FLEXOPTIX

Understanding and Optimizing Transceiver Efficiency



using internal Metrics for improved power savings

Dr. Gerhard Stein and Thomas Weible

Table of Contents

- Versatile Diagnostics Monitoring
- Laser: Laser Power discussion of Transceivers (trc)
- TEC: Thermoelectric Cooler
- Power Budget: How FLEXBOX deals with transceiver power
- Efficiency: Definition
- Results

Devices under Test (DUT)

Transmitter/Receptor -> Transceiver -> Trc:

- 100G QSFP28 (500 m)
- 400G QDD Coherent ZR (120 km)
- 800G QDD (2 km)
- 800G QDD (500 m)

Switches:

- Cisco 93600CD-GX NX OS 10.5.3 (F)
- Cisco C9500 IOS XE 17.14.1
- Juniper QFX5120 JunOS 25.R2R1.9

Versatile Diagnostic Monitoring

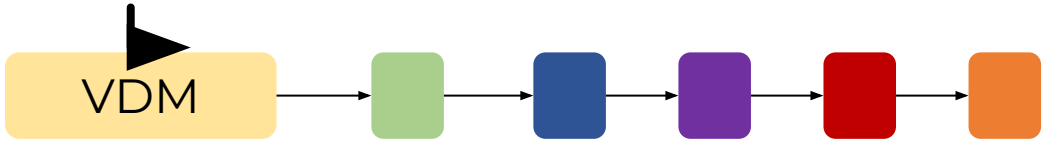
Type ID	Observable Type
0	Not Used indicator[1]
1	Laser Age (0% at BOL, 100% EOL) (Media Lane)
2	TEC Current (Module)
3	Laser Frequency Error (Media Lane)



Compared to: Digital Diagnostic Monitoring (DDM):

Byte	Bit	Name
22	All	Temperature MSB
23	All	Temperature LSB
24-25	All	Reserved

Sources: [2, 15]

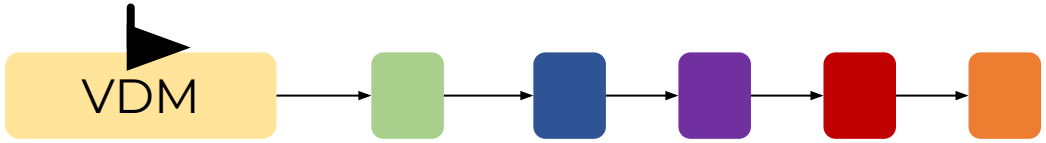


Reading DDM:

Read data from bytes

Byte	Bit	Name
22	All	Temperature MSB
23	All	Temperature LSB

Calculate Value



Reading VDM desc. and value

For every desc. from

Page	Subject Area
20h	Descriptors for VDM Instances 1-64 (Group 1)
21h	Descriptors for VDM Instances 65-128 (Group 2)

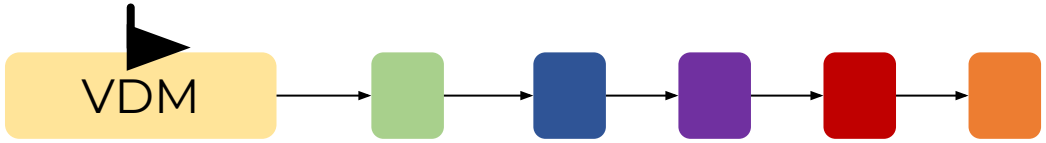
Which one is it?

Type ID	Observable Type
0	Not Used indicator[1]
1	Laser Age (0% at BOL, 100% EOL) (Media Lane)
2	TEC Current (Module)
3	Laser Frequency Error (Media Lane)
4	Laser Temperature (Media Lane)
5	SNR (dB) Media Input (Media Lane) –- see section 7.1.4

Where is the value?

Page	Byte	Register Name
24h	128-129	VDMSample1
	130-131	VDMSample2

Calculate Value



VDM – Support?

DDM only (current values):

```
{master:0}
root@QFX5120-48Y> show interfaces  diagnostics optics et-0/0/49
Physical interface: et-0/0/49
    Module temperature                          :  37 degrees C / 98 degrees F
    Module voltage                              :  3.2700 V
    Module temperature high alarm               :  Off
```

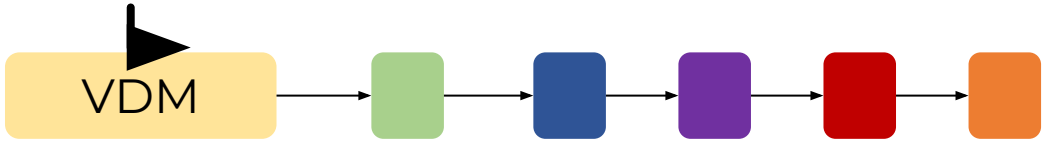
Juniper
QFX5120
JunOS
25.2R1.9
No support ☹

DDM only (thresholds):

```
                                MODULE THRESHOLDS
                      high alarm      high warning    low warning     low alarm
Temperature     C        +076.000         +073.000        -03.000       -06.000
Voltage         V        003.6000         003.5500        003.0500      002.9500

                                LANES THRESHOLDS
                      high alarm      high warning    low warning     low alarm
Bias Current    mA       130.0000         125.0000        015.0000      010.0000
Transmit power  mW       003.1623         002.5119        000.5129      000.4074
Receive power   mW       004.4668         003.5481        000.1819      000.1288
```

Cisco C9500
IOS XE 17.14.1
No support ☹



VDM – Support?

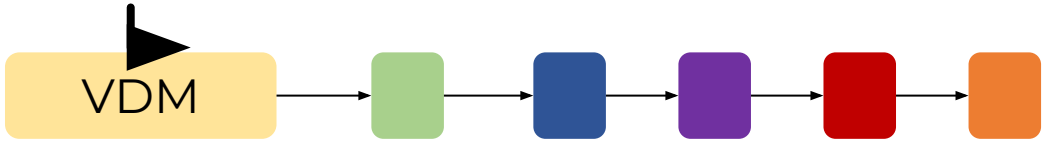
Cisco Nexus 93600CD-GX NX OS 10.5.3 (F) 400G Coherent ZR has support …

	Current Measurement	Alarms High	Low
Temperature	48.89 C	78.00 C	-8.00 C
Voltage	3.30 V	3.63 V	2.97 V
Current	N/A	N/A	N/A
Tx Power	N/A	N/A	N/A
Rx Power	N/A	N/A	N/A
Laser temperature	49.98 °C		
Rx Signal Power	N/A	N/A	N/A
Pre-FEC BER	1.00e+00	N/A	N/A
Post-FEC BER	1.00e+00	N/A	N/A

CMIS VDM

Type ID	Observable Type
0	Not Used indicator[1]
1	Laser Age (0% at BOL, 100% EOL) (Media Lane)
2	TEC Current (Module)
3	Laser Frequency Error (Media Lane)
4	Laser Temperature (Media Lane)

… but …



VDM – Support?

Cisco Nexus 93600CD-GX NX OS 10.5.3 (F) 400G Coherent ZR has support …

… but … Laser temperature 49.98 °C … and CMIS defines that:

7.1.6.3 Laser Temperature

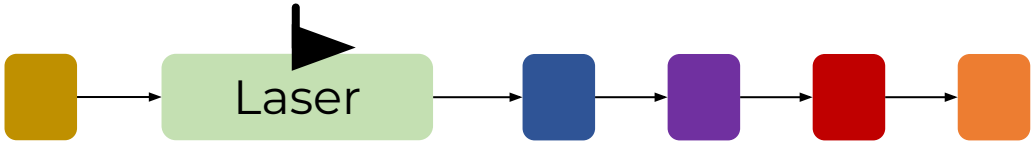
If supported, this monitor observes the laser temperature difference between the target laser temperature for a cooled laser, and the actual current temperature.

Which means: 50.0 °C – 0.02 °C = 49.98 °C

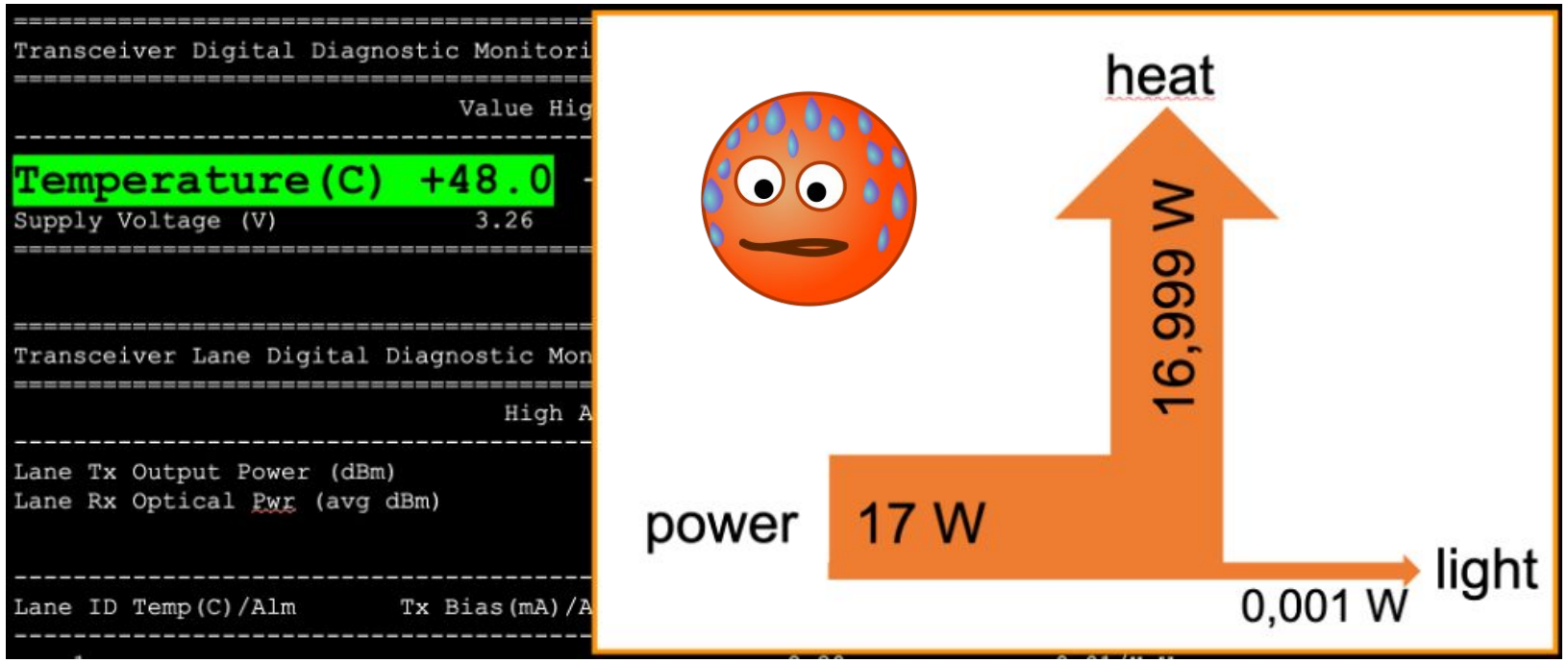
How does that switch conclude with an absolute value then?

Because 50 °C, being typical target temperature, is a switch assumption.

Sources: [10]



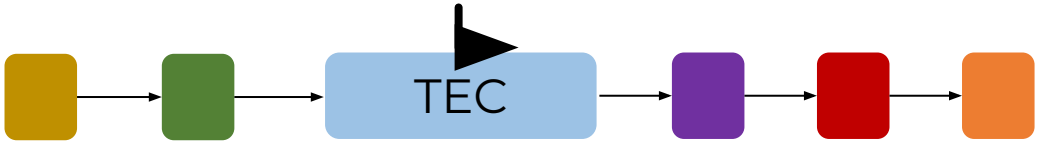
Excursion: Coherent Trc (2023/2024)



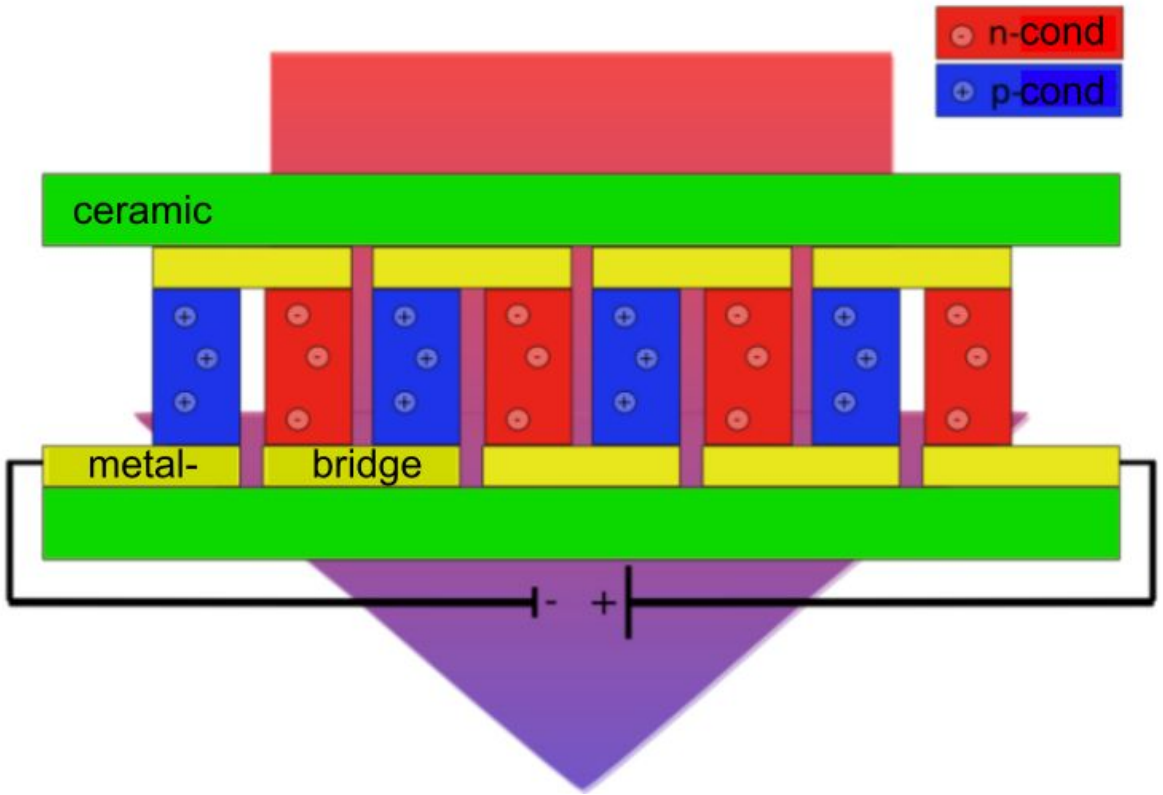
- $Pow_{Laser} = V_{fwd} \times I_{Laser}$ (DDM)
- $Pow_{TEC} = V_{Trc} \times I_{TEC}$ (VDM)

Note: Laser voltage not reported by any specification or agreement.

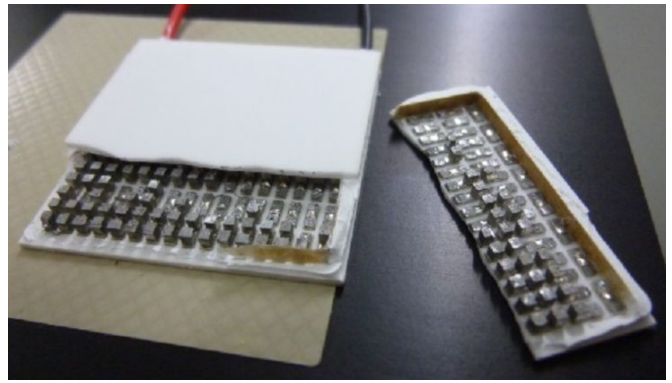
Manufacturers provide that information if asked.

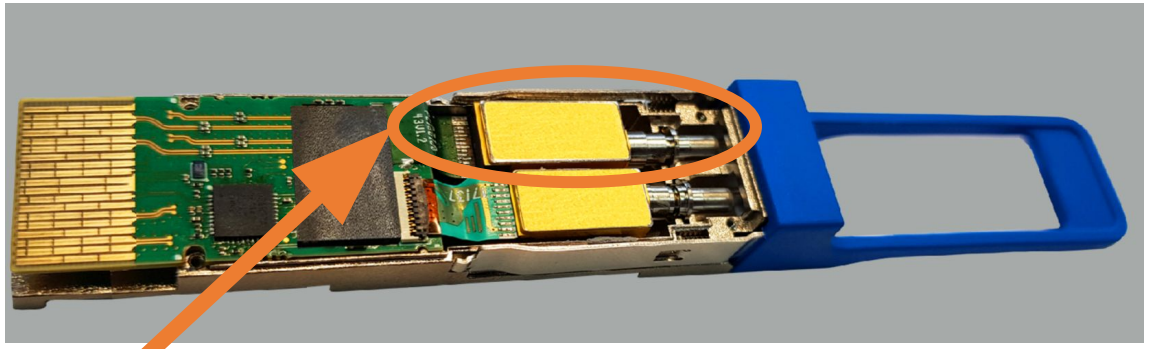


Thermo Electric Cooler (TEC)



Typical Peltier element at large scale …





…but TEC very small (inside the TOSA)

Sources: [6]

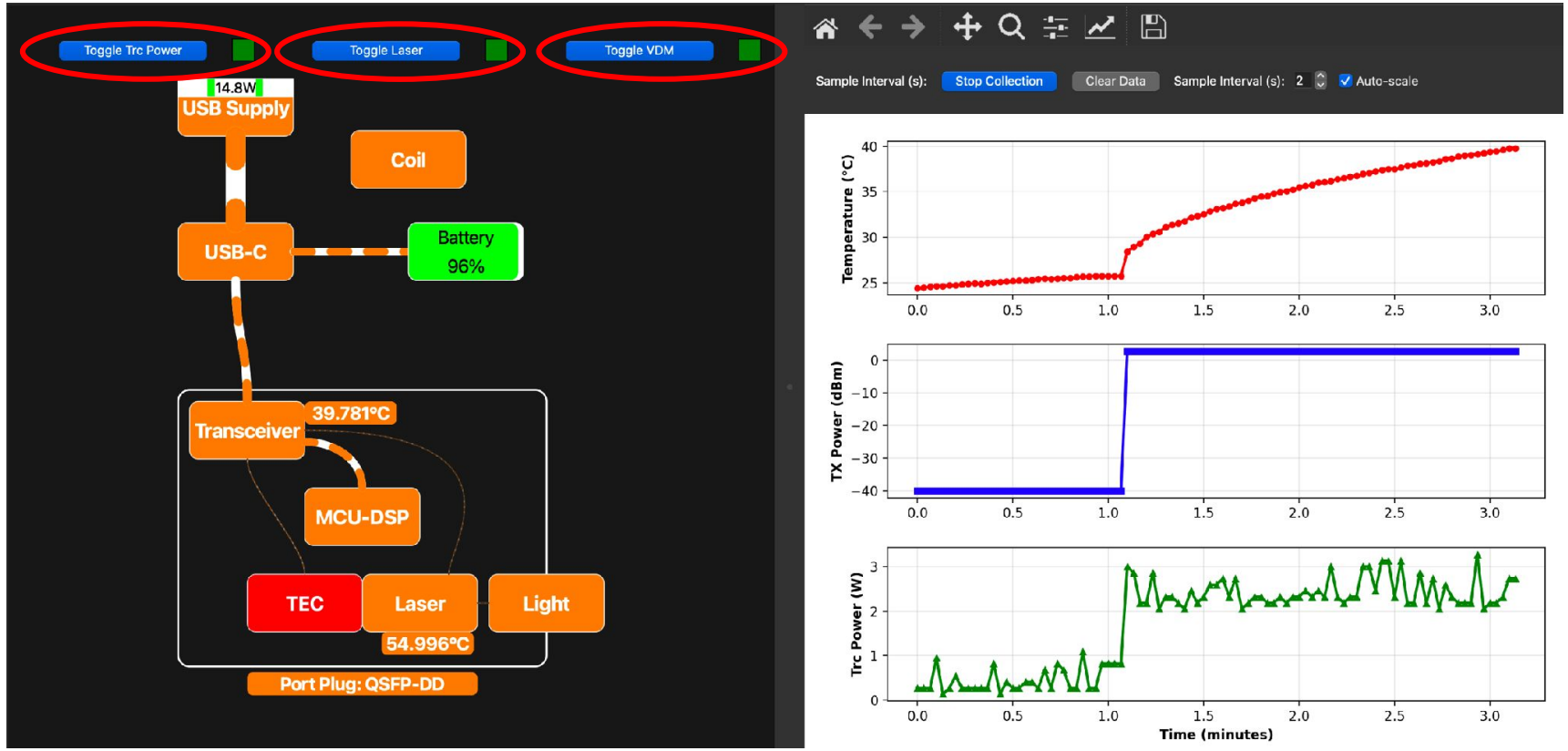
With Flexbox and Research Tool



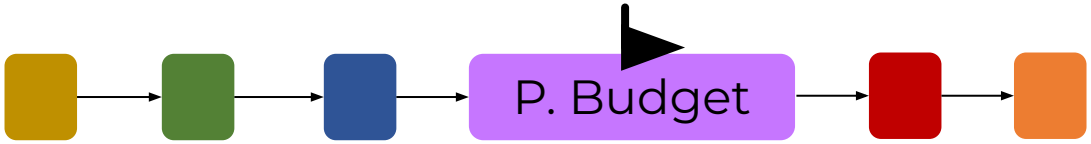


*Python, PyQt and Matplotlib in one application

Go Go Laser (and VDM) !!



High power difference between Laser on and off,
but is it really because of the Laser?

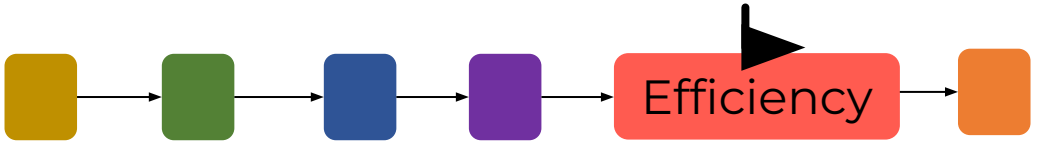


Power improvement evolution

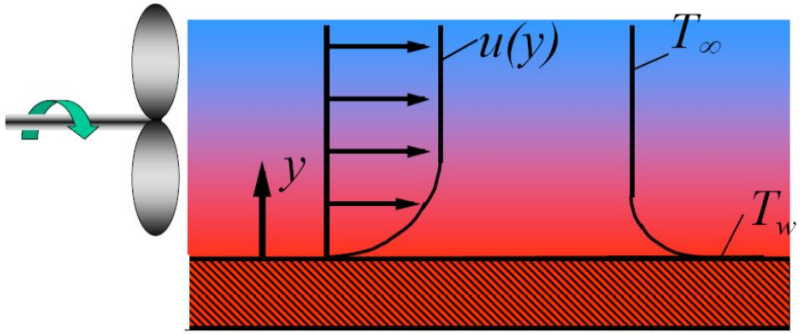


Power (Watts)	2018	2020	2023	2025	2026	Changes
400G QDD FR4 2km	12	10.5		9		Went from 16 to 7nm
800G OSFP LR4			16.5	15.5		Changed EML to SiPho
1.6T OSFP224				30	26	5 reduced to 3nm

Source: [17,18]



Efficiency: Fan Speed and Heat Exchange

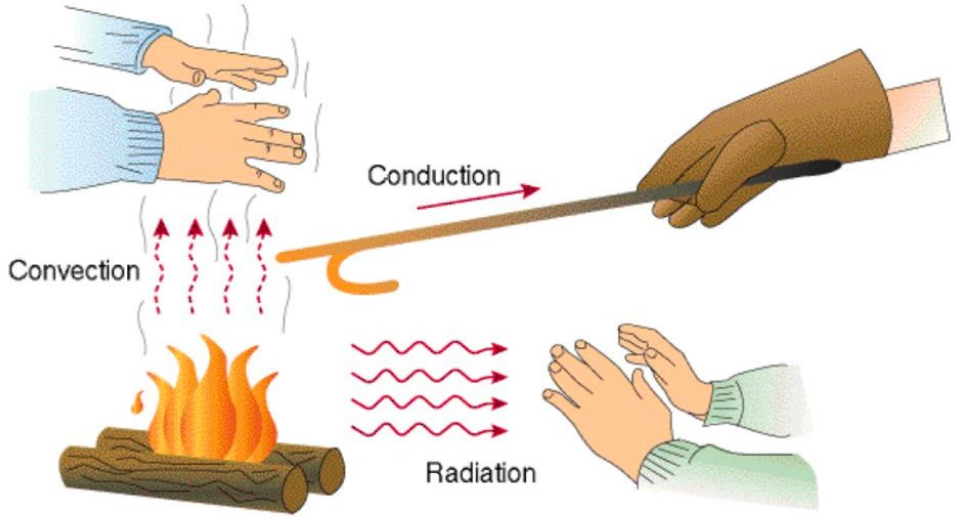


$$P_{Fan} = \frac{\lambda \times Nu}{L} A(T_\infty - T_W)$$

$$Nu = 0.664 \sqrt{Re} \sqrt[3]{Pr}$$

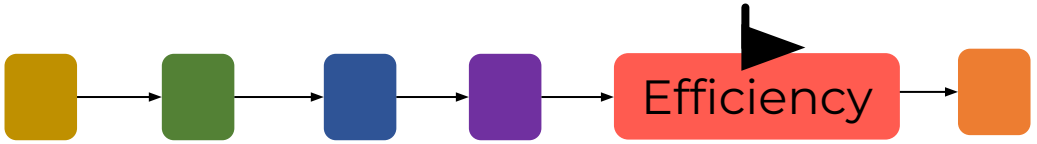
$$Re = \frac{w_\infty L}{\upsilon}$$

- Nusselt (Nu)
- Prandtl (Pr)
- Reynolds (Re)

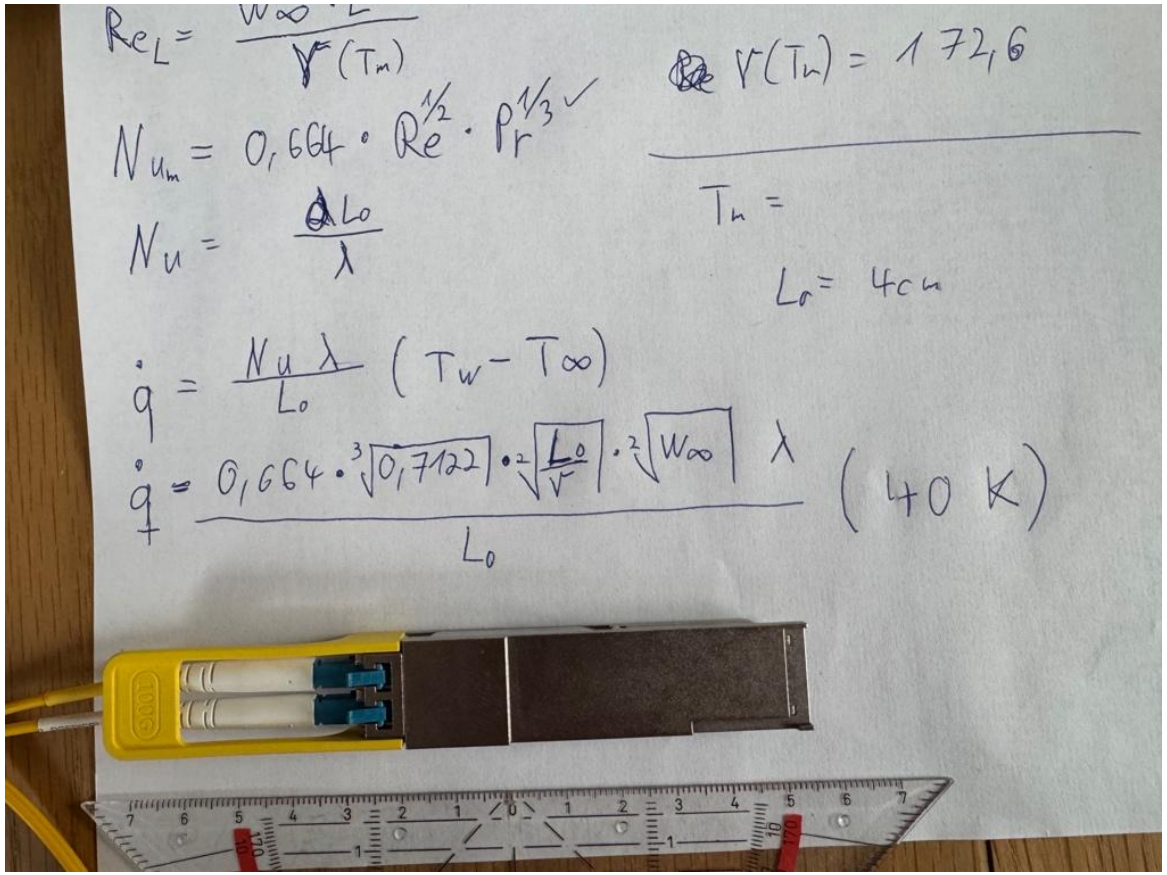


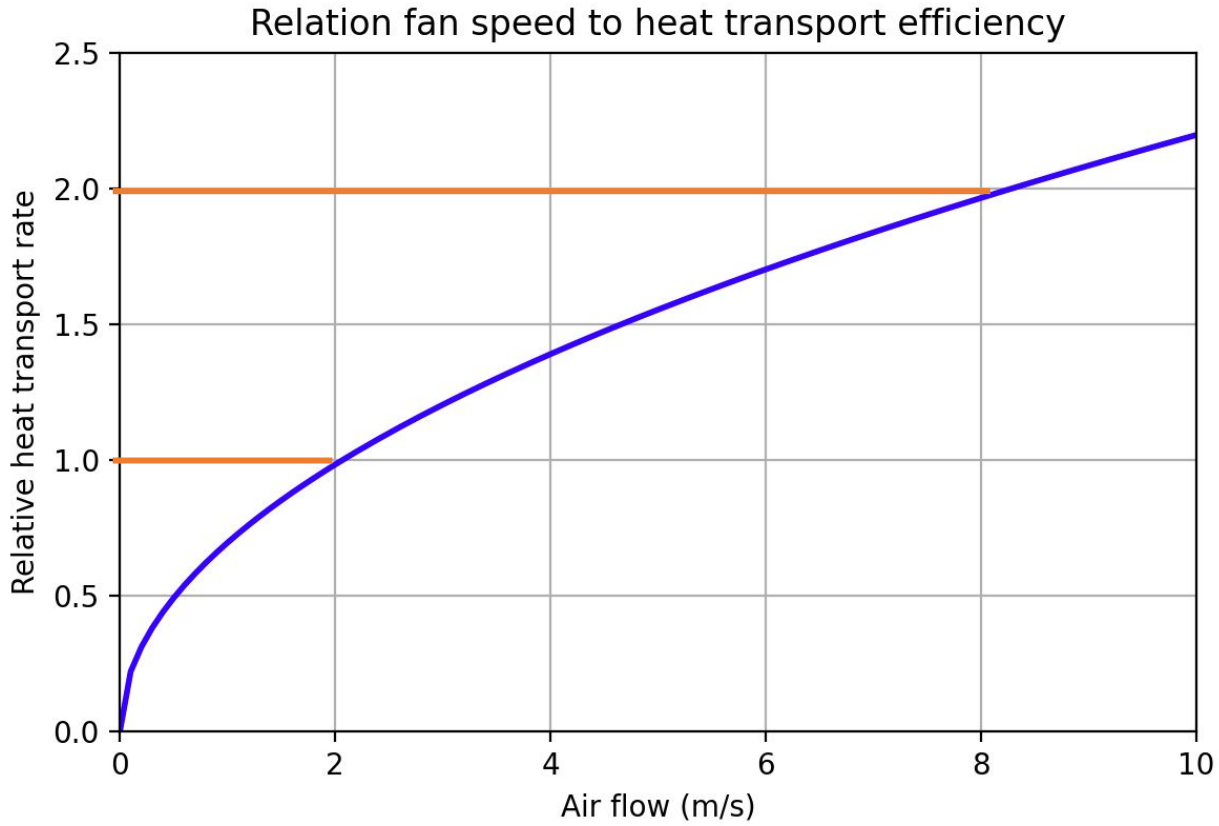


Sources: [13]



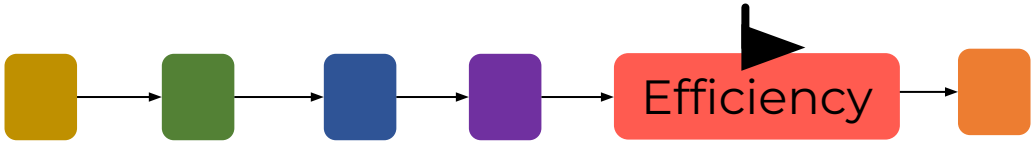
Let’s do the math … and show what matters!





Doubling the speed does not double the Watts!

Sources: [13]



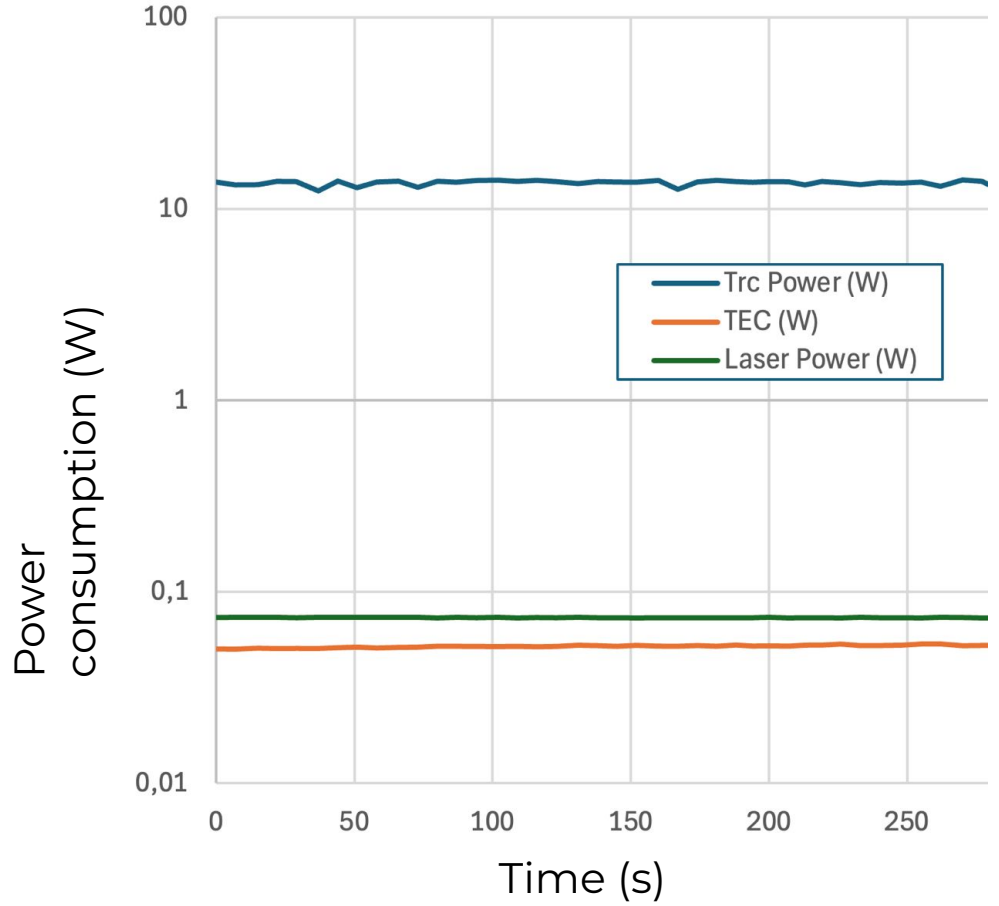
Influence: TEC to Laser Temperatures

Power readings of D.CO164HG.2.yT
400G Coherent with Q1 fan setting

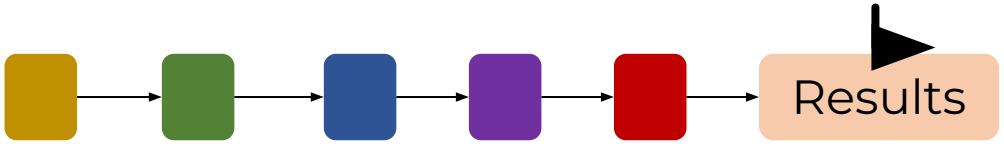
Art No.	Q0 (No Fan)	Q1 (low)	Q2 (mid)	Q3(high)
D.CO164HG.2.yT	75.2	56.49	49.57	47.67



QX	Speed	RPM (approx.)
Q0	0 m/s (obviously)	0
Q1	2.2 m/s	467
Q2	3.0 m/s	637
Q4	3.8 m/s	806



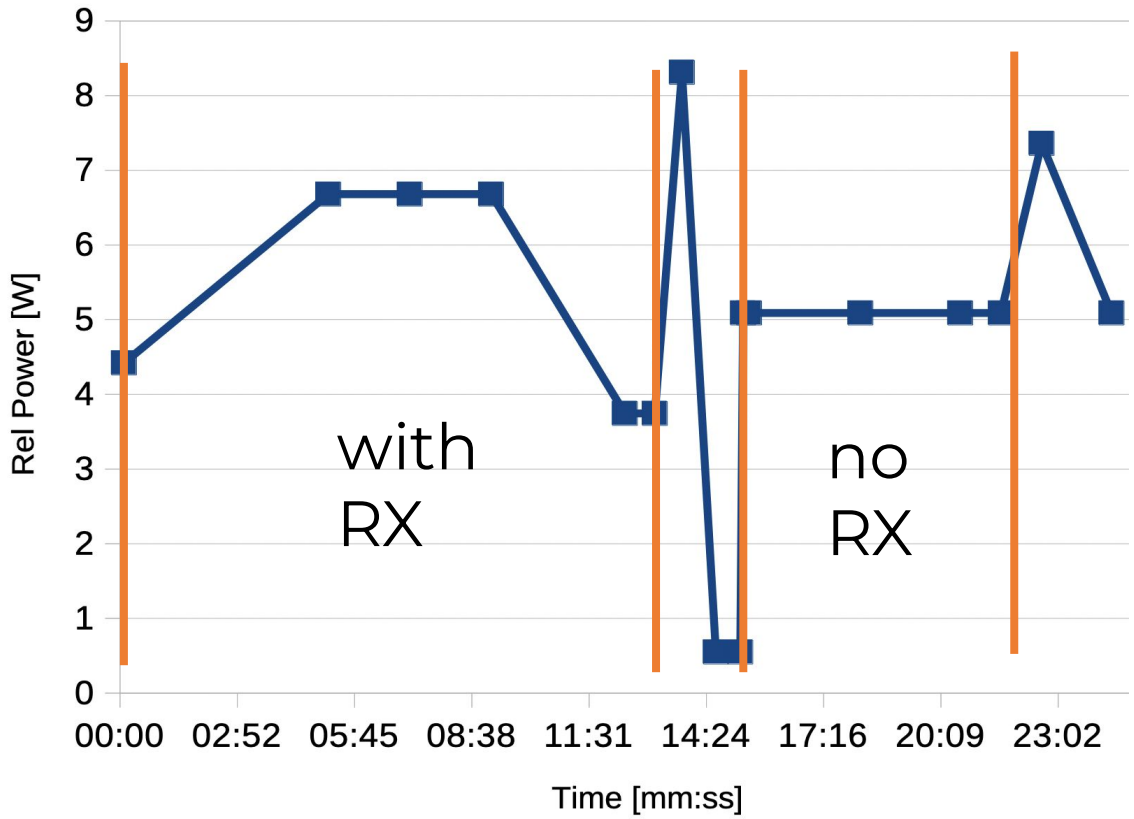
The Laser itself is not the cause!



Tests with Switches and Transceivers

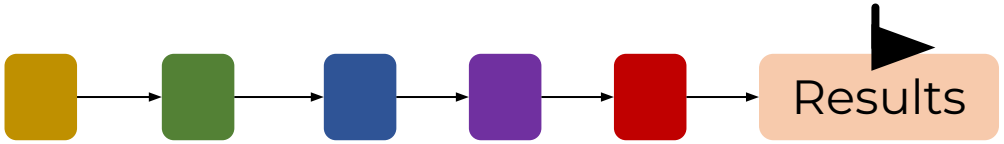
Juniper
(QFX5120-48Y)
with QSFP28DR





Some switches provide overhead power, also without any RX

Plug Trc Replug Trc status



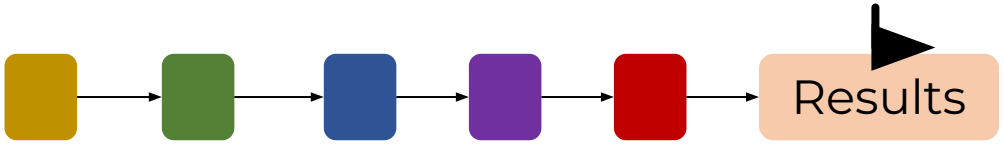
Experiment with Frozen Transceivers

Ice cubes

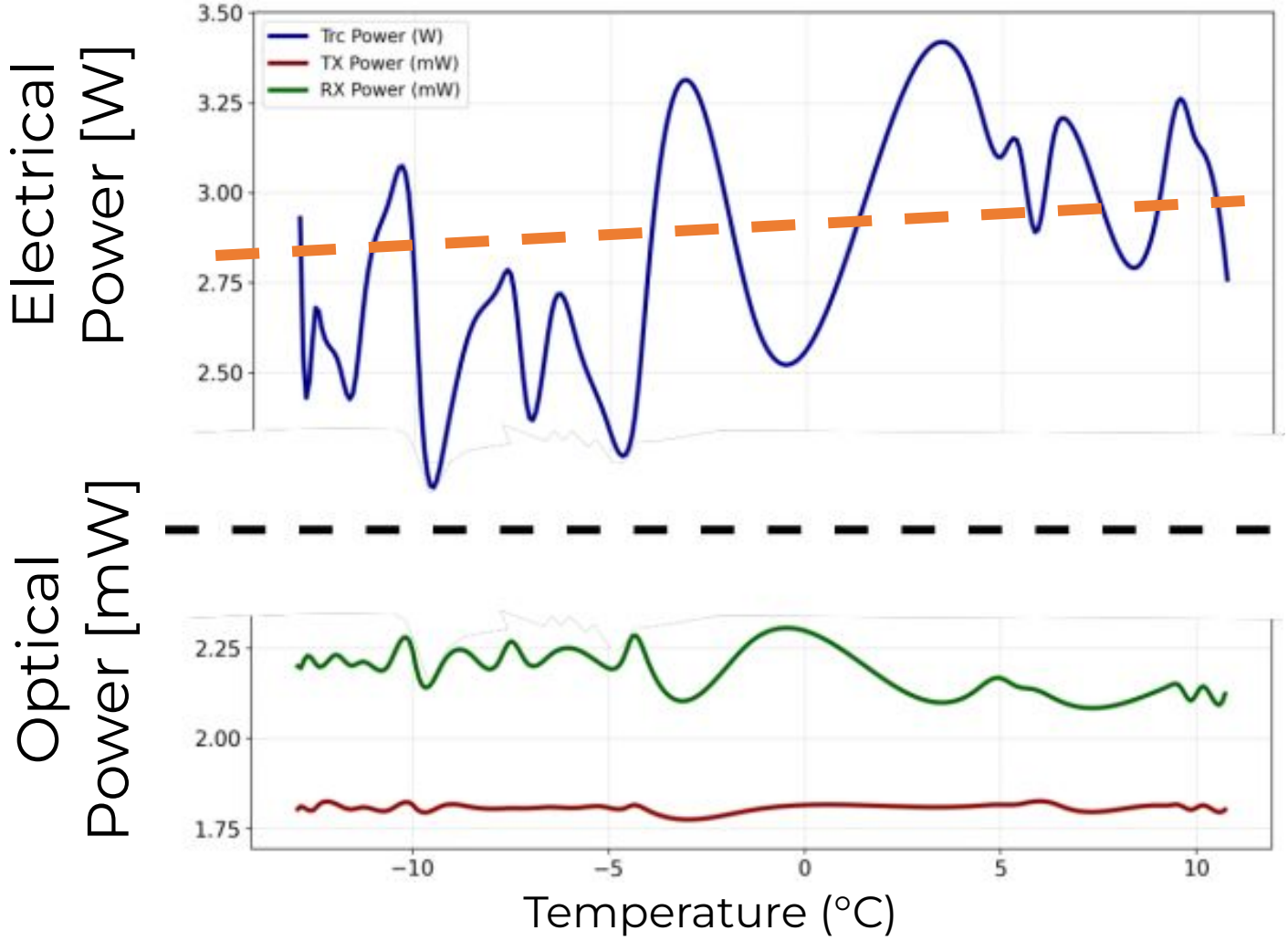
Flexbox 5

Alumnium Foil

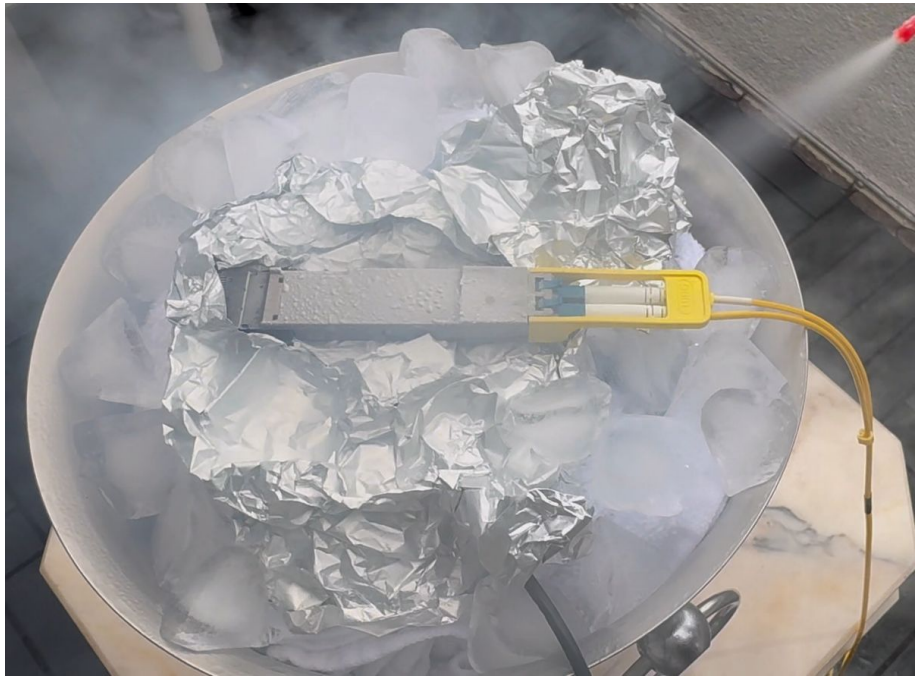




Results: Frozen, but Laser warms up quickly



20K difference, an average increase of around 200 mW is possible but worth?

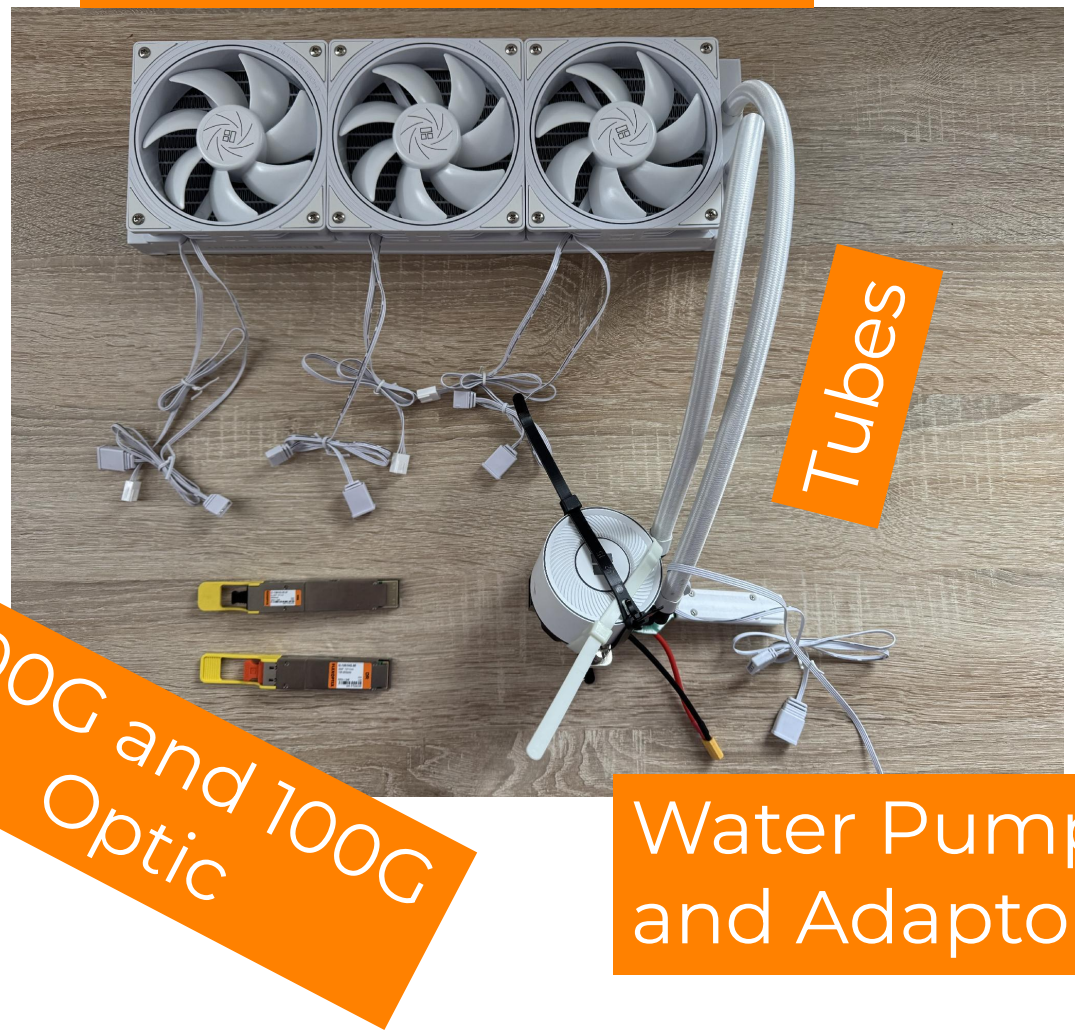


Conclusion

- Laser/TEC not main energy drawer here. Look deeper into MCU/DSP. Running PRBS to find out more.
- Laser temperature @ 50 °C -> most efficient -> But does not matter
  - at any Trc temperature, Laser and TEC power draw negligible
- Shut your Port: Forces Trc to Low Power mode: Consumes ~7-20 fold less energy
- Measuring Power at the switch can help to get more insights

Teaser

- How to shut the Port will be answered
  - SONiC, Mellanox CX, etc. and one Open Source Software for Layer 1 Mgmt
- Is Water Cooling really the future?
- See you next time!



SONiC



Thank you

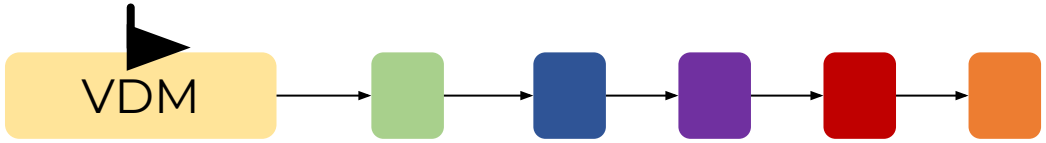
Source: [14]

one more thing



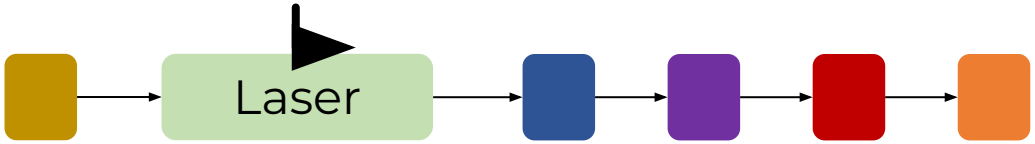
References

1. SFF-8024, SFF Module Management Reference Code Tables, Rev. 4.10, November 24th of 2022
2. OIF-CMIS-05.3, Common Management Interface Specification (CMIS), September 4th of 2024
3. Diode Lasers and Photonic Integrated Circuits, L. A. Coldren, Scott W. Corzine, Milan L. Mashanovitch, year 2012
4. Semiconductor Optoelectronic Devices, Bhattacharya, Pallab, year 1996
5. https://en.wikipedia.org/wiki/Thermoelectric_heat_pump, July 21st of 2025
6. https://de.wikipedia.org/wiki/Peltier-Element, July 21st of 2025
7. https://en.wikipedia.org/wiki/Air_conditioning, July 21st of 2025
8. https://www.naddod.com/blog/silicon-photonics-vs-eml-technology-optimizing-1-6t-osfp224-transceivers?srsltid=AfmBOoq2IkqYYKV_p4FkvkYFM9pdjuBZhvcCwkAigtTqRh_UJEA1xWUQ, July 21st of 2025
9. Fiber Optic Communications, Gerd Keiser, 2021
10. Mitsubishi Electric Corporation. (2018). *Low power-consumption and compact optical transmitter module for 100G Ethernet*. Mitsubishi Electric ADVANCE, 161, 8–11. Retrieved from https://www.advance.mitsubishielectric.com/advance/pdf/2018/161_complete.pdf
11. Vertical Cavity Surface Emitting Lasers (VCSELs) and their Applications (March 2024), https://www.dentonvacuum.com/blog/vertical-cavity-surface-emitting-lasers-vcsels-and-their-applications
12. Lowering the threshold current of photonic crystal vertical-cavity surface-emitting lasers, Yi-Yang Xie at al., 2013
13. VDI-Wärmeatlas, Fachlicher Träger VDI-Gesellschaft Verfahrenstechnik und Chemieingenieurwesen, Peter Stephan et al., 12. Auflage, 2019
14. Orange Peace with Googles Gemini: Generate a Picture of a japanese statue bowing (communicating thankfulness) in orange clothing
15. ChatGPT: “A cartoon about a guy that is very versatile sorting documents into different bins with optical transceiver icons on them”
16. Commander Genius: https://clonekeenplus.sourceforge.io/
17. ChatGPT: “a cartoon of a rocket flying through space from the 31st century”
18. Webshop Flexoptix: https://www.flexoptix.net/
19. ChatGPT: “Cartoon of the scientists Reynold, Prandtl and Nusselt standing in front of a camp fire warming up their hands”



VDM Support – How to find out?

- Network gears do not always tell you explicitly
- Look for Laser Temperature and TEC Current
  - There are more values, but they might be shared with diagnostics feature (BER and OSNR)
  - VDM may choose what to support, but in most cases trc **laser temperature** and **TEC current** are usually shown
- Access to memory pages 20h - 2Fh



Laser Power consumption

- Laser voltage is **not** reported by any specification or agreement. Manufacturers have that information.
- $Pow_{cons} = V_{fwd} \times bias$
- Electro-optical efficiency = $\frac{Tx_{OptPow}}{Pow_{cons}} < 0.1$
- In our software we just map a value depending on given laser type



```
laserTypeToVoltage = {
    'EML': 1.3,
    'VCSEL': 1.85,
    'DFB': 1.5
}
```

Source: [16]