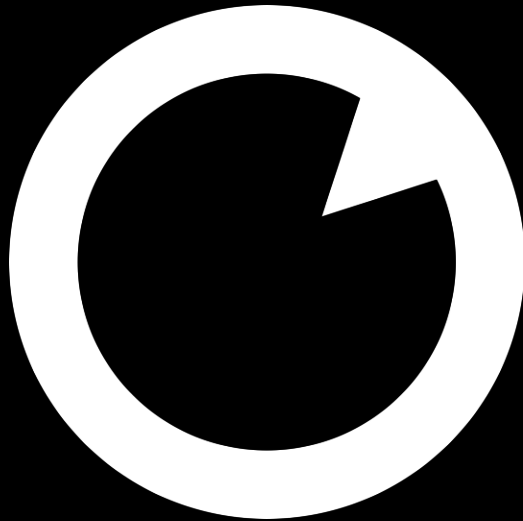
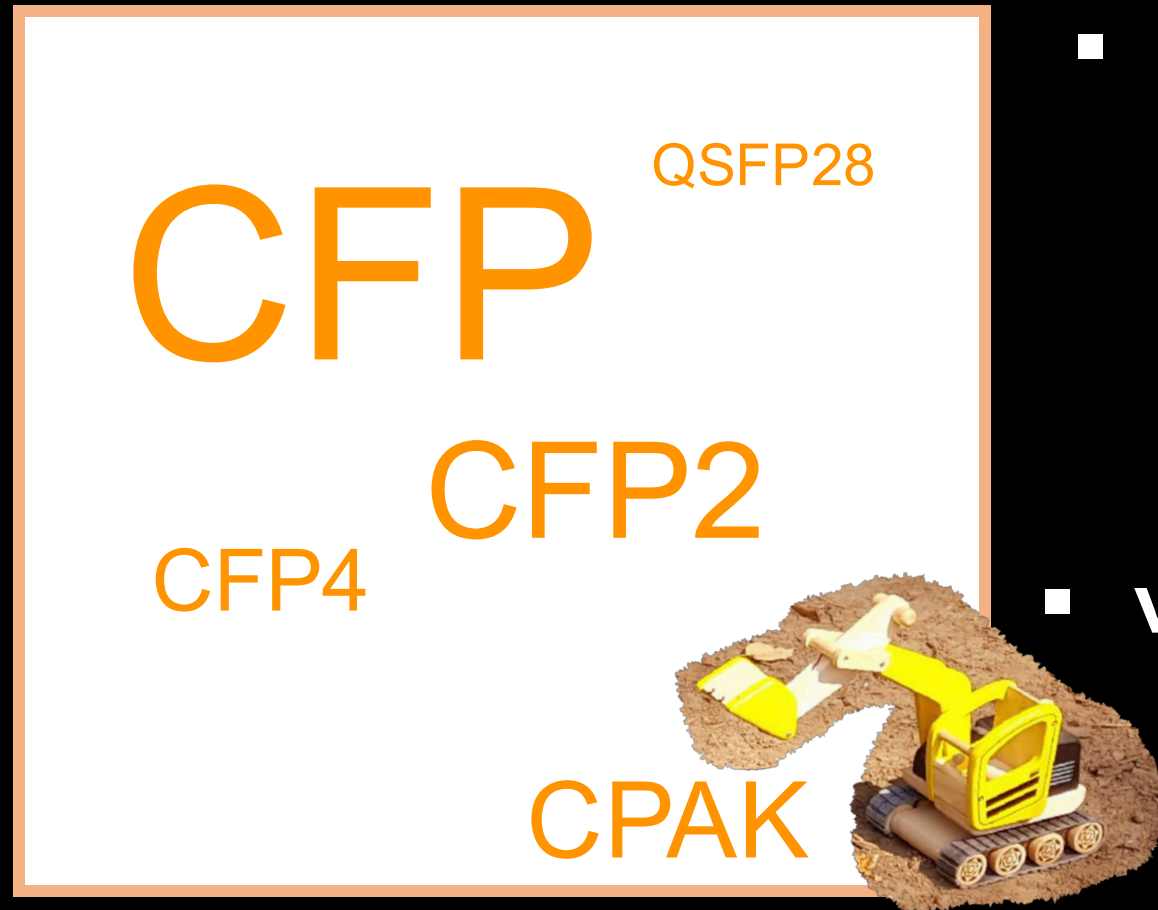


coherent optical transceivers



current capabilities and
future possibilities

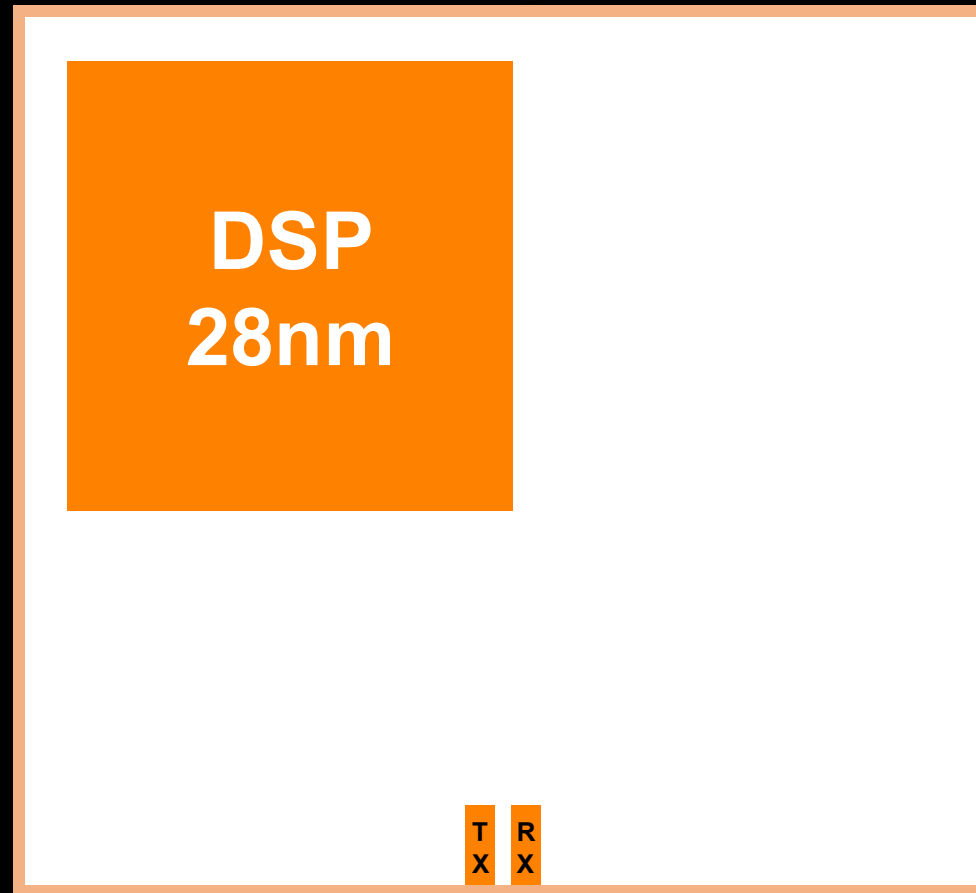
100G ecosystem limits ...



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

... sorted now with 400G

DWDM transponder card

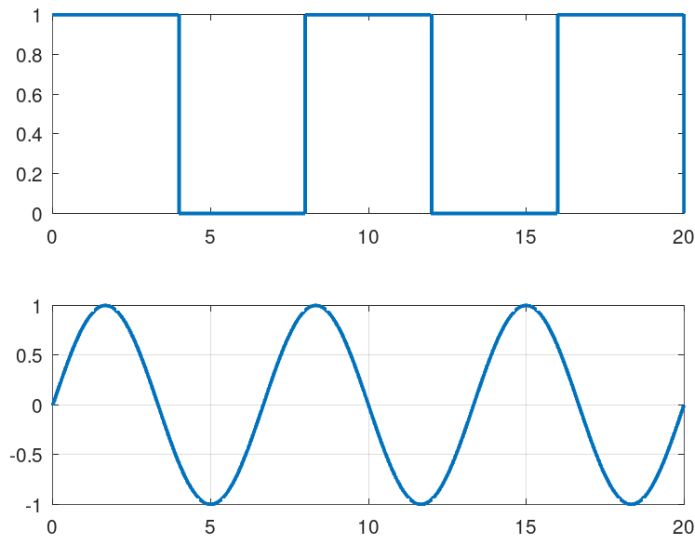


pluggable QSFP-DD



Direct Detection Transceiver limits

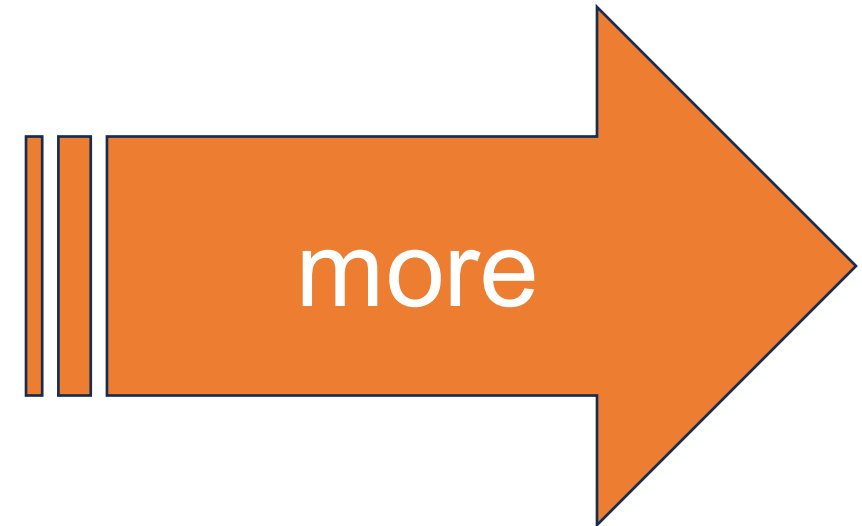
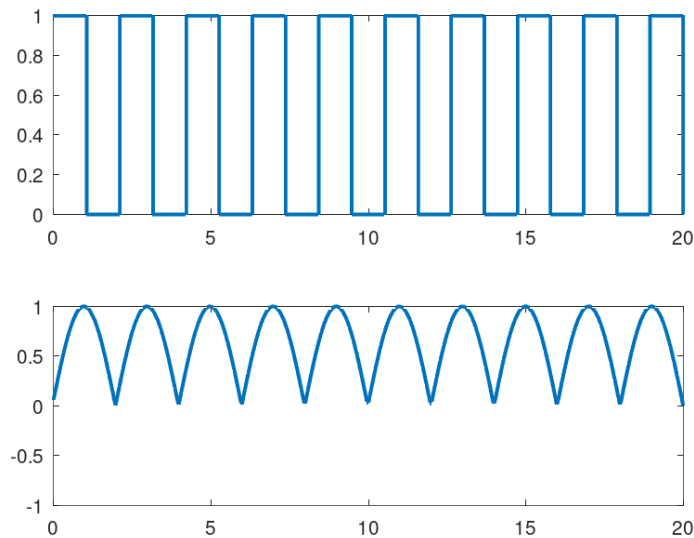
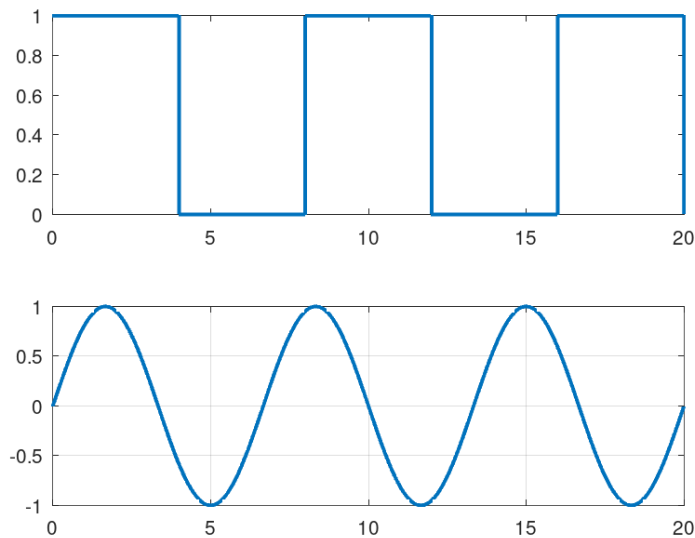
With **higher** frequencies -> harder for Photodiodes to detect



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

Direct Detection Transceiver limits

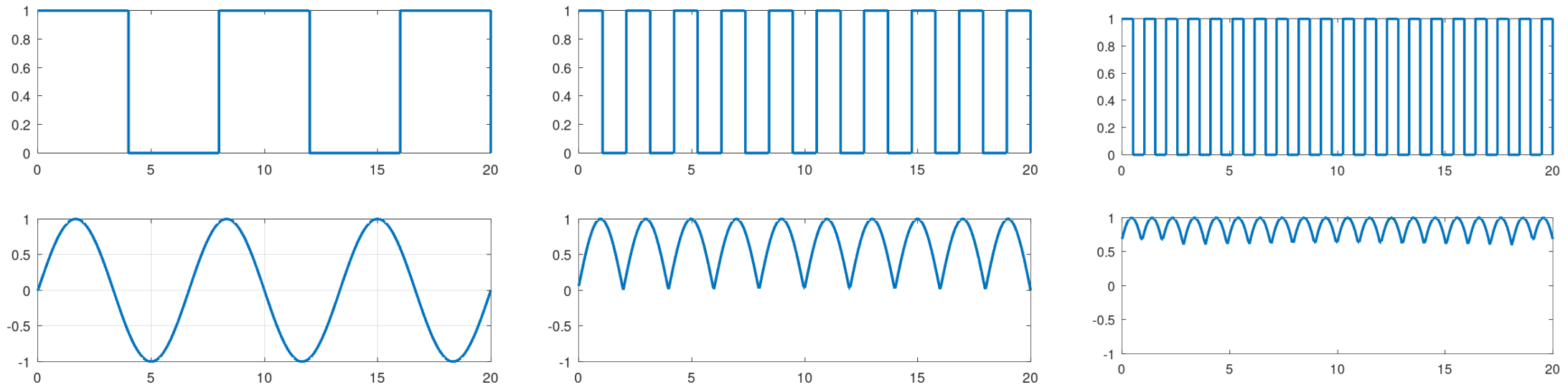
With **higher** frequencies -> harder for Photodiodes to detect



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

Direct Detection Transceiver limits

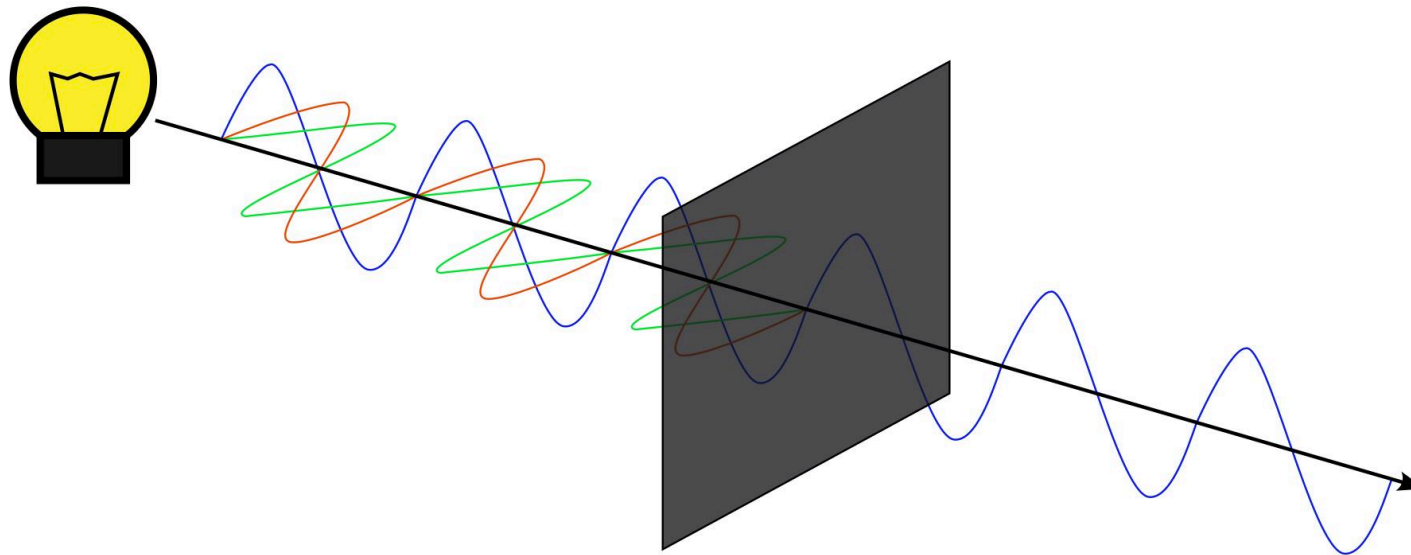
With **higher** frequencies -> harder for Photodiodes to detect



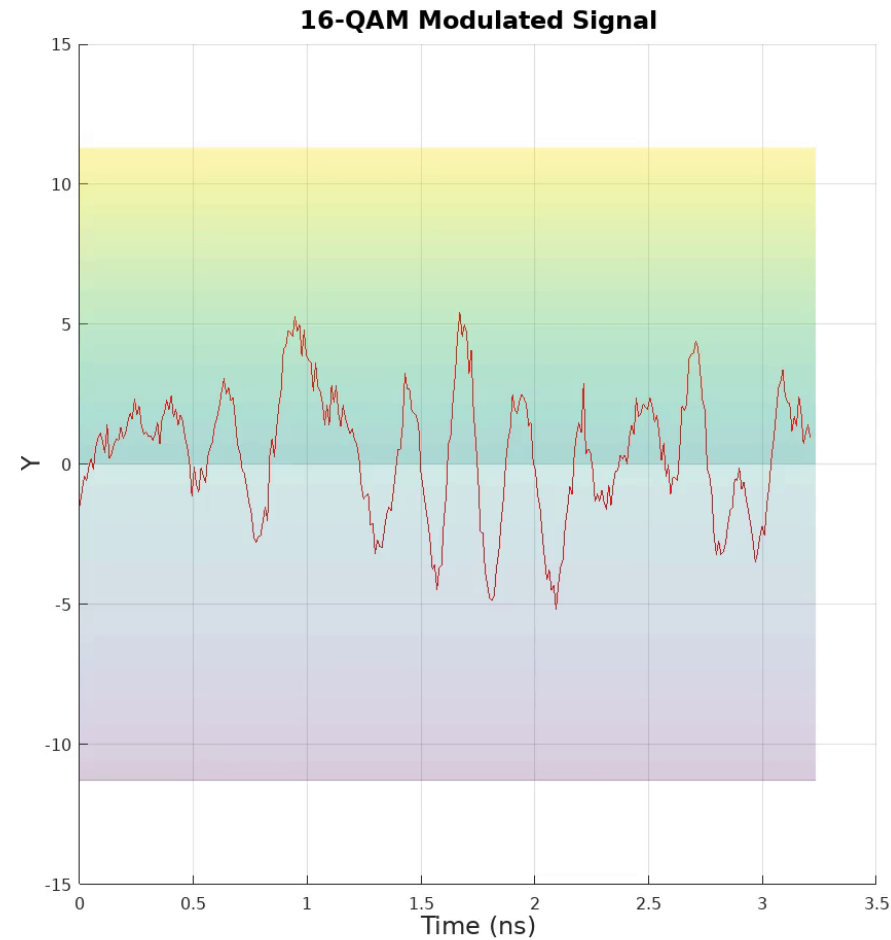
Missed Opportunity: **Light** has more **Properties**

Main Properties of Photonic Waves

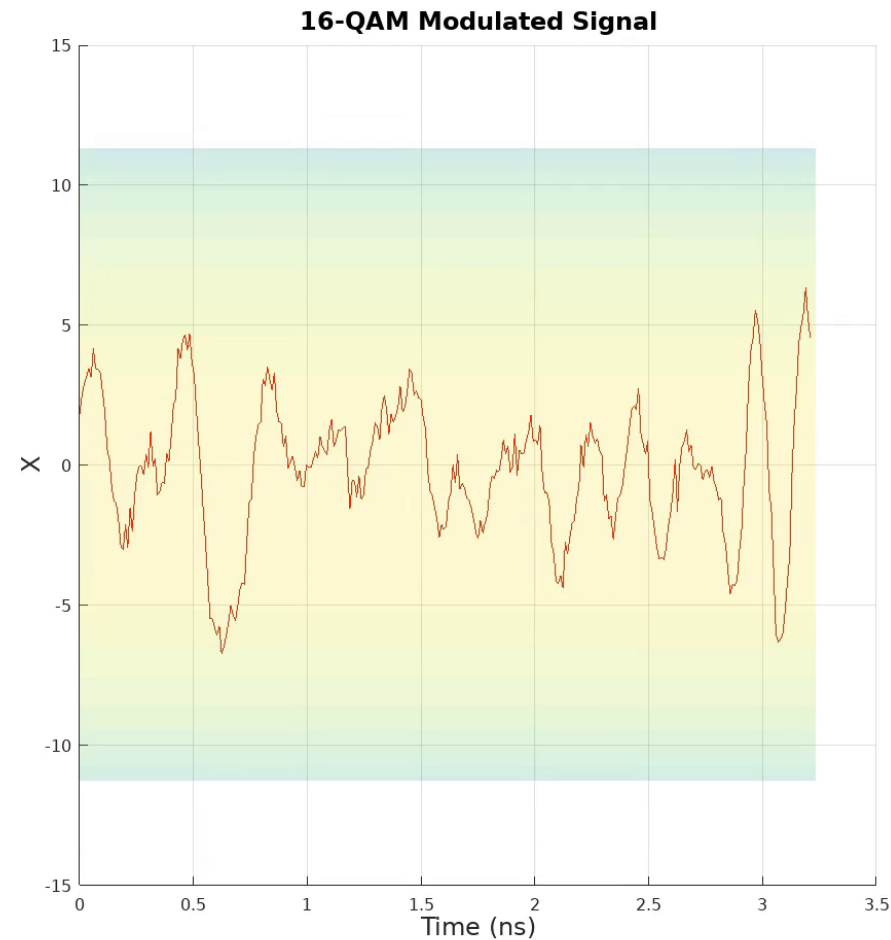
- Besides **Amplitude**, also **Phase** and **Polarisation**
- More properties per Carrier = Higher Bandwidth



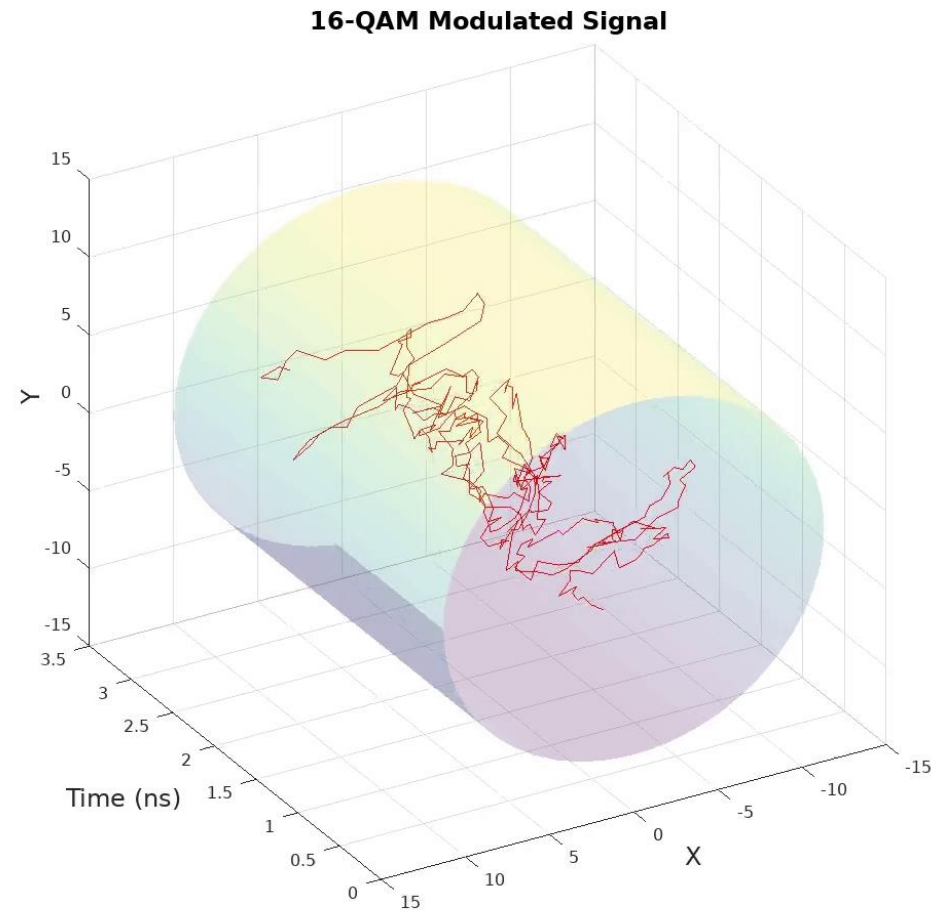
Polarisation Signal on X and Y Plane



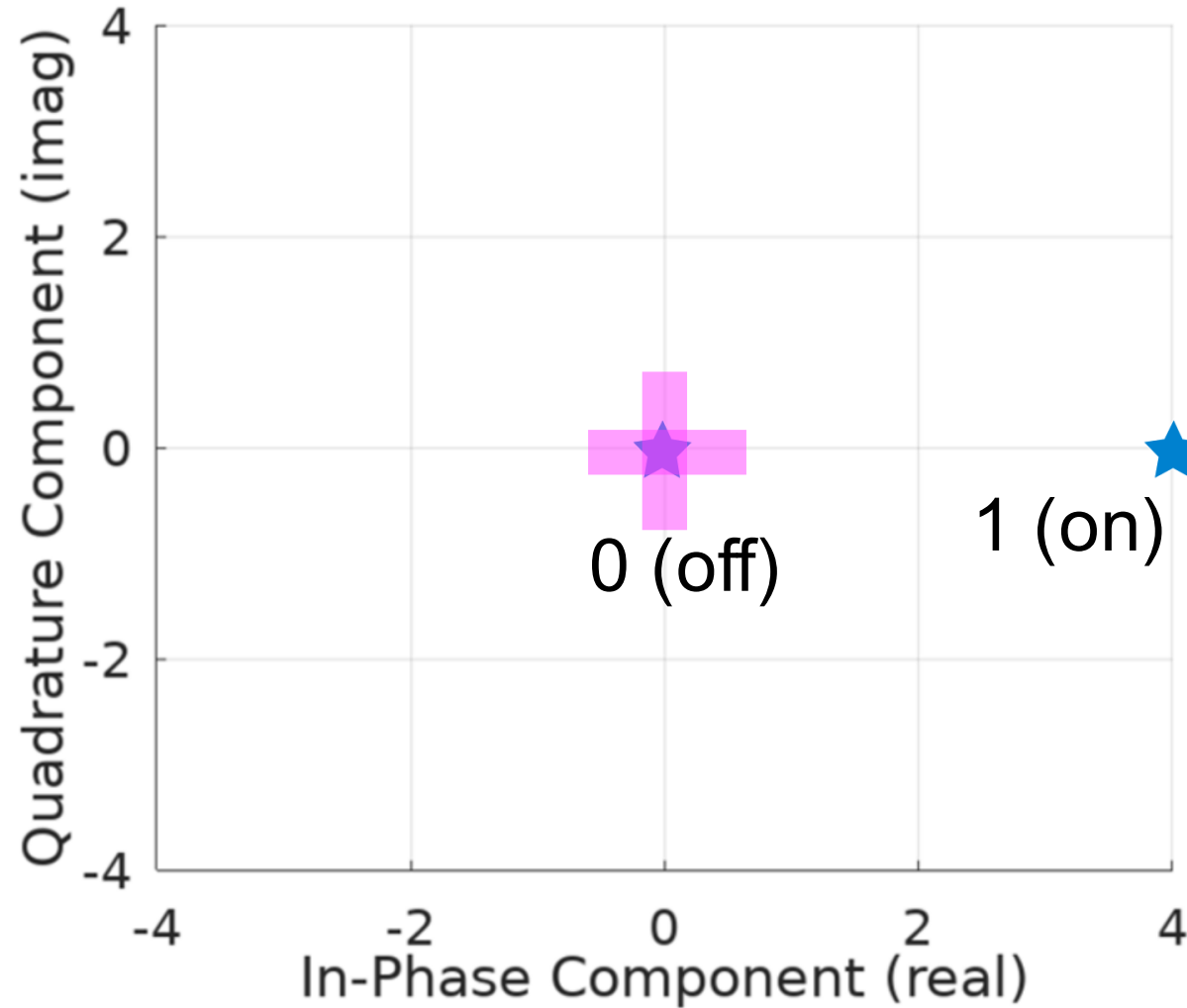
Polarisation Signal on X and Y Plane



Polarisation Signal on X and Y Plane

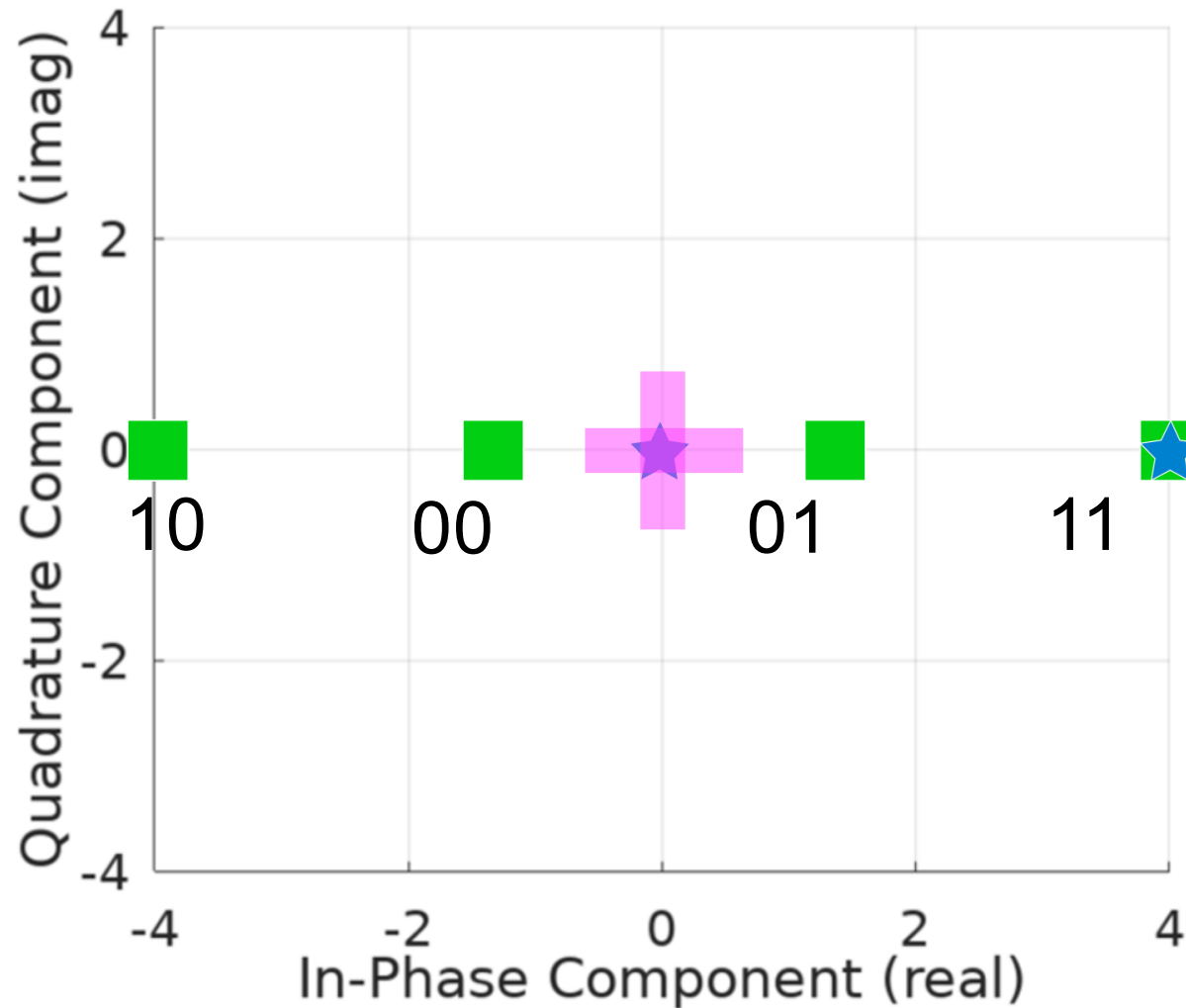


Constellation Diagram



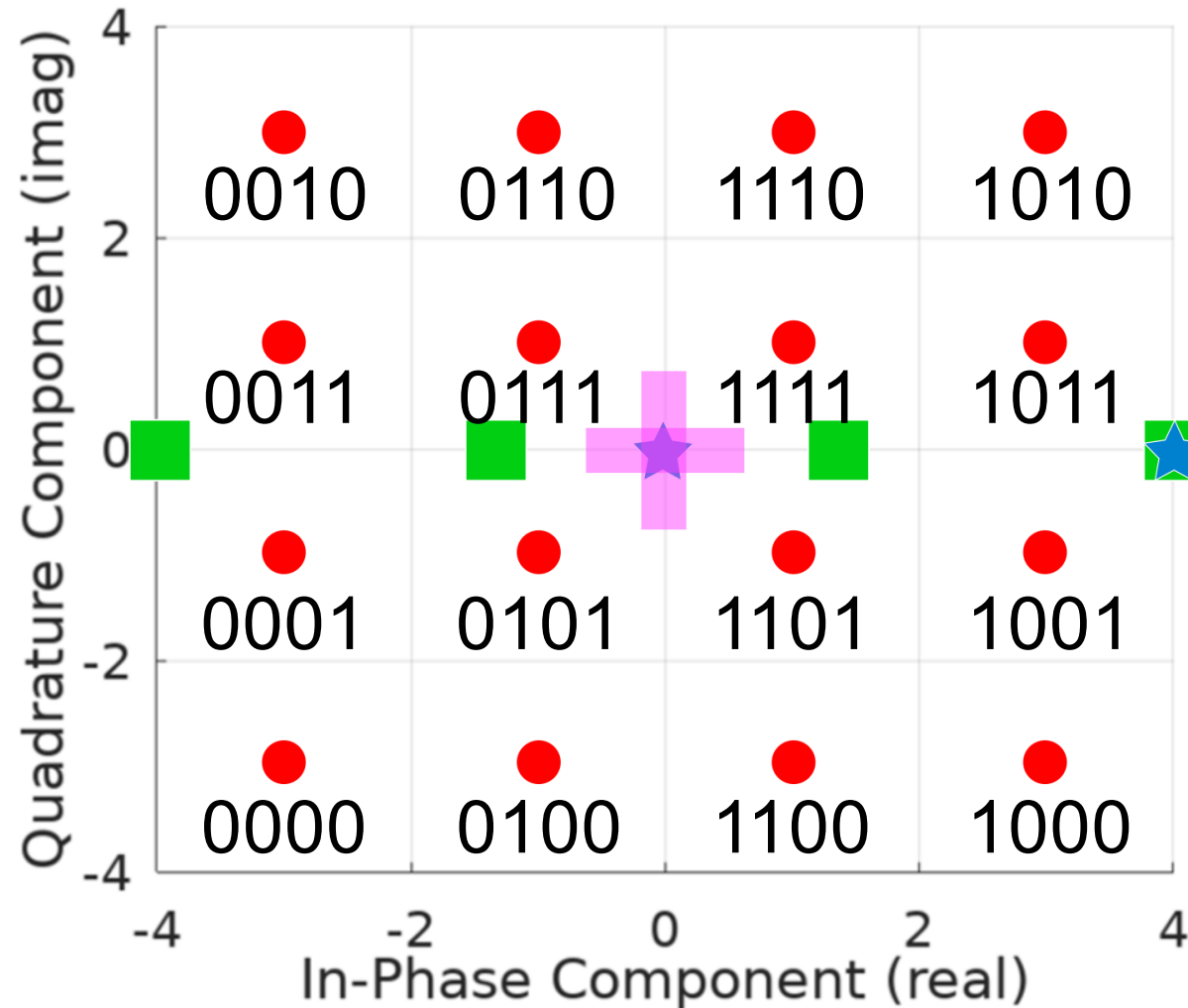
★ OOK

Constellation Diagramm



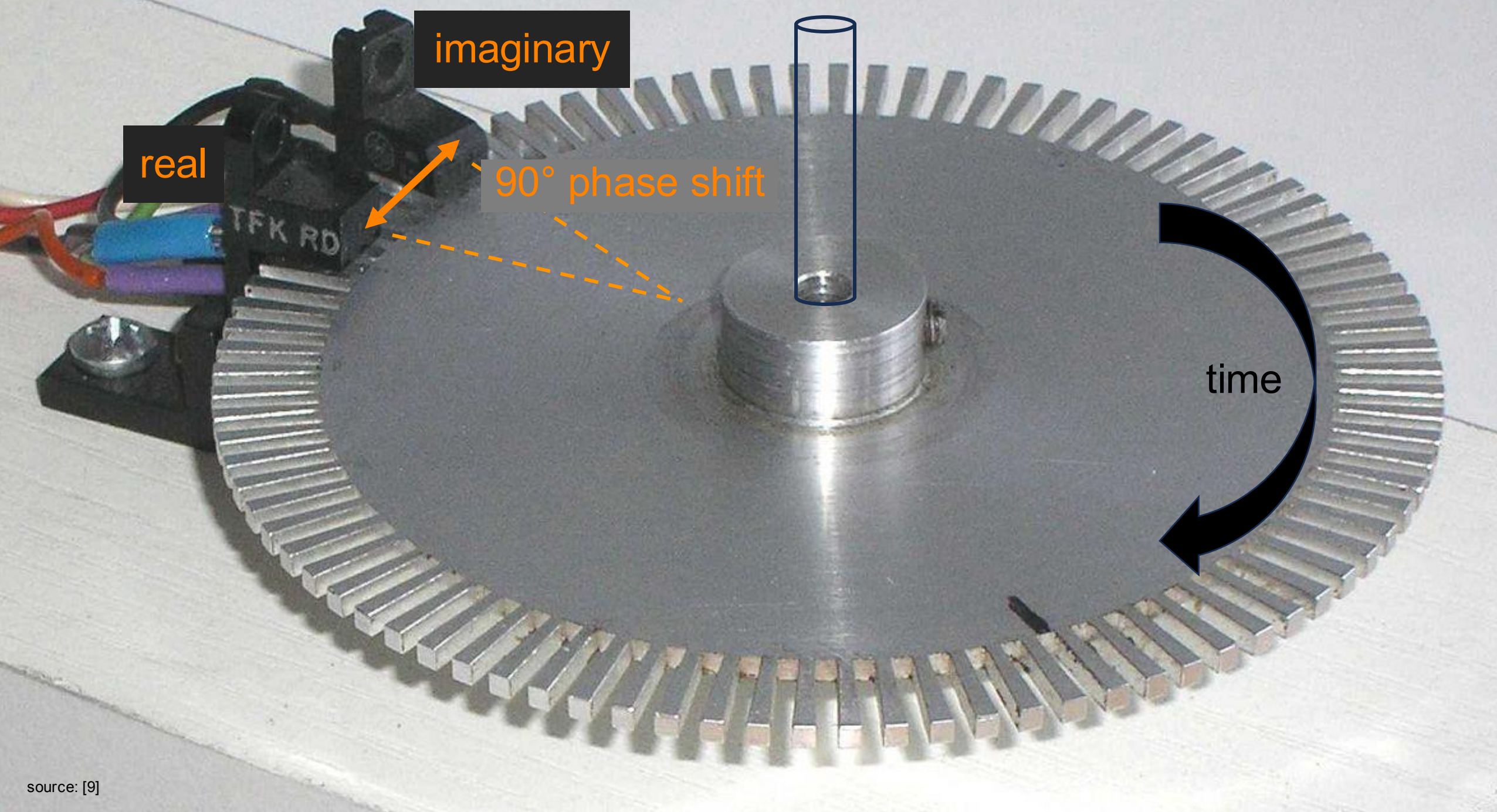
★ OOK
■ PAM4

Constellation Diagramm

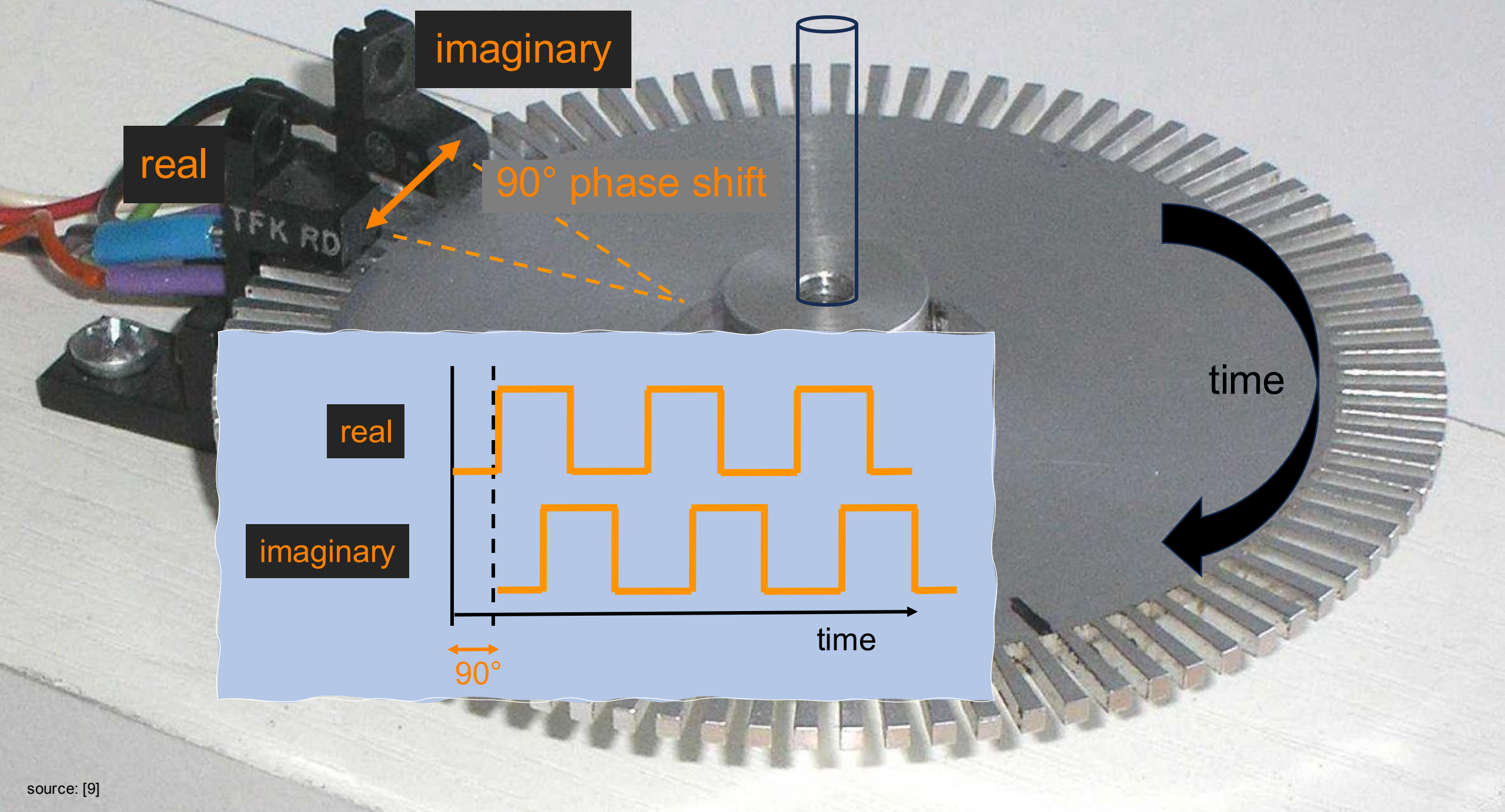


- ★ OOK
- PAM4
- 16QAM

90°
phase
shifted
amplitude



source: [9]



imaginary

real

90° phase shift

real

imaginary

time

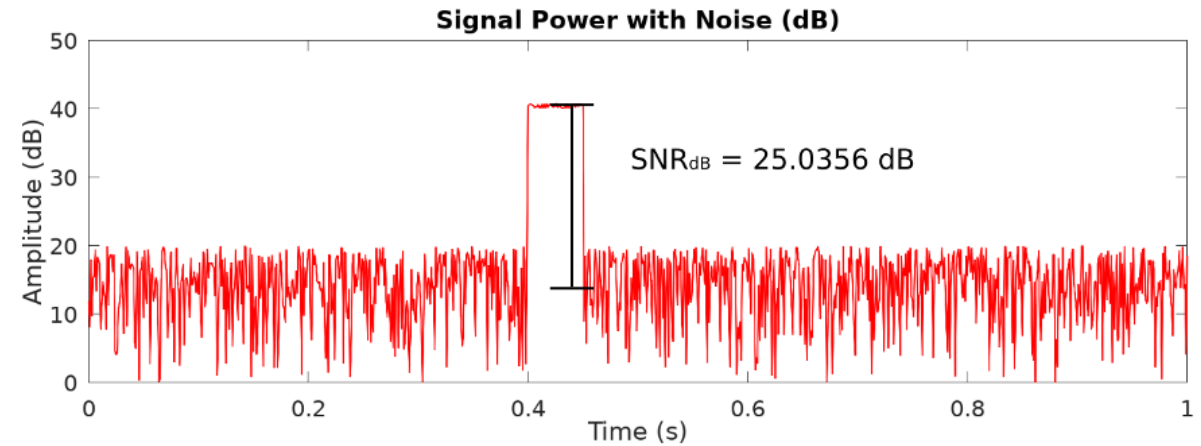
90°

time

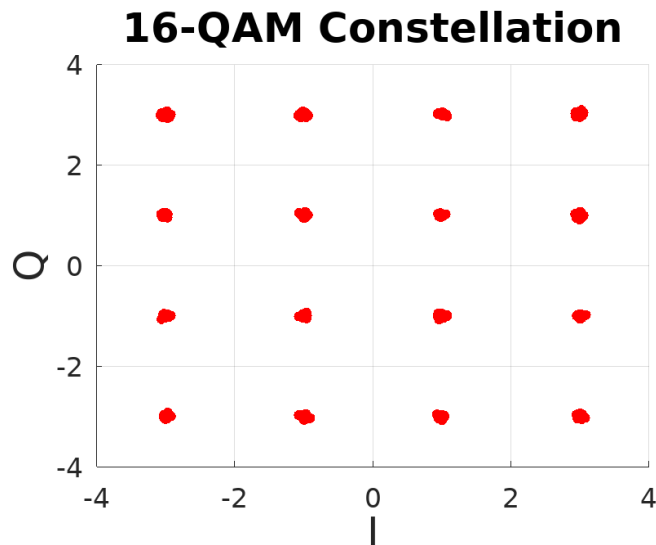
source: [9]

Measuring Signal Quality

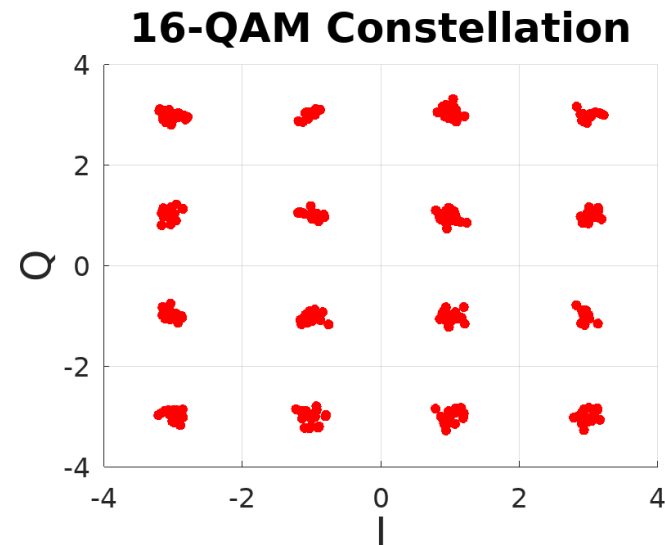
- **SNR** = Signal-to-Noise-Ratio
- Convenience of using decibels for **small** and **large** values
- (e)SNR vs OSNR:
electrical vs optical



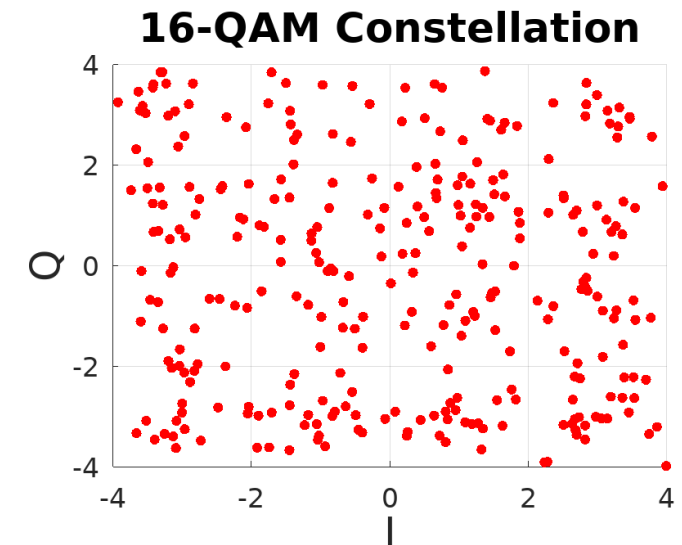
Phase and Amplitude Errors



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-yr.html>

```
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
...
```

```
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

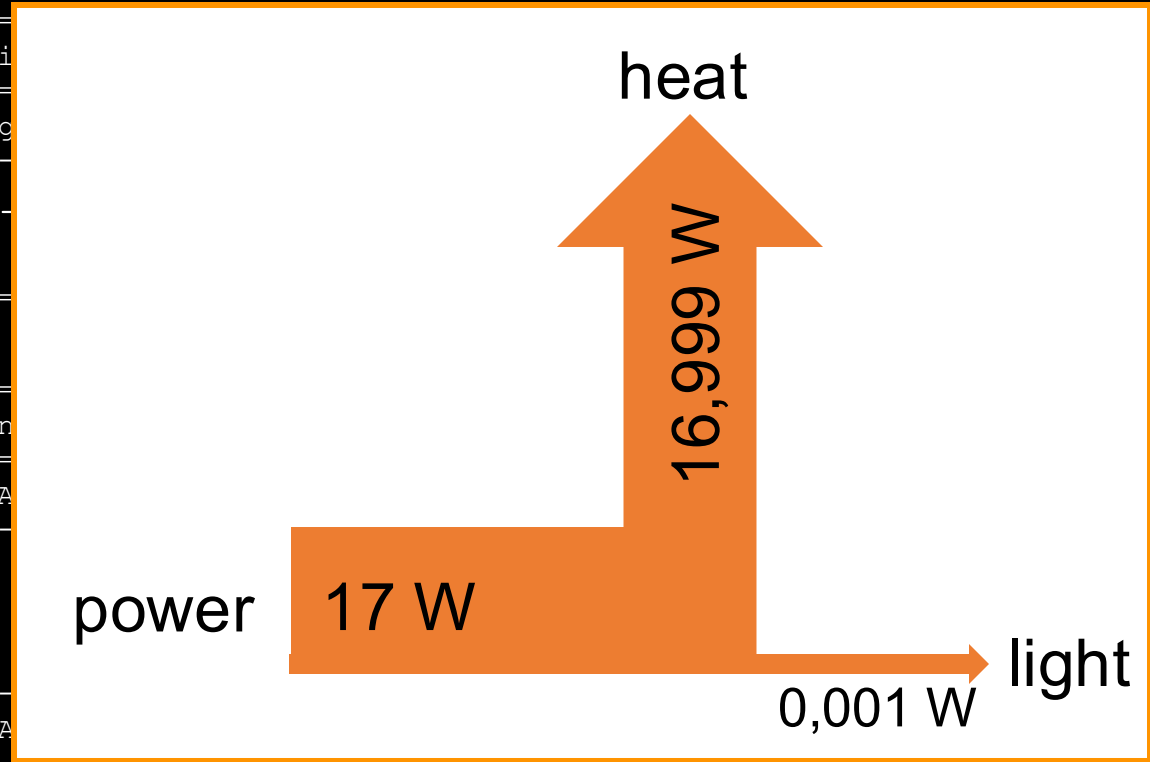
-

-

-8.20

0.01/H-W

...



```

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
Cfg Rx LOS Thresh   : -23.00 dBm

Present Rx Channel : 23
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)

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)

```
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
Cfg Rx LOS Thresh   : -23.00 dBm
```

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

```
Disp Control Mode : automatic
```

```
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
```

```
=====
```

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-FEC BER : 1.213E-03
```

```
ReadyOff laserReady
```

```
outPowerAdjust
```

```
trInput 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 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
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
```

```
Sweep Start Disp : -25500 ps/nm
Sweep End Disp   : 2000 ps/nm
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-aui2	2x 100GAUI-2 (2x 50G)	oFEC	DP-QPSK	60.1GBd
10	OpenZR+ MSA	openZrpOfec2	1x 100GBASE-R	c1-100g-aui2	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-aui2	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: openZ

Cfg Tx Power Min   : -22.90 dBm
```

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	

```
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

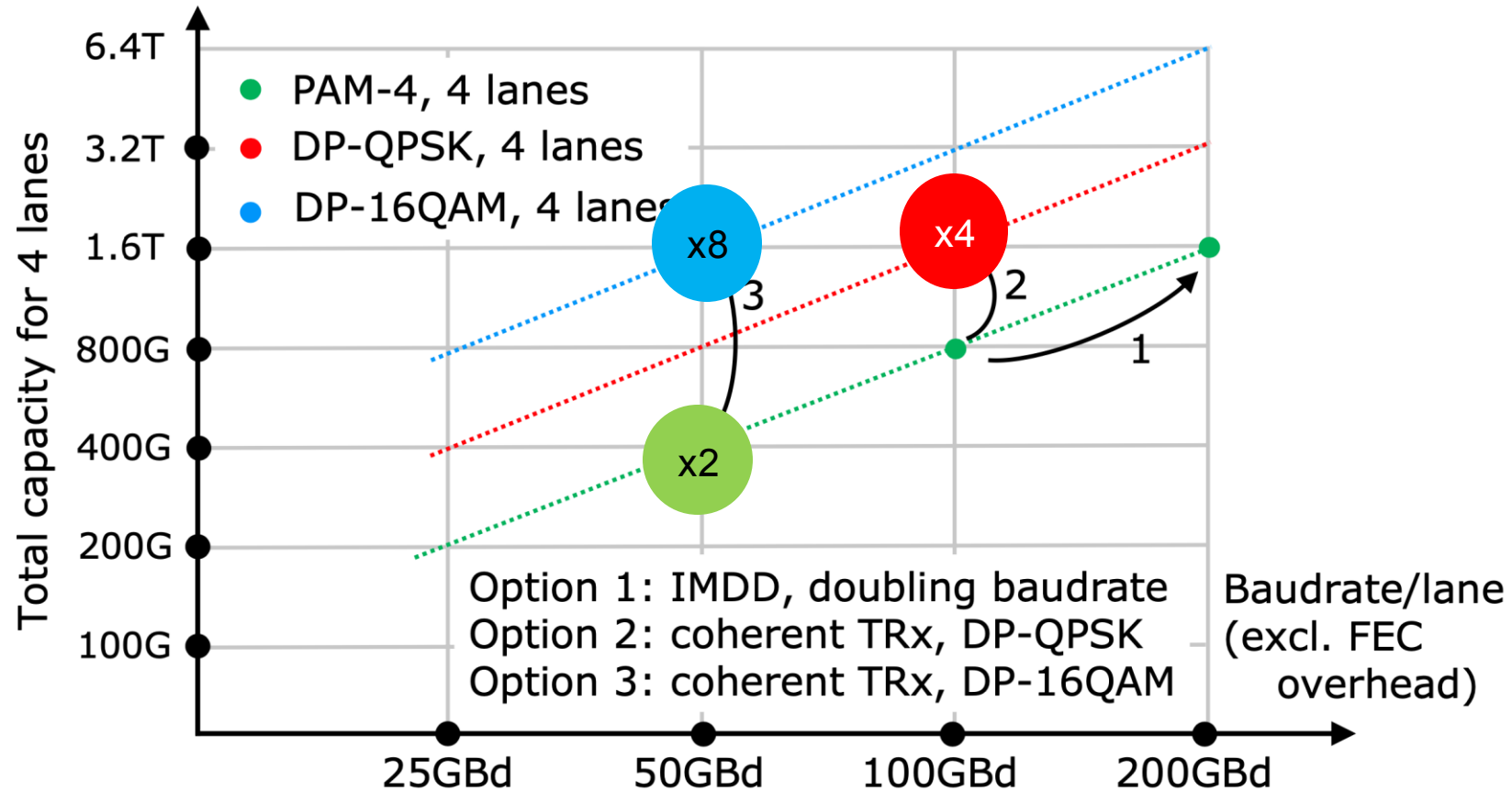
Link Length support: Unknown
...
```

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

OIF 400ZR vs. OpenZR+ MSA optical parameters

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

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



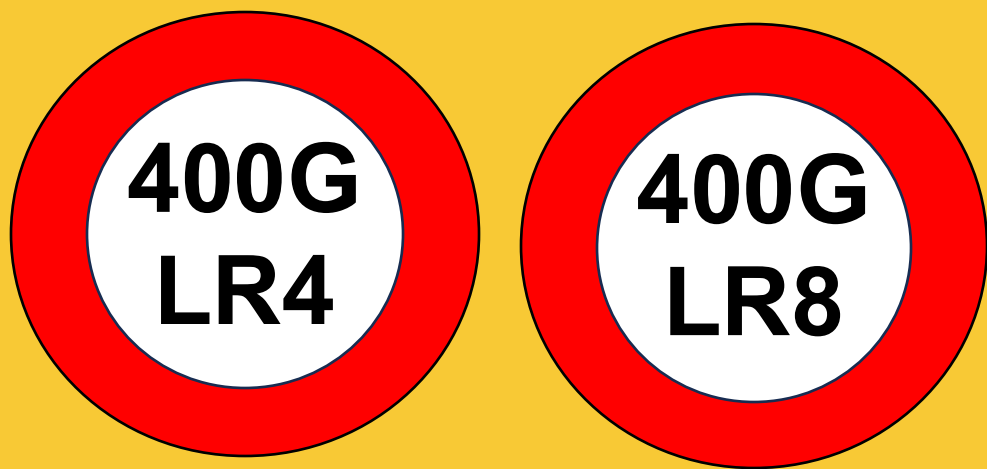
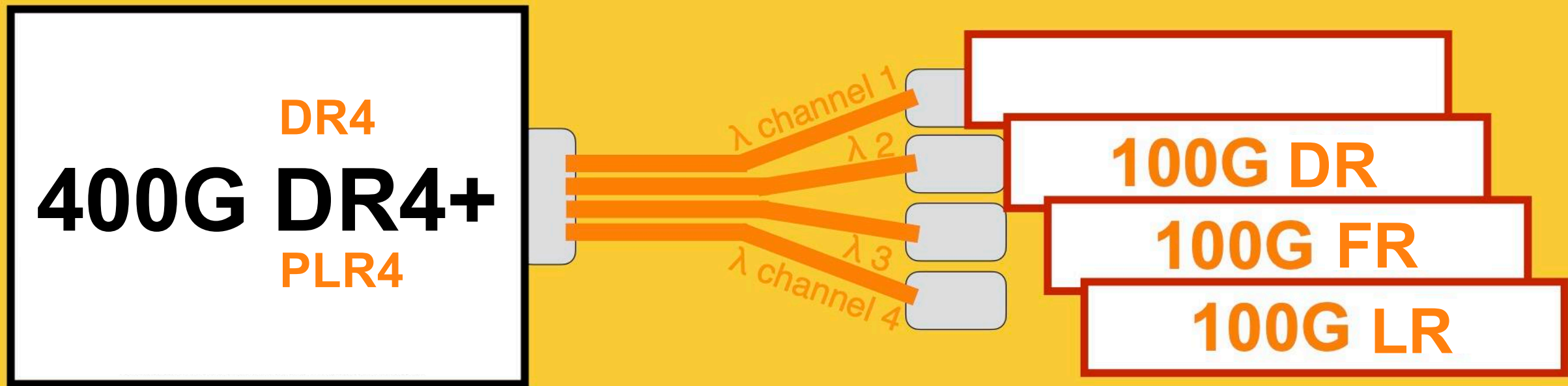
source: [1]

Want to learn for yourself?



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

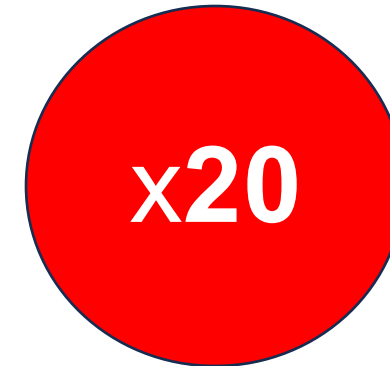
thomas.weible@flexoptix.net
gerhard.stein@flexoptix.net



single λ

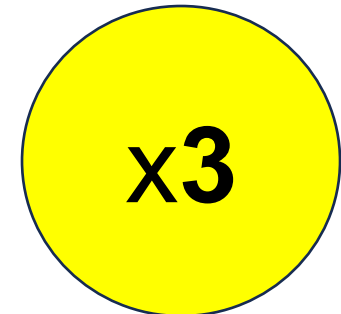
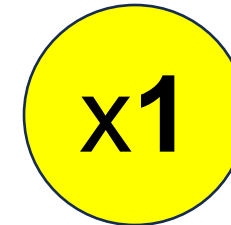
comparison of OPEX CAPEX

100G DCI vs. 400G Coherent

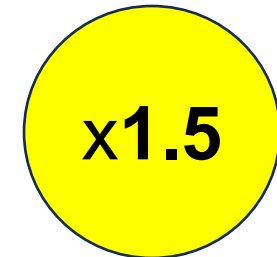
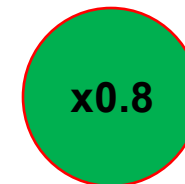


n/a

100G vs. 400G Coherent



400G vs. **800G grey**



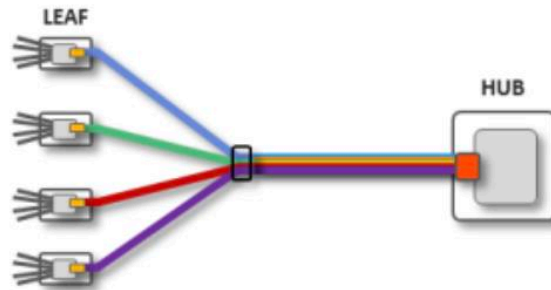
Outlook: OpenXR 16 x 25Gbit/s via DSCM

Point-to-Point



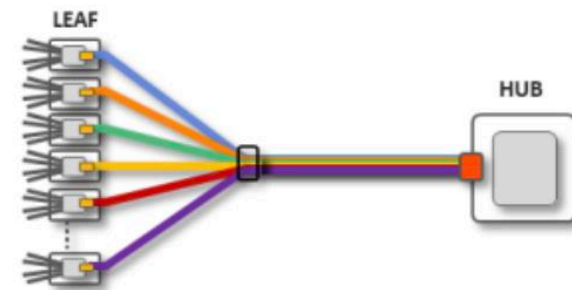
100G/200G/400G P2P

Break-out Mode



4 X 100G LEAFS TO 400G HUB

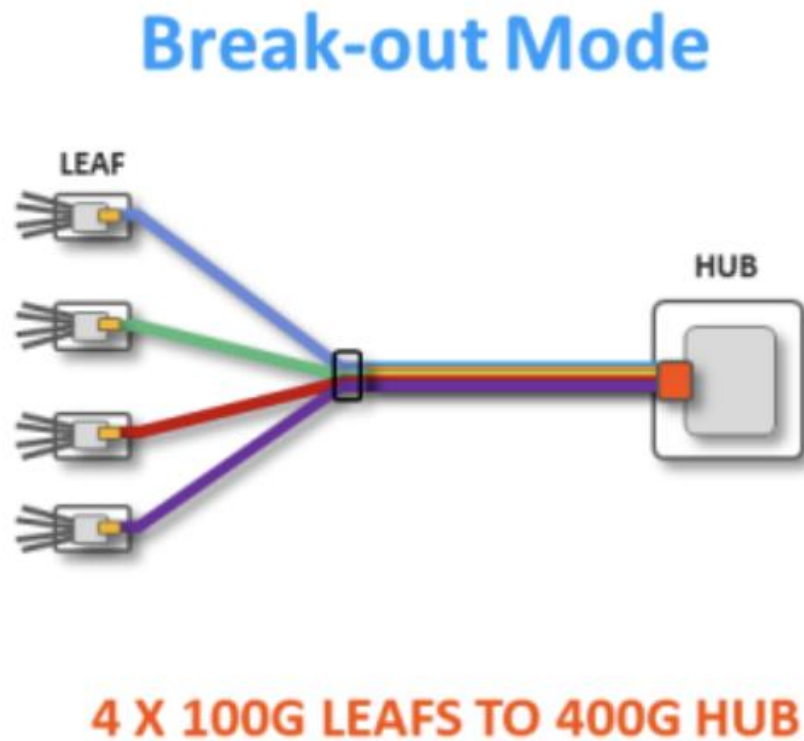
Flexible Point-to-Multipoint



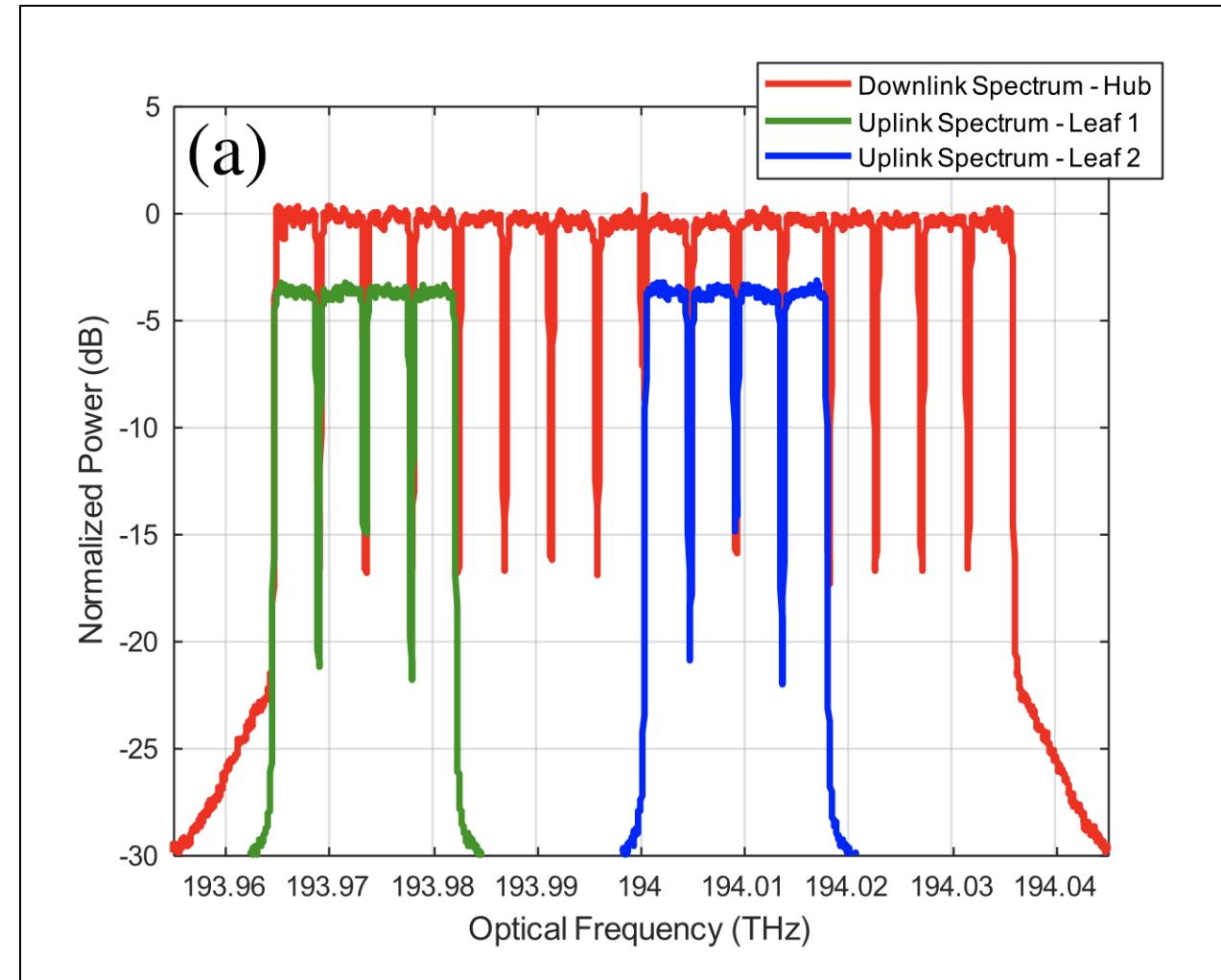
UP TO 16 LEAFS TO 400G HUB

source: [7]

Outlook: DSCM (Digital SubCarrier Multiplexing)



source: [7]



source: [8]

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