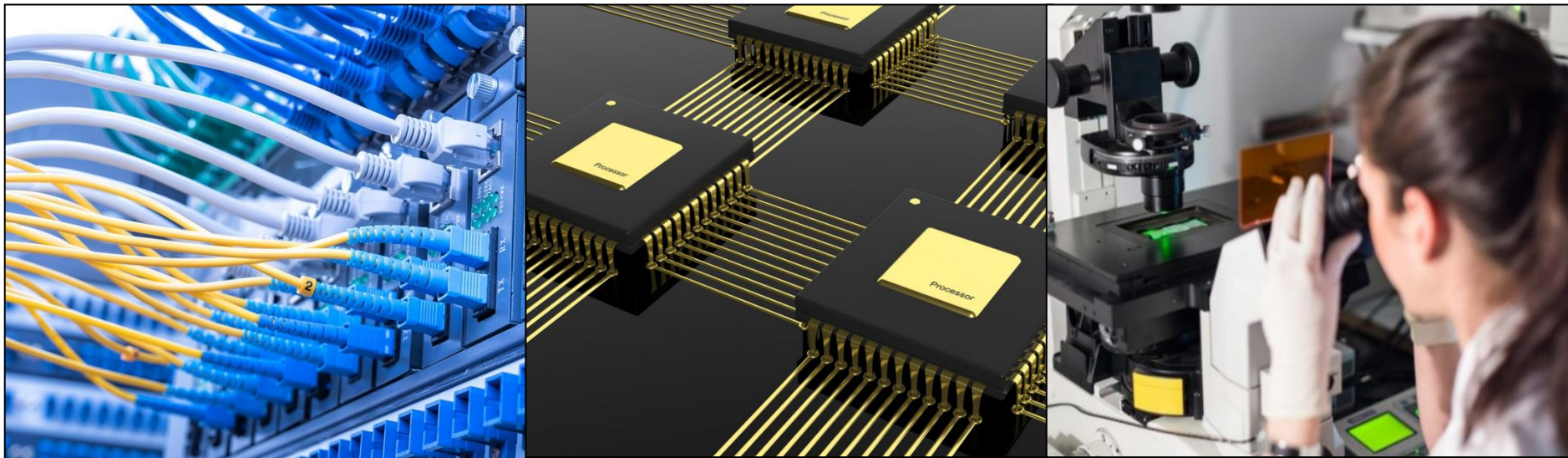


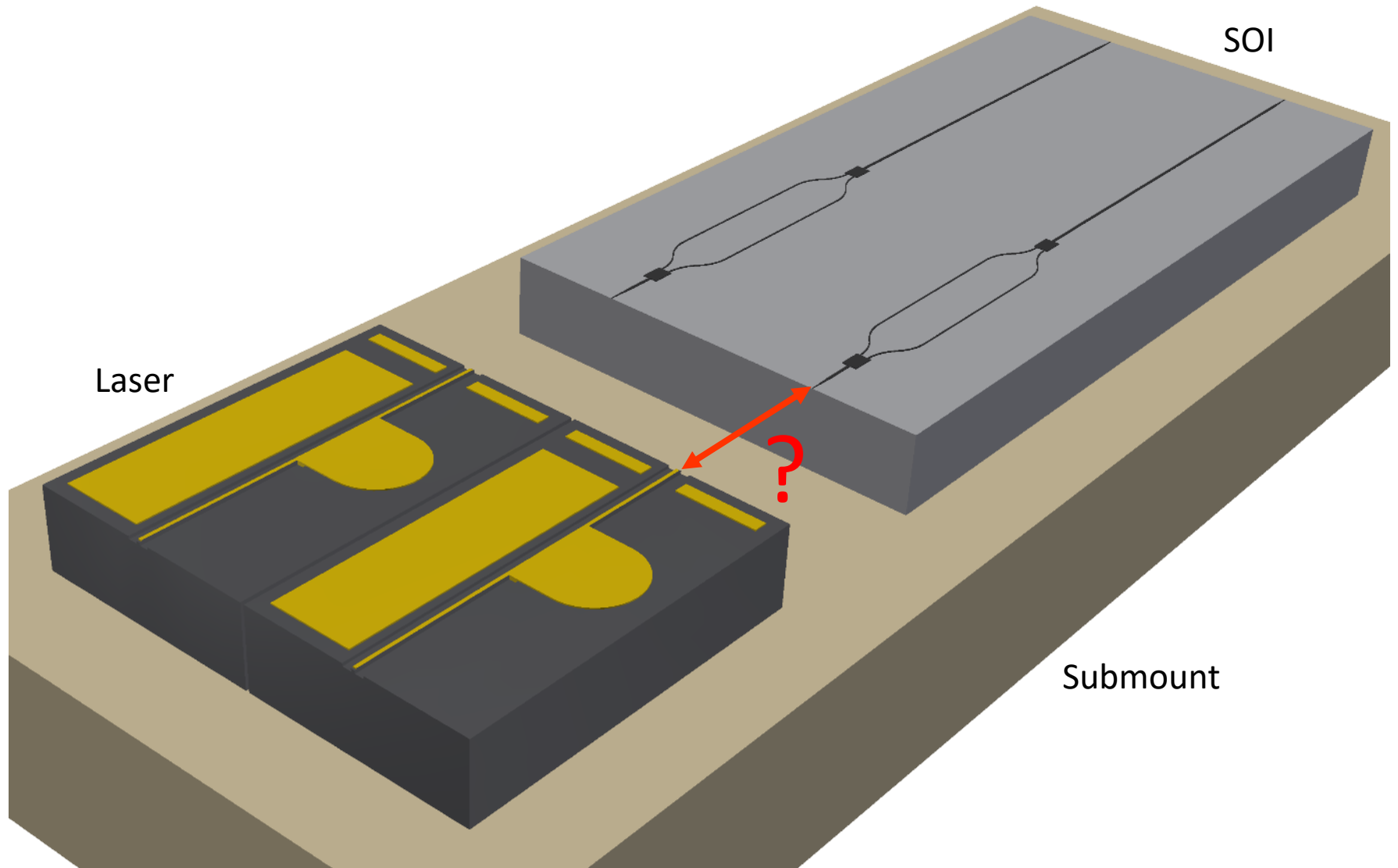
Industrielle Fertigung von Photonischen Wirebonds und Freiformoptiken

Vanguard Automation GmbH

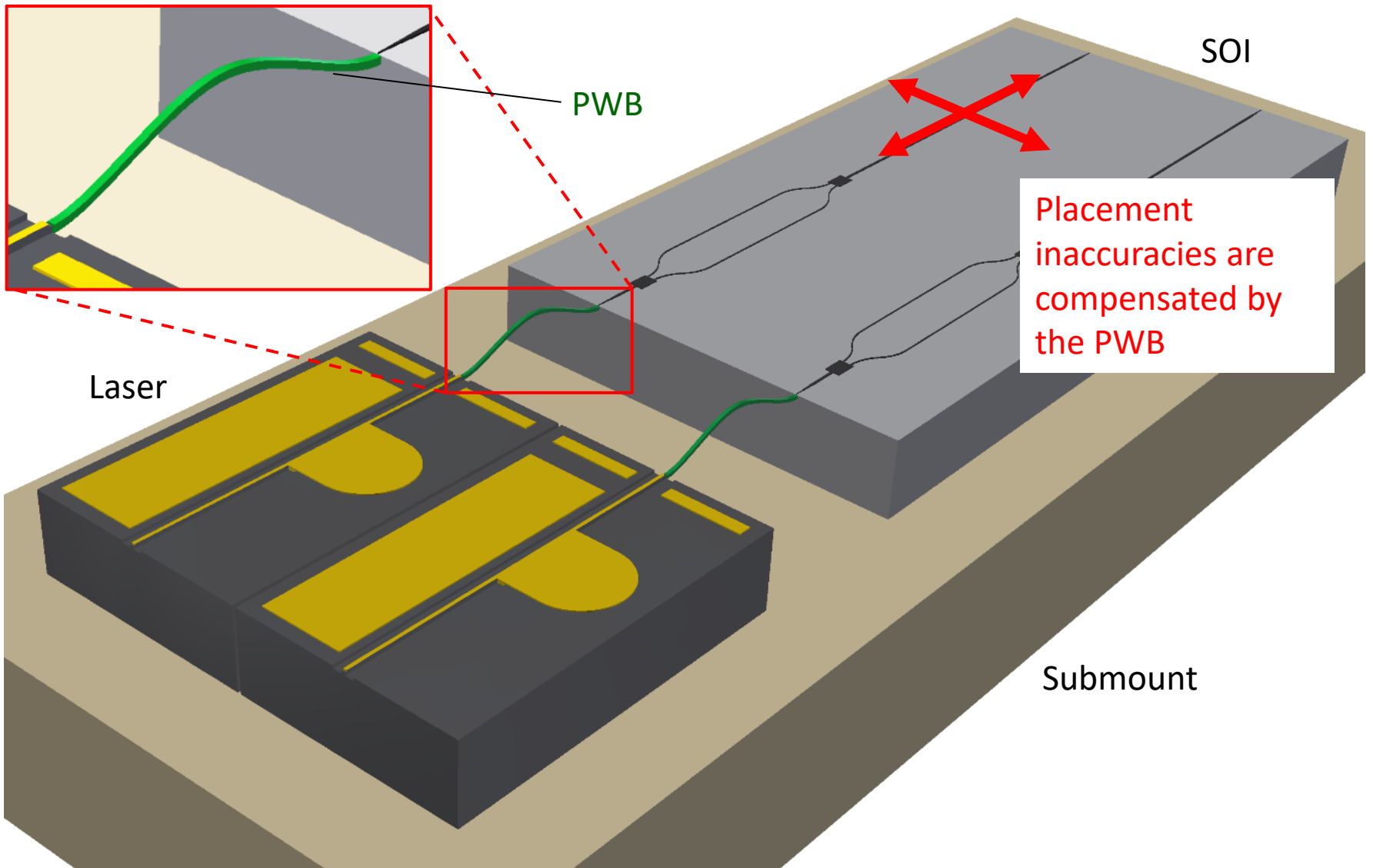
Philipp-Immanuel Dietrich



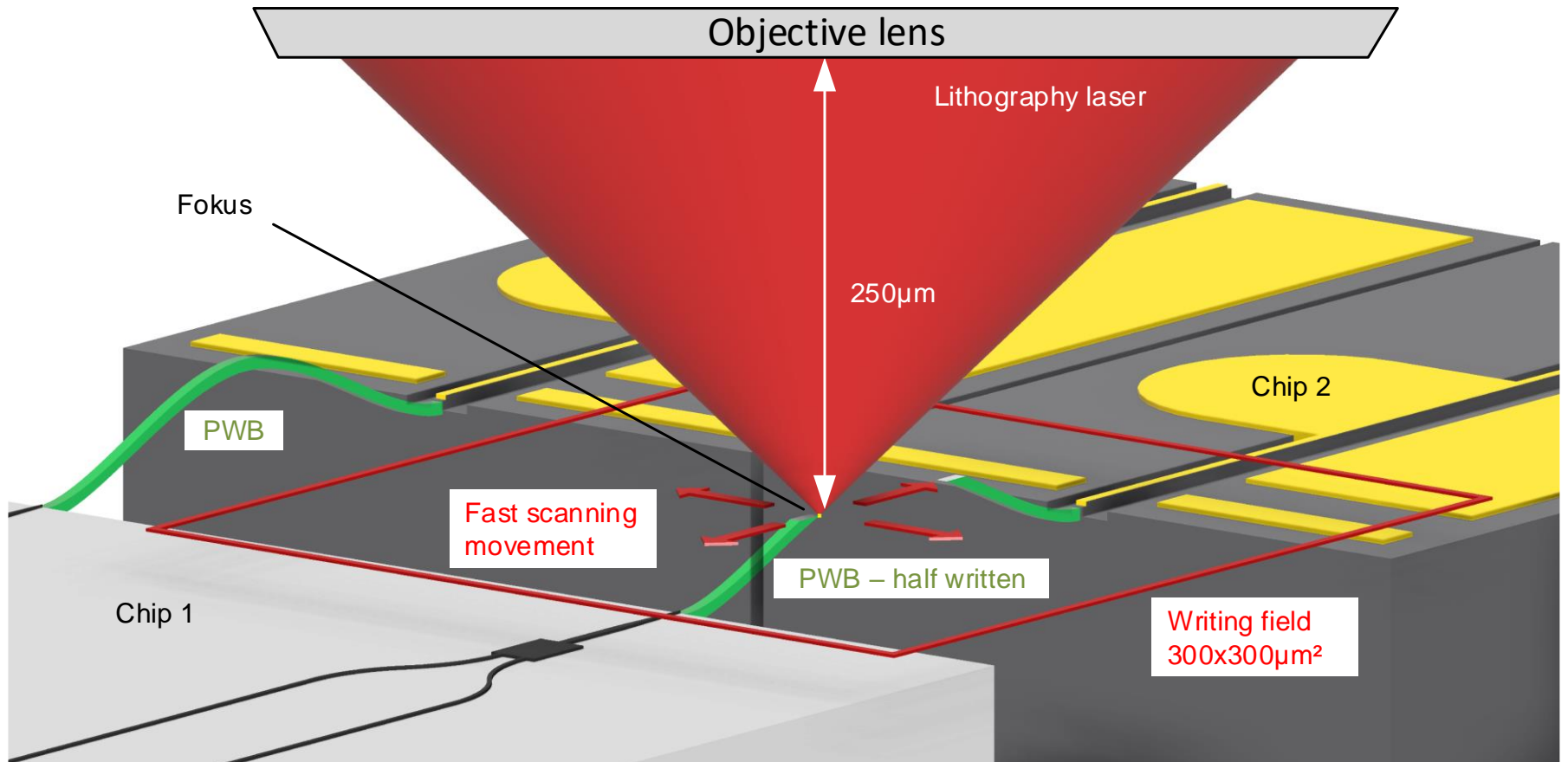
How to Couple Laser with Chips Without Active Alignment?



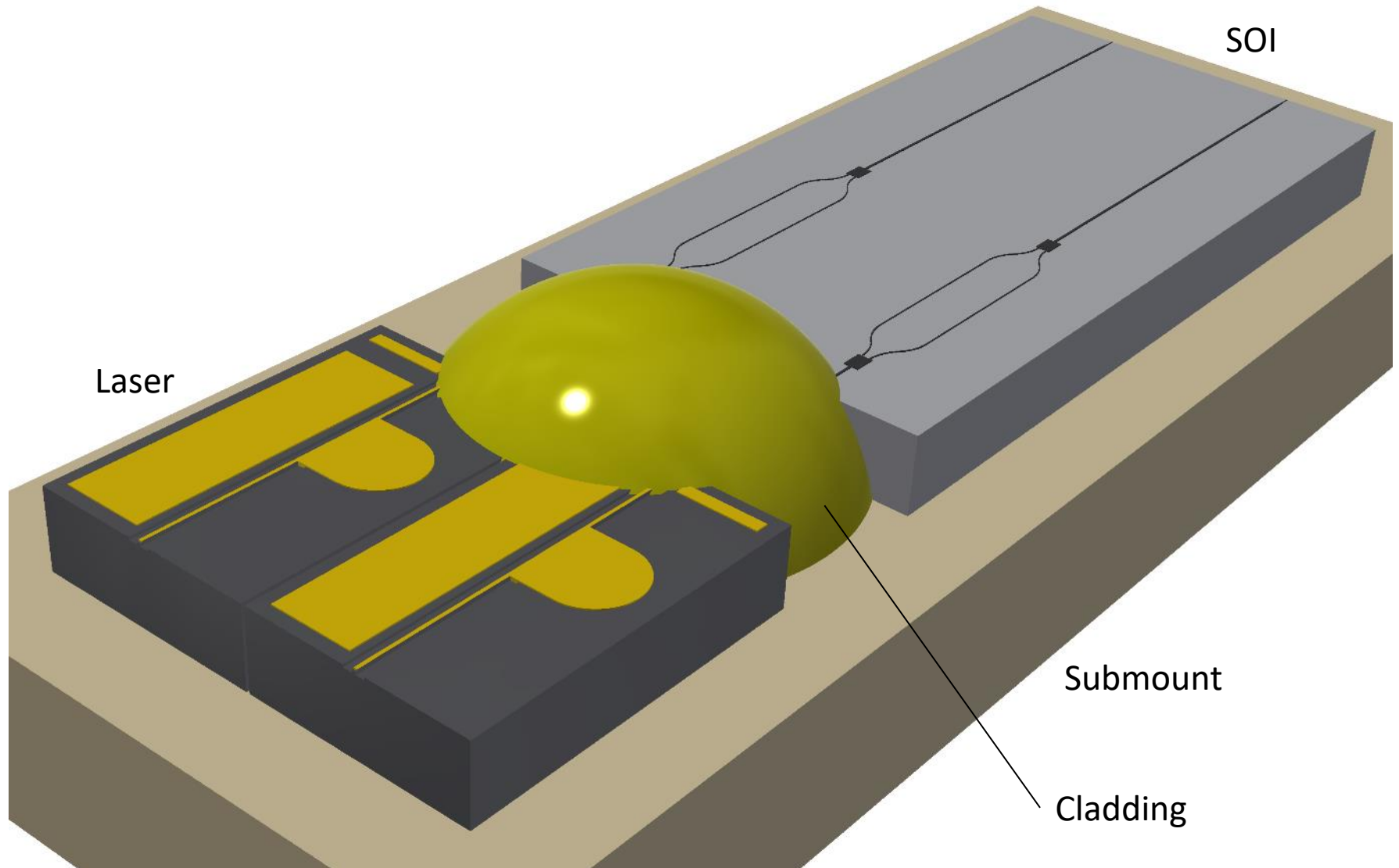
Photonic Wirebonds (PWB)



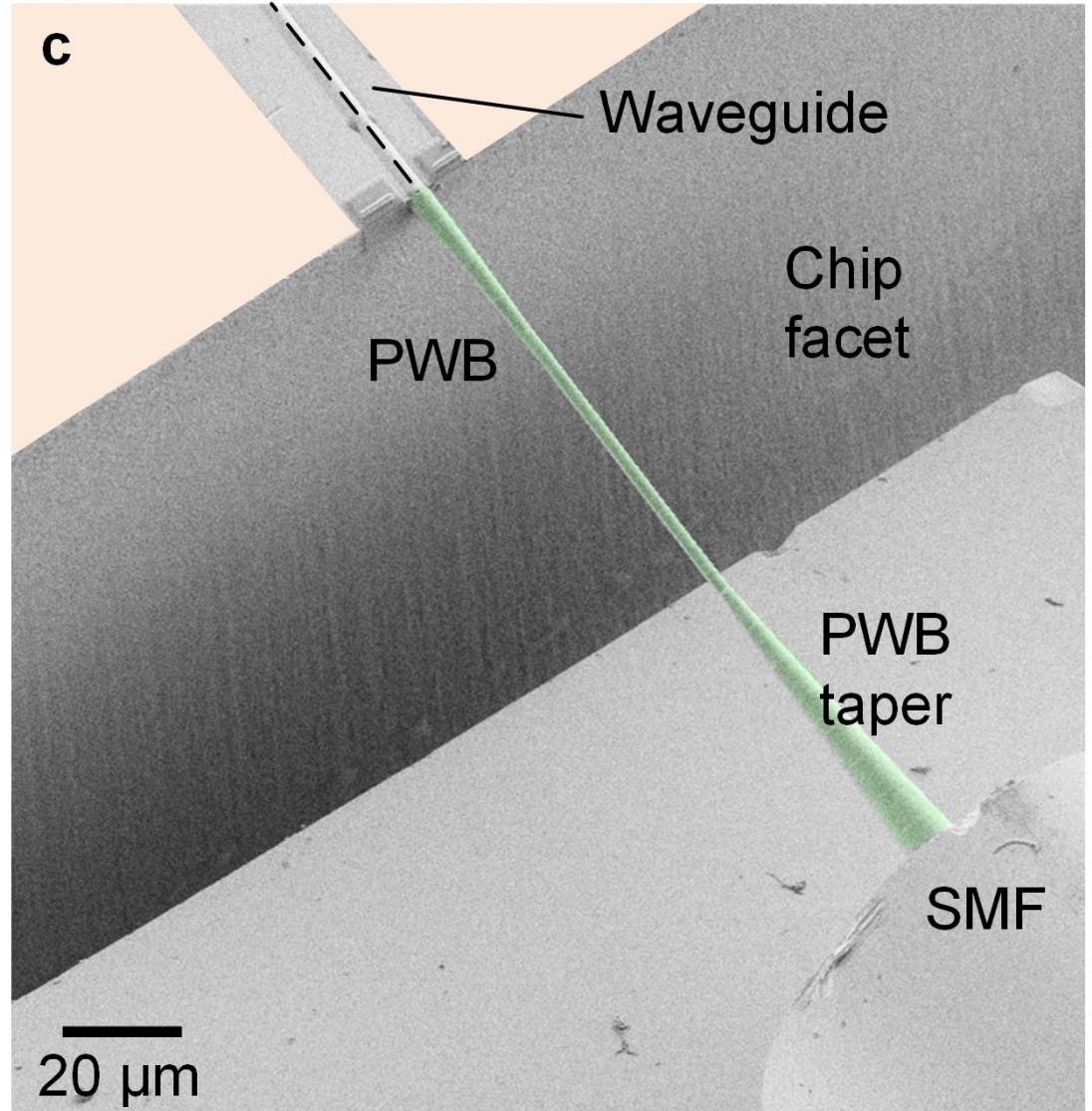
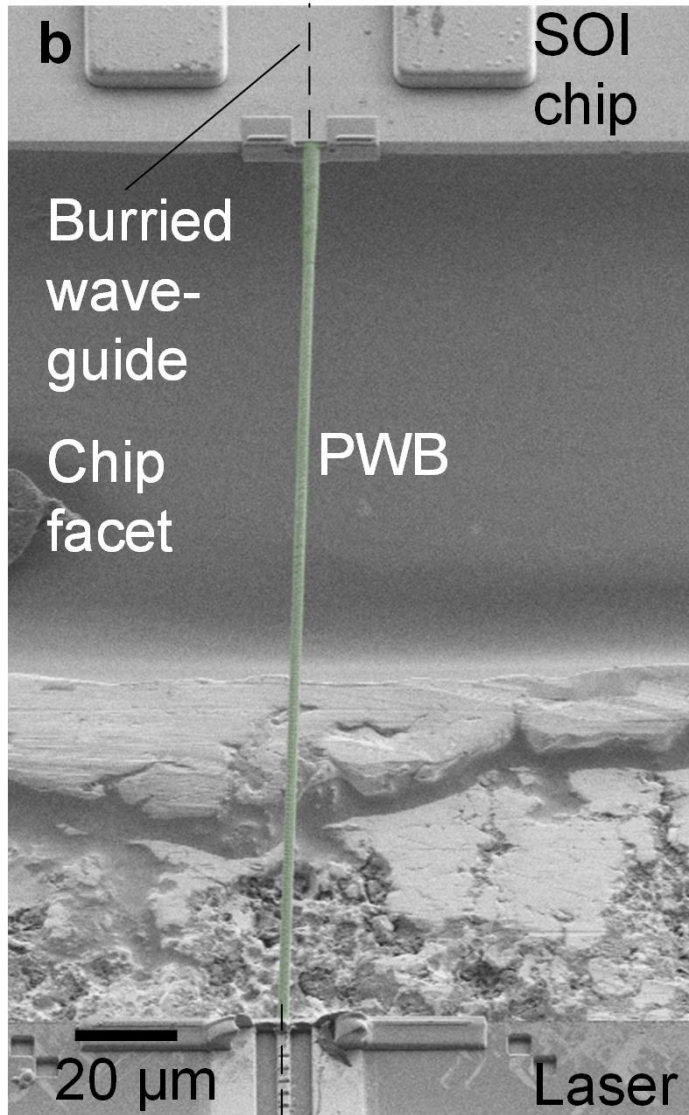
Fabrication with Two-Photon Polymerization



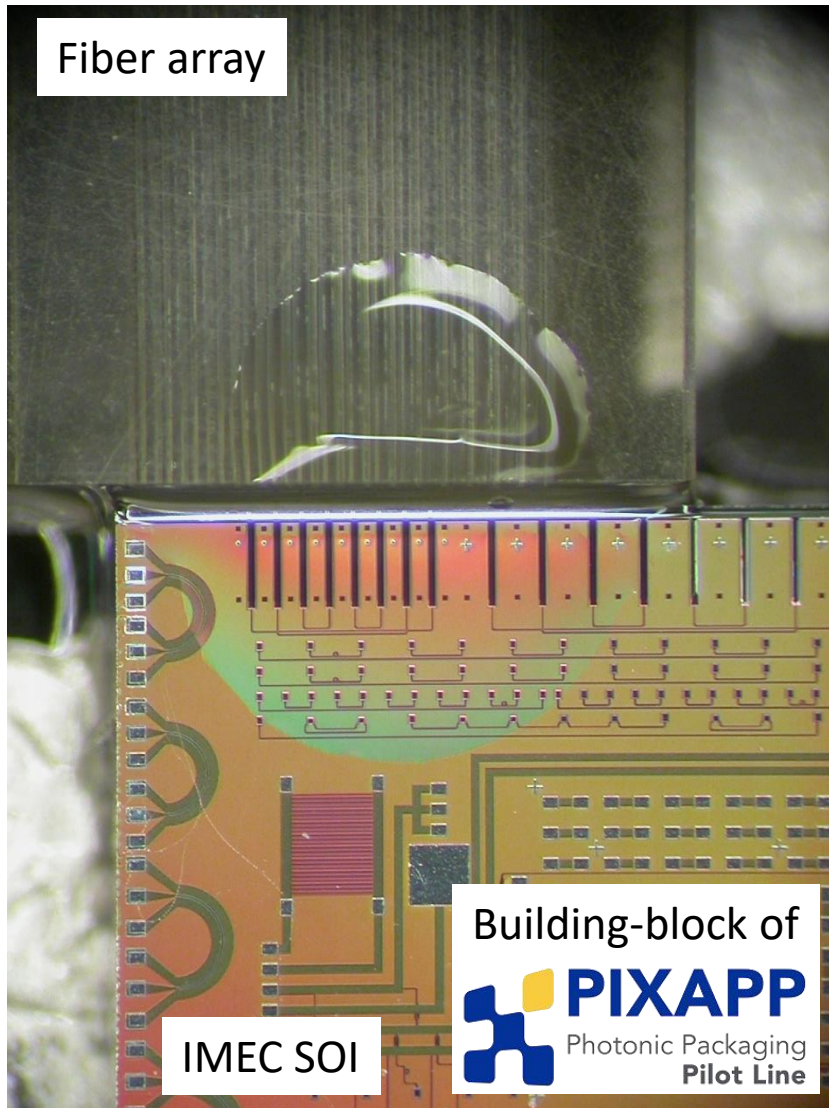
Cladding for Single-Mode Operation and Reliability



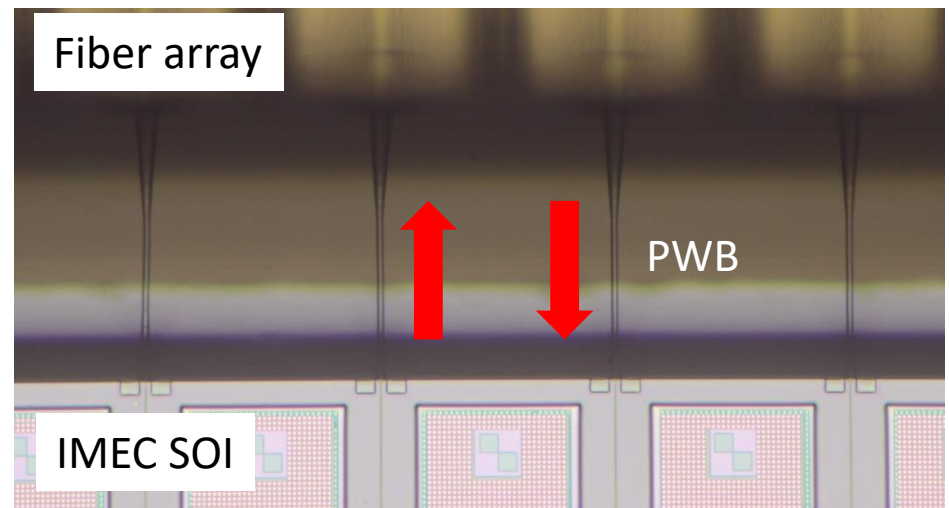
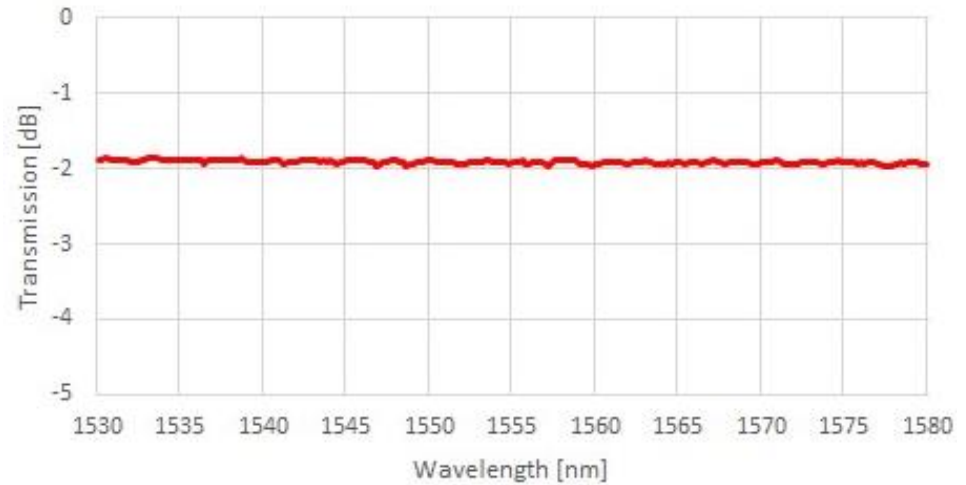
Fabrication Example



Connecting fiber arrays to SOI-chips



Insertion loss per link

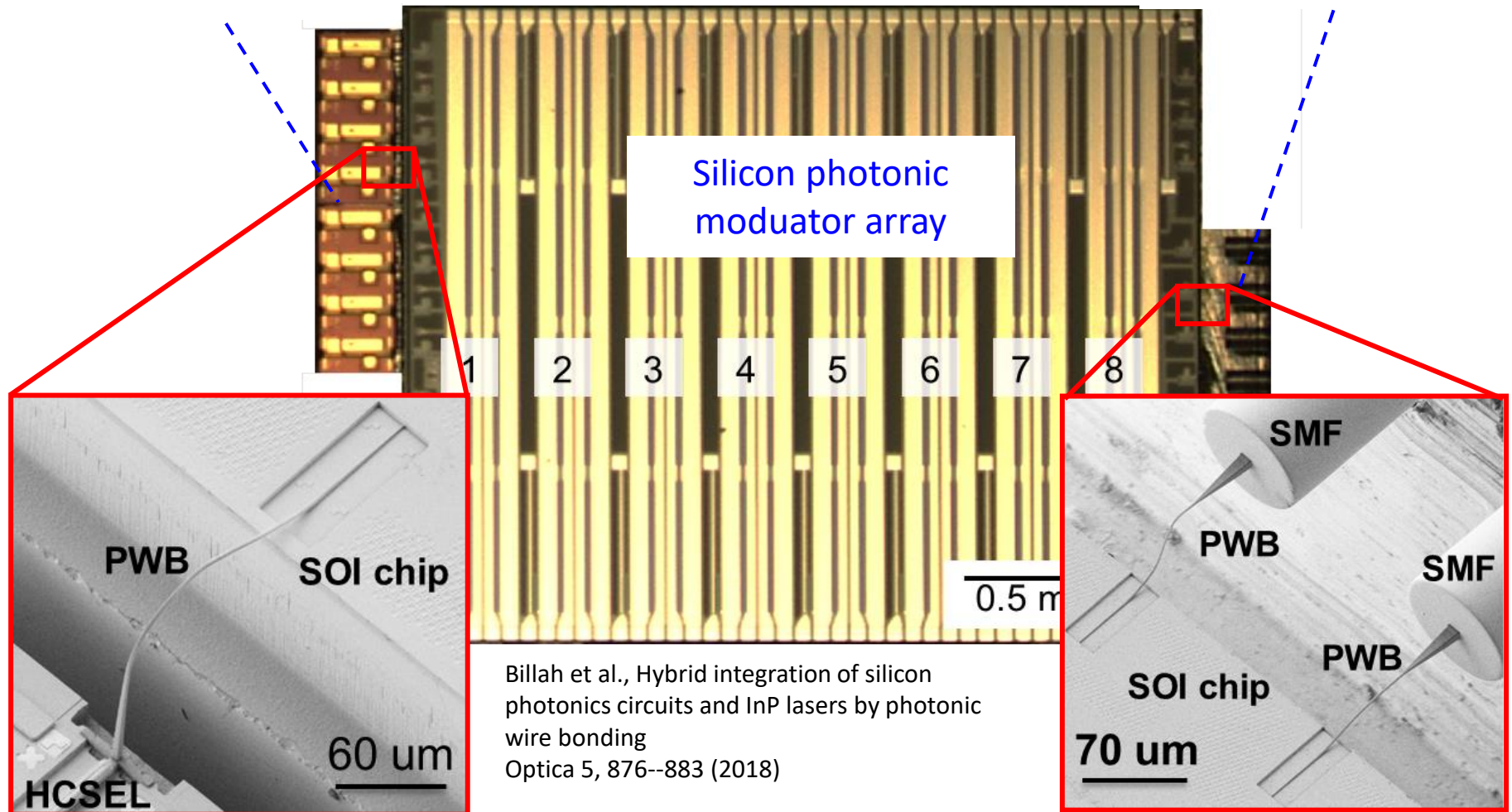


Eight channel transmitter module

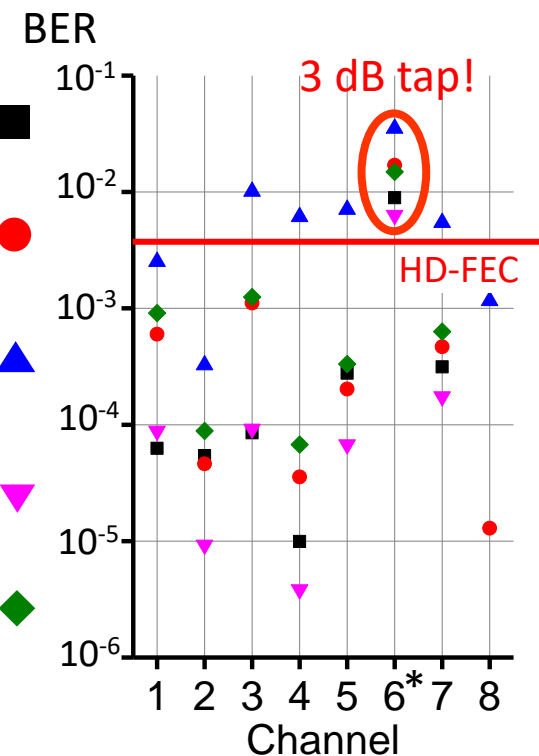
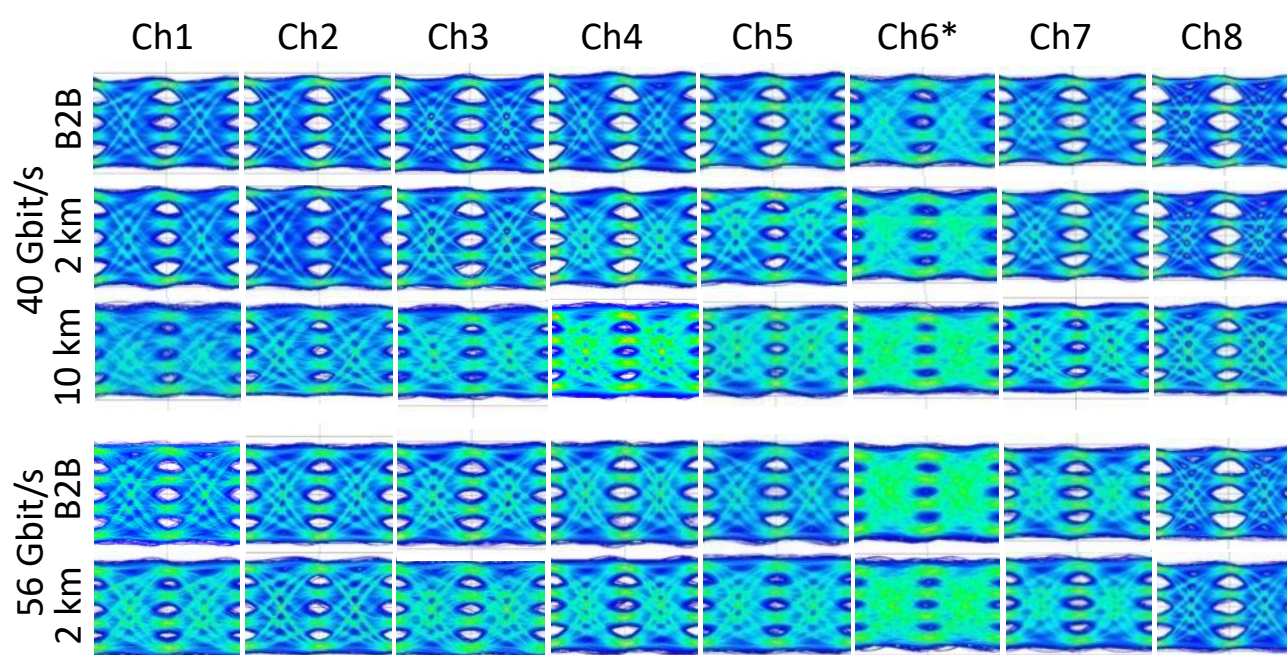
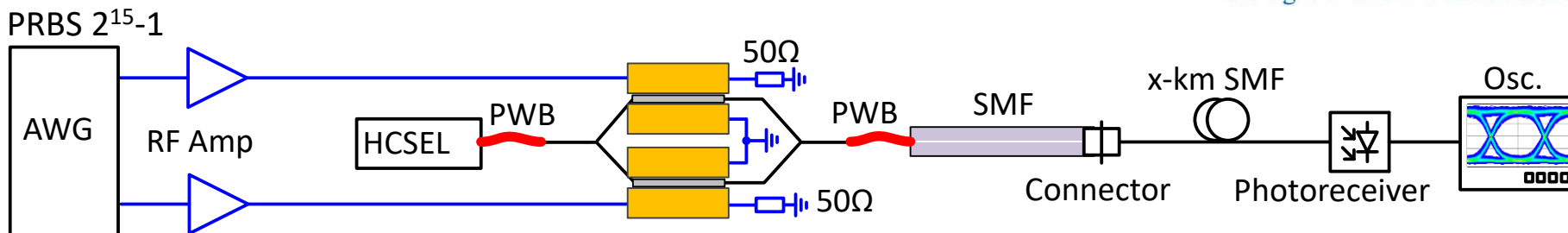
Laser array (HCSEL)



Fibers



Data transmission experiments: PAM-4



- Performance of ch. 6 limited by (avoidable) 3 dB tap
- All other channels below HD FEC for transmission over 2 km
- 448 Gbit/s aggregate line rate

* 3-dB tap

Example for reliability tests

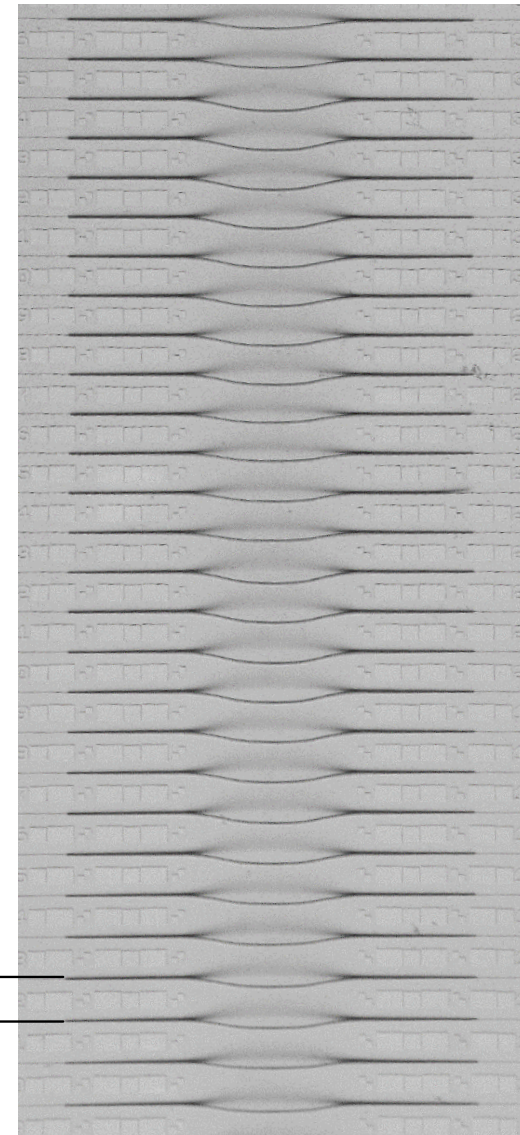
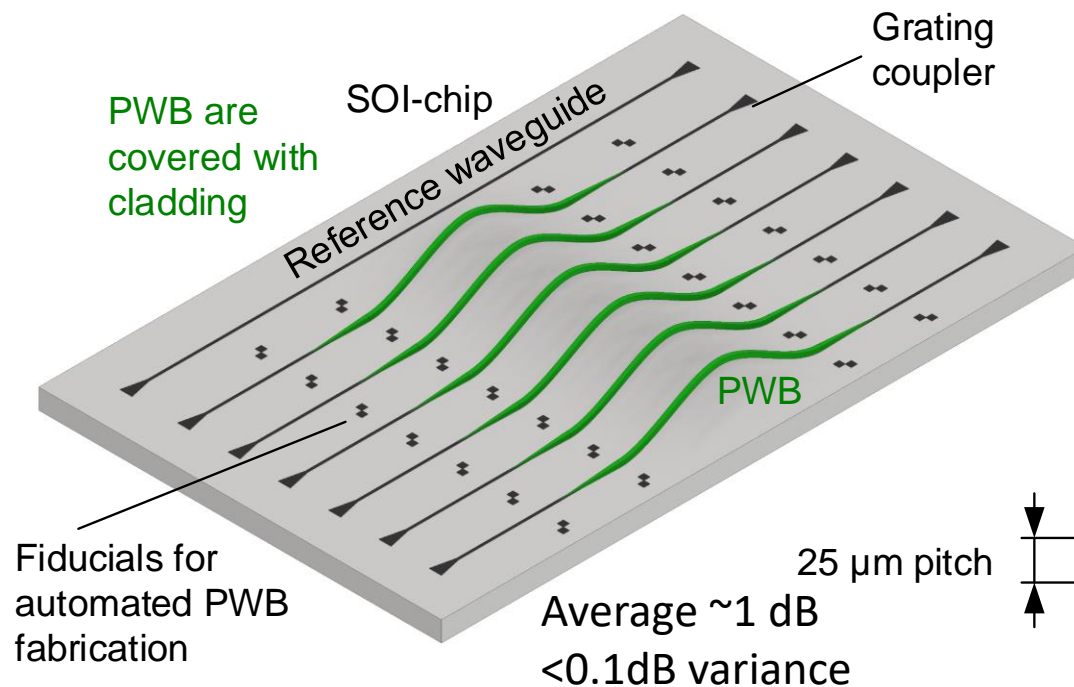
Without failure & degradation:

Telcordia Ref. 3.3.2.2:

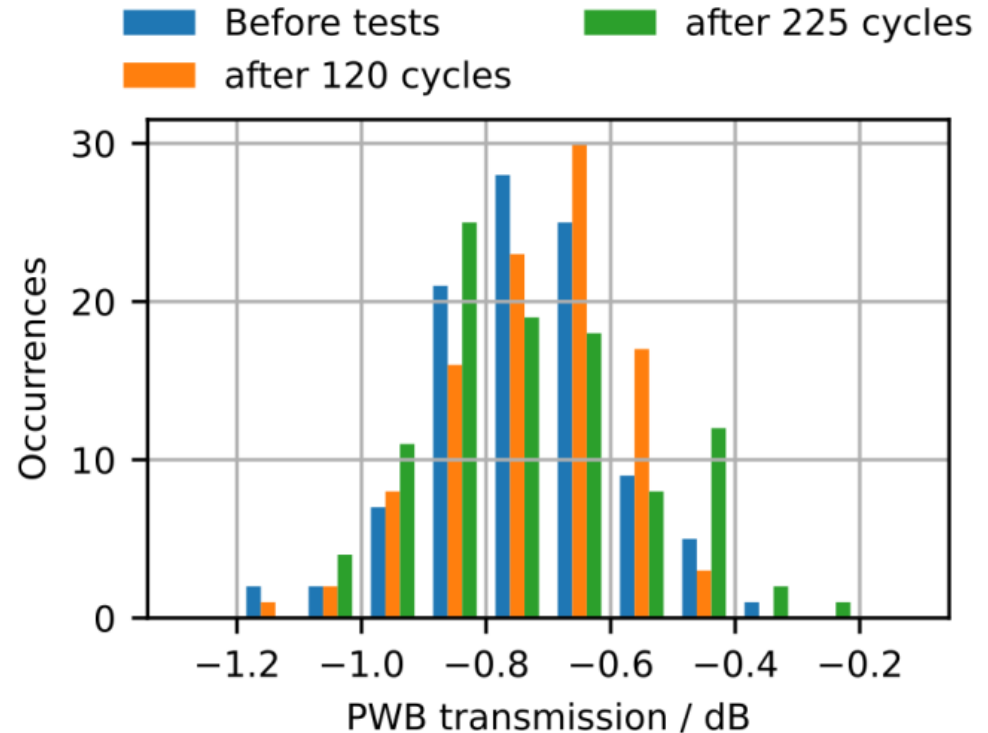
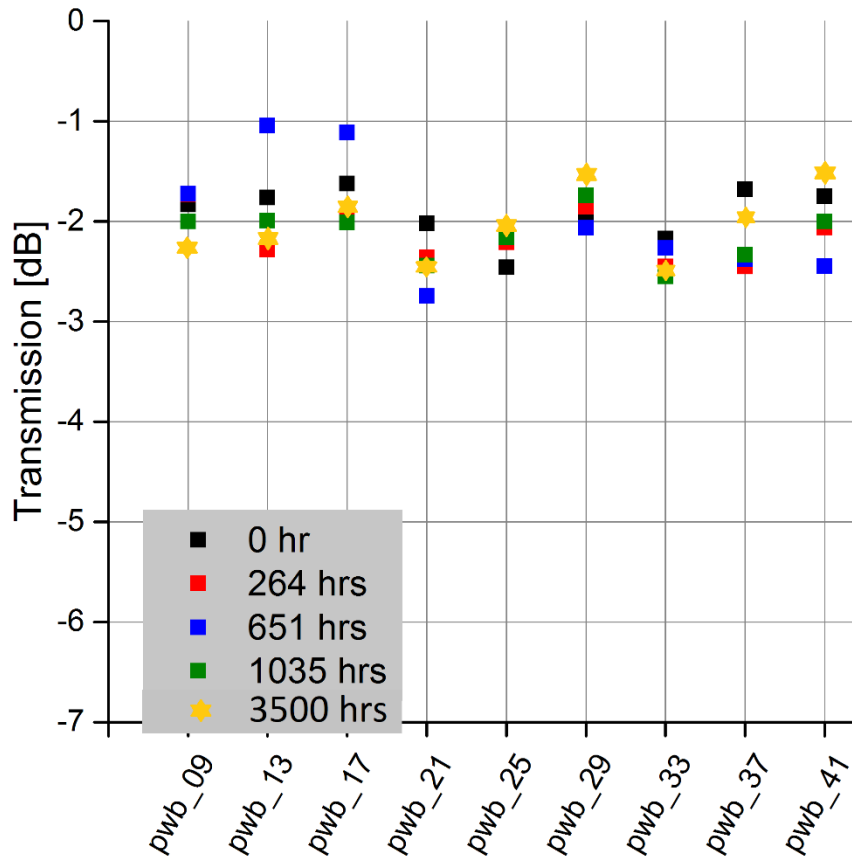
225 cycles of -40 °C to +85 °C (> 200 h)

Telcordia Ref. 3.3.2.3:

85 °C / 85% humidity, 3500 h



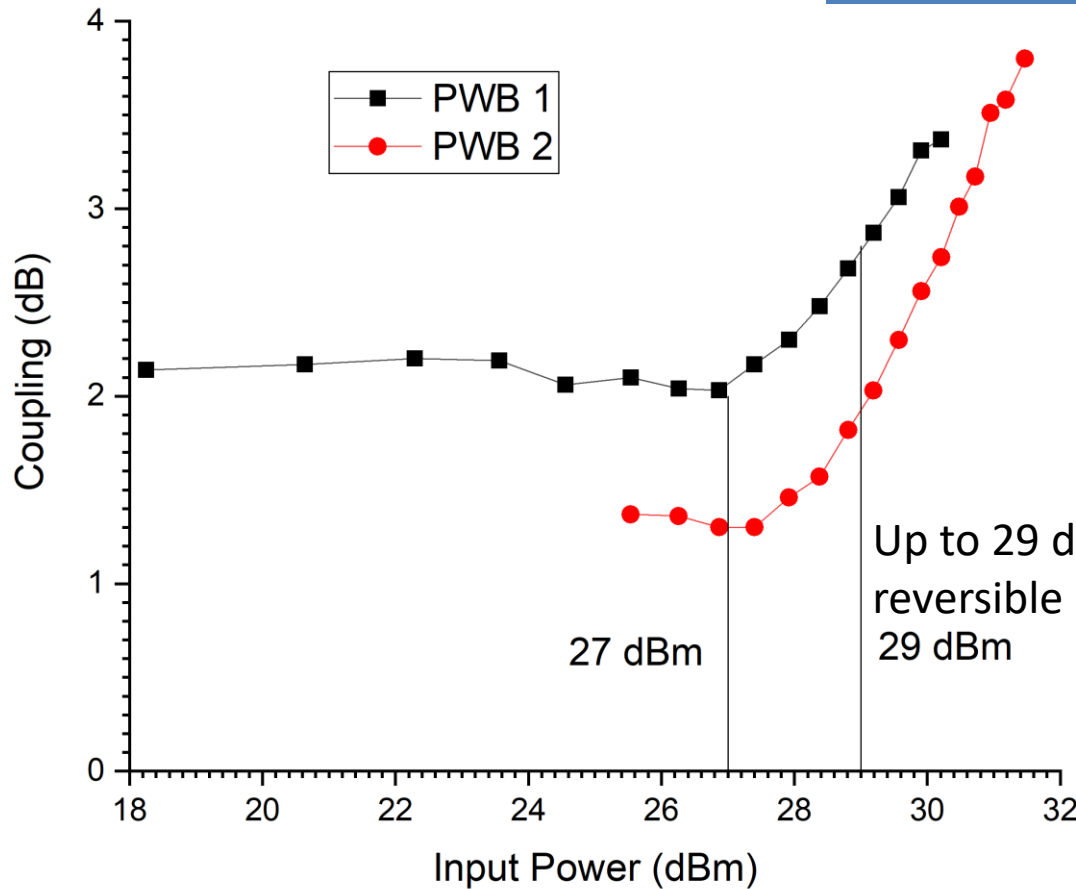
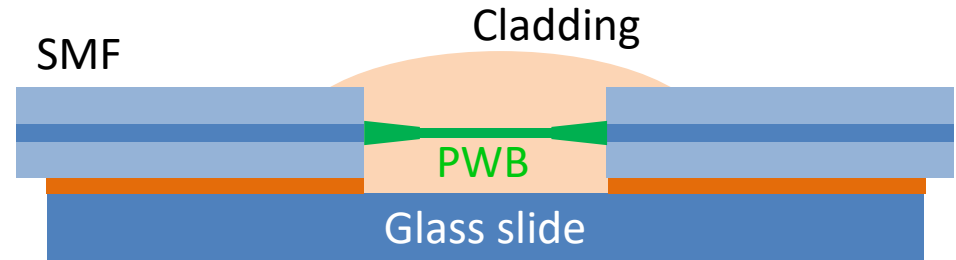
Examples of test results



-40°C-85°C cycles

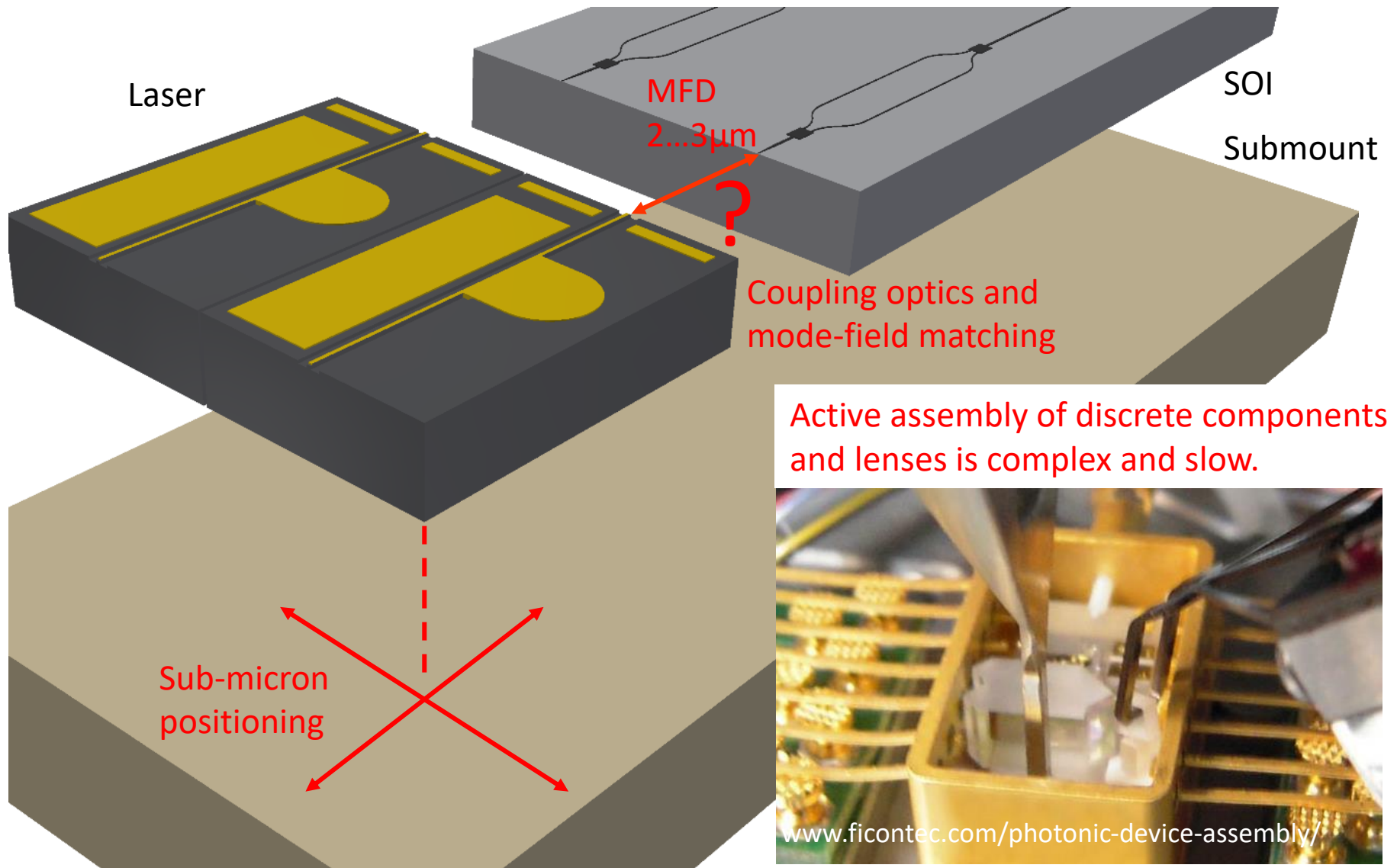
Blaicher et al., Hybrid multi-chip assembly of optical communication engines by in situ 3D nano-lithography *Light: Science & Applications* 9, Article number: 71 (2020)

High power coupling for PWB

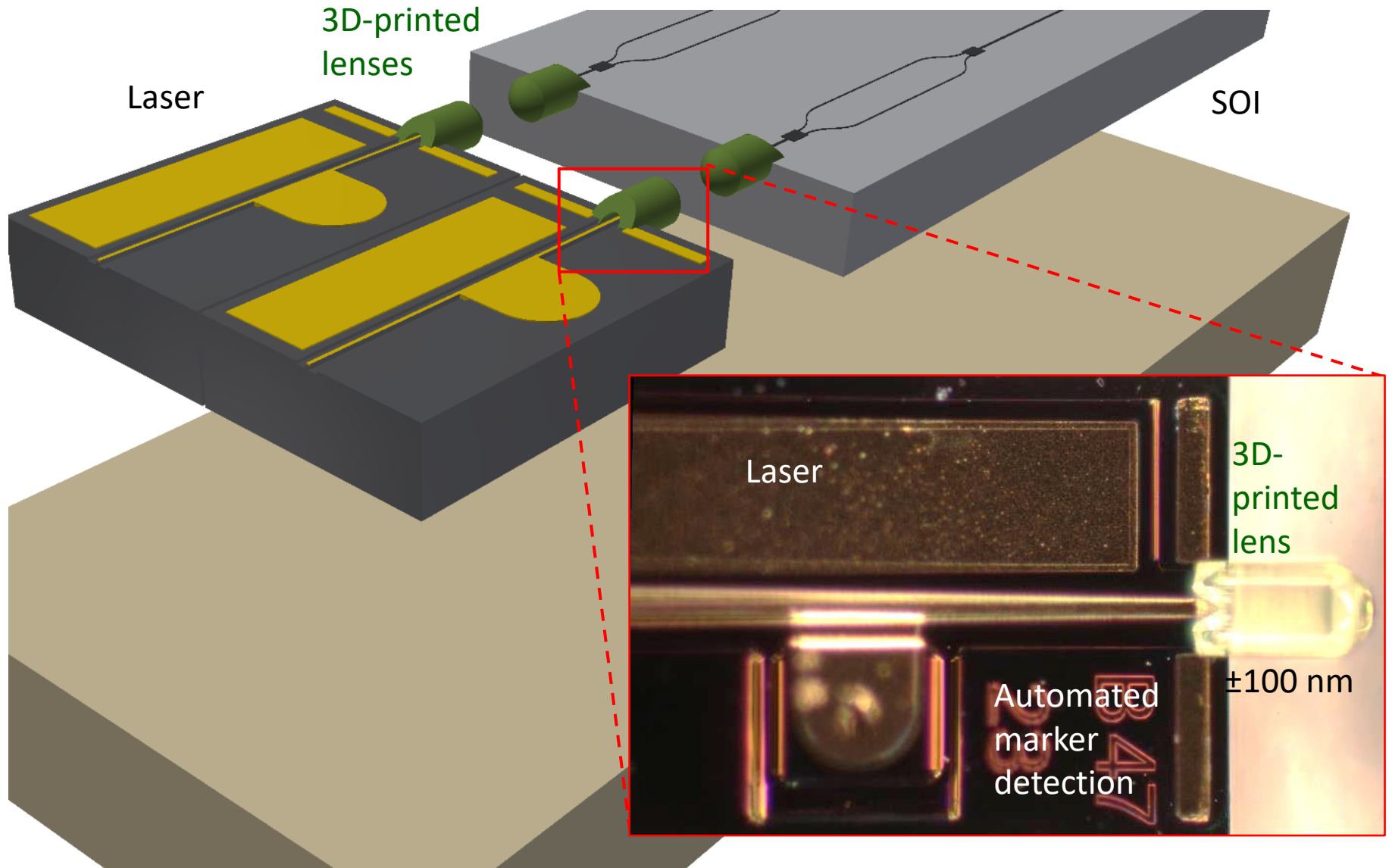


Measurement condition:
 -EDFA with seed laser at 1540nm
 -Power referenced to fiber input in the very same integrating sphere as for the measurement, measured at all power levels

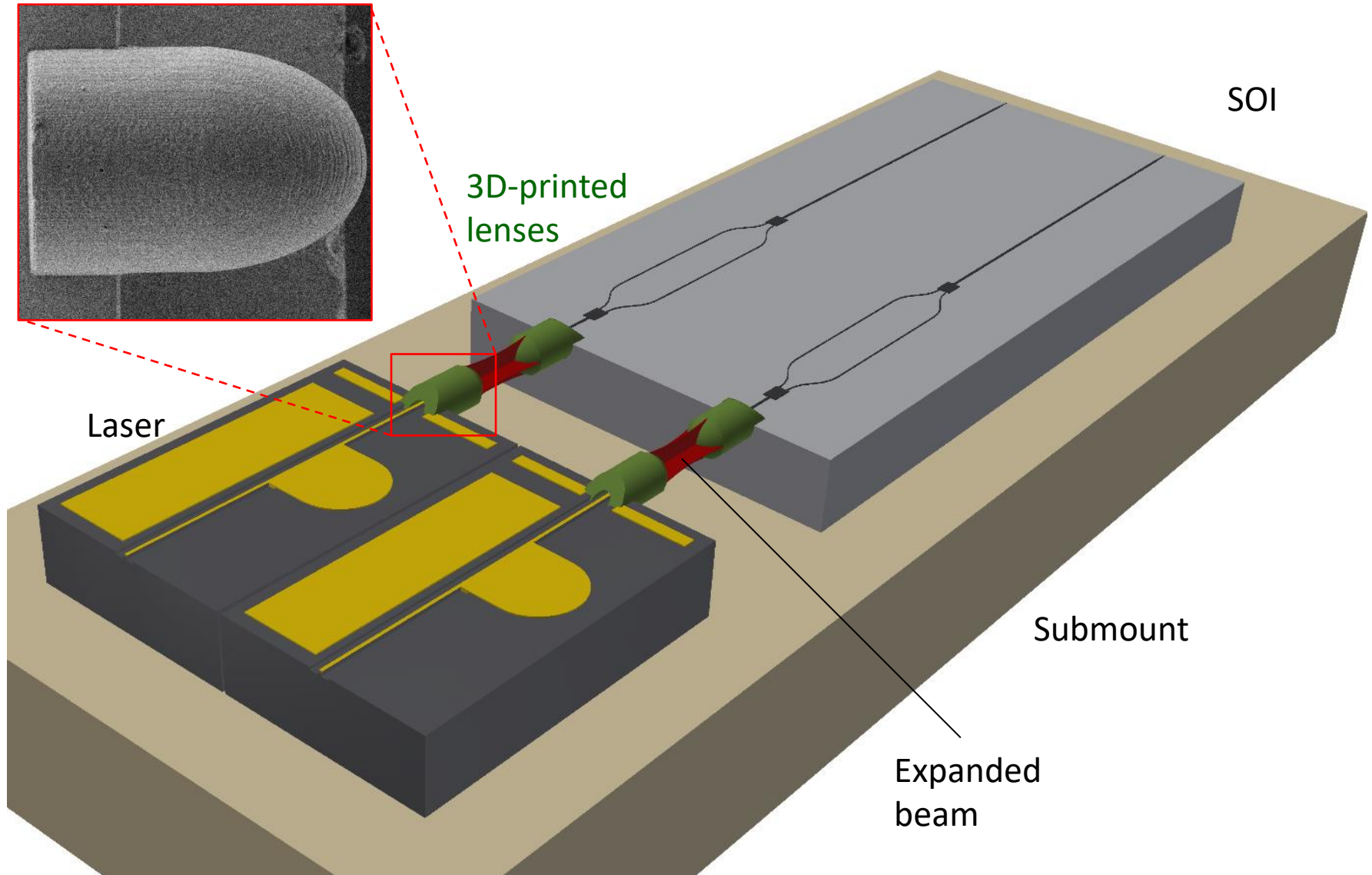
Challenge: Hybrid multi-chip modules



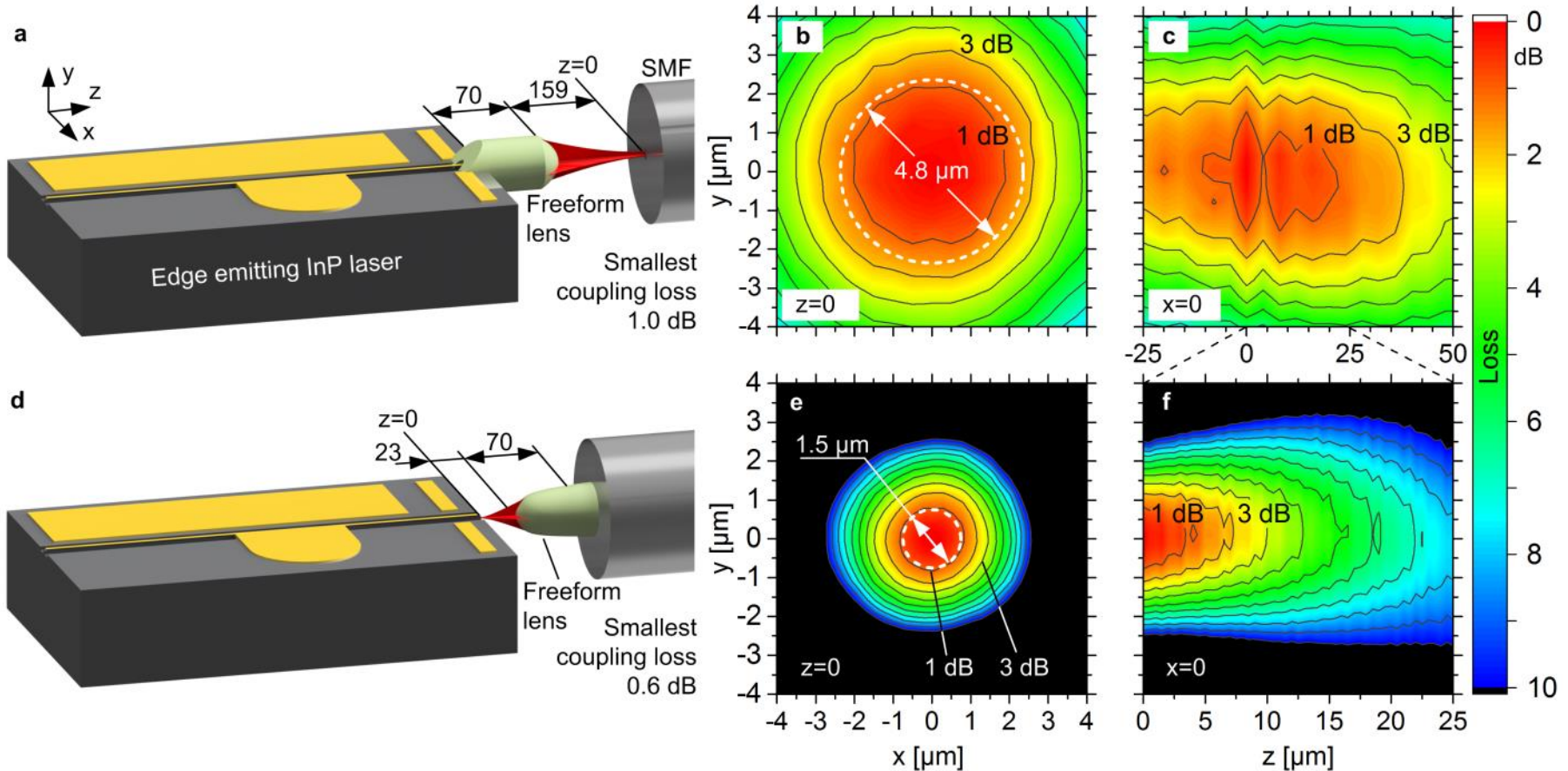
Our approach: In-situ 3D printing before assembly



Coupling with 3D-Printed Lenses



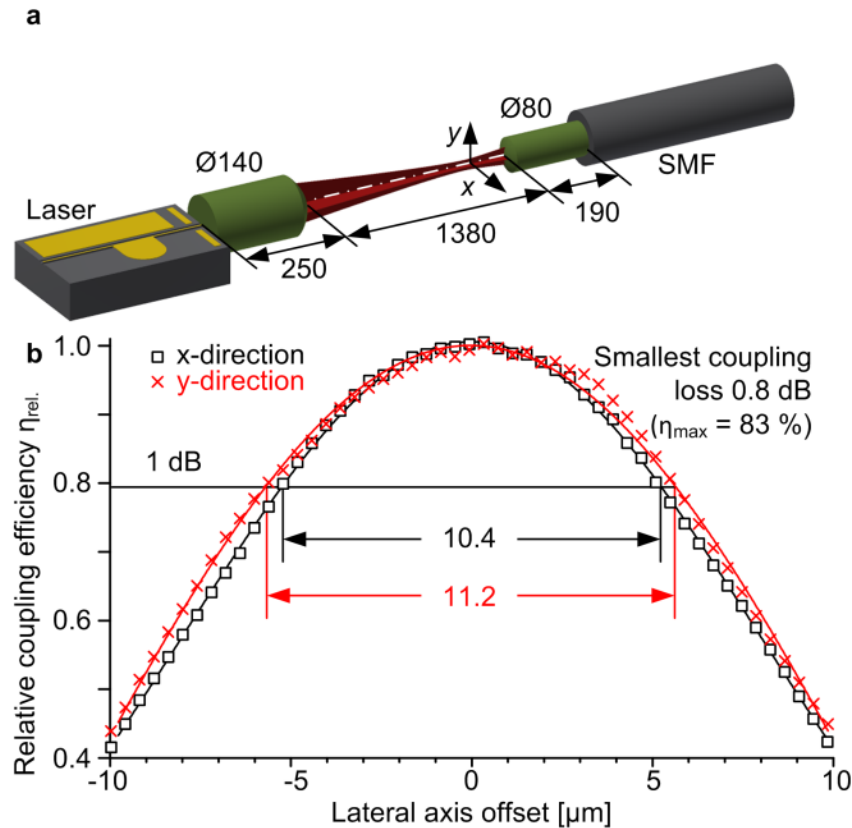
Coupling from laser to SMF



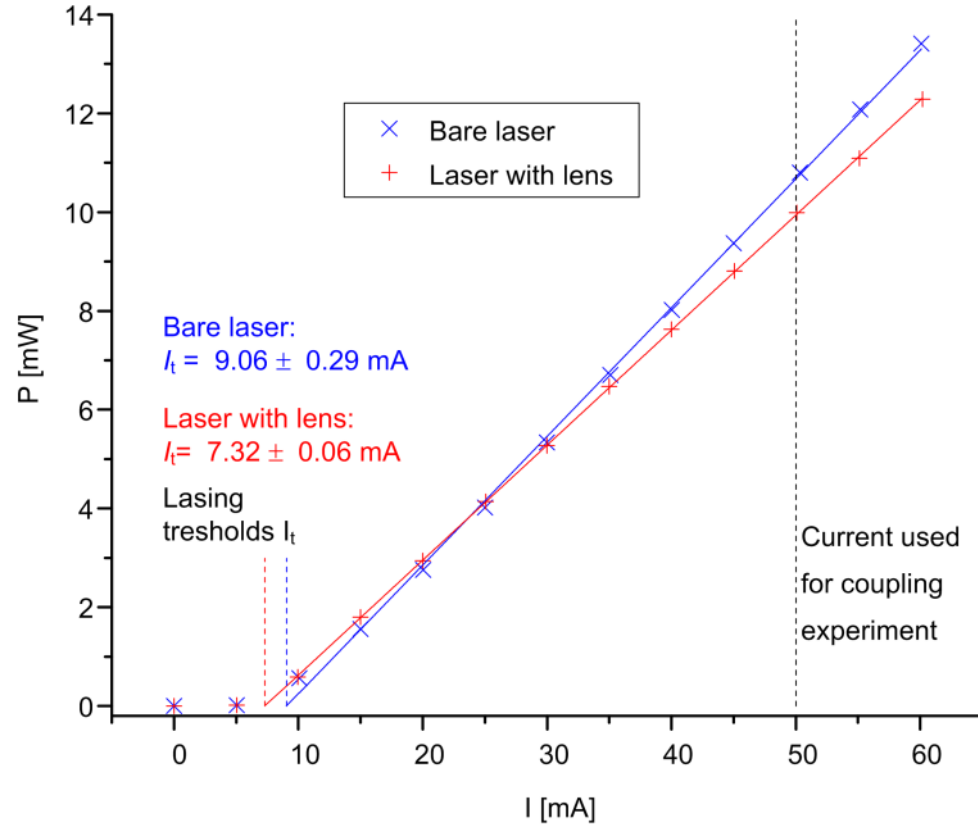
Mode-field adaption of a DFB-laser with 3 μm MFD at 1590 nm to a SMF.

Dietrich et al. In situ 3D nanoprinting of free-form coupling elements for hybrid photonic integration
Nature Photonics 12, 241–247 (2018)

Coupling with expanded beam



Relaxation of 1 dB coupling tolerance to $\pm 5.2 \mu\text{m}$.



Current-power curve for a laser with- and without lens.

VANGUARD SONATA1000 Series Multi-Photon Lithography System

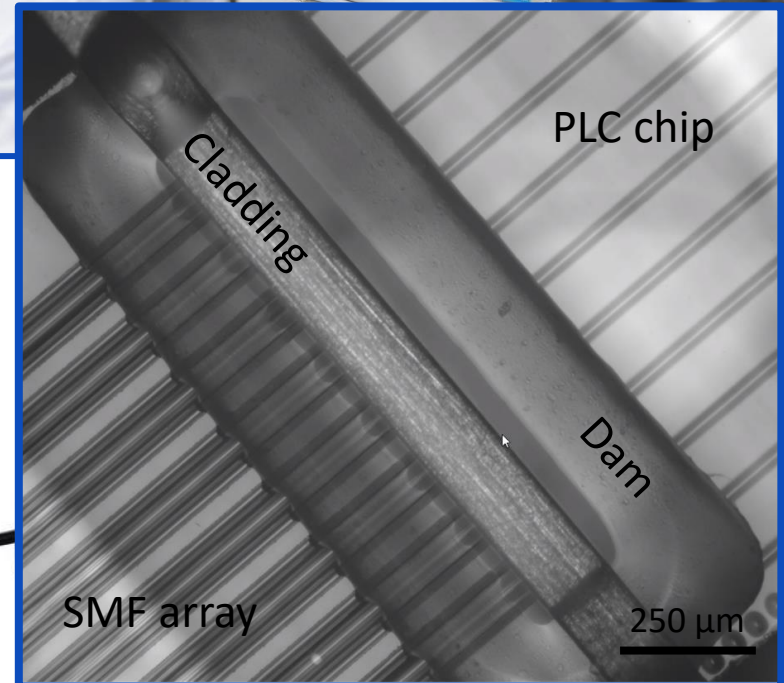
vanguard
AUTOMATION

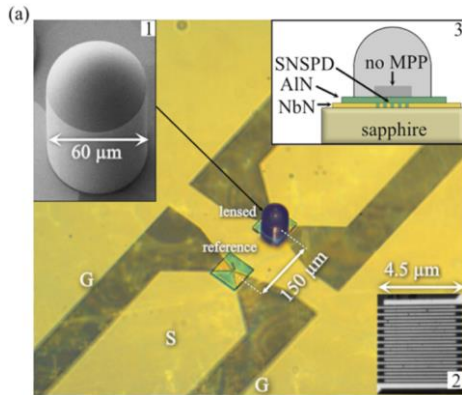


VANGUARD REPRIS1000 Series

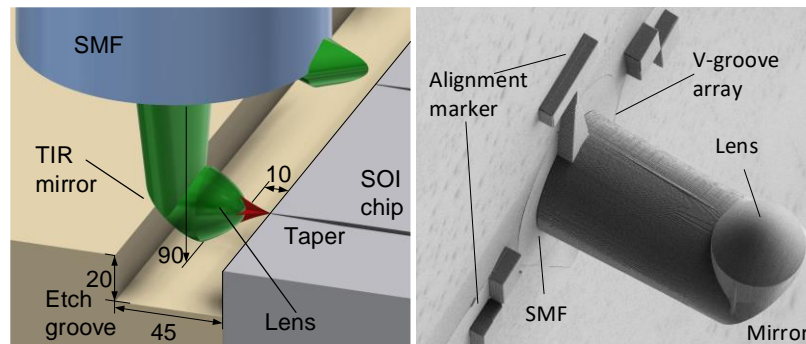
Resist Dispensing, Development, and Overcladding

vanguard
AUTOMATION

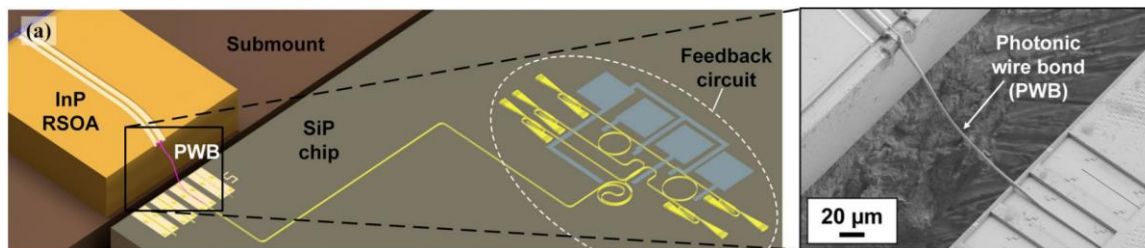




SNSPD detector for quantum application

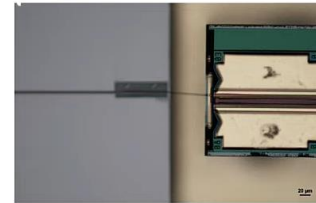


Optical wafer level testing

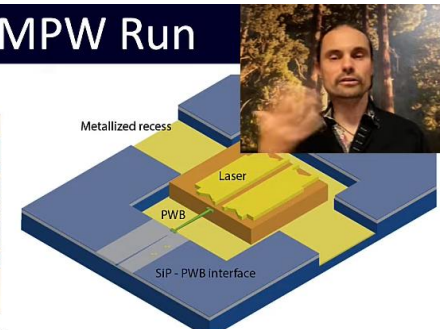


Hybrid external-cavity lasers

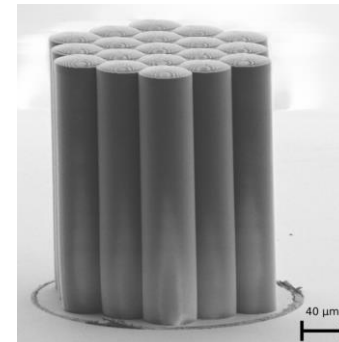
Laser Integration MPW Run



Photonic Wire Bond connecting a DFB laser on a SiP chip



Laser-on-wafer integration,
Chrostowski et al.,
UBC



Astronomy

- Xu et al., Superconducting nanowire single-photon detector with 3D-printed free-form microlenses, *Opt. Expr.* 29, 27708-27731 (2021)
- Trappen et al., 3D-printed optical probes for wafer-level testing of photonic integrated circuits, *Opt. Express* 28, 37996-38007 (2020)
- Xu et al., Hybrid external-cavity lasers (ECL) using photonic wire bonds as coupling elements *Sci Rep* 11, Article Number 16426 (2021)
- Xu et al., 3D-M3: high-spatial-resolution spectroscopy with extreme AO and 3D-printed micro-lenslets *Applied Optics* 60, D108-D121 (2021)

VANGUARD SYMPHONY

3D Lithography for Photonic Integration

Dispensing
(Reprise 1000)

3D Printing
(Sonata 1000)

Developing
(Reprise 1000)



Typical performance:

- 2dB
- -30dB reflection

Tested for:

- 85°C/85% rel. hum.
- -40°C/80°C cycles
- 1500G
- Reflow soldering
- Sn/Au soldering
- Cryo operation
- > 27dBm operation