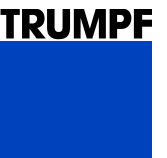




November, 14th 2022

VCSELs – Development – Production – Market

TRUMPF Photonic Components – Dr.-Ing. Roman Koerner, CTO

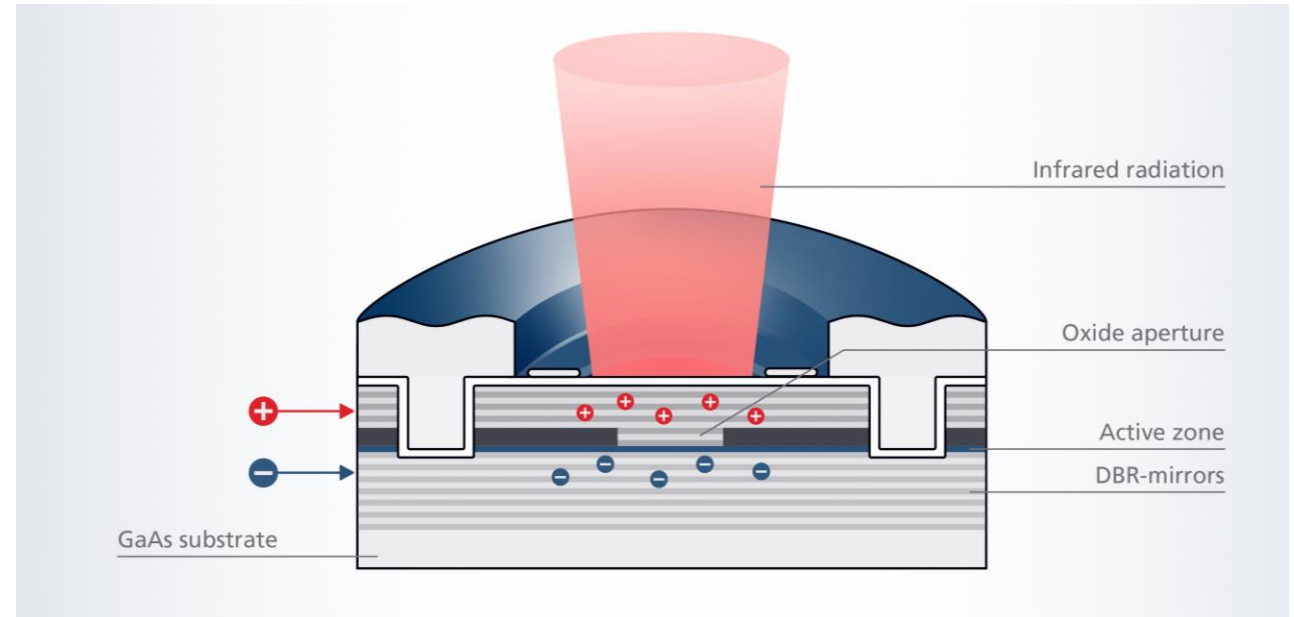


VCSEL – Vertical Cavity Surface Emitting Laser

01 VCSEL Market

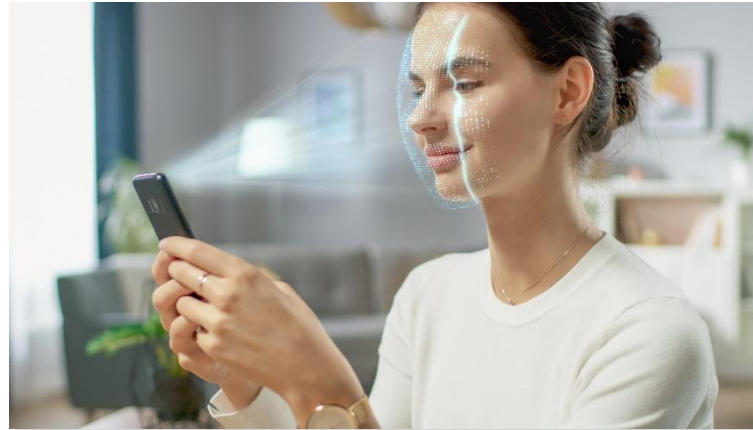
02 III-V Process Technology

03 Emerging applications



- Vertical light emission like an LED
- From μW to kW output power
- 765 nm to 1380 nm

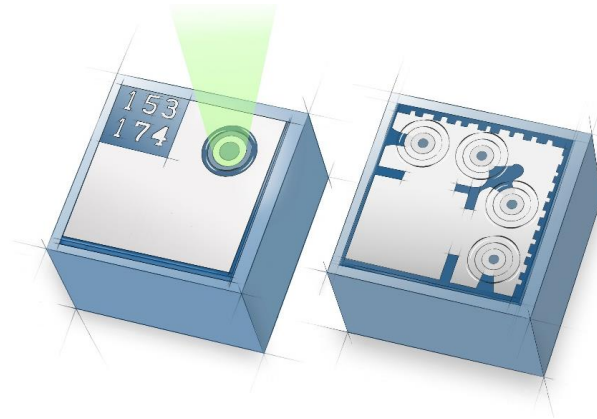
VCSELs are everywhere ...



> 1 200 000 000 VCSEL chips shipped worldwide in 2020 ⁽¹⁾

VCSEL of today:

- Energy efficient and scalable device
- Low cost by fast yield improvement
- Are in every Iphone ... ⁽²⁾



» VCSEL of tomorrow:

- Enhanced functionality per chip area
- Naturally eye safe
- Reduced power consumption

⁽¹⁾ J. Tatum et al. (2021). *Commercialization of VCSELs.*, 10.23919/MOC52031.2021.9598106.

⁽²⁾ Investitionen von Apple in Zulieferer übersteigen 20 Milliarden Euro - Apple (DE)

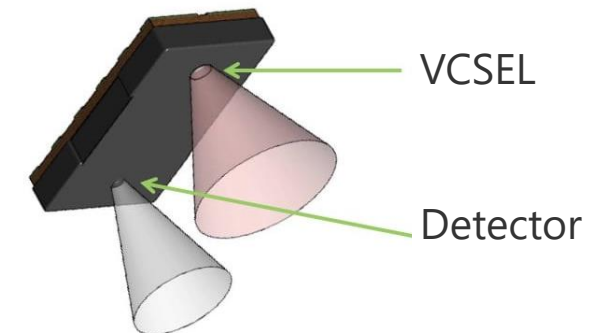
TRUMPF – First laser in an smartphone (iPhone 7)



Application: Proximity sensor



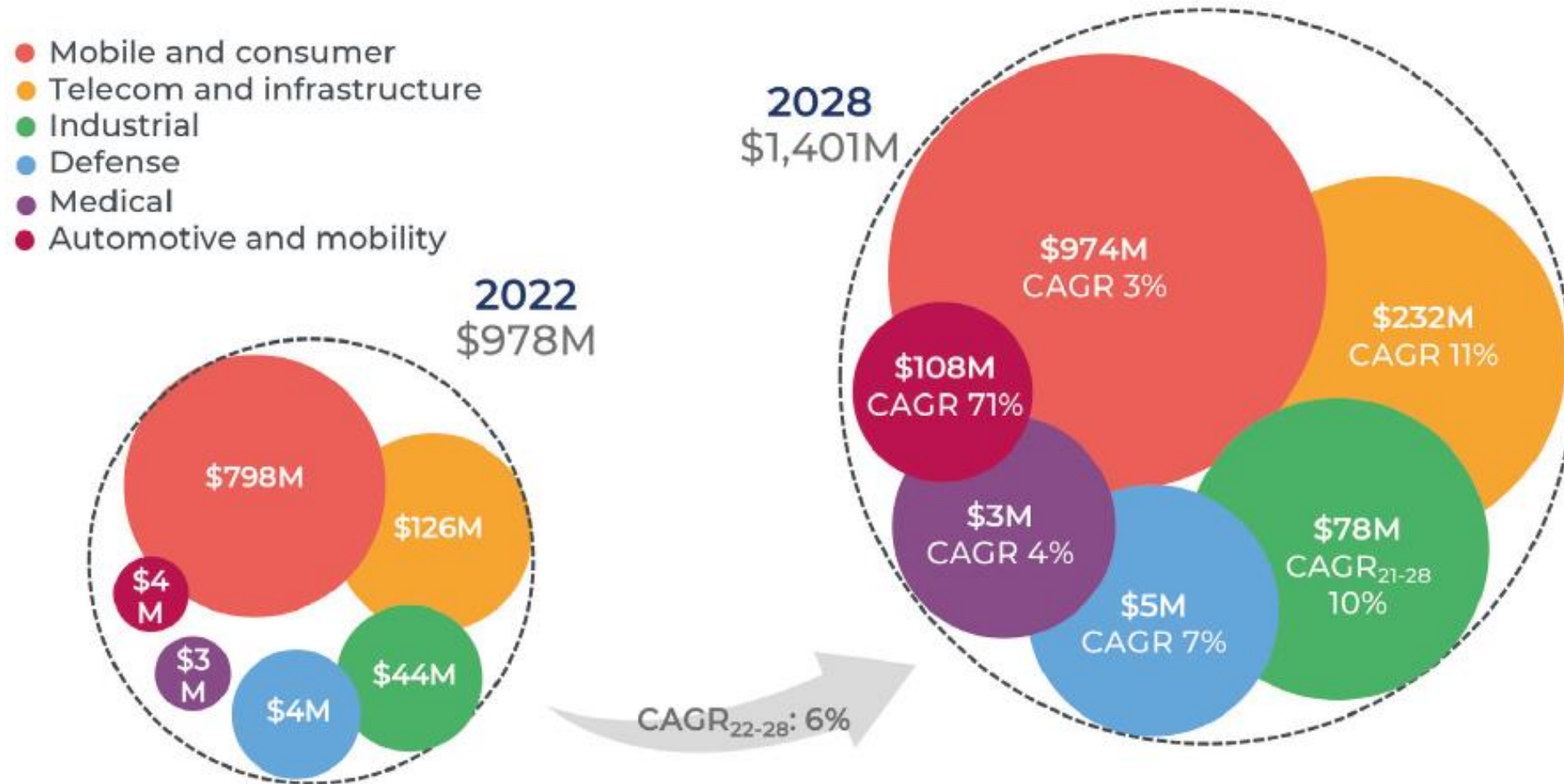
With combination of chip and detector, distance to object can be measured to manage screen status



Quelle: Top Sensors Inside the Smartphone You Want To Know | SAGMart

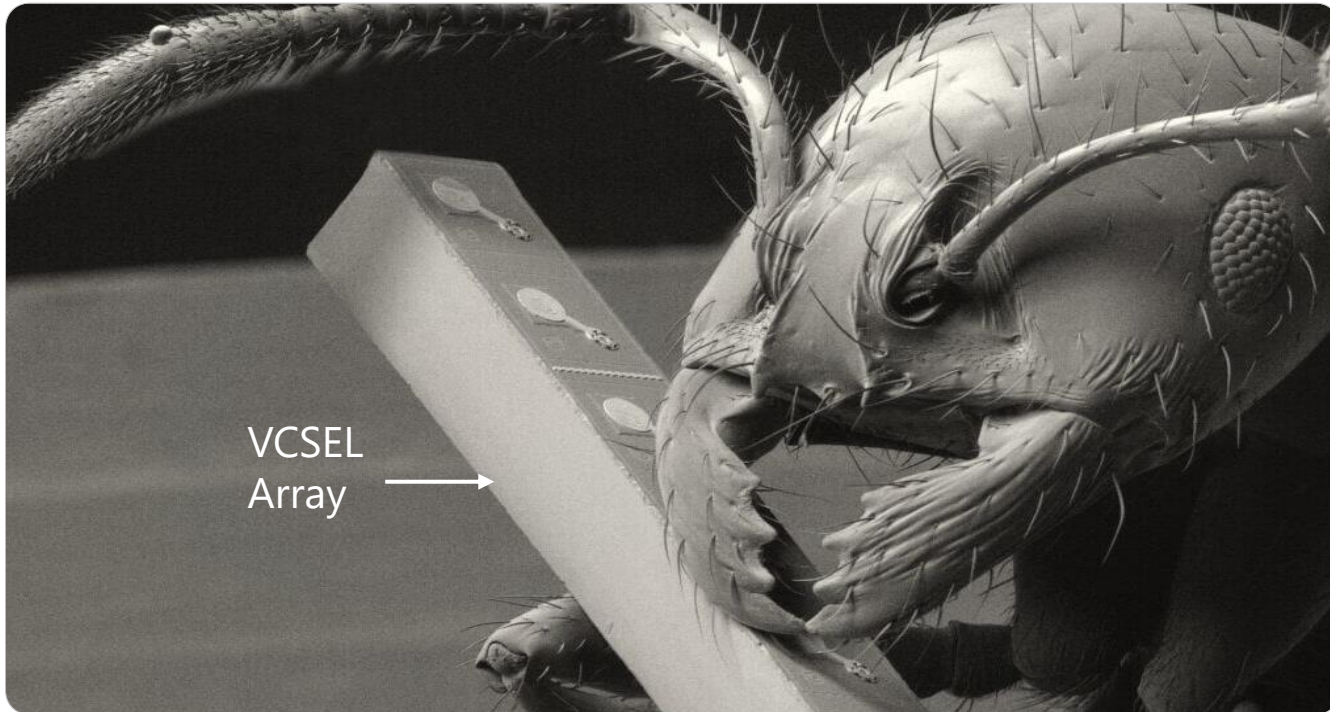
2022-2028 VCSEL market forecast

(Source: VCSEL 2023, Yole Intelligence, October 2023)



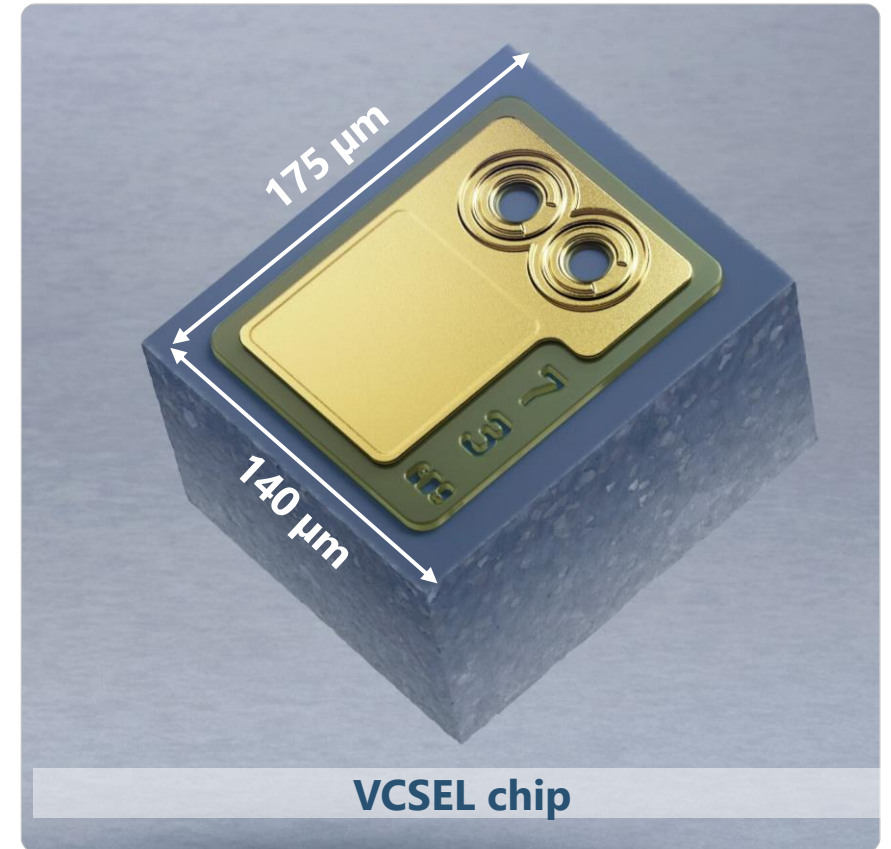
© Yole Intelligence 2023

VCSEL – Small device, but big impact ...



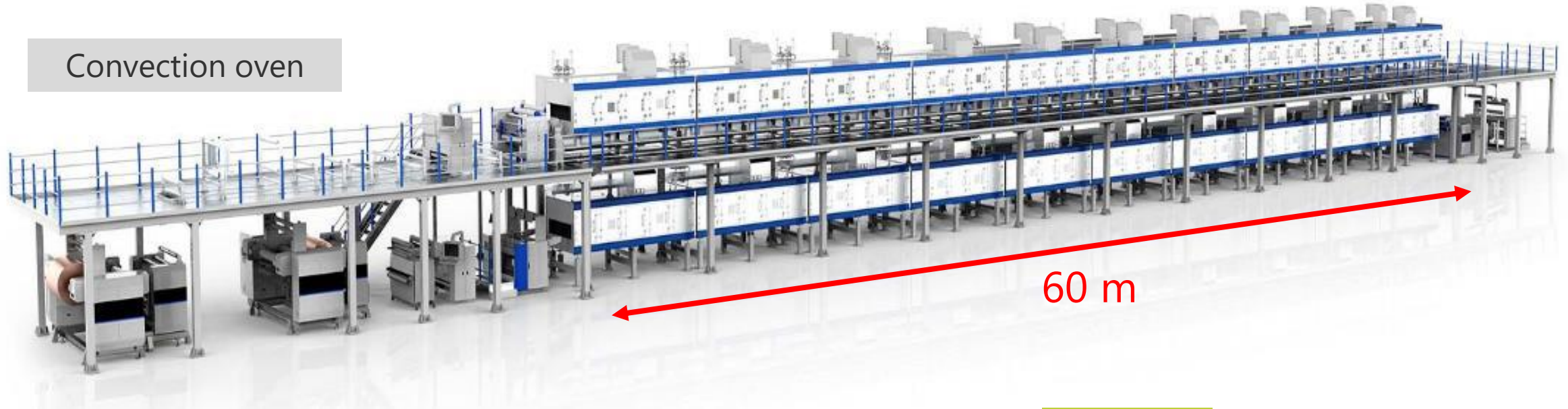
VCSEL
Array

Image credit: Coherent

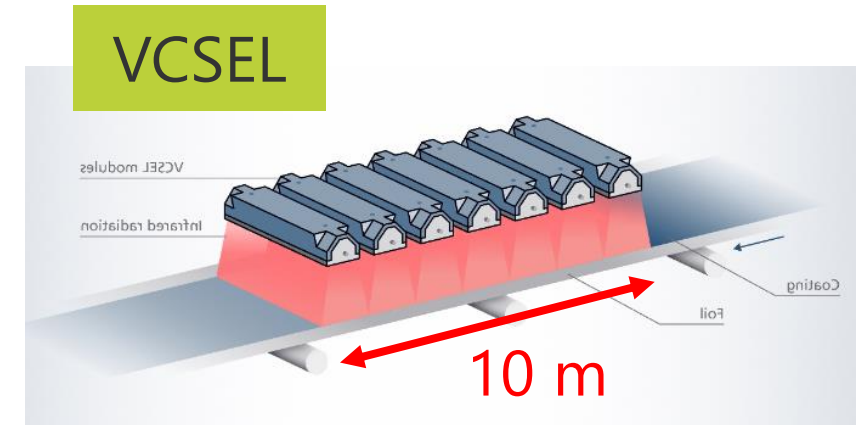


> 300 000 VCSEL chips per 6 inch wafer...

VCSEL Application: Drying of Li-Battery Electrode Foils (e-mobility)

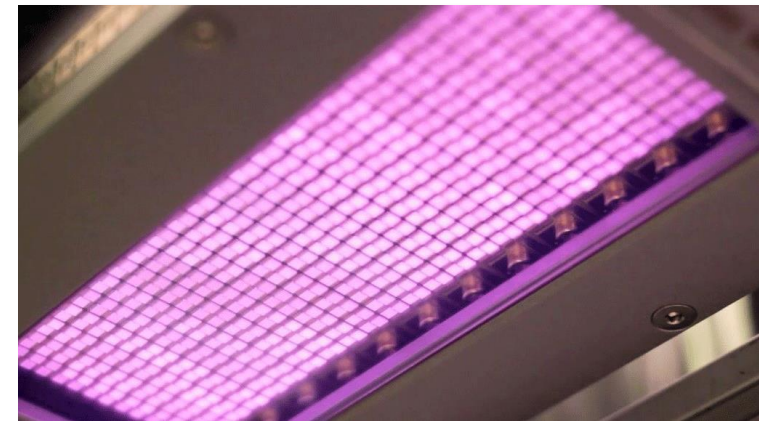
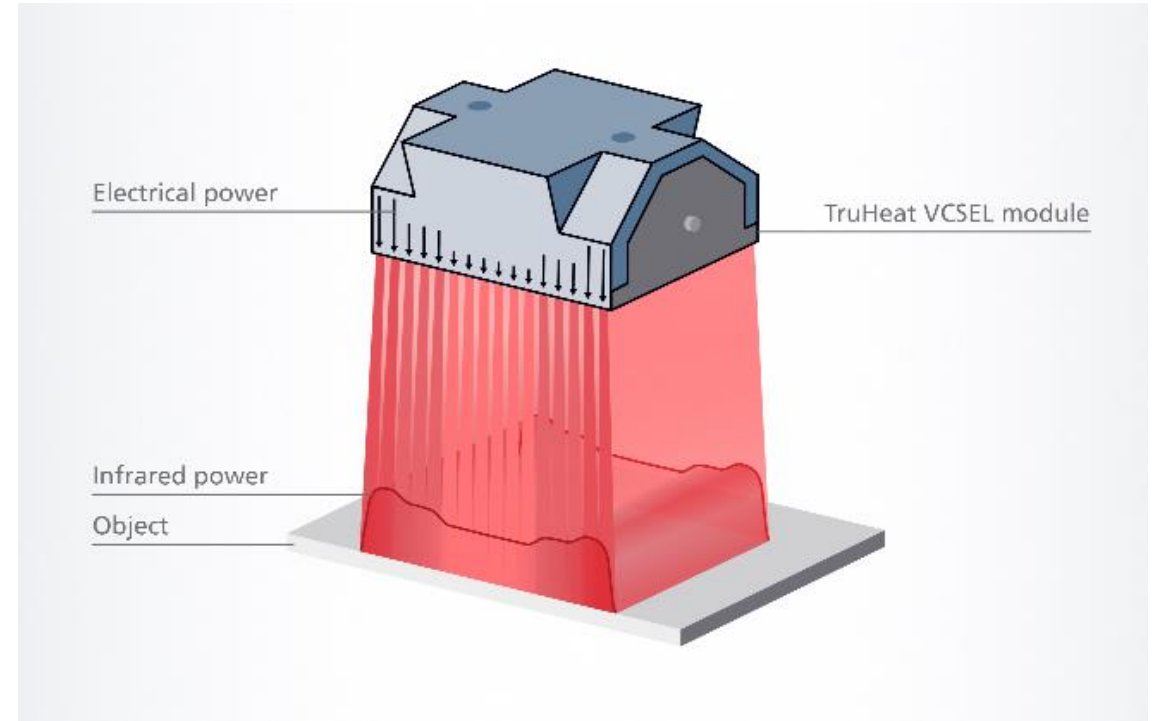
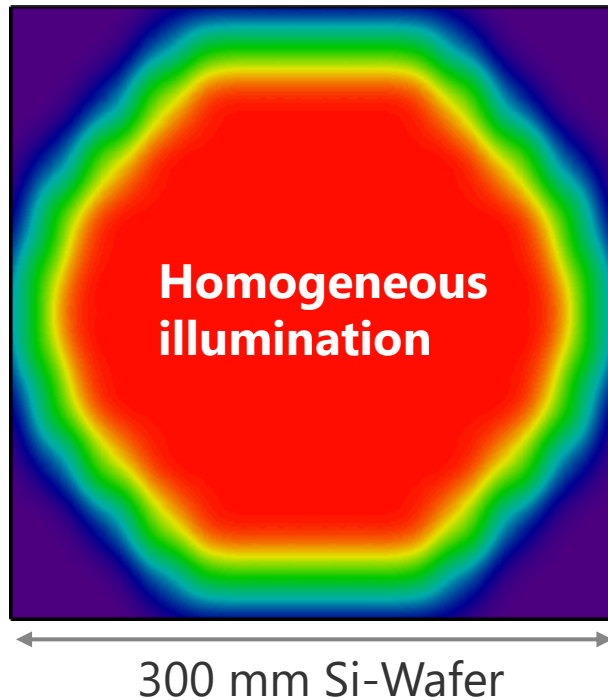


- Drying consumes a very large part of the energy in battery manufacturing (30 - 40%)
- Very large and inefficient (energy-efficiency ~ 15%) → VCSEL-system ~ factor 5 shorter
- ~ **200 kW** output power of the VCSEL system

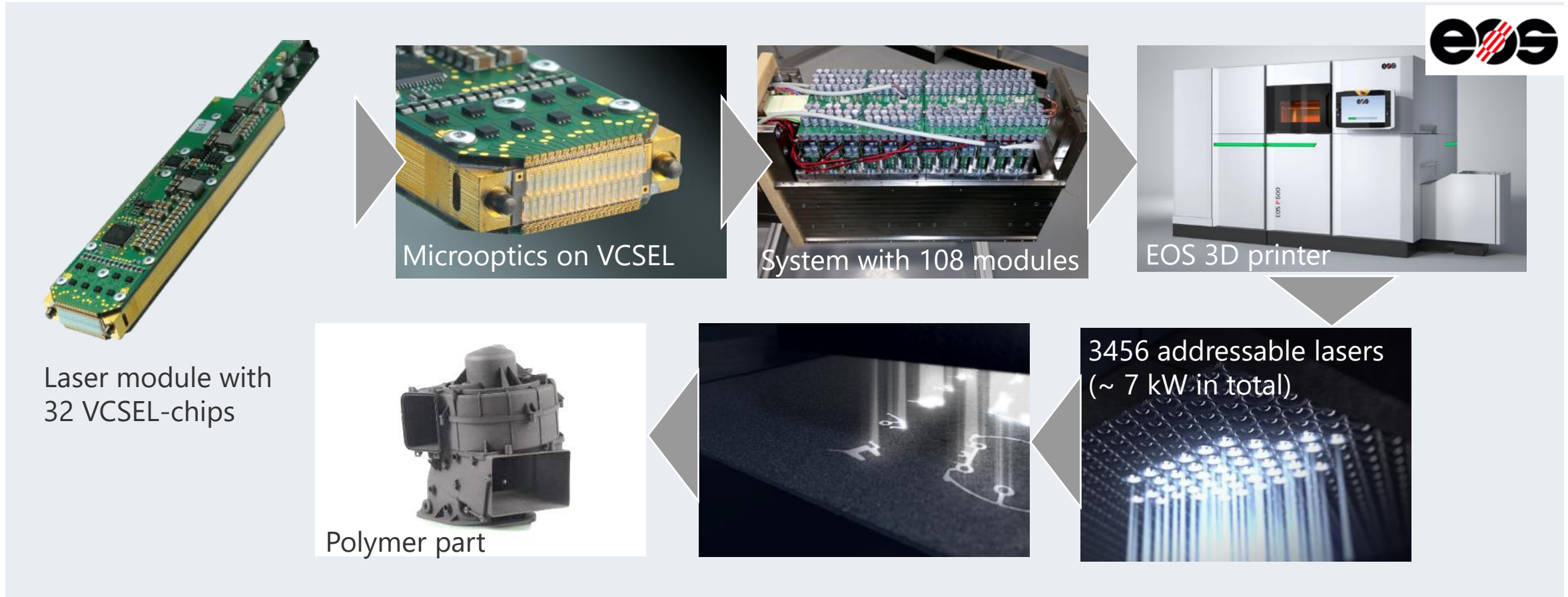


VCSEL Application: Wafer Heating

- 11 – 64 kW total output power
- High absorption in Si
- High power density 12 – 70 W/cm²
- Ultra short processing times
(ramp up of 300-400°C per second)



VCSEL Application: Additive manufacturing of polymers

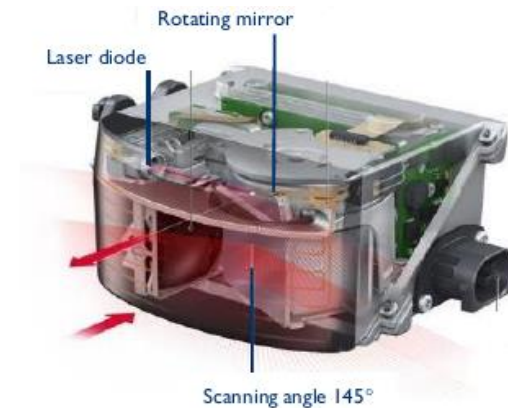


- 10x faster than best existing polymer 3D printers → Industrial high-volume manufacturing
- Superior resolution and part quality

VCSEL Application: Very compact LiDAR



Desire	Challenge
200 m range	System output power ~ 1000-10000W
High resolution	Angular resolution 0.1°
360° view	Field of view >> 30°x10°
Use conditions	-40°C...105°C; vibrations, dirt, water



Source: Valeo Scala

Mechanical scanner:
Bulky and expensive



VCSEL: All solid state, no mechanics, addressable

Technology-Motor: Enhanced functionality per chip area

Silicon Industry:

„Moore's-Law“ drives the silicon industry to shrink the transistor size more and more ...

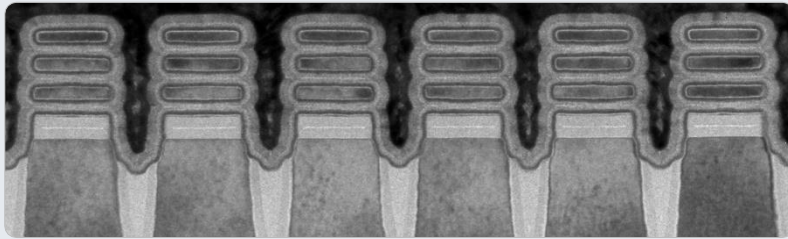
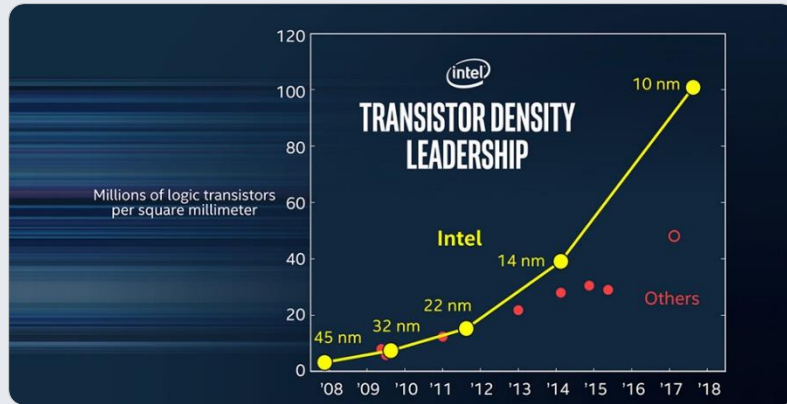
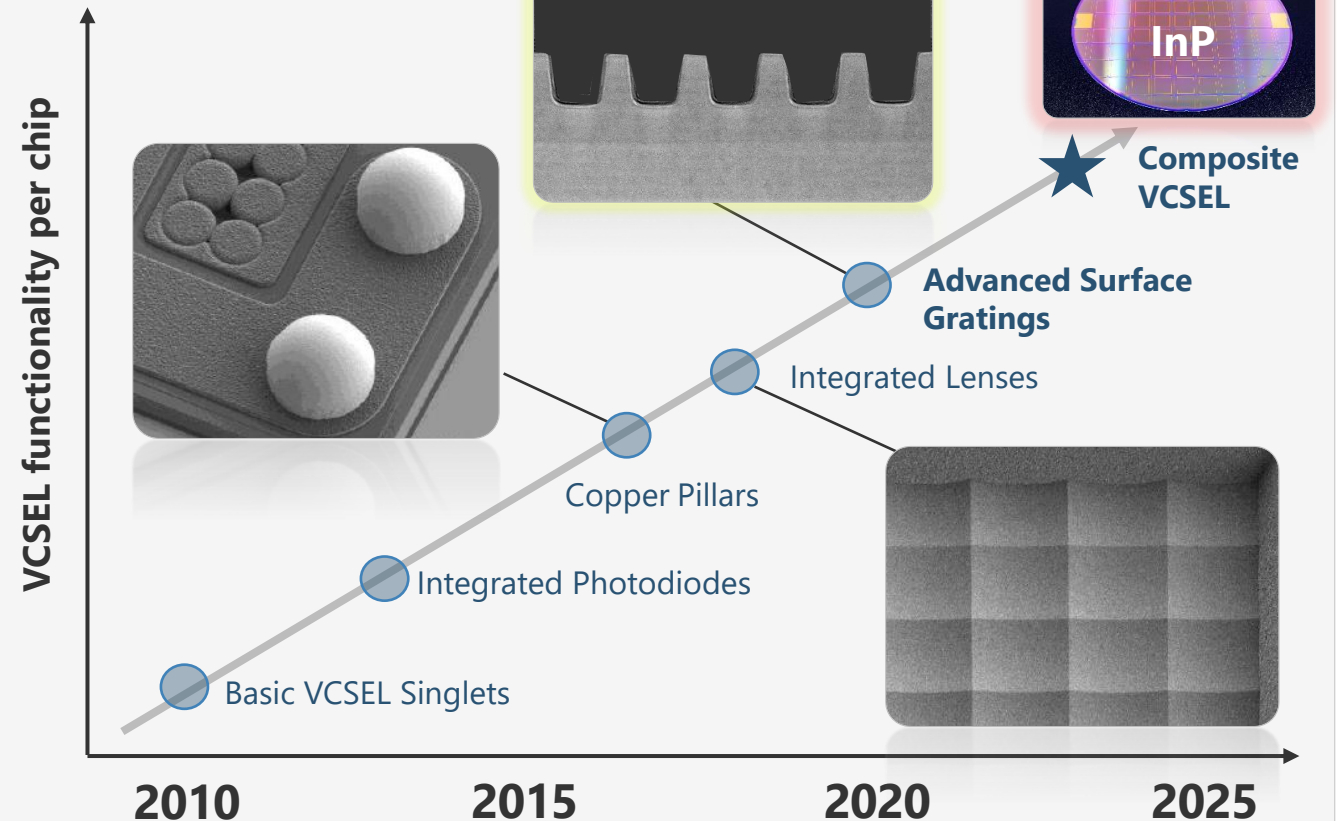


Image credit Intel and IBM

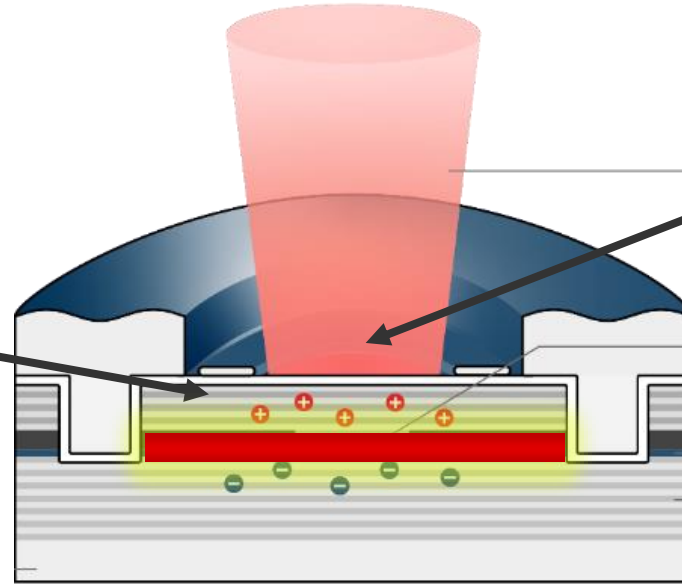
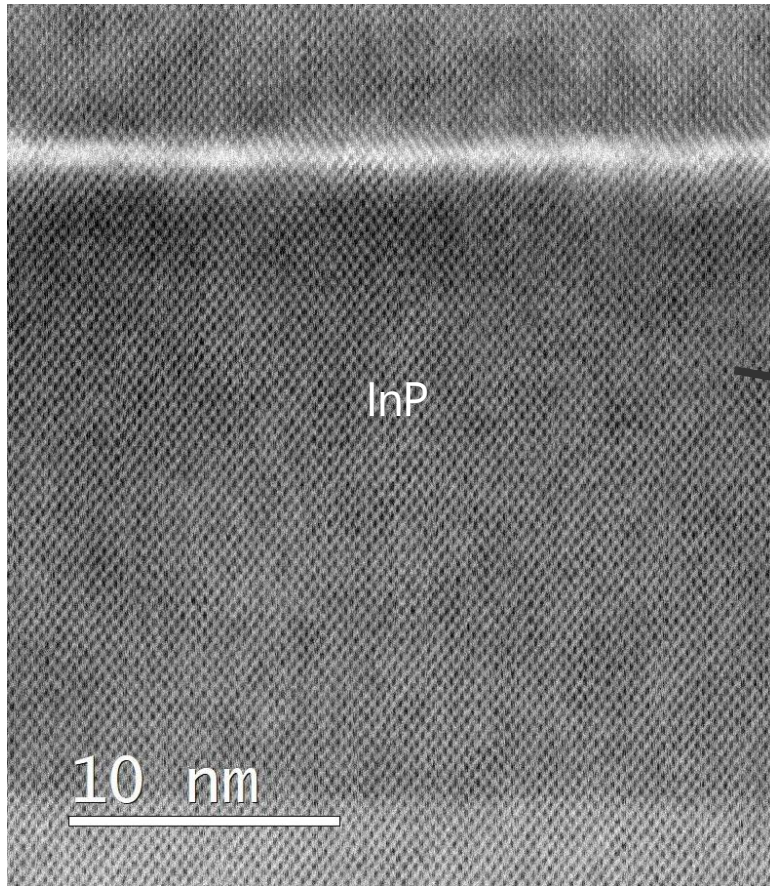
VCSEL Industry:



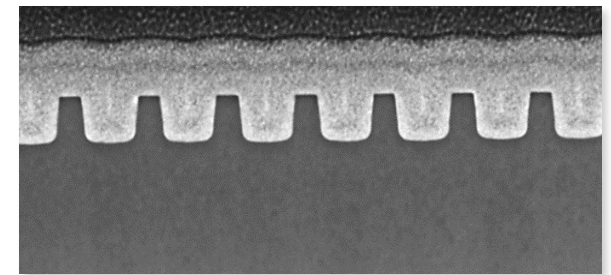
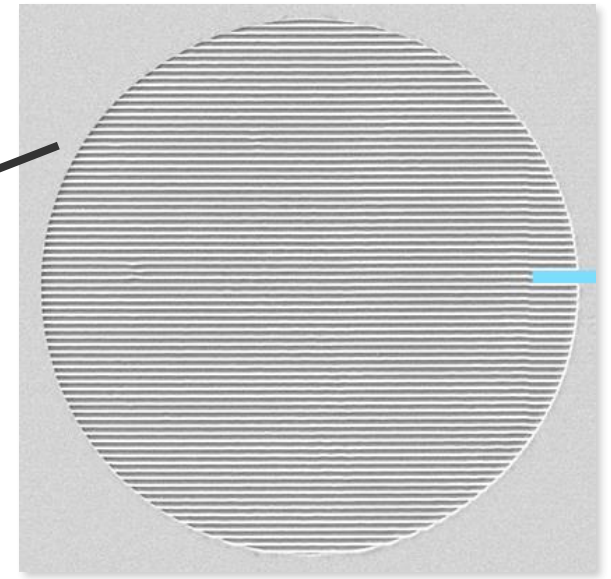
➤ **More functionality per chip area is the “Technology-Motor” of the VCSEL industry**

Advancements in Process Technology lead to new VCSEL features ...

Composite Materials

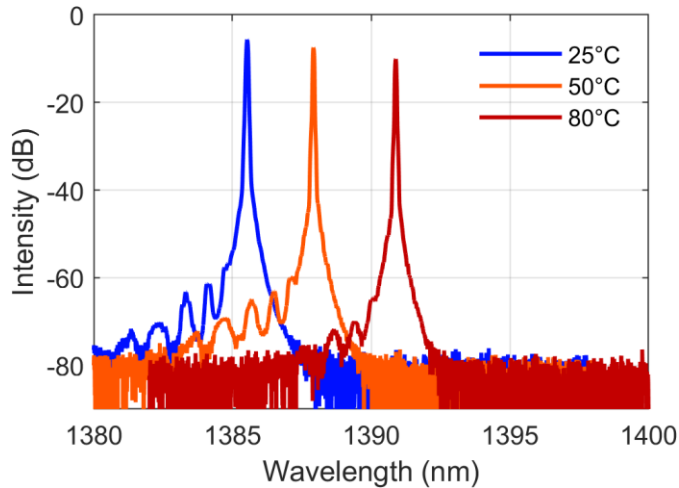


Novel Surface Gratings

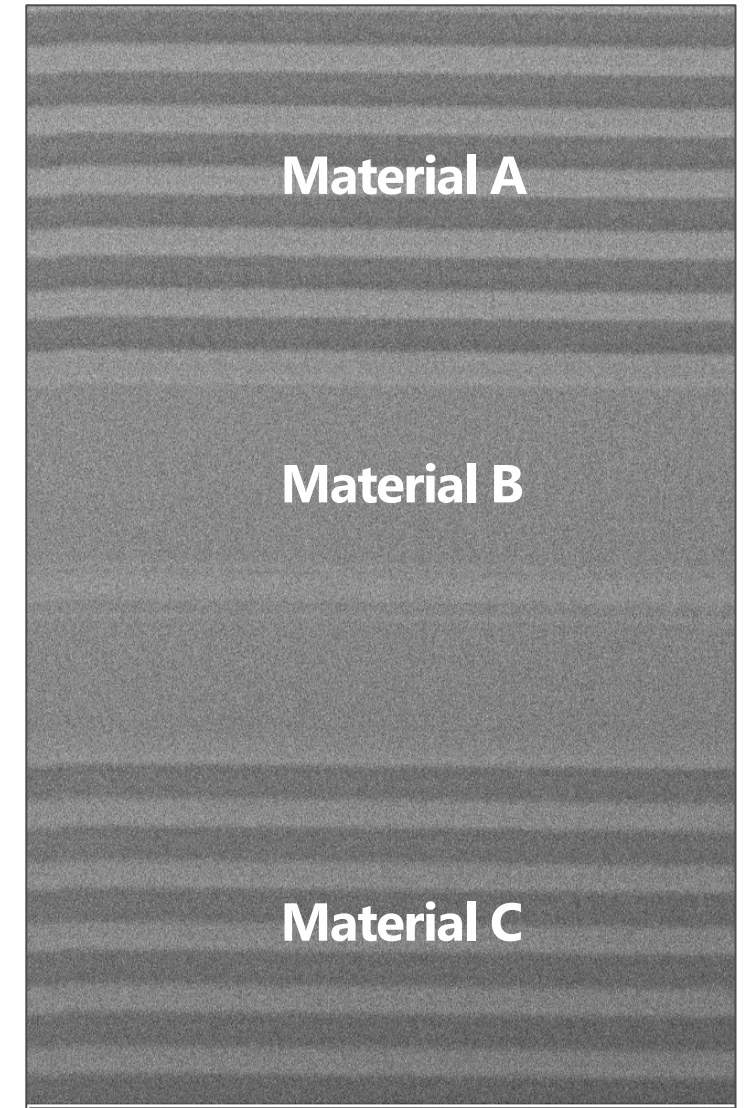


Grating Bar width < 60 nm

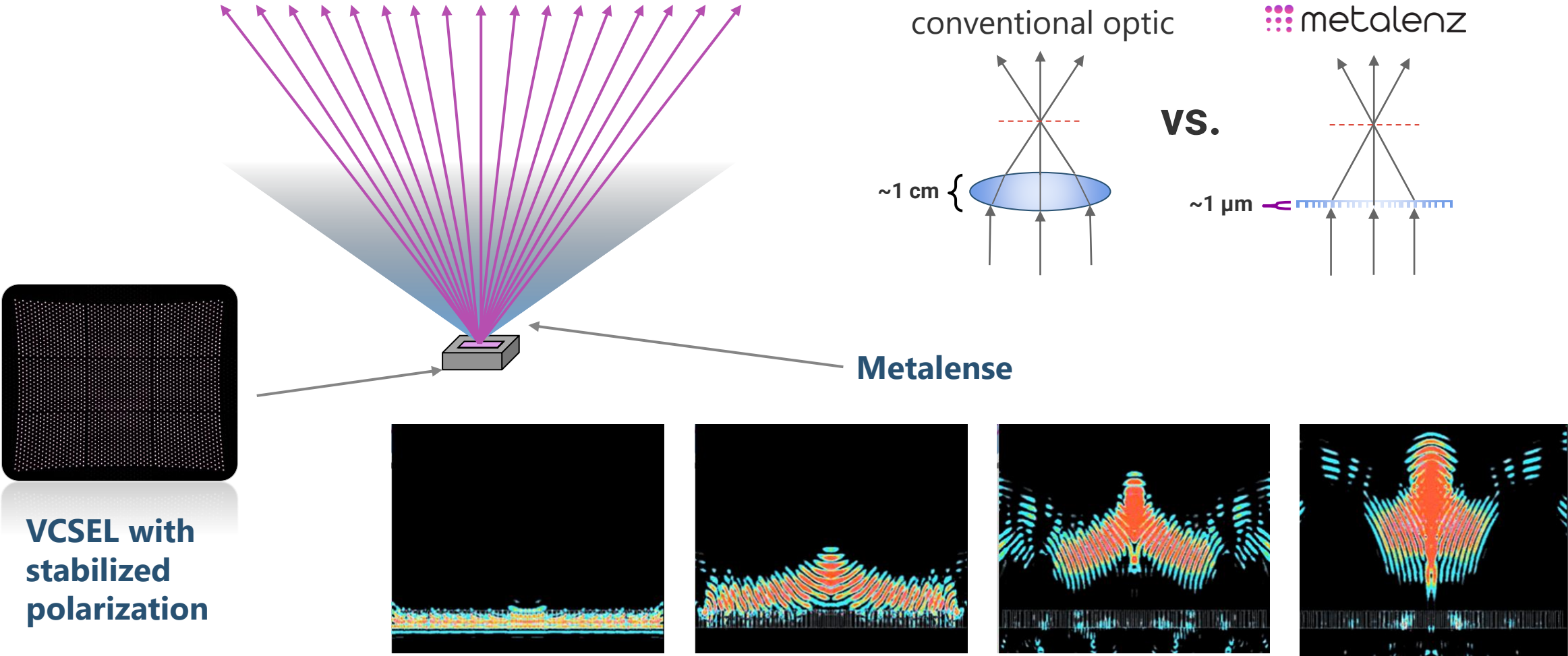
VCSEL Application: 1380 nm SWIR Sensors



- Eye safe VCSEL laser sensors for > 1400 nm wavelength
- Behind the display sensors for next generation smartphones



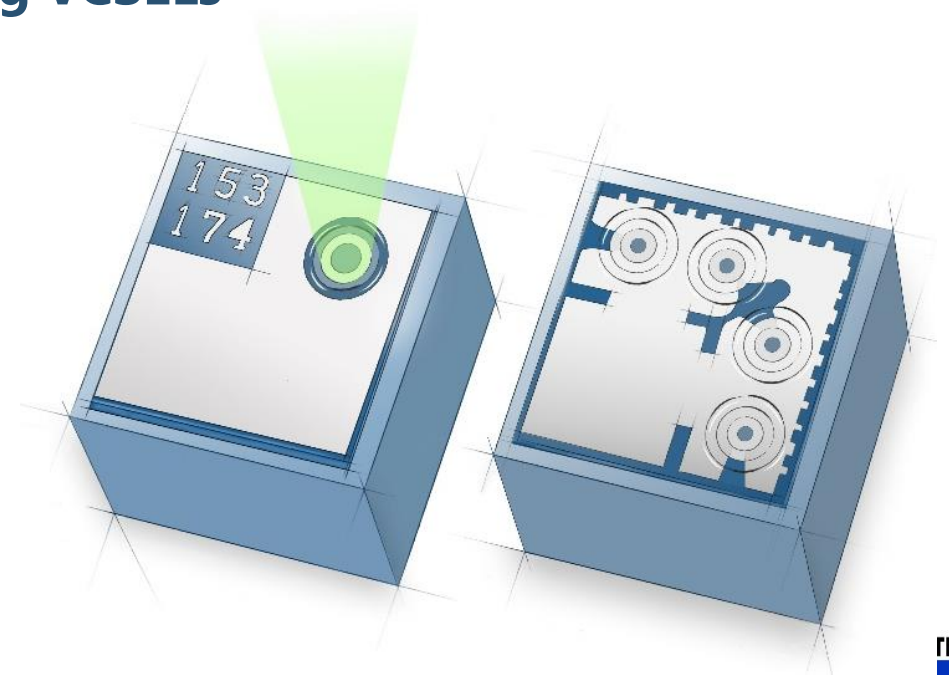
VCSEL Application: Metalenzes



Conclusion

- **VCSELs have today already a large field of applications (from μW to kW)**
- **With around 2 billion shipped devices per year, VCSELs are driving the compound semiconductor manufacturing roadmap**
- **Constant evolution in process technology is pushing VCSELs to the next levels ...**

→ VCSEL heating can reduce **30-40%** energy consumption in Li-battery manufacturing ...





TRUMPF



Thank You.

Dr.-Ing. Roman Koerner

Name