Vertically Integrated Systems

Advanced VCSEL for High Temperature Operation

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Outline

- Introduction
- Relibility of the devices
- LIV study
- Optimal currents and modulation voltage
- 10Gb/s eye diagrams at 105°C at 3 mA
- Multi-rate operation
- Expected lifetime at 10 Gb/s at 105°C

Key Targets

SPEED

10 Gbps

- Cameras
- Displays
- Data Sharing

→ Up to 10 Gb/s at 105°C

→ Electromagnetic interference is not relevant for optical links

Expect to have few, if any, needs for speeds greater than 1 Gbps but less than 10 Gbps

http://ieee802.org/3/NGAUTO/public/jan17/Wienckowski_3NGAUTO_02a_0117.pdf

AUTOMOTIVE ENVIRONMENT

Voltage Requirements

- http://www.ieee802.org/3/bw/public/Wienchowski_3bw_02_0914.pdf

Environmental Requirements

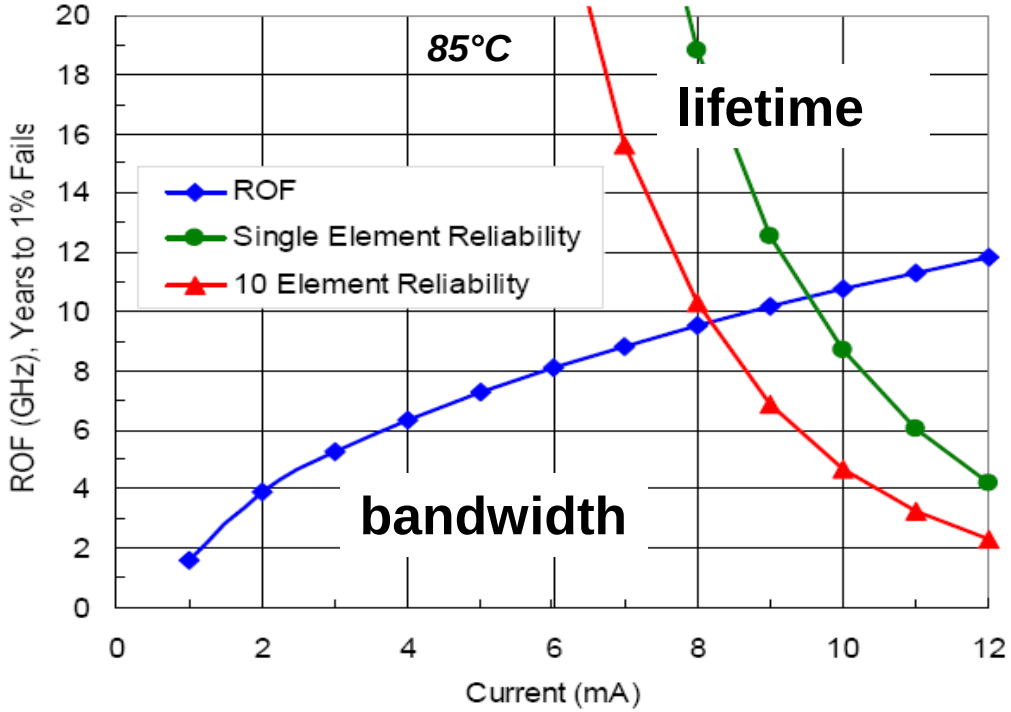
- See 802.3 Clause 96.9
- Max ambient temperature of 105°C

GENERAL MOTORS

EMC Considerations

- Not all frequencies have strict Radiated Emissions limits
- Consider using frequencies whose multiples fall into these "Open" bands
- Even a 59th harmonic can be an issue if the limit line is low

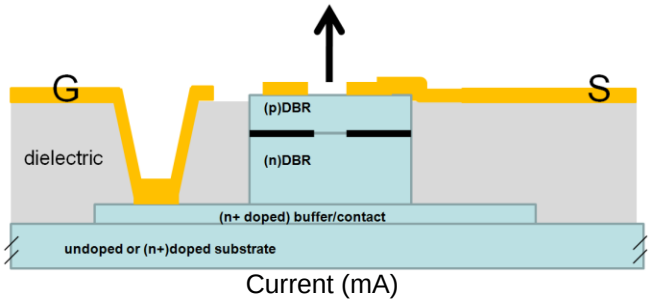
Key issue: Reliability

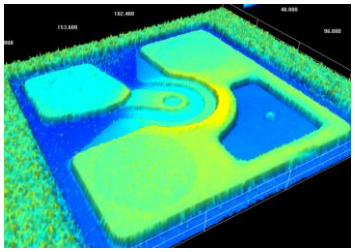


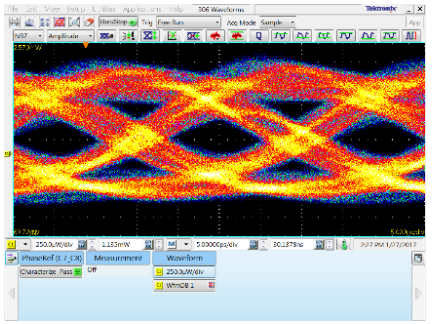
Finisar

- VCSEL lifetime decreases with current increase
- VCSEL lifetime decreases with temperature increase
- **For high temperature operation low current density is needed to ensure reliability**
- **Only VCSELs relaible at very high current density may be suitable for 10G reliable operation at 105ºC**

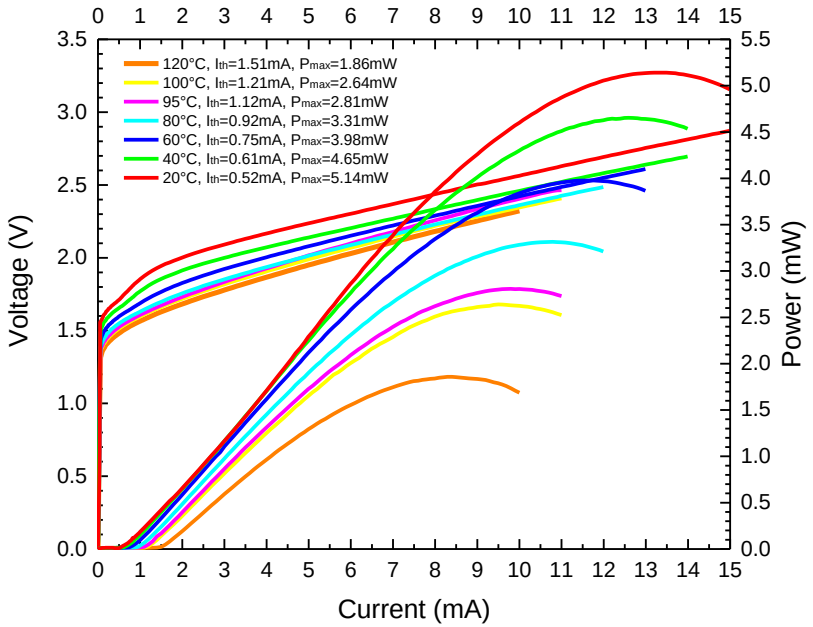
VIS VCSEL: Present Status

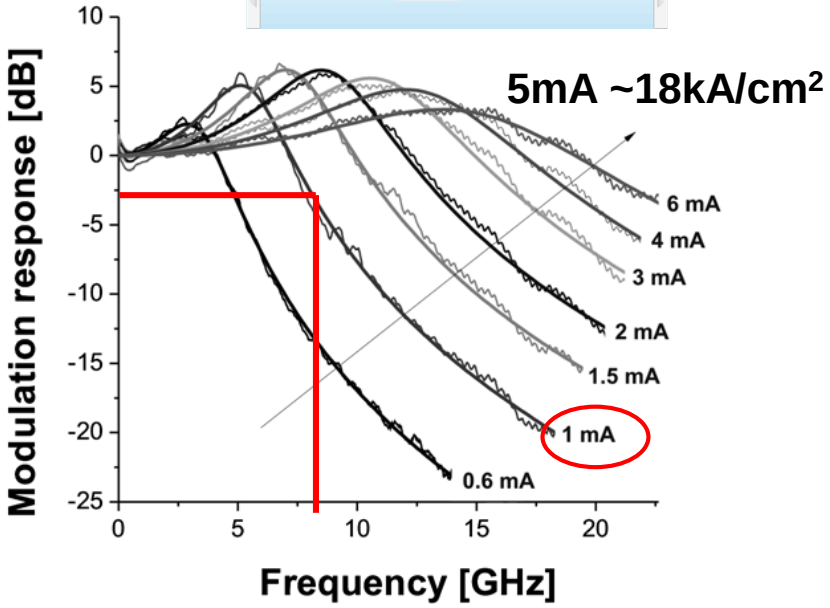






50Gb/s

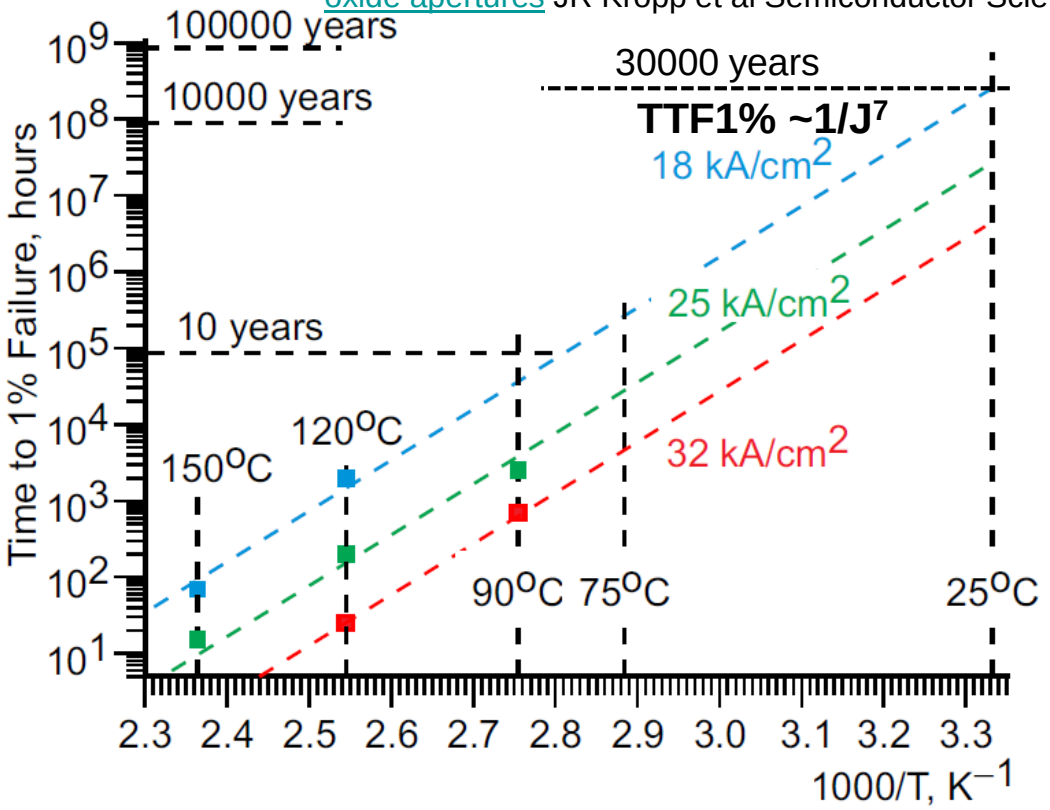


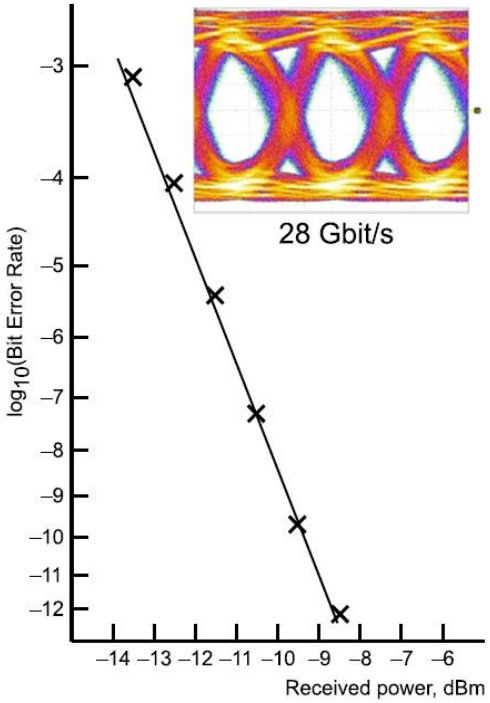


- 1mA (6 µm aperture): f_{-3dB}~8GHz, 10Gb/s operation
- 1 mA at room temperature is enough for 10Gb/s (~3.6kA/cm2)

850 nm VCSEL studied: Accelerated Ageing

Accelerated aging of 28 Gb s− 1 850 nm vertical-cavity surface-emitting laser with multiple thick oxide apertures JR Kropp et al Semiconductor Science and Technology 30 (4), 045001(2015)





- Wafer level tests: 600 chips. Tested at 3 currents each at 3 temperatures
- 30 thousand years extrapolated to 1% failure at RT at 18kA/cm^2 (5mA)
- Lifetime increases as ~1/(current)^7
- Lifetime decreases 30000-fold by temperature increase to 105^{o}C

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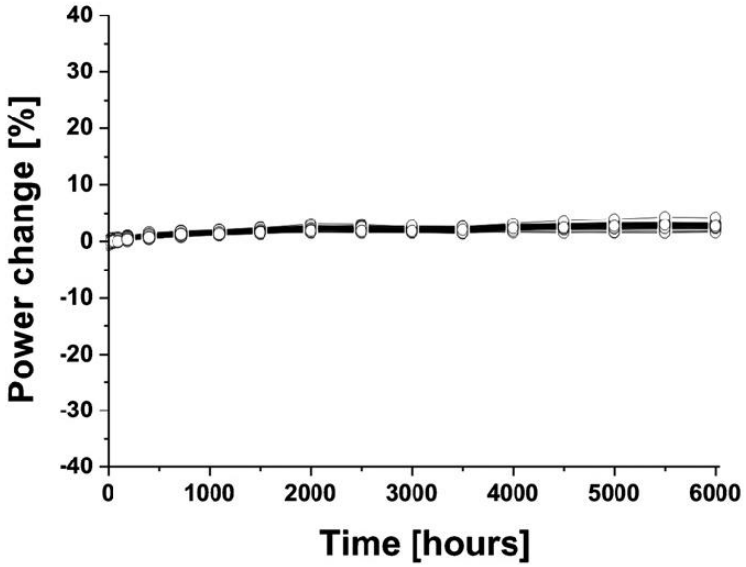
VIS chips studied: Long run reliability



- → >6000h at 95°C (>0.7 years)
- → 18 kA/cm^2 (6 µm aperture)
- → 25Gb/s – compatible at 95°C

References on ageing studies of VIS chips:

„Accelerated aging of 28 Gb s−1 850 nm vertical-cavity surface-emitting laser with multiple thick oxide apertures“

J.R. Kropp et al Semiconductor Science and Technology 30 (4), 045001(2015)

N.N. Ledentsov et al. Proc. SPIE 8276, 82760K (2012); doi:10.1117/12.902643

L. Ya. Karachinsky et al Semicond. Sci. Technol. 28 065010 (2013) doi:10.1088/0268-1242/28/6/065010

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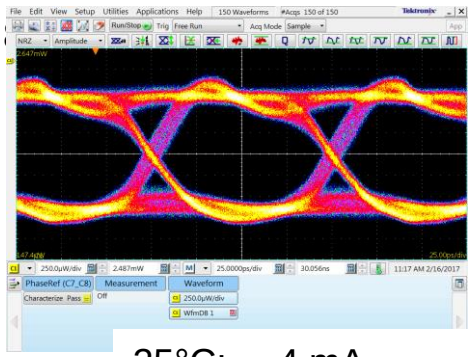
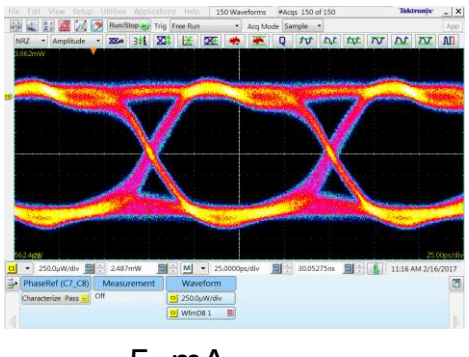
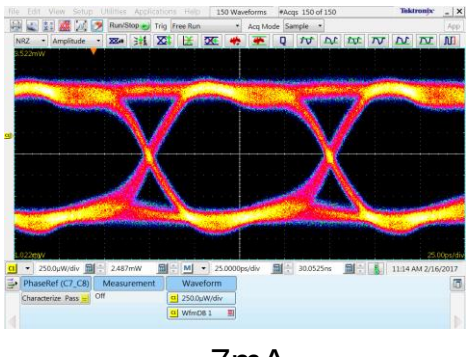
Eye diagrams at 10Gb/s



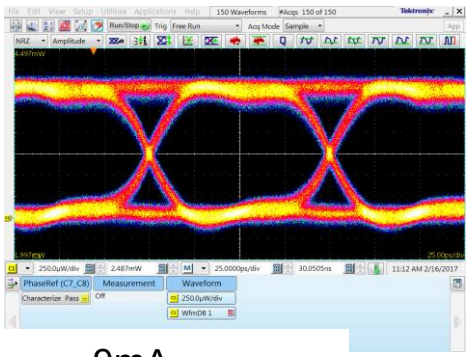
25°C: 4 mA



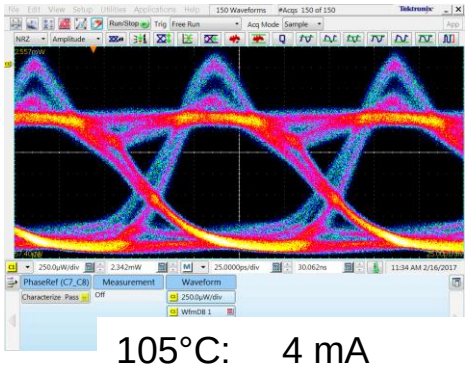
5 mA



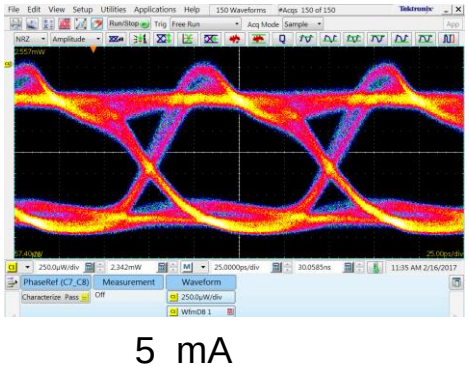
7mA



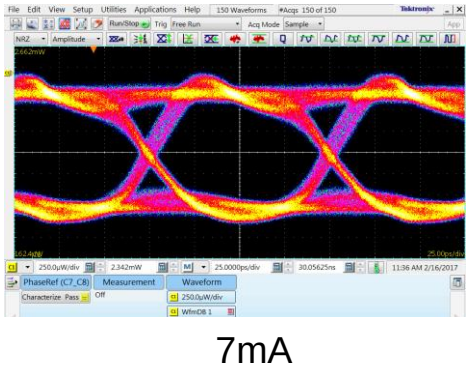
9mA



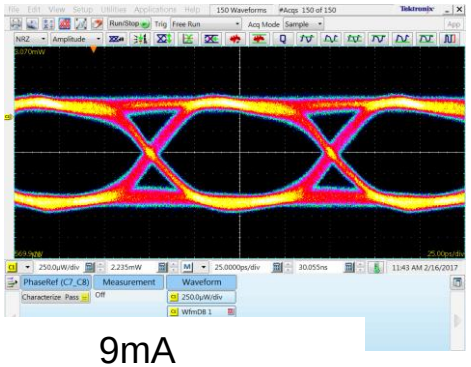
105°C: 4 mA



5 mA

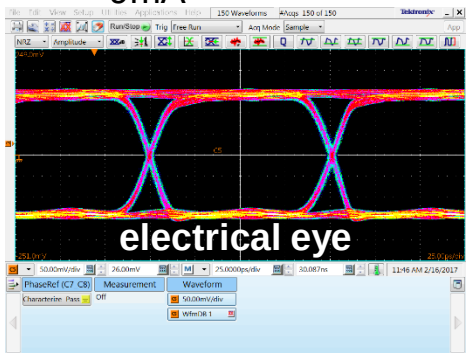


7mA



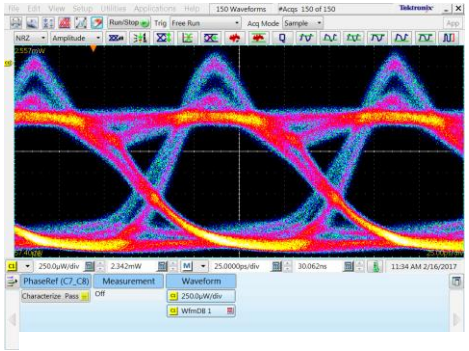
9mA

30GHz linear receiver (not optimal for 10G eyes)

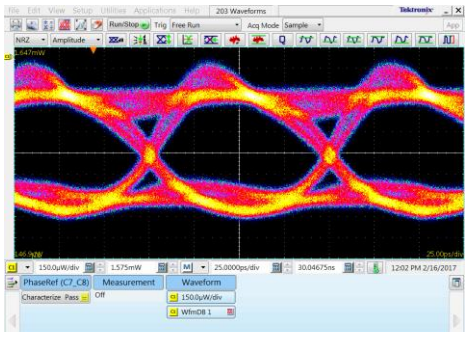


- No significant change in the eye diagram 5 – 9 mA
- Peak-to-pek modulation voltage 0.3V is too high at 105°C

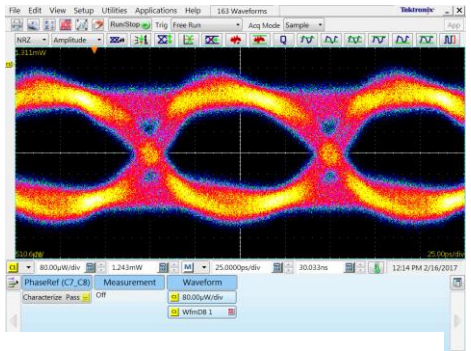
Eye diagrams at 10Gb/s



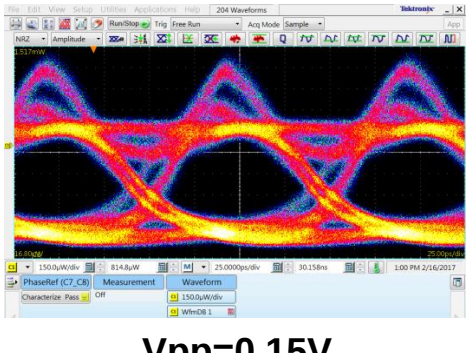
105°C 4 mA Vpp =0.3V



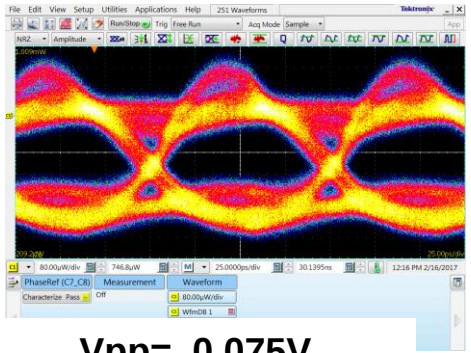
Vpp =0.15V



Vpp= 0.075V



105°C 3 mA



Vpp=0.15V

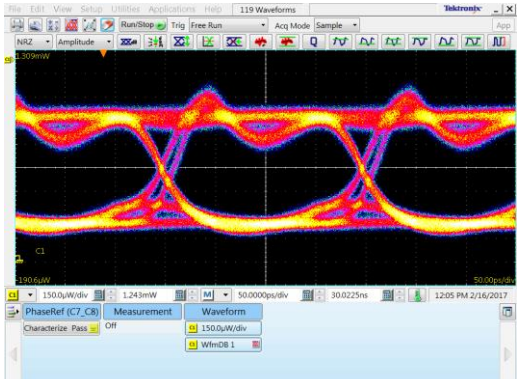
Vpp= 0.075V

30GHz linear receiver (not optimal for 10G eyes)

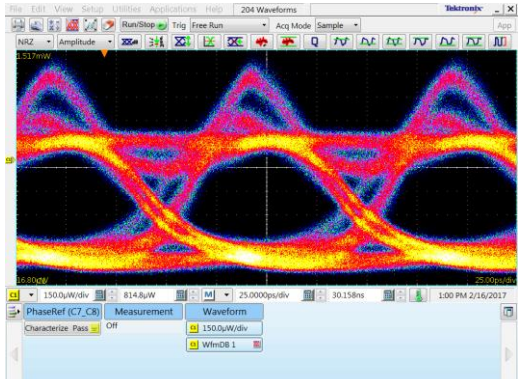
→ At small currents small modulation voltage is applied to avoid signal distortion due to the reaching of the laser threshold current

Different bit rates and receivers

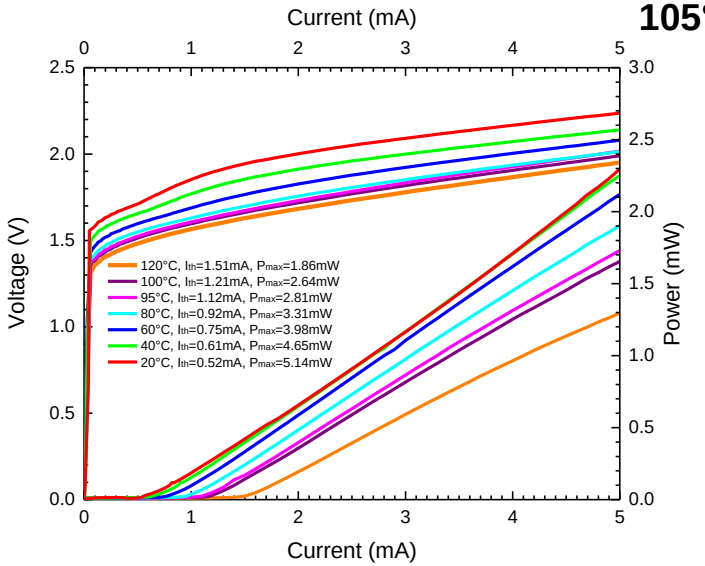
30GHz linear receiver
(evaluation of the optical eye)



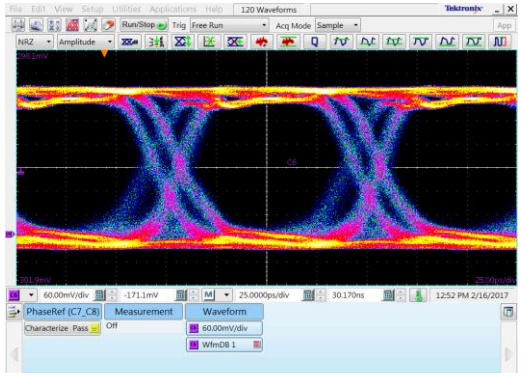
105°C 3 mA Vpp=0.15V 5 Gb/s



10 Gb/s



VIS 40G ROSA
35GHz limiting TIA
(evalutaion of electrical eye)



105°C 3 mA Vpp=0.15V 10 Gb/s

→ Reliable electrical eye at 10 Gb/s 3mA 105°C

Conclusions

- Devices, which passed the qualification test are studied
- 10 Gb/s performance at 105°C at moderate current density (10 kA/cm^2)
- Lifetime increases as ~1/(current)^7: at 3mA lifetime increases 36-fold over the 5mA lifetime
- **36 years of the estimated lifetime to 1% failure at 10Gb/s at 105°C**
- The design is optimized for the range of up to 85°C. Several approaches can be applied to improve temperature stability further to 105°C