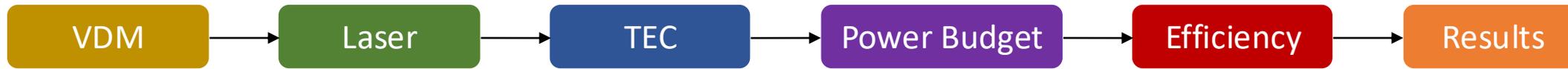


# Understanding and Optimising Transceiver Efficiency

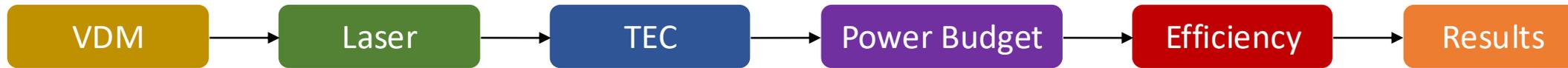


using internal Metrics for improved power savings



# 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**



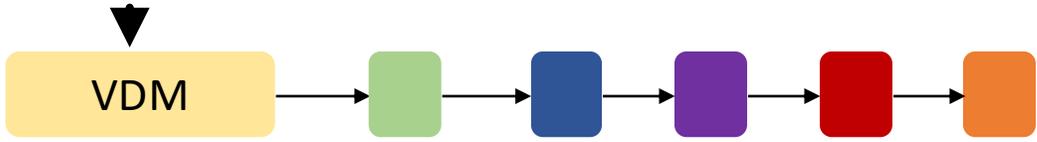
# Devices under Test (DUT)

Transmitter/Receptor -> Transceiver -> Trc:

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

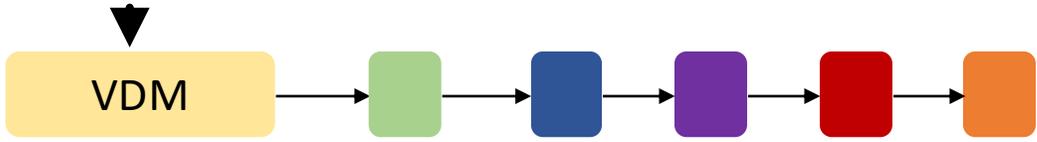
Type ID	Observable Type	Instance Type	Data Type	Unit Scale	Unit
0	Not Used indicator <sup>1</sup>	N/A	N/A		
1	Laser Age (0% at BOL, 100% EOL) (Media Lane)	Basic	U16	1	%
2	TEC Current (Module)	Basic	S16	100/32767	%
3	Laser Frequency Error (Media Lane)	Basic	S16	10	MHz
4	Laser Temperature (Media Lane)	Basic	S16	1/256	C
5	SNR (dB) Media Input (Media Lane) -- see section 7.1.4	Basic	U16	1/256	dB
6	SNR (dB) Host Input (Lane) -- see section 7.1.4	Basic	U16	1/256	dB
7	PAM4 Level Transition Parameter Media Input (Media Lane)	Basic	U16	1/256	dB
8	PAM4 Level Transition Parameter Host Input (Lane)	Basic	U16	1/256	dB
9	Pre-FEC BER Minimum Sample Media Input (Data Path)	Statistic	F16	N/A	
10	Pre-FEC BER Minimum Sample Host Input (Data Path)	Statistic	F16	N/A	
11	Pre-FEC BER Maximum Sample Media Input (Data Path)	Statistic	F16	N/A	

## Comparison to: Digital Diagnostic Monitoring (DDM)

Byte	Bit	Name	Description
22	All	Temperature MSB	Internally measured temperature (MSB)
23	All	Temperature LSB	Internally measured temperature (LSB)
24-25	All	Reserved	
26	All	Supply Voltage MSB	Internally measured supply voltage (MSB)
27	All	Supply Voltage LSB	Internally measured supply voltage (LSB)



Sources: [2, 15]



# Versatile Diagnostic Monitoring

## DDM

Read data from bytes

Byte	Bit	Name
22	All	Temperature MSB
23	All	Temperature LSB

Calculate Value

## VDM

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)

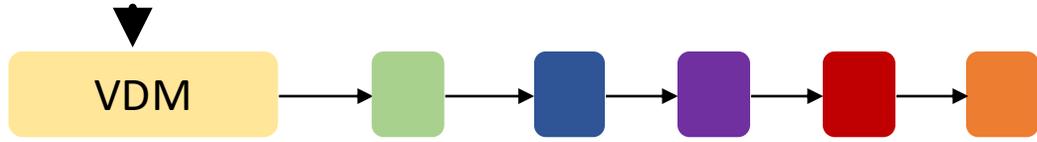
Which one is it?

Calculate Value

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

Where is the value?

Type ID	Observable Type
0	Not Used indicator <sup>1</sup>
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



# 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
```

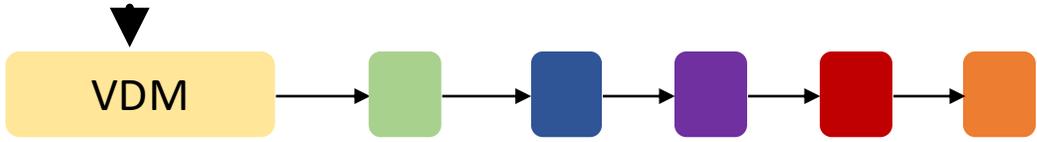
Juniper QFX5120  
**JunOS 25.2R1.9**  
 No support ☹️

## DDM only (thresholds):

```
MODULE THRESHOLDS
Temperature C      high alarm  high warning  low warning  low alarm
Voltage V         003.6000    003.5500     003.0500    002.9500

LANES THRESHOLDS
Bias Current mA   high alarm  high warning  low warning  low alarm
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

	Current Measurement	Alarms		Warnings	
		High	Low	High	Low
Temperature	48.89 C	78.00 C	-8.00 C	73.00 C	-3.00 C
Voltage	3.30 V	3.63 V	2.97 V	3.46 V	3.13 V
Current	N/A	N/A	N/A	N/A	N/A
Tx Power	N/A	N/A	N/A	N/A	N/A
		N/A	N/A	N/A	N/A
		N/A	N/A	N/A	N/A
Pre-FEC BER	1.00e+00	N/A	N/A	N/A	N/A
Post-FEC BER	1.00e+00	N/A	N/A	N/A	N/A
CD (Short Link)	0.00 ps/nm	N/A	N/A	N/A	N/A
CD (Long Link)	0.00 ps/nm	N/A	N/A	N/A	N/A
Diff. group delay	0.00 ps	N/A	N/A	N/A	N/A
SOPMD	0.00 ps^2	N/A	N/A	N/A	N/A
PDL	0.00 dB	N/A	N/A	N/A	N/A
OSNR	0.00 dB	N/A	N/A	N/A	N/A
ESNR	0.00 dB	N/A	N/A	N/A	N/A
Carrier freq off	0.00 MHz	N/A	N/A	N/A	N/A
Err Vector Mag.	0.00 %	N/A	N/A	N/A	N/A
SOP Rate of Chg	0.00 krad/s	N/A	N/A	N/A	N/A
Laser bias	227.62 mA	N/A	N/A	N/A	N/A
SOPMD LO GR	0.00 ps^2	N/A	N/A	N/A	N/A
Modulation Err R	385.30 dB	N/A	N/A	N/A	N/A
Clock recovery	0.00 %	N/A	N/A	N/A	N/A
Transmit Fault Count = 0					

**Laser temperature 49.98 °C**

## CMIS VDM

Type ID	Observable Type
0	Not Used indicator <sup>1</sup>
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)

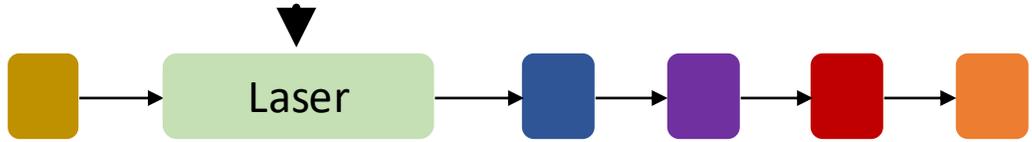
... but ...

### 7.1.6.3 Laser Temperature

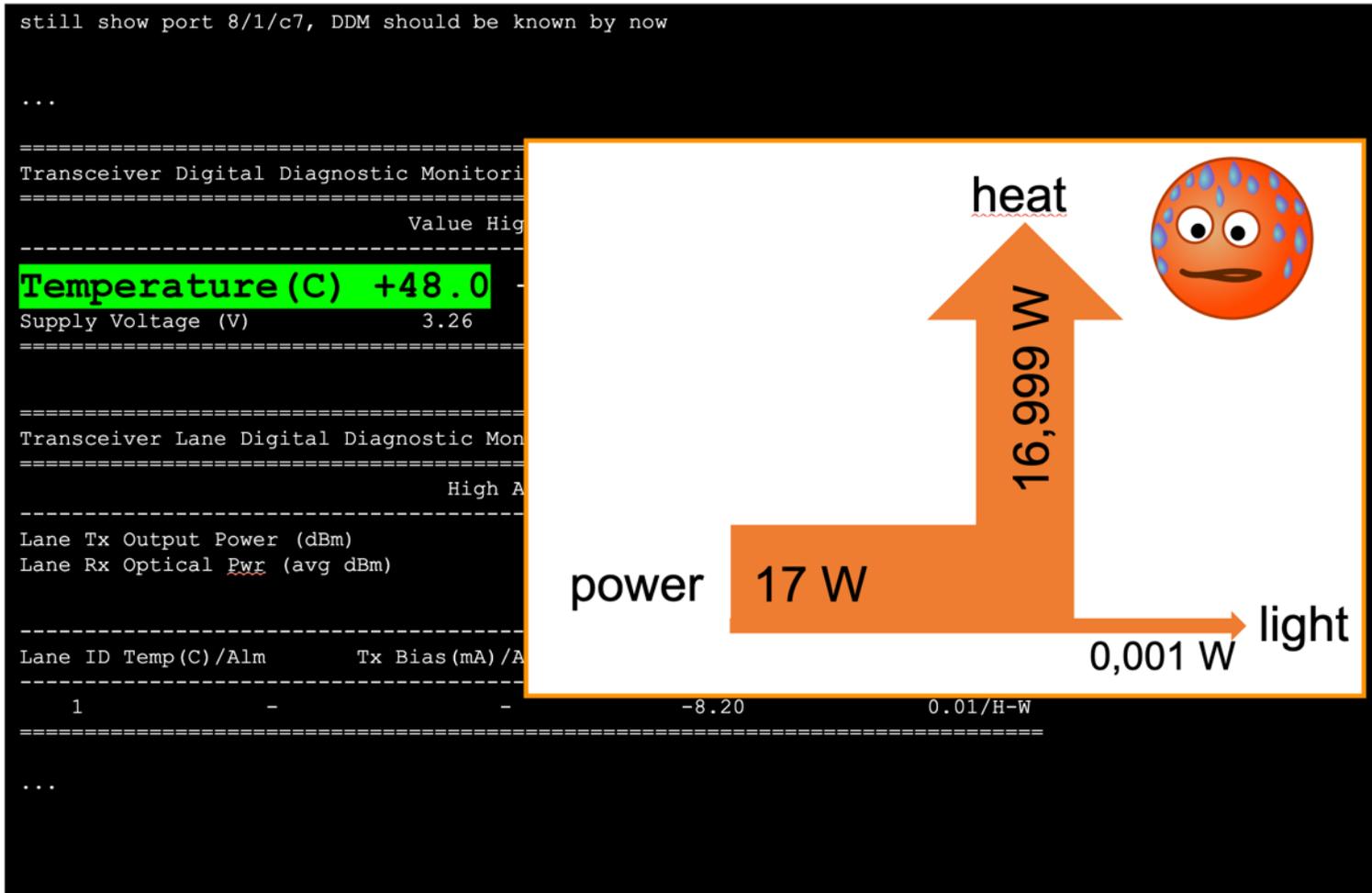
If supported, this monitor observes the laser temperature **difference** between the target laser temperature for a cooled laser, and the actual current temperature.

Which means.  $50.0\text{ °C} - 0.02\text{ °C} = 49.98\text{ °C}$

Value **50 °C** is the typical target temperature of a Laser[10]. The switch assumes that.



# Excursion: Coherent Trc (2023/2024)



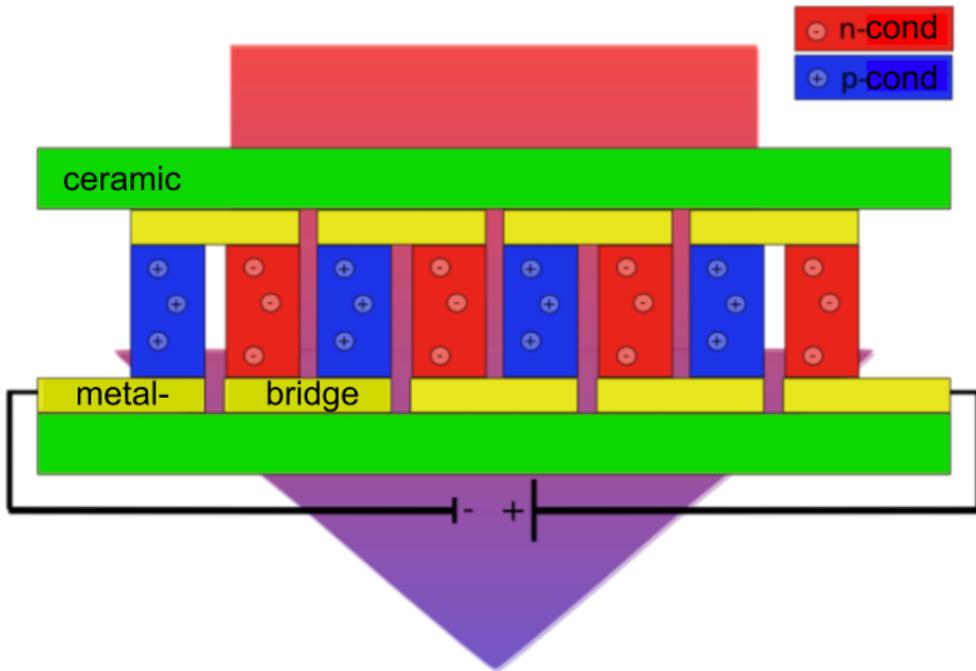
- $POW_{Laser} = V_{fwd} \times I_{Laser}$  (DDM)
- $POW_{TEC} = V_{Trc} \times I_{TEC}$  (VDM)

Note: Laser voltage is **not** reported by any specification or agreement. Manufacturers have that information.

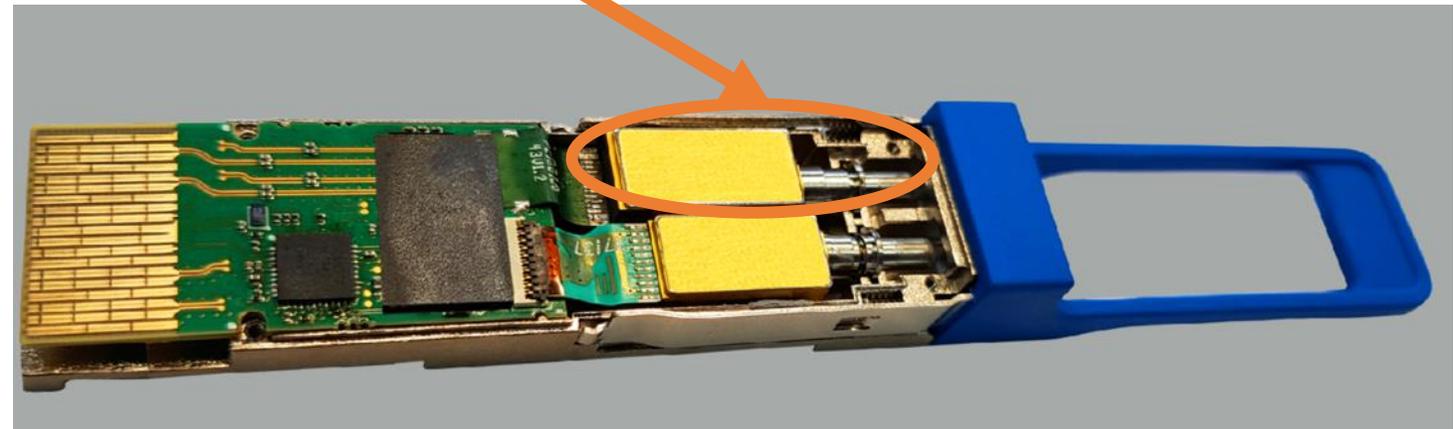


# Thermo Electric Cooler (TEC)

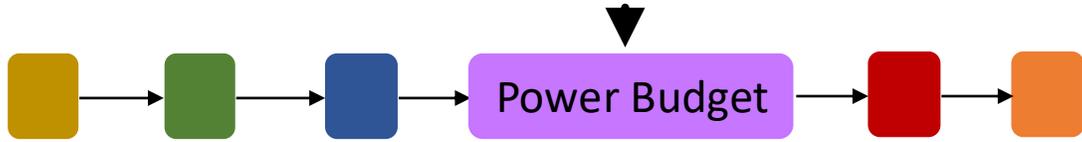
Typical Peltier element at large scale ...



...but TEC very small -> TOSA



Sources: [6]



# Power Budget



**Example:** D.CO164HG.16.yTM  
(480km @ Multirate 400G SR8 ZR+)

Our shop tells you  
about max power



DIGITAL DIAGNOSTIC MONITORING (DDM)	Yes, internally calibrated
<b>POWER CONSUMPTION</b>	22 W
CDR	TX and RX
SGMII	No
INBUILT FEC	Yes, OFEC
POWERBUDGET (DB)	15 dB
TRANSMIT MIN/MAX PER LANE	-5 dBm / 3 dBm
RECEIVER MIN/MAX PER LANE	-12 dBm / 0 dBm (overload) @400G
WAVELENGTH TX (TYPICAL)	tunable Coherent high-power DWDM

Source: [18]



# With Flexbox and Research Tool

The screenshot displays a software interface for a research tool. On the left, a block diagram shows the system architecture. At the top, there are three toggle switches: 'Toggle Trc Power', 'Toggle Laser', and 'Toggle VDM'. Below them, the power flow starts with a 'USB Supply' providing 15.2W to a 'USB-C' port. A 'Battery' is shown at 93% charge. A 'Coil' is connected to the system. A 'Transceiver' block contains an 'MCU-DSP' and is currently marked with a question mark. Below the transceiver are 'TEC', 'Laser', and 'Light' components, with the 'Laser' also marked with a question mark. A status bar at the bottom of the diagram indicates 'No Transceiver Plugged'.

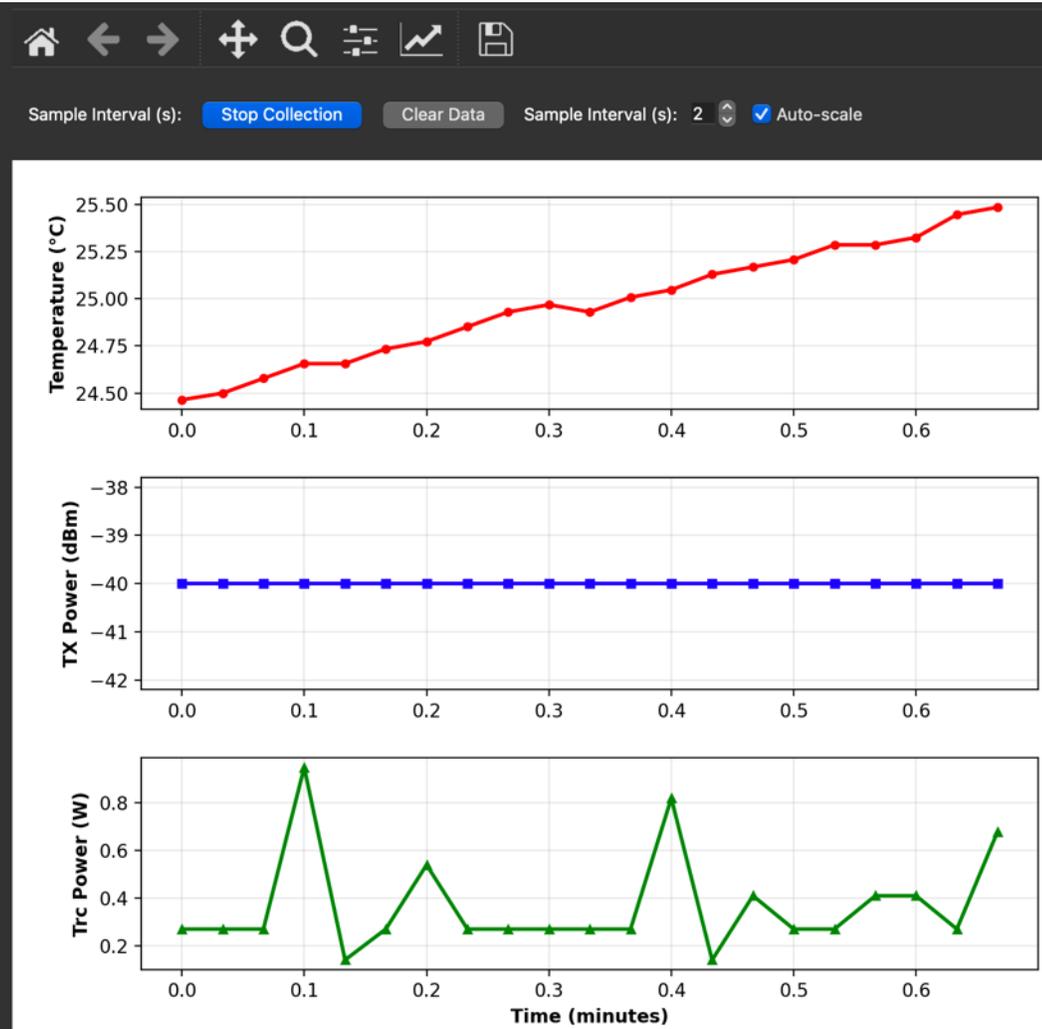
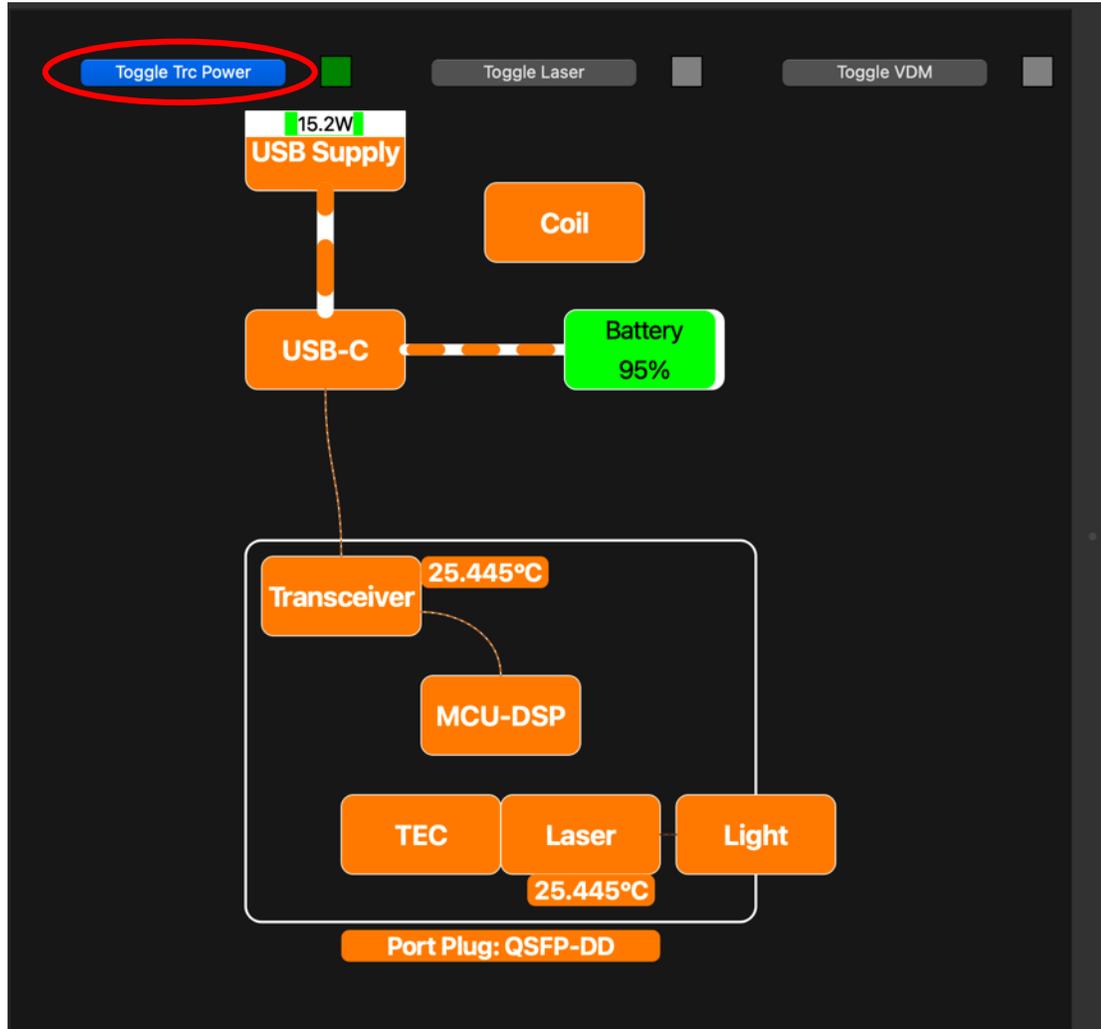
The right side of the interface contains three vertically stacked graphs, all with a 'Time (minutes)' x-axis ranging from -0.04 to 0.04. The top graph is 'Temperature (°C)', the middle is 'TX Power (dBm)', and the bottom is 'Trc Power (W)'. All three graphs are currently empty. Above the graphs, there are controls for 'Sample Interval (s): 2' and a checked 'Auto-scale' option. At the top right of the interface, there are icons for home, back, forward, zoom, search, and save.

In the bottom right corner, there is a photograph of the physical device, a black, multi-ported power supply unit with red LEDs and a USB-C port. The device is labeled 'FLEXOPTIX' and 'OSFP'.

\*Python, PyQt and Matplotlib in one application

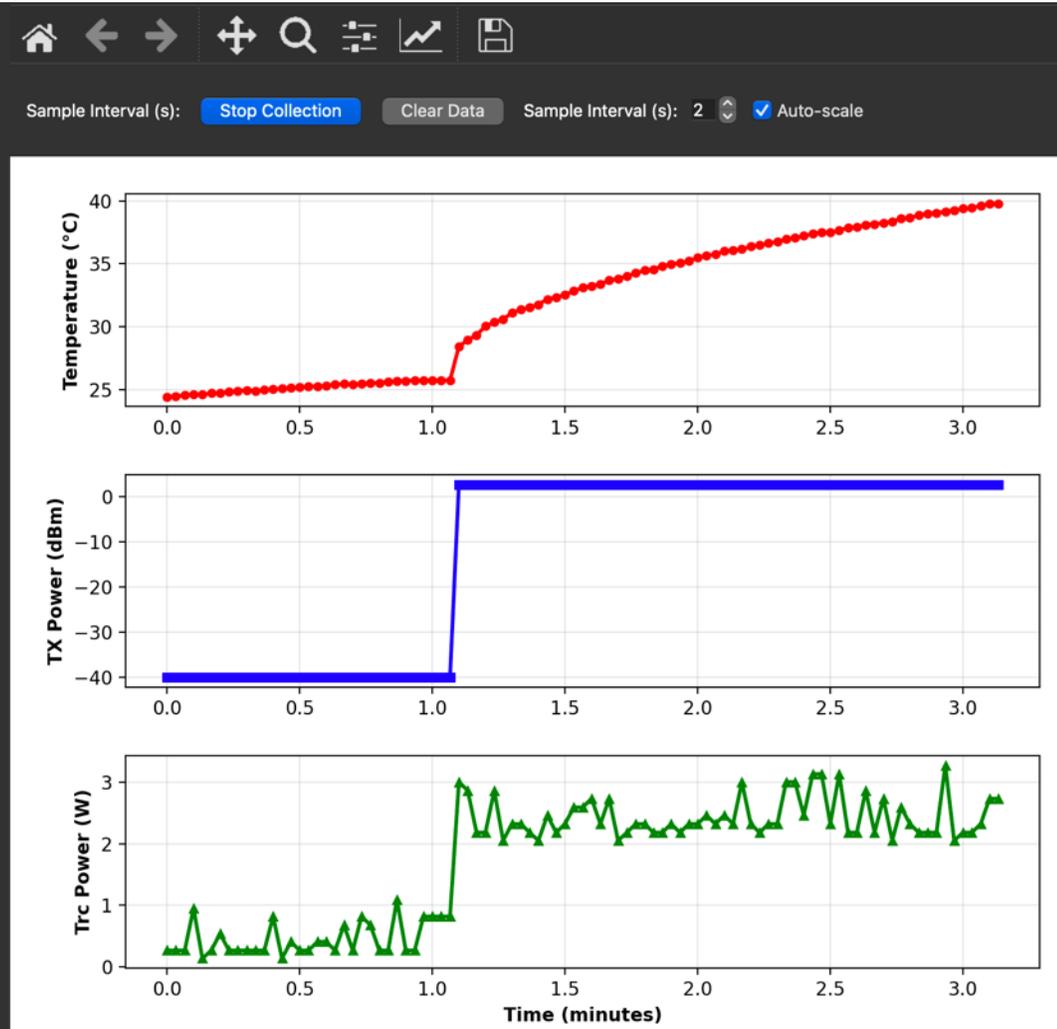
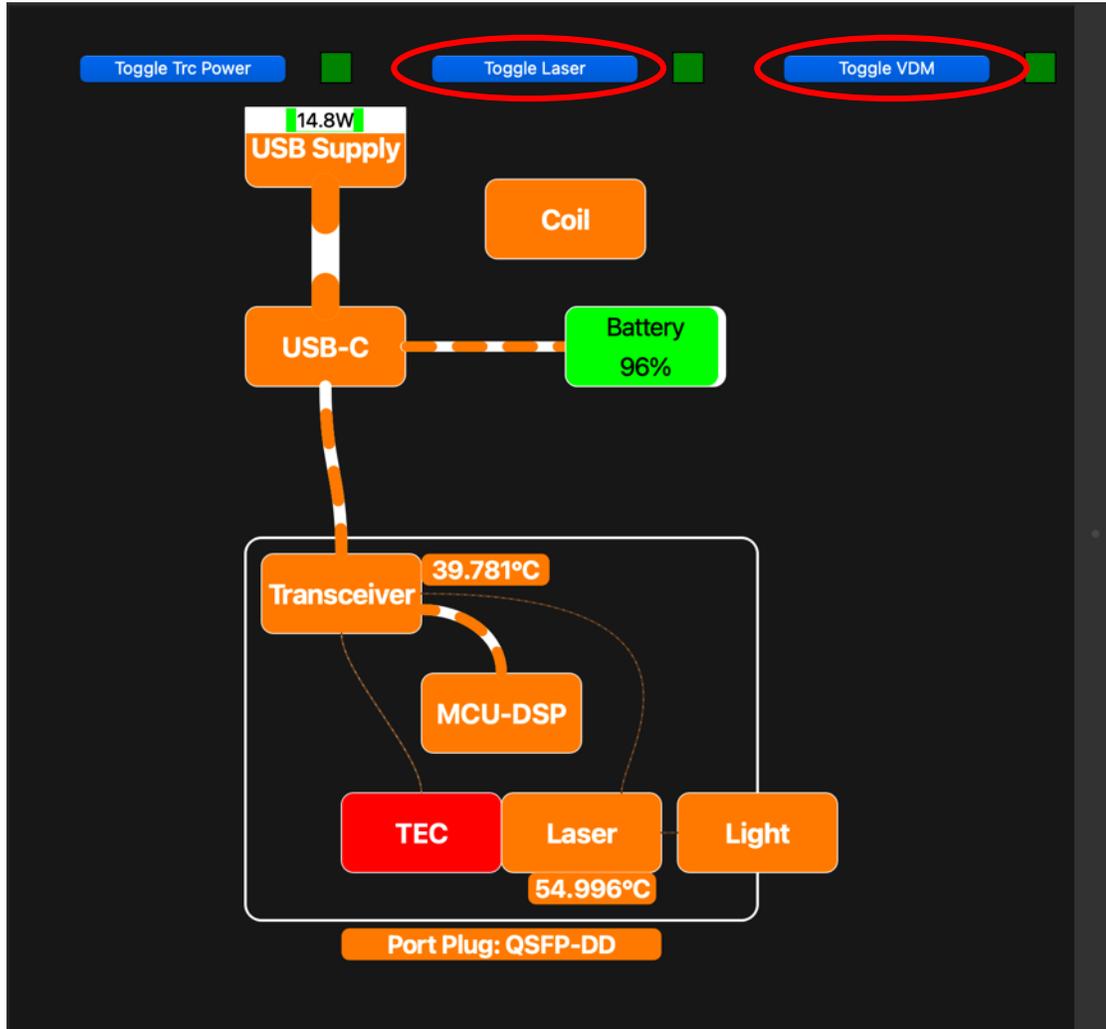


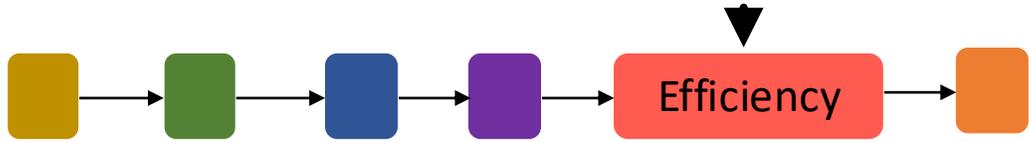
# Give the transceiver some power!



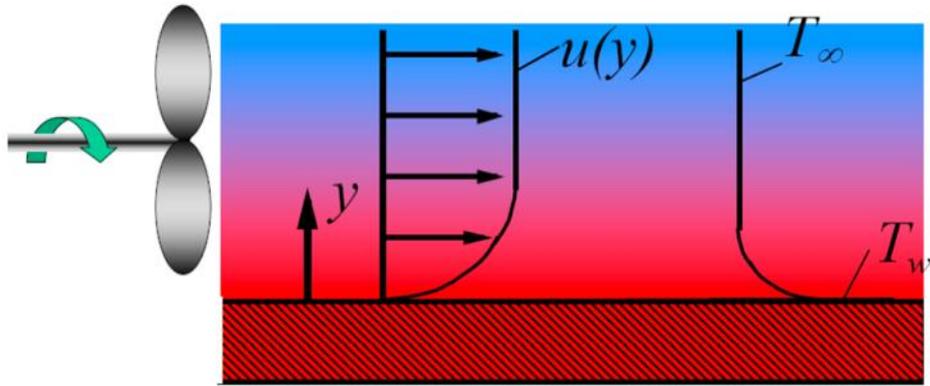


# Go Go Laser (and VDM) !!





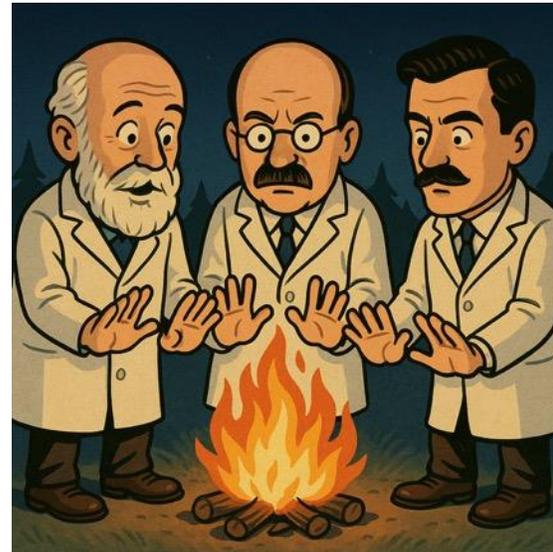
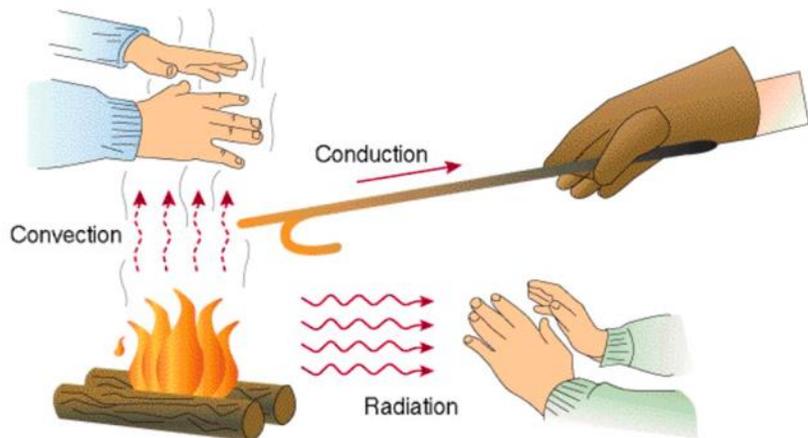
# Efficiency: Fan Speed and Heat Exchange



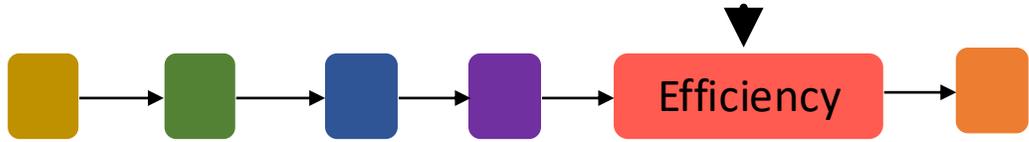
$$P_{Fan} = \frac{\lambda \times Nu}{L} A(T_{\infty} - T_w)$$

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

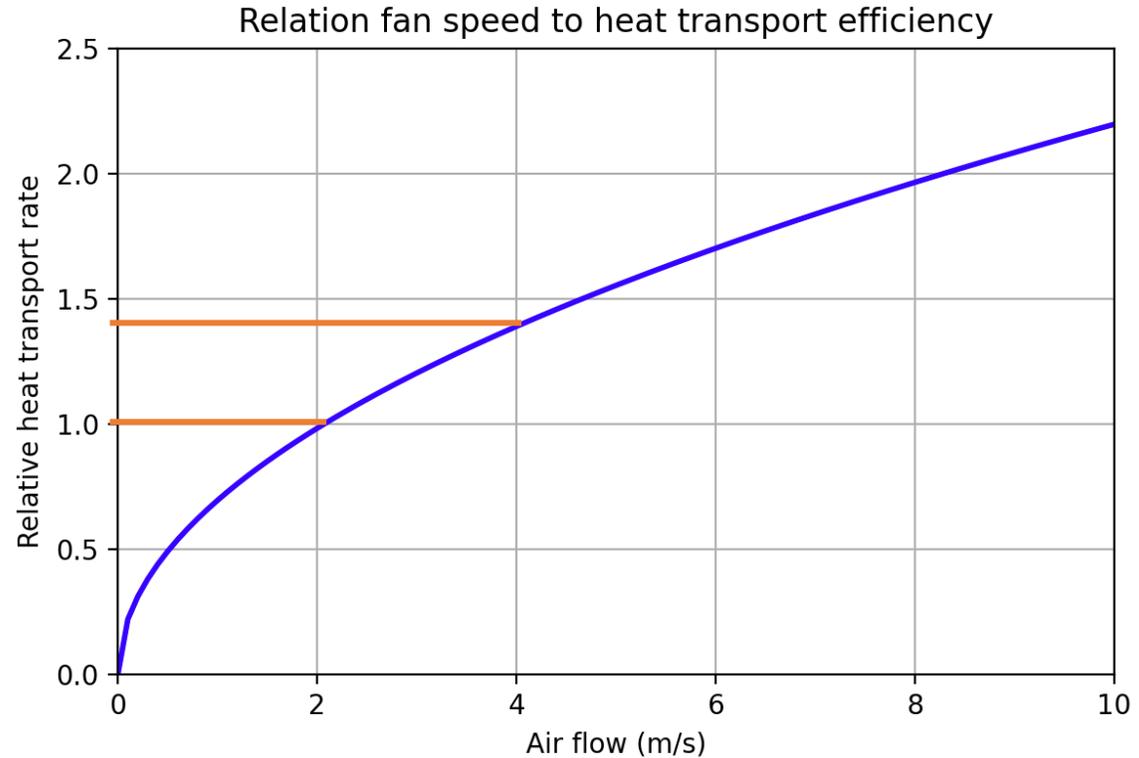
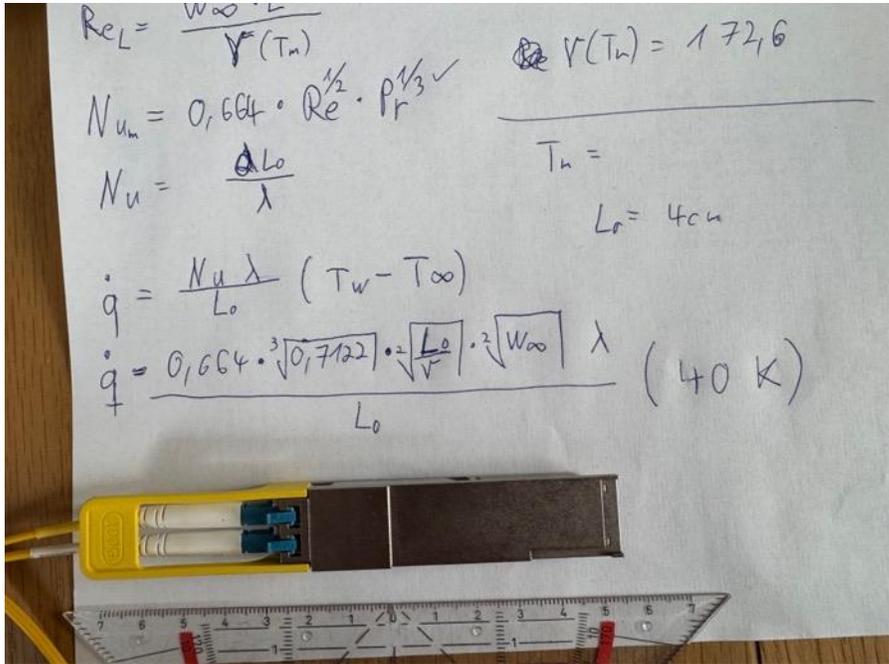
$$Re = \frac{w_{\infty} L}{\nu}$$



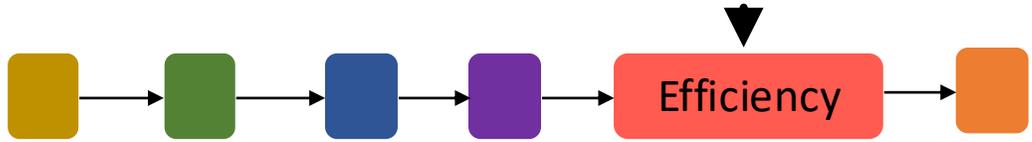
- Nusselt (Nu)
- Prandtl (Pr)
- Reynolds (Re)



# Let's do the math ... and show what matters!



Doubling the Speed does not double the Watts!



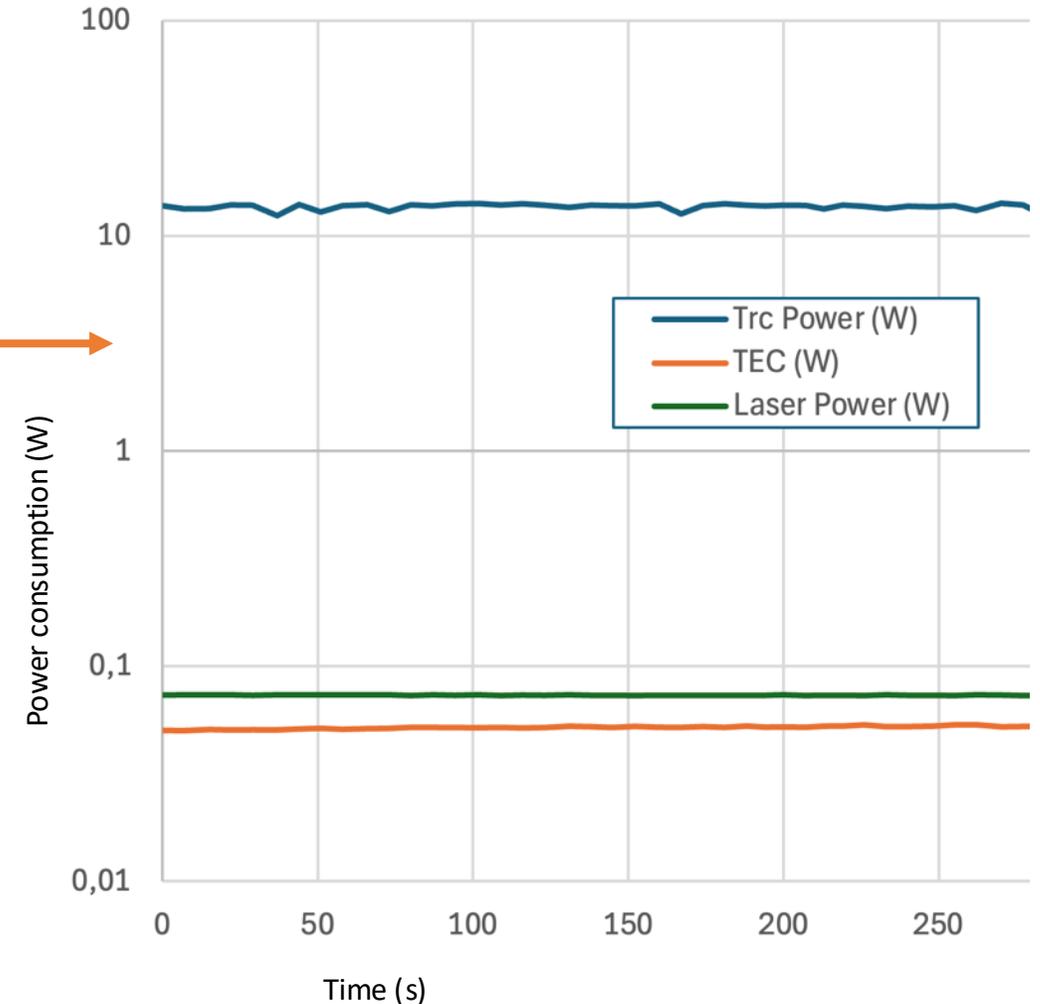
# Influence of TEC and Laser Temperatures?

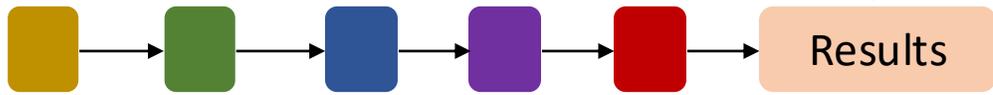
Power readings of D.CO164HG.2.yT  
400G Coherent with Q1 Fan Setting

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



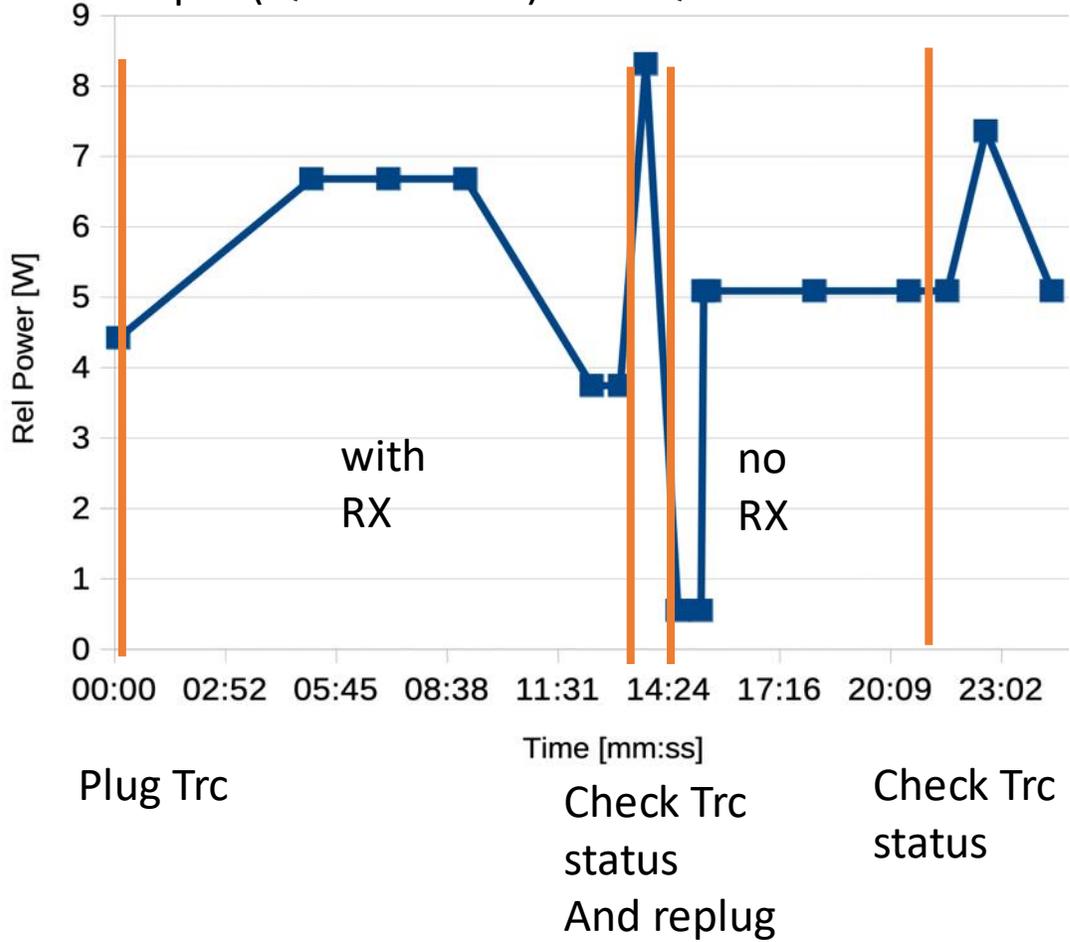
QX	Speed	RPM (approx.)
Q0	0 m/s (obviously)	0
Q1	2.2 m/s	467
Q2	3.0 m/s	637
Q4	3.8 m/s	806



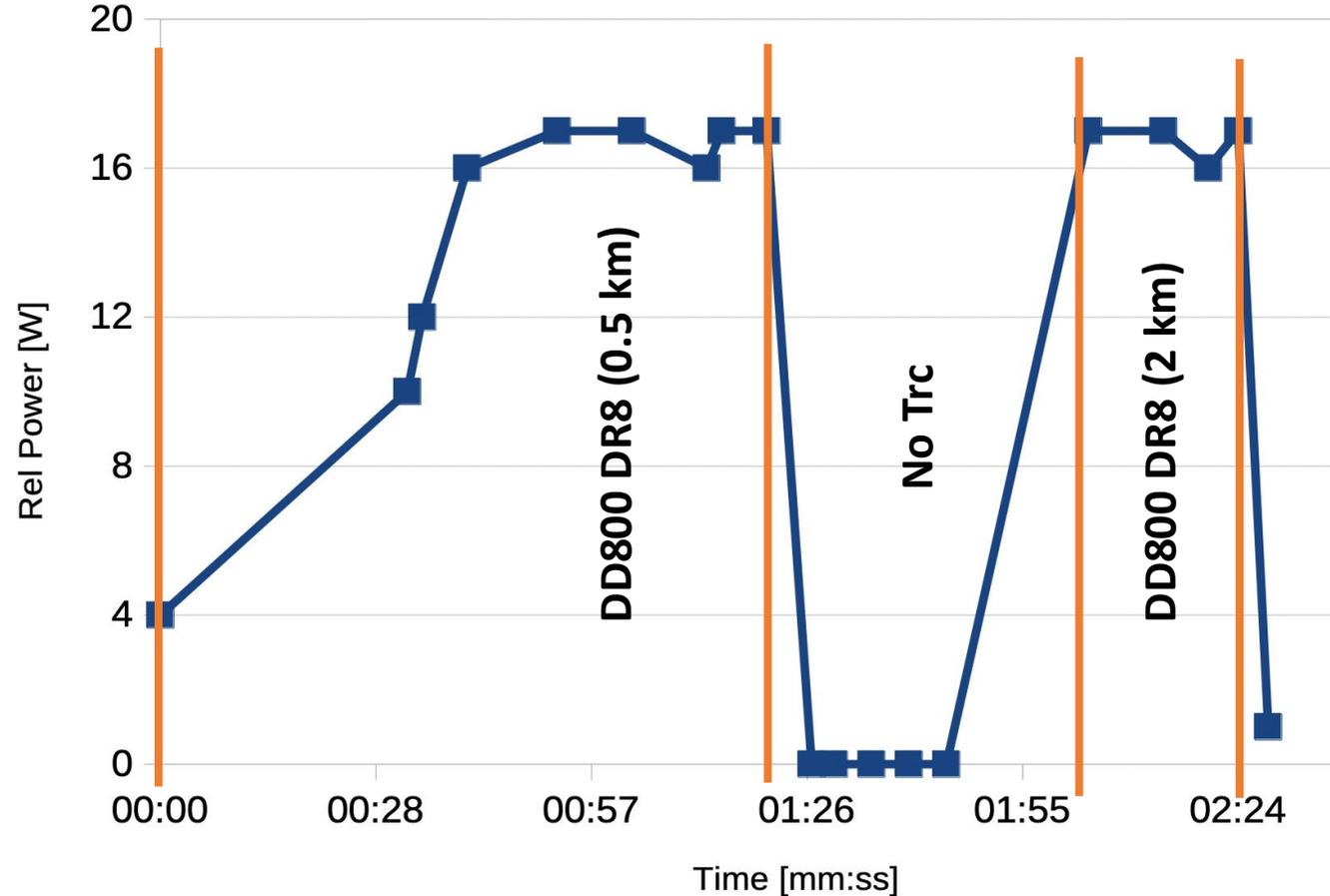


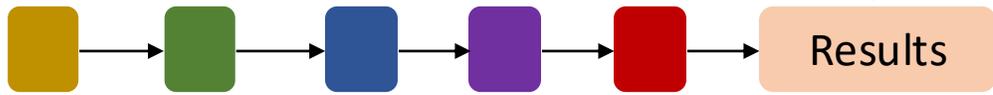
# Results: Tests with Switches and Transceivers

Juniper (QFX5120-48Y) with QSFP28DR



Cisco Nexus with 800G Transceivers





# Experiment with Frozen Transceivers

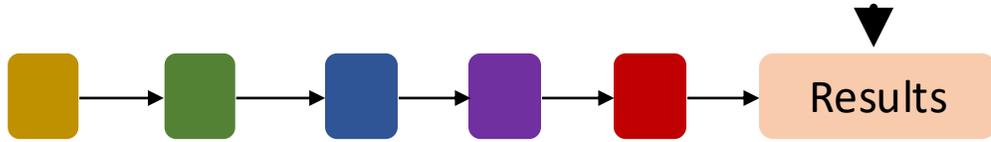
Ice cubes

Transceiver (100G QSFP28)

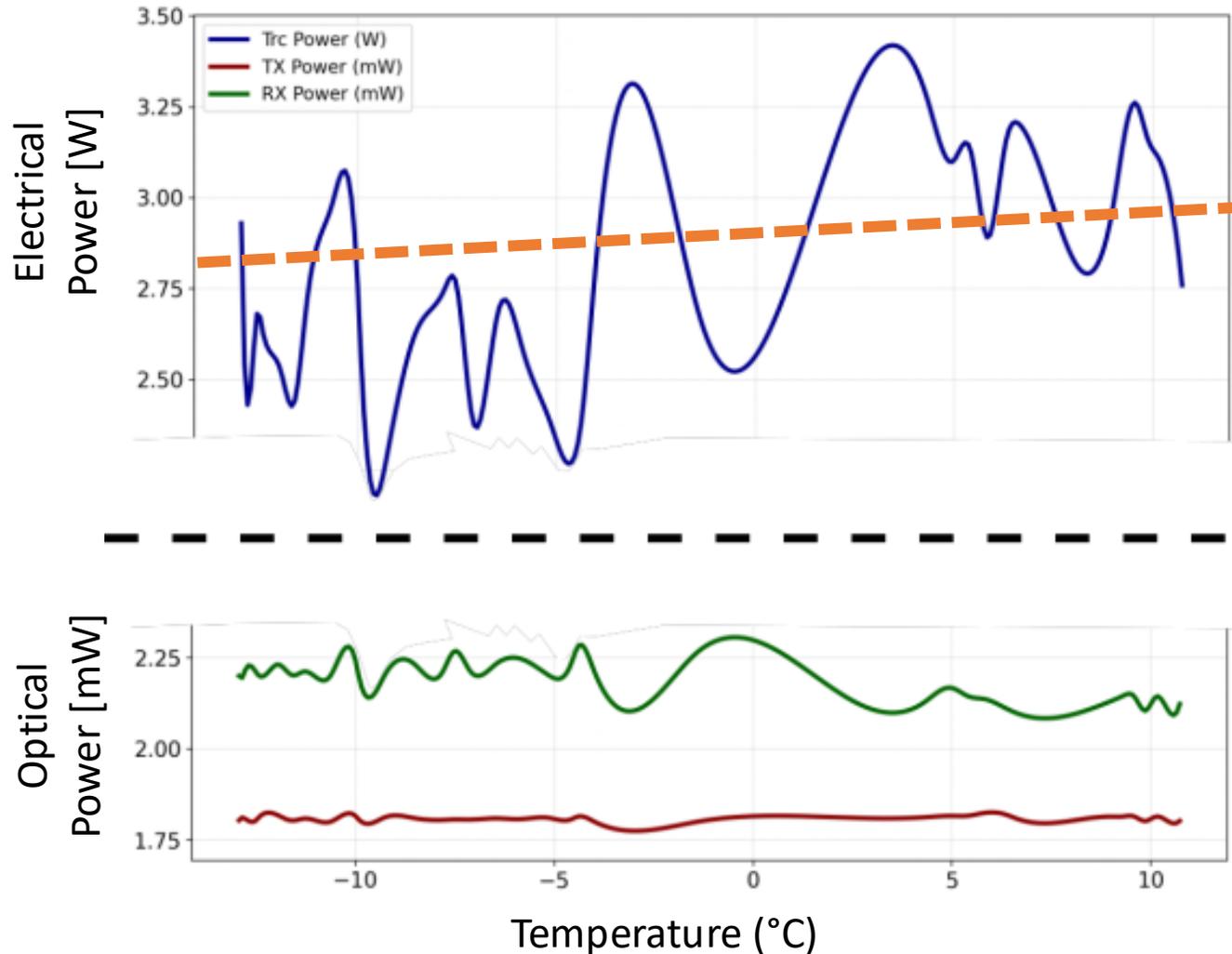
Flexbox 5

Alumnium Foil



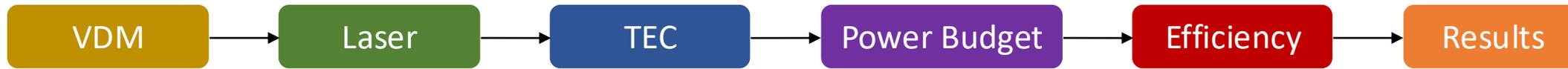


# Results: Frozen, but Laser warms up quickly



With about 20°C difference an average increase of around 200 mW is possible





# Conclusion

- Laser and TEC are not the main energy drawer here. Let's look deeper into the MCU/DSP combi and running PRBS to find out how much power these features require.
- Laser temperature @ 50 °C -> most efficient -> but does not matter
  - at any Trc temperature, the Laser and TEC power draw is negligible
- Shut your Port: Trc will be forced to Low Power mode and consume around 7-20 fold less energy
- Measuring Power at the switch can help to get more insights
- You can measure the Trc draw power of different states with the Flexbox



**Thank you**

# References

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14. Orange Peace with Googles Gemini: Generate a Picture of a japanese statue bowing (communicating thankfulness) in orange clothing
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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"