FLEXOPTIX

Understanding and Optimising Transceiver Efficiency

using internal Metrics for improved power savings

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- **Laser**: Laser Power discussion of Transceivers (trc)
- **TEC:** Thermoelectric Cooler
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- **Efficiency:** Definition
- **Results**

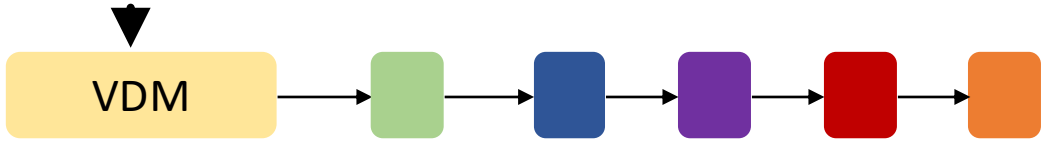
Devices under Test (DUT)

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



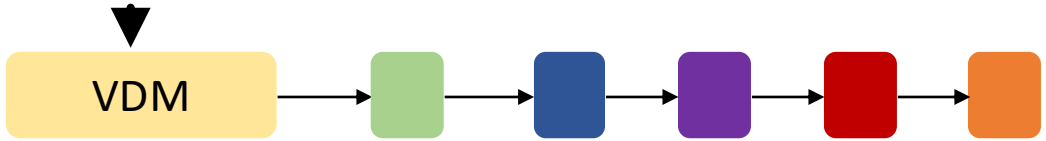
Versatile Diagnostic Monitoring

Type ID	Observable Type	Instance Type	Data Type	Unit Scale	Unit
0	Not Used indicator[1]	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	

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)

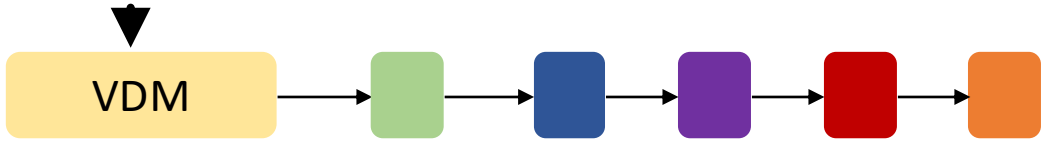
Which one is it?

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):

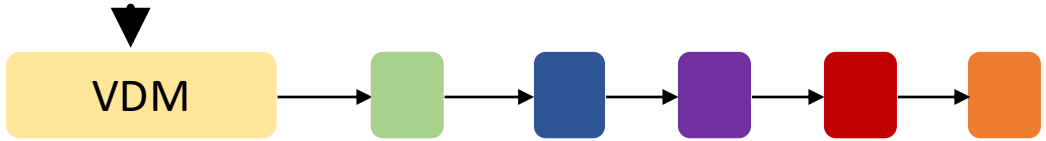
```
{master:0}
root@QFX5120-48Y> show interfaces  diagnostics optics et-0/0/49
Physical interface: et-0/0/49
    Module temperature                          :  37 degrees C / 98 degrees F
    Module voltage                              :  3.2700 V
    Module temperature high alarm               :  Off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

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

	Current Measurement	Alarms High	Alarms Low	Warnings High	Warnings 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
Laser temperature	49.98 °C				
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

Note: ++ high-alarm; + high-warning; -- low-alarm; - low-warning

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)

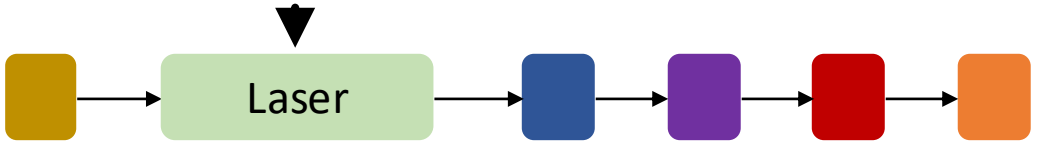
… but …

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.

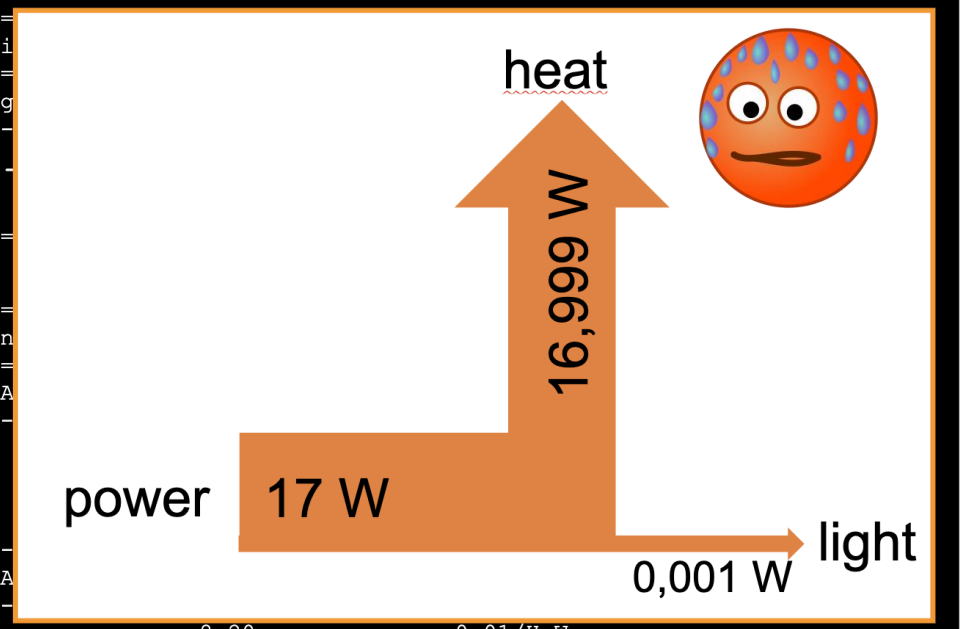
Which means. 50.0 °C – 0.02 °C = 49.98 °C

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



Excursion: Coherent Trc (2023/2024)

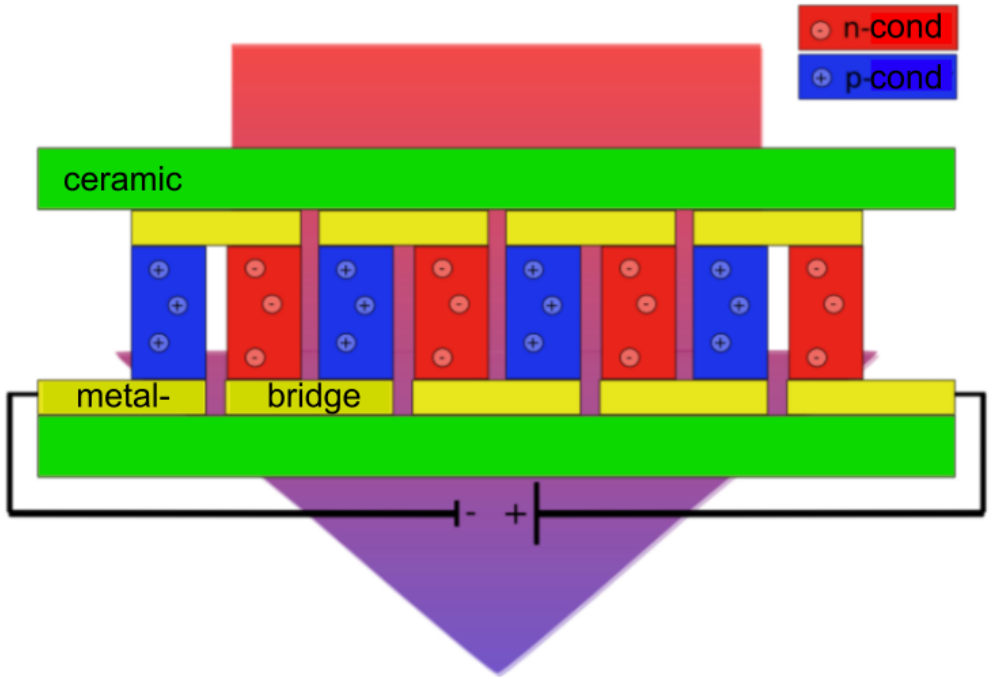
```
still show port 8/1/c7, DDM should be known by now

...

==========================================
Transceiver Digital Diagnostic Monitori
==========================================
                             Value Hig
------------------------------------------
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
==========================================================================

...
```



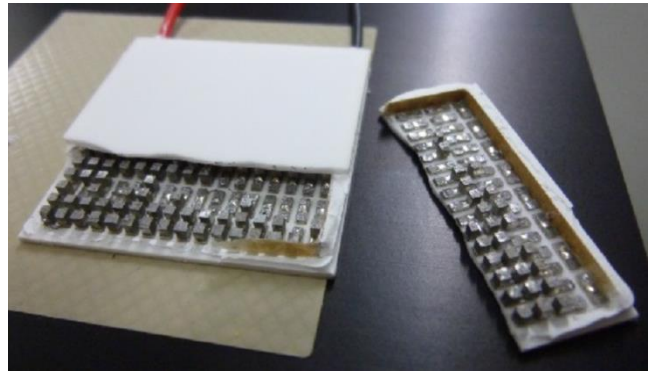
- $Pow_{Laser} = V_{fwd} \times I_{Laser}$ (DDM)
- $Pow_{TEC} = V_{Trc} \times I_{TEC}$ (VDM)

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

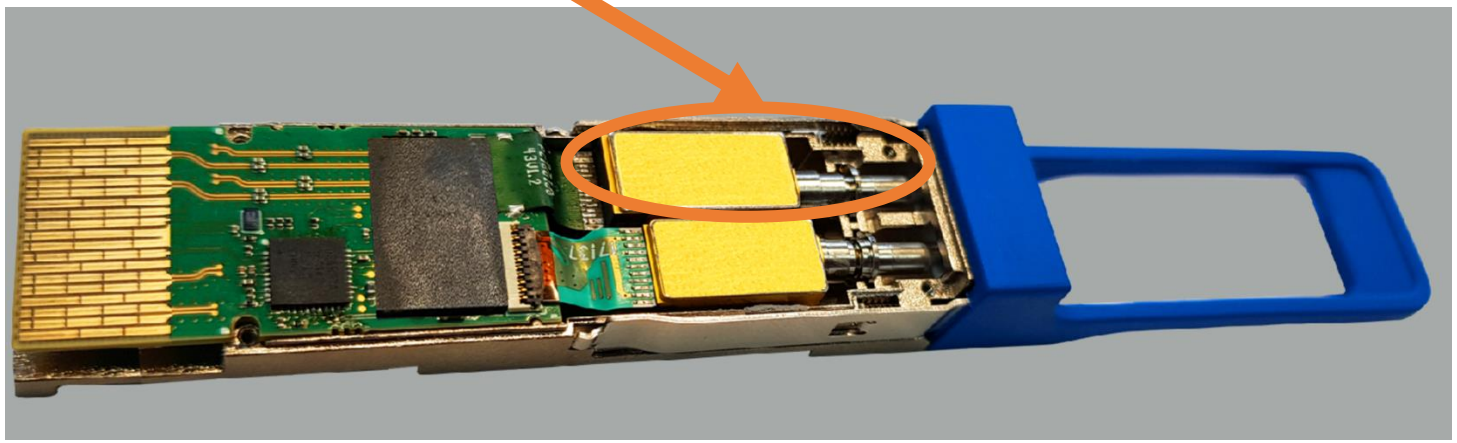
Thermo Electric Cooler (TEC)



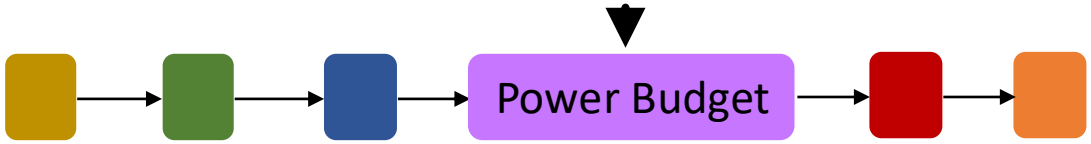
Typical Peltier element at large scale …



…but TEC very small -> TOSA



Sources: [6]



Power Budget

Bit	Device Type
7-6	00: Power Class 1 (1.5 W max.)
	01: Power Class 2 (2.0 W max.)
	10: Power Class 3 (2.5 W max.)
	11: Power Class 4 (3.5 W max.) and Power Classes 5, 6 or 7
5	Power Class 8 implemented (Max power declared in byte 107)
4	0: No CLEI code present in Page 02h
	1: CLEI code present in Page 02h
3	0: No CDR in Tx, 1: CDR present in Tx
2	0: No CDR in Rx, 1: CDR present in Rx
1-0	00: Power Classes 1 to 4
	01: Power Class 5 (4.0 W max.) See Byte 93 bit 2 to enable.
	10: Power Class 6 (4.5 W max.) See Byte 93 bit 2 to enable.
	11: Power Class 7 (5.0 W max.) See Byte 93 bit 2 to enable.

Byte	Bits	Field Name	Field Description
200	7-5	ModulePowerClass[1]	000: Power class 1 001: Power class 2 010: Power class 3 011: Power class 4 100: Power class 5 101: Power class 6 110: Power class 7 111: Power class 8
	4-0	-	**Reserved**
201	7-0	MaxPower	Maximum power consumption in multiples of 0.25 W rounded up to the next whole multiple of 0.25 W

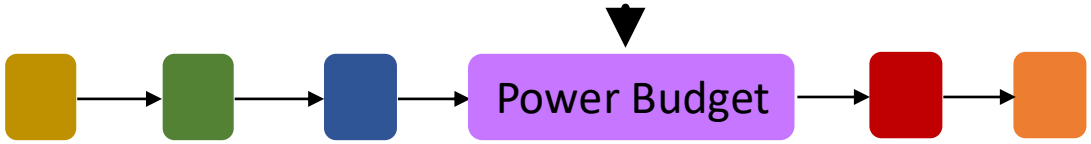
SFF8636 (QSFP+, QSFP28)

Max. power already specified

CMIS (QSFP-DD, OSFP)

Vendor may decide max. power for each class

Source: [1,2]



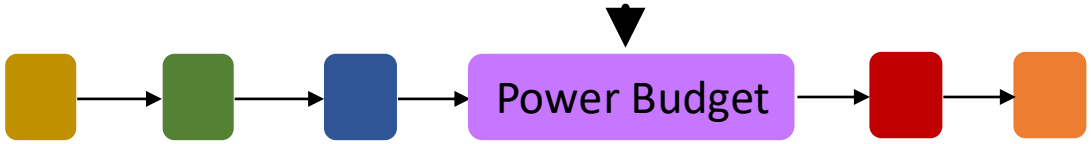
Power Budget

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

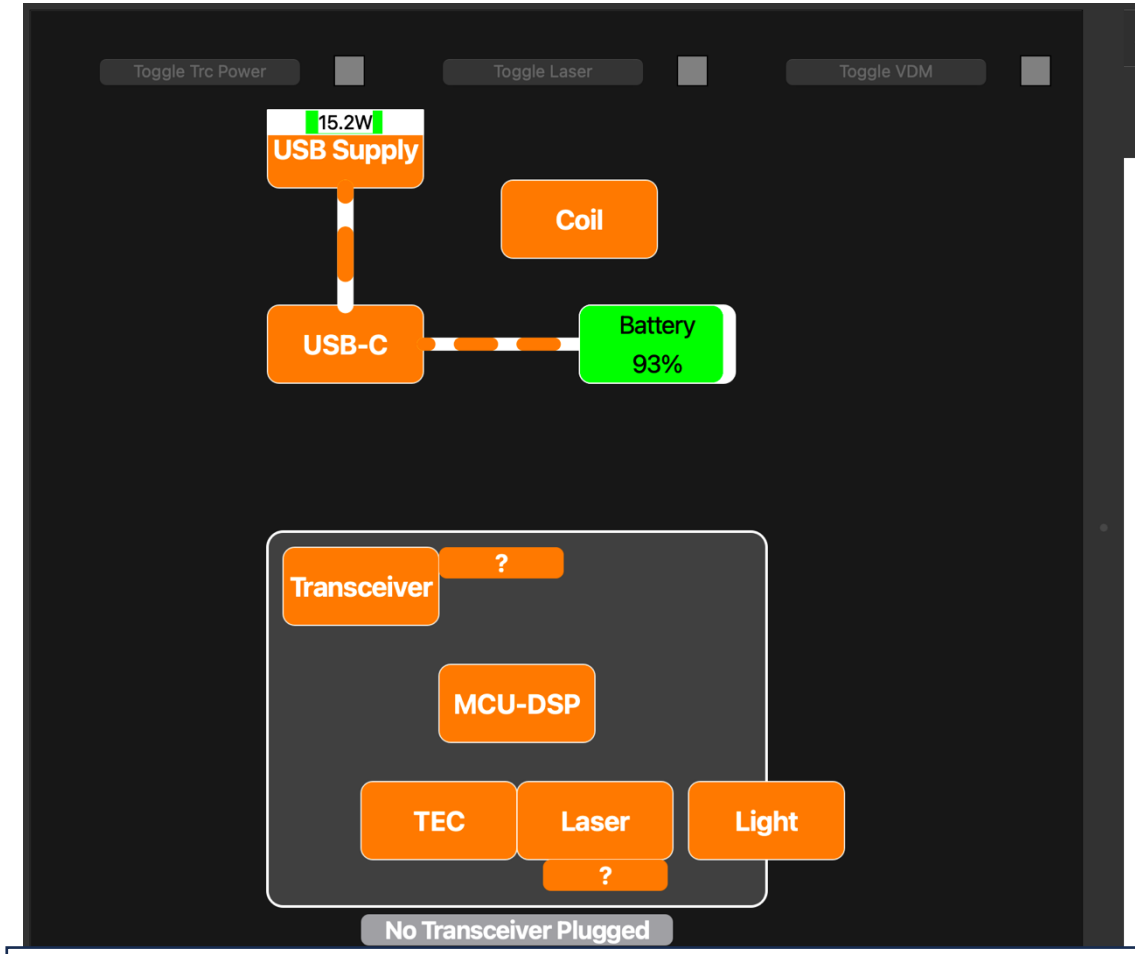
Our shop tells you about max power

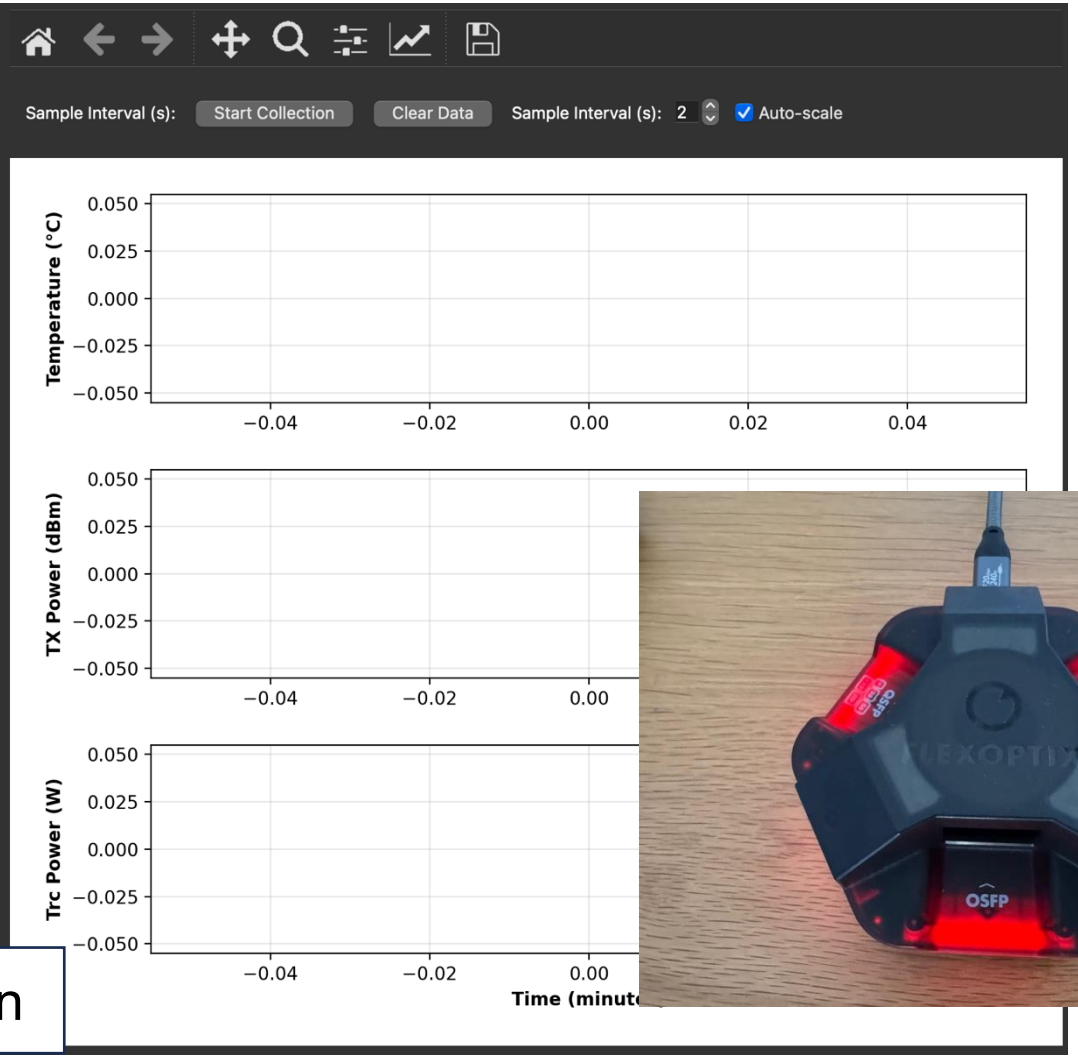
DIGITAL DIAGNOSTIC MONITORING (DDM)	Yes, internally calibrated
POWER CONSUMPTION	22 W
CDR	TX and RX
SGMII	No
INBUILT FEC	Yes, OFEC
POWERBUDGET (DB)	15 dB
TRANSMIT MIN/MAX PER LANE	-5 dBm / 3 dBm
RECEIVER MIN/MAX PER LANE	-12 dBm / 0 dBm (overload) @400G
WAVELENGTH TX (TYPICAL)	tunable Coherent high-power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

Source: [18]

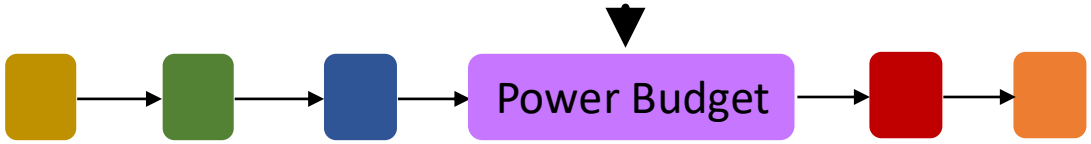


With Flexbox and Research Tool

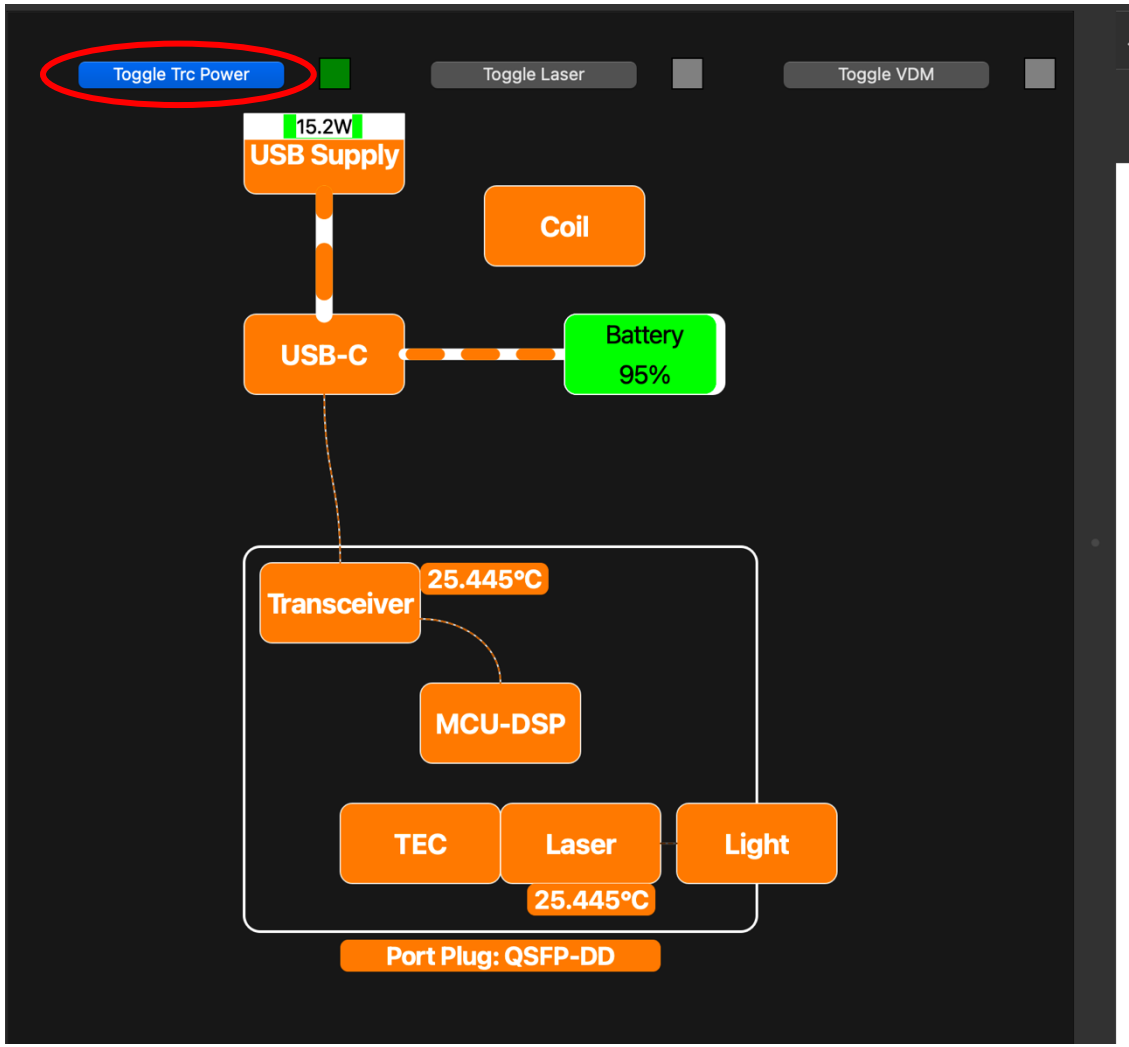


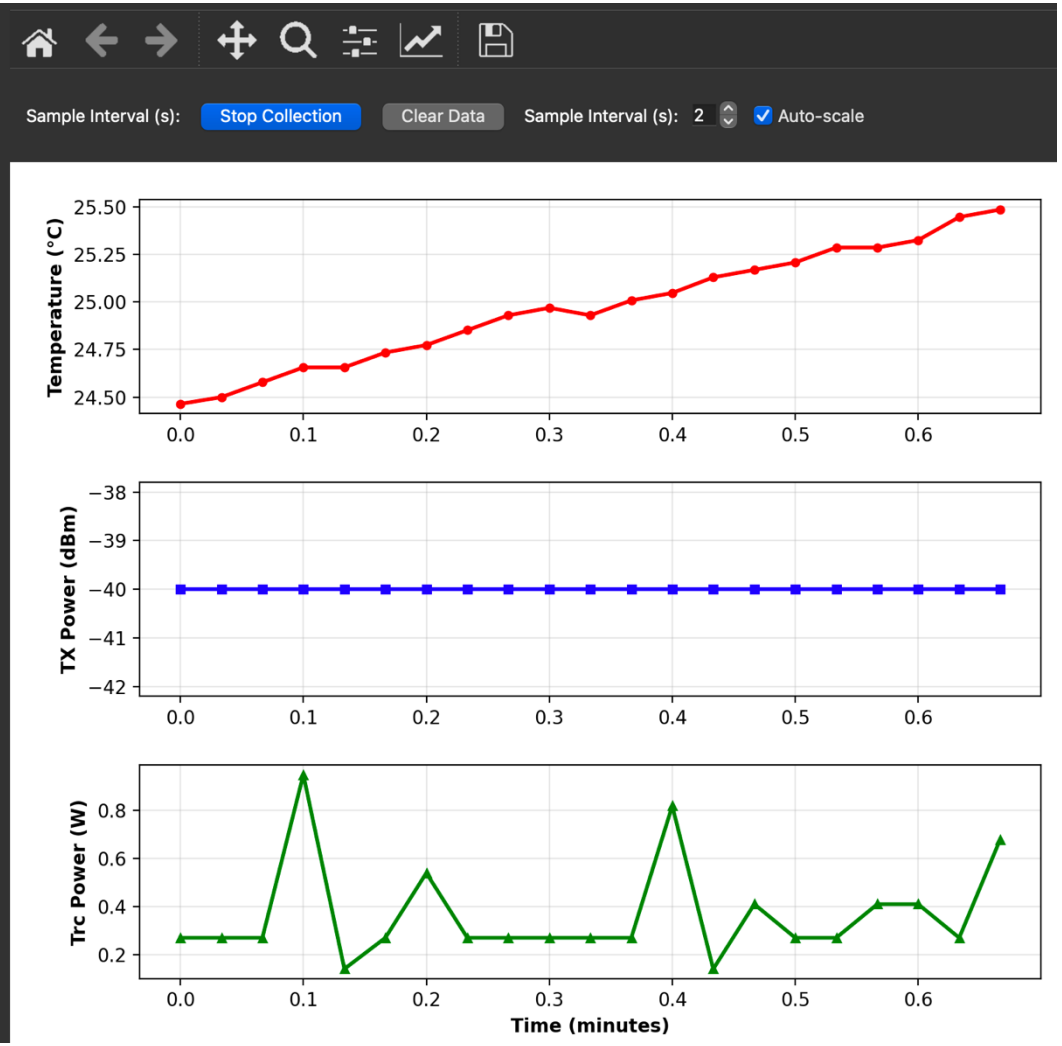


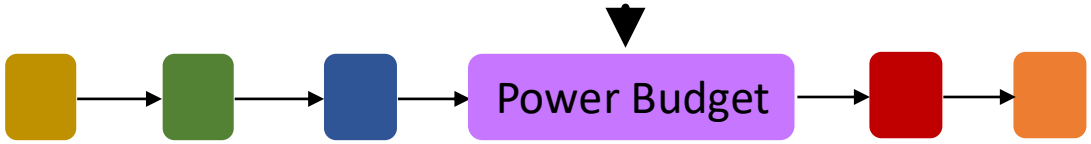
*Python, PyQt and Matplotlib in one application



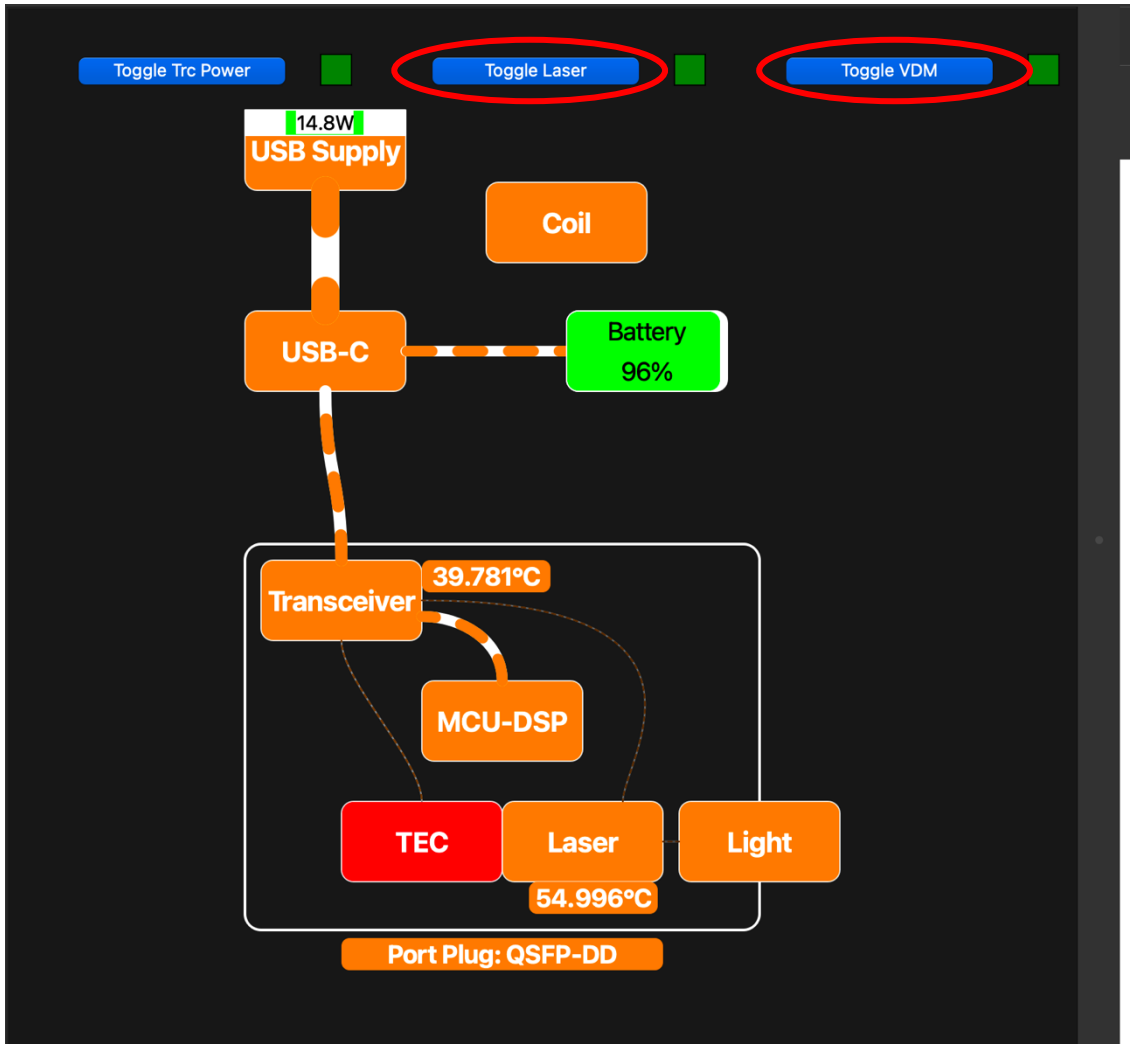
Give the transceiver some power!

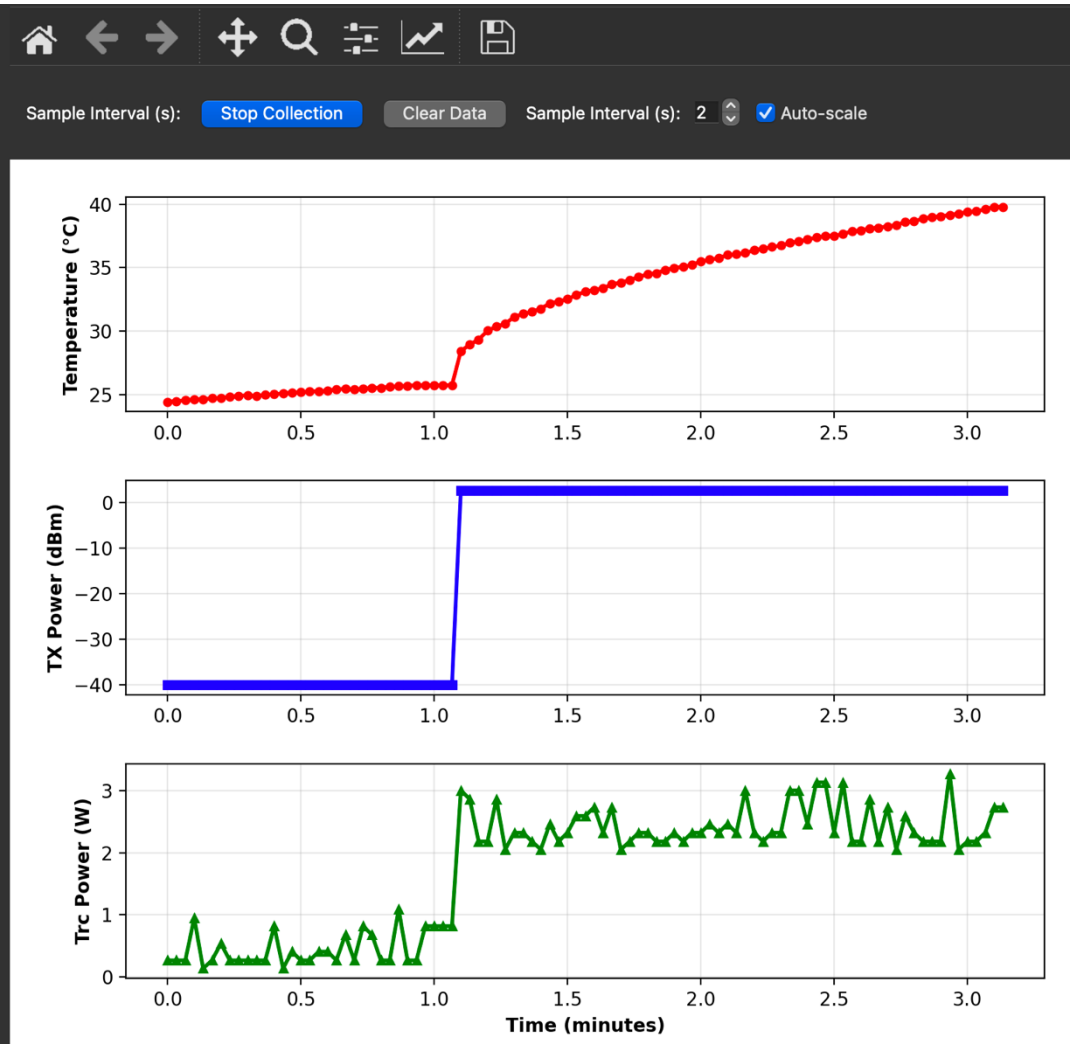


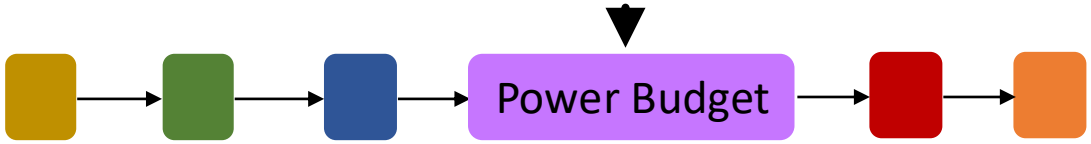




Go Go Laser (and VDM) !!



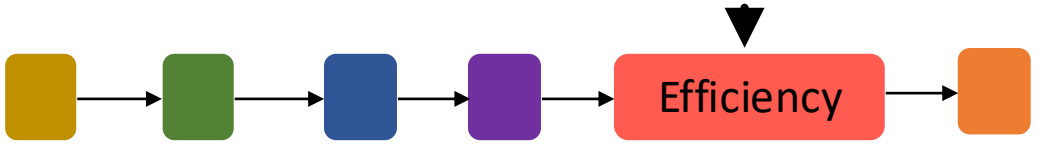




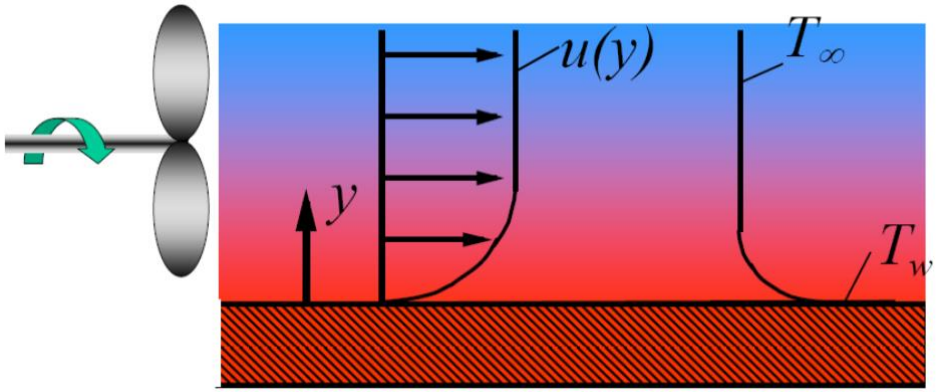
Power Budget – Tech Leap with Trc

Power consumption (Watts)	2018	2020	2023	2025	2026	Changes
400G QDD FR4 2km	12	10.5		9		ASIC swapped by PAM4 DSP with integrated EML Driver. Went from 16 to 7 nm
800G OSFP 2xLR4 Dual Duplex LC			16.5	15.5		Changed EML to SiPho
1.6T OSFP224 2xDR4				30	26	DSP CMOS Node from 5nm reduced to 3nm

Source: [17,18]



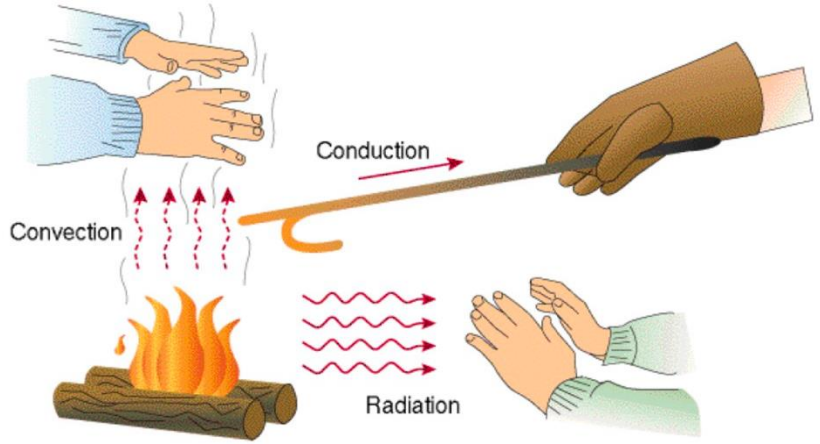
Efficiency: Fan Speed and Heat Exchange

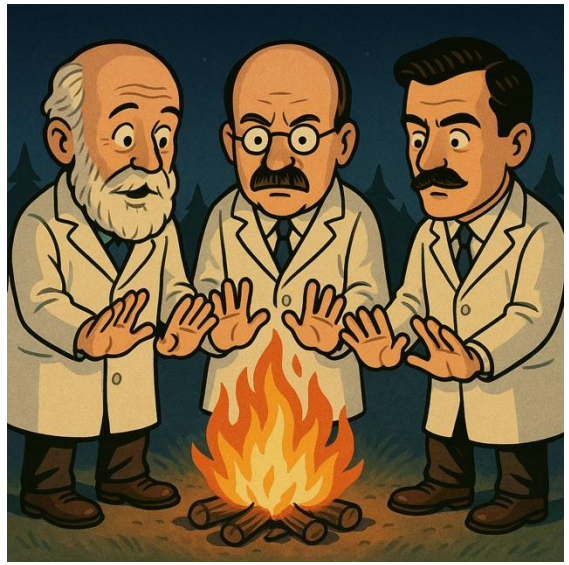


$$P_{Fan} = \frac{\lambda \times Nu}{L} A(T_\infty - T_W)$$

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

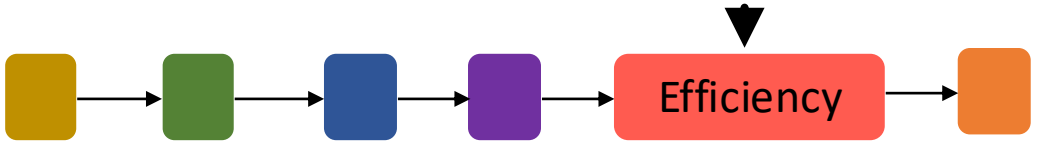
$$Re = \frac{w_\infty L}{\upsilon}$$



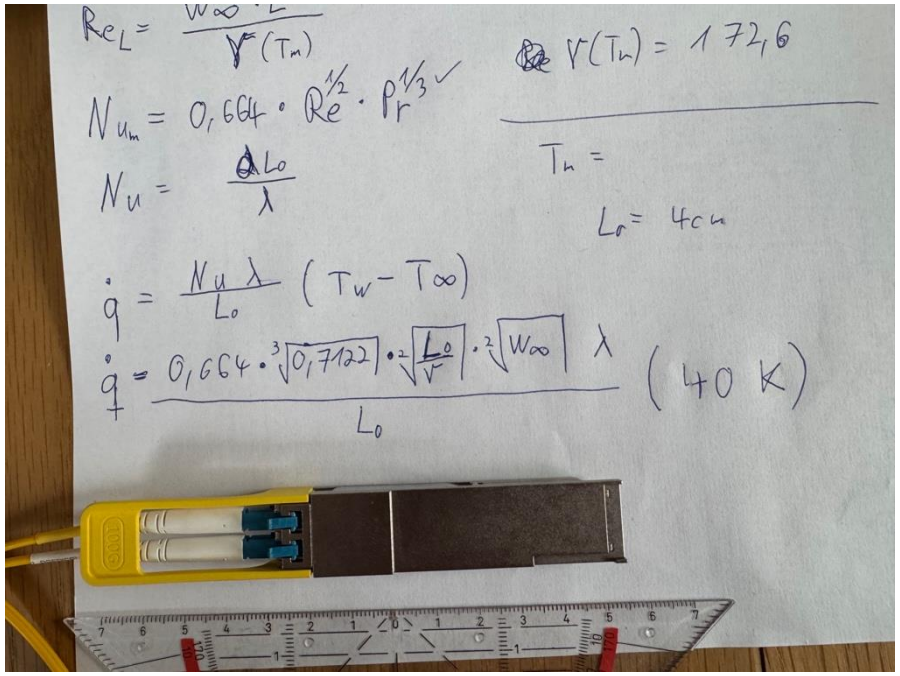


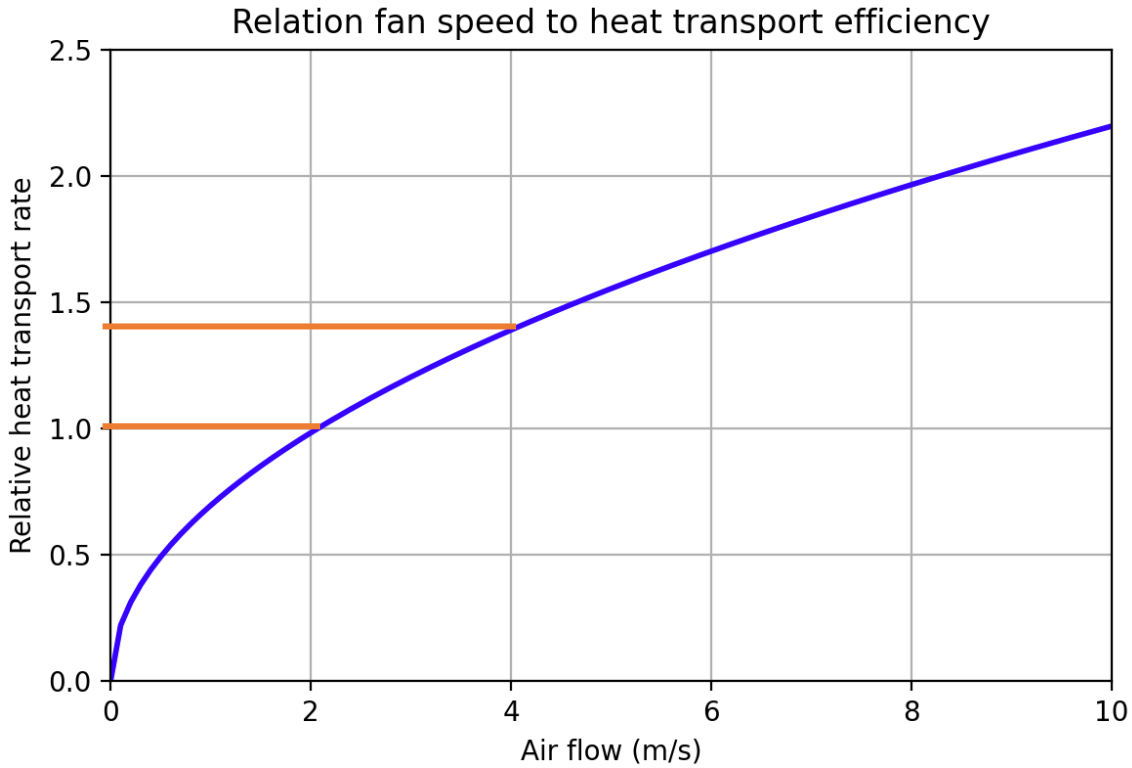
- Nusselt (Nu)
- Prandtl (Pr)
- Reynolds (Re)

Sources: [13]



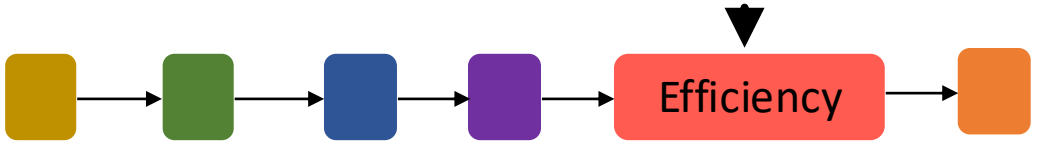
Let's do the math ... and show what matters!





Doubling the Speed does **not** double the Watts!

Sources: [13]

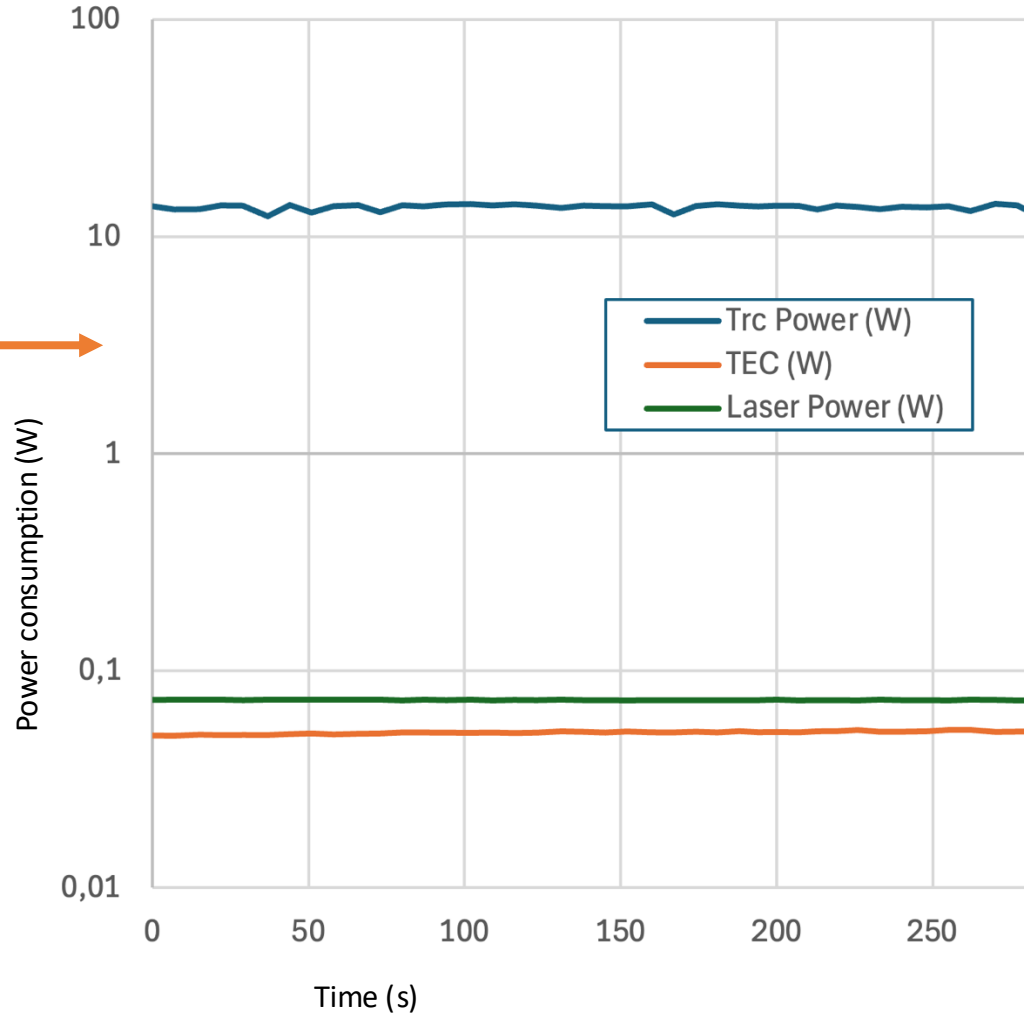


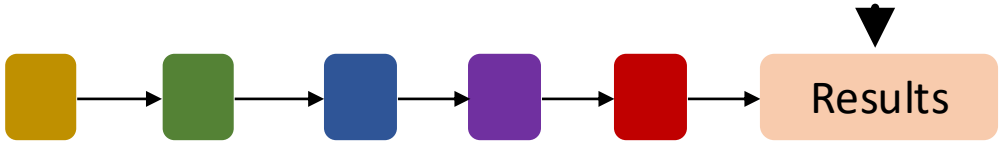
Influence of TEC and Laser Temperatures?

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

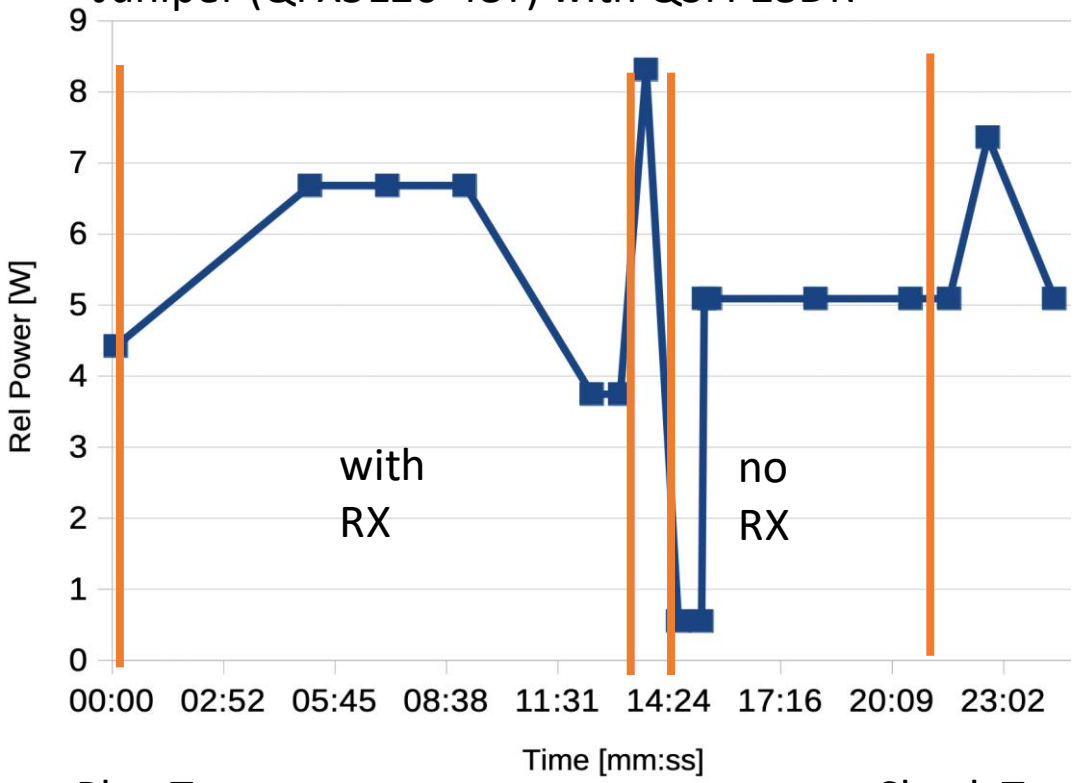
QX	Speed	RPM (approx.)
Q0	0 m/s (obviously)	0
Q1	2.2 m/s	467
Q2	3.0 m/s	637
Q4	3.8 m/s	806





Results: Tests with Switches and Transceivers

Juniper (QFX5120-48Y) with QSFP28DR

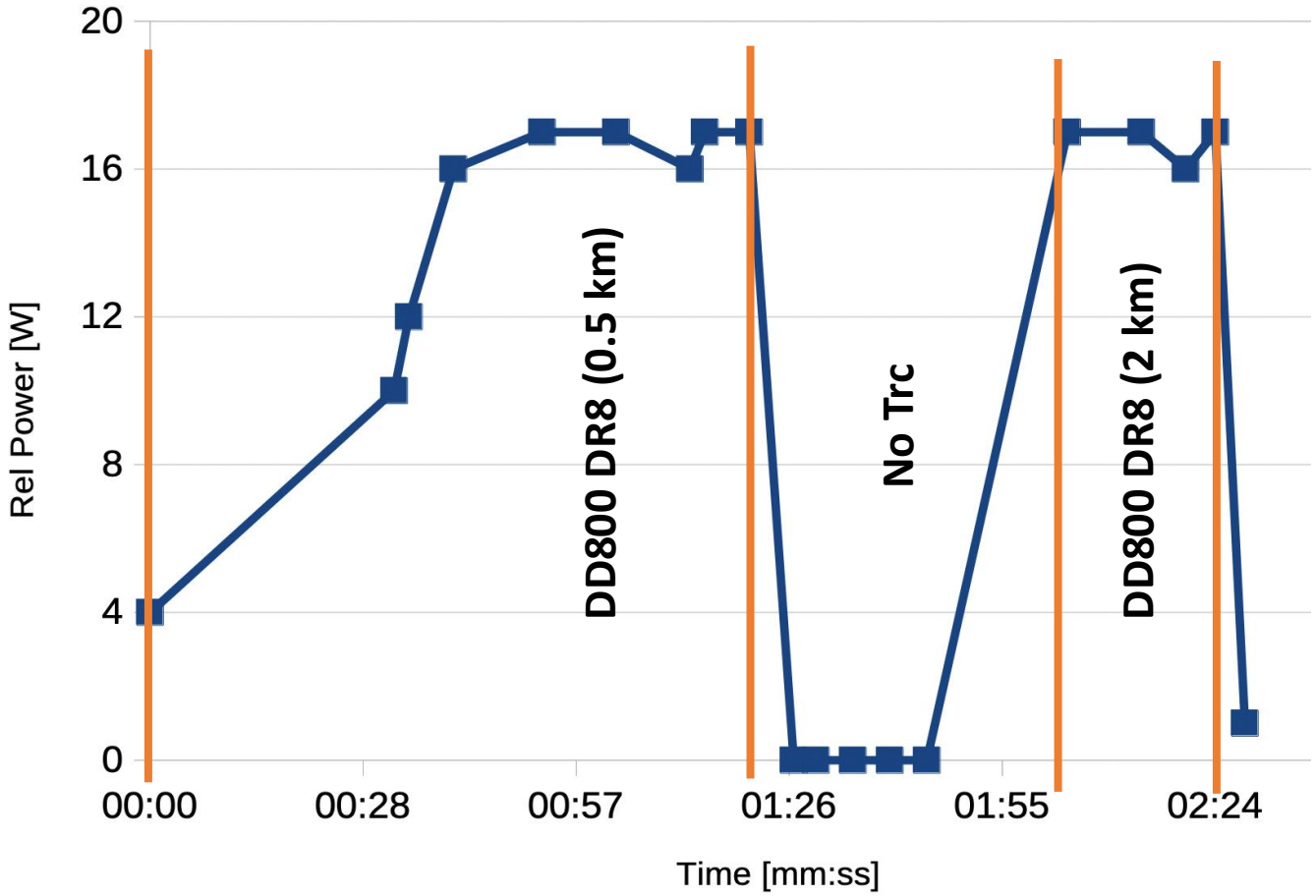


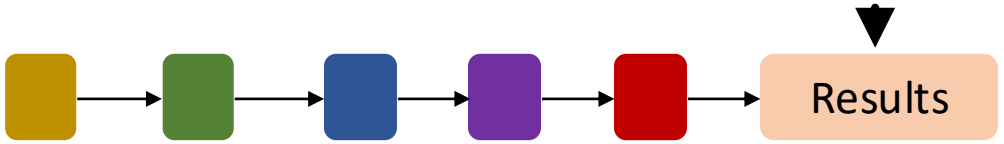
Plug Trc

Check Trc status And replug

Check Trc status

Cisco Nexus with 800G Transceivers



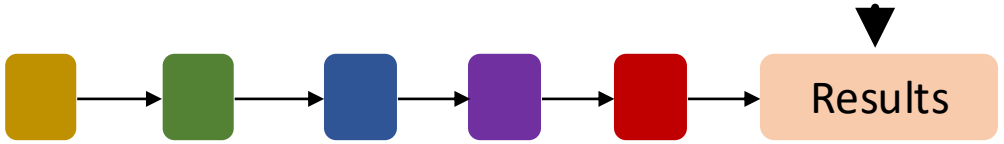


Experiment with Frozen Transceivers

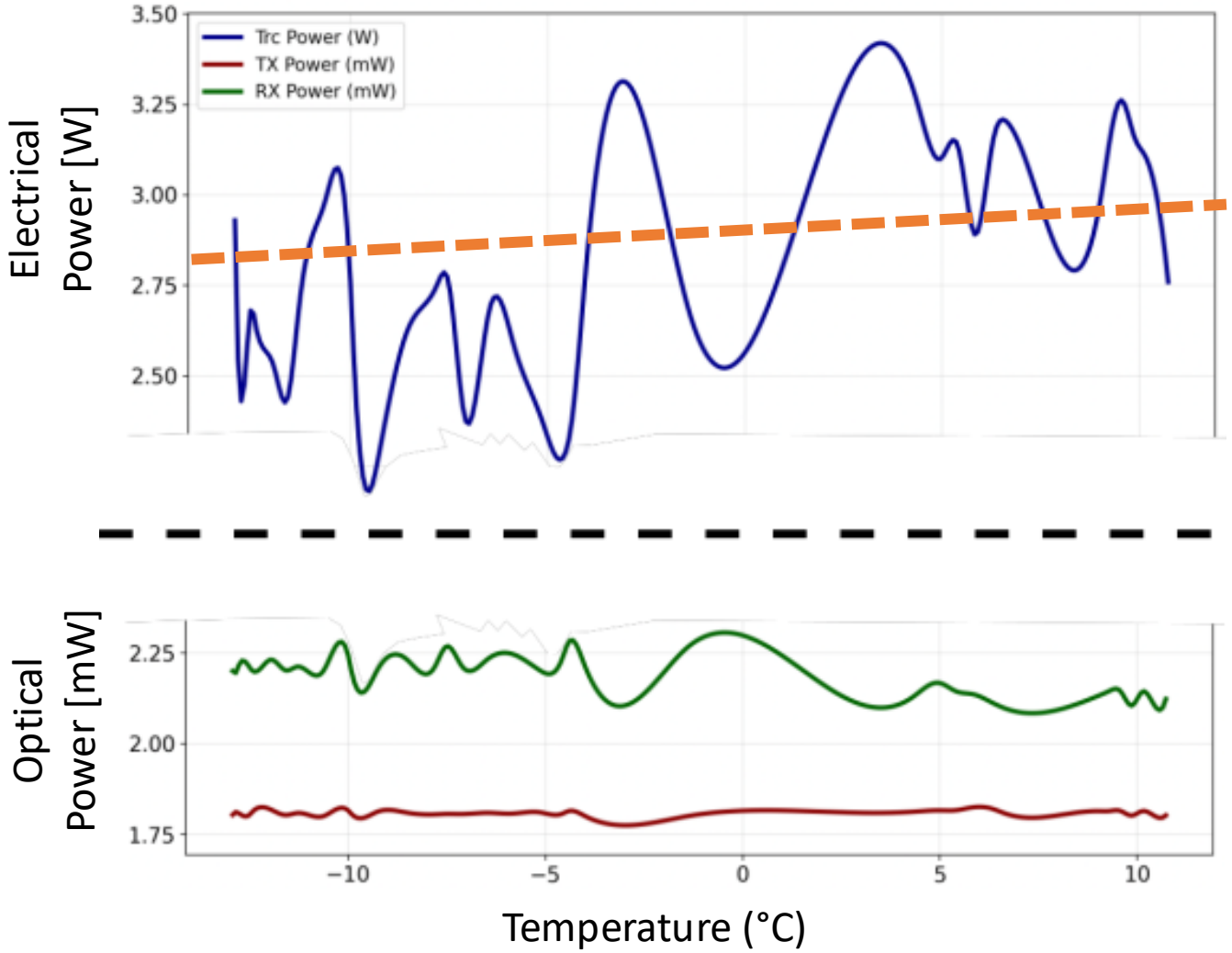
Ice cubes

Flexbox 5

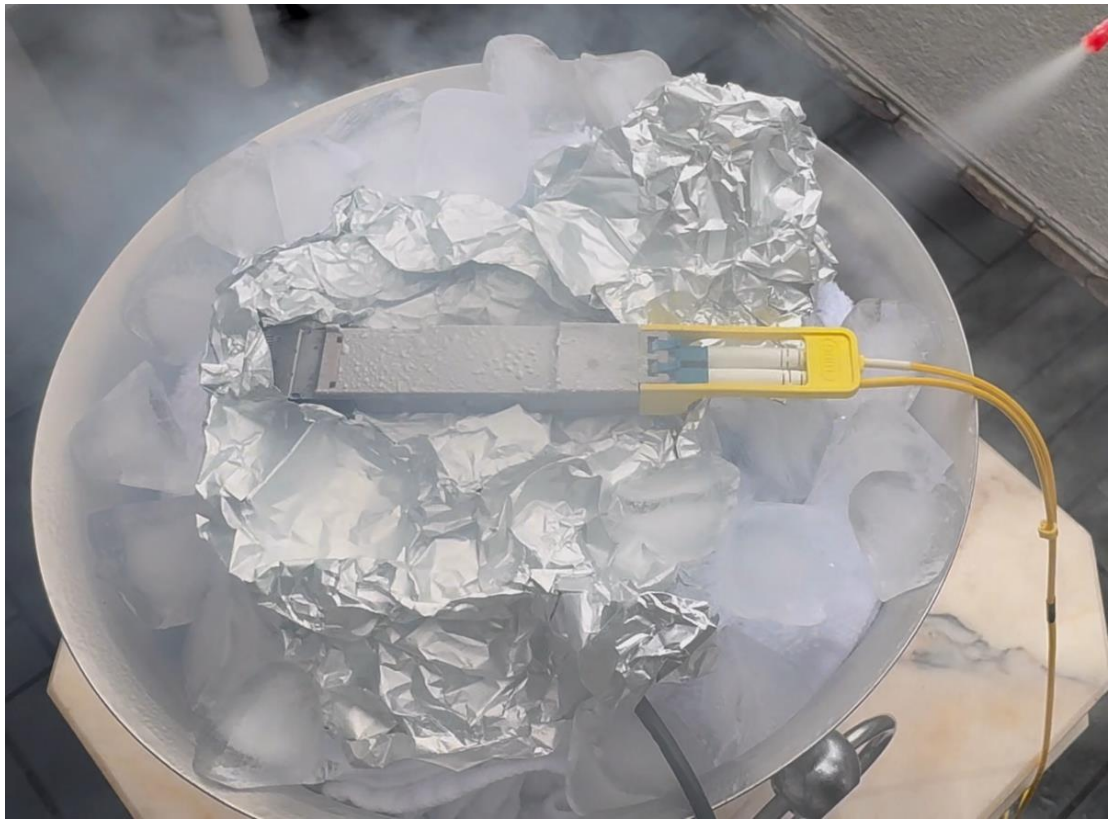
Alumnium Foil



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

Source: [14]

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