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EPIC
European Photonics Industry Consortium

Multi-aperture VCSELs for LiFi and 100G applications

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VCSEL technology

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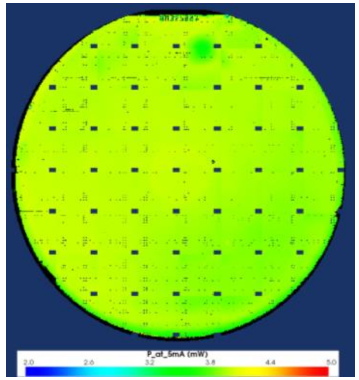
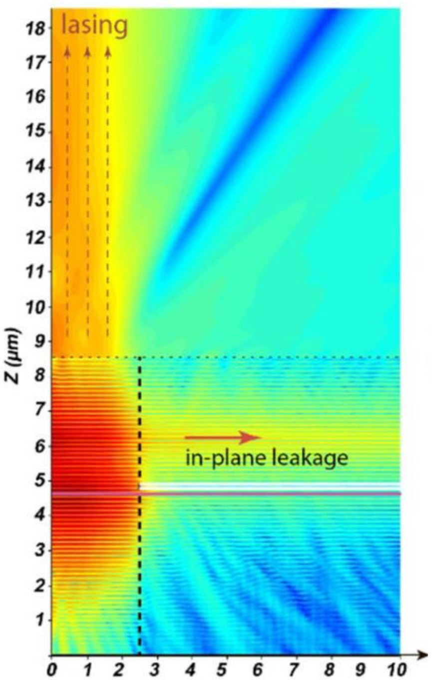
Est. 2006

Pioneer in datacom VCSEL technology development



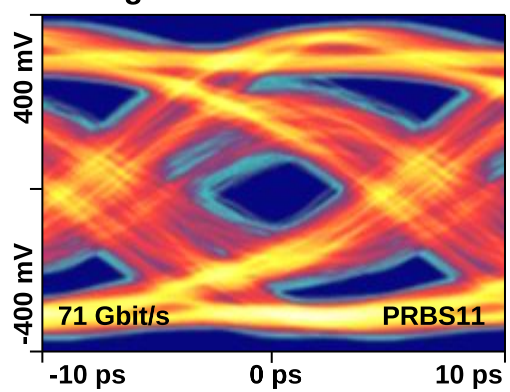
>100 000 chips 4“ wafer

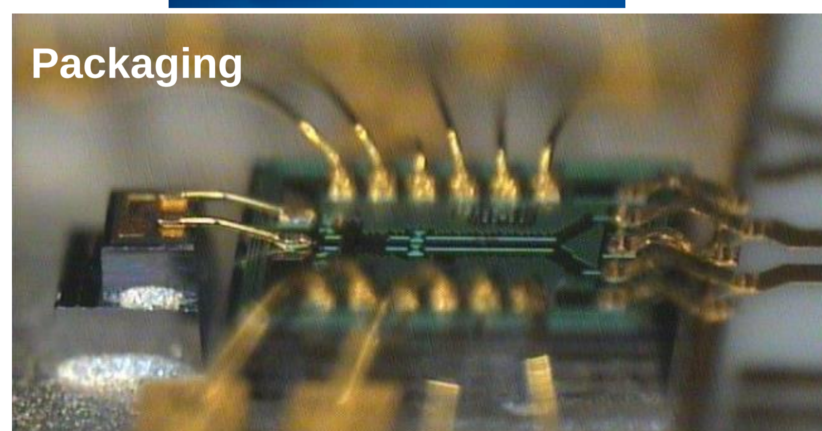
Manufacturing



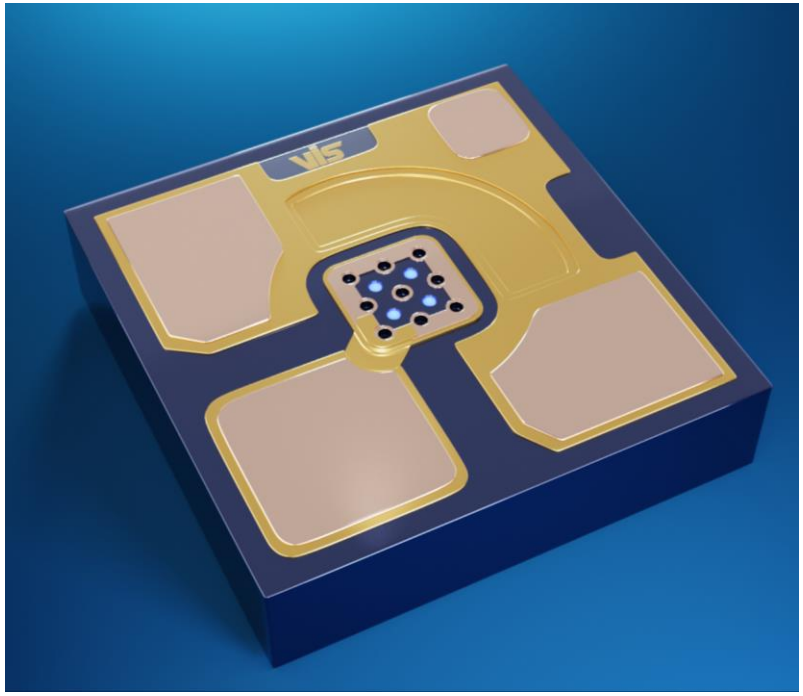
Simulation and Design

Testing





Multi-aperture compact VCSEL „mini-arrays“



Limitation of single aperture VCSEL in terms of high power:
High power -> Large aperture -> High capacitance -> Low bandwidth -> Wide optical spectra

“Mini-arrays” break these dependencies and reach excellent performance:

• >5mW • ~0.1 nm FWHM • 12° divergence

• 50 Gbaud • RIN <-150dB/Hz

Motivation

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Motivation

SM VCSELs

Hyperscale datacenters
up to 2km distnace

>100Gbit >100m
Requires ~0.1nm spectral width

Sensoric
Low cost fiber sensors

Optical wireless (LiFi)

Military
Detectability / Security

5G/6G
Access points in close proximity between each other

Enterprise
Huge bandwidth demand in single room

Sensoric
Ultra-fast TOF measurements

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Opportunity

Compact multi-aperture VCSEL design aims to solve two problems

SM VCSELs

Reduction of chromatic dispersion
Increase in transmisison distance through multi-mode-fiber

>100 Gbit/s to >100m OM4 requires ~0.1nm spectral width

Reduction of spectal width while maintaining the same output power and high bandiwdth

Optical wireless

For optical wireless applications >15mW @ 20 GHz are required

Increase in aperture size does not increase the output power due to thermal rollover and leads to reduced bandwidth

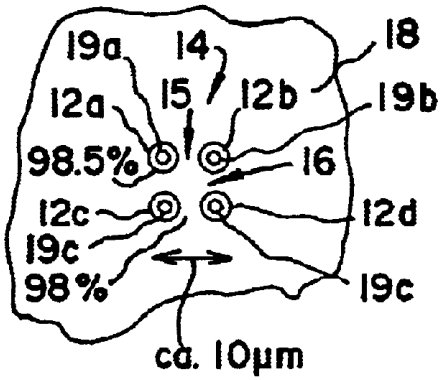
Increase of the output power while maintaining high bandwidth and directionality

And in the future: photon-photon resonance effects used in edge emitters may increase the VCSEL bandwdith >50 GHz

Technology

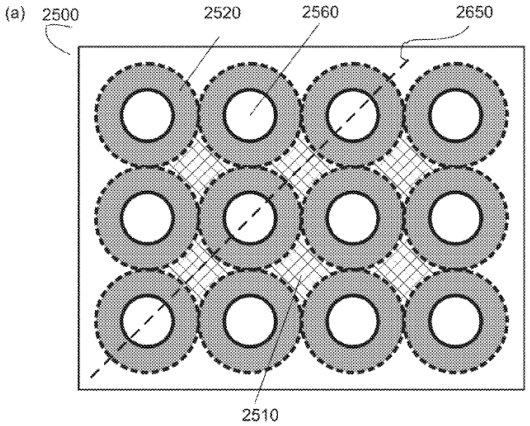
The concept of mini-arrays is that they are so compact that their light can be coupled into single fiber.

Coherent emission

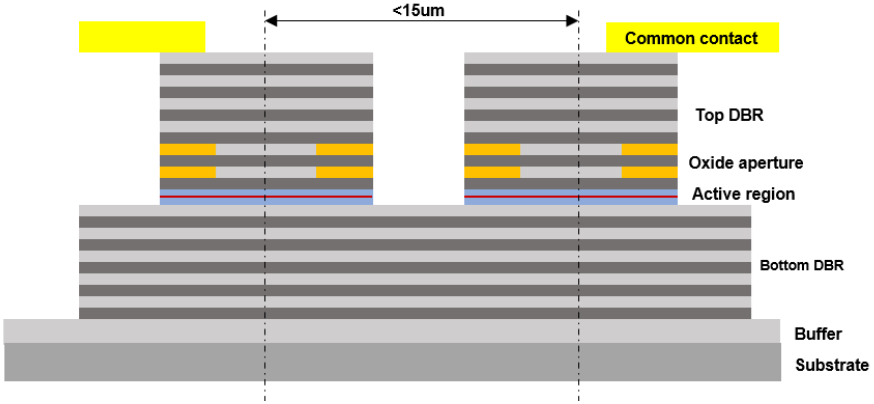


J. Kropp, US Patent 6,785,476

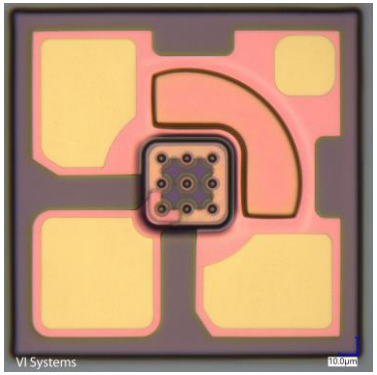
Oxidation through holes



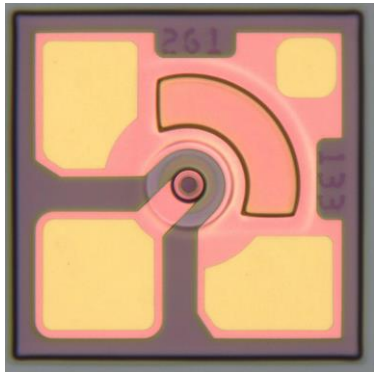
Ledentsov, Shchukin, US Patent 10,243,330



Oxidation through holes allows to reduce distance between the oxide apertures



Compact mini-array



Regular VCSEL with similar active areas

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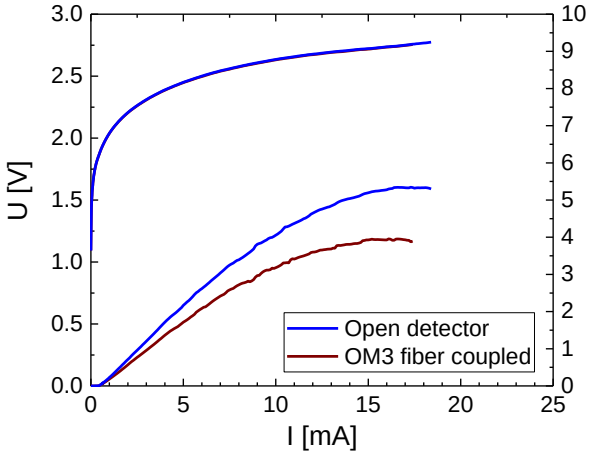
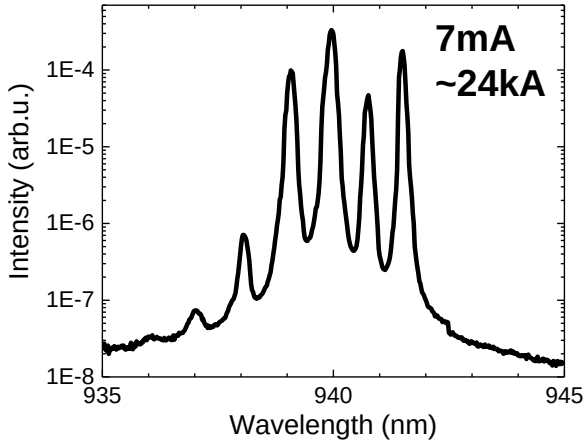
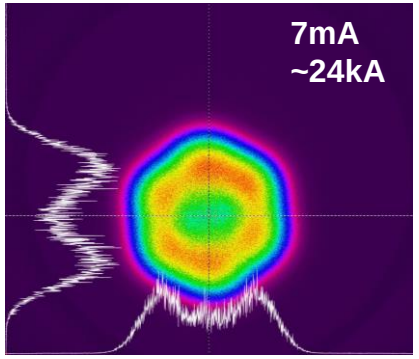
Comparison to regular VCSEL

Regular VCSEL

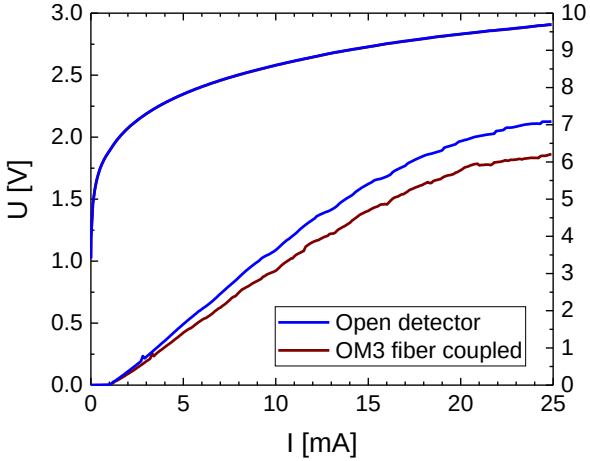


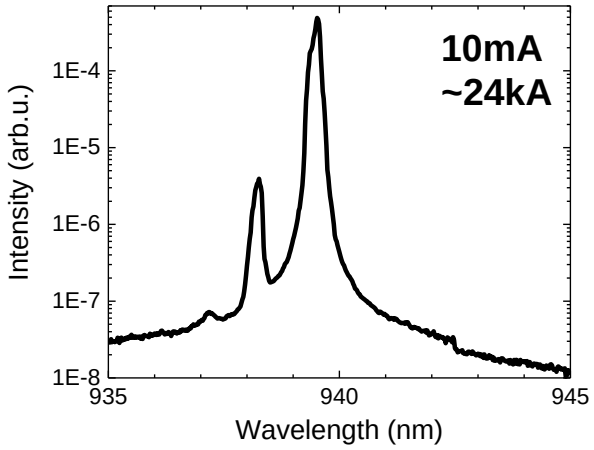


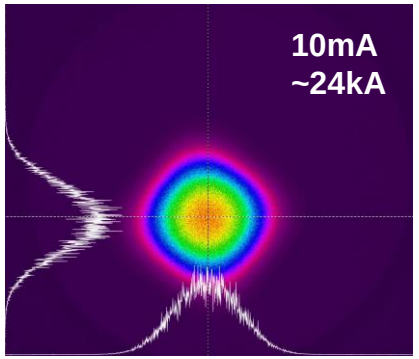


FF FWHM ~30°

Compact multi-aperture array* *(*output power can be further increased through AR coating)*







FF FWHM ~12° !!!

Similar coupling efficiency in 50µm OM3 fiber

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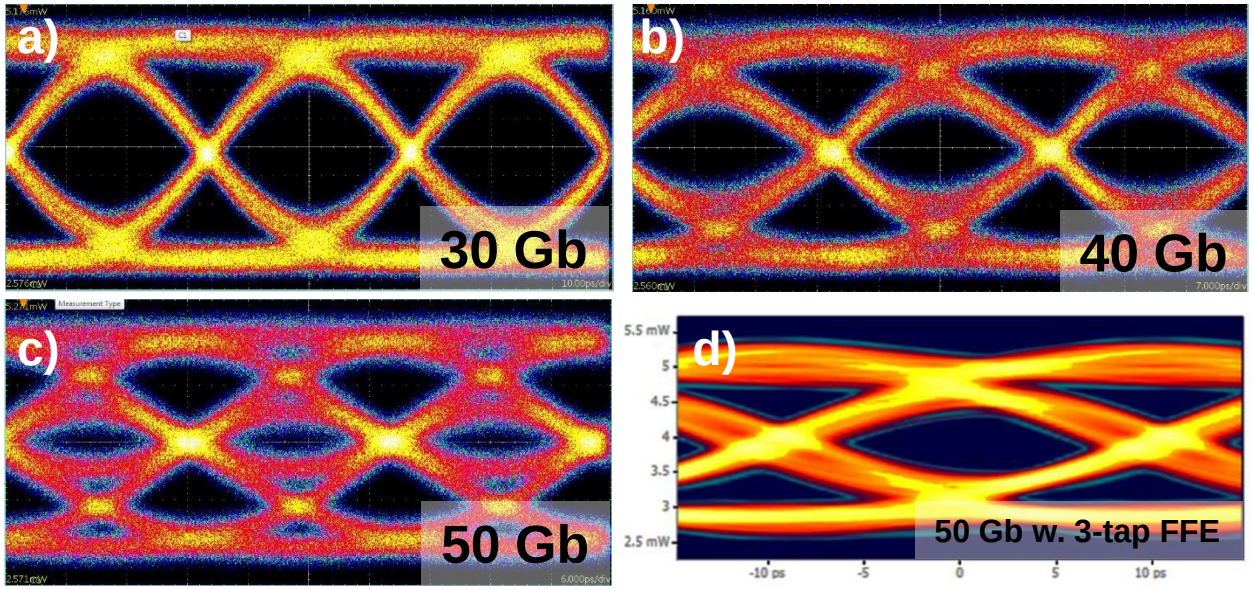
Up to 50 Gbaud data transmission



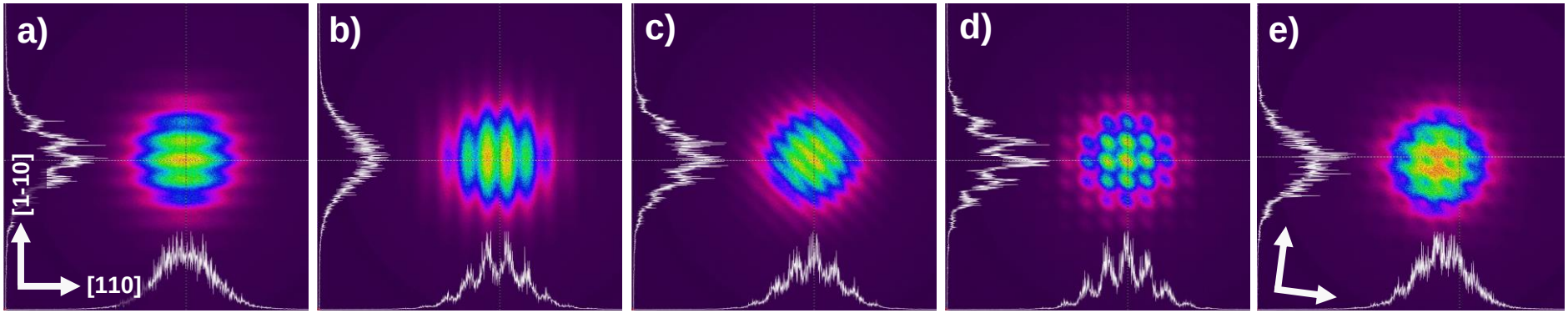
50 Gbit/s NRZ w. 3-tap FFE at receiver equalization

Increased area of the top mesa incerases the parasitic capacitance, although thorugh proprietary design, still 50 Gbaud transmission can be realized while maintaning high power and narrow spectral width.

Usually, coherency of emitters is observed at very small separating distances and applying apertures formed either by **selective tunnel junctions or by proton bombardment**. We report **oxide-confined** and electrically driven coherent emission in arrays for the first time.

Leakage of the optical mode from one emitter into another allows to enable coherent emission at distances of 10-15µm between emitters.

Coherent emission can enable beam steering, Bessel-like beams (very long diffraction enabled focal length), reduction of spectral width and bandwidth enhancement through photon-photon resonance.



Different coherent modes measured in the far-field at different currents

Available prototypes

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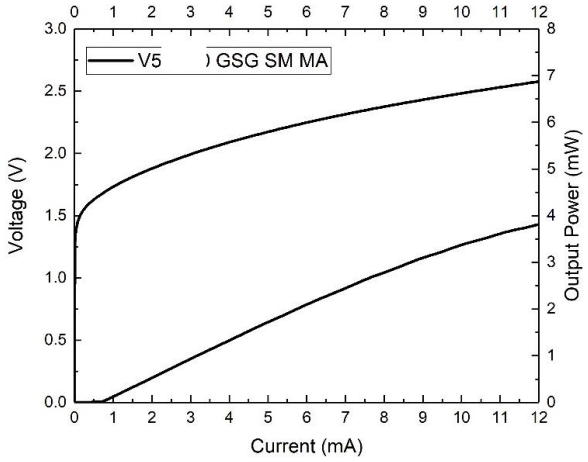
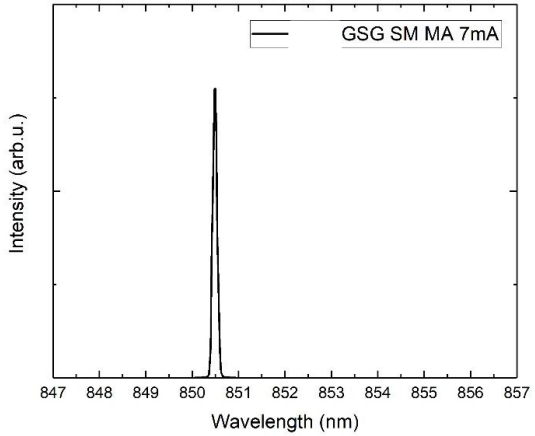
100 Gbit/s PAM4 SM VCSELs

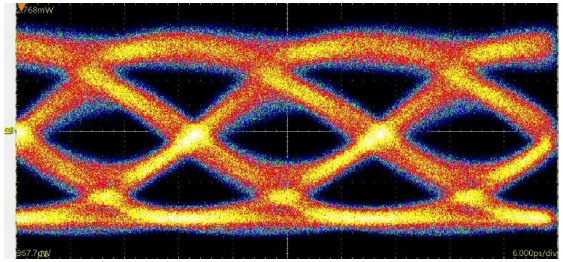
New multi-aperture VCSELs available as R&D samples 850nm



2mW SM

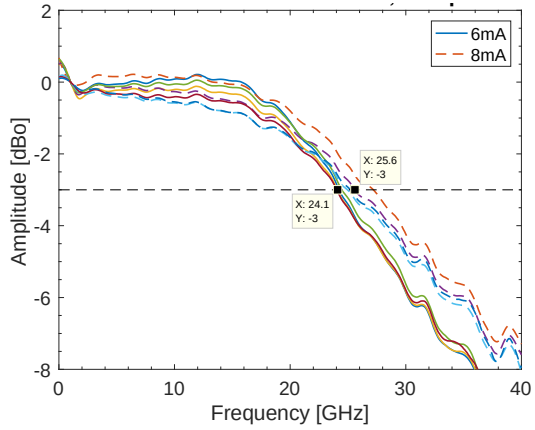


Single mode



100G

7mA 50 Gbit/s NRZ eye diagram
without equalization and processing



~30 GHz

Up to 30 GHz optical bandwidth (-3dBo)

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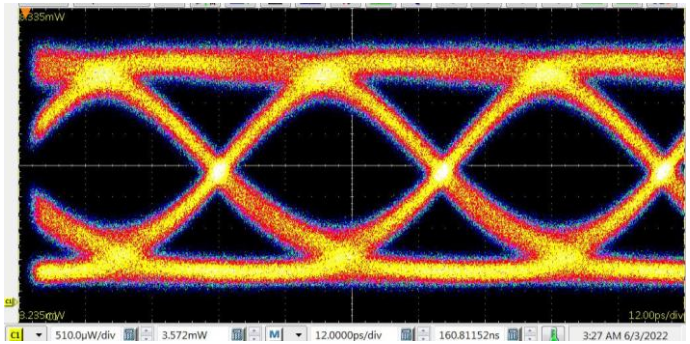
New modules for LiFi trials with VCSELs at 940nm

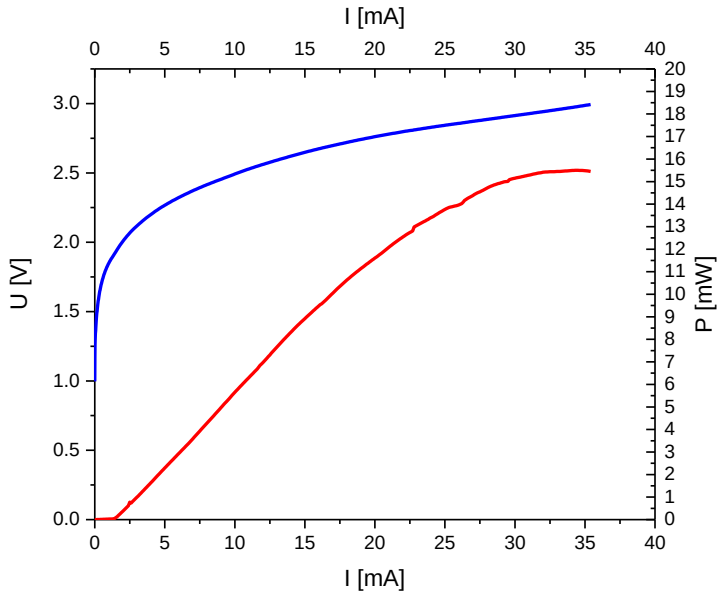
New Modules available upon request for LiFi trials

VCSELs on HF connector
(Requires external bias-T and current supply to operate)

>10 mW output power
Up to 40 Gbit/s NRZ, 50 Gbit/s PAM4



Fiber coupled 25 Gbit/s eye without equalization and pre-emphasis



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Conclusion

Status of the VCSEL technology

- **NRZ: 100 Gbit/s (50Gbit/s @ 2 km) / up to 71 Gbit/s @ 3.4 pJ/bit**
- **PAM4: 160 Gbit/s (100Gbit/s @ 1 km)**
- **DMT: 224 Gbit/s**
- **SWDM: 600 Gbit/s**
- **SDM: 600 Gbit/s**
- **LiFI arrays: up to 50 Gbit/s at high power. (new)**
- **Development of 1.3um and 1.5um VCSELs**

Passed qualification in 2021

InP Photo-Diodes for 112 Gbit/s PAM-4
>0.5 A/W from 850 nm to 1550 nm

VCSELs for 112 Gbit/s PAM-4 in SWDM range
850 nm, 880 nm, 910 nm, 940 nm

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Thank you!