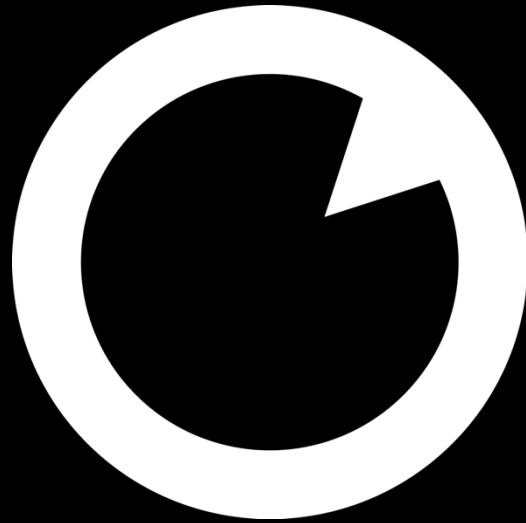


Analyzing network reliability up to 800G



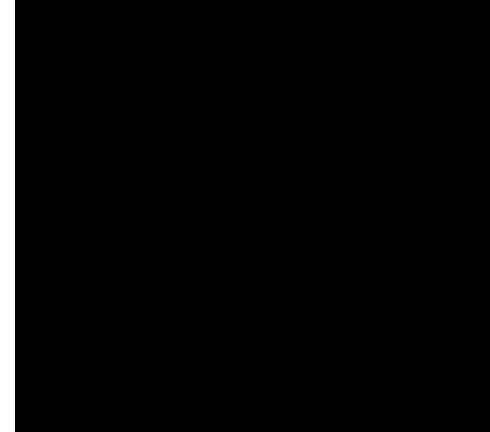
Impact of SNR thresholds on BER for Coherent and Non-Coherent transceivers

1

**Intro and
recap**

2

**Bit Error Rate
dependency**



4

Distance

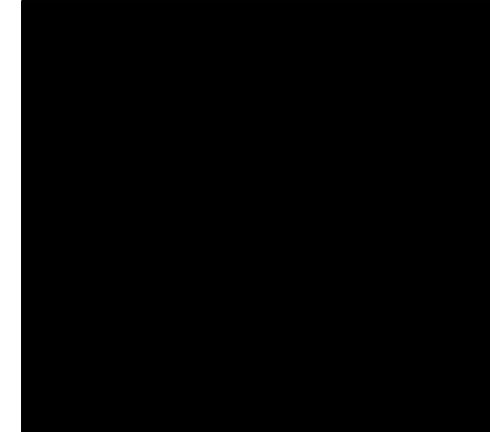
5



Temperature

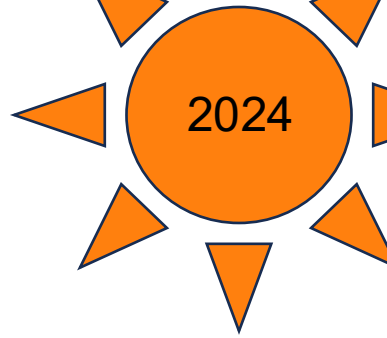
6

Live Demo



8

Take Away



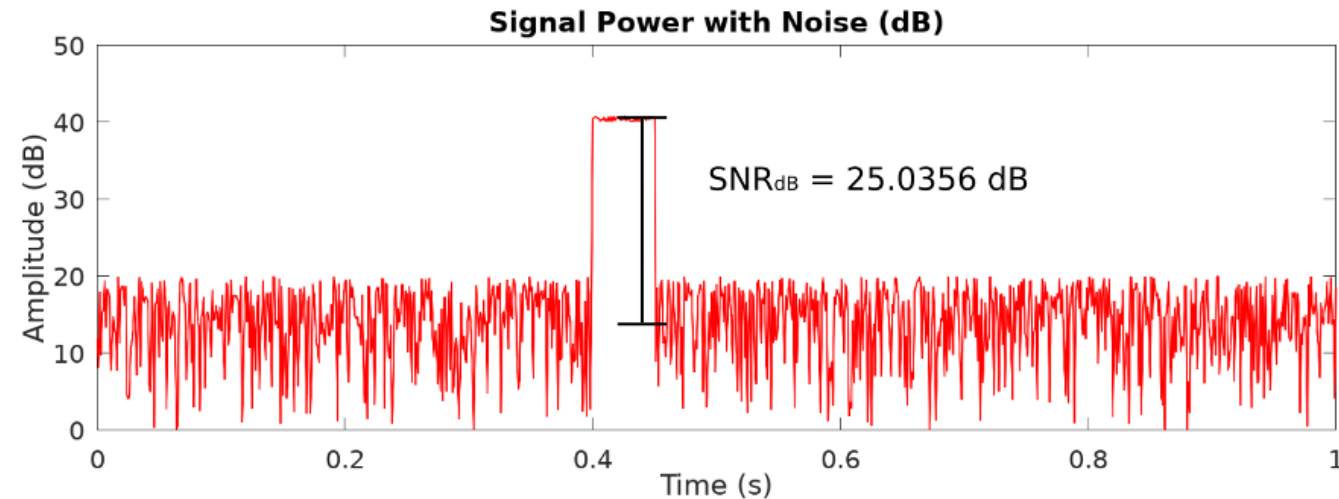
Measuring Link Quality

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

Data POV

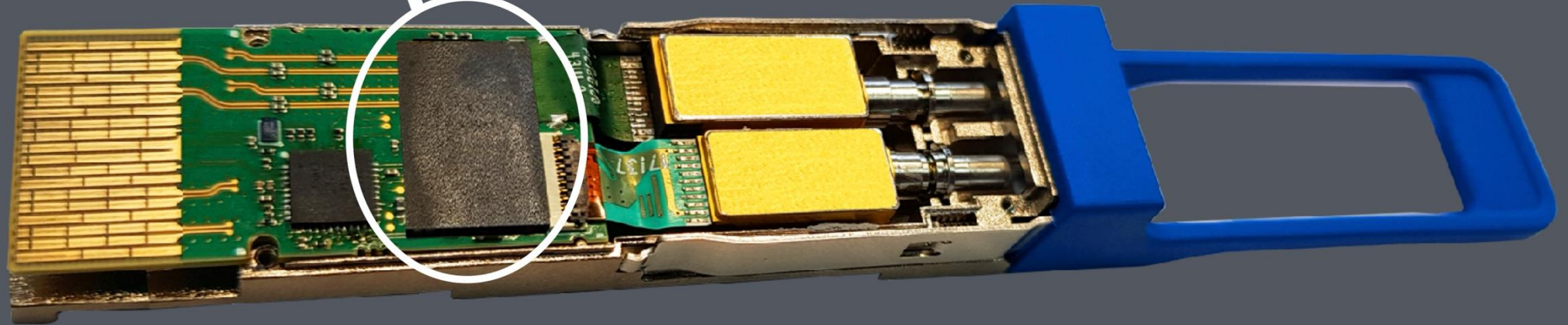
$$\text{BER} = \frac{\text{Number of Erroneous Bits}}{\text{Total of Bits}}$$

Communication POV



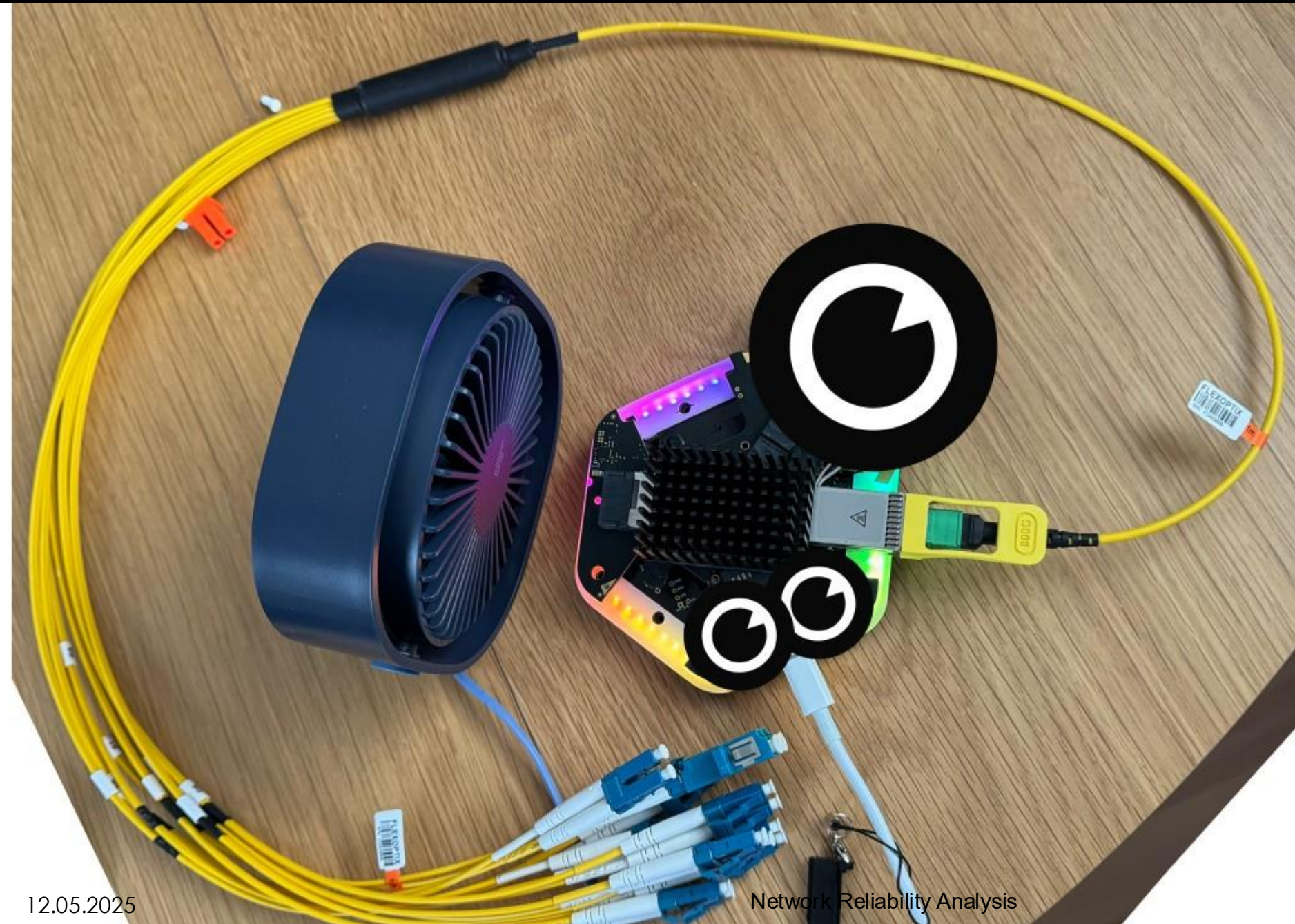
DigitalSignalProcessor

- + FEC
- + BERT
- + OSNR
- + ...



lab setup

FLEXBOX5
with
800G DD,
heat sink
and fan



DUTs* are

1. 100G QSFP28 Single Lambda DR 500m
2. 100G QSFP28 Single Lambda ER 40km
3. 400G QSFP-DD Coherent ZR low power
4. 400G QSFP-DD LR4 10km
5. 400G QSFP112 DR4 500m
6. 800G QSFP-DD DR8 500m

*Device Under Test

Watch for attenuation with short cables!

CAUTION: you may damage the photodiodes of long range transceivers!

Shopping List:

1. The Transceiver

100G QSFP28 ER WITH DUAL CDR

40 km, $\lambda 1310$ nm, LC-Duplex, Singlemode

Q.13S1HG.40
QSFP28
ER



- ✓ Universal QSFP28 Transceiver
- ✓ Use FLEXBOX to configure to almost any vendor
- ✓ For 100GBASE-ER Ethernet links
- ✓ Integrated Clock-Data-Recovery (CDR)
- ✓ PAM4 modulated signal
- ✓ Supported Data Rates: 106.25 Gbit/s
- ✓ Up to 40 km via Singlemode OS2
- ✓ LC-Duplex Connector

2. Fiber Cable (Drums)



10 + 20km G.652.D
@1310nm ≤ 0.35 dB/km

3. Attenuators



Q.13S1HG.40 attenuation calculation

fiber length + attenuator	cable (0.35 dB/km)	used attenuator
2 meter	about 0 dB	11 dB
10 km	3.5 dB	11 dB
20 km	7 dB	11 dB
30 km	10.5 dB	5 dB
40 km	14 dB	2 dB
50 km	17.5 dB	2 dB

TRANSMIT MIN/MAX PER LANE	4.5 dBm / 7.9 dBm
---------------------------	-------------------

RECEIVER MIN/MAX PER LANE	-14 dBm / -3 dBm (overload) @100G
---------------------------	-----------------------------------

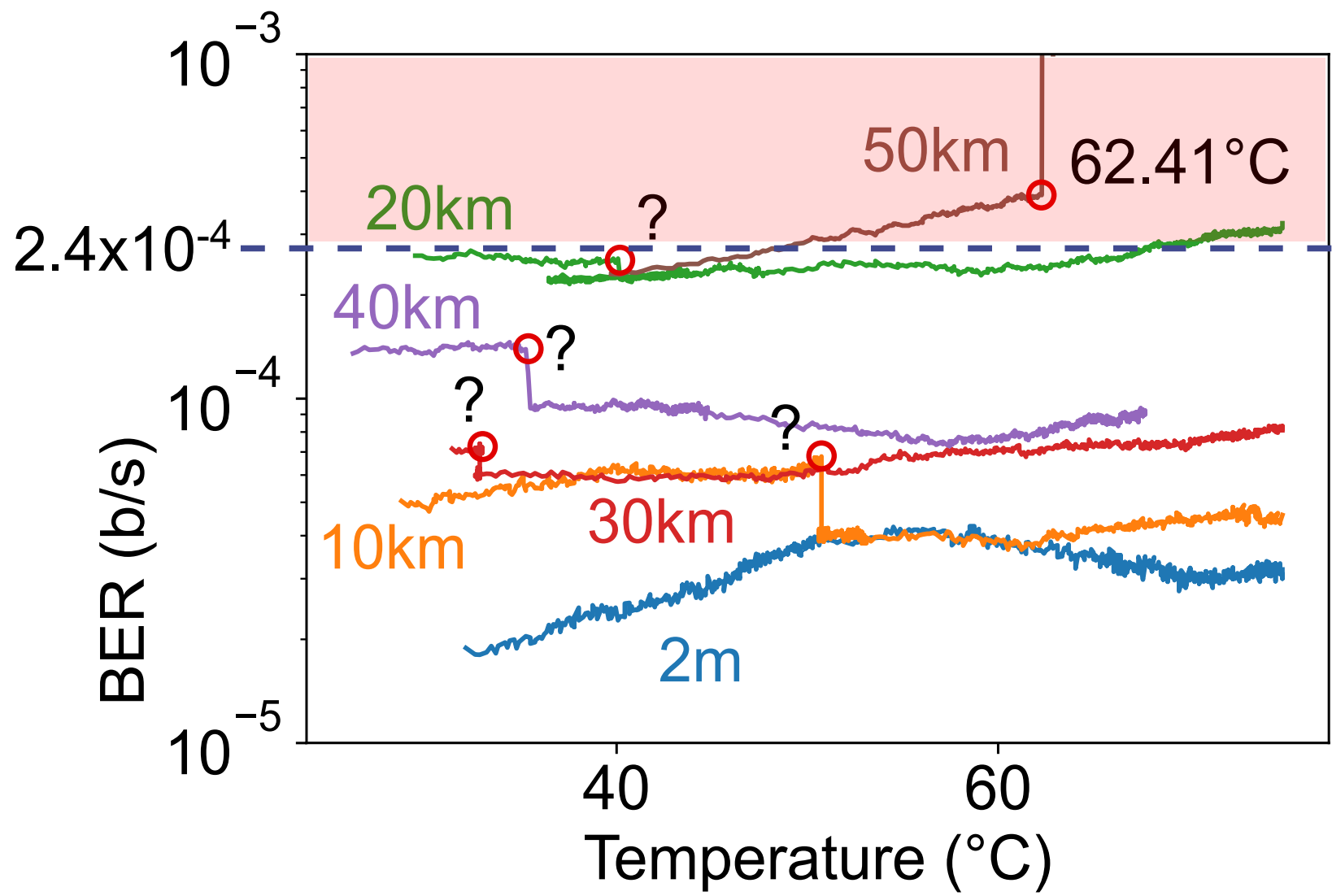
WAVELENGTH TX (TYPICAL)	1310 nm
-------------------------	---------

WAVELENGTH TX (RANGE)	1308.1 - 1310.2 nm
-----------------------	--------------------

WAVELENGTH RX (TYPICAL)	1310 nm
-------------------------	---------

At least **11dB** attenuation is required to ensured safety

100G BER on attenuation



fiber length + attenuator	TX Power (dBm)	RX Power (dBm)
2 m 11 dB	+ 4.8	- 7.1
10 km 11 dB	+ 4.8	- 10.0
20 km 11 dB	+ 4.8	- 13.4
30 km 5 dB	+ 4.8	- 11.9
40 km 2 dB	+ 4.8	- 11.1
50 km 2 dB	+ 4.8	- 14.6

Q.13S1HG.40

IEEE 802.3db BER range : max. 2.4×10^{-4}

Source [11]

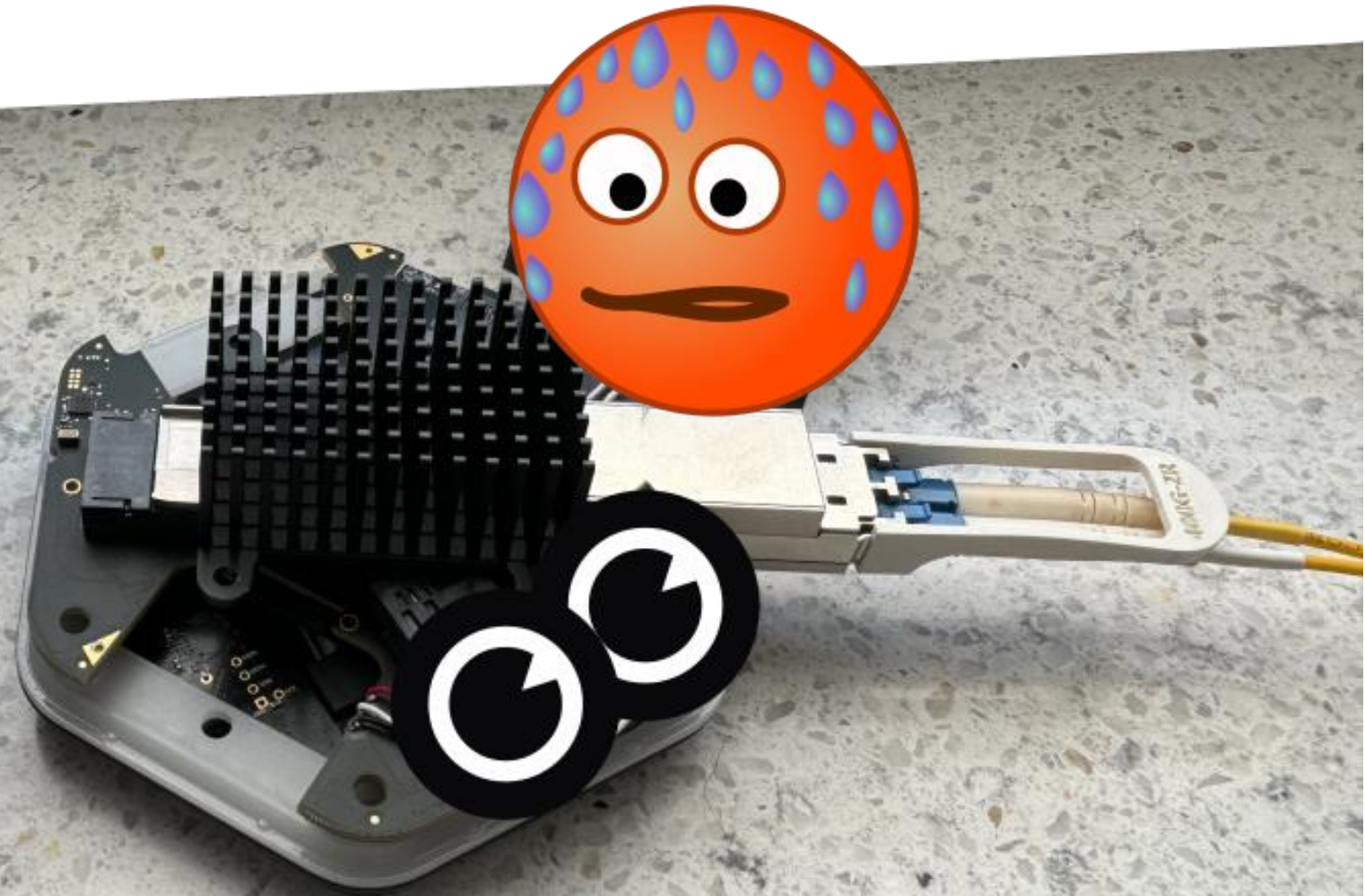
About BER max. 2.4×10^{-4} b/s

- PreFEC value

$$BER = \frac{N_e}{B \Delta T}$$

- Assume $N_e = 100$ errors, $B = 100$ Gbps and $BER = 1.0 \times 10^{-12}$ b/s
 - gating time ΔT is about 16 min
 - But with $BER = 2.4 \times 10^{-4}$ b/s you get $\Delta T = \underline{\underline{4 \mu s}}$!

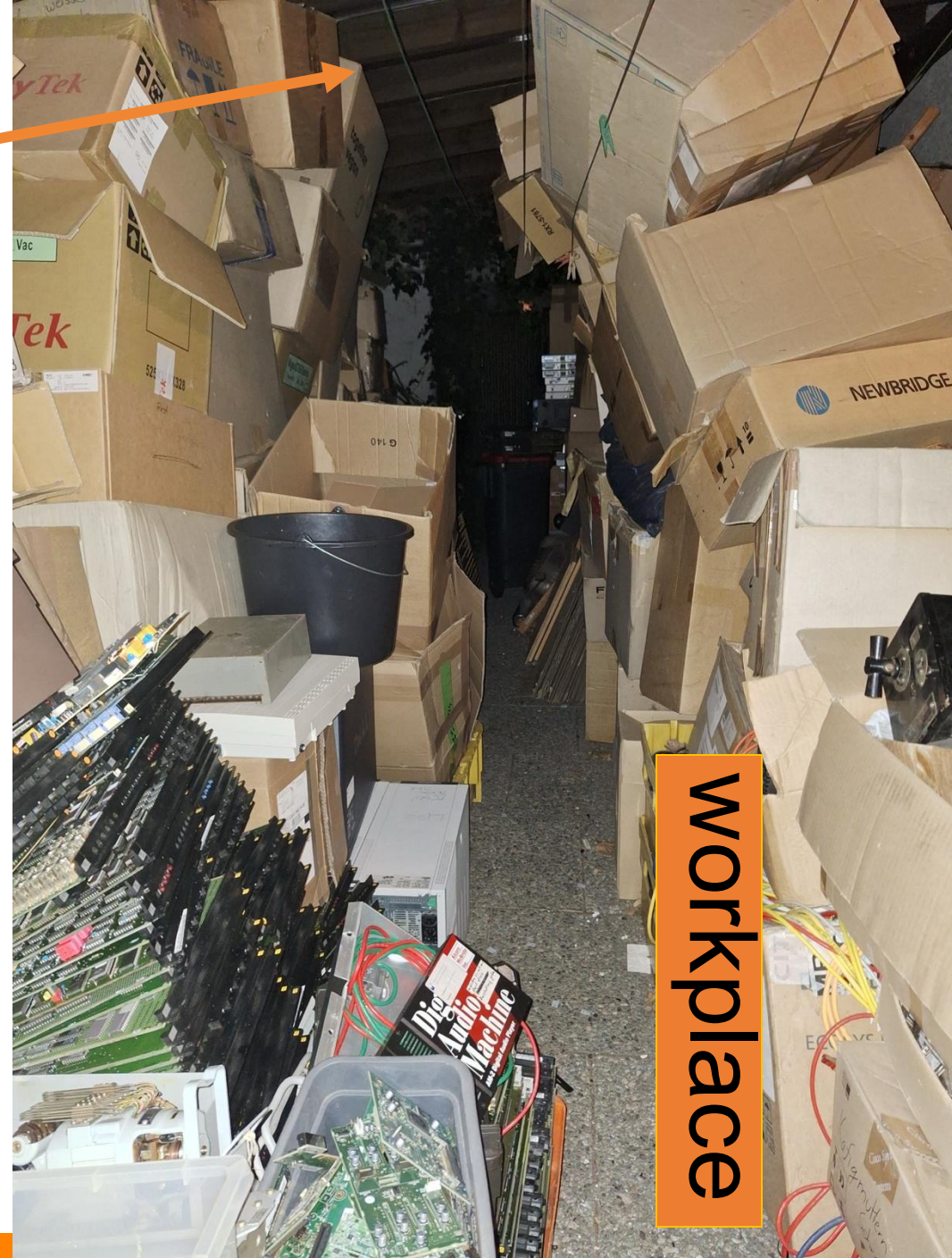
lab setup with cooler (400G DD ZR)



heat sink taken from an old Cisco 800

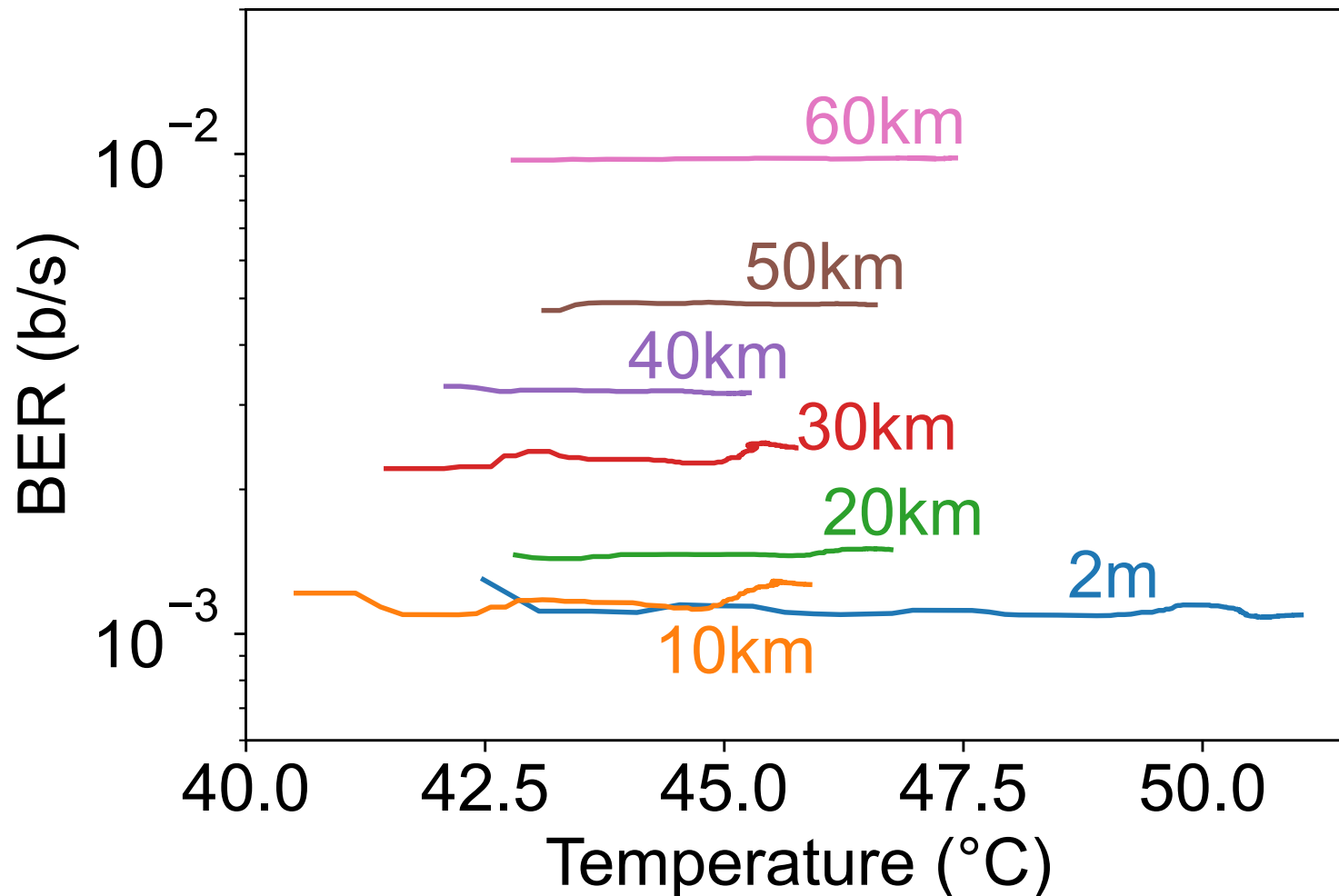
roof top

detailed separation



workplace

The coherent DD with cooling



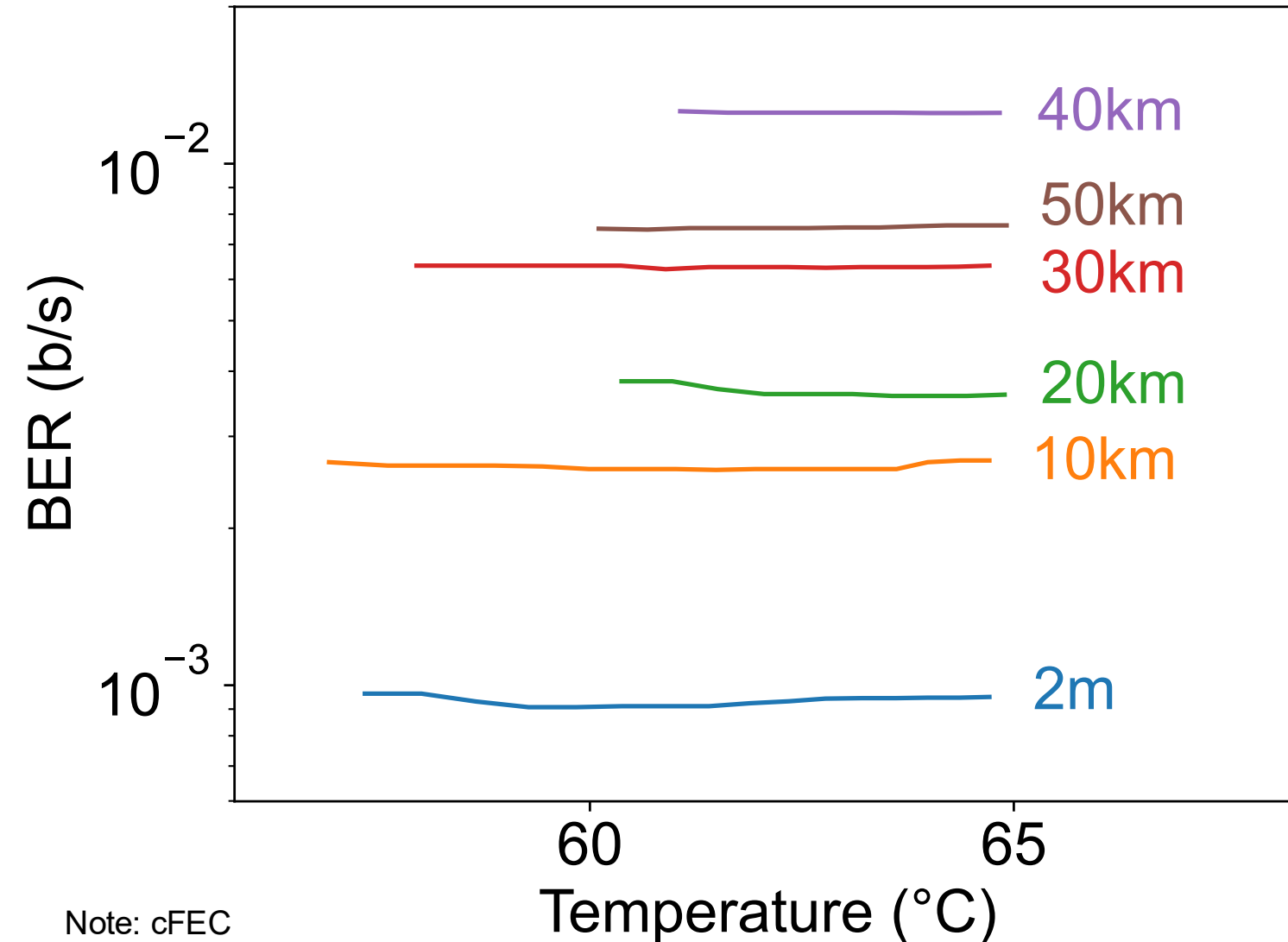
Note: cFEC

Fiber Length	TX Power (dBm)	RX Power (dBm)
2 m	-10.0	-10.2
10 km	-10.0	-11.7
20 km	-10.0	-13.1
30 km	-10.0	-14.9
40 km	-10.0	-16.7
50 km	-10.0	-18.5
60 km	-10.0	-20.9

OIF BER Range:
 1.5×10^{-4} to 1.3×10^{-2}

Source [13]

The coherent DD without cooling



Fiber Length	TX Power (dBm)	RX Power (dBm)
2 m	-10.0	-9.2
10 km	-10.0	-11.6
20 km	-10.0	-13.3
30 km	-10.0	-15.0
40 km	-10.0	-16.7
50 km	-10.0	-18.6

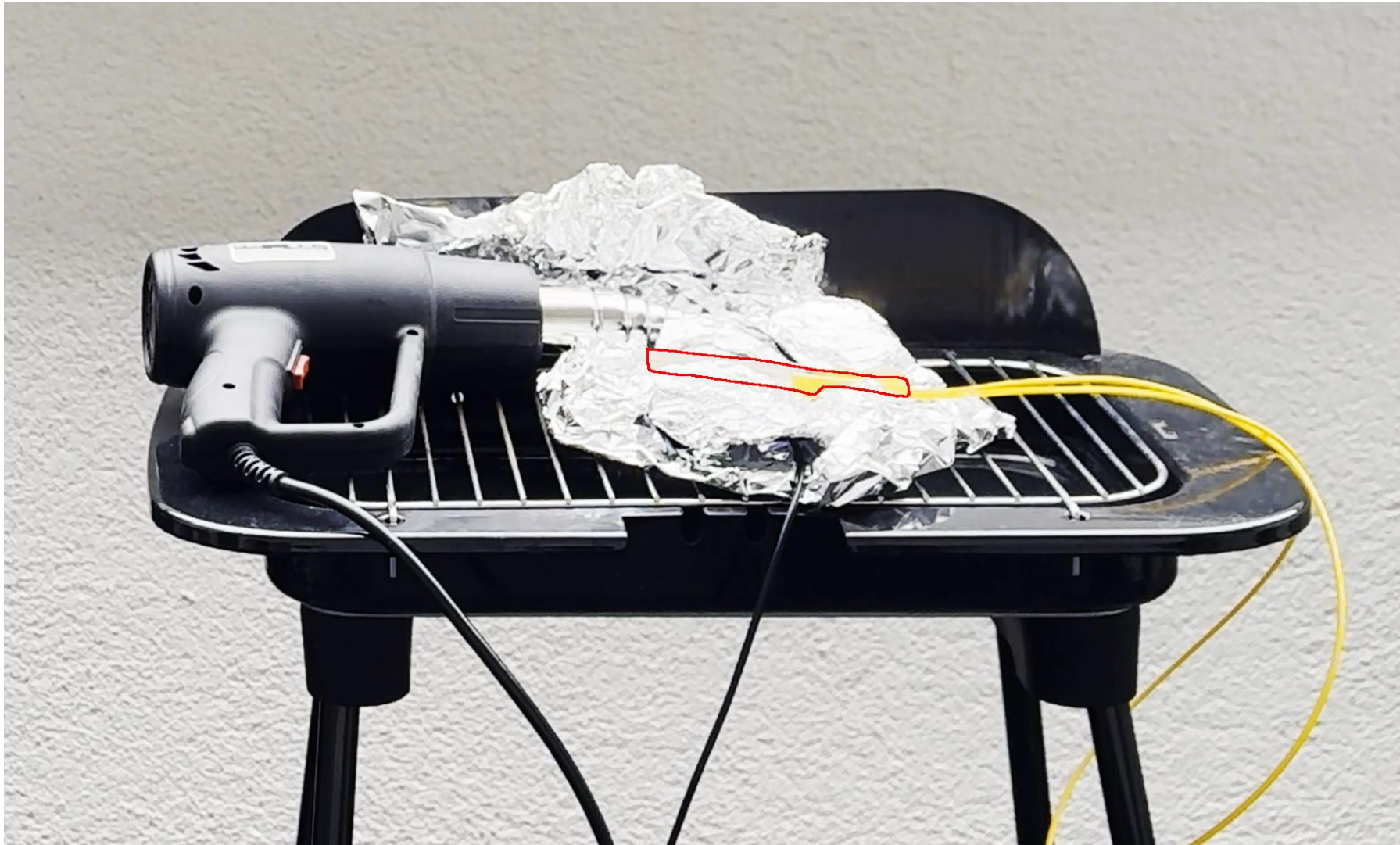
BER Range:
 1.0×10^{-4} to 1.0×10^{-2}

What if we go over the specs, up to $\sim 120^{\circ}\text{C}$?



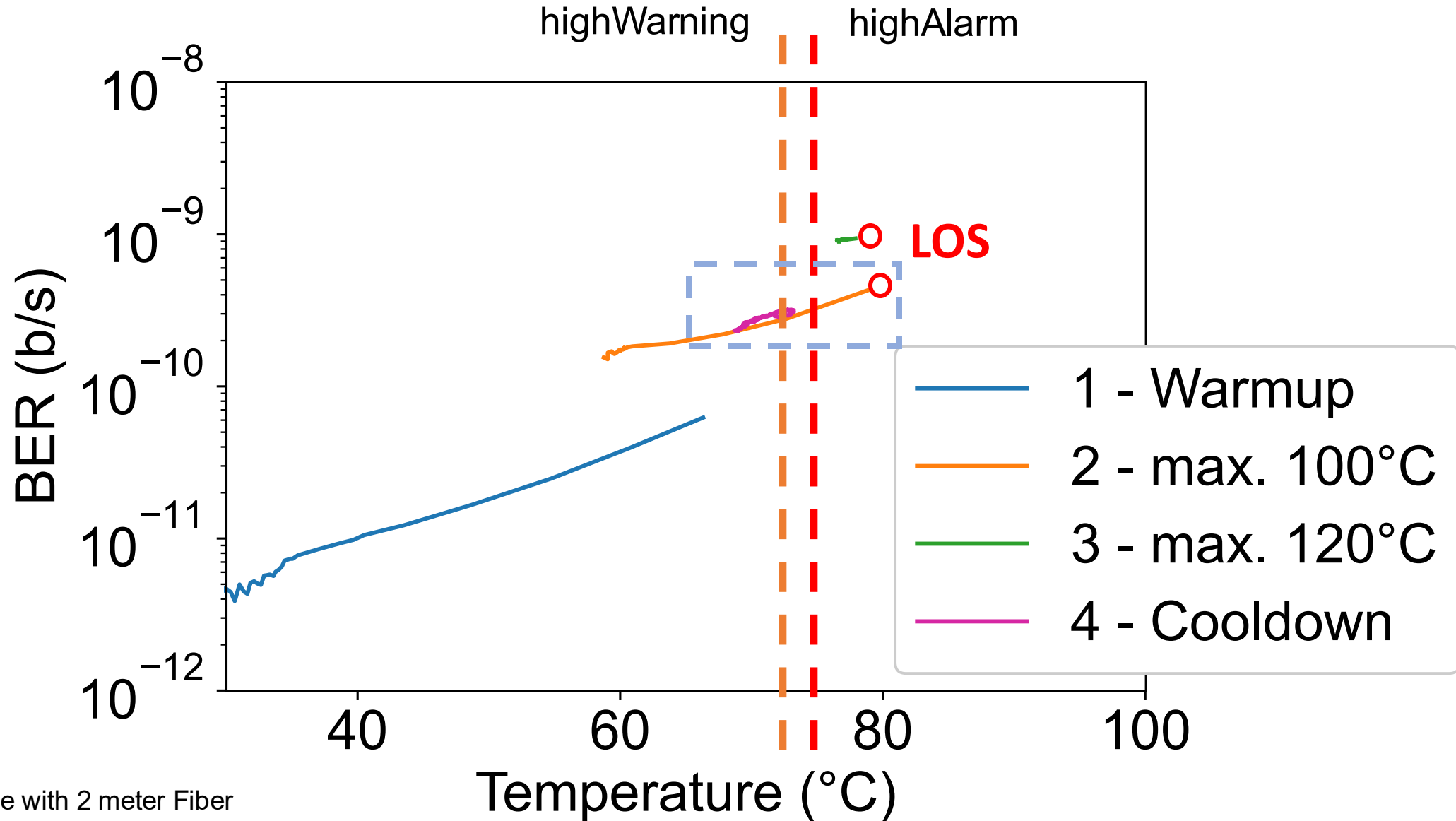
Note: example with 2 meter Fiber

What if we go over the specs, up to $\sim 120^{\circ}\text{C}$?



Note: example with 2 meter Fiber. Q.13S1HG.05

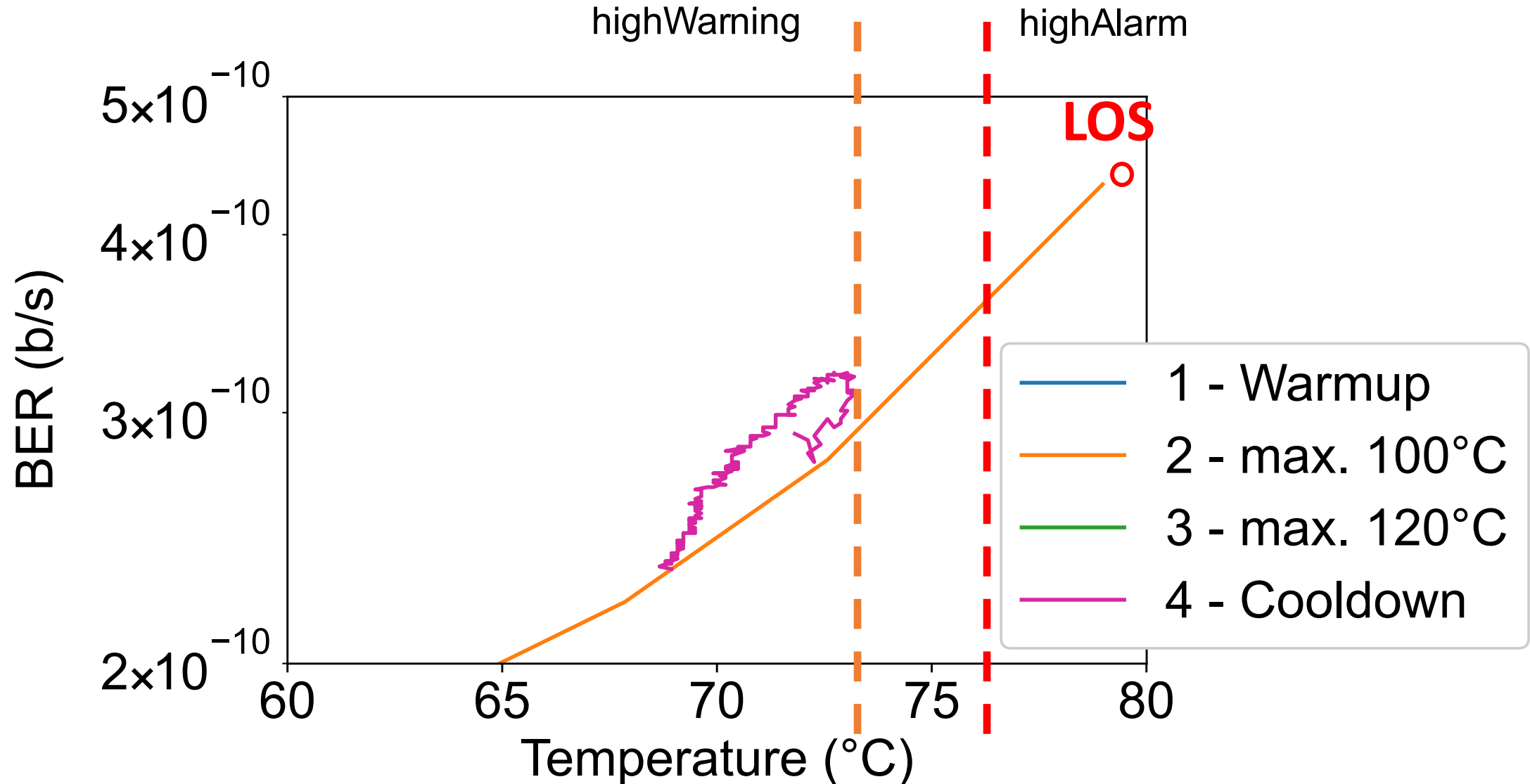
What if we go over the specs, up to $\sim 120^{\circ}\text{C}$?



Note: example with 2 meter Fiber

source: [15]

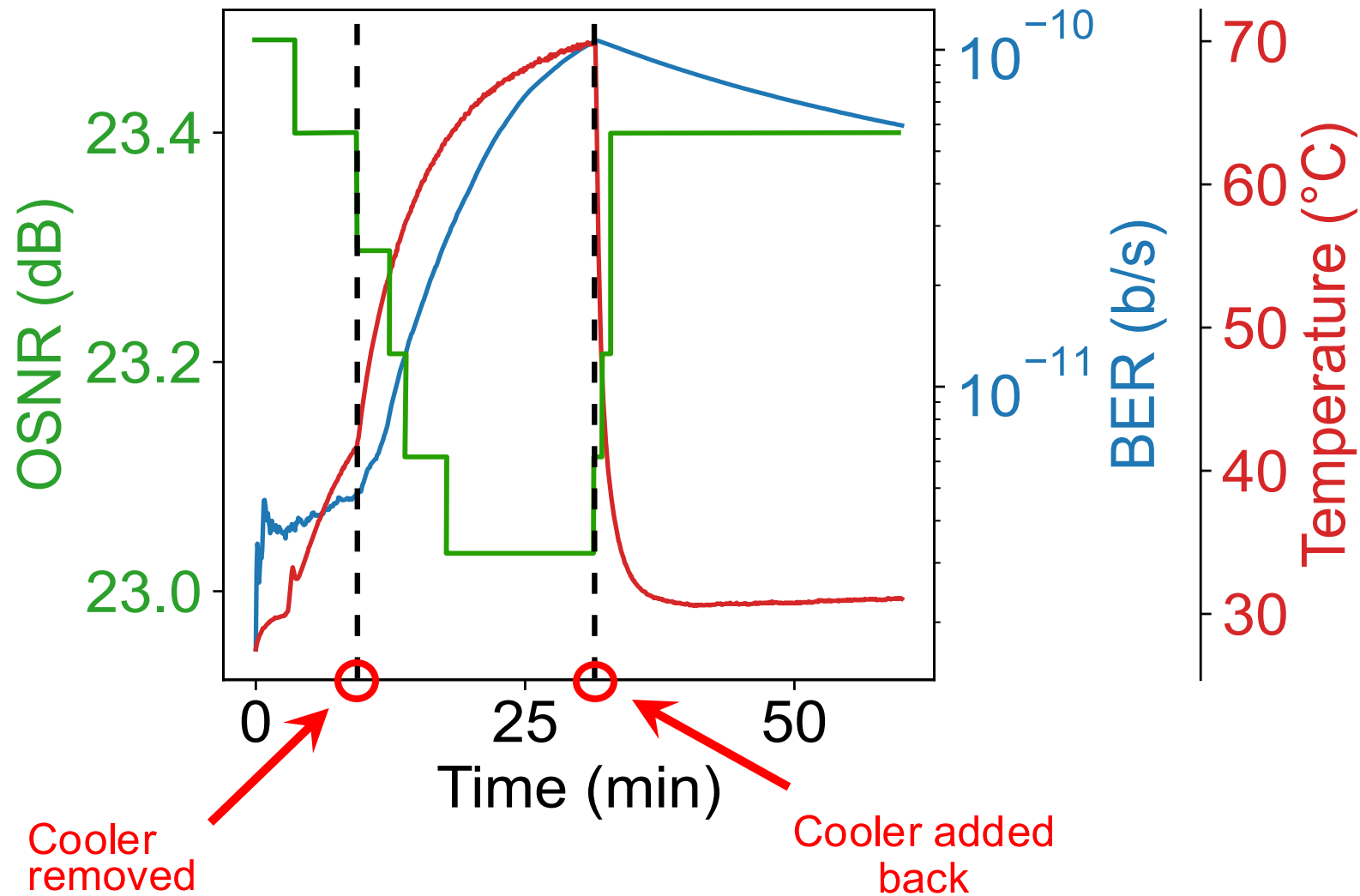
What if we go over the specs, up to ~120°C ?



Note: example with 2 meter Fiber

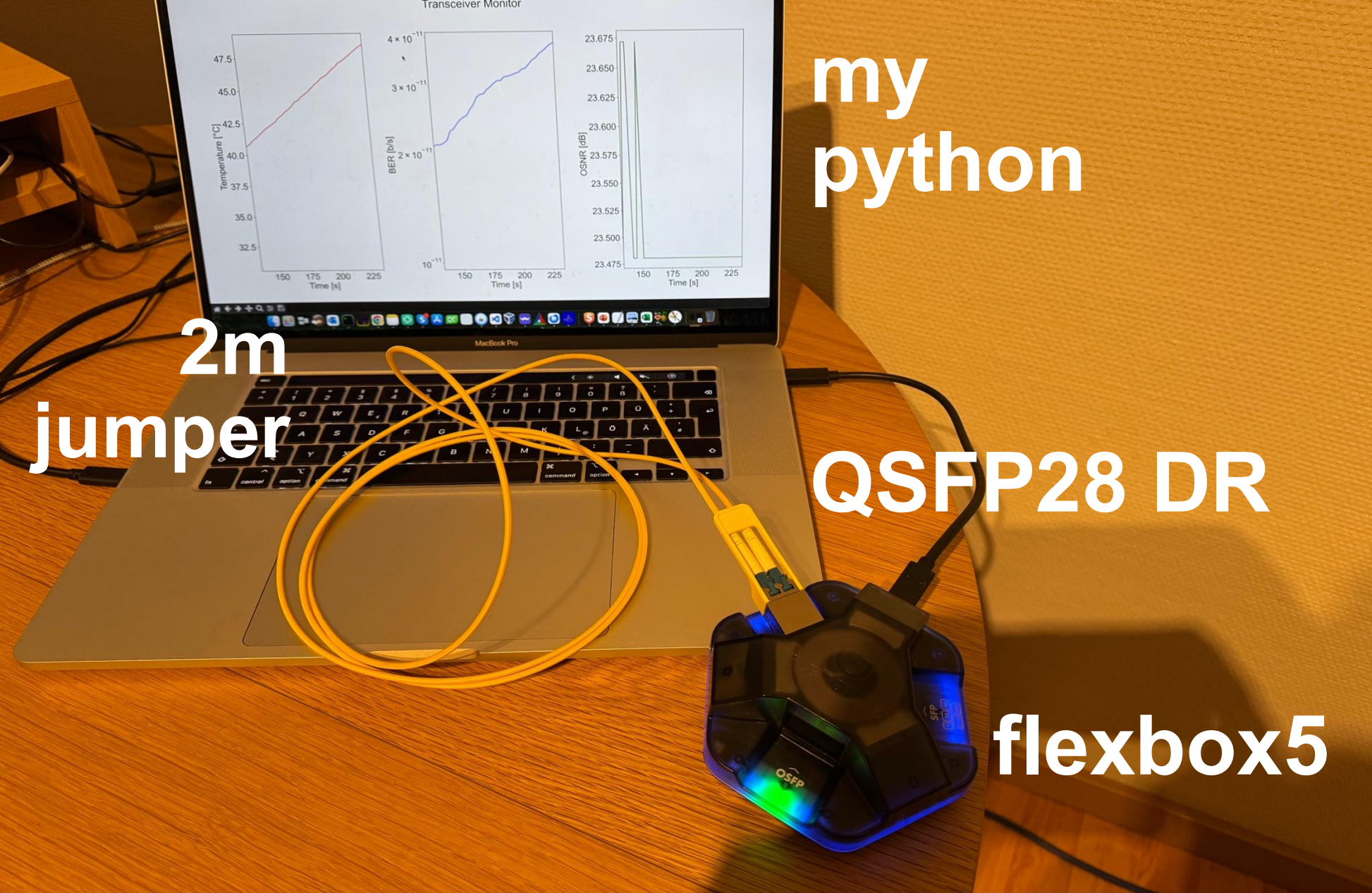
source: [15]

Initial BER recoverable?



after recovering
10 times worse!

Example with Q.13S1HG.05 and PostFEC values.



my
python

live
demo

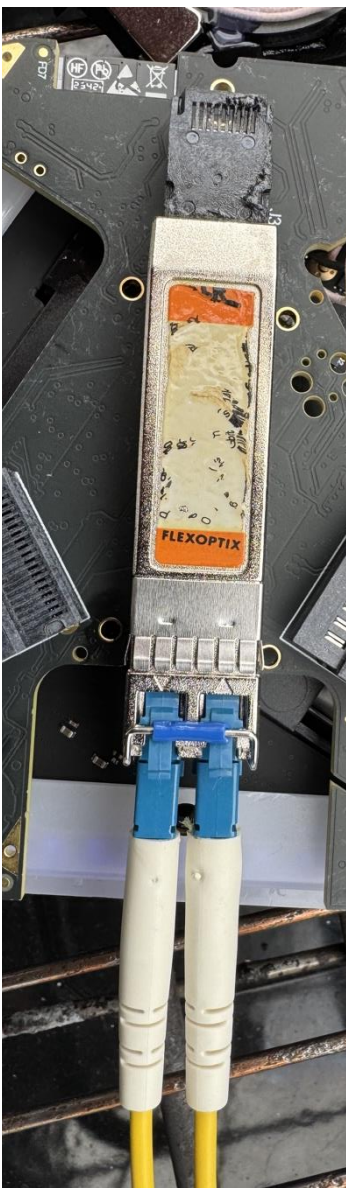
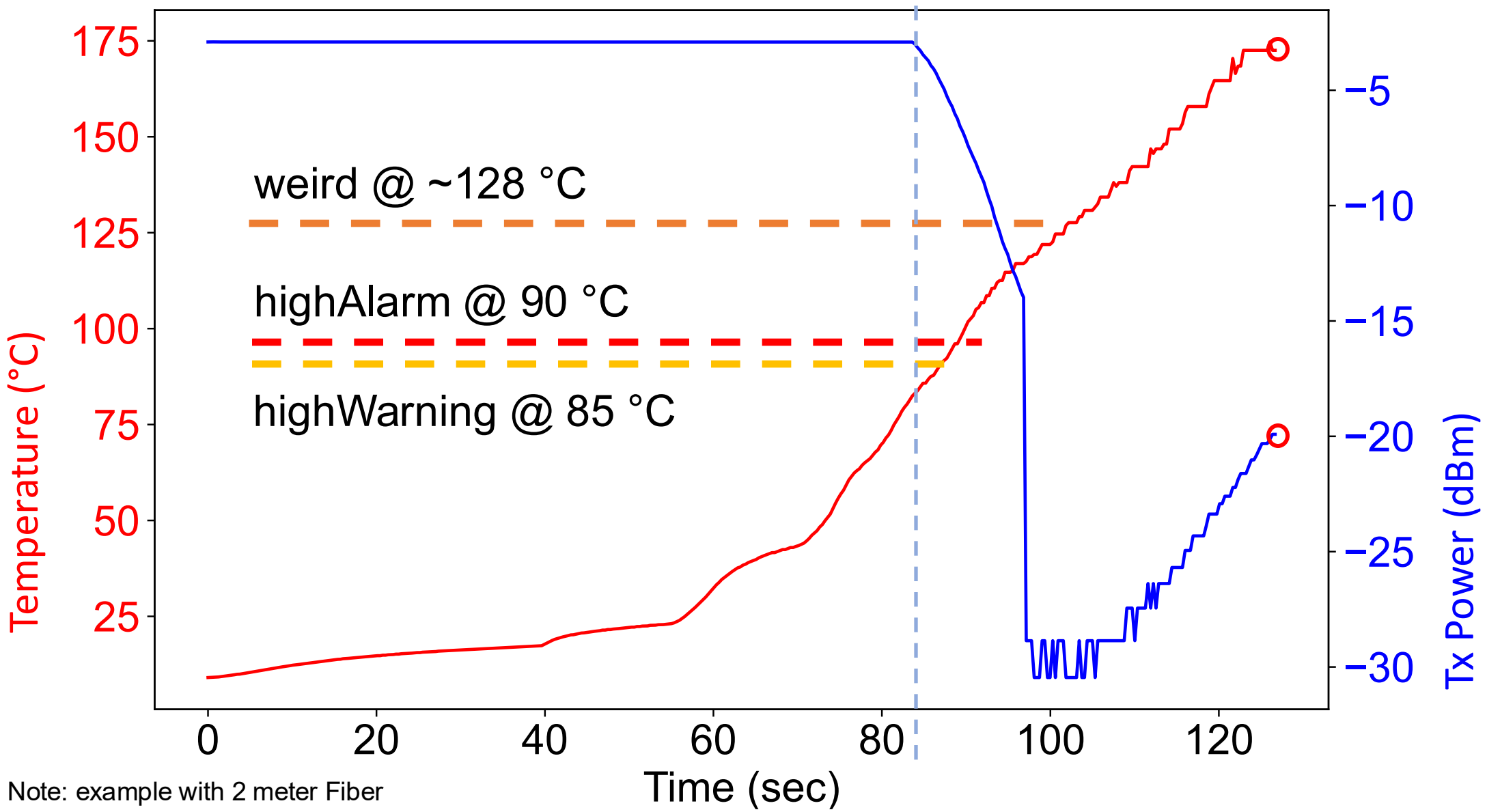
2m
jumper

QSFP28 DR

flexbox5

Video Link: <https://cloud.flexoptix.net/index.php/s/X2zKs7WtSfPagay>

Behavior of SFP+ up to ~250°C



- BER on Direct Detection Transceiver (DDT, grey transceivers) depends on both temperature and fiber length
- BER is rolling average value, not an instant snapshot
- There isn't so much margin above high Alarm Temperature and LOS
- Coherent Transceivers benefit more from the properties of light, but also require a DSP with more features for proper signal recovery
- Coherent Transceivers BER do not bother with temperatures changes, mainly on fiber length
- The specified BER values are defined in IEEE802.3df for such devices in general. for DDT: when your BER is fine OSNR won't be your enemy.

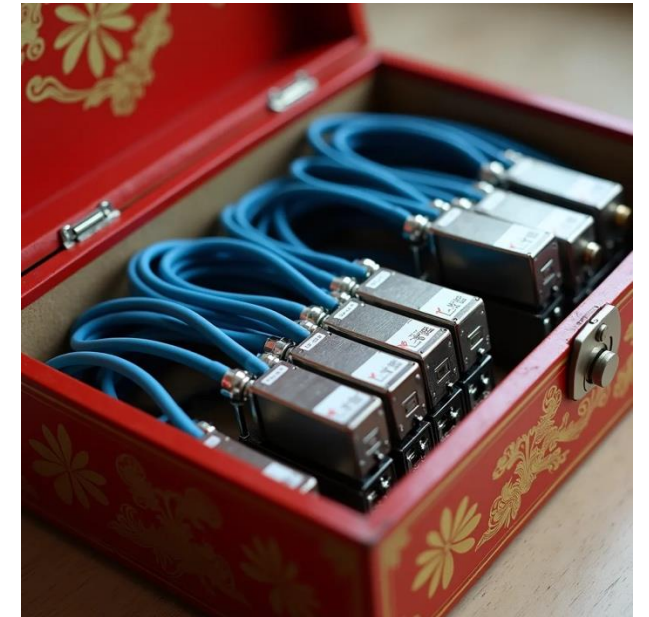
take aways



FLUX AI: "Chinese take away box from a restaurant filled with noodles" !!!

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take aways



FLUX AI: "Chinese restaurant take away box filled with transceivers" !!!

Thank you



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References

1. SFF-8024, SFF Module Management Reference Code Tables, Rev. 4.10, November 24th of 2022
2. Rotary optical encoder model, <https://commons.wikimedia.org/wiki/File:Encoder.jpg> by Rrudzik (accessed Mar. 2024)
3. Everything You Need to Know About Complex Optical Modulation, Keysight (accessed Nov. 2024)
4. Fibre Sensing with and for Optical Networks, Ezra Ip et al., ECOC 2024 (Sept. 2024)
5. First Field Demonstration of Hollow-Core Fibre Supporting
6. Distributed Acoustic Sensing and DWDM Transmission, Ezra Ip et al., ECOC 2024 (Sept 2024)
7. Acoustic Sensing with Correlation and Coherent Detection using an Integrated Coherent Transceiver, André Sandmann et al., ADTRAN-ADVA (May 2023)
8. Fiber Optic Communications, Gerd Keiser, ISBN 978-981-33-4667-3 (Newton Center, MA 2021)
9. Understanding EVM, Paul Denisowki, Rhode&Schwarz, https://cdn.rohde-schwarz.com.cn/pws/dl_downloads/premiumdownloads/premium_dl_pdm_downloads/3683_8038_52/Understanding-EVM_wp_en_3683-8038-52_v0100.pdf, Version 01.00 (accessed Nov 2024)
10. Understanding FEC and Its Implementation in Cisco Optics, <https://www.cisco.com/c/en/us/products/collateral/interfaces-modules/transceiver-modules/implementation-optics-wp.html>, (May 13, 2022)
11. IEEE Standard for Ethernet, Amendment 3: Physical Layer Specifications and Management Parameters for 100 Gb/s, 200 Gb/s, and 400 Gb/s Operation over Optical Fiber Using 100 Gb/s Signaling, (802.3db-2022)
12. IEEE Standard for Ethernet, Amendment 9: Media Access Control Parameters for 800 Gb/s and Physical Layers and Management Parameters for 400 Gb/s and 800 Gb/s Operation, (802.3df-2024)
13. OIF-400ZR-02.0, Implementation Agreement 400ZR, www.oiforum.com (November 3, 2022)
14. Smiley from the sMirC-series. Hot, <https://commons.wikimedia.org/wiki/File:SMirC-hot.svg>
15. Common Management Interface Specification 5, (CMIS) (November 2021)
16. Electrical Interface Optic Type Data rate FEC Standard Clause, Cisco (November 2024)