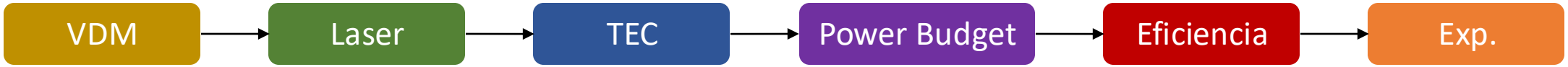
FLEXOPTIX

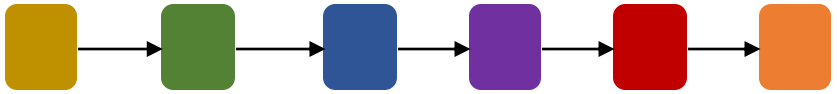
Comprehensión y optimización de la eficiencia de transceptores ópticos

utilizando métricas internas para mejorar el ahorro de energía

Contenido



- **Versatile Diagnostics Monitoring**
- **Laser**: Discusión sobre el rendimiento de lasers (trc)
- **TEC:** El refrigerador termoeléctrico
- **Power Budget:** Como la FLEXBOX administra la energía de transceptores
- **Eficiencia:** Una definición
- **Un Experimento:** Con hielos



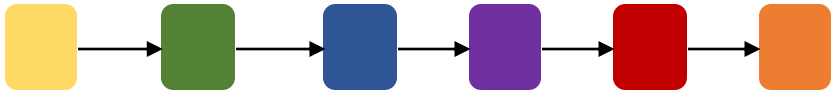
Devices under Test (DUT)

Transceptor/Receptor -> Transceptor -> 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 23.4R2-S5.8



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 Data Monitor (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)

Versatile Diagnostic Monitoring

DDM

Leer datos

Byte	Bit	Name
22	All	Temperature MSB
23	All	Temperature LSB

Calcular valor

VDM

Para cada uno de los desc.

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

¿Cuál es?

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

¿Dónde está el valor?

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

Calcular valor

VDM - Tratamiento

	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
Rx Power	N/A	N/A	N/A	N/A	N/A
Laser temperature	49.98 C	N/A	N/A	N/A	N/A
RX Signal Power	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

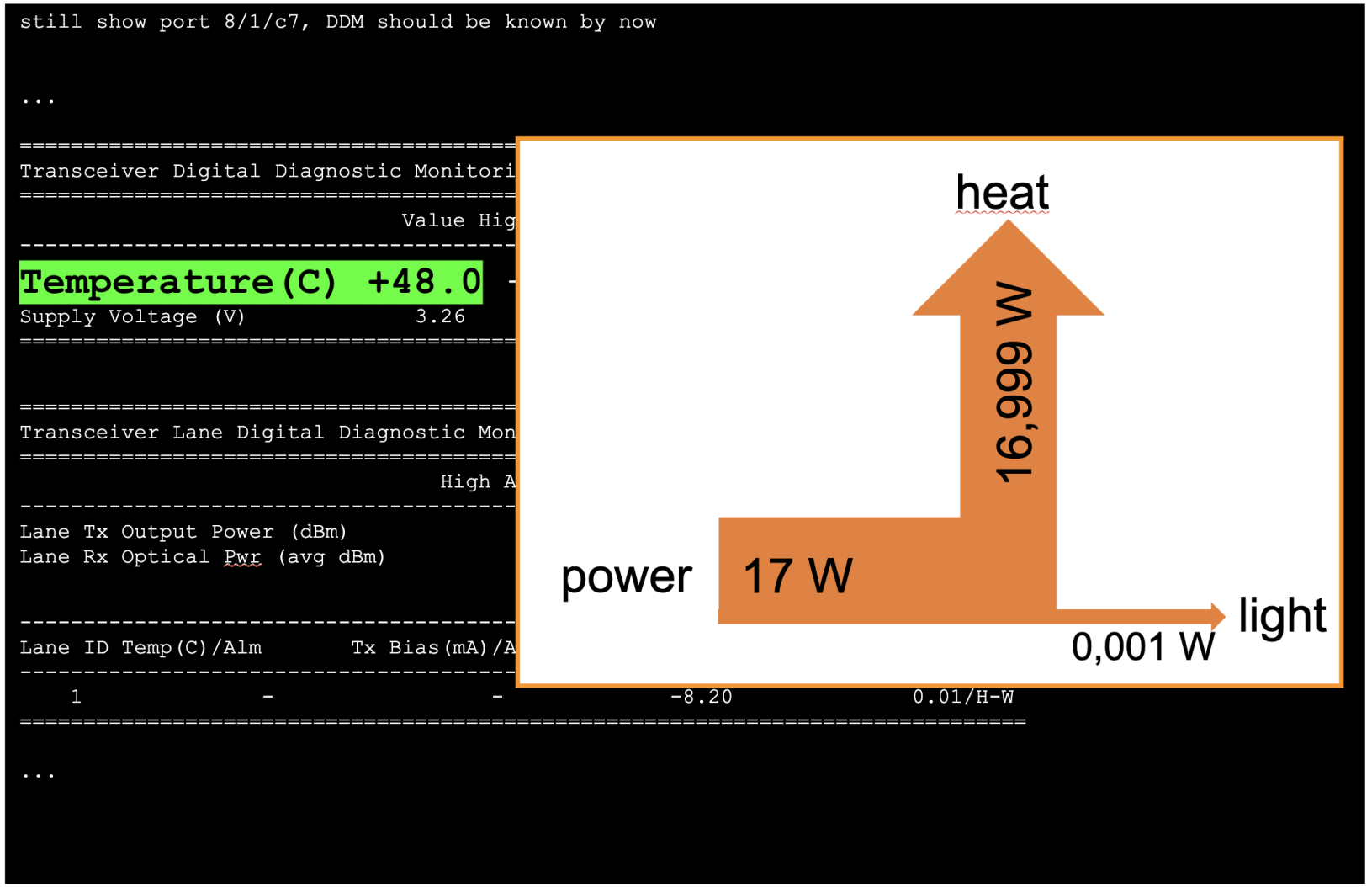
Note: ++ high-alarm; + high-warning; -- low-alarm; - low-warning

Cisco Nexus **93600CD-GX** NX OS 10.5.3 (F)

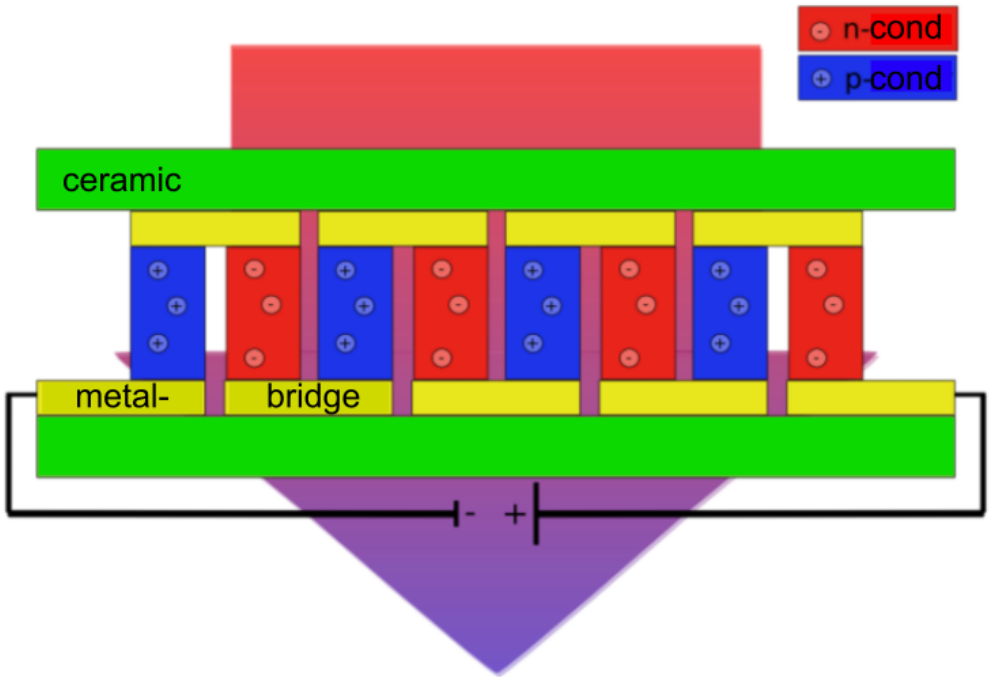
```
ObsCfg(thId=00, lane=Module, type=Laser Age (0% at BOL, 100% EOL) (Media Lane))= 0.0 %
ObsCfg(thId=01, lane=Module, type=TEC Current (Module))= 37.461470381786555 %
ObsCfg(thId=03, lane=Module, type=Laser Temperature (Media Lane))= 0.0 C
ObsCfg(thId=00, lane=0, type=Pre-FEC BER Minimum Sample Media Input (Data Path))= 1.0
ObsCfg(thId=00, lane=0, type=Pre-FEC BER Maximum Sample Media Input (Data Path))= 1.0
ObsCfg(thId=00, lane=0, type=Pre-FEC BER Sample Average Media Input (Data Path))= 1.0
ObsCfg(thId=00, lane=0, type=Pre-FEC BER Current Sample Media Input (Data Path))= 1.0
ObsCfg(thId=01, lane=0, type=Pre-FEC BER Minimum Sample Host Input (Data Path))= 0.000421
ObsCfg(thId=01, lane=0, type=Pre-FEC BER Maximum Sample Host Input (Data Path))= 0.001979
ObsCfg(thId=01, lane=0, type=Pre-FEC BER Sample Average Host Input (Data Path))= 0.0014939999999999999
ObsCfg(thId=01, lane=0, type=Pre-FEC BER Current Sample Host Input (Data Path))= 20470000000
ObsCfg(thId=02, lane=0, type=FERC Minimum Sample Value Media Input (Data Path))= 1.0
ObsCfg(thId=02, lane=0, type=FERC Maximum Sample Value Media Input (Data Path))= 1.0
ObsCfg(thId=02, lane=0, type=FERC Sample Average Value Media Input (Data Path))= 1.0
ObsCfg(thId=02, lane=0, type=FERC Current Sample Value Media Input (Data Path))= 1.0
ObsCfg(thId=03, lane=0, type=FERC Minimum Sample Value Host Input (Data Path))= 3.0
ObsCfg(thId=03, lane=0, type=FERC Maximum Sample Value Host Input (Data Path))= 5.0
ObsCfg(thId=03, lane=0, type=FERC Sample Average Value Host Input (Data Path))= 438000
ObsCfg(thId=03, lane=0, type=FERC Current Sample Value Host Input (Data Path))= 0
```

Flexoptix Research Application

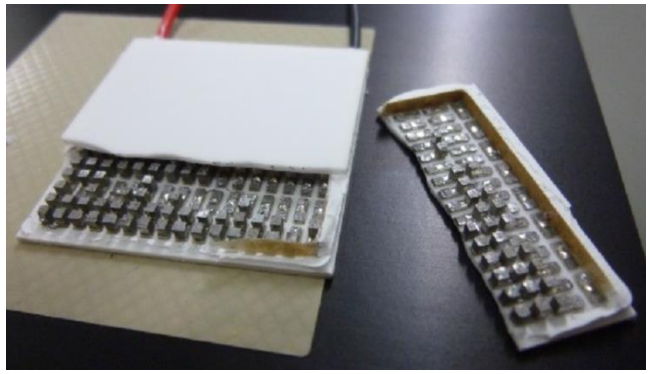
Excursión: Trc coherente (2023/2024)



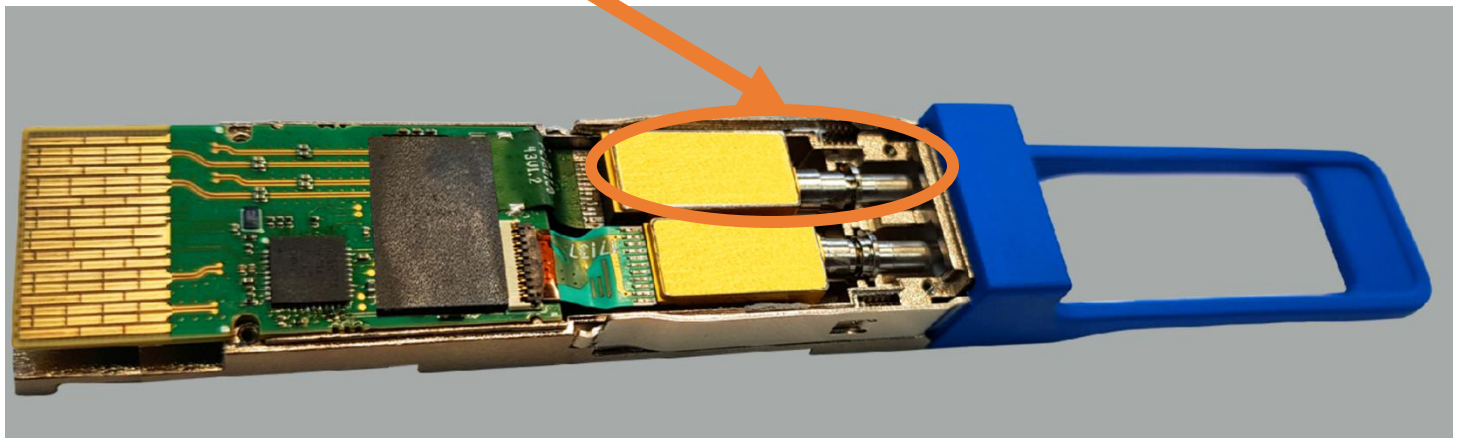
Refri eléctrico (TEC)



Un elemento Peltier típico en grande …



…pero el TEC es muy pequeño -> TOSA



Sources: [?]

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.

SFF8636 (QSFP+, QSFP28) ->
Aquí ya está el max. power establecido
(con excepción de clase 8)

Byte	Bits	Field Name	Field Description	Type
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	RO Rqd.
	4-0	-	**Reserved**	RO
201	7-0	MaxPower	Maximum power consumption in multiples of 0.25 W rounded up to the next whole multiple of 0.25 W	RO Rqd.

Note 1: See relevant hardware specification for maximum power allowed in each Power class

CMIS (QSFP-DD, OSFP) ->
Vendor puede poner la clase que quiera, poner el max. power que pide

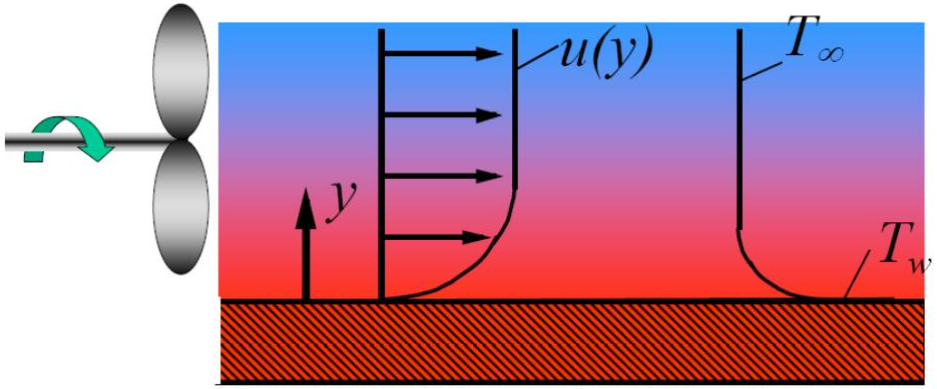
Example: D.CO164HG.2.yTP
(480km @ 400G ZR+)

Nuestra tienda lo sabe…

DIGITAL DIAGNOSTIC MONITORING (DDM)	Yes, internally calibrated
POWER CONSUMPTION	21 W
CDR	TX and RX
SGMII	No
INBUILT FEC	Yes, OFEC
POWERBUDGET (DB)	6 dB
TRANSMIT MIN/MAX PER LANE	-10 dBm / -6 dBm
RECEIVER MIN/MAX PER LANE	-12 dBm / 0 dBm (overload) @400G
WAVELENGTH TX (TYPICAL)	tunable Coherent DWDM

Source: [1,2]

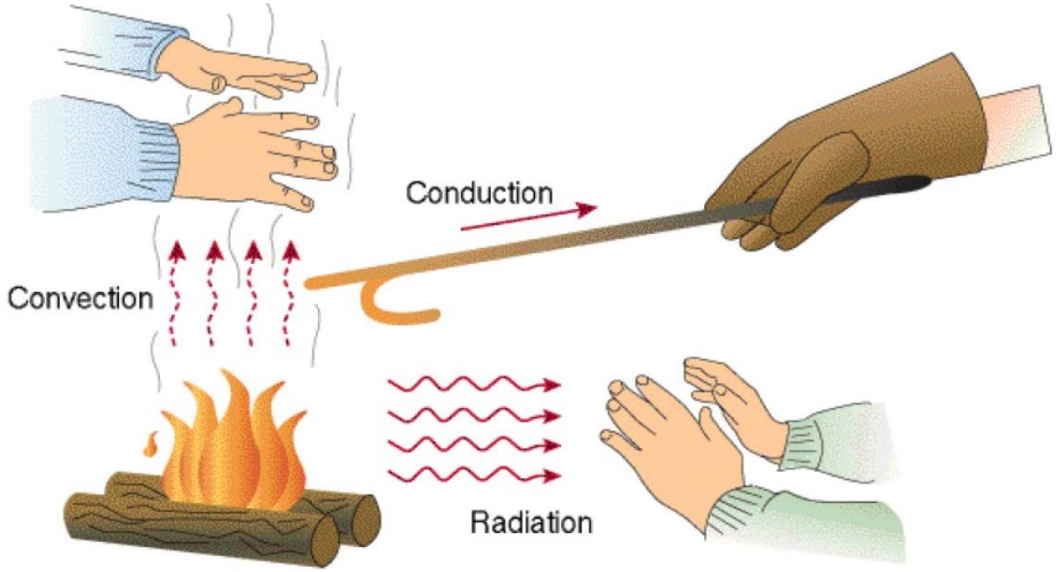
Eficiencia: Como un ventilador transfiere calor

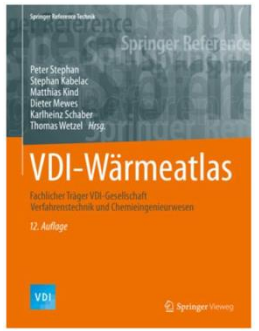


$$P_{Fan} = \frac{\lambda \times Nu}{L} A(T_\infty - T_W)$$

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

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





Sources: [13]

Experimento con un transceptor congelado

Cubos de hielo

Flexbox 5

Láminas de aluminio

Estrenando la version completa en

DENOG 17

GERMAN NETWORK OPERATORS GROUP

Con resultados y más:

Nos vemos en la

ESNOG 35

Source: [14]

Muchas gracias

Source: [14]

References

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