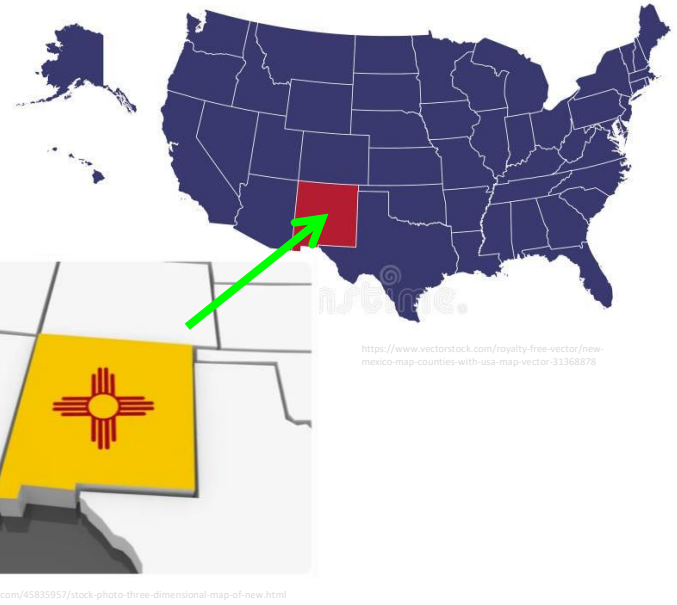
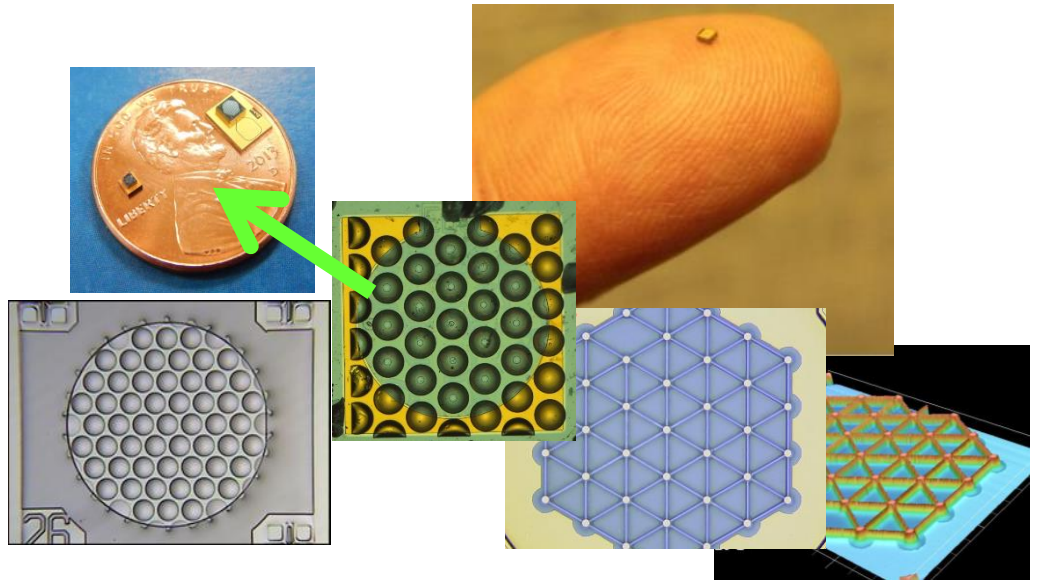
LiFi Connections using Optical Wireless Near Infrared LightGrids

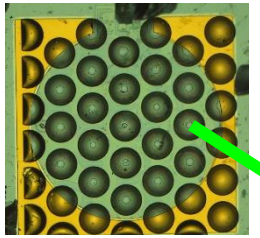
John R. Joseph

optiPulse Inc.
Farmington, New Mexico, USA



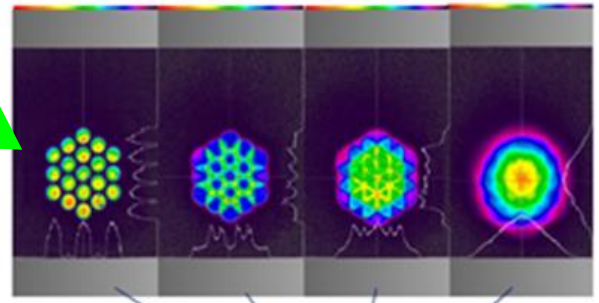


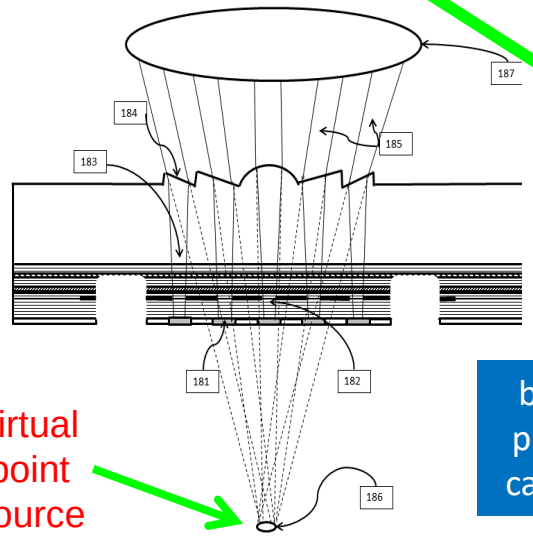
Propagating high power and light uniformity with ultra high bandwidth



19-element array
with etched lenses

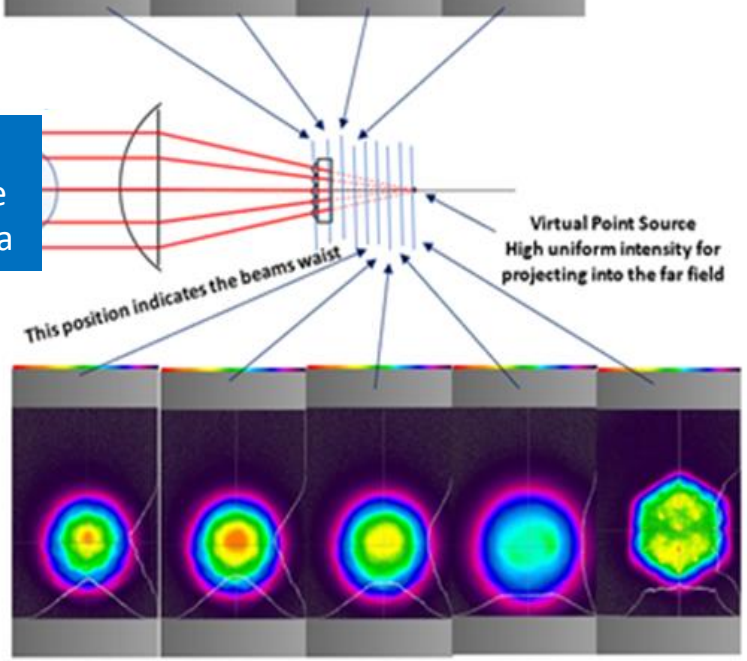
free space beam intensity patterns

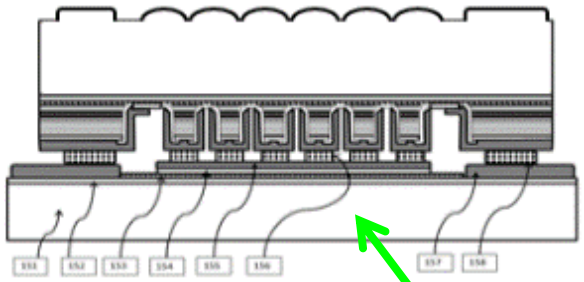




virtual
point
source

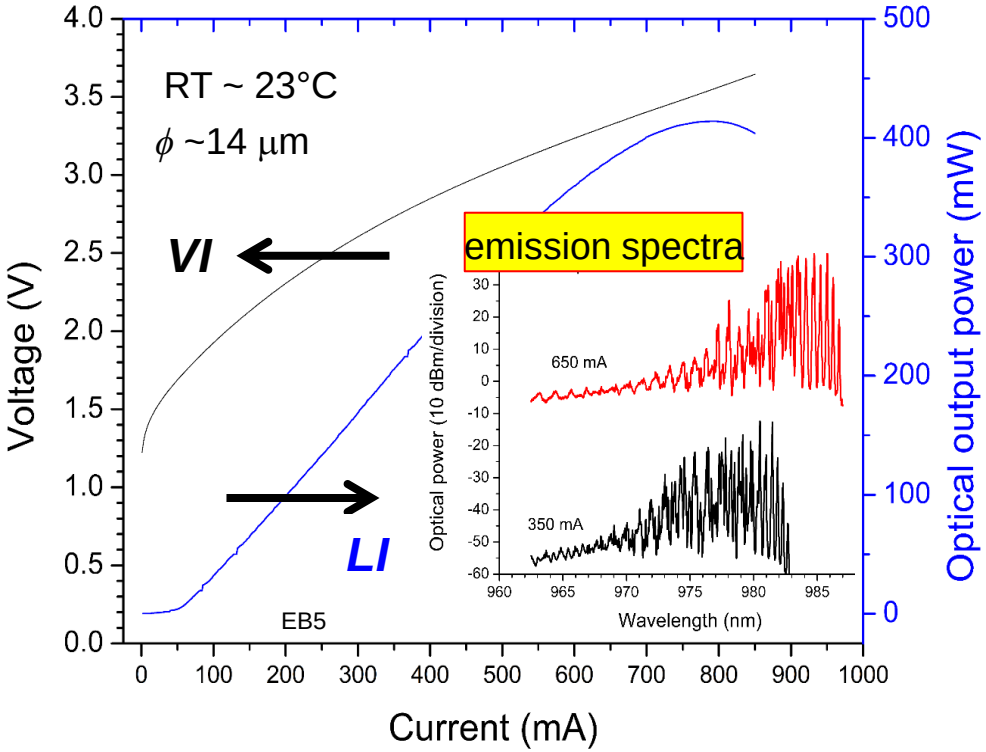
beam
profile
camera



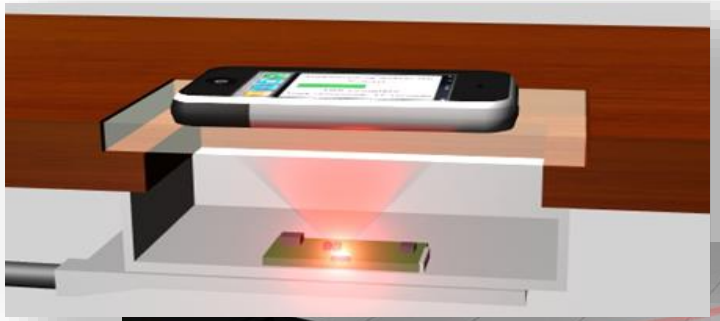


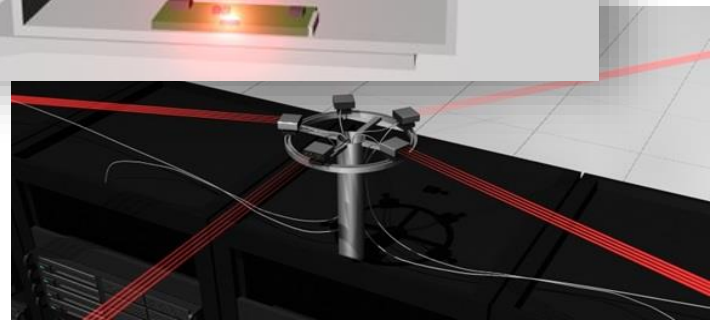
patented VCSEL array geometry and packaging

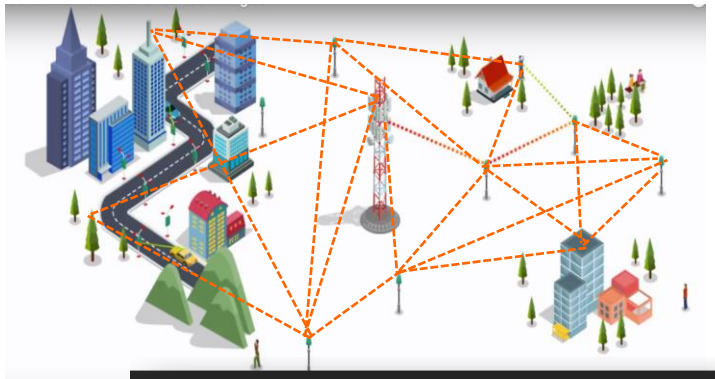
continuous wave (CW)
light power-current-voltage (*LIV*)

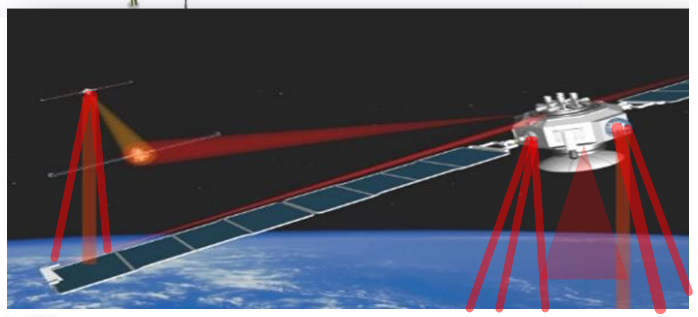


400 mW/19 VCSELs
~21 mW/VCSEL









range definitions based on text from the OWCC website

see: https://www.owcconference.com
https://owcc.jakajima.eu

- **Ultra-short range**:
  chip-to-chip communications

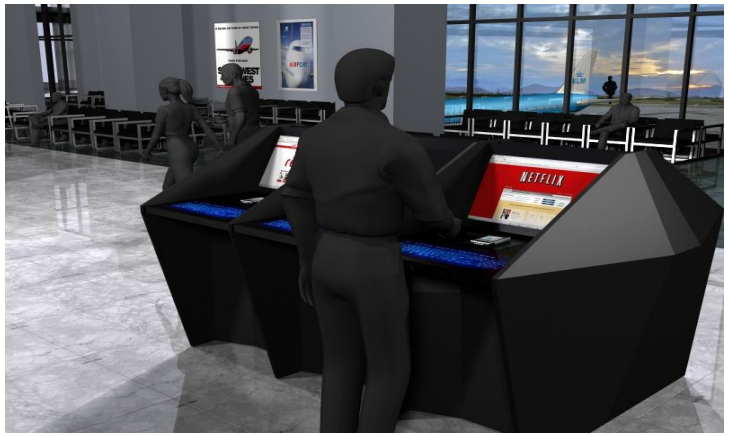
- **Short range**:
  wireless personal area networks (WPAN) and underwater communications; Internet of Things (**IoT**) data; LiFi?

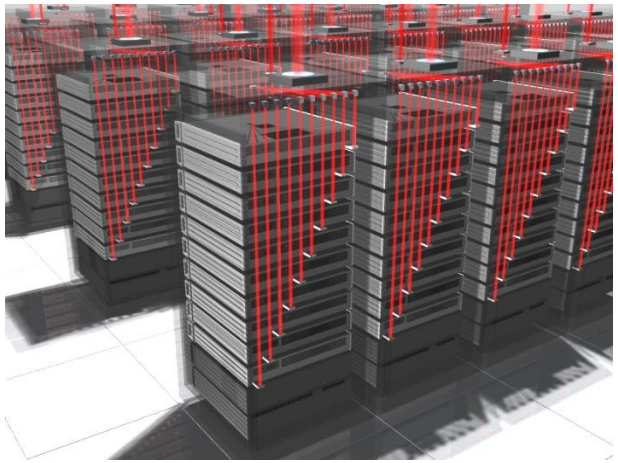
- **Medium range**:
  indoor IR and visible light communications (**VLC**), wireless local area networks (WLANs); inter-vehicular and vehicle-to-infrastructure communications; **light fidelity (LiFi)**; data centers, **6G** communication and sensing

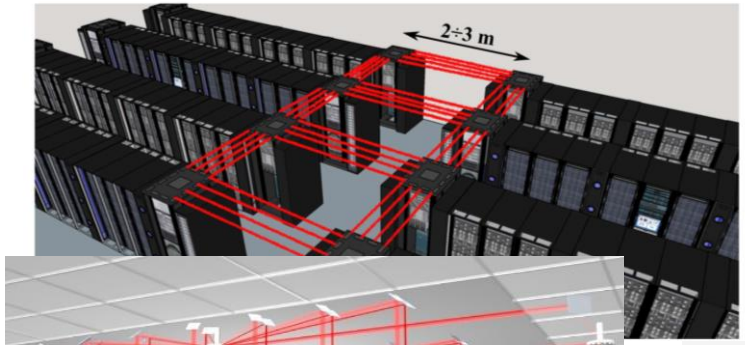
- **Long range**:
  inter-building links, free-space optical (**FSO**) communications**;** **backhaul/fronthaul**, high altitude platform stations (HAPS)

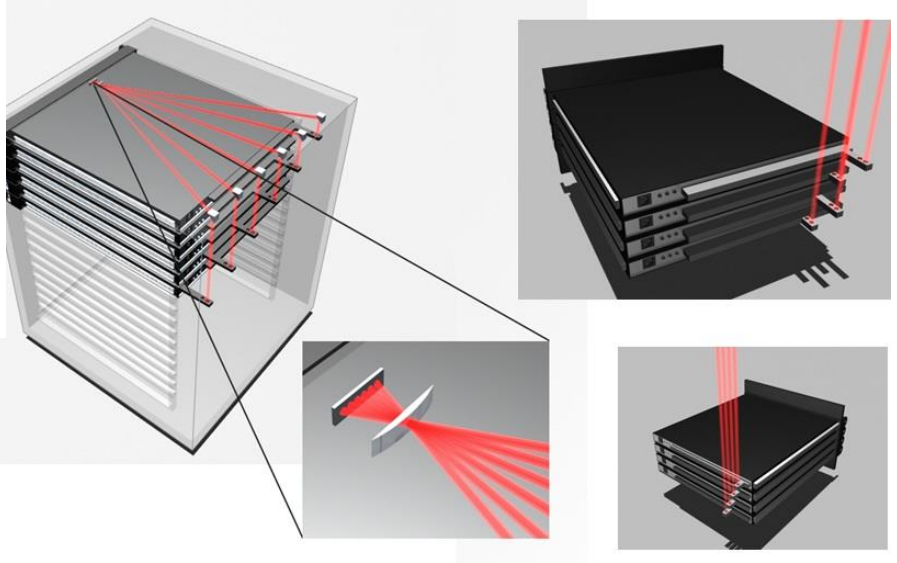
- **Ultra-long range**:
  laser communication in space especially for **inter-satellite links** and from satellite constellations to/from Earth

Some of OptiPulse's targeted LiFi applications









Li-Fi Conference

A classic VCSEL trade off: *bandwidth vs. optical output power*

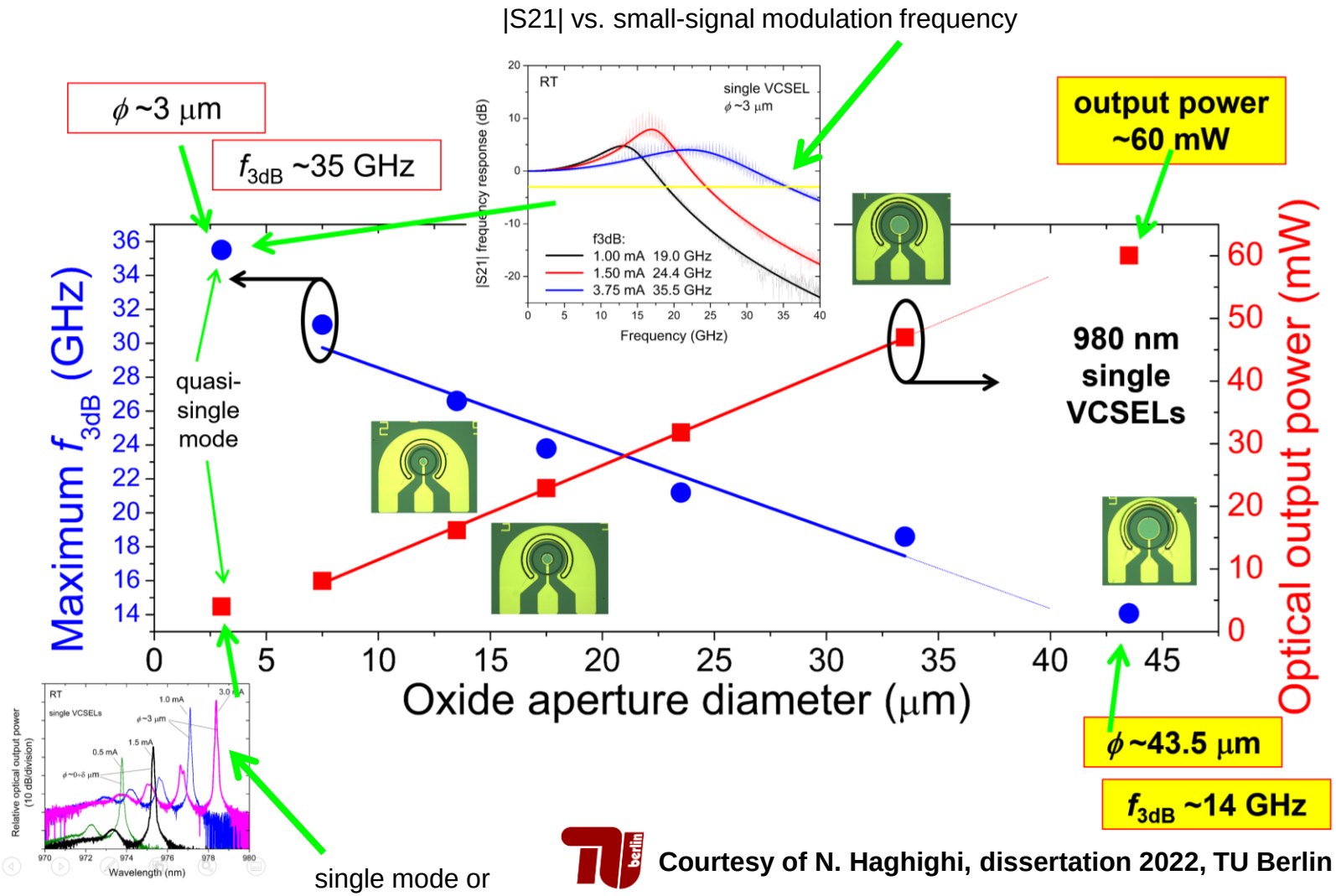
Generally, increasing the top-emitting single VCSEL aperture diameter (ϕ):

1) **increases** the optical output power;

2) **decreases** the bandwidth;

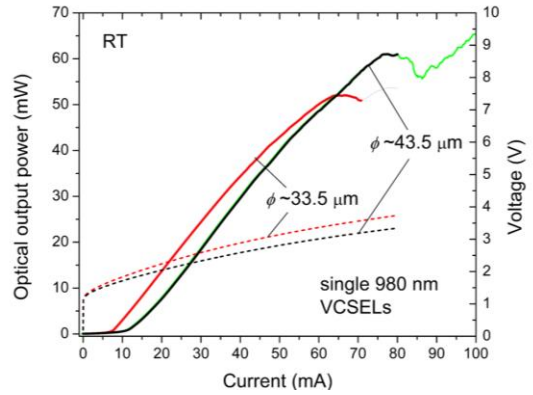
3) **increases** the number of **lateral modes** – moving the emission from a Gaussian intensity far field toward a "donut" shape; and

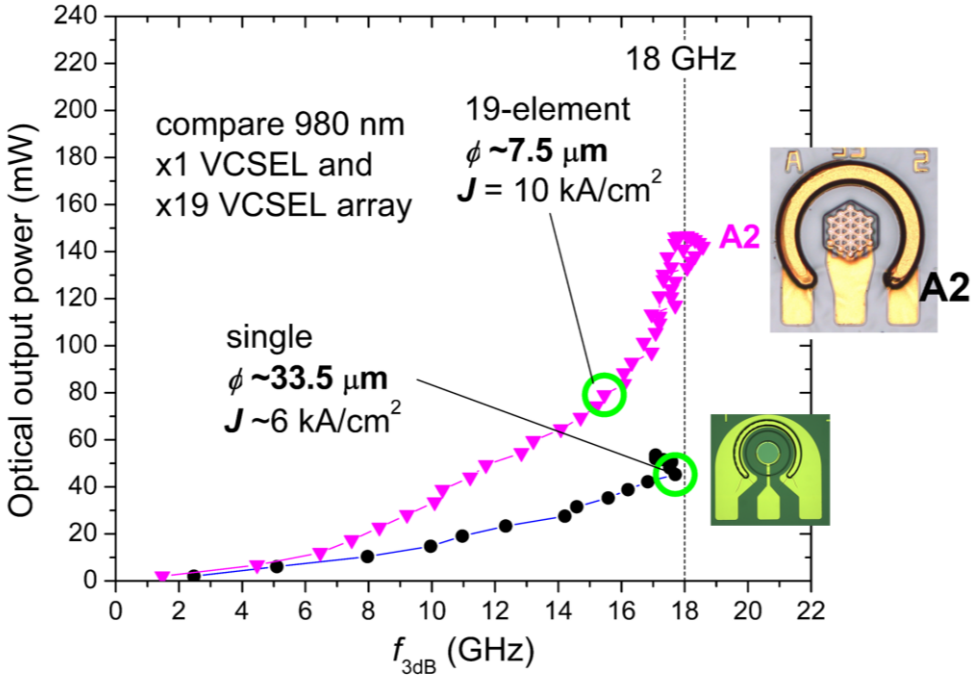
4) the **power conversion efficiency** peaks around ϕ ~10-12 μm then decreases.

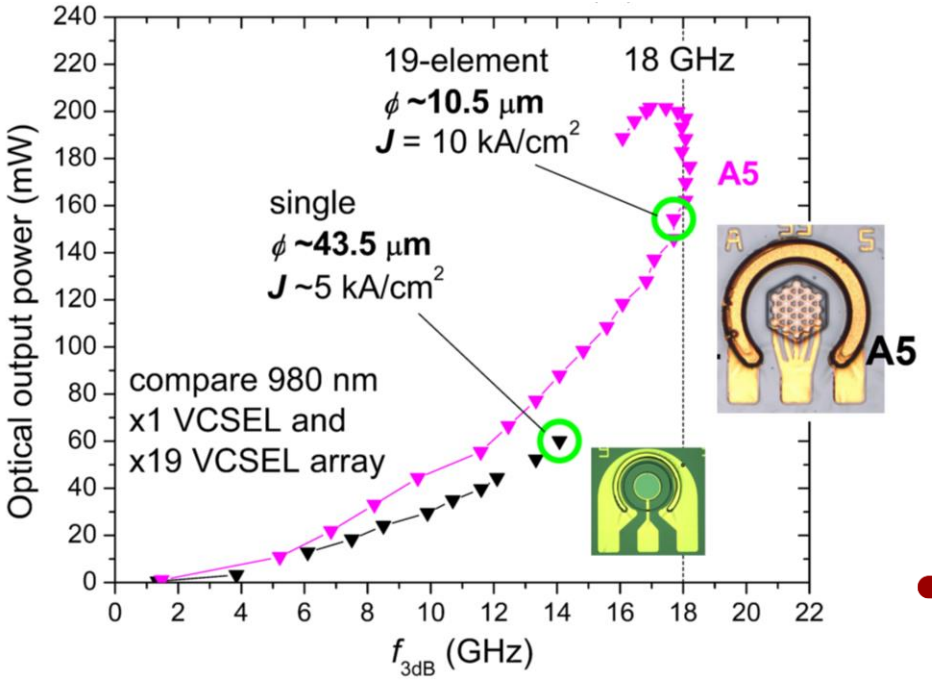


Compare single VCSELs to ~equal emission area 19-element arrays

- Arrays have equal or **higher bandwidth**
- Arrays have 3 to 4 times **higher optical output power**
- The array far field pattern (with or without micro-lenses) is much better suited for optical wireless communication links (e.g.; a Gaussian or top hat profile compared to a “donut” or “daisy” mode profile)







Courtesy of N. Haghighi, dissertation 2022, TU Berlin

Genesis of our light emitting chip testing – test of a single VCSEL vs.a 105-element electrically parallel VCSEL array circa 2009

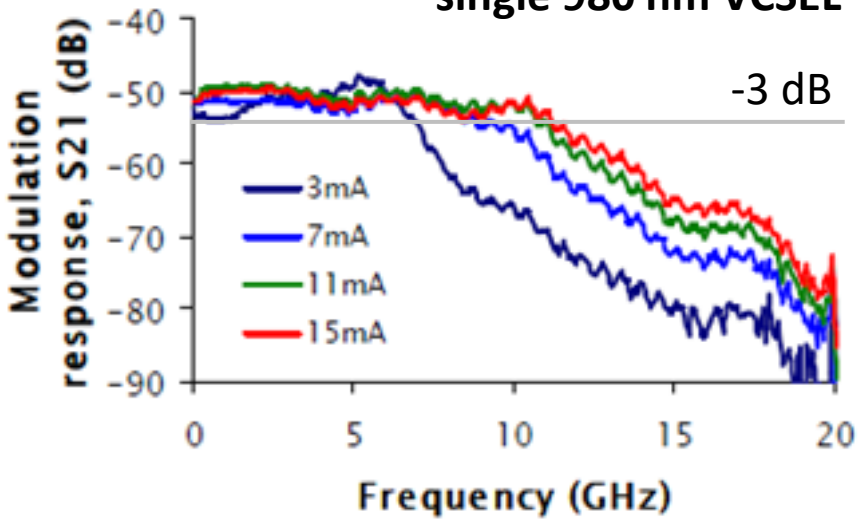
Early CSU work shatters record for single chip power/speed combo

Record combination of bandwidth and optical output power for a VCSEL array

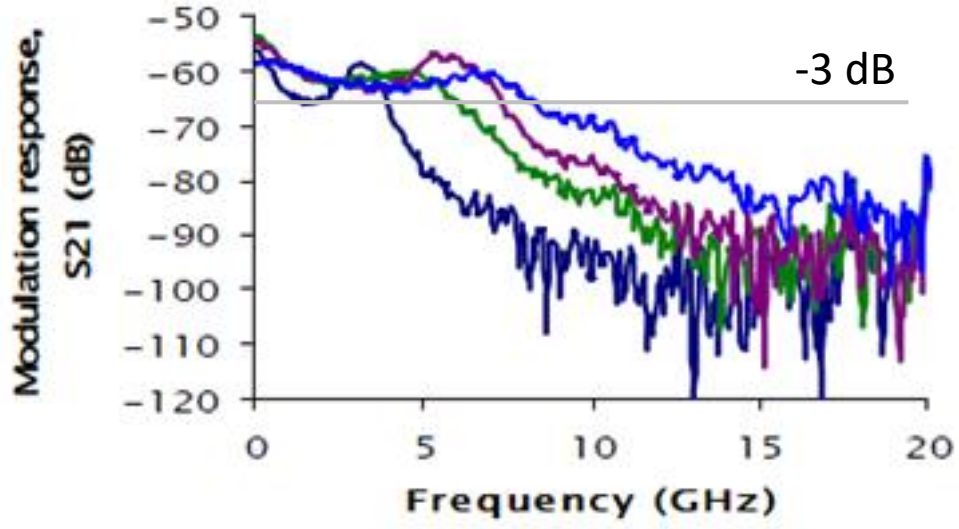
ϕ ~16 μm
L_{max} **~25 mW**
f_{3dBmax} > 10 GHz

ϕ ~16 μm each VCSEL
L at I = 3 mA/VCSEL = **1.5 Watts**
f_{3dB} at I = 3 mA/VCSEL > 7.5 GHz → data transmission at 10 Gbps

single 980 nm VCSEL

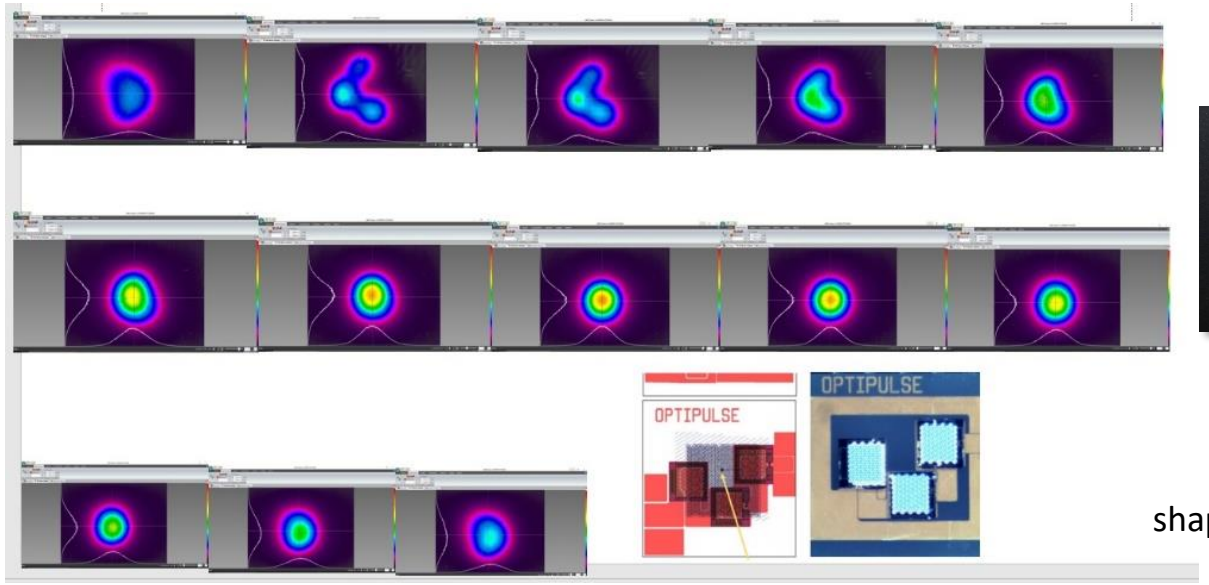


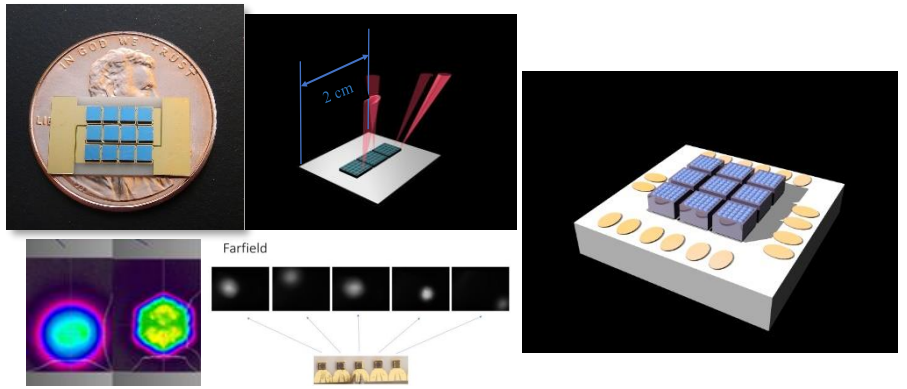
105-element 980 nm VCSEL array



Data: J. R. Joseph *et al.*, CSU, 2009, unpublished

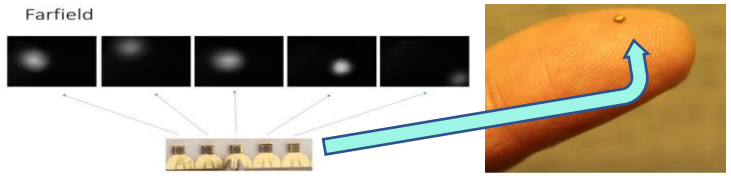
Multiple chips summed on a single beam

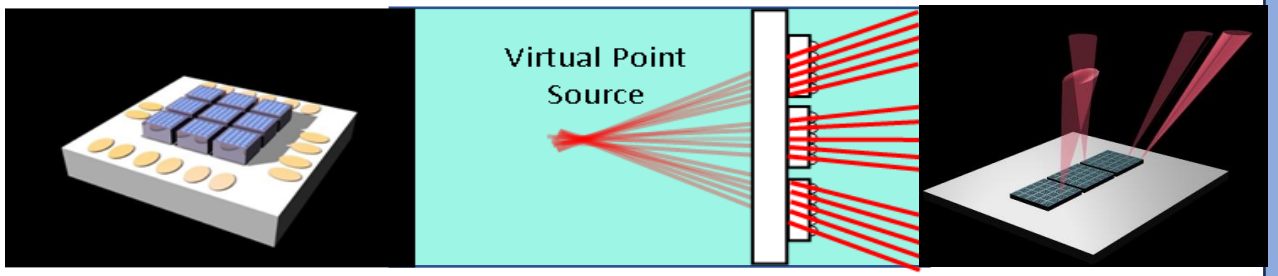




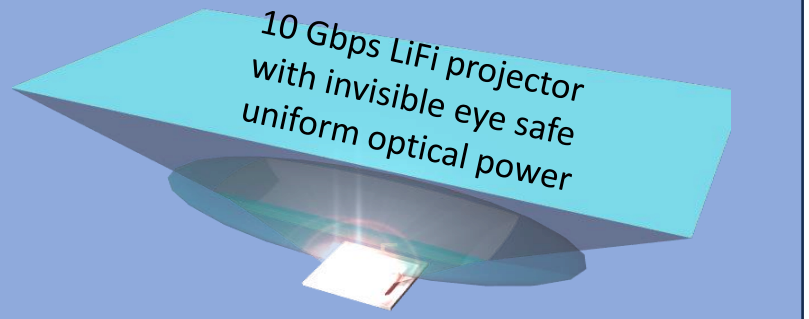
shaping beams steering beams

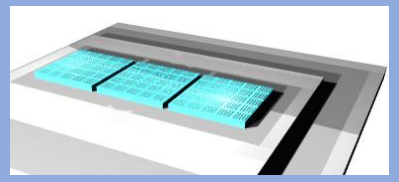
Phase I successful in demonstrating 1D non-mechanical beam steering





In the design phase





rendered elongated array

105 lasers on a chip

Tx and Rx evaluation boards – for OEM systems development

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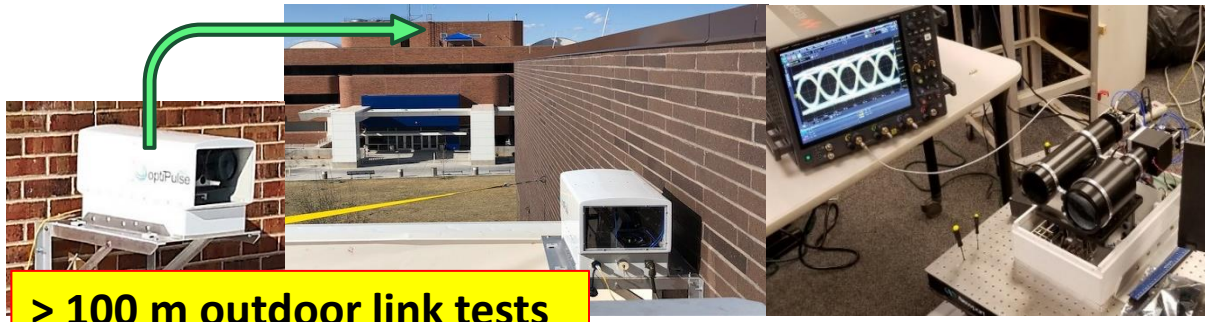
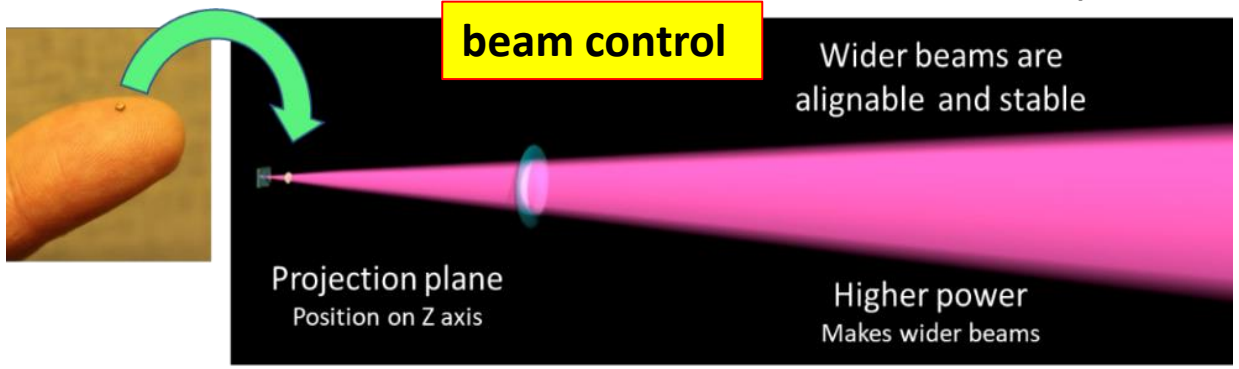
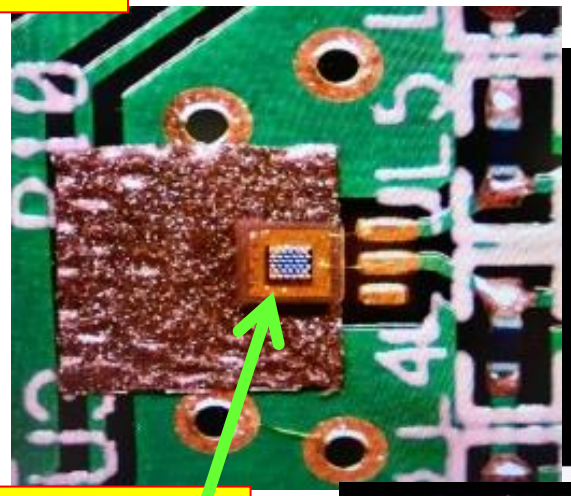
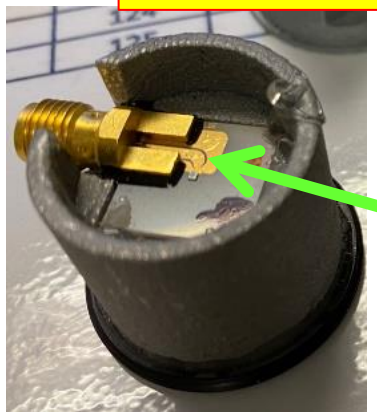


> 100 m outdoor link tests

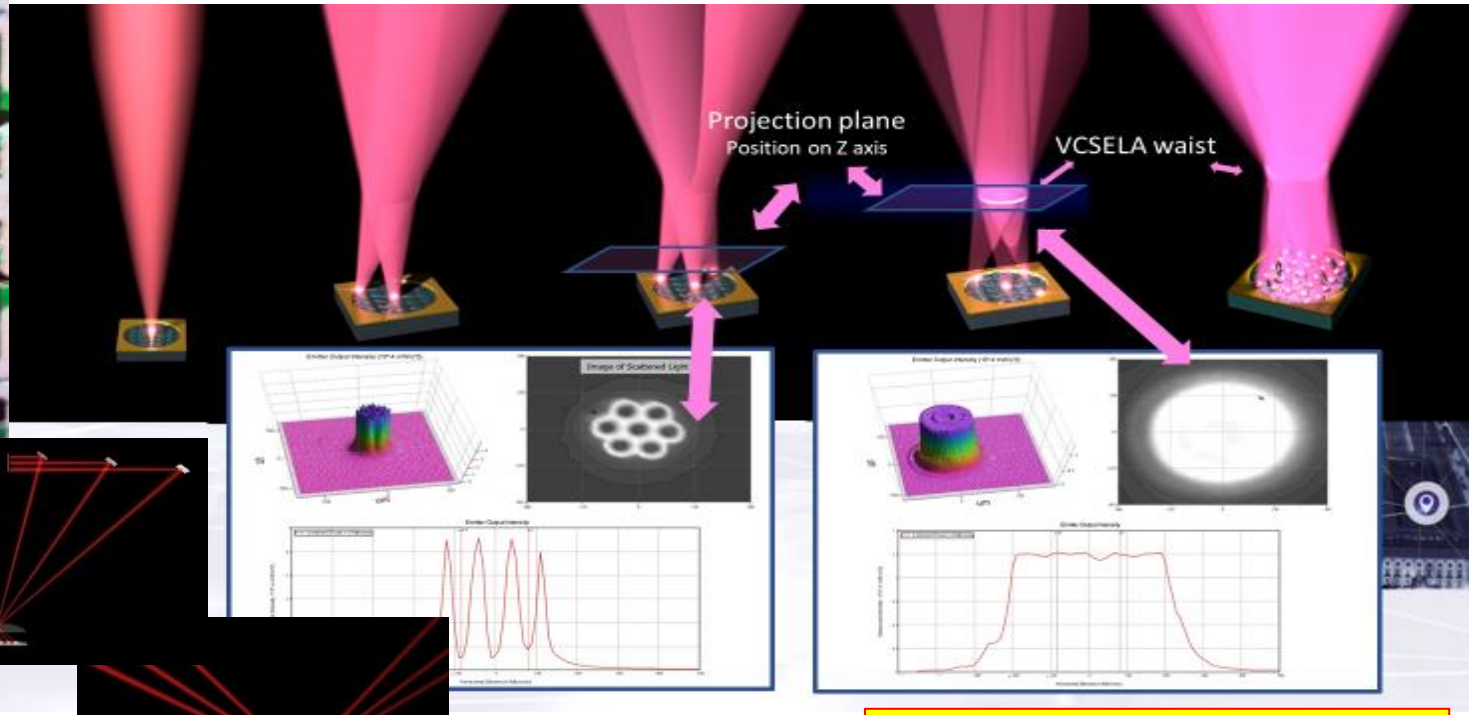


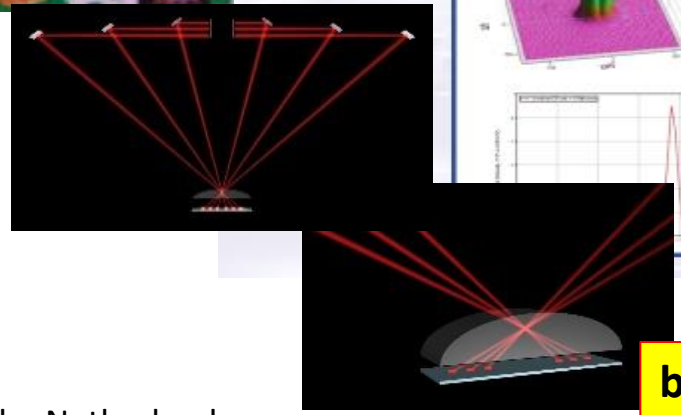
eval Tx/Rx boards





packaged VCSEL array





beam steering

“top hat” far field pattern

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Fiber to wireless demonstration

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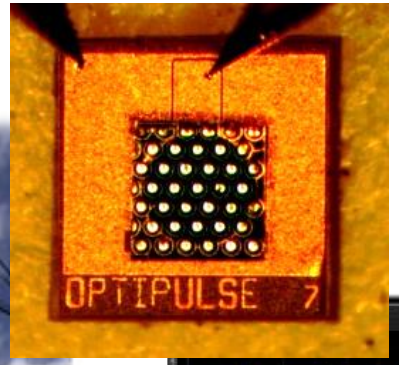
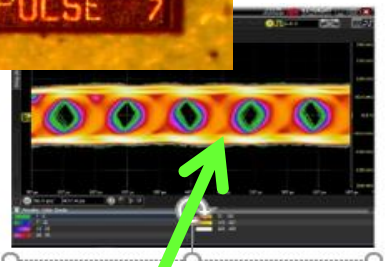
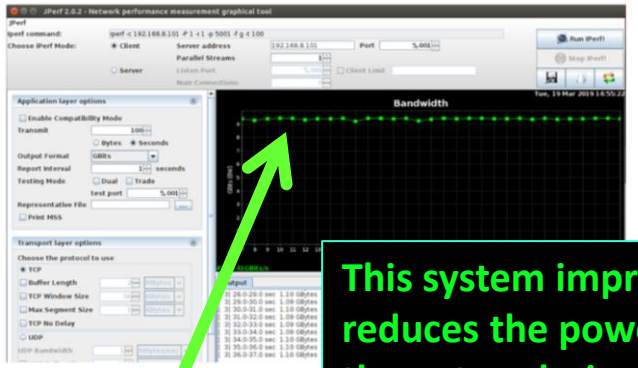
Prototype 3 (Tx and Rx)





poor Internet signal in

bit error ratio (BER) ~1x10^{-8}



excellent signal out

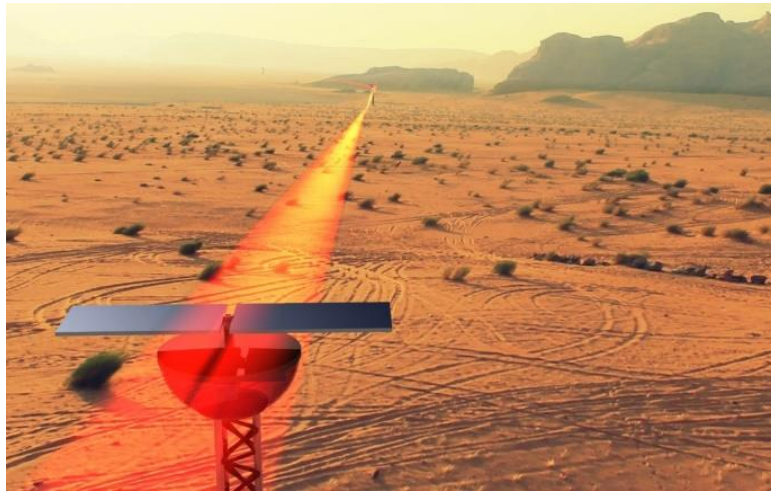
BER < 1x10^{-12}

This system improves signal integrity which reduces the power needed to boost/correct the network signal – reduces power consumption

NRZ OOK bit rate stable at 10 Gbps

THANK YOU for your attention

The Future of Next Generation Communication Technology is here



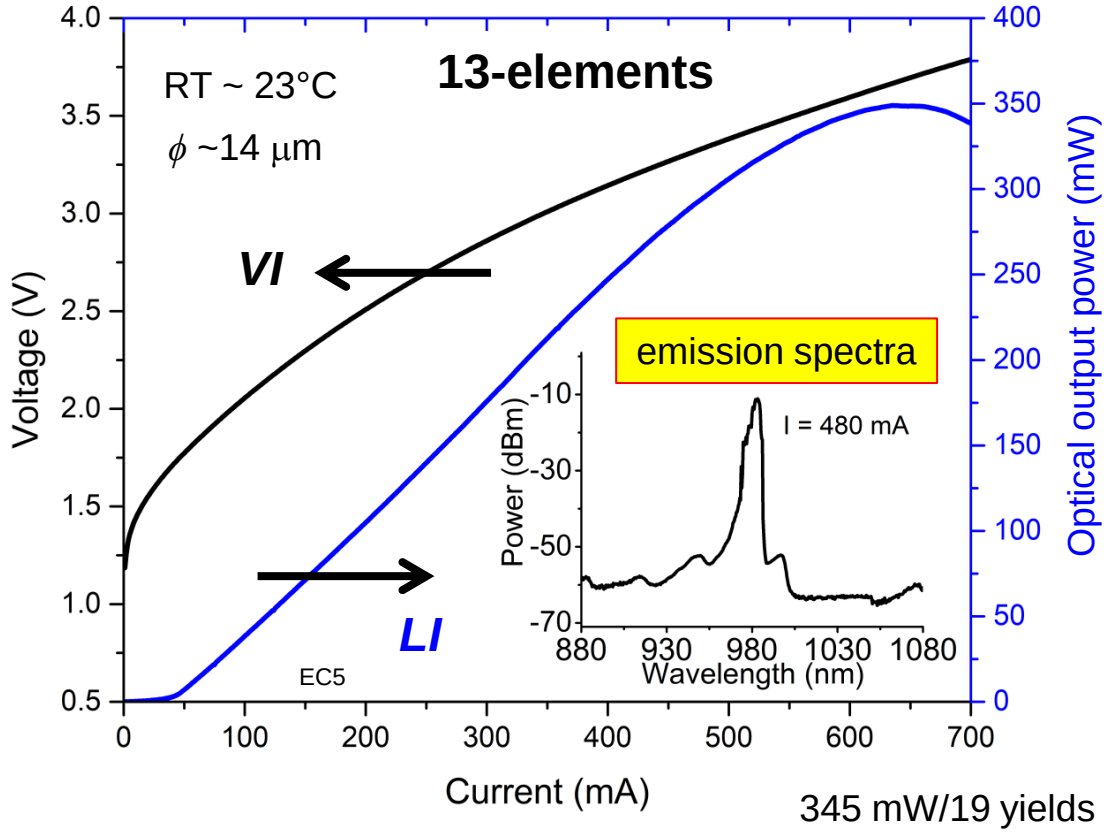
OptiPulse.com
Opticalwireless.net

John Joseph | CEO Principle| M 480-652-0717 | jjoseph@optiPulse.com
Prof. J. A. Lott | CTO | Chief Technology Officer jlott@optiPulse.com
Rex Thompson| COO | Chief Operating Officer| rthompson@optiPulse.com
William Nunn| CDO | Chief Defense Officer| wnunn@optiPulse.com

Back upslide: test data from a 13-element 980 nm VCSEL array

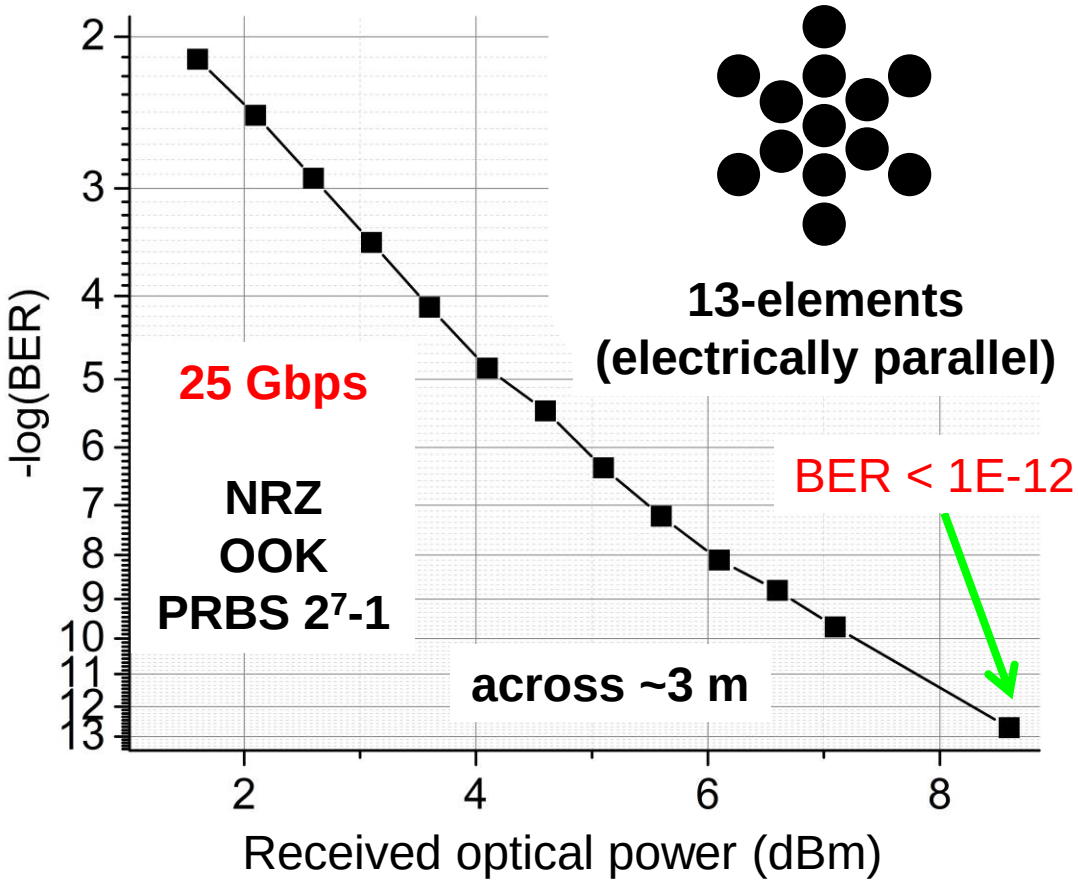
optiPulse INC

CW light power-current-voltage (*LIV*)



345 mW/19 yields
~18 mW/VCSEL

data transmission test



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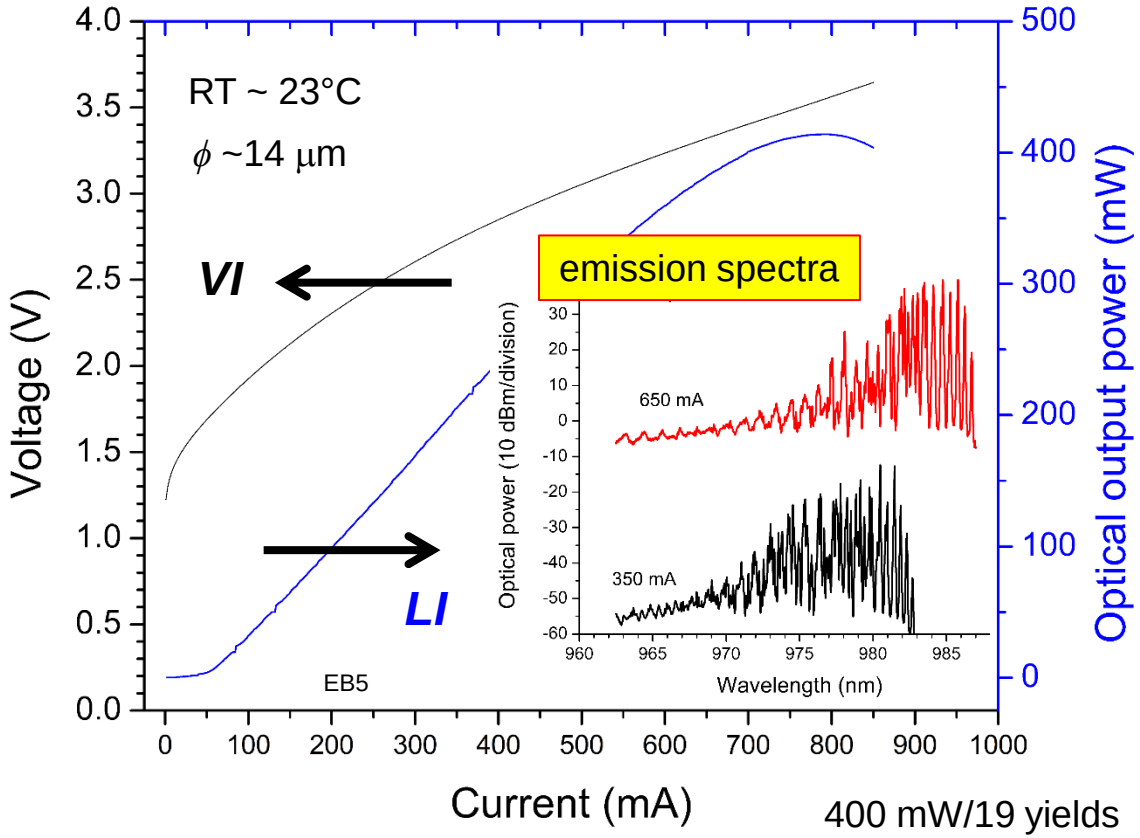

400 mW/19 yields
~21 mW/VCSEL

far field 1/e² full divergence angle ~11-14°