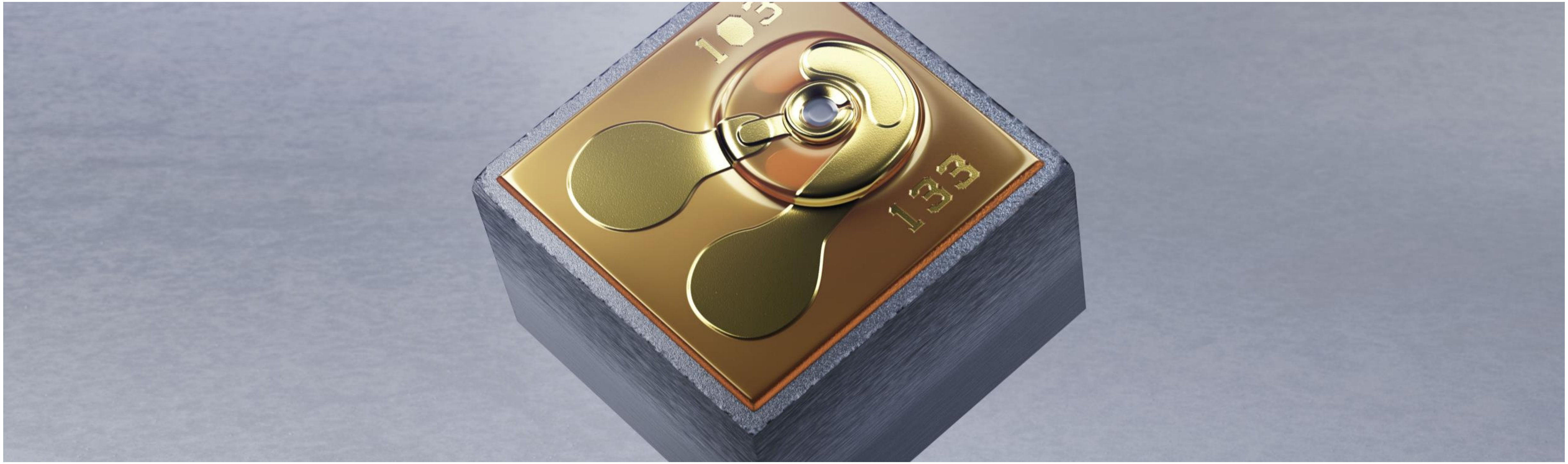

IEEE 802.3cz Multi-Gigabit Optical Automotive Ethernet Task Force – May 18, 2021 Teleconference

VCSEL design for automotive datacom
Experimental results for 980 nm versus 850 nm

Roger King, TRUMPF Photonic Components GmbH

Supported by Joseph Pankert, TRUMPF Photonic Components GmbH

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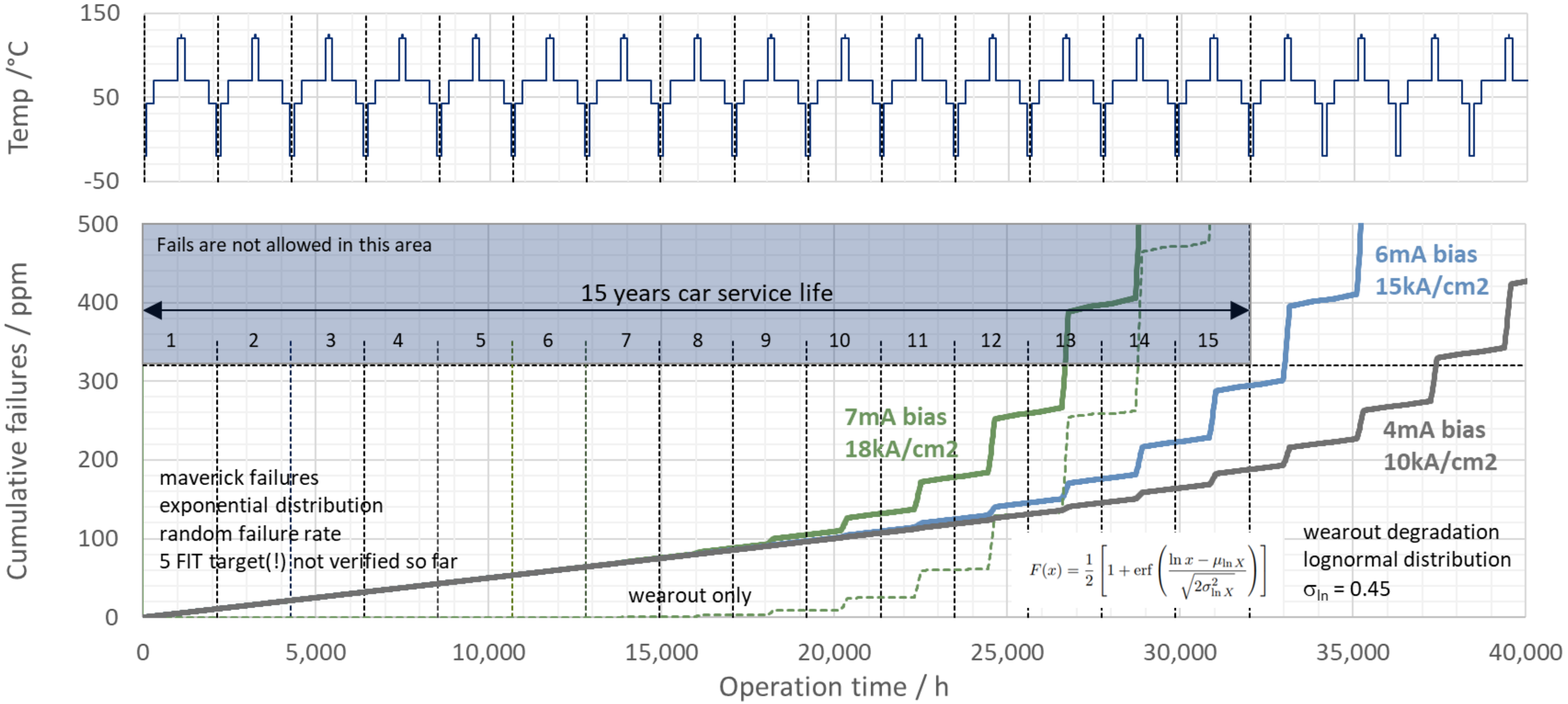
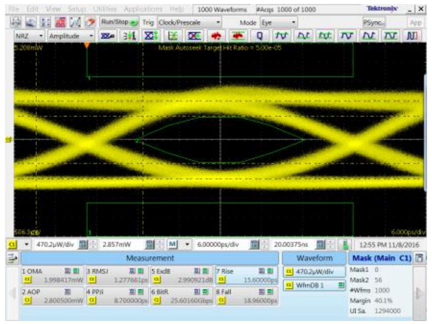
VCSEL design for 25/50 Gb/s automotive datacom

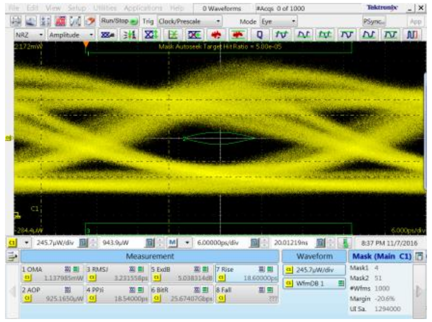
Todays 850nm 25G VCSEL design is on the edge for automotive



Today
850 nm VCSEL @ 7mA, 70°C



Todays VCSEL at automotive
850 nm VCSEL @ 4mA, 100°C



Todays 25/50 Gb/s VCSELs are operated at 18 kA/cm2, 70°C
But operation with <15 kA/cm2 at chip backside up to 125°C is required to support 15 years car service life

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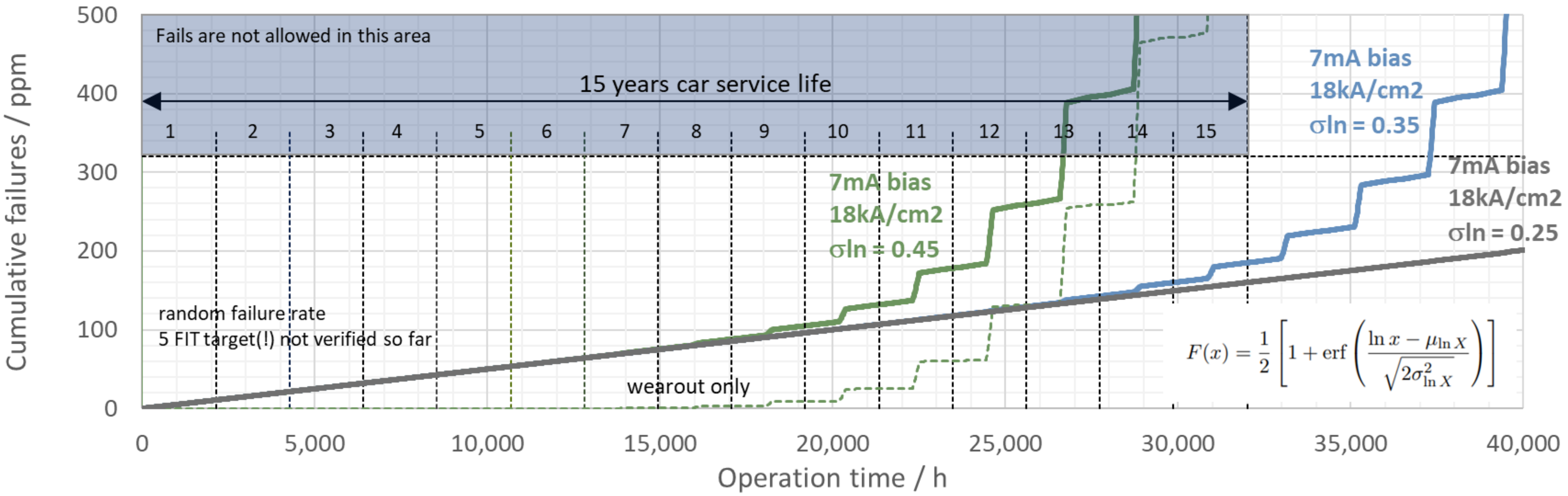
Improvement strategy "reduce wear out scale"

The "how" is not clear



"σln < 0.45" is already very challenging for todays 850nm VCSEL

"σln < 0.25" is an unrealistic target for long term production

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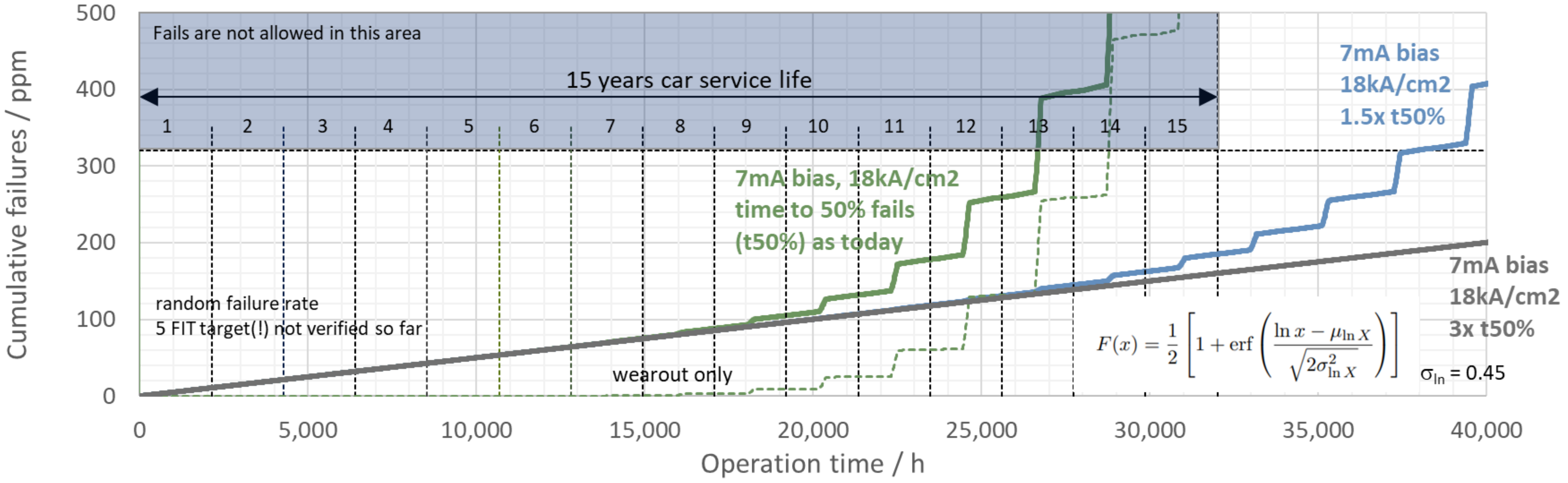
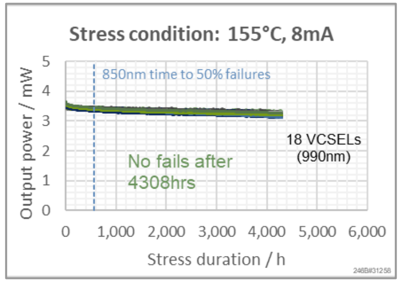
Improvement strategy “improve wear out location”

The how is clear: 980nm instead of 850nm VCSEL



“>3x of todays t50%“ is a realistic design target

Wearout data 980nm → see pages 7,8,9



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VCSEL design options for 25/50 Gb/s automotive datacom

980nm is the preferred design from a pure VCSEL point of view

	850nm VCSEL	980nm VCSEL
lower current, lower power dissipation, higher heat removal @ 25/50 Gbd, 125°C operation		
compressive strain (for differential gain)	lower	higher
thermal conductivity of Bragg mirror	lower	higher
free carrier absorption	less	more
DBR layer stack	thinner	thicker
turn on voltage	higher	lower
thermal escape of carriers from quantum wells	more	less
less variability in wearout		
quantum well growth window	tighter	wider
quantum well thickness	thinner	thicker
wafer quantities	low	high (at 940 nm)
higher resistance to maverick defect propagation		
compressive strain (for dislocation pinning)	lower	higher
better robustness		
flip-chip	top emission	top or bottom emission

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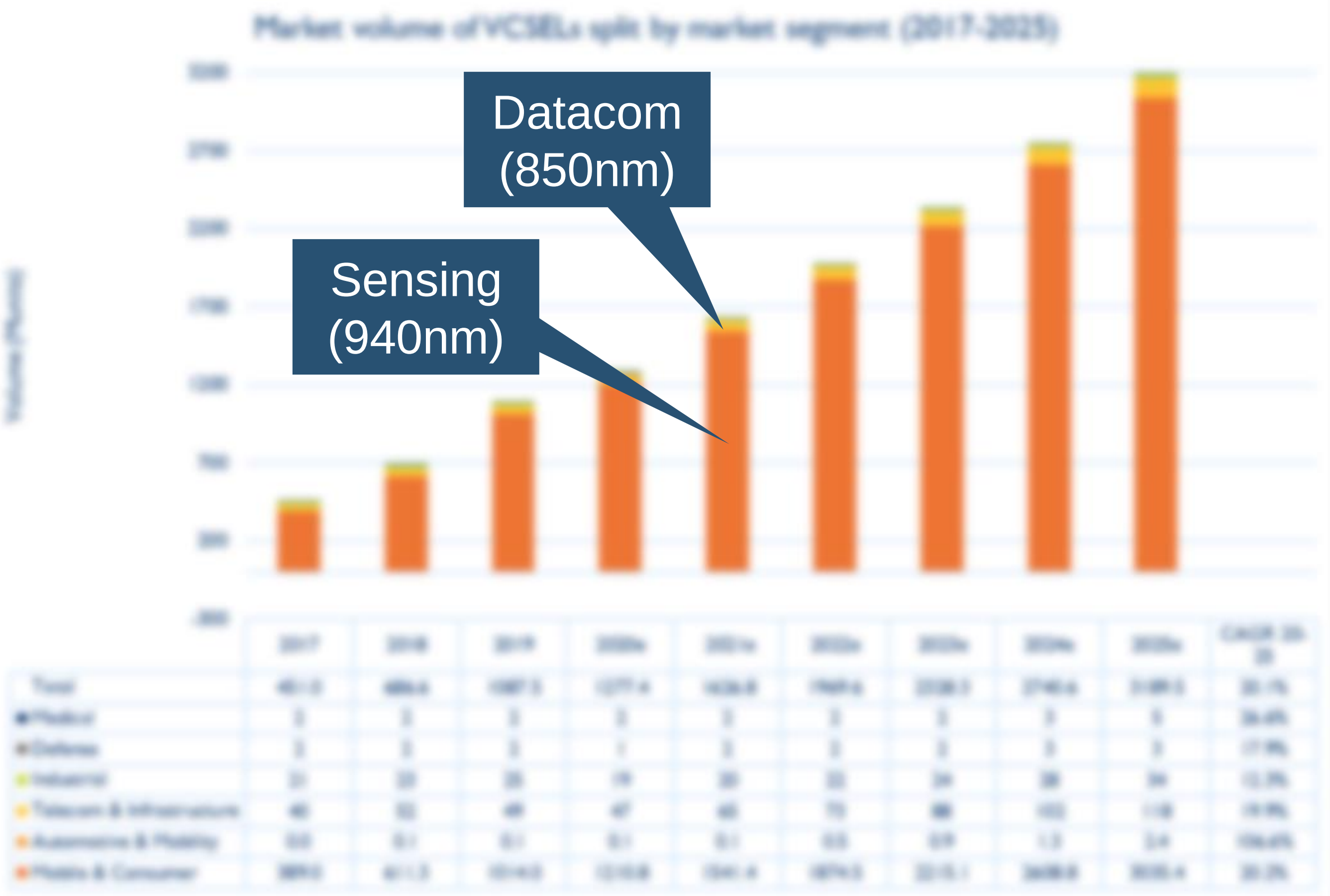
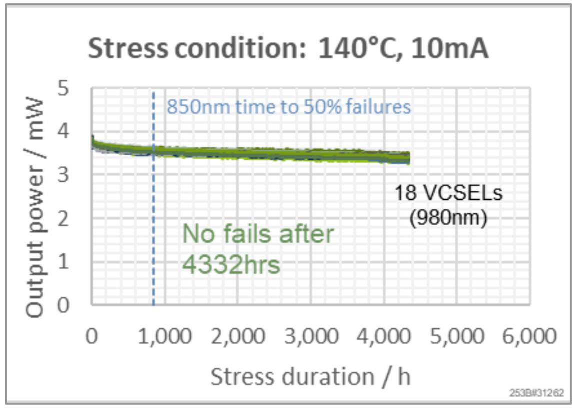
Industrialization of 980nm VCSELs

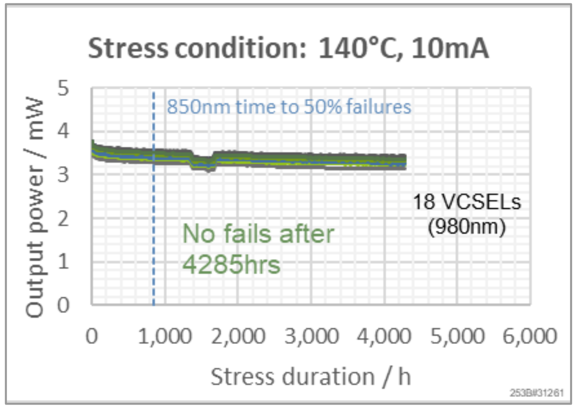
The majority of VCSELs are 940nm. 850nm is the exception!

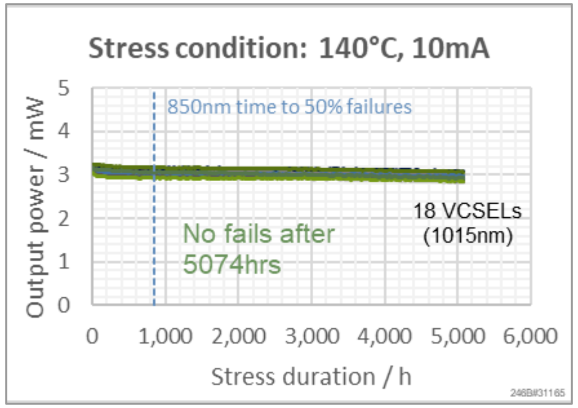
- **Yole Développment 2020 report:**
  - 2021 sensors VCSEL count: 1.6 billion units
  - 2021 datacom VCSEL count: 65 million units
- **The majority of the ~50 VCSEL suppliers is active in 940nm and 850nm**
  - Biggest hurdle at 850nm: epitaxial “alchemy”
    - Therefore, most VCSEL suppliers fail
    - “Reliable” QWs at 940nm are much easier
- **940nm .. 1065nm is very similar in terms of material composition, overall reliability and datacom performance**
- **No significant difference in cost between 850nm and 980nm VCSEL chips**
- **InGaAs PDs for 980nm are available**

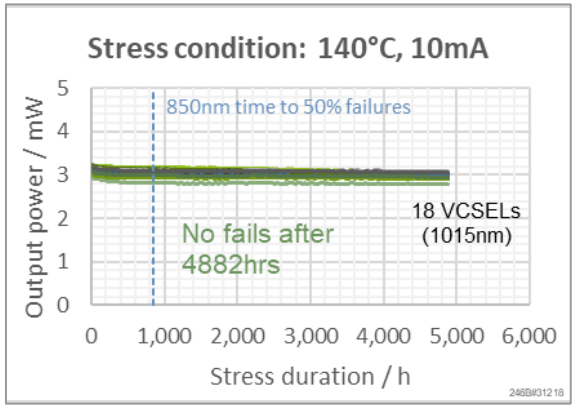


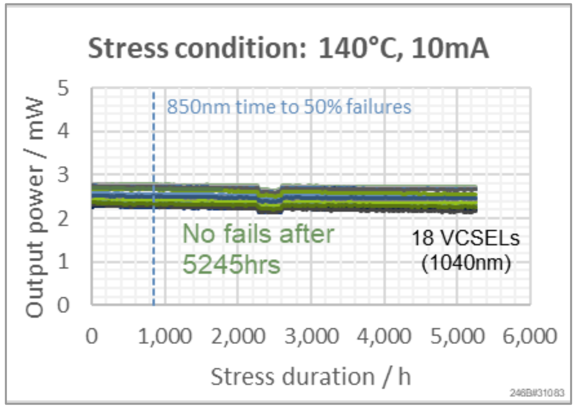
980nm versus 850nm 25G VCSEL design wear out reliability at 140°C, 10mA stress

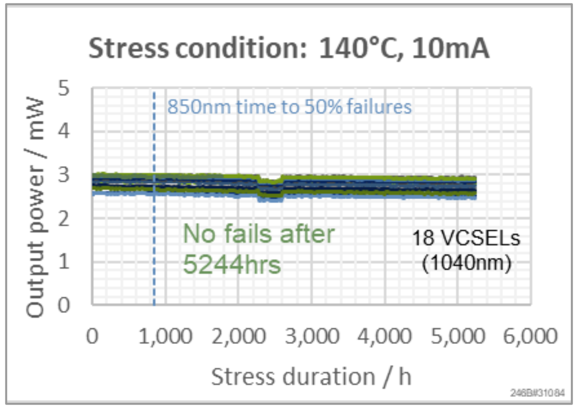












Stress condition: 140℃ chip backside (substrate) temperature, 10mA continuous wave laser current
Every 24h the VCSEL is cooled down to ~40℃ and the output power at 7mA drive current is recorded

850nm VCSEL

- Time to 50% fails = 853hrs @ 140°C, 10mA

Long wavelength VCSEL

- No wearout fails so far

980nm endurance advantage already >5x

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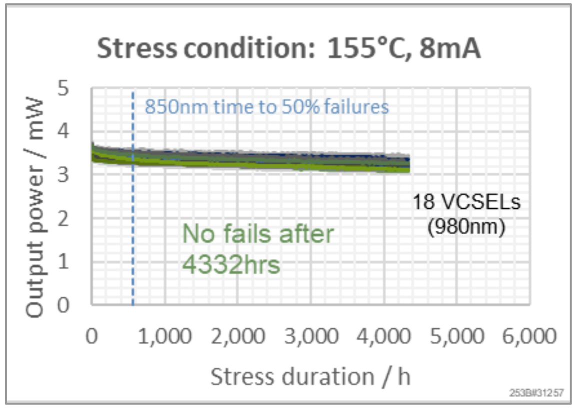
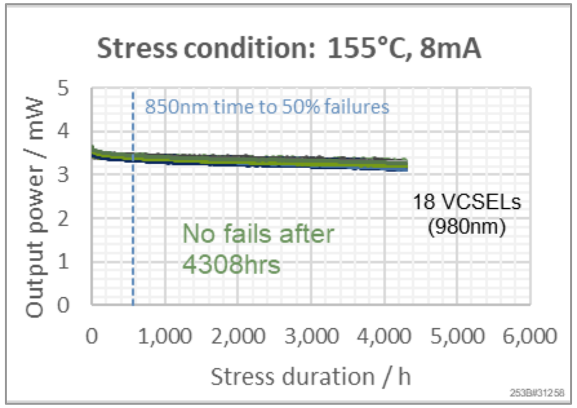
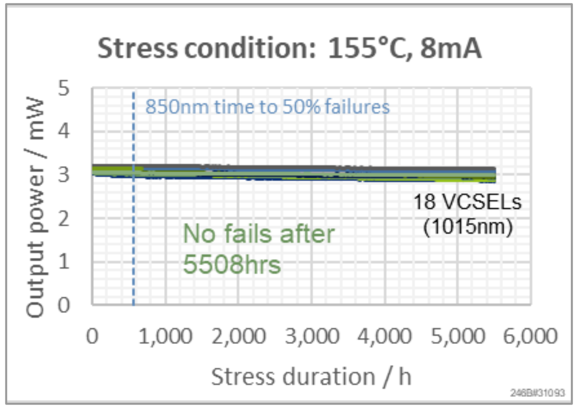
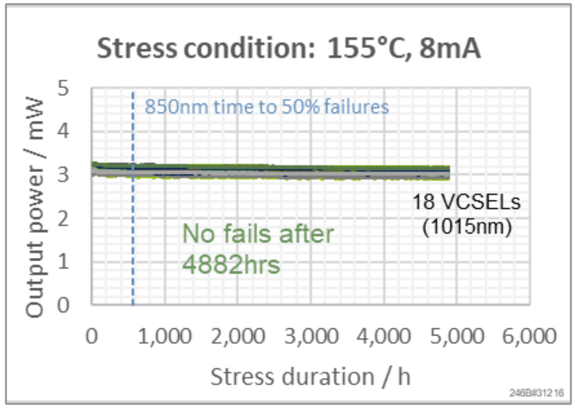
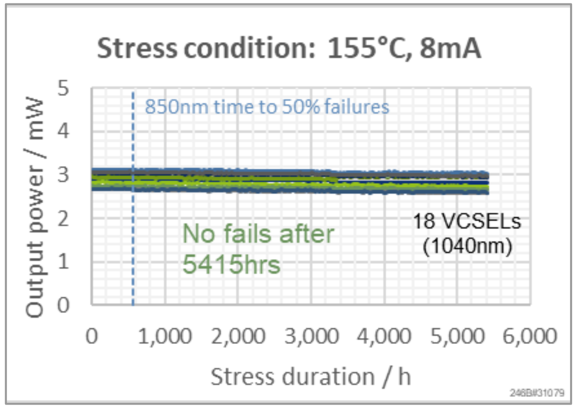
980nm versus 850nm 25G VCSEL design wear out reliability at 155°C, 8mA stress

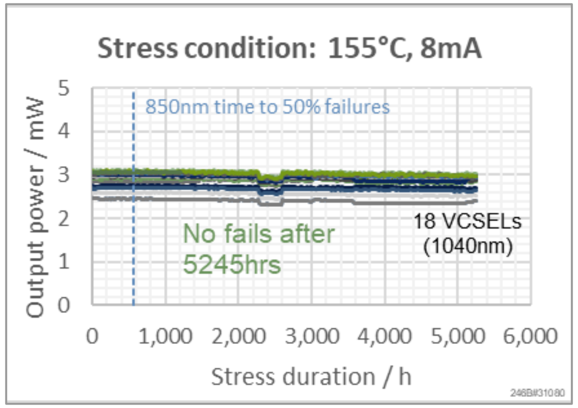












850nm VCSEL

- Time to 50% fails = 561hrs @ 155°C, 8mA

Long wavelength VCSEL

- No wearout fails so far

980nm endurance advantage already

>9x

Stress condition: 155℃ chip backside (substrate) temperature, 8mA continuous wave laser current
Every 24h the VCSEL is cooled down to ~40℃ and the output power at 7mA drive current is recorded

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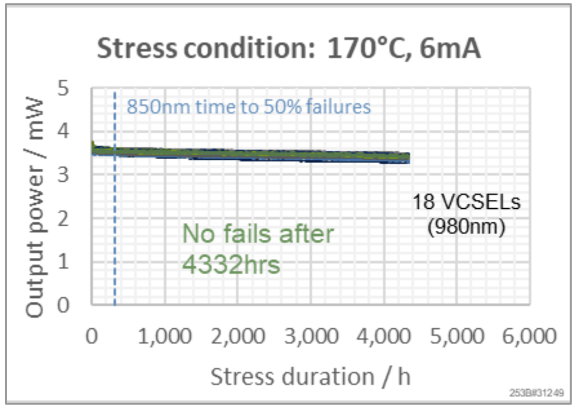
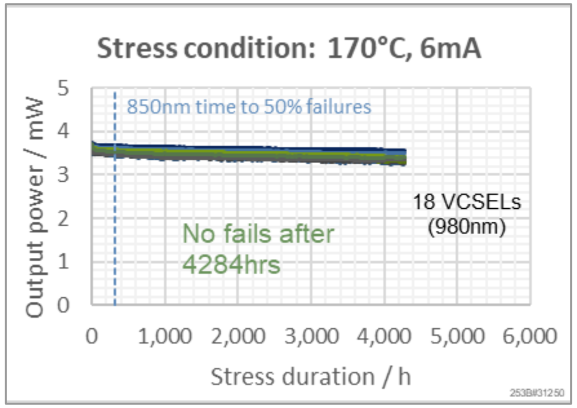
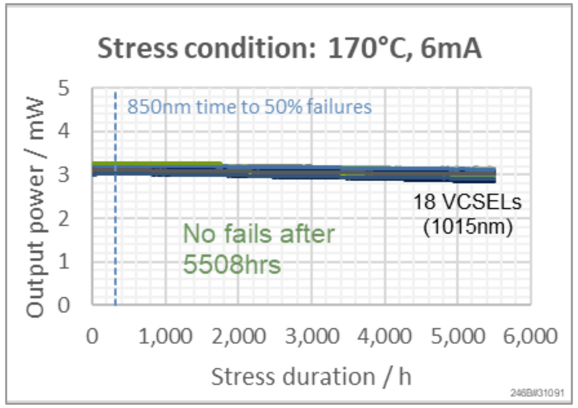
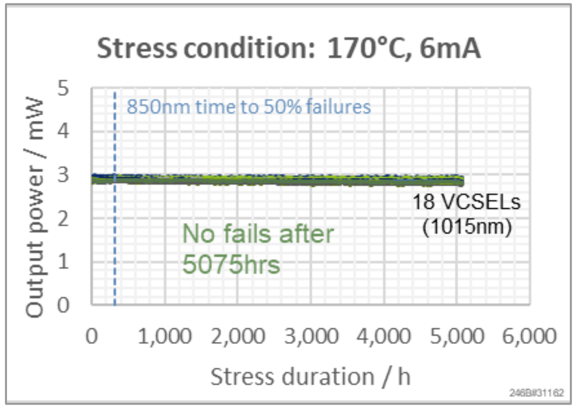
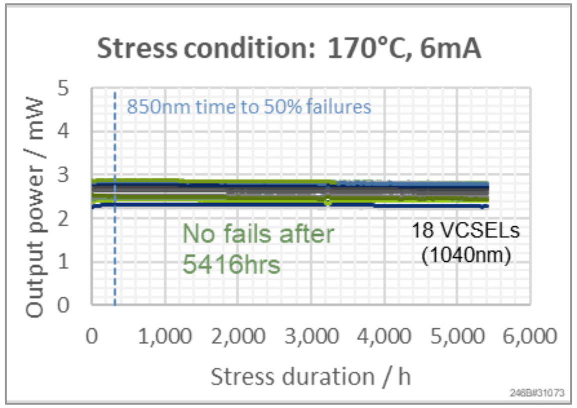
980nm versus 850nm 25G VCSEL design wear out reliability at 170°C, 6mA stress

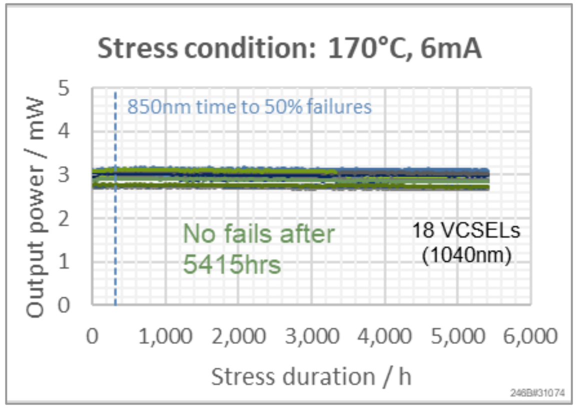












Stress condition: 170℃ chip backside (substrate) temperature, 6mA continuous wave laser current
Every 24h the VCSEL is cooled down to ~40℃ and the output power at 7mA drive current is recorded

850nm VCSEL

- Time to 50% fails = 307hrs @ 170°C, 6mA

Long wavelength VCSEL

- No wearout fails so far

980nm endurance advantage already

>>10x

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Summary

From a VCSEL point of view the 980nm design is the better choice for 25/50 Gb/s automotive applications

- 980nm VCSELs are far more robust than 850nm VCSELs
  - Use of aluminum-free quantum well barriers is the game-changer
- Automotive is not requiring backwards compatibility and offers the chance to take advantage of higher reliability at 980nm
  - Shorter link lengths (<40m) tolerate more dispersion in the optical fiber at 980nm
- There are plenty of suppliers capable of delivering 980nm VCSELs

Transferring the 980nm 25/50 Gb/s automotive VCSEL design to production is the next step

- Wearout test on 980 ..1040nm feasibility samples at TRUMPF will be concluded after 5000hrs → no fails observed so far
- Design for 980nm available at TRUMPF and likely at other vendors
- Manufacturing will be done on existing and released production equipment and processes
  - Automotive grade product prototypes for qualification testing are planned for Q3 2022

Thank you!

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