 ps	20 ps	
<b><i>OSNR Tolerance</i></b>	26 dB	24 dB	

# more bandwidth for 800G, 1.6T or 3.2T with coherent



source: [1]

# Want to learn for yourself?

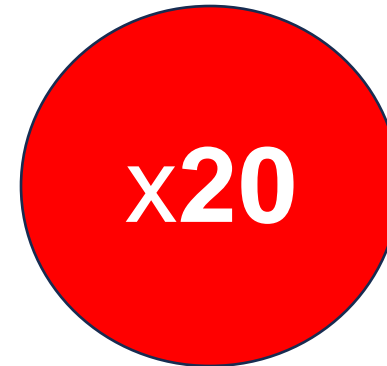
Your switch gear  
+ our coherent optics  
= **less hickups, more knowhow**



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

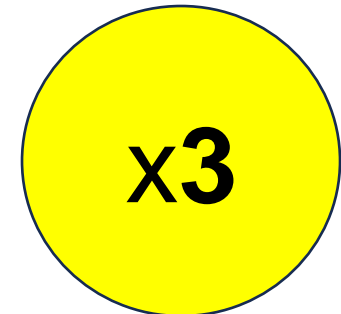
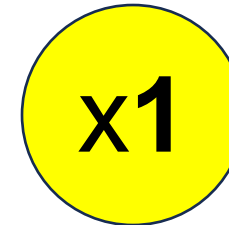
# comparison of OPEX      CAPEX

**100G DCI** vs. 400G Coherent

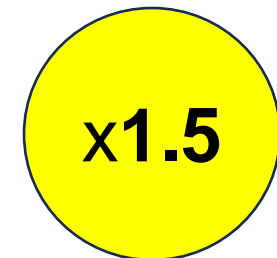
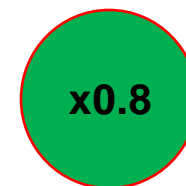


n/a

**100G** vs. 400G Coherent



400G vs. **800G grey**





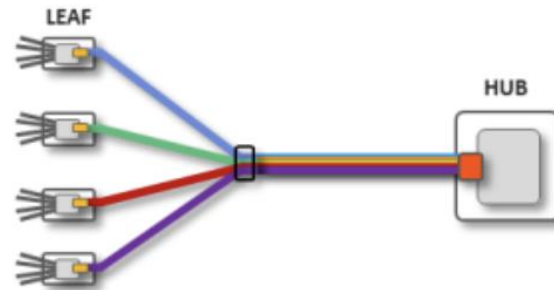
# Outlook: OpenXR 16 x 25Gbit/s via DSCM

Point-to-Point



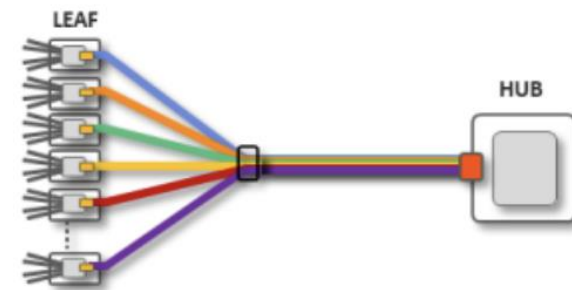
100G/200G/400G P2P

Break-out Mode



4 X 100G LEAFS TO 400G HUB

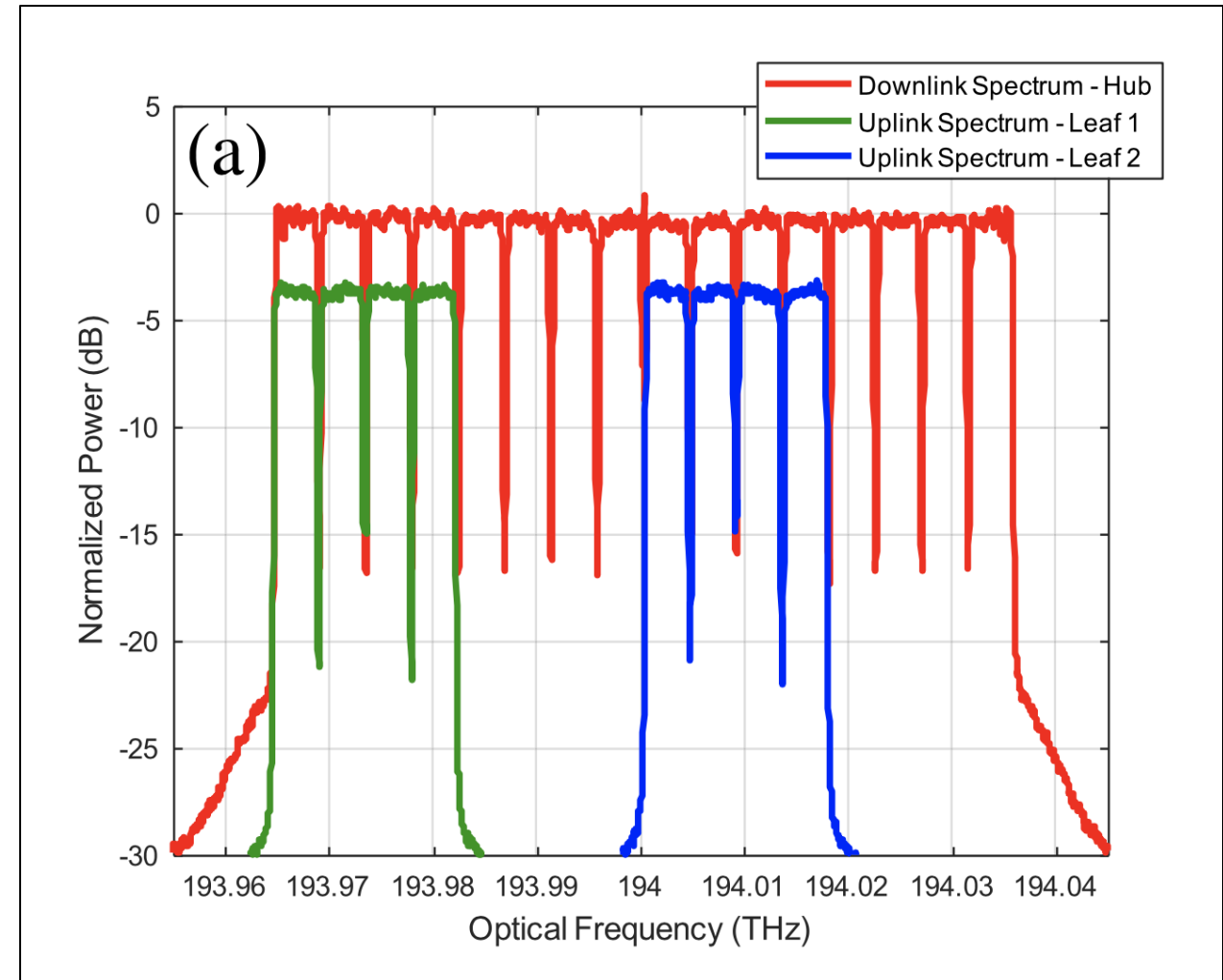
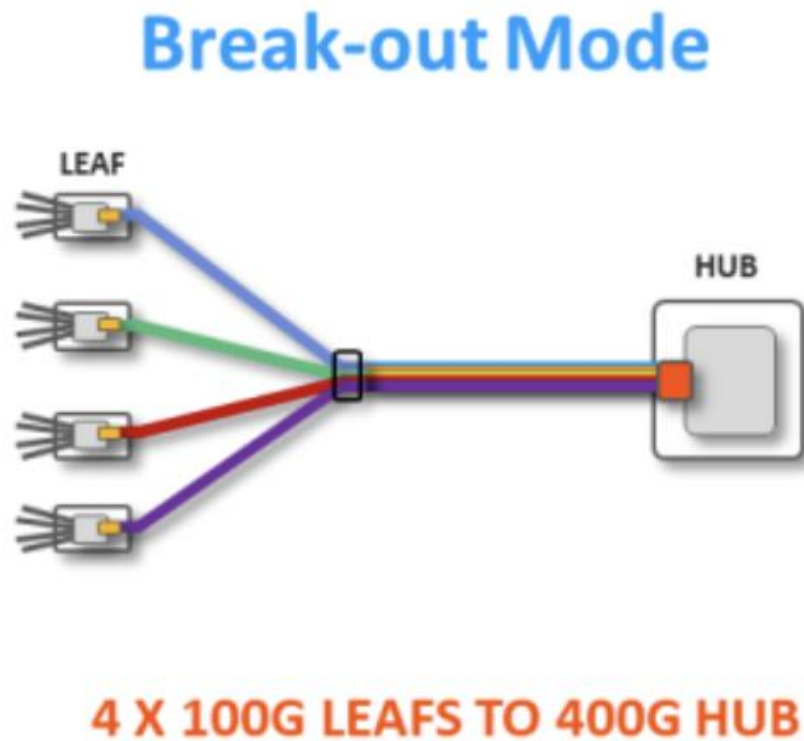
Flexible Point-to-Multipoint



UP TO 16 LEAFS TO 400G HUB

source: [7]

# Outlook: DSCM (Digital SubCarrier Multiplexing)



source: [7]

source: [8]

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