Chiral Photonics

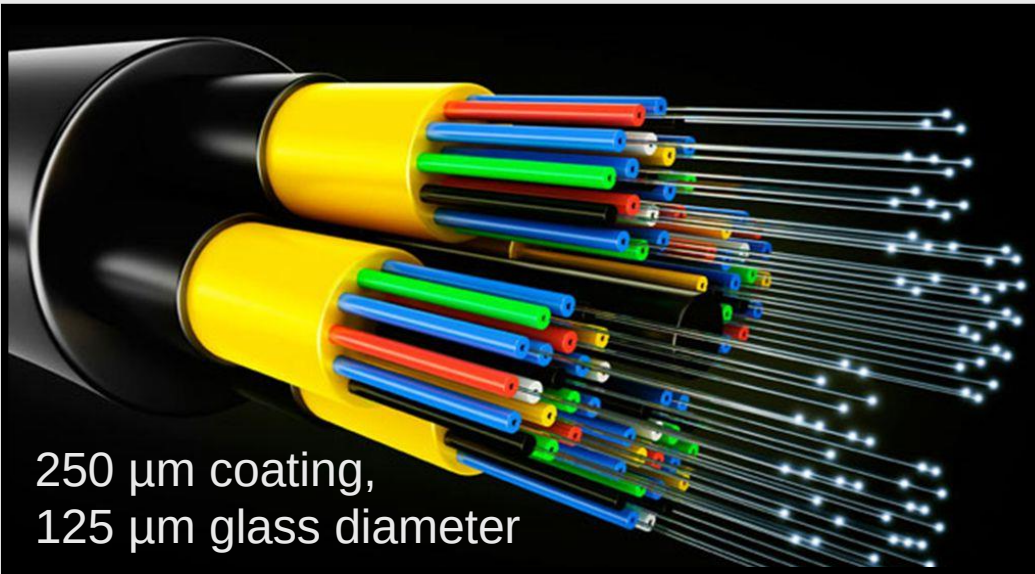
# Pitch Reducing Optical Fiber Array – Bridging the Gap Between Fiber Infrastructure and Dense Multichannel Optical Interface

Pitch Reducing Optical Fiber Arrays (PROFAs), developed at Chiral Photonics, enable optical fiber connections to ultra-dense multichannel i/o of photonic integrated circuits and multicore fibers for sensing and telecom applications

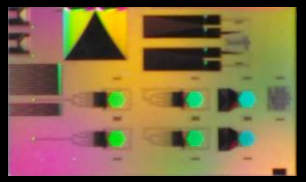
*Victor Kopp, Director of Research and Development*

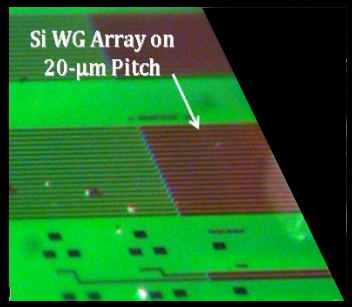
*Chiral Photonics, Inc., Pine Brook, New Jersey, USA*

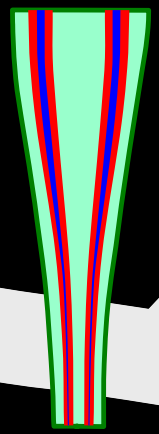
# Bridging the Gap

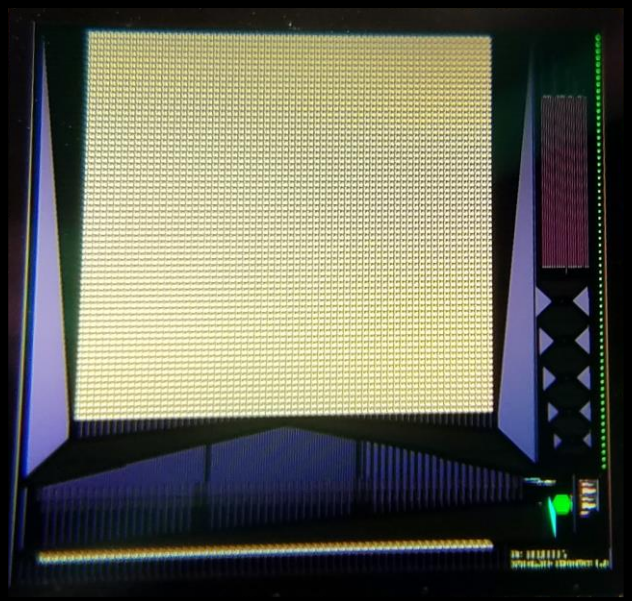


250 µm coating,
125 µm glass diameter

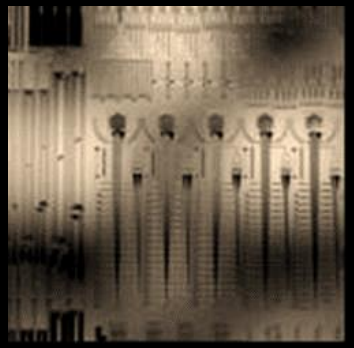




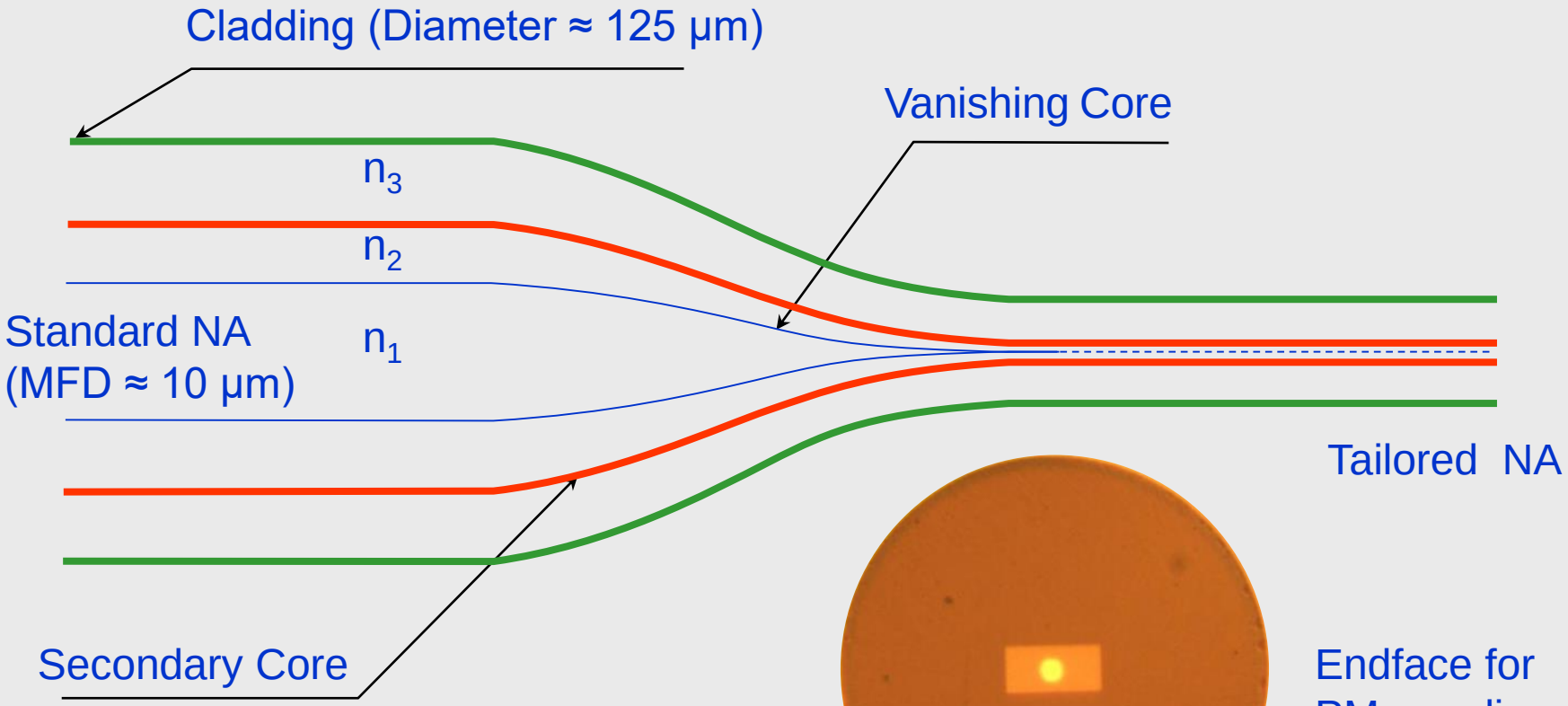





20 - 50 µm
channel spacing



# “Vanishing Core” Concept





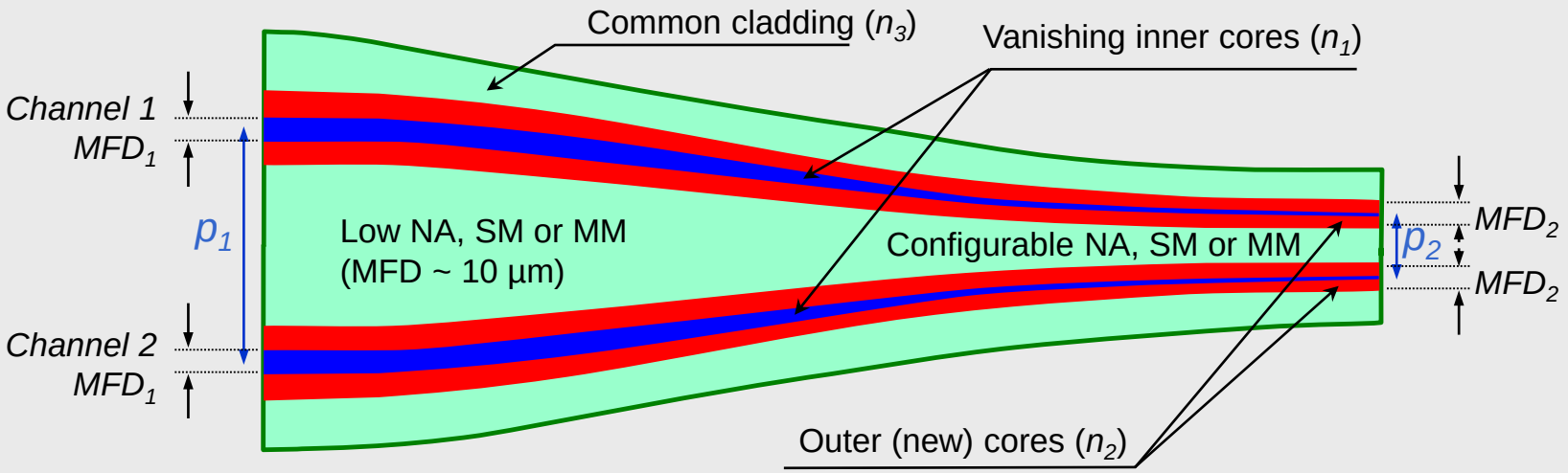

Endface for
PM coupling

$n_1 - n_2 < n_2 - n_3$ - reduced MFD
$n_1 - n_2 > n_2 - n_3$ - expanded MFD
$n_1 - n_2 = n_2 - n_3$ - preserved MFD

*Configurable output geometry for polarization control and mode shape adaptation*

V.I. Kopp and A.Z. Genack, *Nature Photonics* **5**, 470 (2011)

# Pitch Reducing Optical Fiber Array (PROFA)




In conventional single-lens focusing approach:

if $p_1 > p_2$ then $MFD_1 > MFD_2$

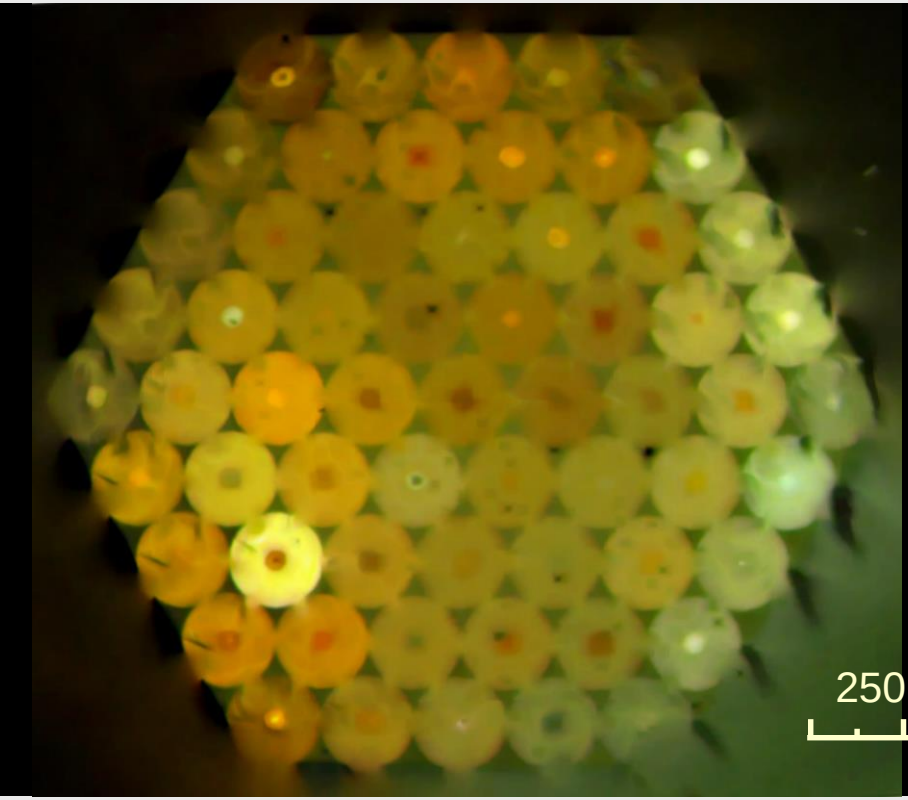
In array case:

if $p_1 > p_2$ then $MFD_1 > MFD_2$ **OR**

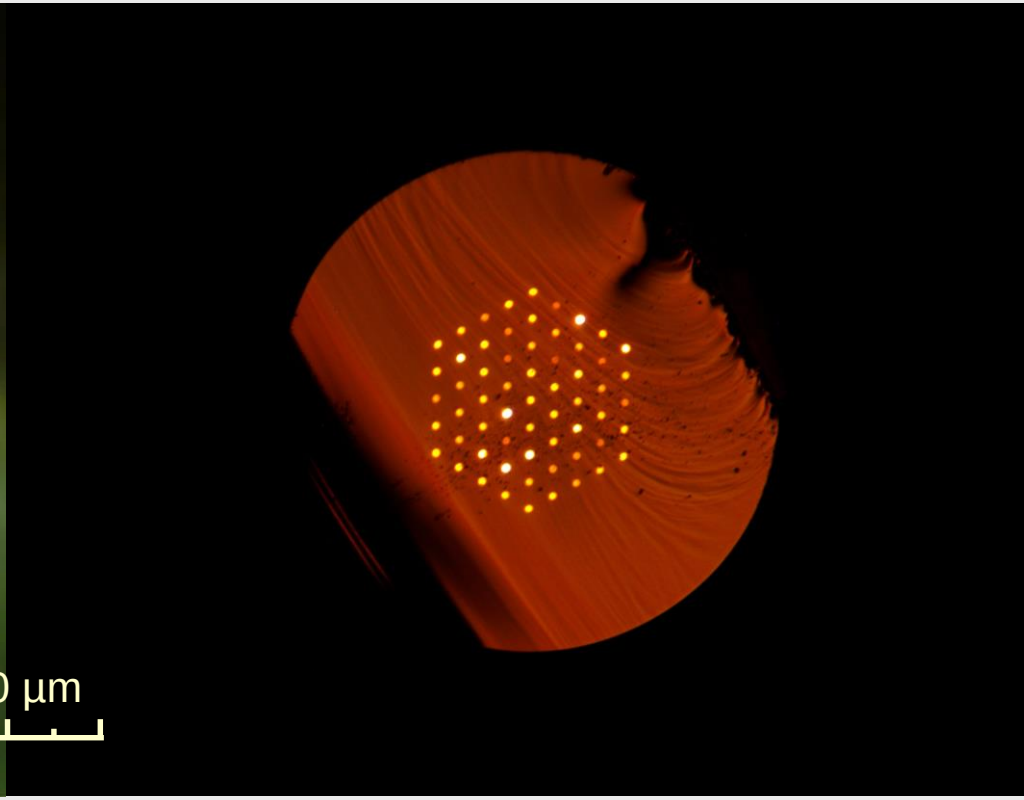
$MFD_1 < MFD_2$ **OR**

$MFD_1 = MFD_2$

# PROFA Fabrication

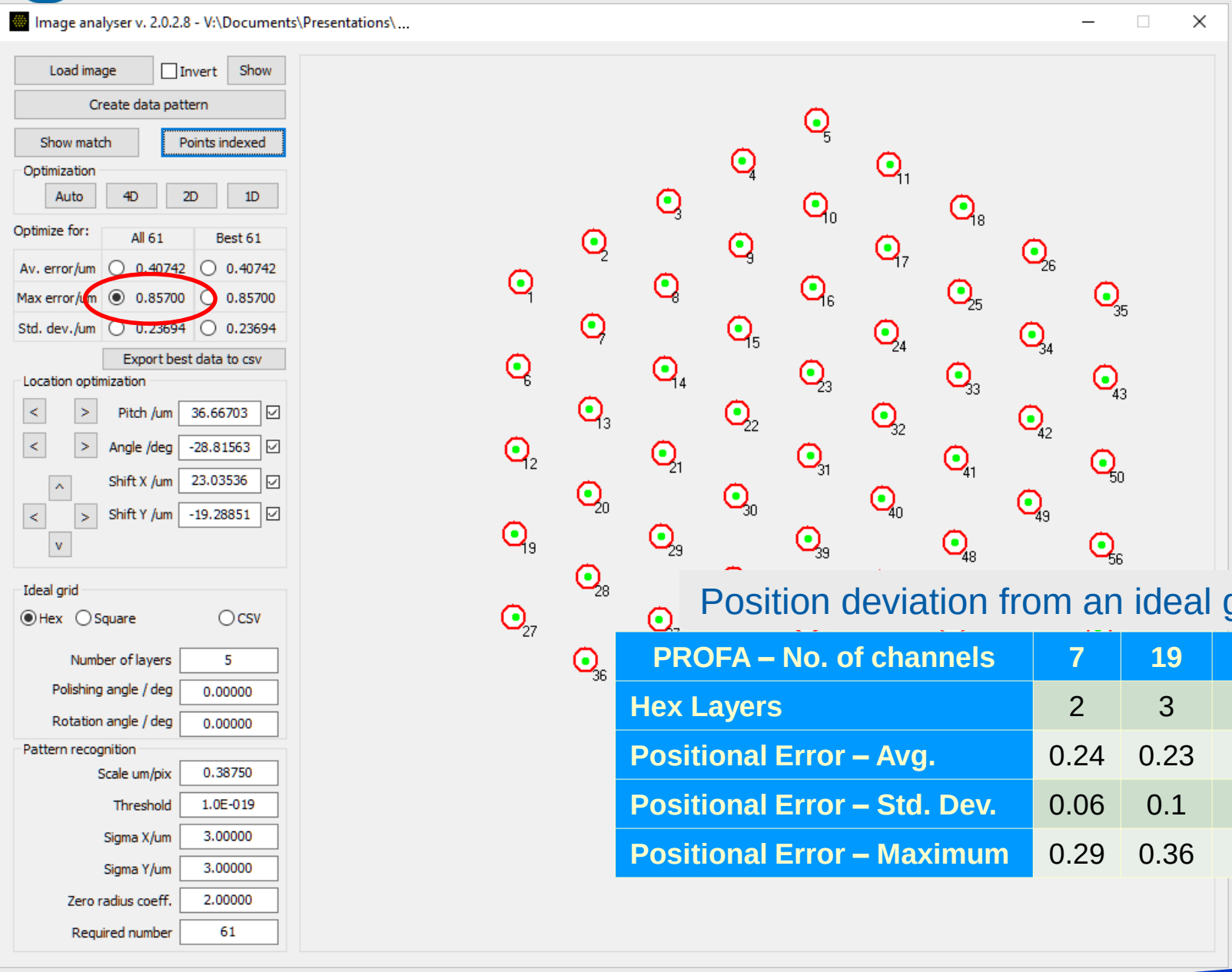



61-channel PROFA assembly



Drawn and fused cleaved endface

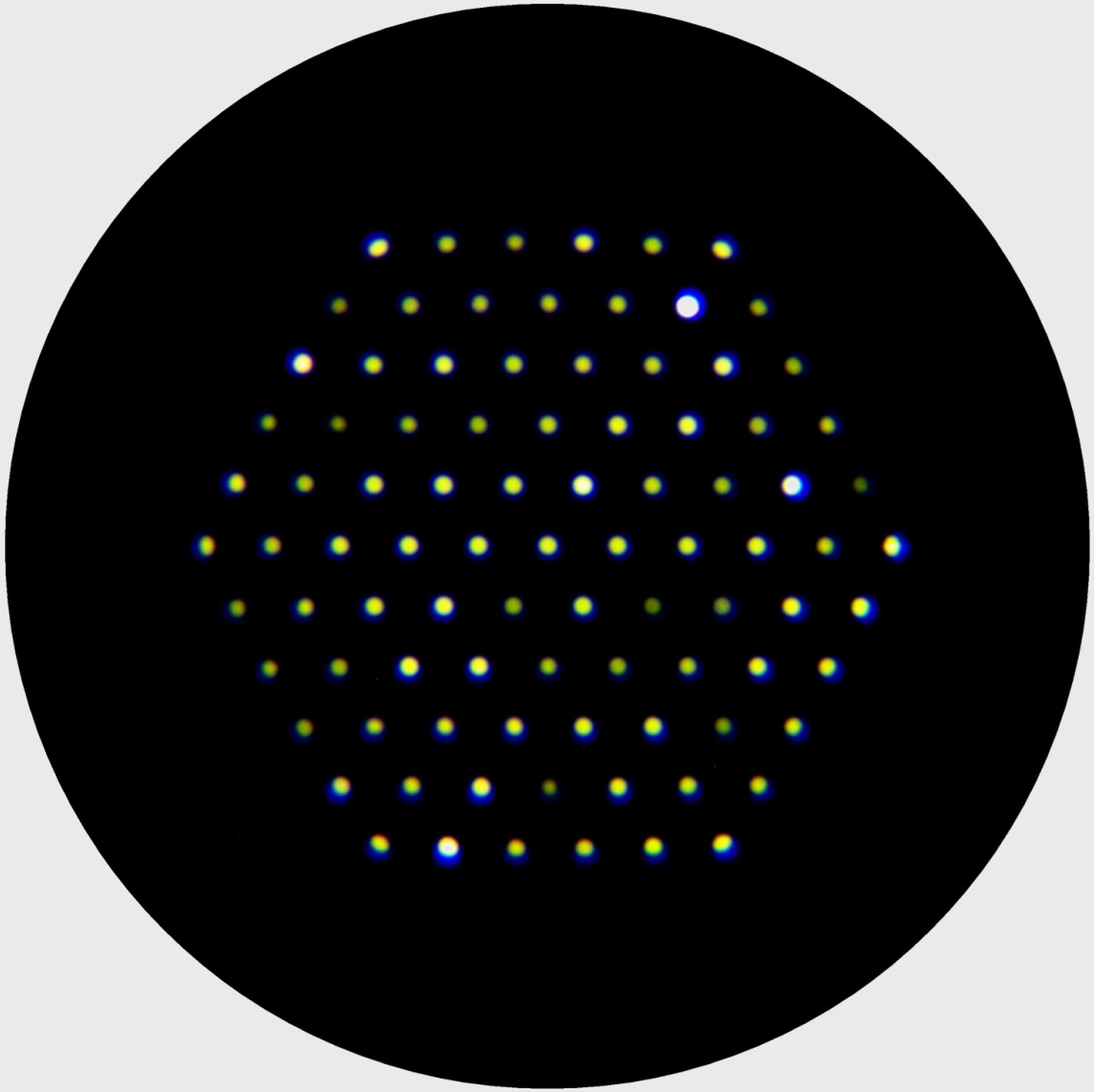
# 61-channel PROFA Positioning Accuracy



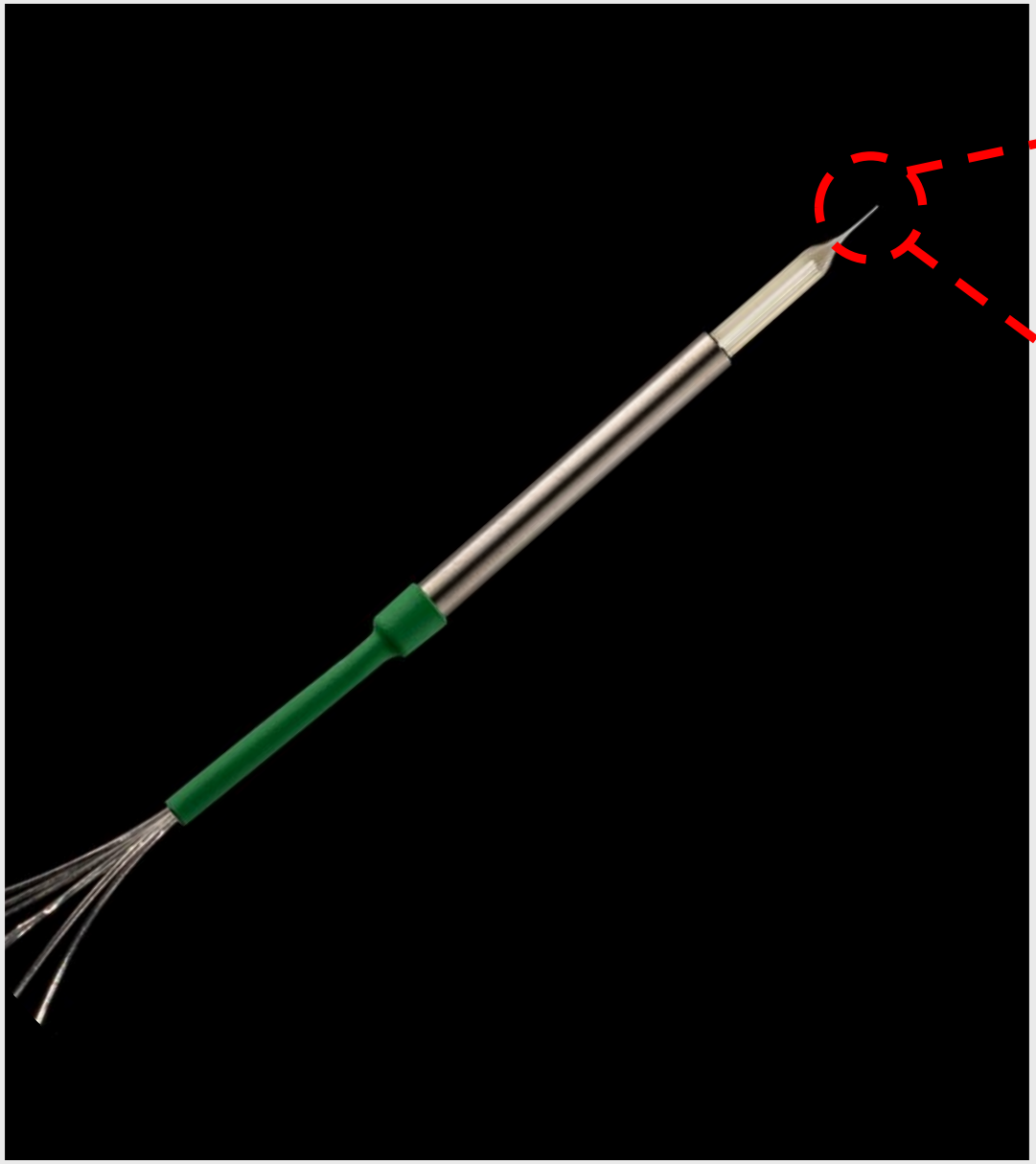

Position deviation from an ideal grid (µm):

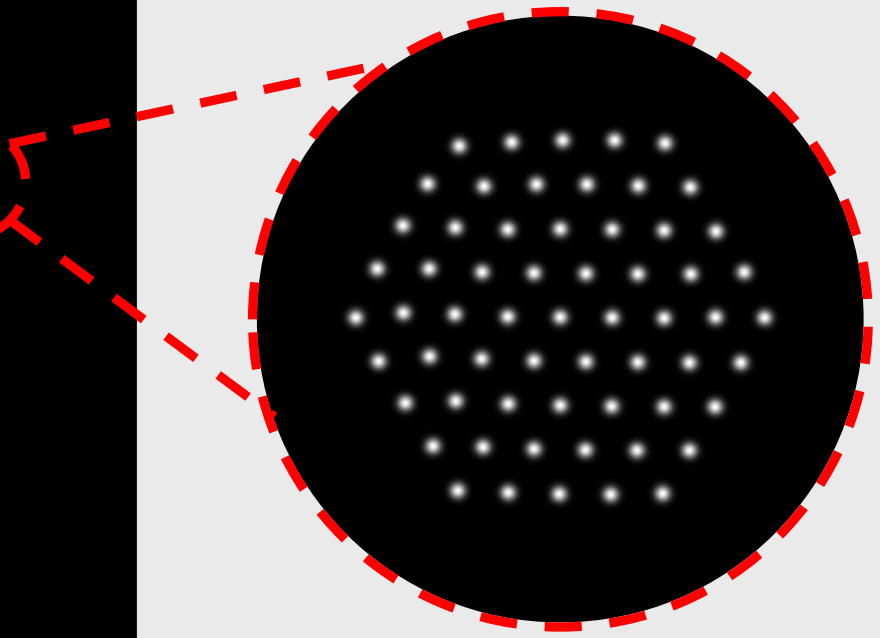
| PROFA – No. of channels | 7 | 19 | 37 | 61 |
|---|---|---|---|---|
| Hex Layers | 2 | 3 | 4 | 5 |
| Positional Error – Avg. | 0.24 | 0.23 | 0.25 | 0.4 |
| Positional Error – Std. Dev. | 0.06 | 0.1 | 0.14 | 0.23 |
| Positional Error – Maximum | 0.29 | 0.36 | 0.48 | 0.85 |

# 91-channel PROFA Endface



# PROFA Products

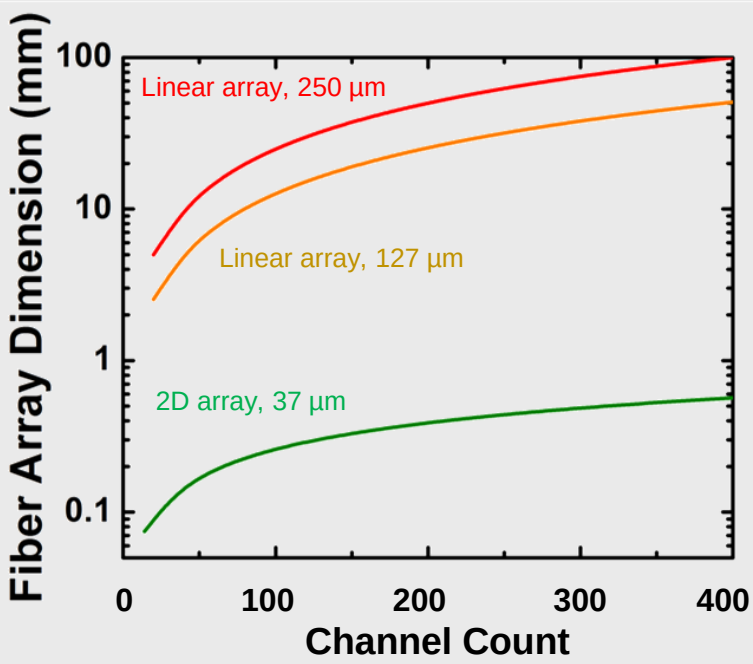




**PROFA endface**

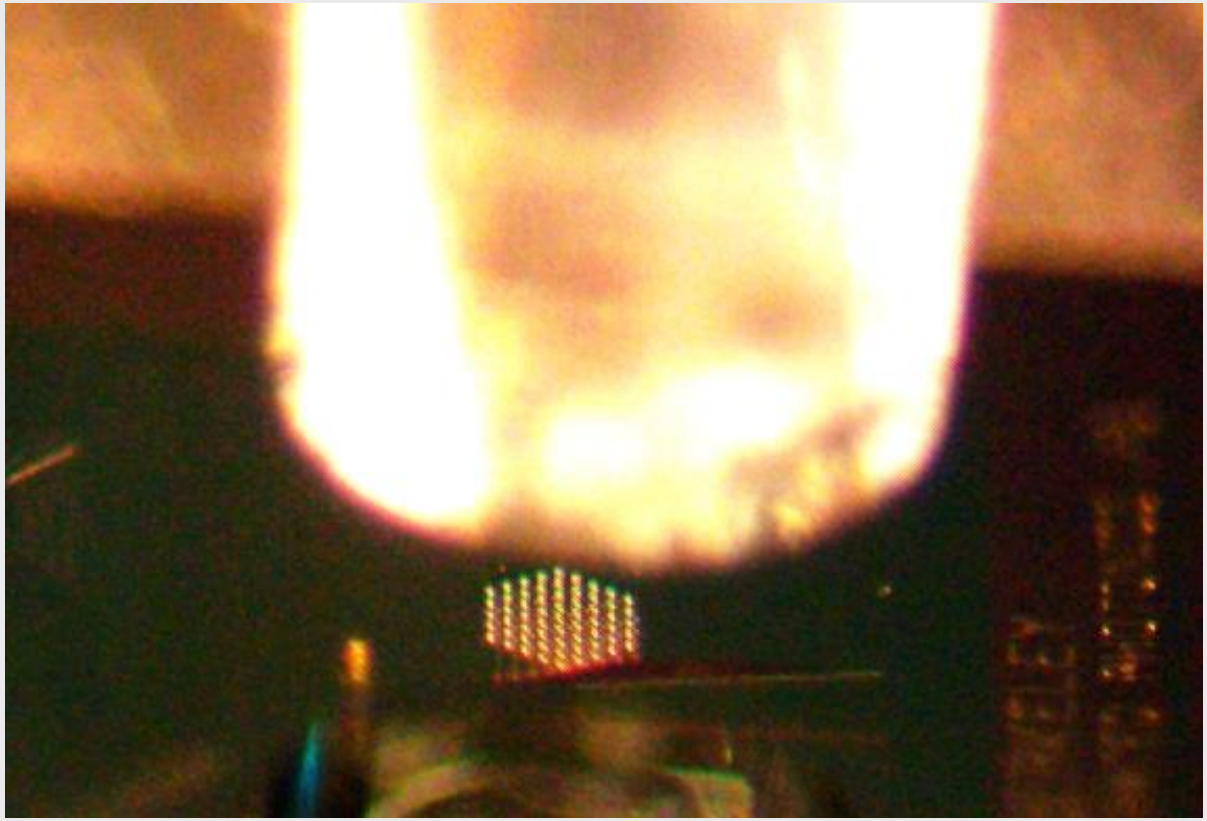
- Up to 91 channels
- 4-10 µm MFD on 10-40 µm spacing
- Single port alignment of all channels for probing or packaging
- Crosstalk < -35 dB

# Large Channel Count, High-Density Optical Interface




- PROFA typical spacing is 37 µm, enabling much smaller optical I/O
- Aligned with single port alignment
- Scalable channel count
- Available as:
  - *Rigid PROFAs for probing*
  - *Flexible PROFAs for robust and low-profile packaging*

# PROFAs for Probing



PROFA tip above array of vertical grating couplers on photonic integrated circuit

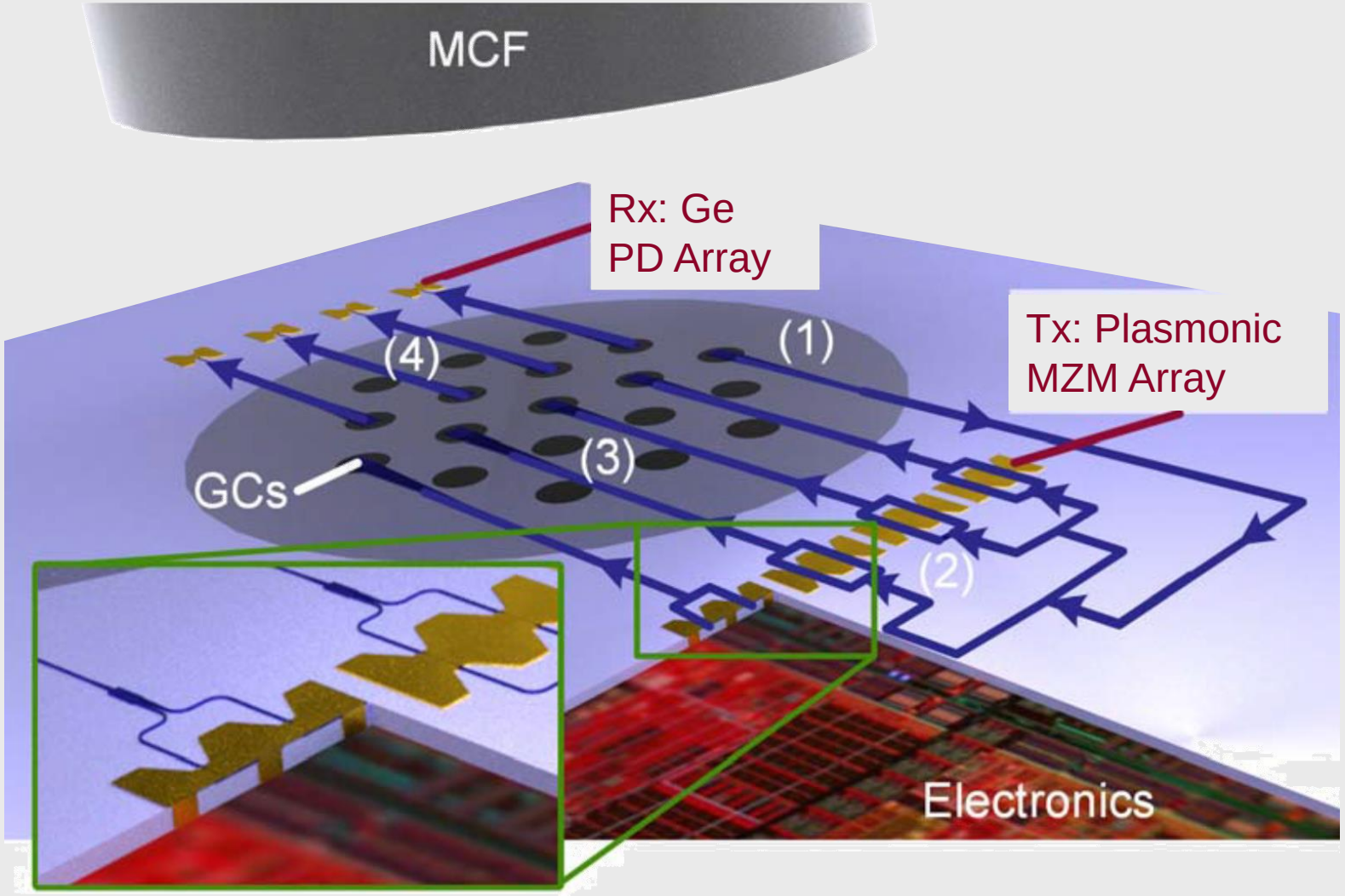
# Probing Demo with Physik Instrumente (PI)

*All 61 channels easily accessed via standard pigtails and patch panel*

PIC featuring 37 channel array of vertical grating couplers

PI's exhibition booth at OFC 2019, San Diego, CA

# Chip-to-chip interconnect concept (ETH Zurich)




Hoessbacher *et al.* "Optical interconnect solution with plasmonic modulator and Ge photodetector array", *IEEE Photonics Technology Letters* **29**, 1760-1763 (2017)

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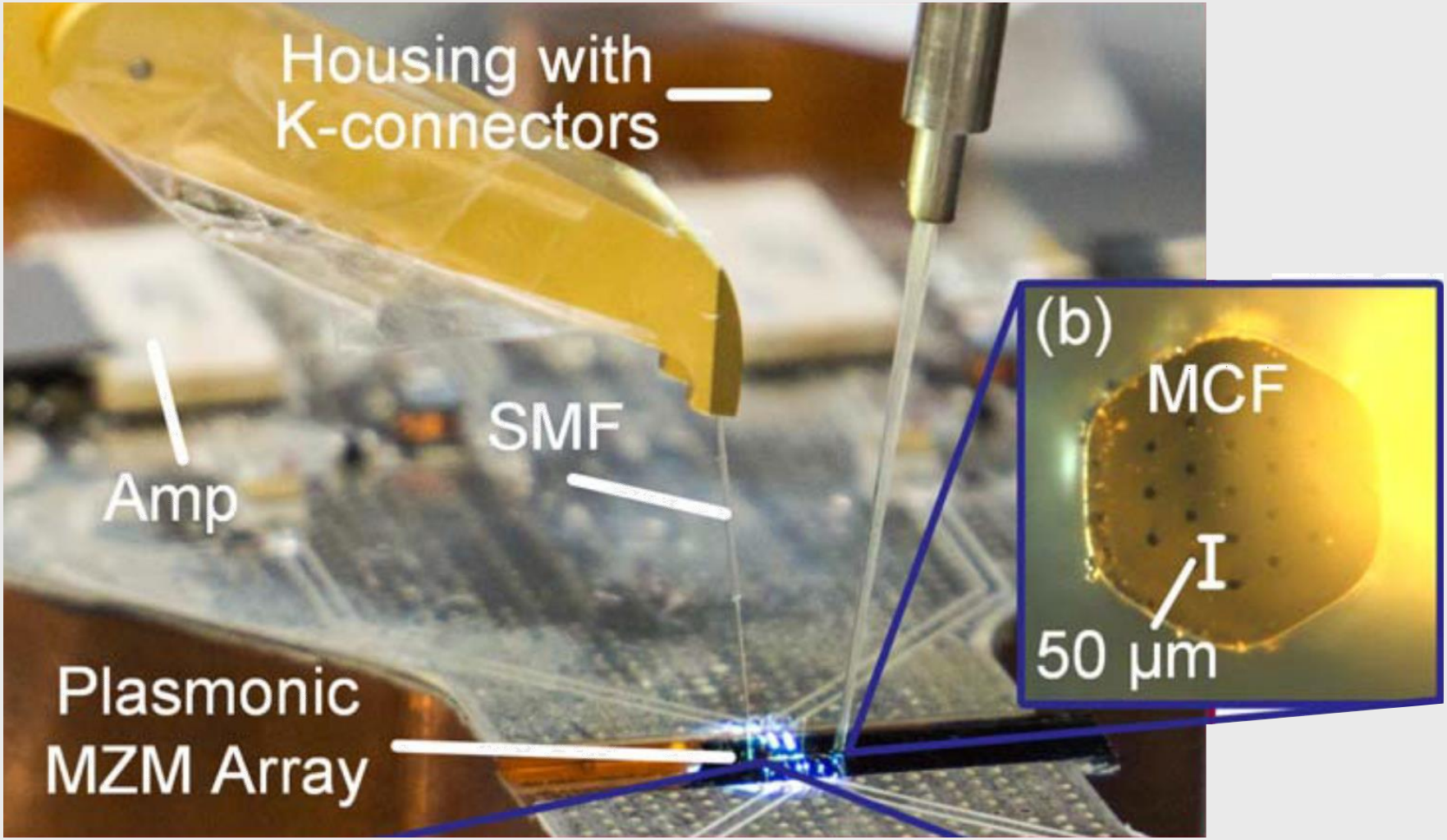
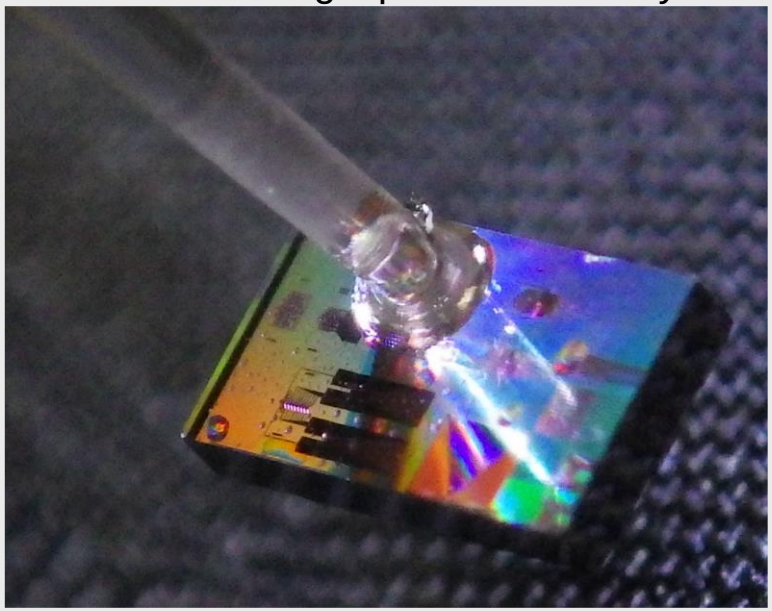
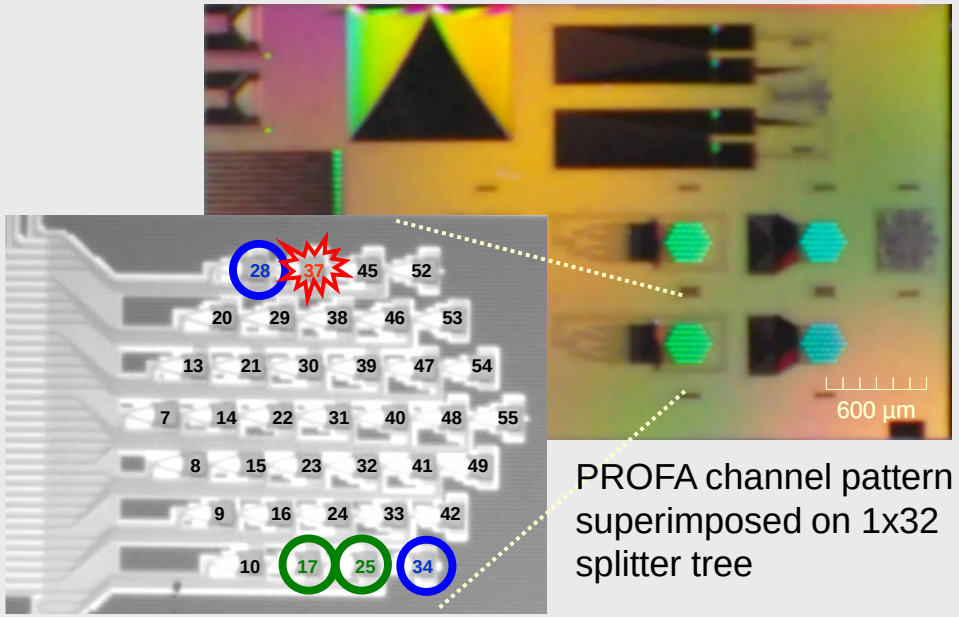



Hoessbacher *et al.* "Optical interconnect solution with plasmonic modulator and Ge photodetector array", *IEEE Photonics Technology Letters* **29**, 1760-1763 (2017)

# Packaging with PROFAs: 37 Channels, 1 Port

Pitch Reducing Optical Fiber Array





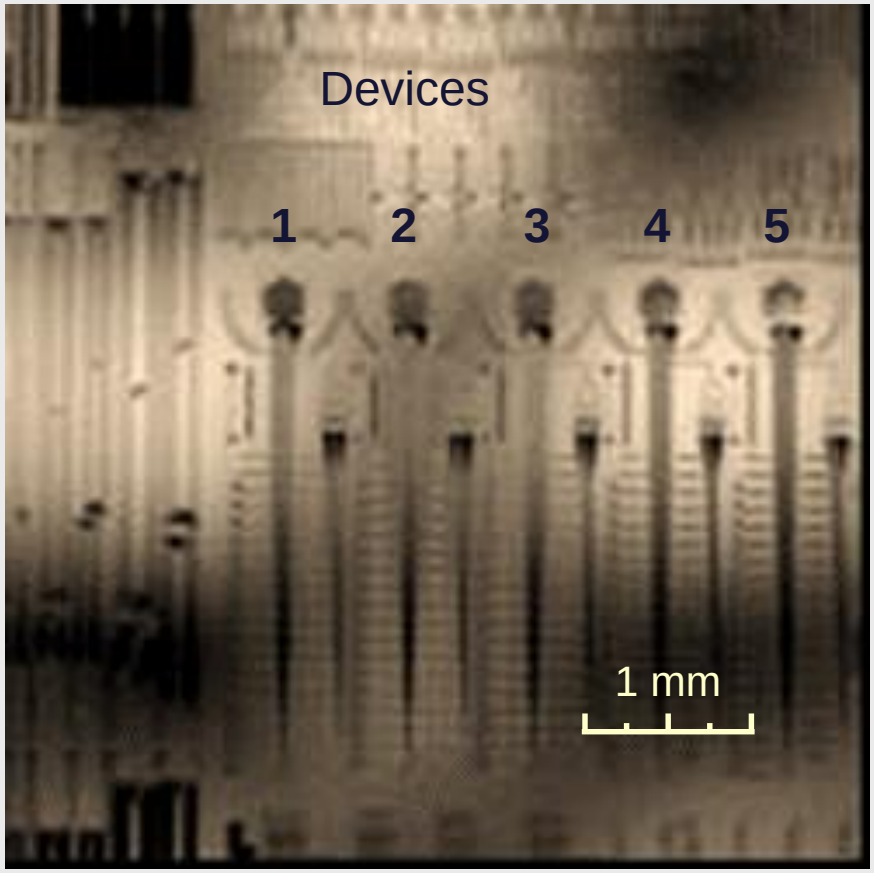

PROFA channel pattern superimposed on 1x32 splitter tree

- Coupling loss 3 dB (1 dB on top of VGC coupling loss)
- 0.7 dB standard deviation across all 37 channels

Kopp *et al.* "Two-dimensional, 37-channel, high-bandwidth, ultra-dense silicon photonics optical interface“, Journal of Lightwave Technology **33**(3)**,** 653-656 (2015)

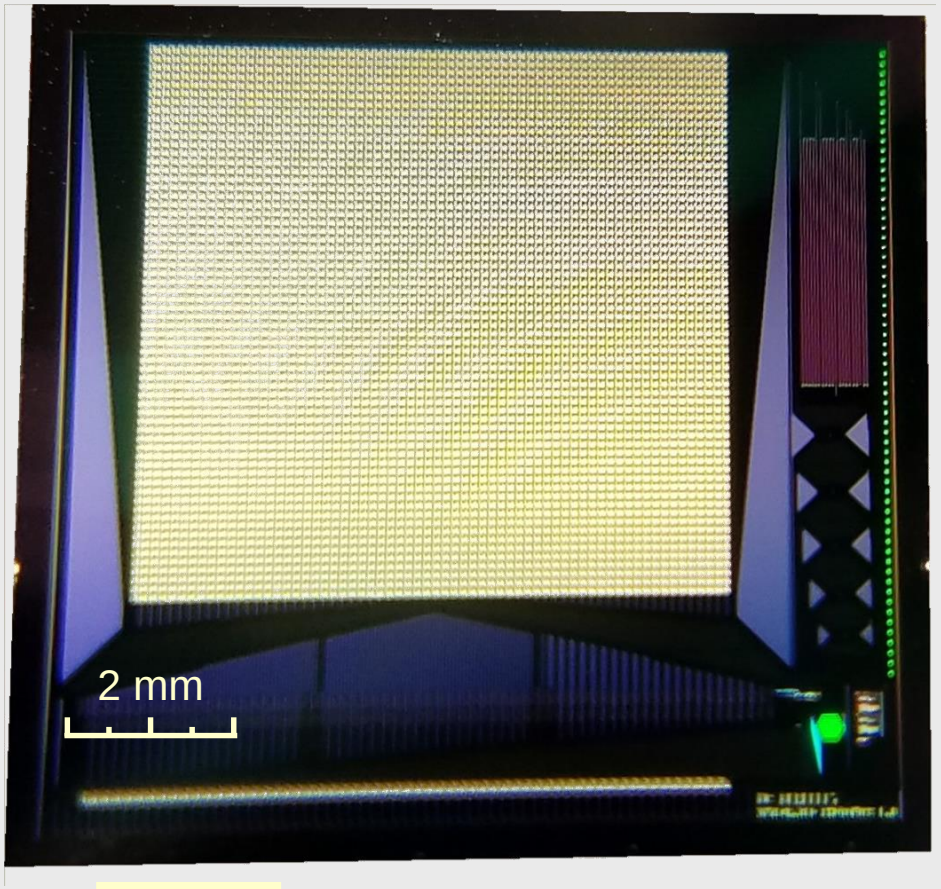
# Large Channel Count SiP I/O Ports

*IMEC, Leuven, Belgium*




**Multichannel transceiver prototype (16 Tx/16 Rx)**
1,600 Gb/s aggregate bandwidth (50 Gb/s/channel)

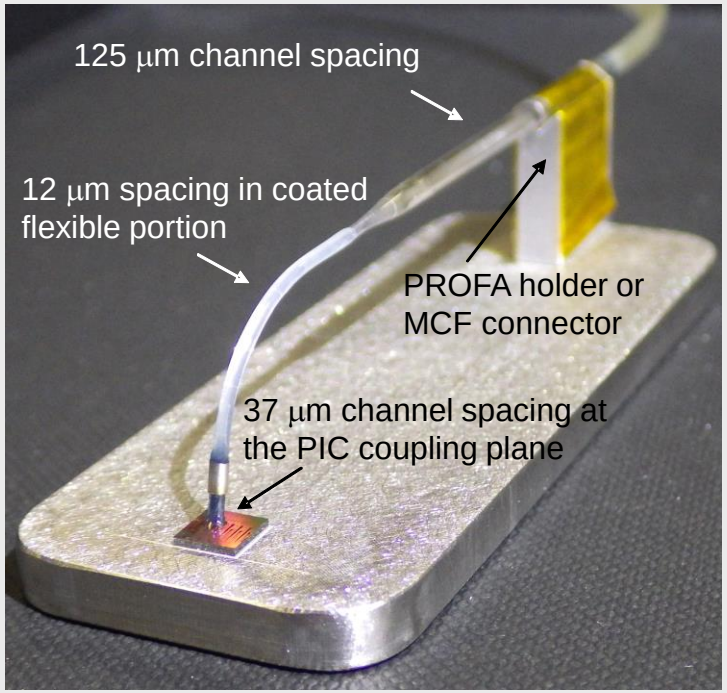
*University of California, Berkeley*




**64x64 Silicon Photonic MEMS Switch**

# Flexible PROFAs for Packaging: 61 channels, 1 Port

- Flexible design for robust and low-profile package
- Up to 91 channels, scalable to higher channel counts
- Fiber-to-chip coupling losses: < 1 dB on top of VGC losses (~ 3 dB)
- 0.58 dB standard deviation of losses across all channels

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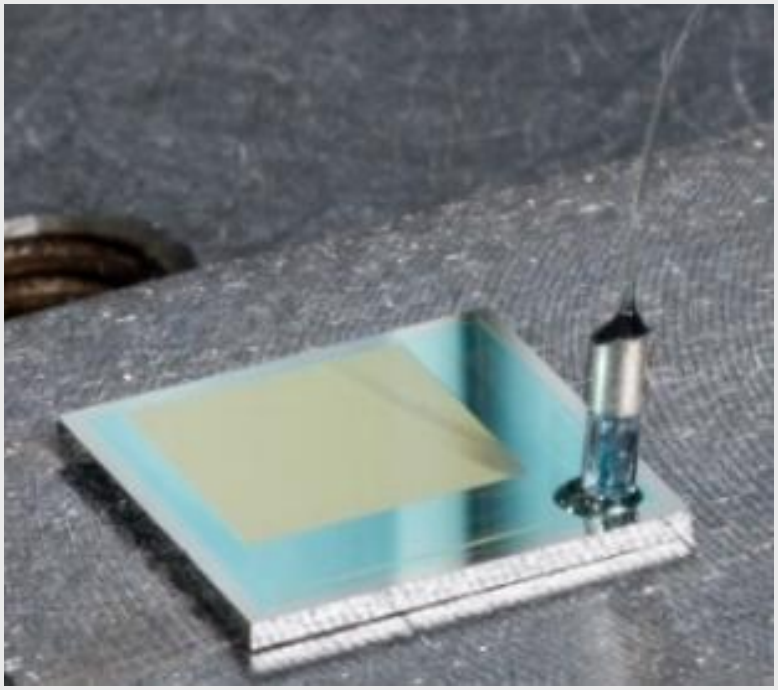
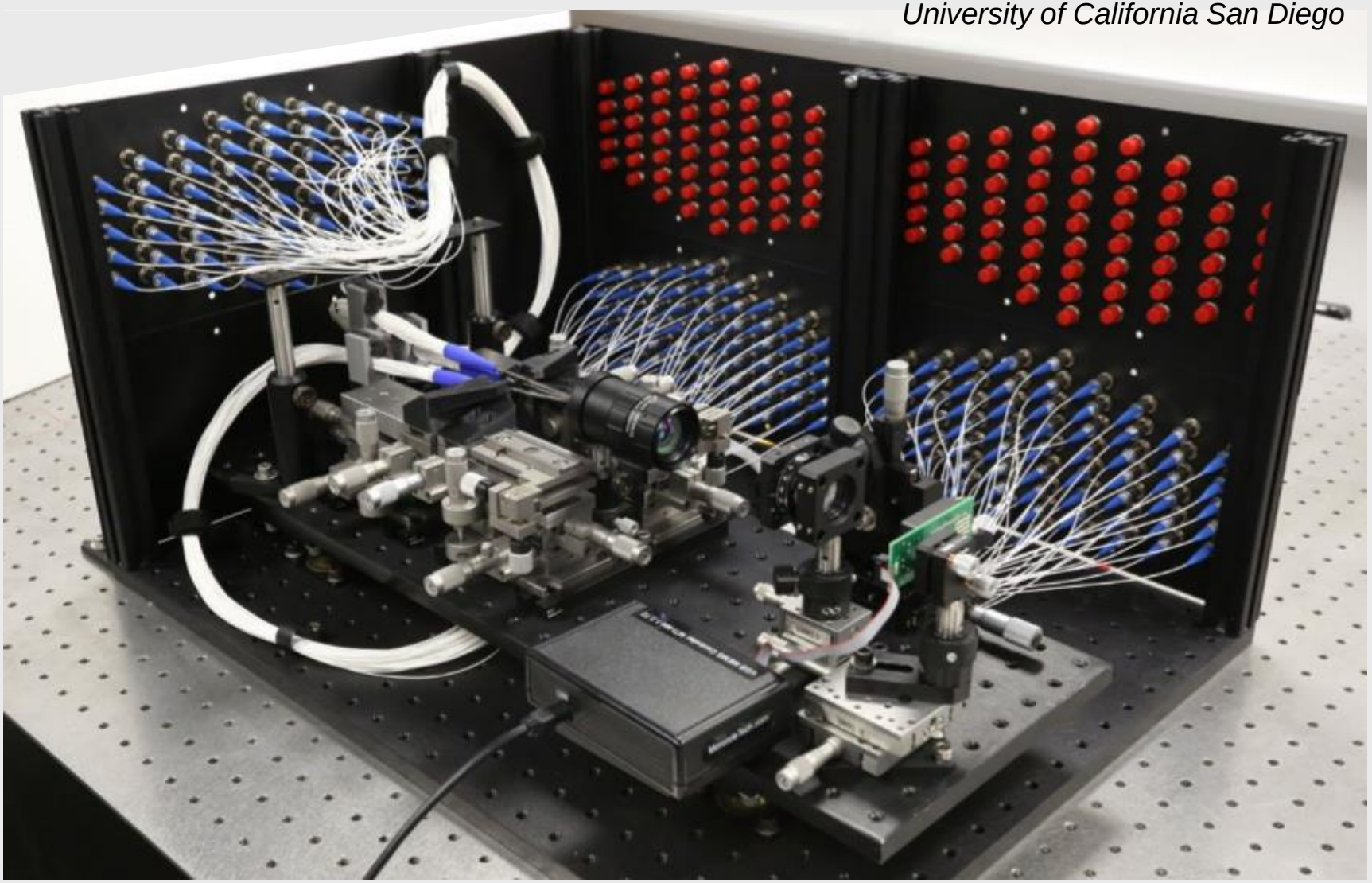


**64x64 Silicon Photonic MEMS Switch**

♦ Seok *et al. OFC* **Th5D.7** (2017) ♦ Kopp *et al. ECOC*, p.755 (2016)
♦ De Heyn *et al. OFC* **Th1B.7** (2017)

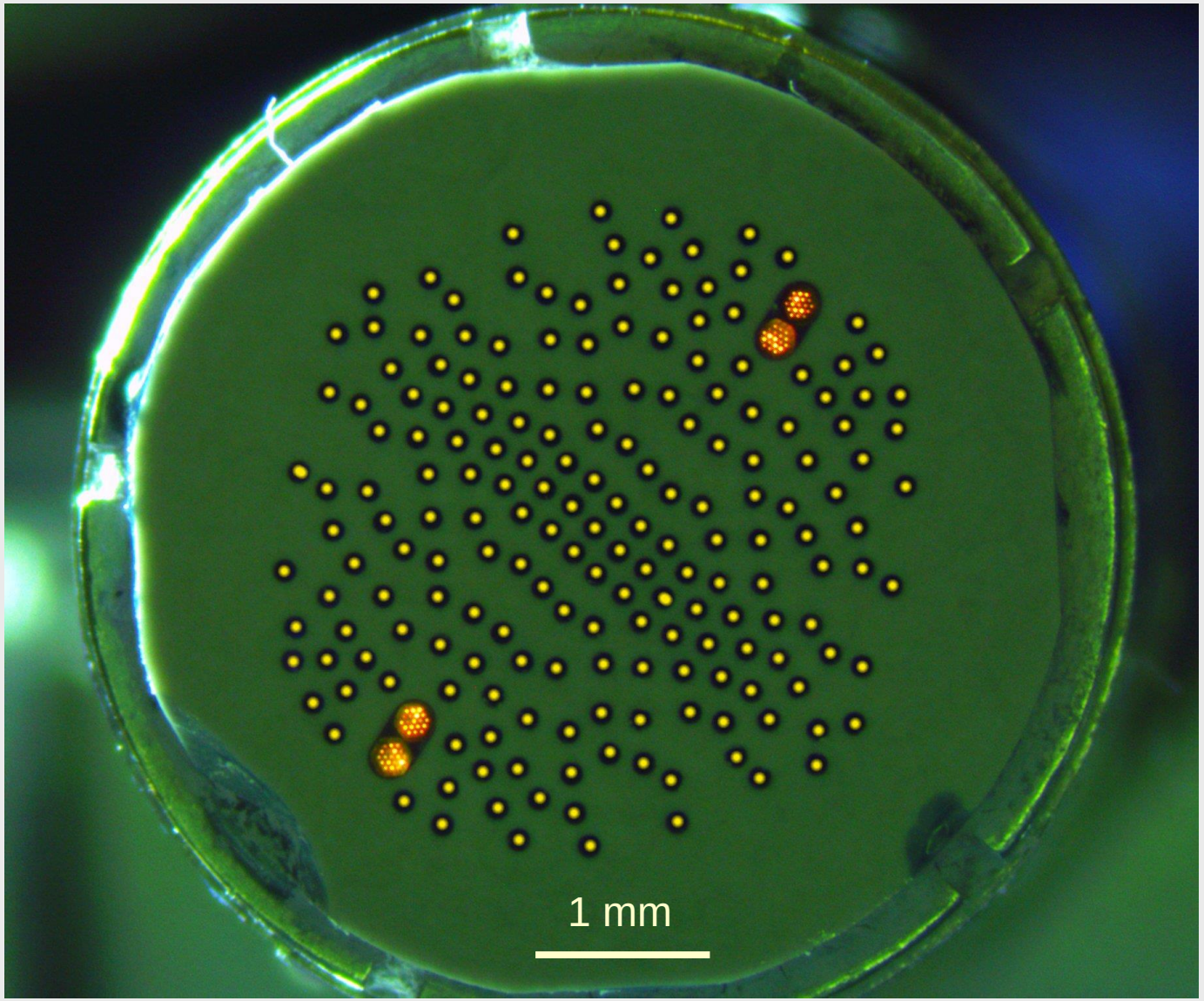
# PROFA in Novel Switch Designs

*University of California San Diego*



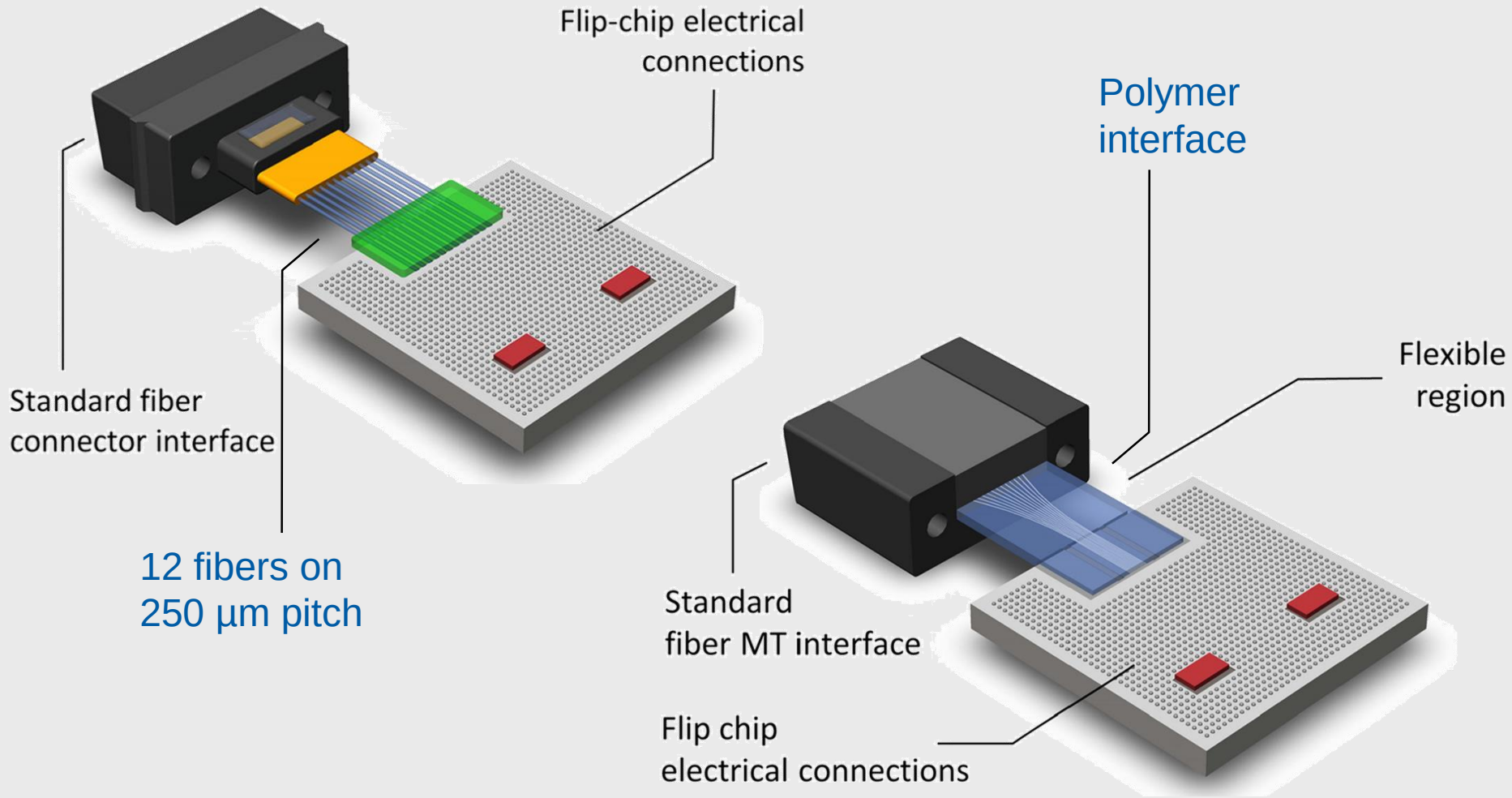
Mellette *et al.* “61 port 1×6 selector switch for data center networks”, *OFC* **M3I.3** (2016)

# High-Density Hybrid Fiber Array for Doppler Velocimetry




Four 19-channel PROFAs in a hybrid fiber array

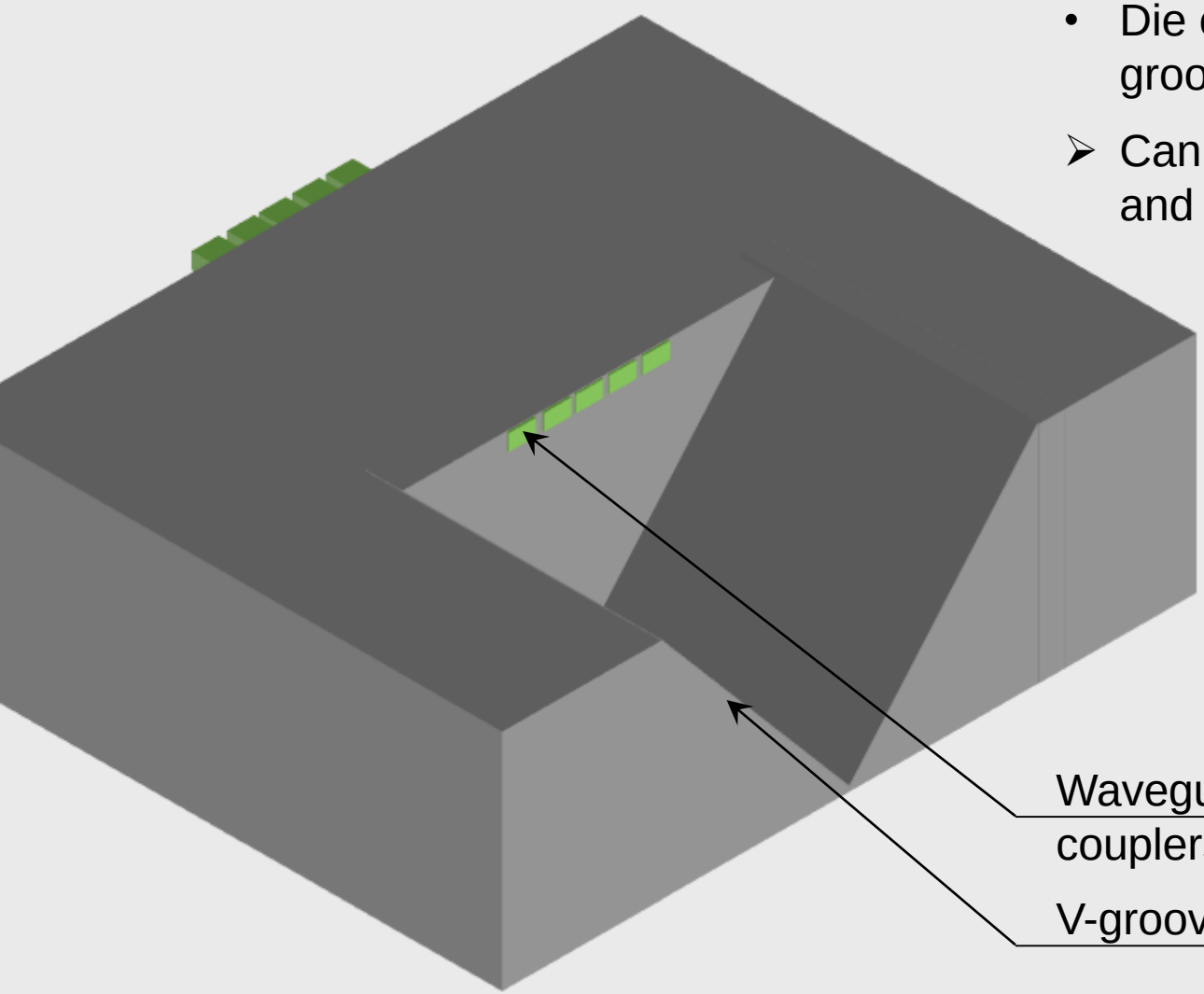
# Multifiber connect concepts (IBM T. J. Watson RC)



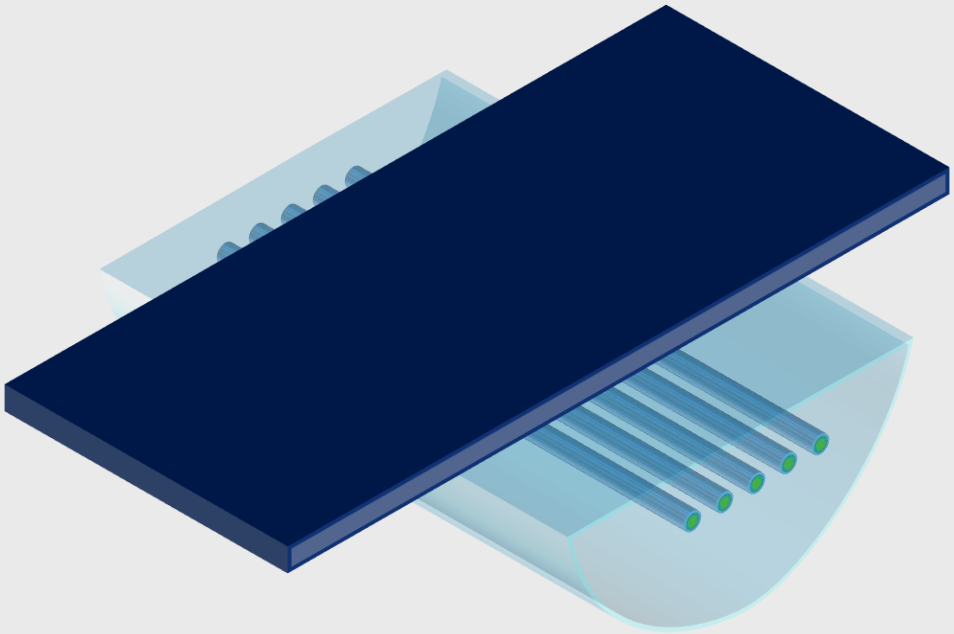

Barwicz *et al.* "A novel approach to photonic packaging leveraging existing high-throughput microelectronic facilities", *IEEE Journal of Selected Topics in Quantum Electronics* **22**, 8200712 (2016)

# Multicore Fiber to Chip Edge - V-groove at Die edge

- Die edge integrates registered v-groove
- ➢ Can include features for coupling and index matching / filling

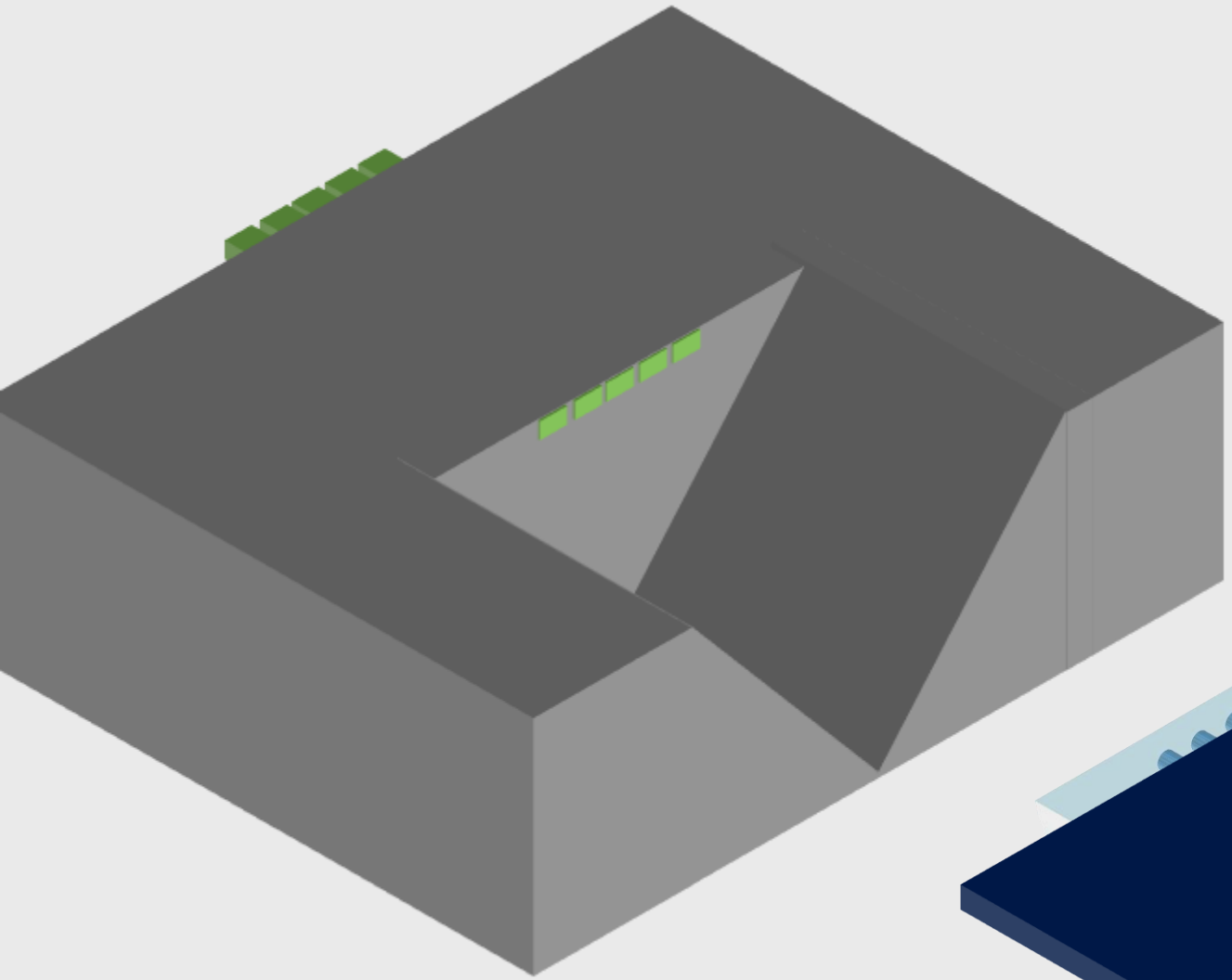


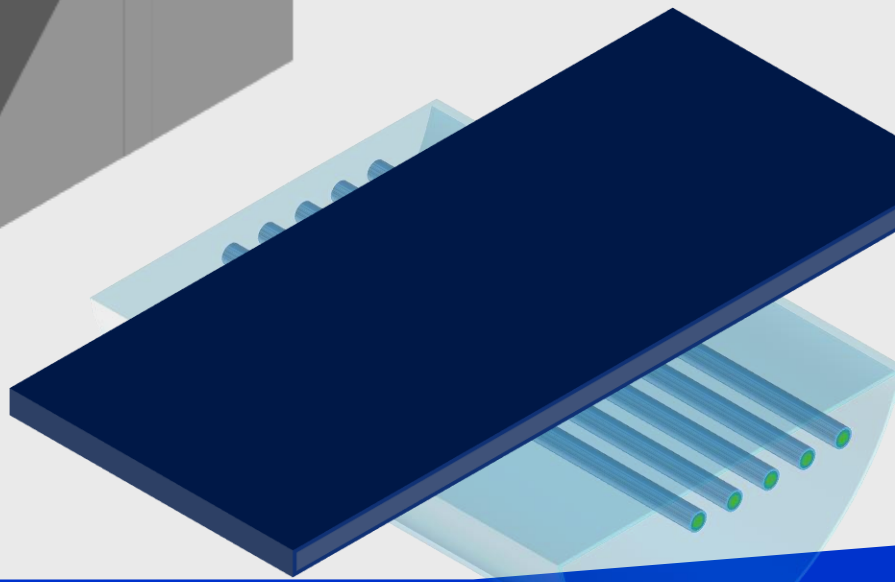
# Multicore Fiber to Chip Edge – D-shaped MCF



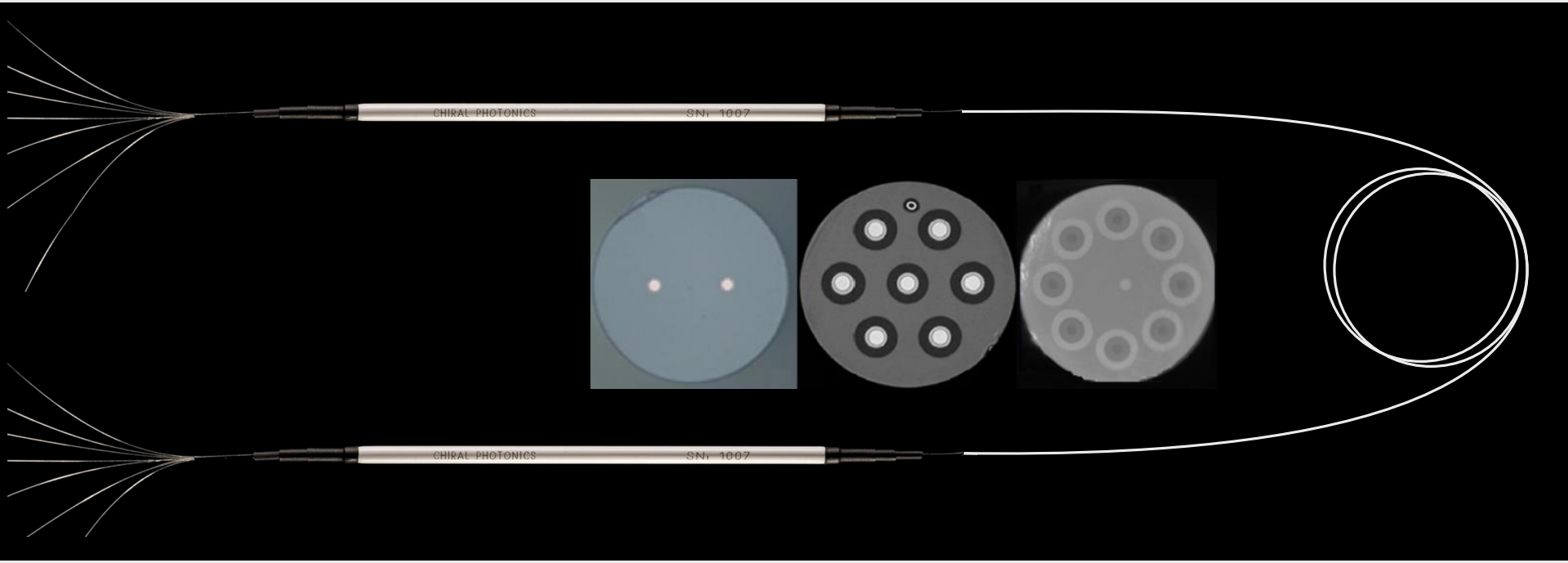
- D-shaped multicore fiber
- Add “holder” for pick and place

# Multicore Fiber to Chip Edge – Pick & Place Compatible





# PROFA-based Multicore Fiber Fanouts




- 2 to 20+ channels in a variety of configurations (hexagonal, square, circular and others)
- Typical specifications:
  - Average insertion loss < 0.6 dB
  - Average crosstalk < -40 dB
  - Back reflection < -60 dB

| Channel number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | -1.0 | -48.1 | -45.0 | -49.0 | X | X | X |
| 2 | | -1.3 | X | -53.7 | -46.9 | X | X |
| 3 | | | -1.8 | -46.2 | X | -48.7 | X |
| 4 | | | | -1.3 | -53.9 | -49.4 | -51.8 |
| 5 | | | | | -0.7 | X | -45.5 |
| 6 | | | | | | -1.1 | -46.4 |
| 7 | | | | | | | -0.8 |

| | |
|---|---|
| | Insertion Loss (dB) |
| | Crosstalk (dB) |
| X | Channels more than one pitch spacing apart |

Geng *et al*. *Proc. SPIE* **9390**, 939009 (2015)
Kopp *et al. IEEE Phot. Soc. Summer Topical,* p.99, 8-10 July (2013)
Hayashi *et al. OFC PD* **Th5C.6** (2015)

# Conclusion

- There are a number of emerging applications requiring a dense multichannel optical interface
  - Telecommunications
  - Sensing
    - 3D shape sensing
    - Interferometric
  - Switching
- All-silica PROFAs deliver robust connections to
  - Multicore fibers
  - Edges or surfaces of PICs
  - Free-space optics

# This presentation was presented at EPIC World Photonics Technology Summit 2019

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