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EUROPEAN UNION
North-West Europe
OIP4NWE
European Regional Development Fund

OIP4NWE
Open Innovation PIC Pilot

WebTalk on PIC technology and Innovation Support Funds

10th February 2021

Agenda

- **Welcome and Introduction**
  Dr. Victor Dolores-Calzadilla - Eindhoven University of Technology (TU/e)

- **Manufacturing of Photonic Integrated Circuits**
  Nazanin Shafiee - SMART Photonics

- **Optical interfacing of PICs with the outside world**
  Prof. Jürgen van Erps - Vrije Universiteit Brussel

- **Integrated Photonics Packaging**
  Donal Behal - Tyndall National Institute

- **Introduction of the Innovation Support Fund and how to apply**
  Prof. Jürgen van Erps - Vrije Universiteit Brussel

- **Open Discussion**
  Giuseppe Coppola – PhotonDelta

Welcome and Introduction

Dr. Victor Dolores-Calzadilla

Eindhoven University of Technology

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Open -Innovation Photonics pilot for North West Europe

Victor Calzadilla, TU/e

10.02.2021

Open -innovation photonics consortium

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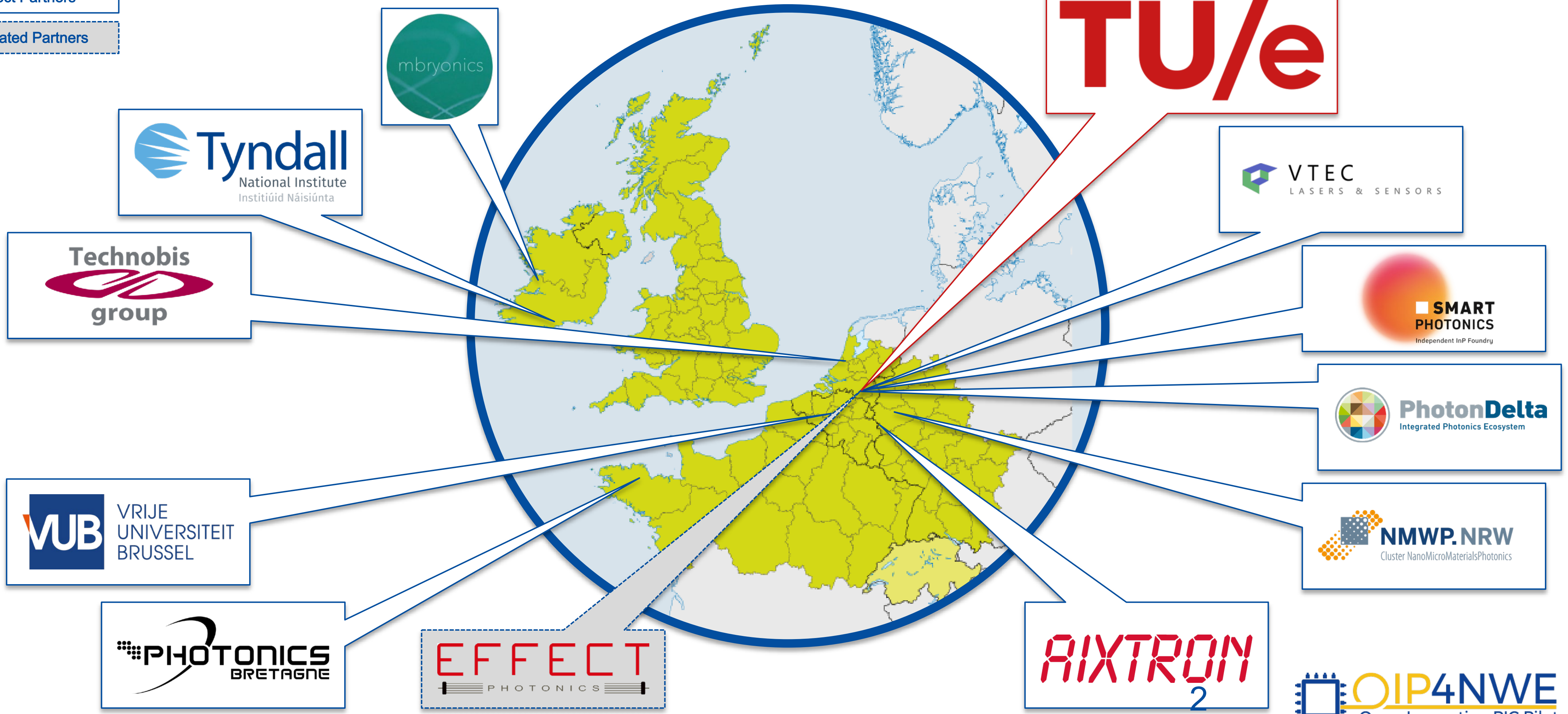
Project Partners

Associated Partners



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Open Innovation PIC Pilot

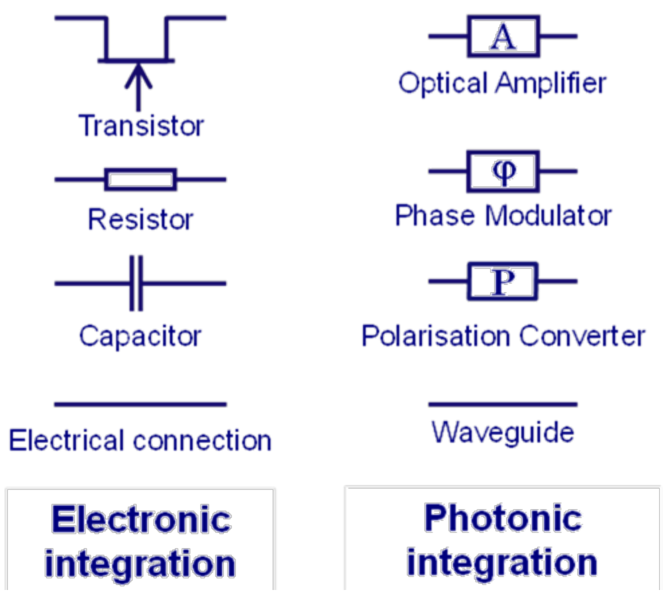
Our targets

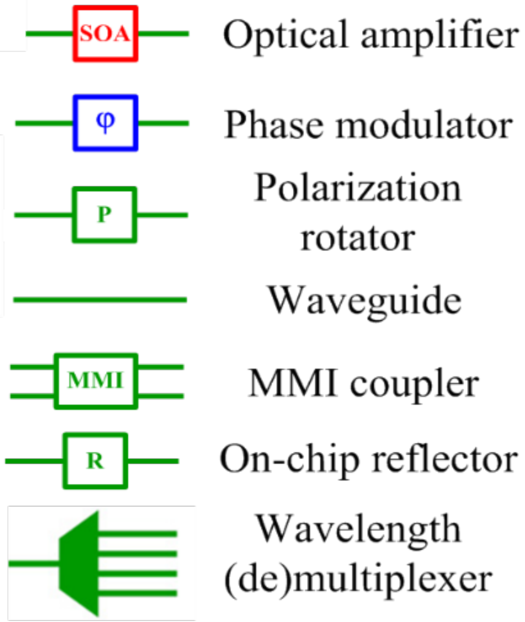
- Contribute to increase maturity and scaling of open access InP Photonic Integrated Circuits (PICs).

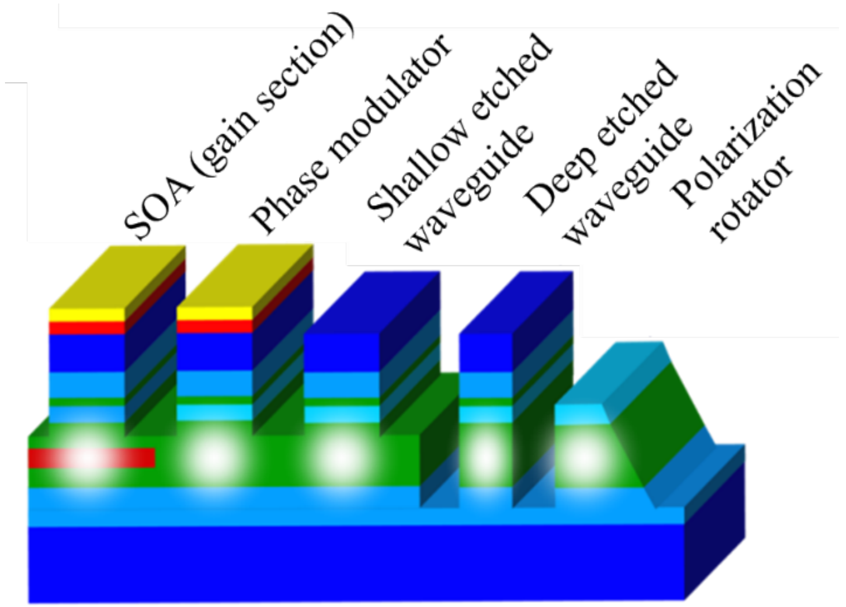
- Provide technology support to SMEs looking to mature their PIC -based products through open collaboration

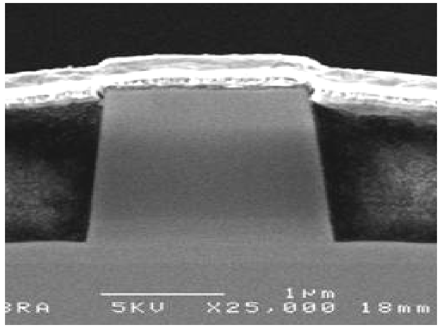
- Establish an open innovation environment for generic InP PIC technology in Europe:
  - Collaborative ecosystem: researchers, foundries, equipment manufacturers, application developers
  - Working on state -of-the-art equipment development and fabrication methods

Generic Photonic Integration in InP

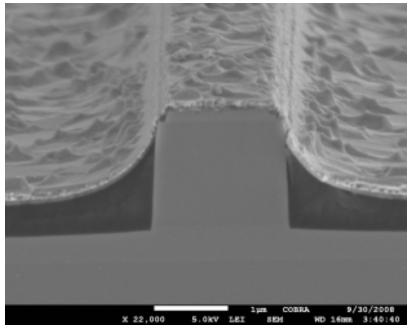




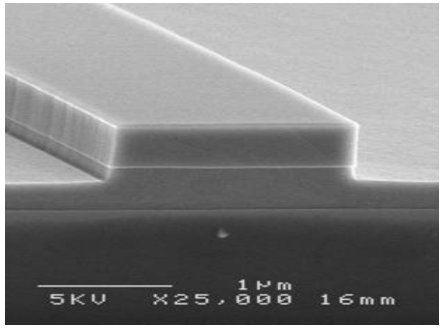




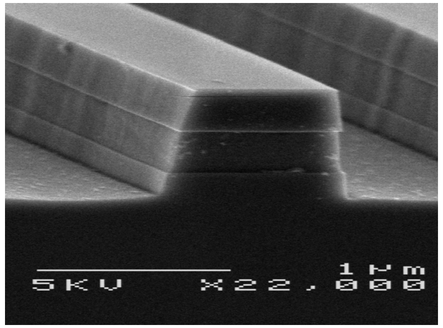
Amplifier



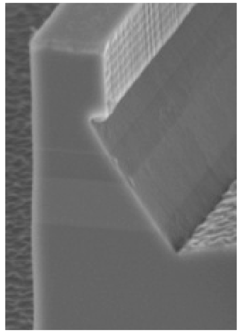
Phase Modulator



Shallow waveguide

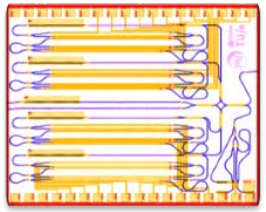
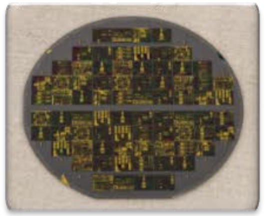
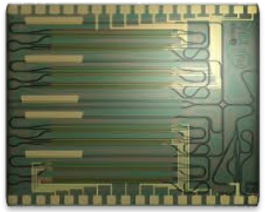


Deep waveguide



Polarization converter

The development cycle in photonic ICs


Application needs
- Market demand
- Application idea

Design
- Design support
- Design automation
- Simulations

Fabrication
- Foundry services
- Crystal growth
- Device fabrication
- Accessibility via MPW

Packaging
- Assembly processes
- Electrical interconnects
- Optical interconnects
- Thermal management

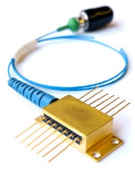
Product
- Integration of PIC into product
- Functional module
- Application specific

OIP4NWE supports SMEs via Innovation Support Fund

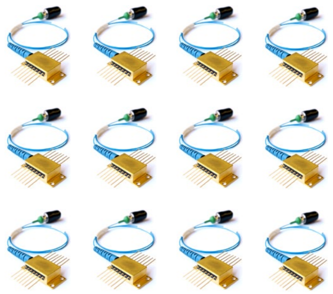
From prototype to pilot production

Idea | Research | Prototyping | Piloting | Manufacturing

TRL1 → TRL2 → TRL3 → TRL4 → TRL5 → TRL6 → TRL7 → TRL8 → TRL9



OIP4NWE: path to manufacturing



Main hurdles:

Reliability, Cost, Yield, Scalability

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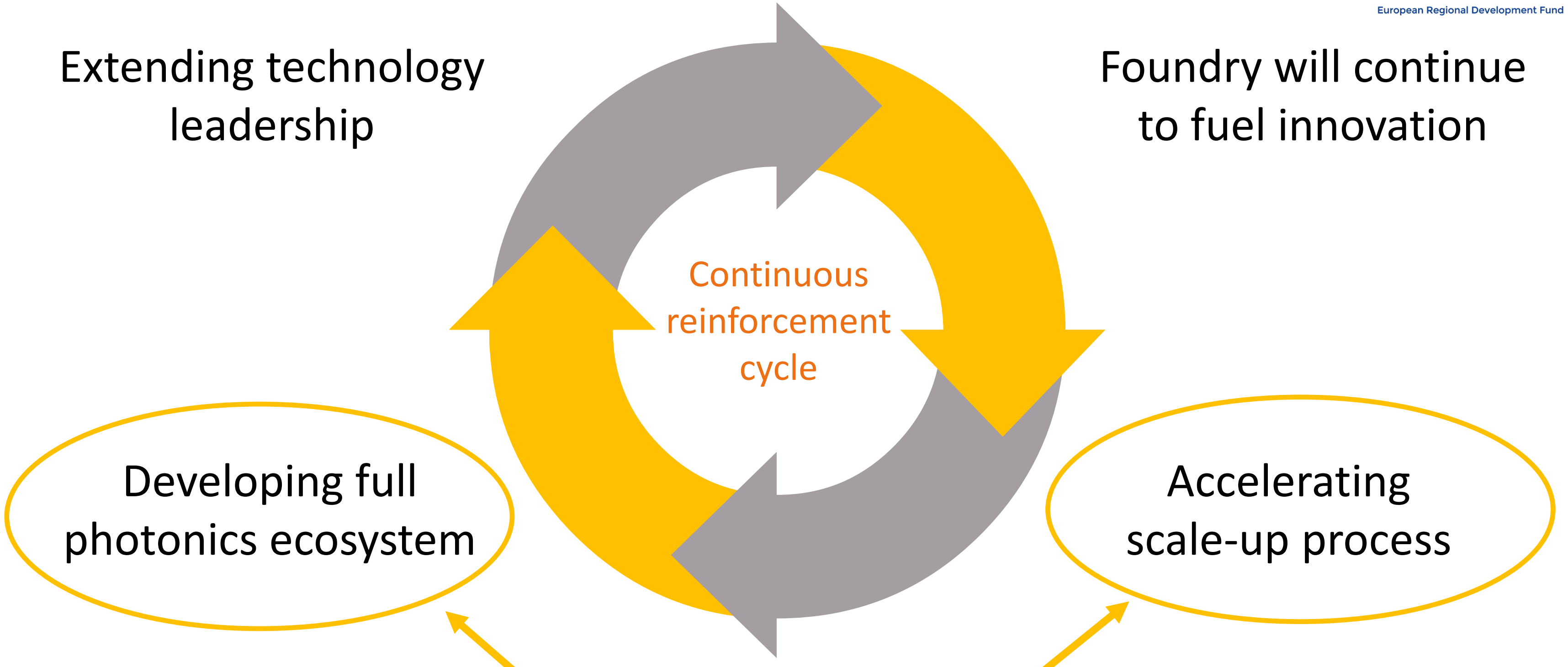
Accelerate PIC industry through open innovation



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Photonic Integrated Chips (PIC's) based on Indium Phosphide (InP) will play a key role in the lives of many people as they enable new and improved functionalities, ultimately making our world better, greener and safer

Design and manufacturing of photonic ICs

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- Broad set of building blocks for Integrated Photonics
- Process Design Kit
  - Design manual and Functional building block description
  - Enables Circuit simulation and Mask design in a full layout-aware design flow
- Technology developments
  - Process improvements
    - Epitaxy
    - Yield
    - Stability
  - Functionality (new building blocks)

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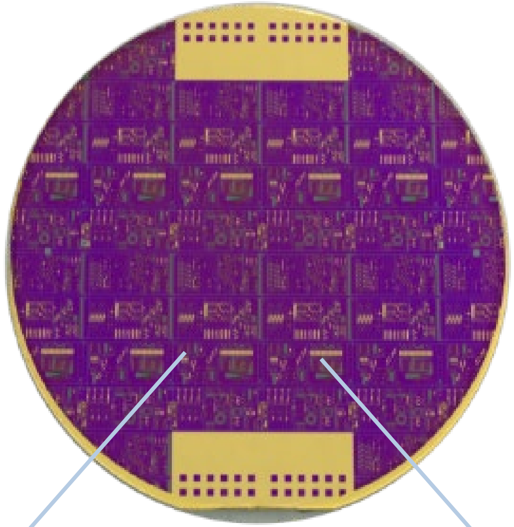

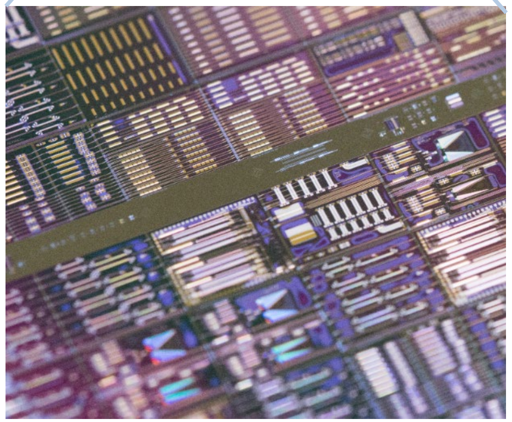

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Packaging of photonic integrated circuits

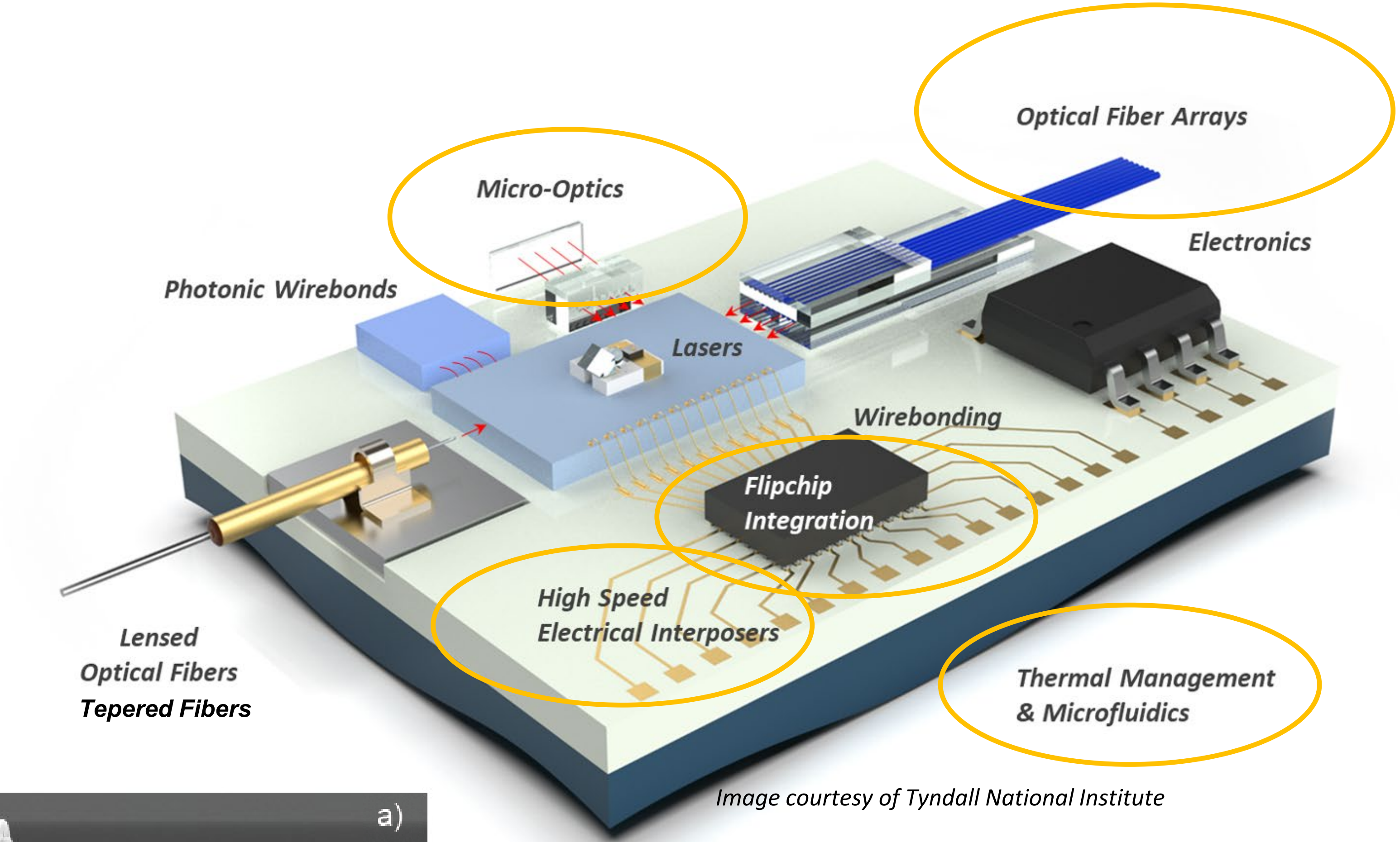
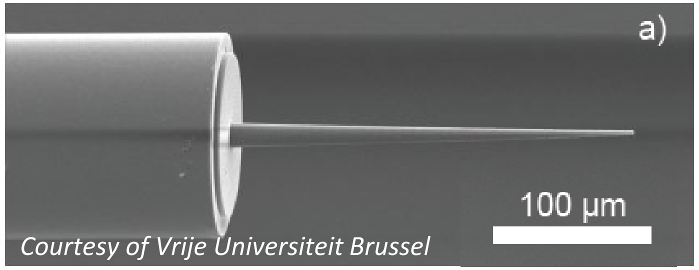


Image courtesy of Tyndall National Institute



Courtesy of Vrije Universiteit Brussel

Developments in the project:

- ➢ Optical connections:
- \- Fiber to Edge Coupler (horizontal)
- \- Micro-lenses
- \- Microfluidic channels

- ➢ Electrical connections:
- \- Flip Chip Bonding

- ➢ Thermal management

Innovation Support Fund

Call is open (3 months)

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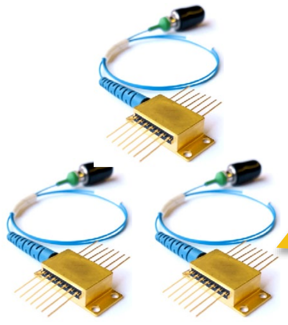
Fabrication of PICs

VRIJE UNIVERSITEIT BRUSSEL

External optics design

Tyndall National Institute

Packaging



www.oip4nwe.eu/vouchers

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http://www.oip4nwe.eu

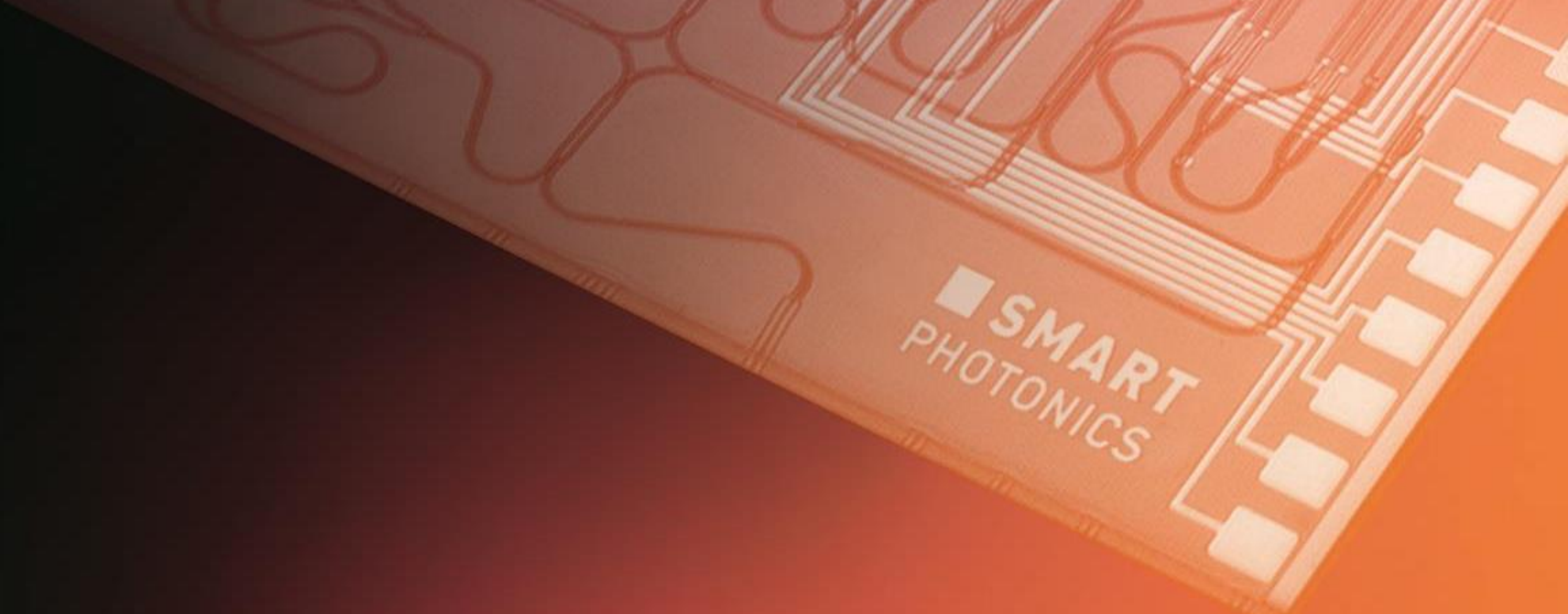
Presentation

Manufacturing of Photonic Integrated Circuits

Nazanin Shafiee

SMART Photonics

Open Innovation PIC Pilot



MANUFACTURING of InP PHOTONICS INTEGRATED CIRCUITS

NAZANIN SHAFIEE

FEB 10, 2021

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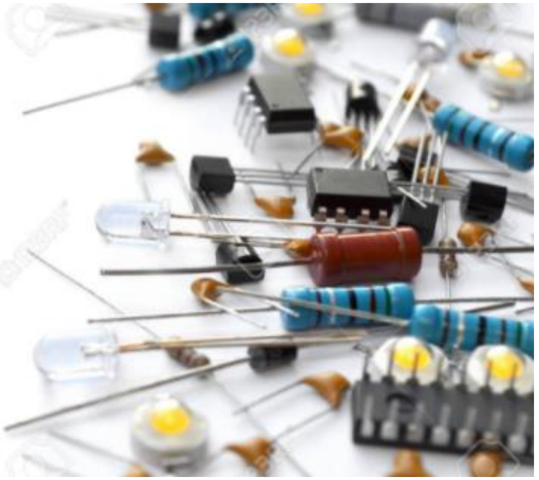
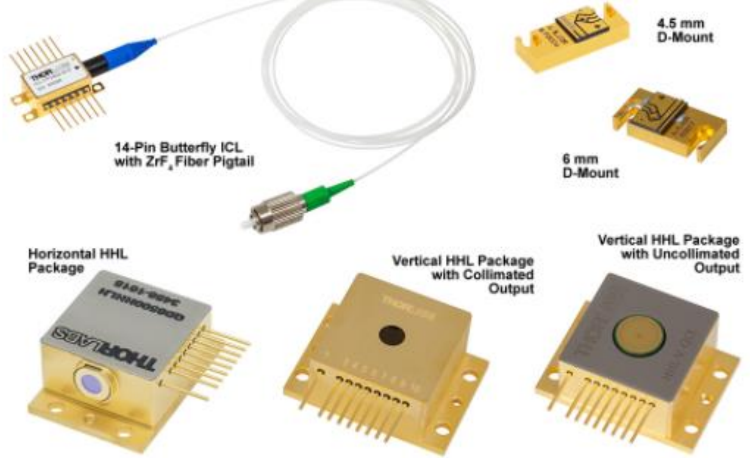
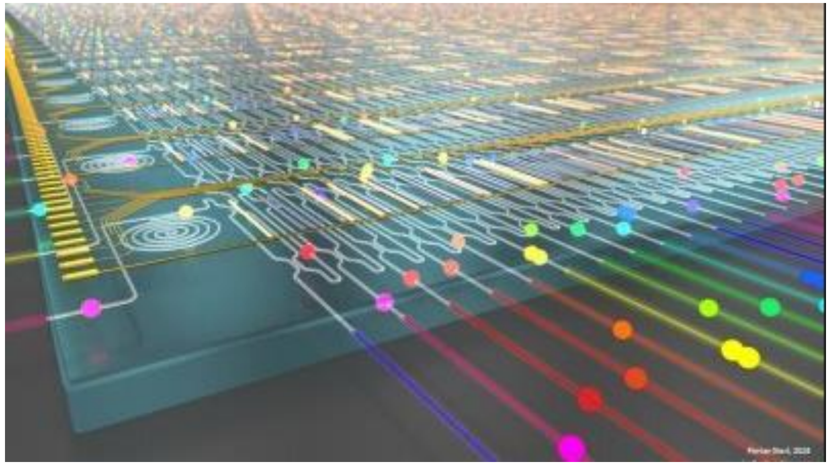
INTEGRATION (ELECTRONICS)



Electronic integration has changed the world!

INTEGRATION (PHOTONICS)





Photonic integration will change the world again!

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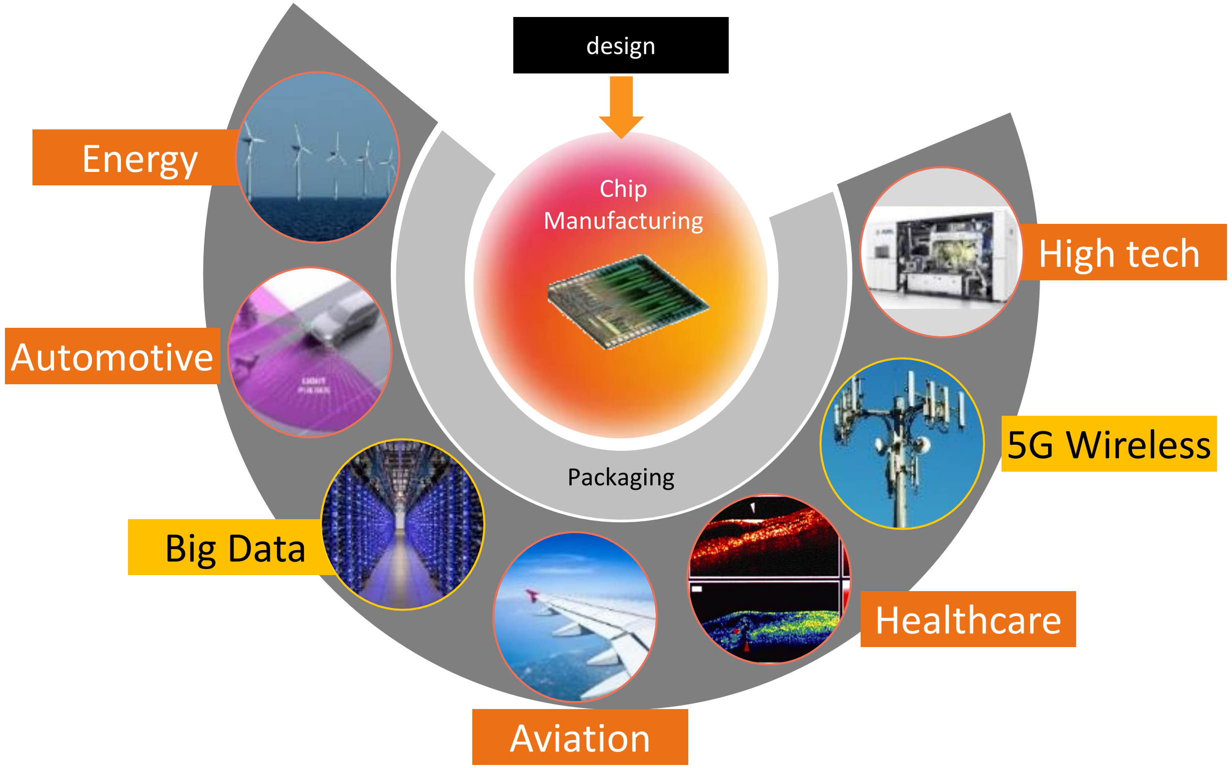
KEY MARKET OPPORTUNITIES



- Communication applications key trends:
  - Ongoing transition to higher network speed
  - Access networks are migrating from DSL towards Fiber (FttX)
  - 5G
  - Ongoing rise in data traffic
  - Increasing cloud-based storage capacity (datacenters) required
  - Transition towards advanced coherent optical to technology
- PICs on InP create disruptive sensing solutions for many sectors:
  - Health & Medical
  - Automotive
  - Aerospace / Aviation
  - Machinery
  - Energy
  - Consumer Electronics

Communication applications

Sensing applications

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OUTLINE

- Introduction to SMART Photonics
- PIC Technology
  - Applications
  - Platforms
- Generic platform
  - Building blocks and devices
- Wrap up

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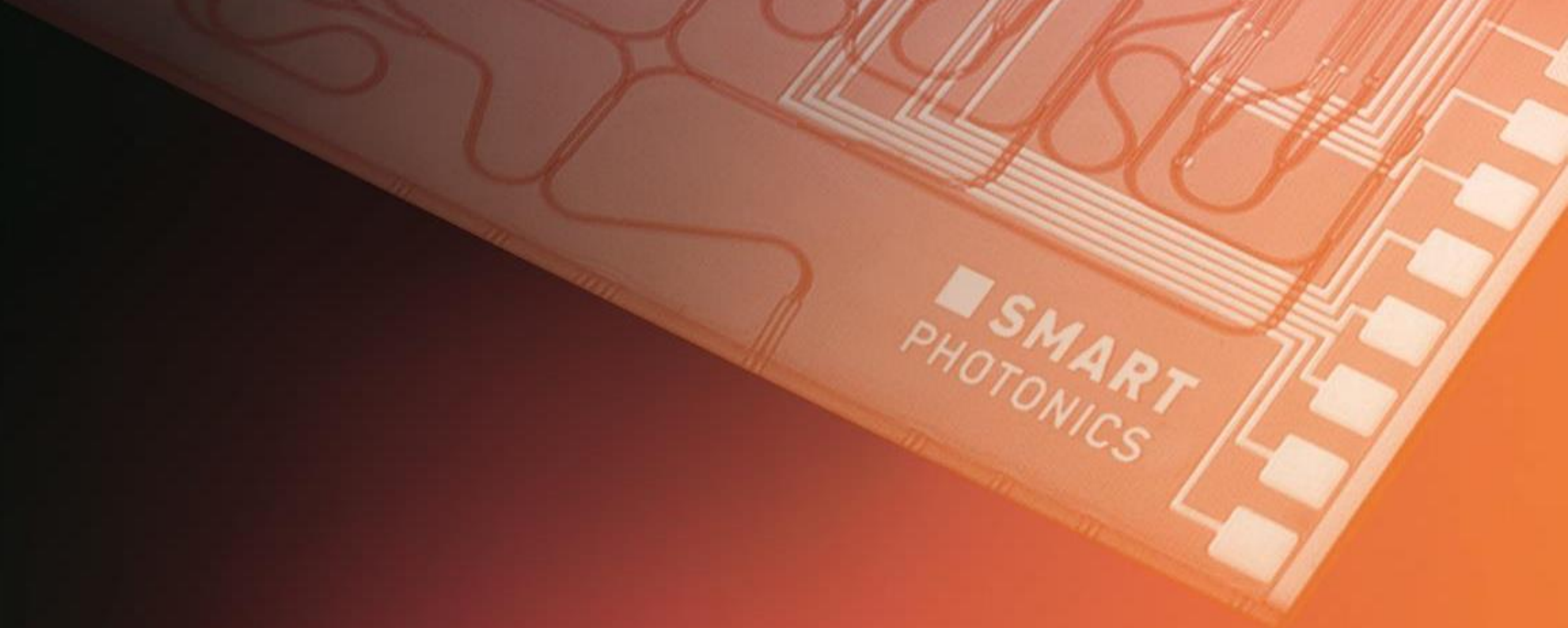

INTRODUCTION TO SMART PHOTONICS

ABOUT SMART PHOTONICS FOUNDRY

- Independent Pure-play Foundry for InP based Photonic components
- Building on more than 40 years of technology heritage

Early 1980's – Origin: PHILIPS

1991 – First commercialization components

1994 – Cooperation with Eindhoven University of Technology (TU/e)

1998 – Acquisition: acquired by Uniphase for €1.2B

2002 – NanoLab established: Established first shared facility for integrated Photonics prototyping

2012 – Spin-off SMART Photonics

2013 – First production: First Multi Project Wafer produced

2017 – First step in control: Move to HTC and installation of tool set in HTC facility (50% of process)

2020 – Full Control: €35M Investment round

>2022 – New fab: Scale up to serve global customers as state of the art photonics foundry

Total investment in fundamental InP and Photonics research estimated at €300M

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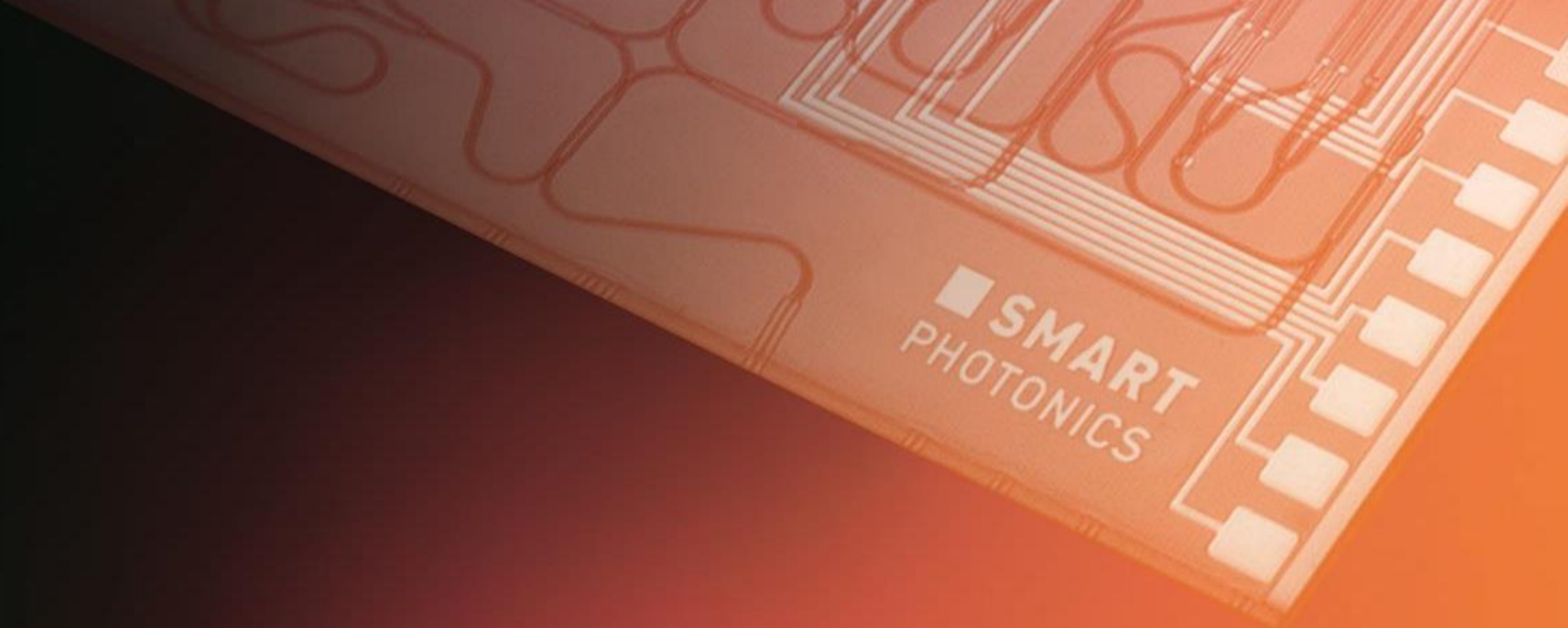


PIC TECHNOLOGY APPLICATIONS

ENABLING THE SOLUTIONS OF TOMORROW

IoT & Edge computing

Telecom/Datacom

Medical diagnostics

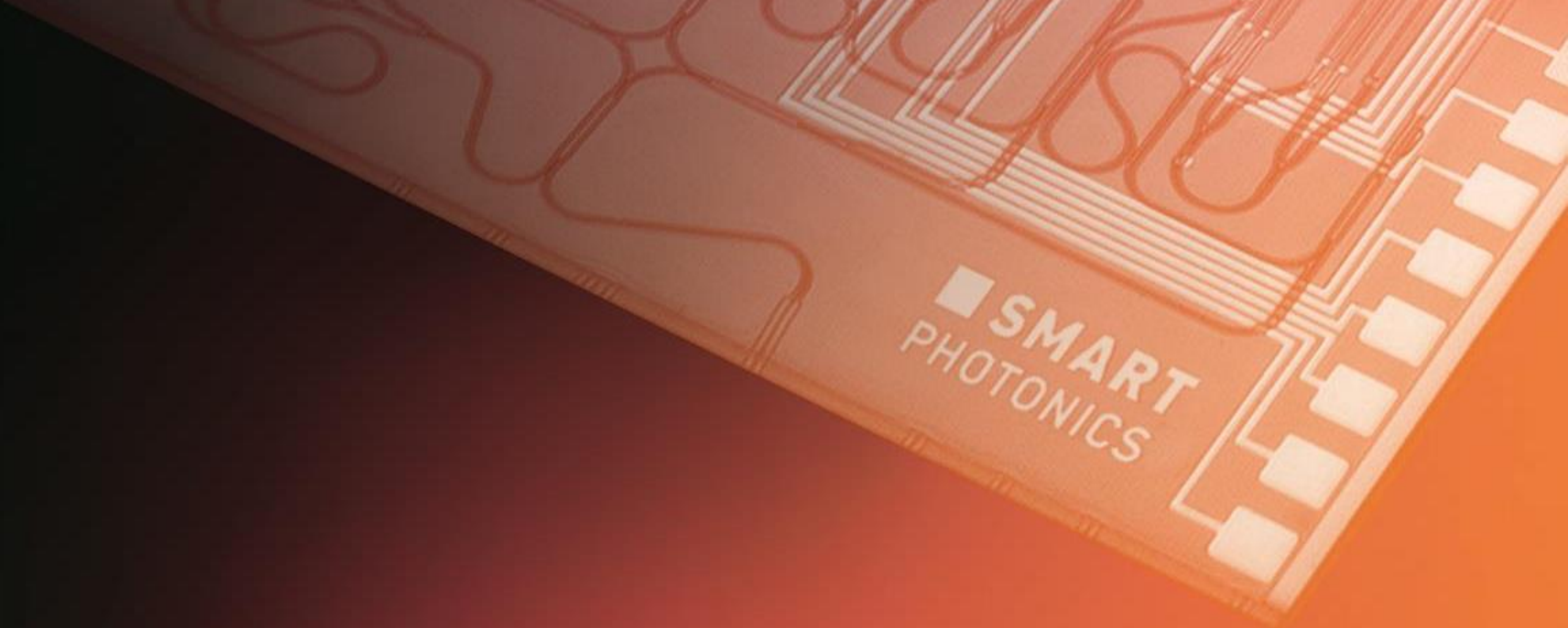
Immersive technologies
(Virtual / Augmented / Mixed Reality)

Commercial sensing

Autonomous driving
LIDAR

DATACOM: TRANSCEIVER

Local Area Network



PIC TECHNOLOGY PLATFORMS

PIC TECHNOLOGY COMPARISON

Building block	Performance		
	InP	**SiP**	**SiN**
Passive components	●●	●●	●●●
Lasers	●●●	H	H
Modulators	●●●	●●	●
Switches	●●●	●●●	●
Optical amplifiers	●●●	H	H
Detectors	●●●	●●●	H

Performance	
●●●	Very good
●●	Good
●	Modest

Fabrication Technology	
H	Hybrid/Heterogeneous

InP advantage:

- Monolithic integration of components

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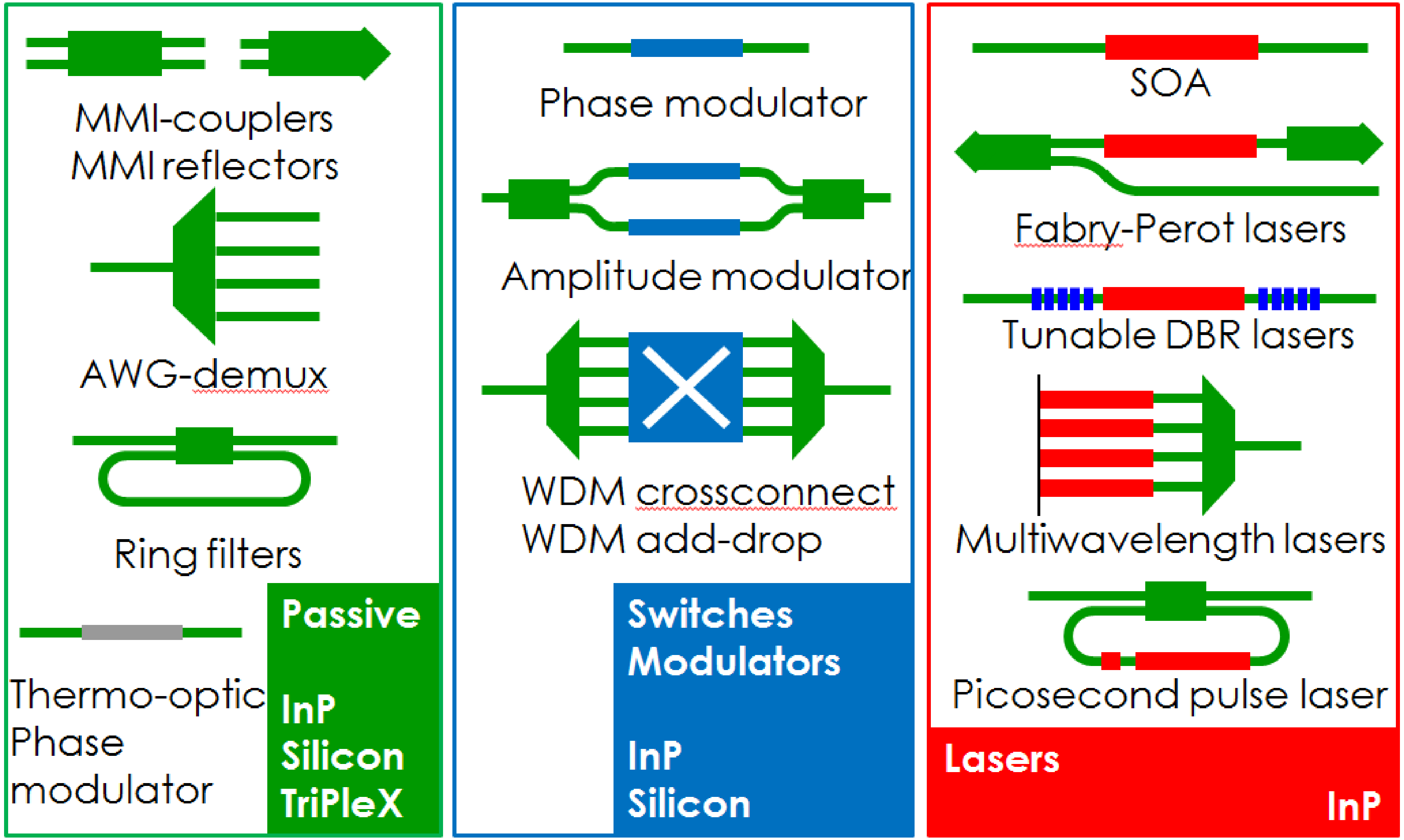
COMPONENT POSSIBILITY BY PLATFORM



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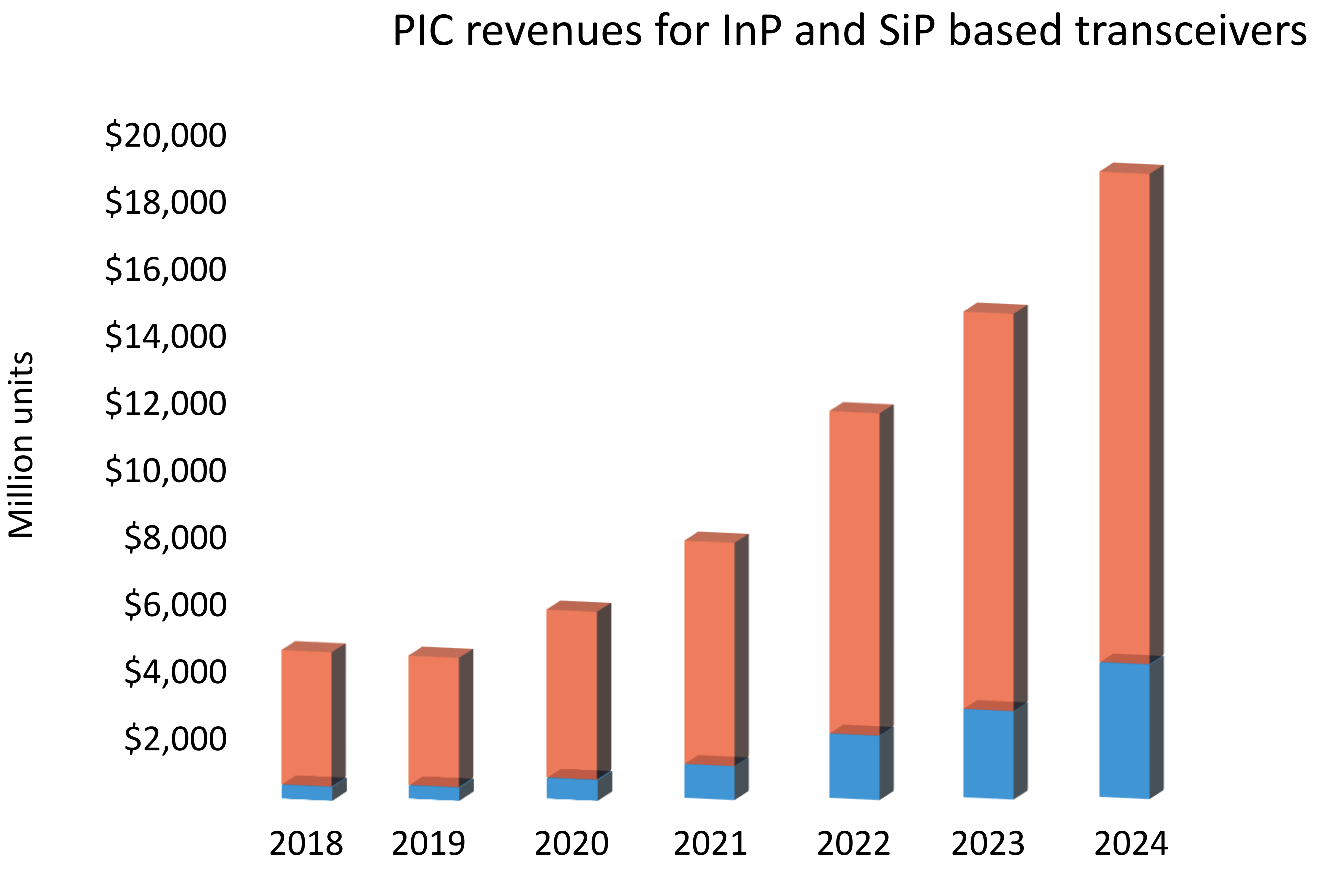
MARKET PROSPECTS



	2018	2019	2020	2021	2022	2023	2024
(orange)	$ 4,086	$ 3,934	$ 5,011	$ 6,784	$ 9,750	$ 11,907	$ 14,756
(blue)	$ 455	$ 484	$ 740	$ 1,154	$ 1,966	$ 2,822	$ 4,144

Source: Yole Development 2019

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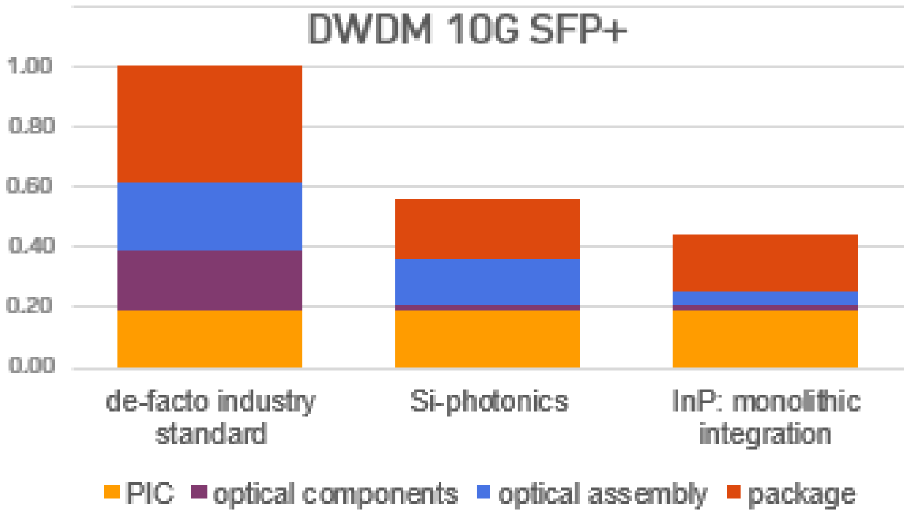
REDUCING COST

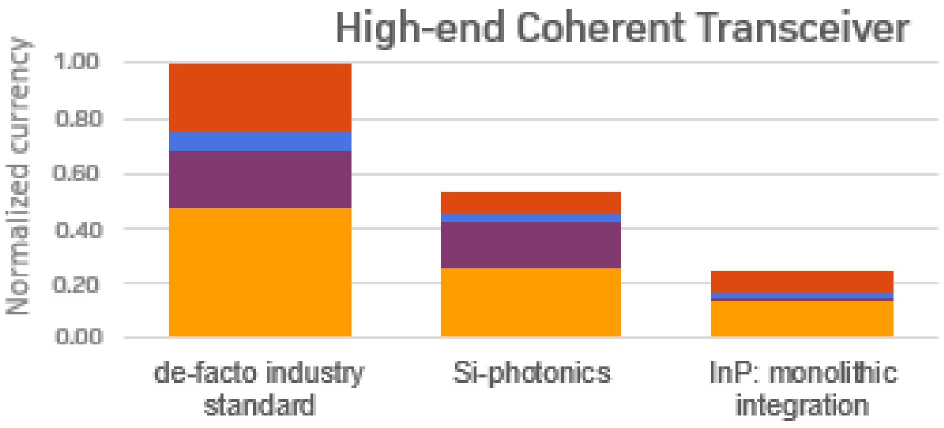
Photonic integration enables cost-down:

- Reduced optics BOM: integrated optics: e.g. wavelength locking, power control. No auxiliary optics needed (reducing module cost 4x)
- Reduced packaging BOM: no gold-boxes required

InP integration reduces assembly costs further:

- Si photonics requires optical assembly of laser/amplifiers to Si
- Assembly costs proportional to number of active components





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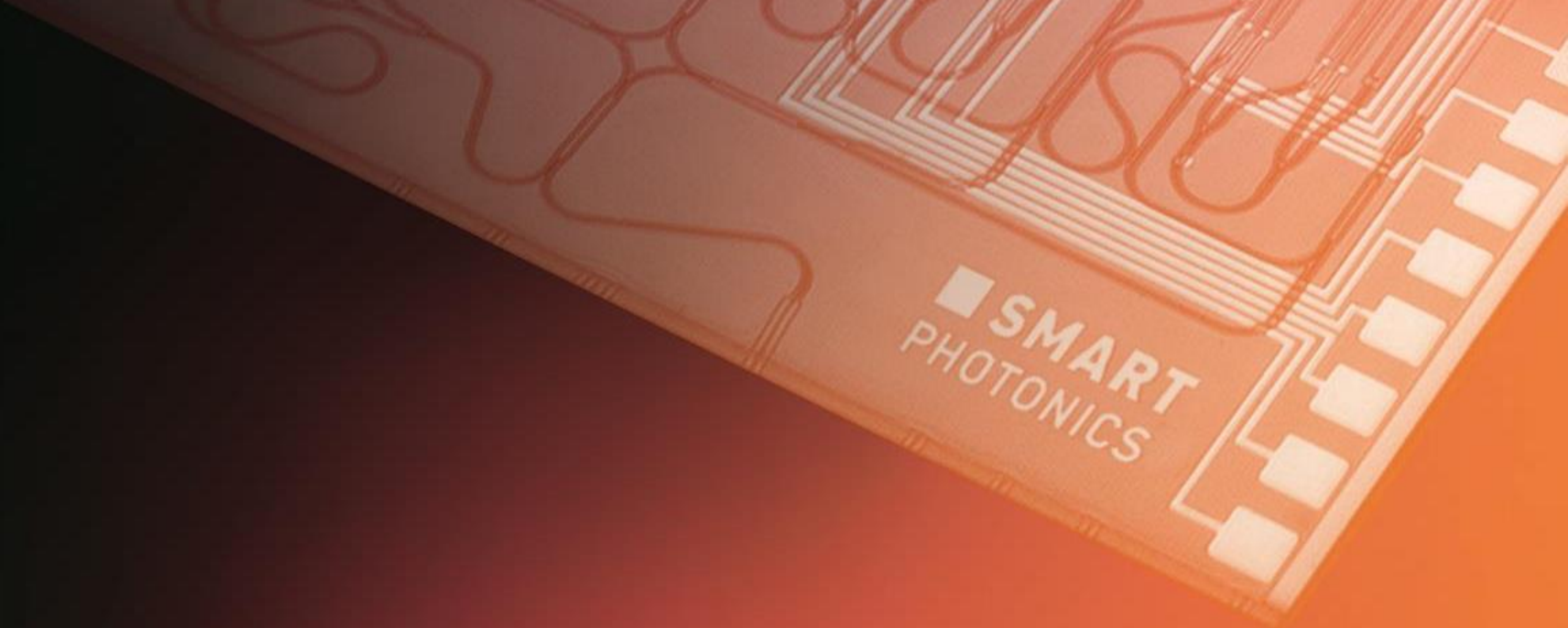


GENERIC PLATFORM
BUILDING BLOCKS
DEVICES

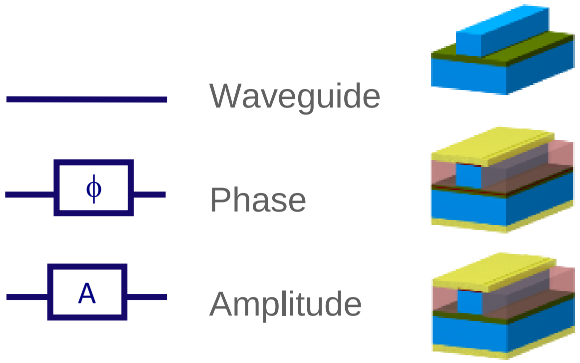
WHY: GENERIC INTEGRATION PLATFORM

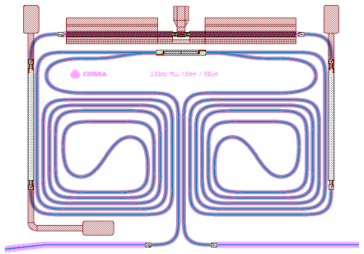
- High performance
- Versatile and easy
  - integration of amplifiers and lasers without compromise
- Low cost
- Standardized processes
- Scalable and ready for volume manufacturing

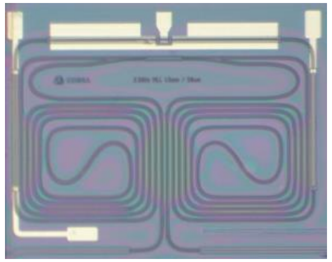
HOW: GENERIC INTEGRATION PLATFORM

- Process Design Kit (PDK)
  - An integration platform with an underlying epitaxy design
  - Design on *functional level* by using building block approach
  - Higher efficiency in design:
    - Faster development
    - Lower-cost optics

SMART IN2PIC PDKs



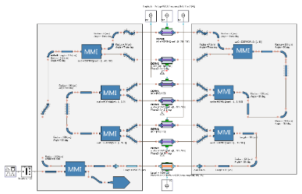


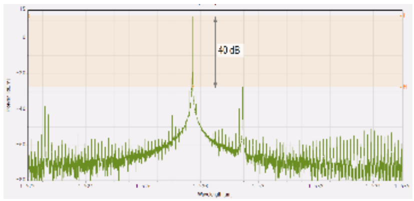


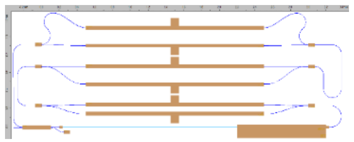
LAYOUT-AWARE SCHEMATIC DESIGN FLOW

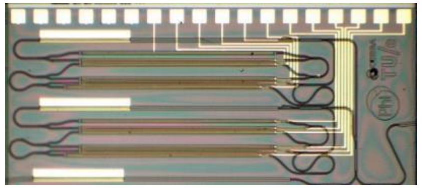
- For **circuit simulation** and **mask design**
- **Design manual** and **Functional** building block description
- Full **layout-aware** design flow
- Access via **state-of-the-art software tools**

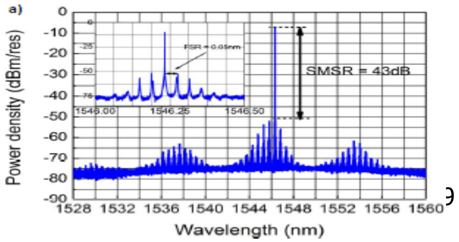
VPIphotonics DESIGN AUTOMATION · Photon Design · lumerical · SYNOPSYS · Nazca design photonic IC design framework · LUCEDA PHOTONICS · Mentor A Siemens Business











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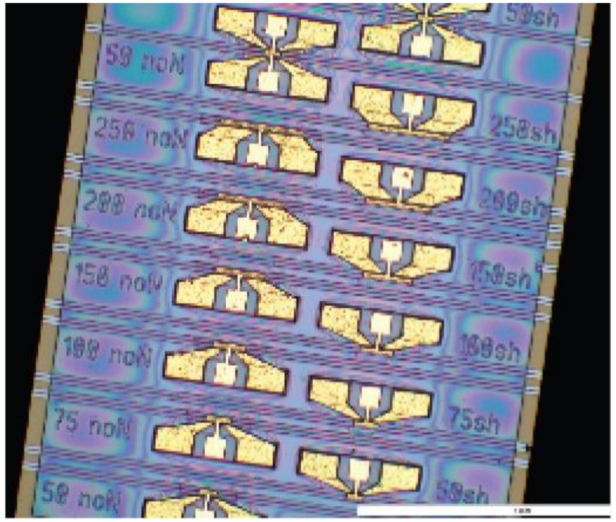
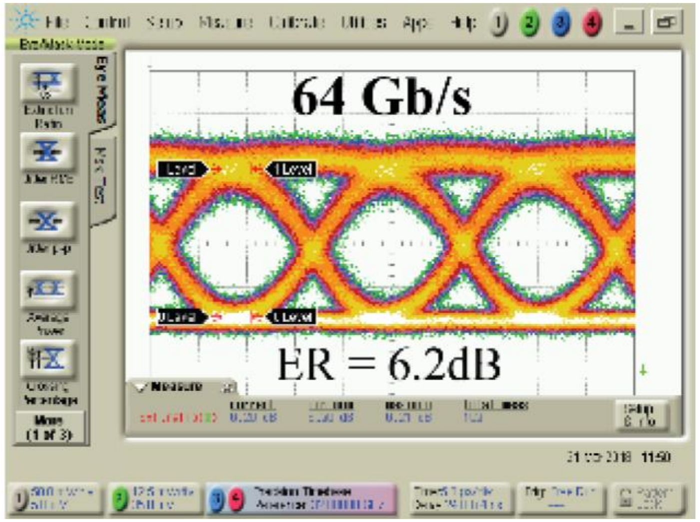
ELECTRO ABSORPTION MODULATOR (EAM)



M. Trajkovic, CLEO2018



- EAM demonstrated with > 55 GHz bandwidth
- Available in MPW at ~30 Gb
- High speed available in MPW in 2021

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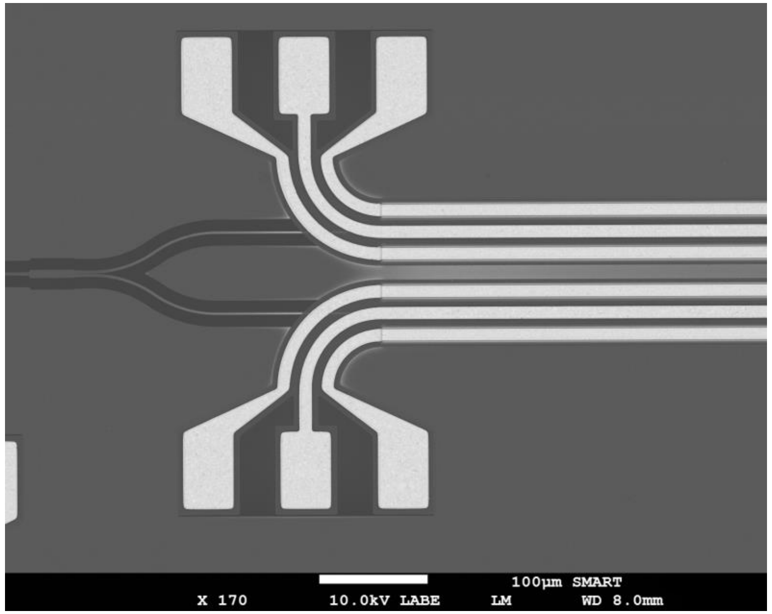
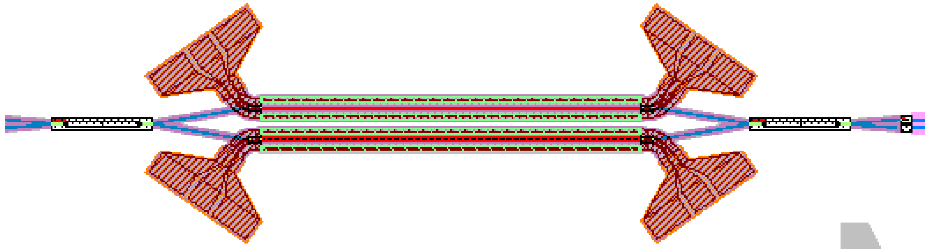
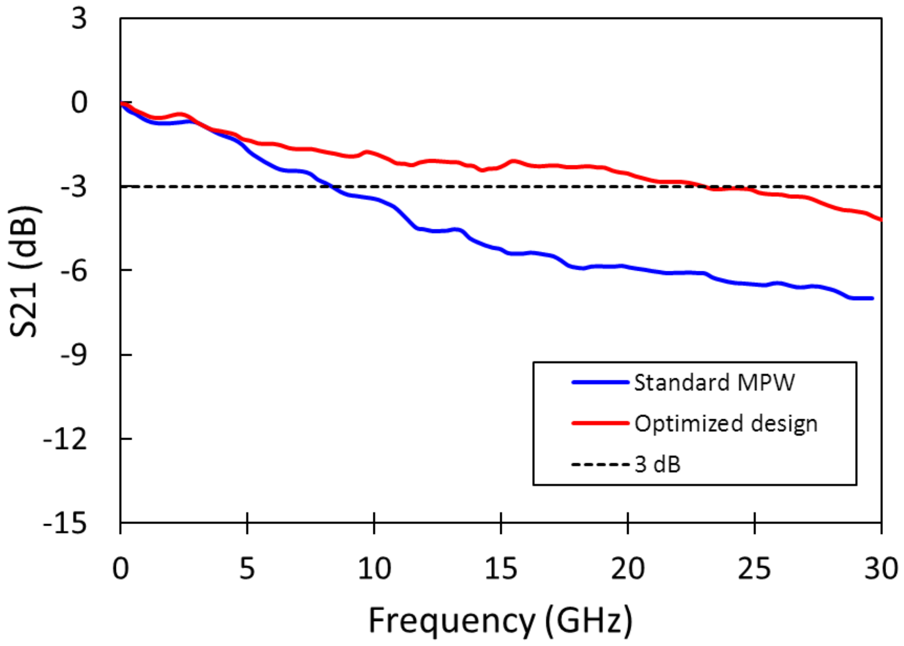
PHASE MODULATOR



- > 10 GHz bandwidth
- Optimized design: > 25 GHz and Vpi 3V available on dedicated run





Developed with W. Yao, COBRA

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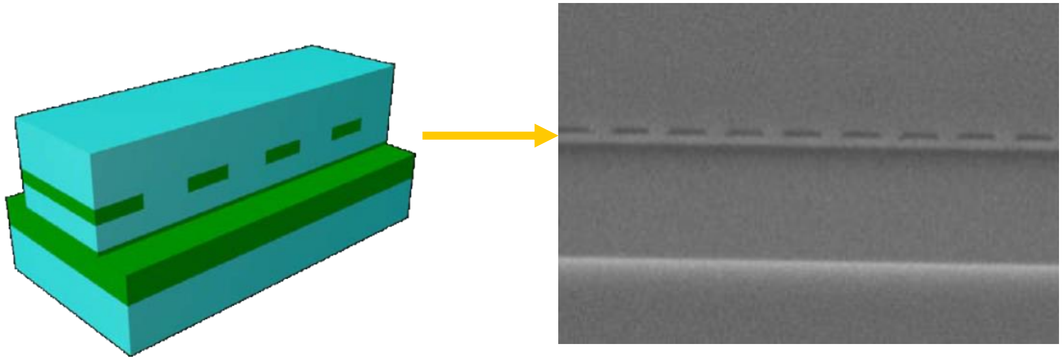
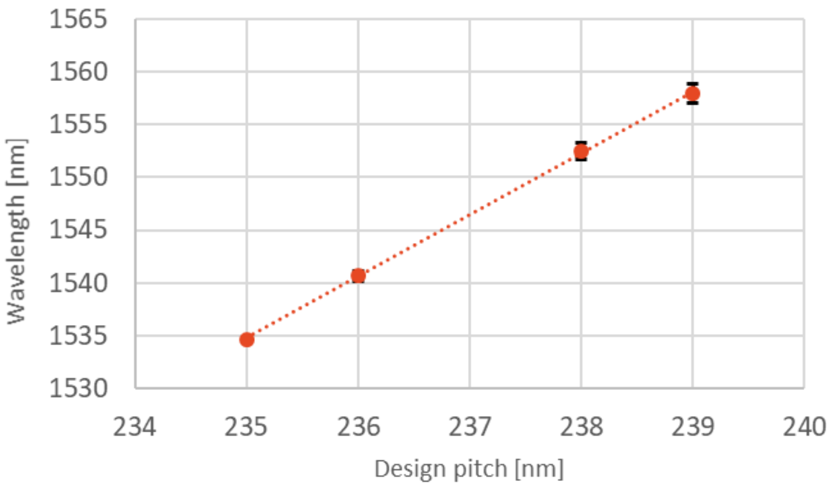
DBR GRATINGS



Developed with D. Zhao, COBRA



- DBR gratings available in PDK
- ArF litho: Scale-up to high volume and high-yield
- DFB lasers < 1 nm wavelength variation over whole range

D. Zhao, IPC Poster WP26

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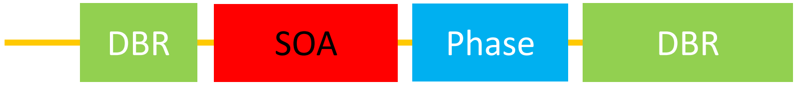
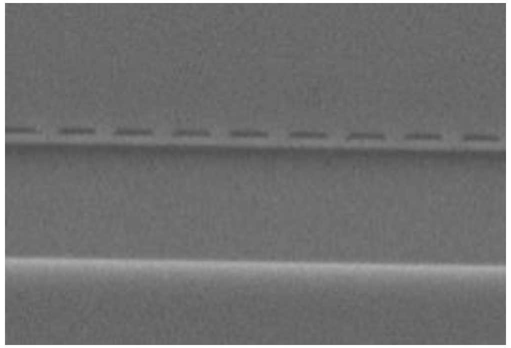
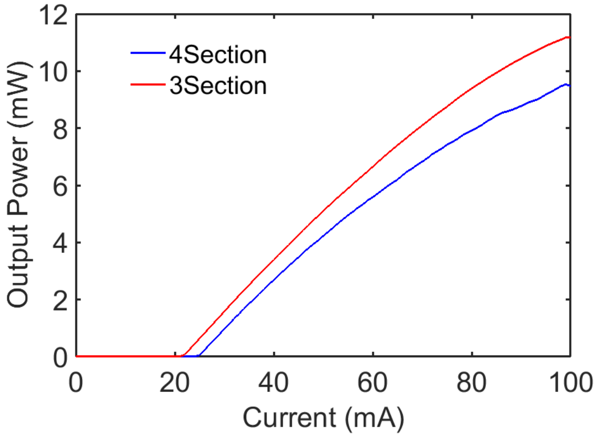
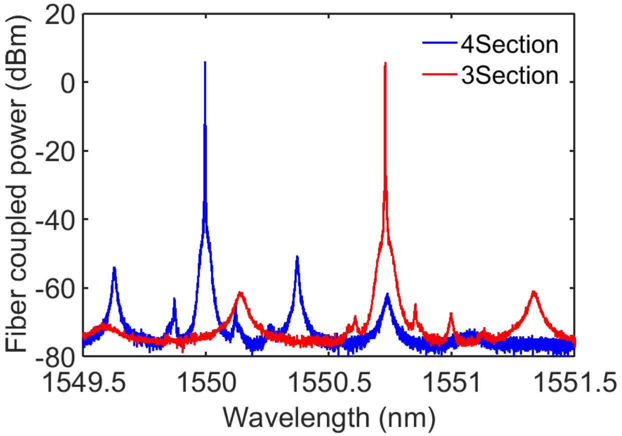
DBR LASER





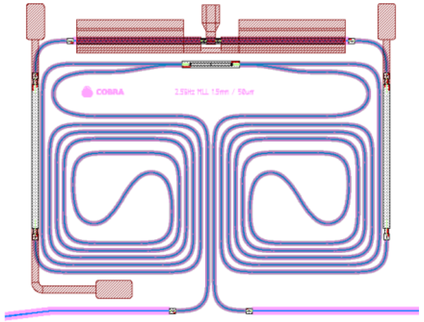


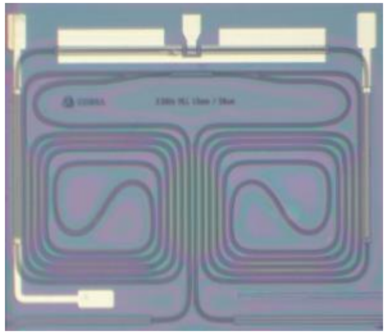


- DBR lasers > 10mW output power
- Available in standard MPW platform

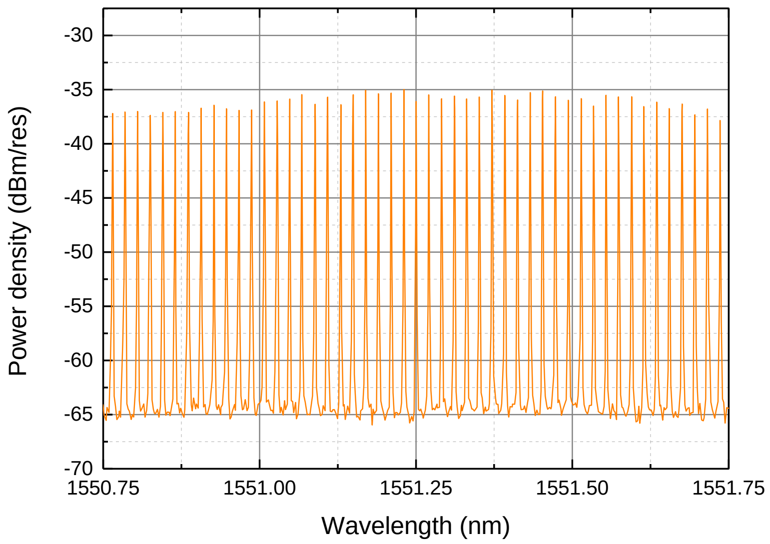
Developed with D. Zhao, COBRA

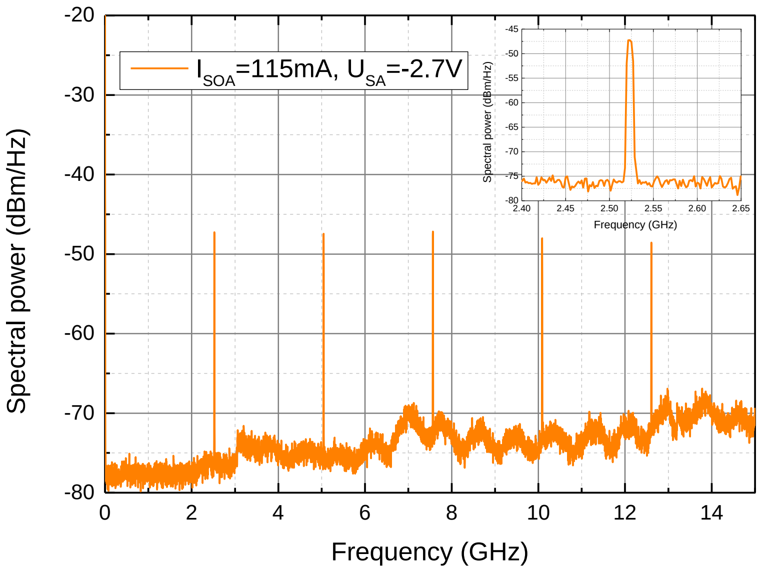
2.5 GHZ MODE LOCKED LASER





- Frequency comb laser for gas sensing
- 30 mm cavity
- < 4 mm^2





S. Latkowski et al. *Optics Letters*, *40*(1), 77-80, 2015

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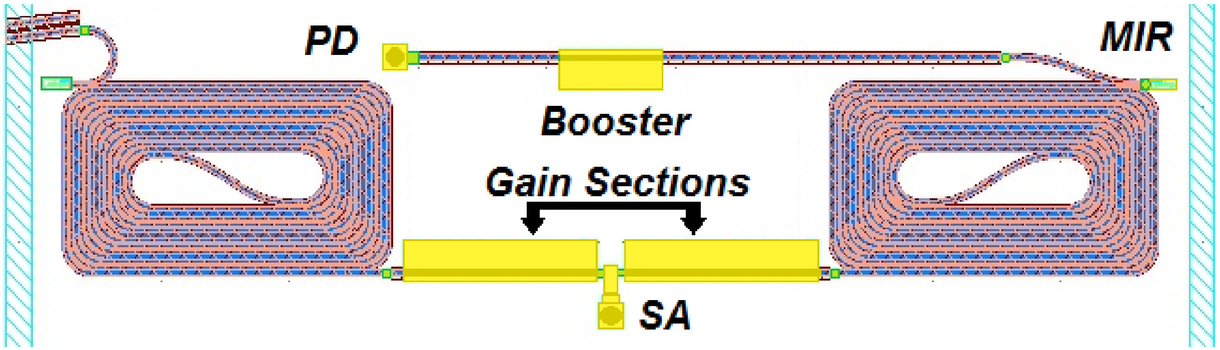
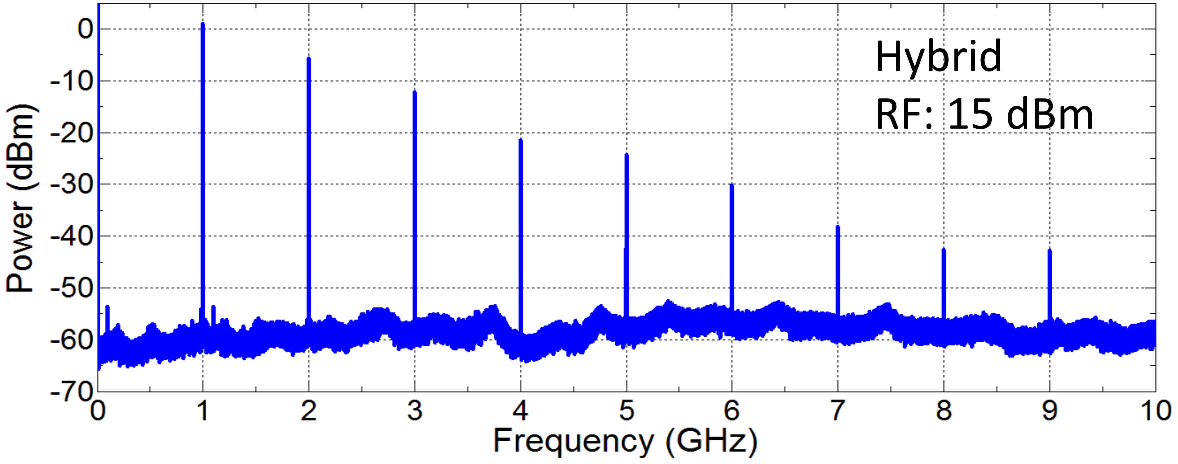
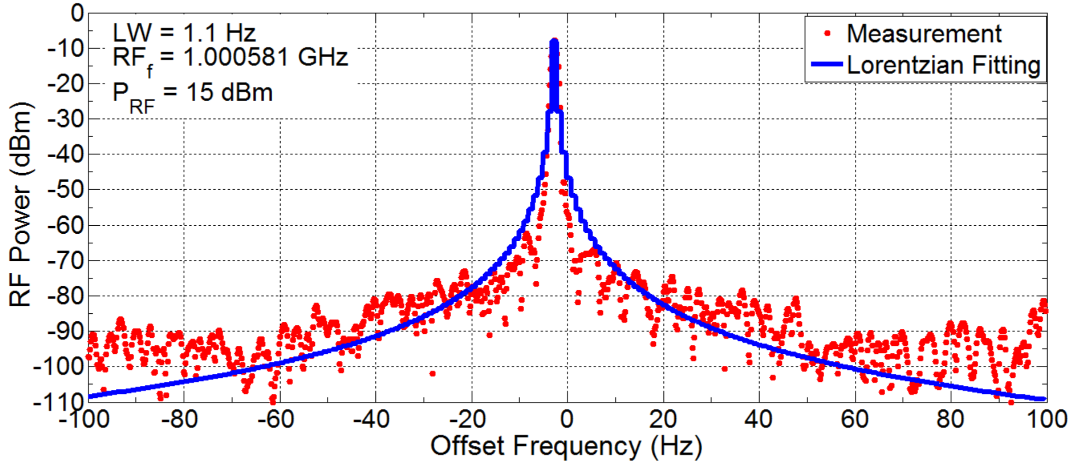
Independent InP Foundry

TU/e Technische Universiteit Eindhoven University of Technology

LOWEST REP RATE MONOLITHIC MODE LOCKED LASER



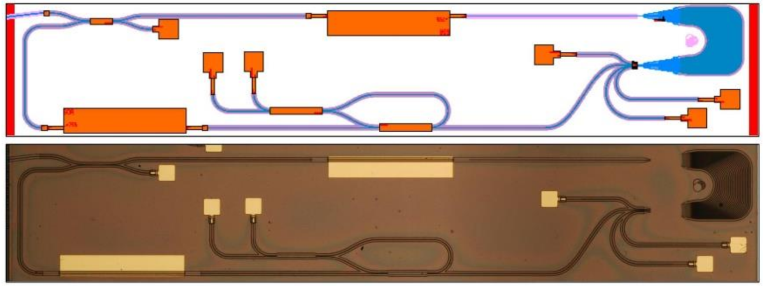


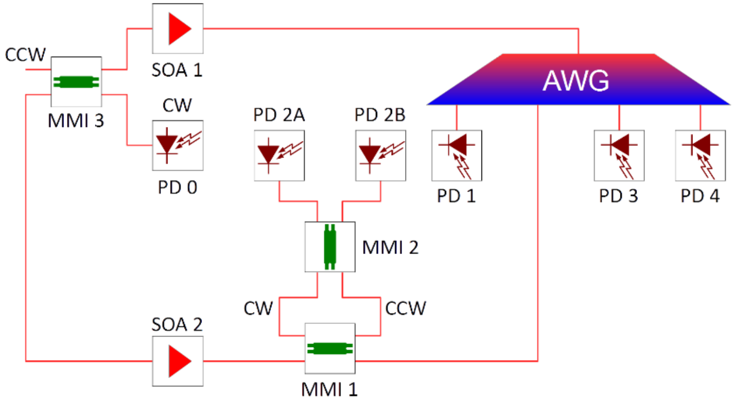


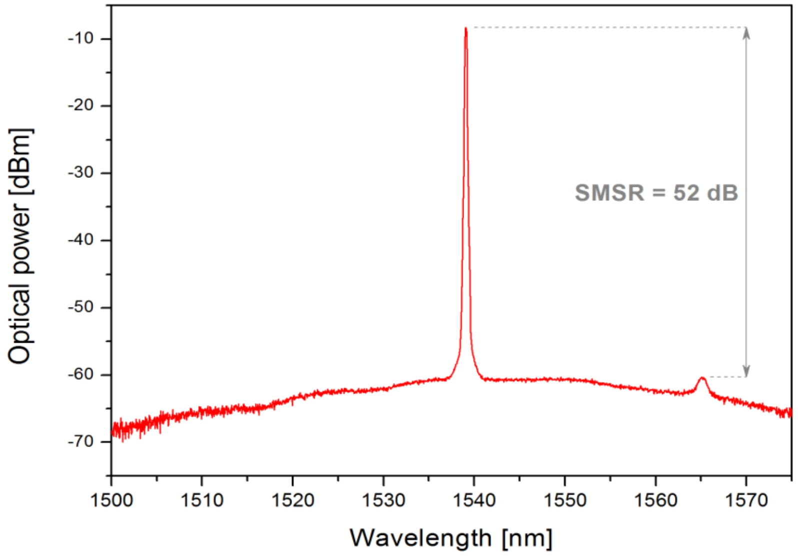
1GHz repetition rate

Courtesy: G. Carpintero, UC3M

RING LASER FOR APPLICATION IN OPTICAL GYROSCOPE SYSTEMS







S. Stopinski, WUT

Single frequency with side mode suppression ratio over 50 dB

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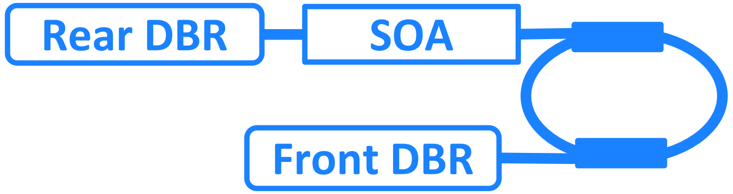
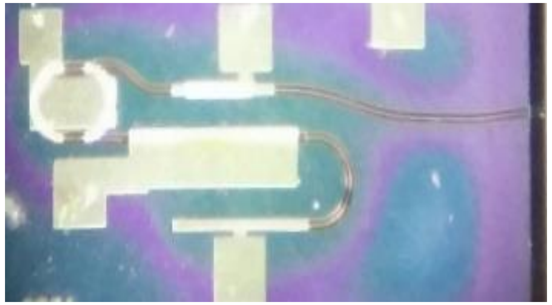
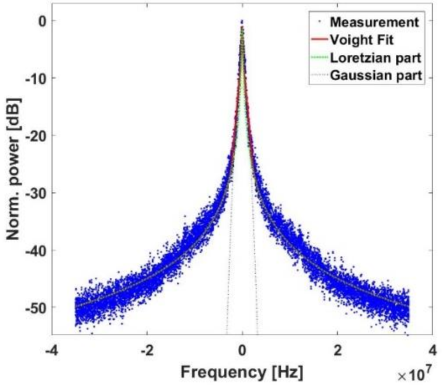
POLITECHNIKA WARSZAWSKA

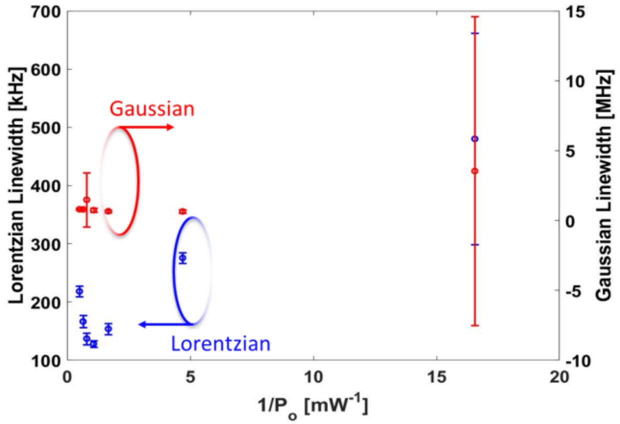
LOW LINEWIDTH LASER



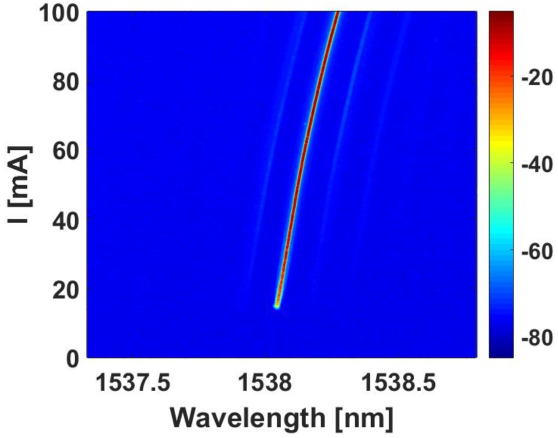
- DBR laser with an intra-cavity ring resonator

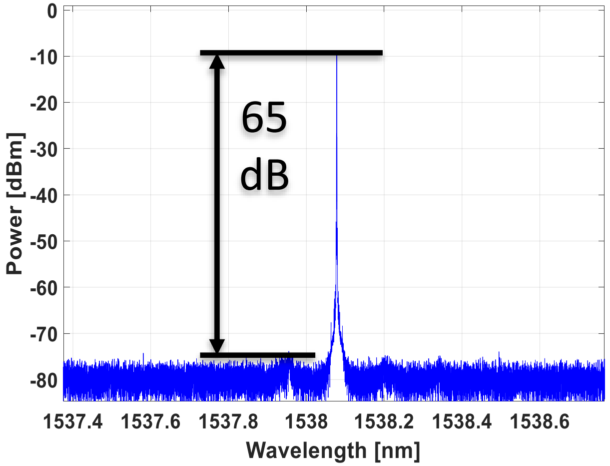


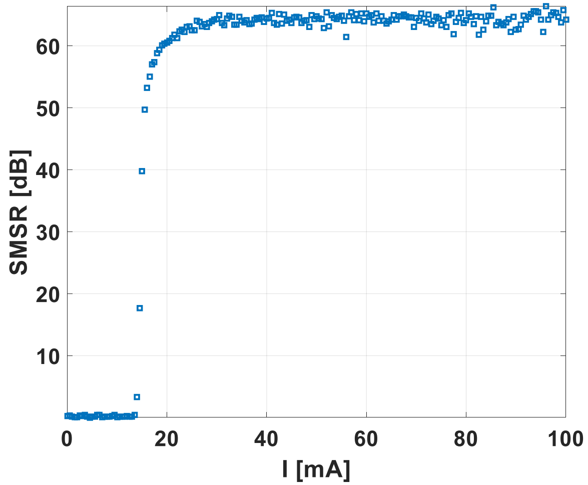




S. Andreou, IEEE ISLC 2018, Santa Fe, US

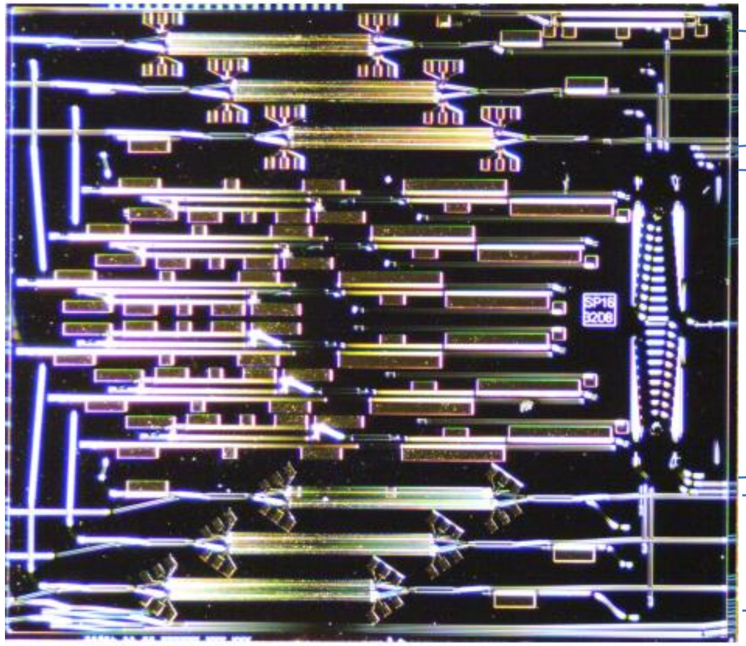






INTEGRATION ON AN InP PIC

Small footprint: dense integration on a PIC

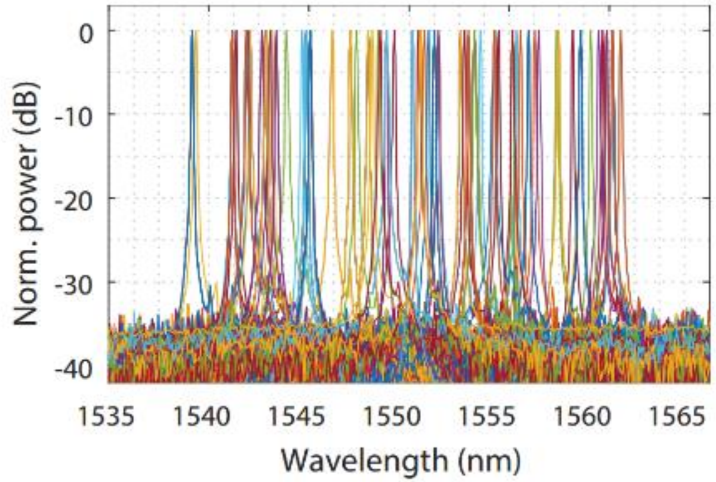


3 x MZM modulator

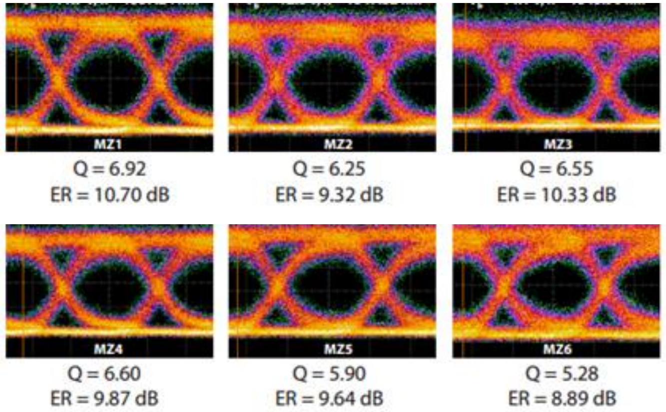
6 x 22 nm tunable laser

3 x MZM modulator

Wavelength tuning



Up to 25 Gbaud at high ER



Building blocks for 400GBASE-ZR and transferable to LR8 and ER8

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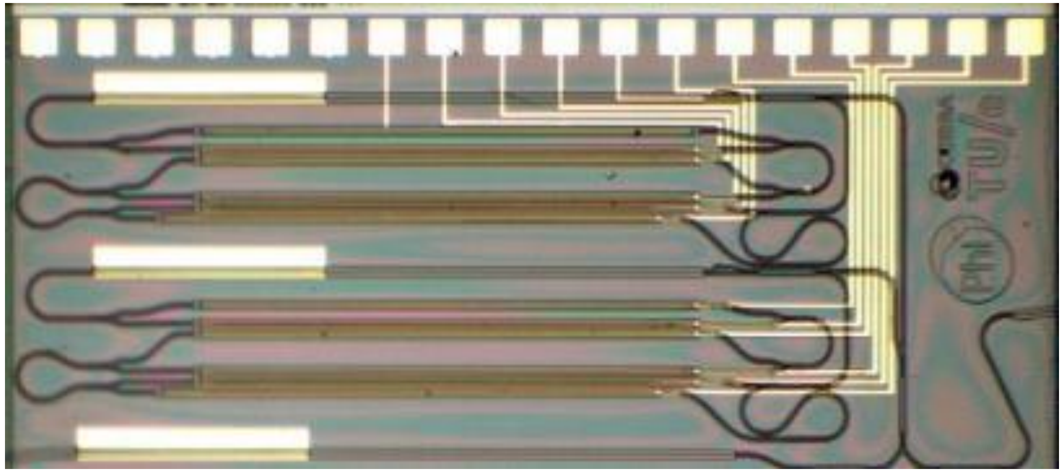
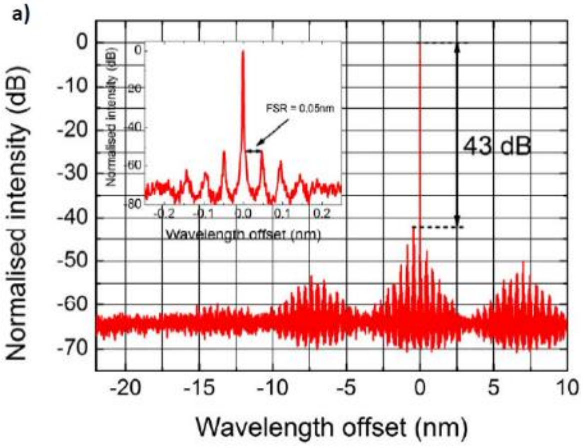
LOW LINEWIDTH FULL BAND TUNABLE LASER

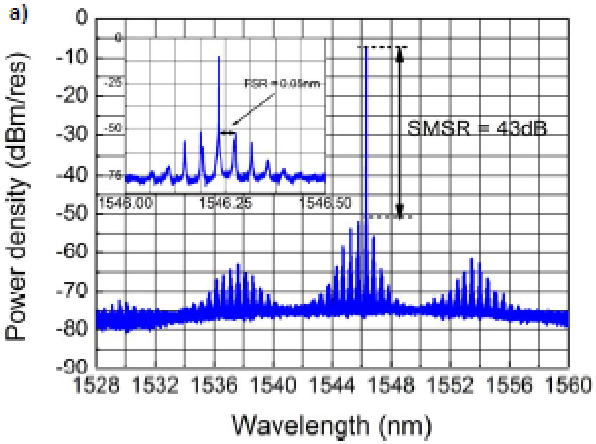


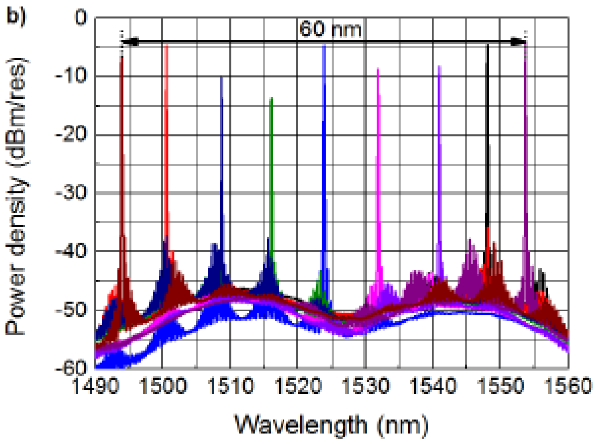
- Low linewidth
- Full band tunable
- Ideal source for coherent
- C-band demonstrated
- Easily applicable to O-band

Simulations

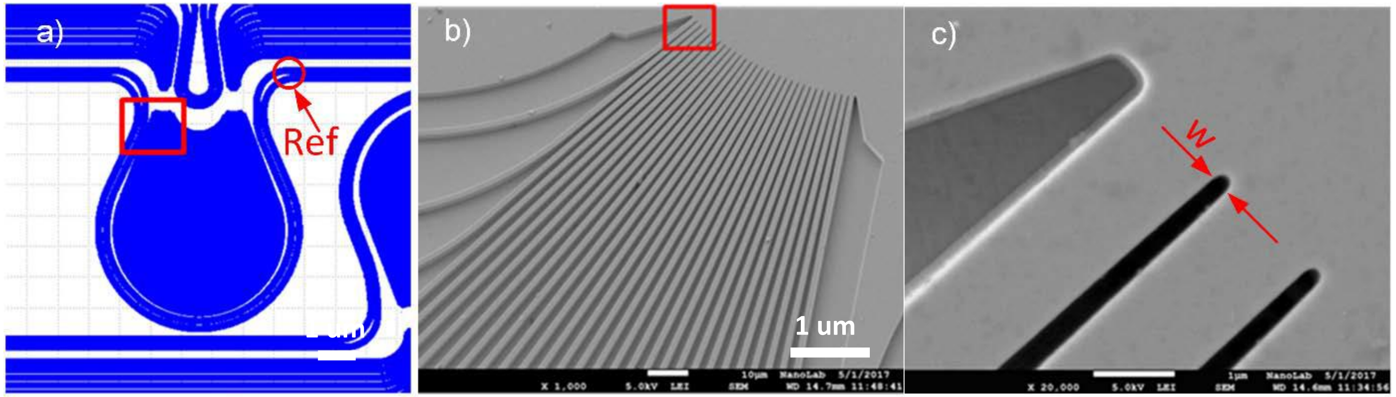


Prototype

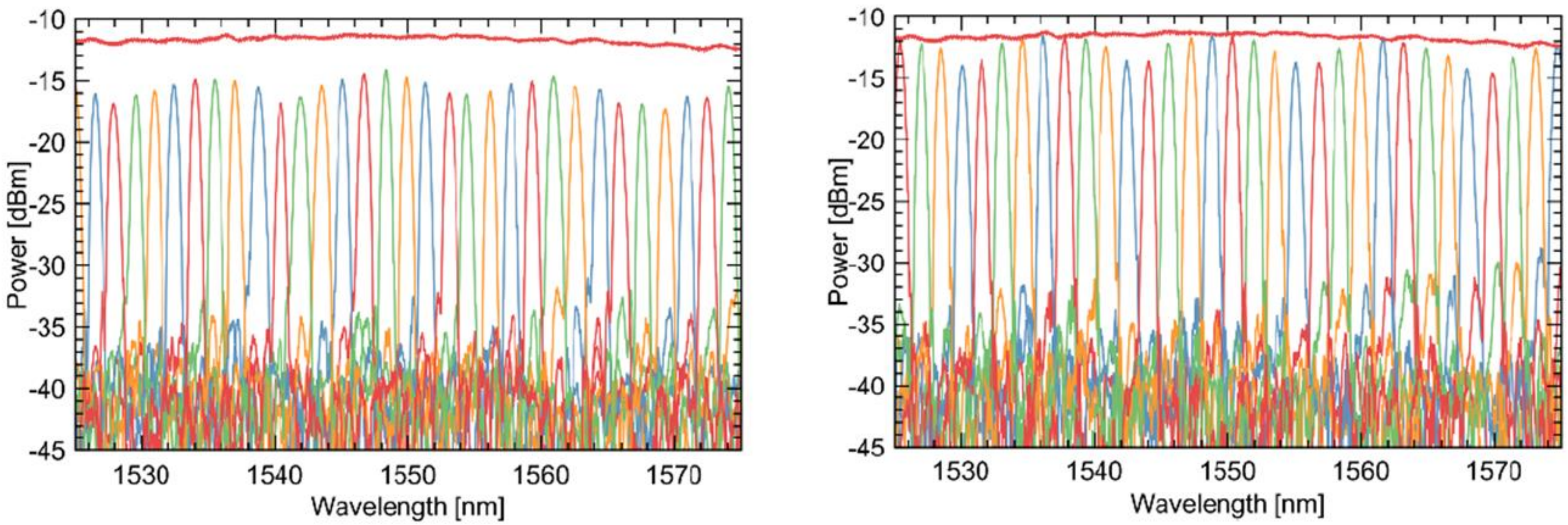




HIGH RESOLUTION LITHOGRAPHY: AWGS



- Insertion losses <0.5 dB
- Crosstalk < -20 dB



w= 300 nm

w= 100 nm

L. Augustin et al. *JSTQE* 2018

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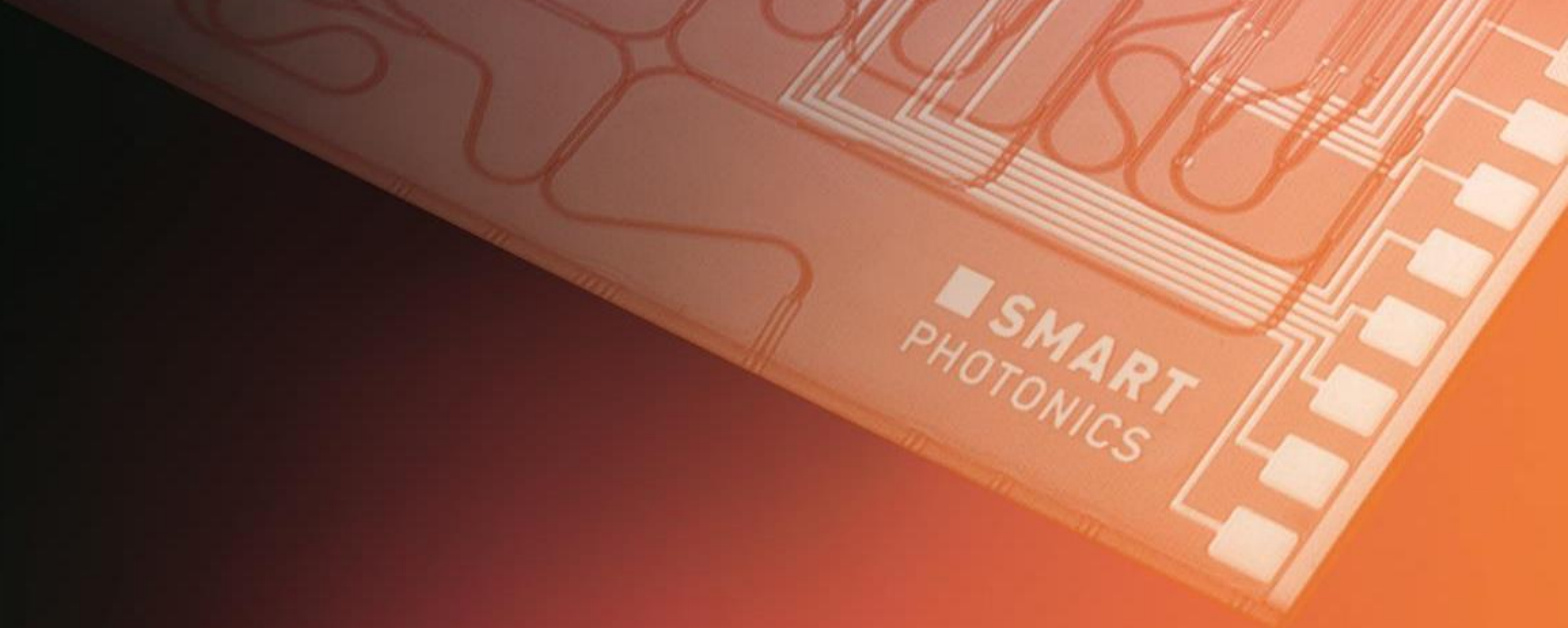
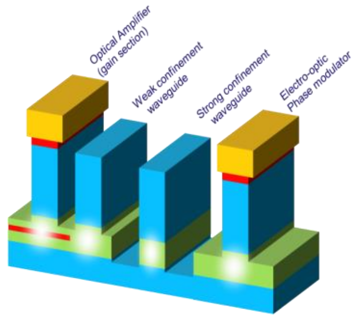


WRAP UP

InP BASED INTEGRATION IS KEY TO SUCCESS!

- Faster
- Cheaper
- Miniaturized
- Robust
- Greener
- Accurate

- InP offers monolithic integration of all functionalities!



- Mature technology: no compromise on laser reliability
- Butt-joint integration: no compromise associated in active and passive component integration
- Full on-wafer electrical testing
- Enabler for low-cost integrated circuits

SMART PHOTONICS
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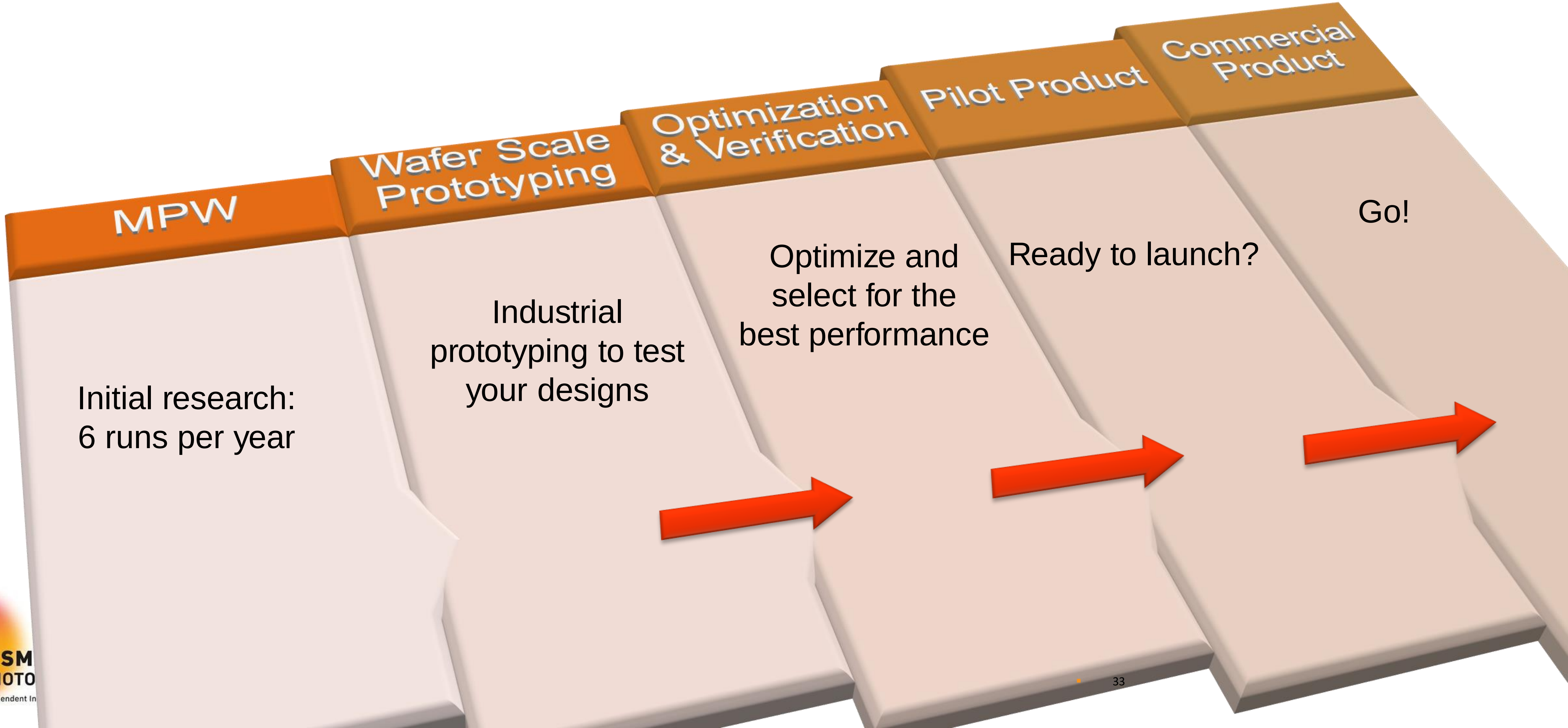
OUR PILOT LINE HELPS YOU TO REDUCE TIME TO MARKET

- A clear path to volume production



MULTI PROJECT WAFER (MPW)

https://smartphotonics.nl/our-offering/mpw/mpw-runs/

MPW **34**

DESIGN SUBMISSION DEADLINE	EXPECTED DELIVERY	PDK VERSION
October 01st 2020	March 16th 2021	Optodesigner: 1.0.11 & Nazca: 1.4.5
MASK TAPE-OUT	**STATUS**	**BROKER**
October 15th 2020	Open for registration	JePPIX

SUBSCRIBE

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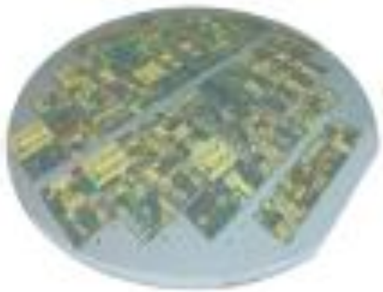
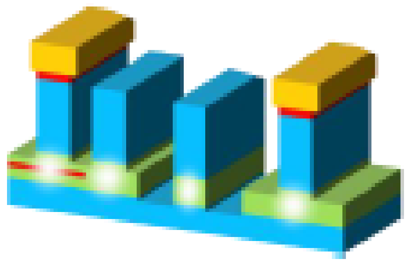
OFFERING





MPW	PICs
▪ Low threshold access to new technology ▪ Combines multiple projects on single wafer ▪ Generic building block approach	▪ Standardized industrial integration process ▪ Design using generic building blocks to create integrated chips ▪ PDK streamlines design process for generic PICs process

❖ **Innovation Support Fund and how to apply**

SMART PHOTONICS
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Presentation

Interreg North-West Europe OIP4NWE

European Regional Development Fund

Optical interfacing of PICs with the outside world

Prof. Jürgen van Erps

Vrije Universiteit Brussel

Interreg North-West Europe
EUROPEAN UNION
OIP4NWE
European Regional Development Fund

OIP4NWE
Open Innovation PIC Pilot

Optical interfacing of PICs with the outside world

Prof. Jürgen Van Erps, Vrije Universiteit Brussel

Brussels Photonics (B-PHOT)

Interreg North-West Europe OIP4NWE
European Regional Development Fund

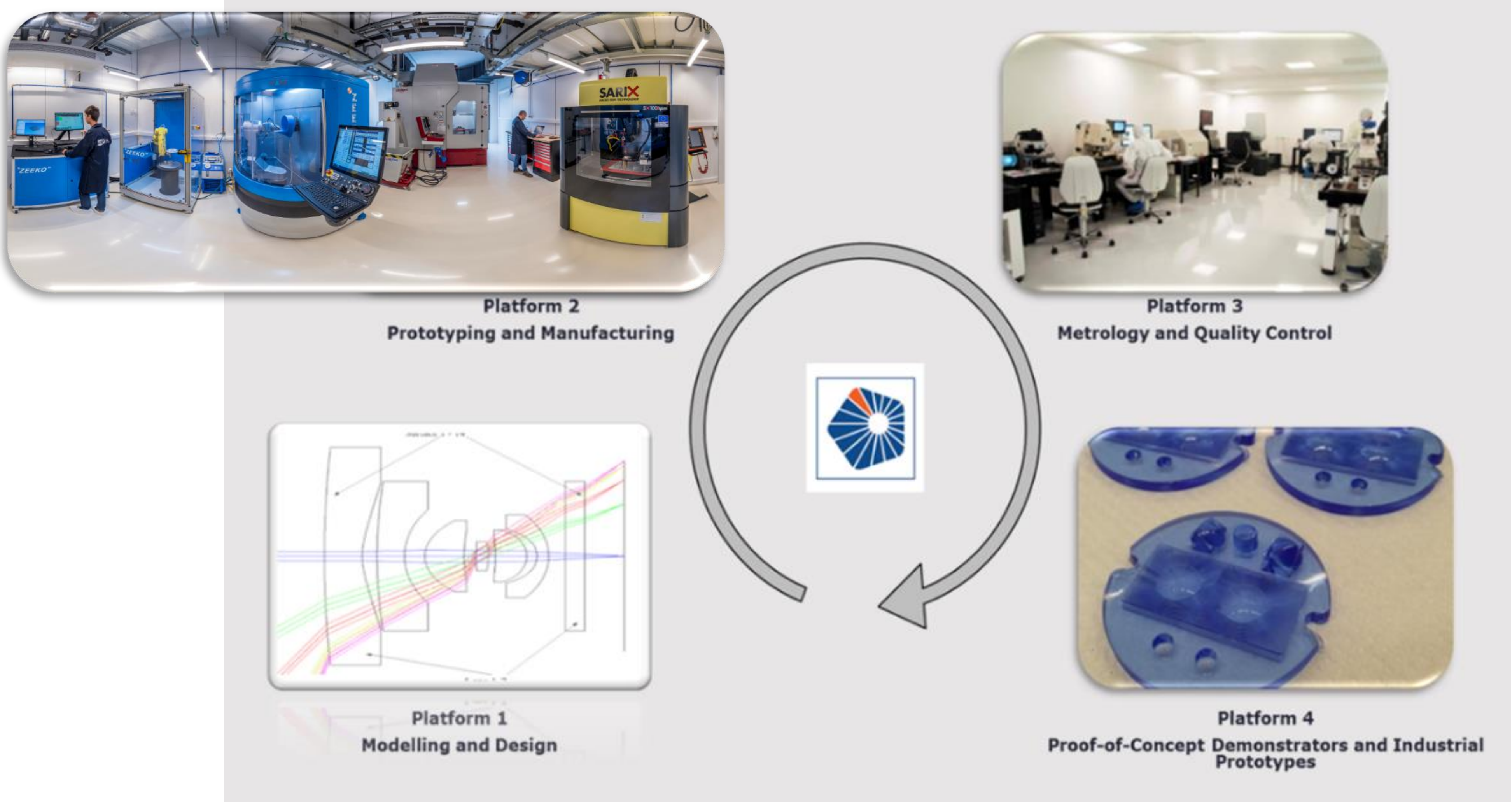
Photonics Campus of the Vrije Universiteit Brussel
Gooik, Belgium

www.b-phot.org

OIP4NWE Open Innovation PIC Pilot

B-PHOT's Research and Innovation is supported by a Supply-Chain of Cutting-Edge Technology Platforms TRLs 3-6

Interreg
EUROPEAN UNION
North-West Europe
OIP4NWE
European Regional Development Fund

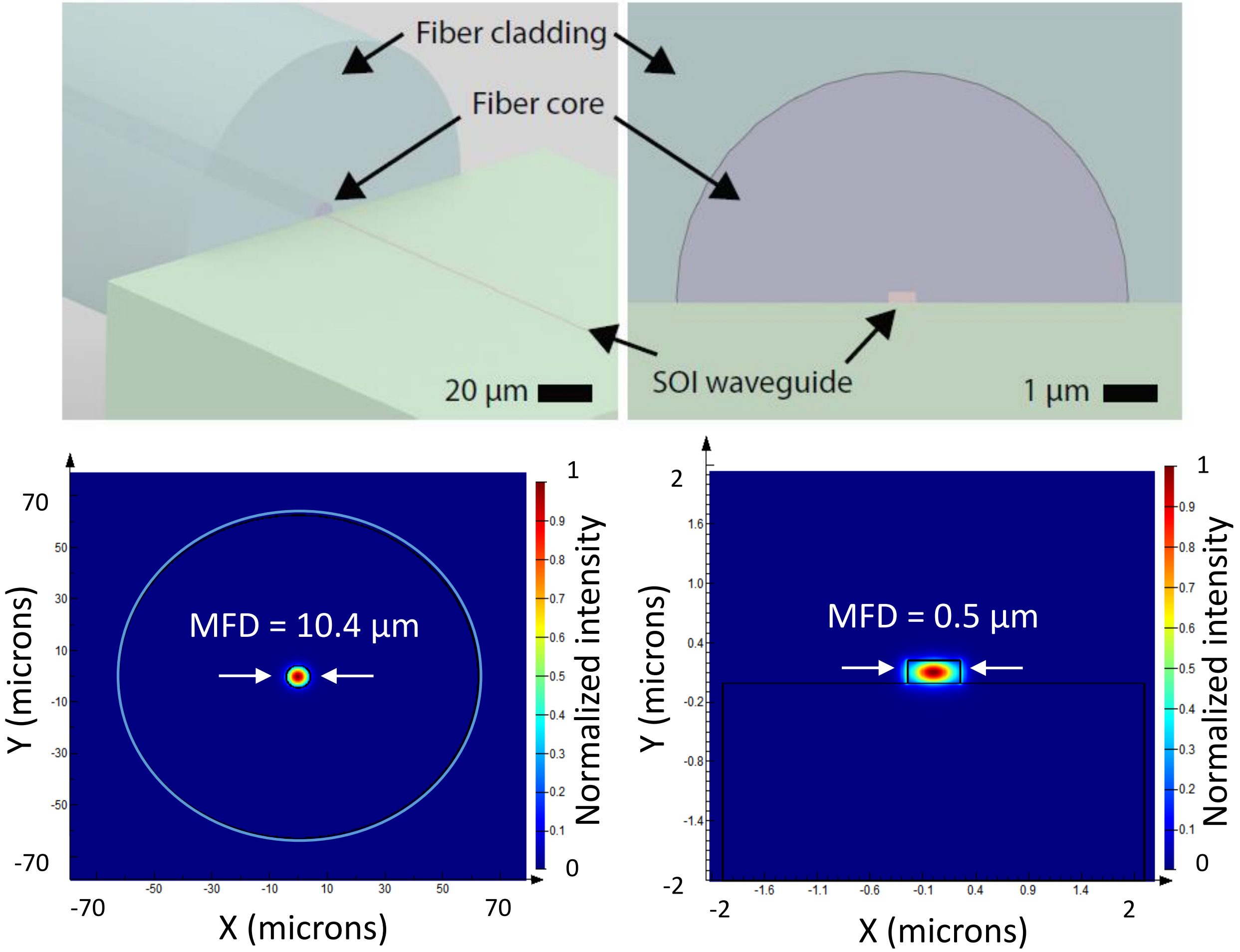


Overview

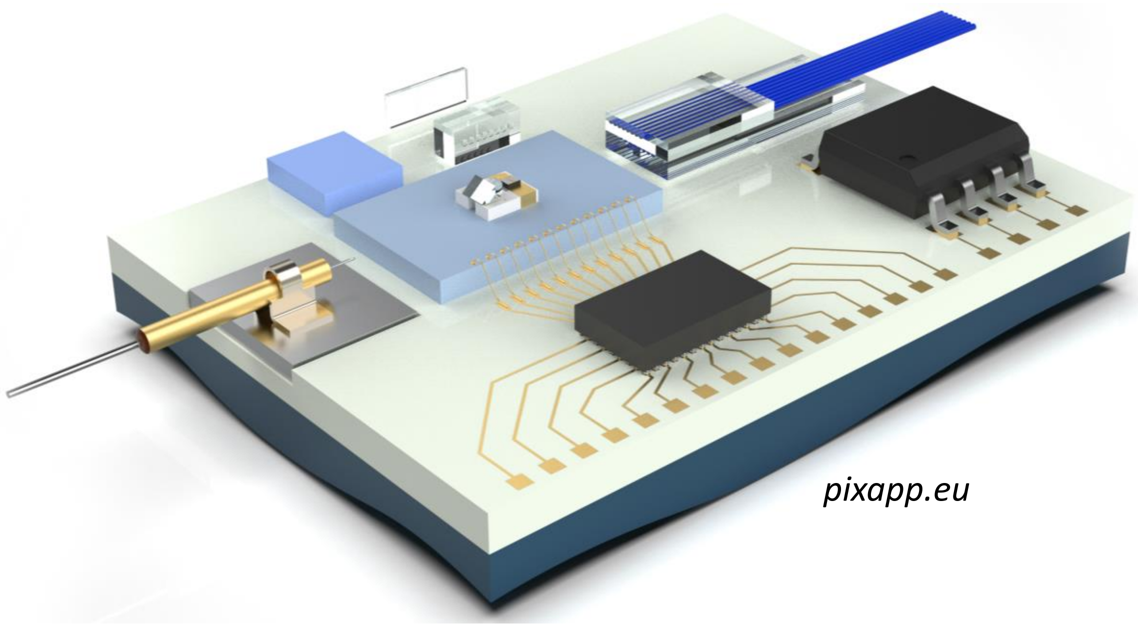
1. **Fiber-to-PIC coupling**
    1. Mode conversion down-tapered fibers
    2. Mode conversion up-tapered fibers for expanded beam connections
    3. Controlled thermal core expansion of specialty UHNA fibers
2. **PIC to free space coupling using external**
    1. Refractive optics
    2. Diffractive optical elements
3. **Microfluidics for PIC-based sensing**

1. Interfacing Fibers and Photonic Integrated Circuits

Dimensional mismatch between single-mode fiber and PIC-embedded waveguides



Matching different mode field sizes is one of the great challenges

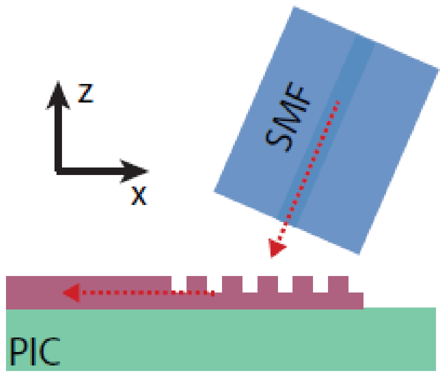


pixapp.eu

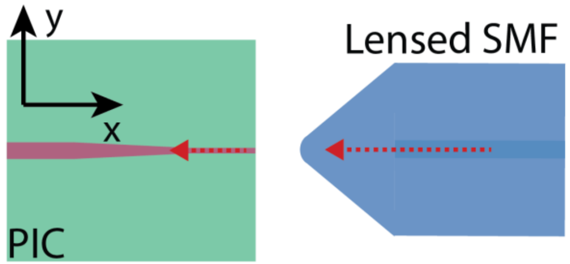
VUB B-PHOT BRUSSELS PHOTONICS

State-of-the-art fiber-to-chip coupling schemes

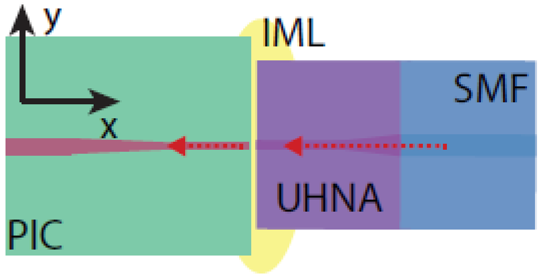
- Grating couplers



- Lens-based edge coupling

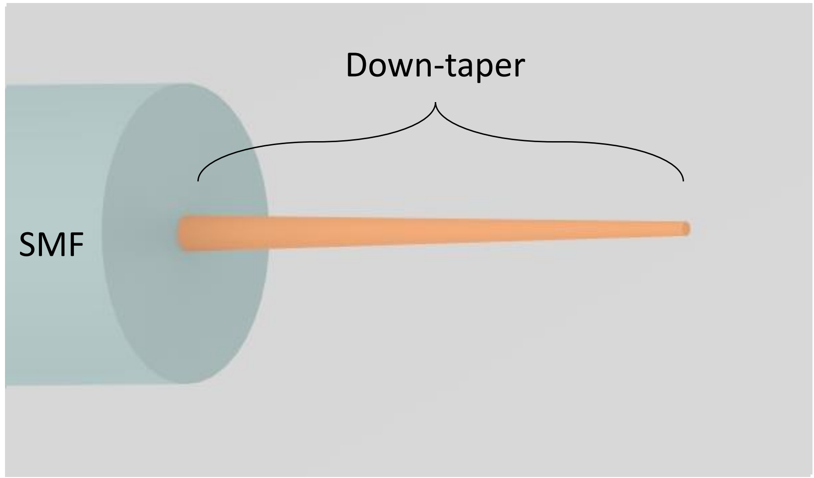


- Physical contact-based coupling



UHNA: ultra-high numerical aperture
IML: index-matching liquid

- Our proposal: integrating a mode conversion down-taper on a single-mode fiber (SMF)



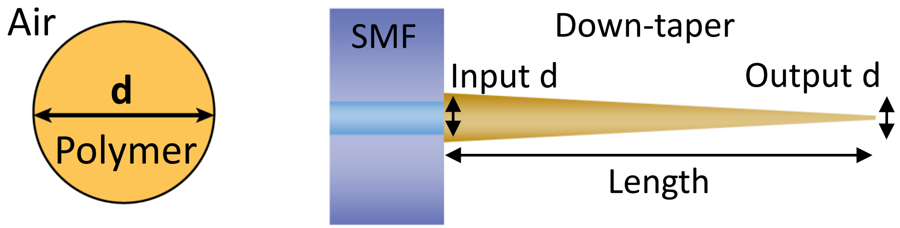
✓ Allow for physical contact edge coupling
✓ Allows to tailor the output mode to the waveguide mode of the PIC
✓ Allows to save real estate on the PIC because there is less need to include mode conversion structures on the chip

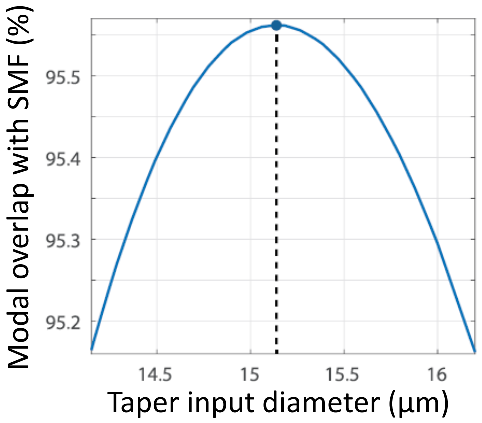
VUB B-PHOT BRUSSELS PHOTONICS

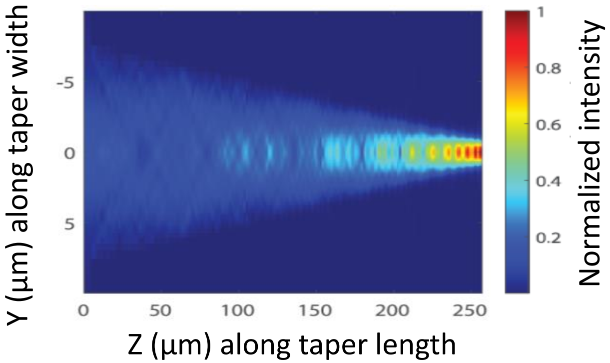
Design and fabrication of mode conversion downtapers

Simulations performed with *Lumerical Mode Solutions*
(Finite Difference Eigenmode & Eigenmode Expansion solvers)
and Lumerical FDTD Solutions

- **Step-index design:** air-cladding





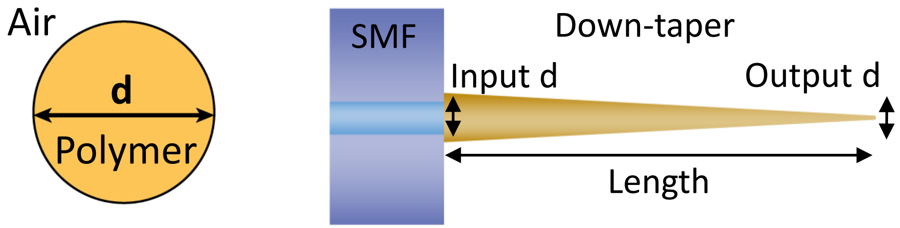


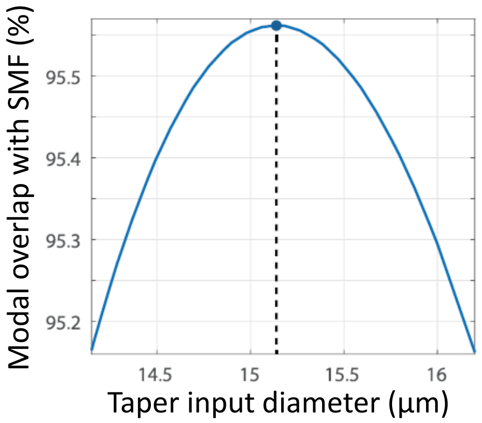
- λ = 1550 nm
- Input d = 15.1 µm
- Output d = 1-7 µm
- Length = 250 µm

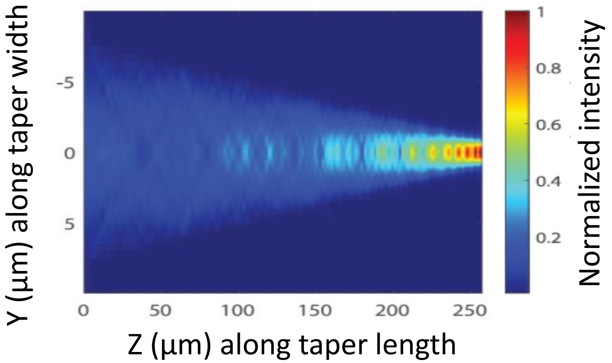
K. Vanmol et al., J. Lightwave Technol. Vol. 38, pp. 4834-4842, 2020.

Design and fabrication of mode conversion downtapers

➢ **Step-index design:** air-cladding

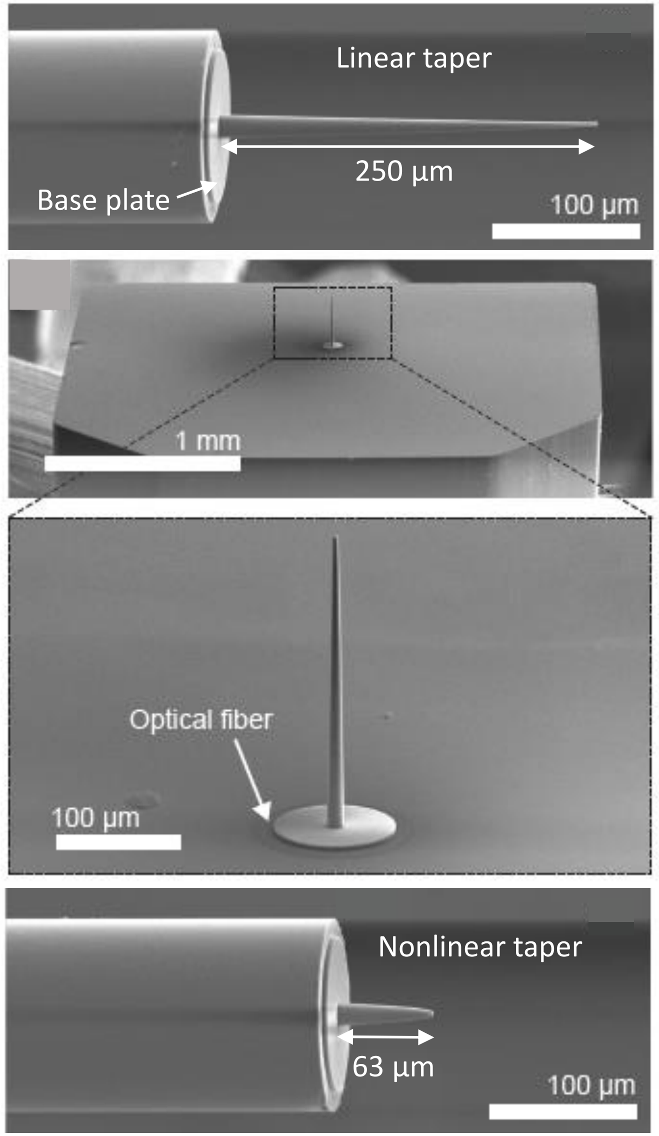






- λ = 1550 nm
- Input d = 15.1 µm
- Output d = 1-7 µm
- Length = 250 µm

➢ **Fabricated structures:**



Fabrication using:
- 63x objective
- IP-Dip photoresin

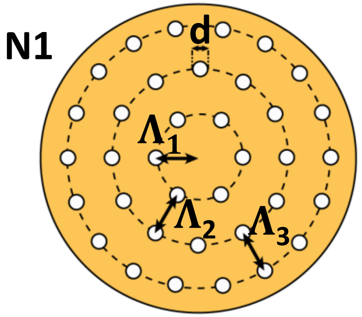
Fabrication time:
- 30 min. silanization
- 30 min. fiber mounting and alignment
- **5 min. printing per taper**
- 20 min. developing process

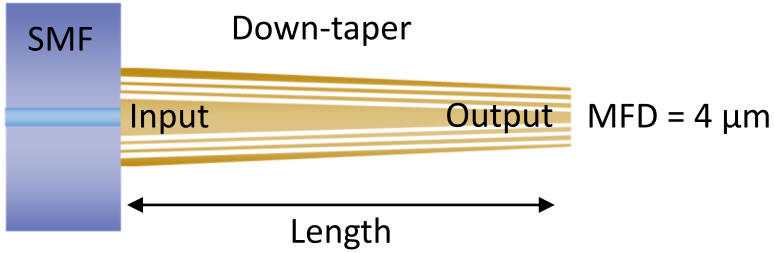
K. Vanmol et al., J. Lightwave Technol. Vol. 38, pp. 4834-4842, 2020.

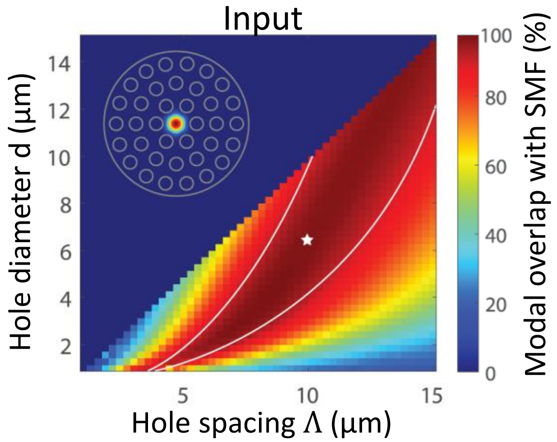
Design and fabrication of mode conversion downtapers

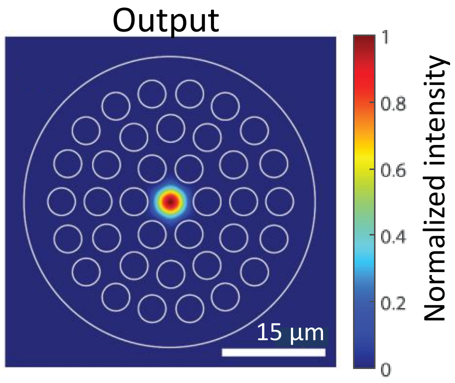
Simulations performed with *Lumerical Mode Solutions*
(Finite Difference Eigenmode & Eigenmode Expansion solvers)
and Lumerical FDTD Solutions

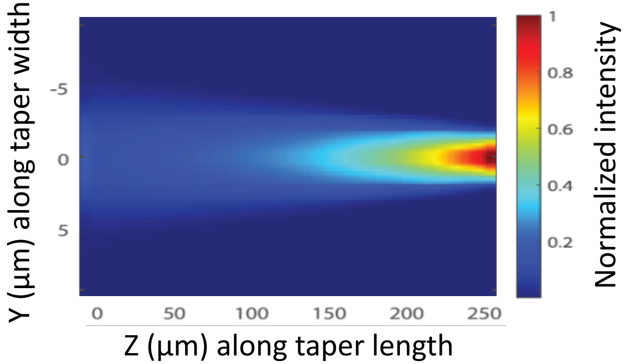
- **Microstructured optical fiber design:** circular distribution of air holes











- λ = 1550 nm
- N_1 = 6
- Input (Λ = 10 µm, d = 6.3 µm)
- Output (Λ = 4 µm, d = 3 µm)
- Length = 250 µm

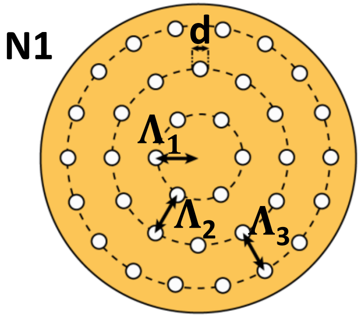
Advantages compared to step-index taper:

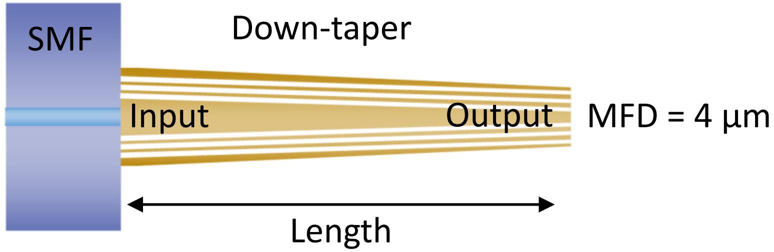
- ✓ perfectly adiabatic mode conversion
  (e.g. endlessly single mode)
- ✓ no need for a cladding
- ✓ robust base
- ✓ additional functionality
  (e.g. birefringence)

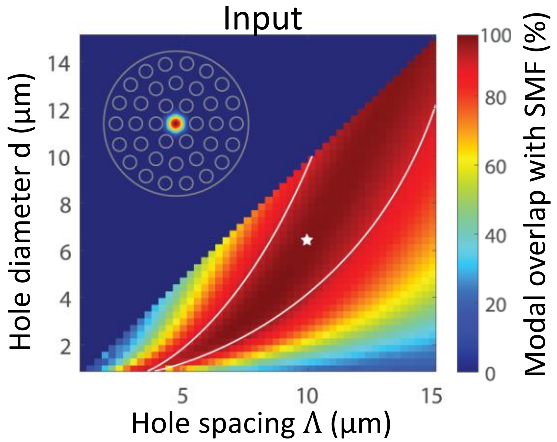
K. Vanmol et al., Opt. Express Vol. 28, pp. 36147-36158, 2020.

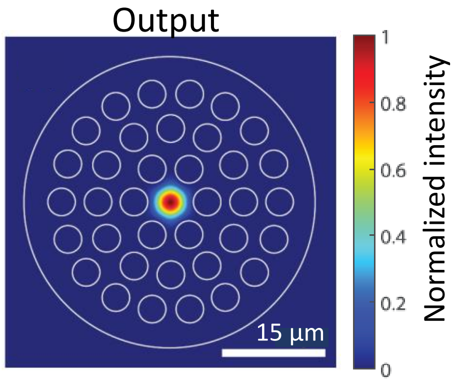
Design and fabrication of mode conversion downtapers

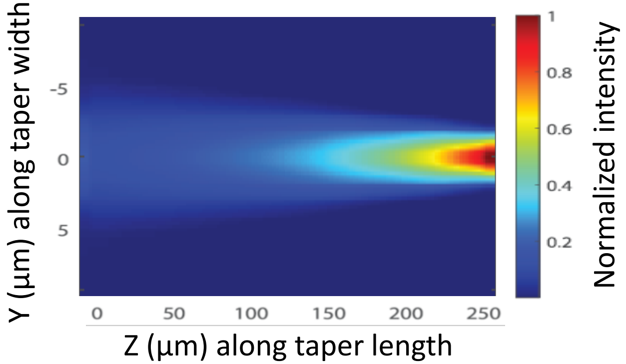
➢ **Microstructured optical fiber design:** circular distribution of air holes





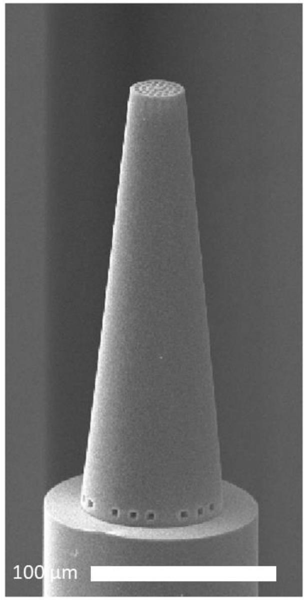


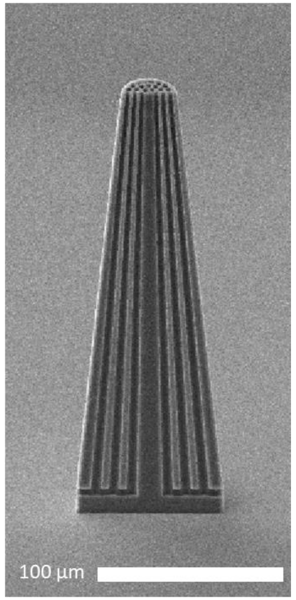




- λ = 1550 nm
- N_1 = 6
- Input (Λ = 10 µm, d = 6.3 µm)
- Output (Λ = 4 µm, d = 3 µm)
- Length = 250 µm

➢ **Fabricated structures:**





Fabrication using:

- 63x objective
- IP-Dip photoresin

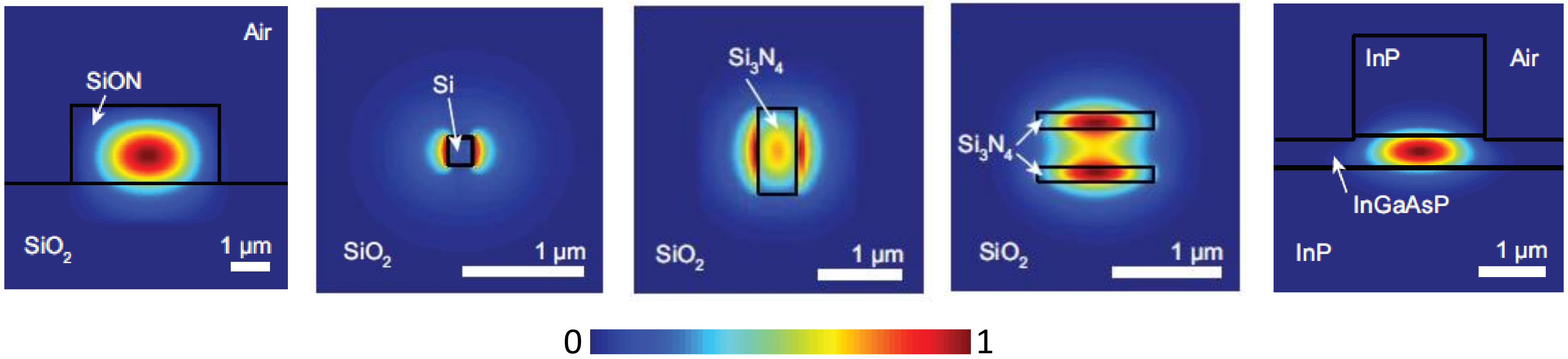
Fabrication time:

- 30 min. silanization
- 30 min. fiber mounting and alignment
- **20 min. printing per taper**
- >40 min. developing process

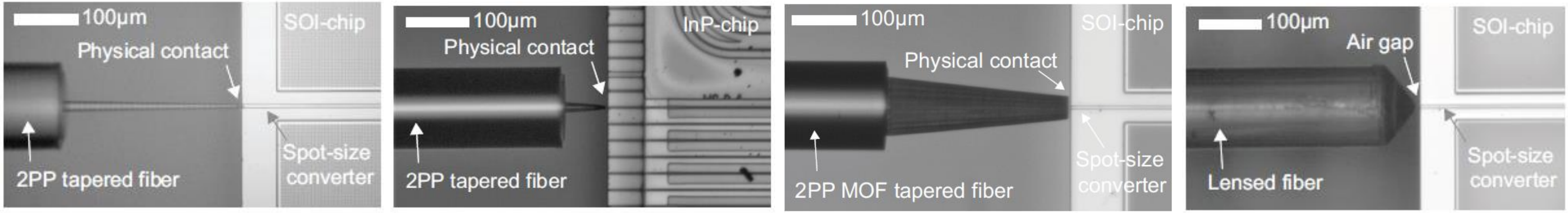
K. Vanmol et al., Opt. Express Vol. 28, pp. 36147-36158, 2020.

Fiber-to-chip coupling to 5 generic PIC platforms

Silicon platform | Silicon Nitride platform | Indium Phosphide platform



Normalized electric field intensity



Benchmarking with state-of-the-art

B-PHOT BRUSSELS PHOTONICS

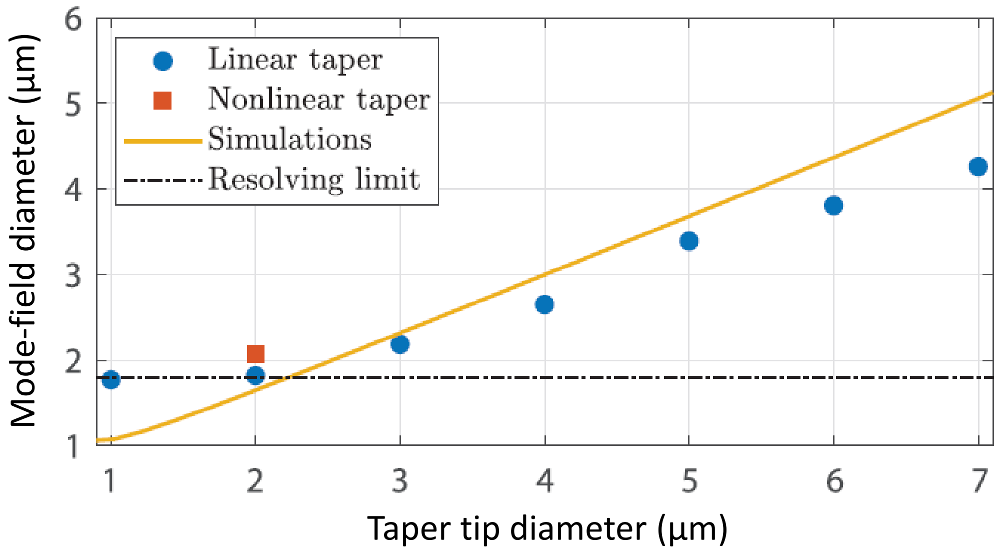
K. Vanmol et al., J. Lightwave Technol. Vol. 38, pp. 4834-4842, 2020.
K. Vanmol et al., Opt. Express Vol. 28, pp. 36147-36158, 2020.

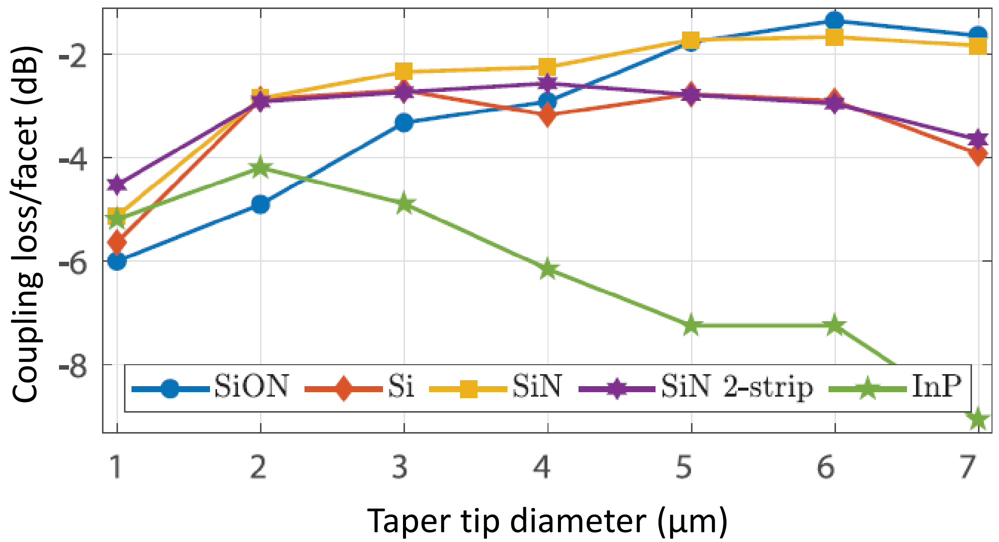
Tailored modal field conversion for efficient fiber-to-chip coupling

Potential in packaging processes

➢ **Step-index tapered fibers**

✓ Tailored modal fields → generally applicable





✓ Performance outperforms or matches state-of-the-art lensed fibers (except 1 case)

✓ Compact nonlinear taper shapes with small coupling loss penalty

PIC platform	Linear taper vs. Lensed (dB/facet)	Linear vs. Nonlinear (dB/facet)
(1) SiON	0.97	n/a
(2) Si	-0.59	0.09
(3) SiN	0.44	n/a
(4) SiN	0.03	n/a
(5) InP	1.43	0.09

K. Vanmol et al., J. Lightwave Technol. Vol. 38, pp. 4834-4842, 2020.

➢ **MOF tapered fibers**

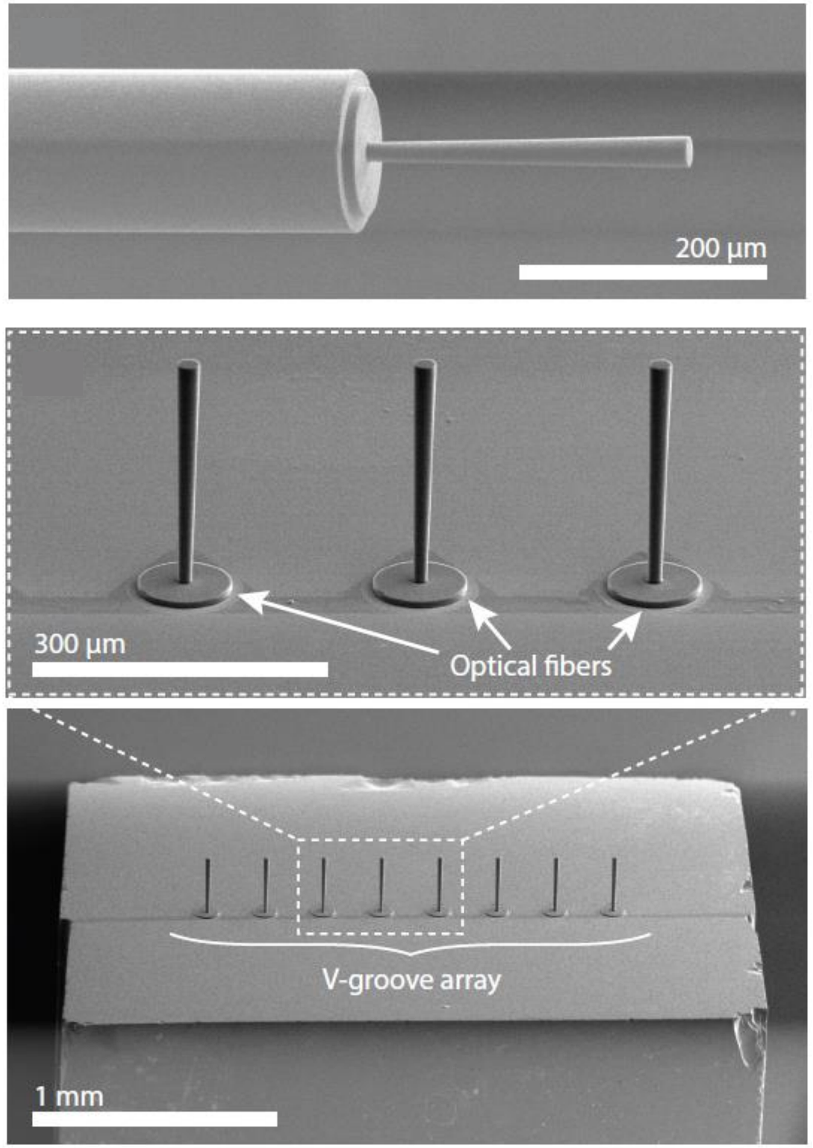
✓ MOF tapers eliminate the need for applying a cladding

Parameter	MOF down-taper	Step-index down-taper	Lensed SMF
MFD (µm)	3.4 ± 0.1	3.6 ± 0.2	2.7 ± 0.1
SiON-coupling (dB/facet)	1.53 ± 0.03	1.53 ± 0.03	2.32 ± 0.03
SiN-coupling (dB/facet)	1.59 ± 0.04	1.60 ± 0.06	2.06 ± 0.06

K. Vanmol et al., Opt. Express Vol. 28, pp. 36147-36158, 2020.

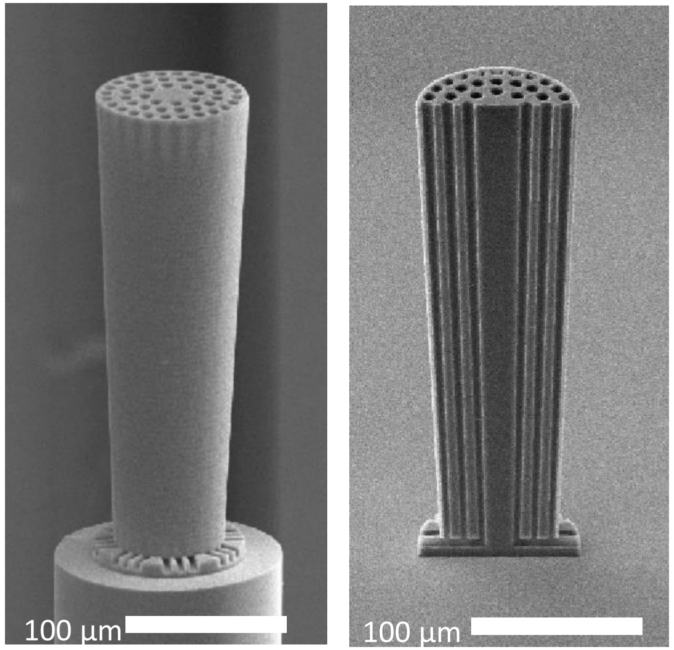
2. Mode conversion up-tapers for expanded beam connections

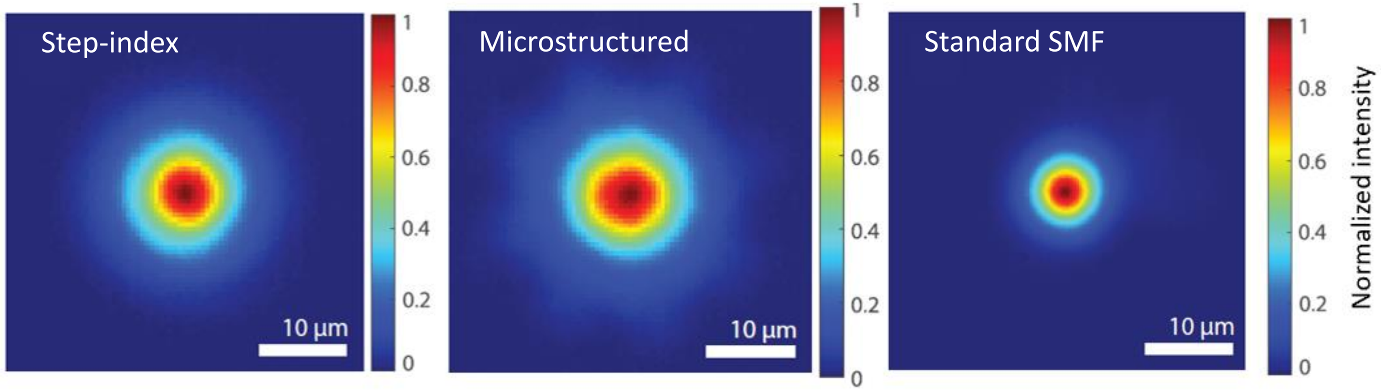
➢ **Step-index design:**



K. Vanmol et al., Optics and Laser Technol. Vol. 112, pp. 292-298, 2019.

➢ **Microstructured up-taper design:**

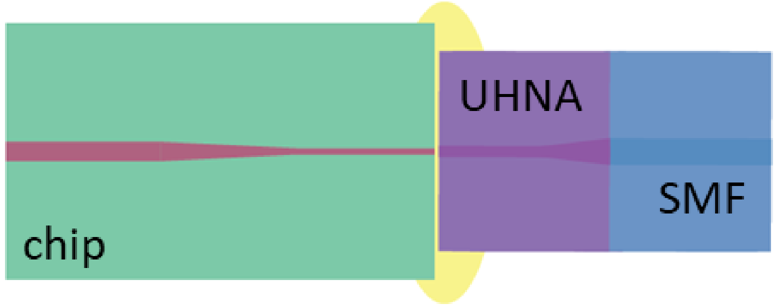




K. Vanmol et al., Opt. Express Vol. 28, pp. 36147-36158, 2020.

(1) Fiber-to-PIC coupling:
3. Mode matching using UHNA fiber

Processing of ultra-high numerical aperture fibers (UHNA) to achieve high-efficiency fiber-to-chip coupling. Here, the UHNA fiber has a very small core, matching the mode field diameter of the PIC-embedded waveguide. The coupling to a standard single-mode fiber on the other hand is done by thermal core expansion.



The thermal core expansions of the UHNA fiber can be achieved using traditional electrode-based splicing equipment, but very long discharge times are required which makes that these electrodes degrade very quickly. As an alternative, VUB B-PHOT has developed a process based on **CO_2 laser-based splicing** equipment.

(2) PIC to free-space coupling using micro-optics:
Refractive micro-optics

At VUB B-PHOT, we have many years of experience in designing and fabricating freeform optics, with a dimension ranging from the macro-scale (up to 15mm diameter) down to the microscale (<1mm diameter). For the design, we make use of in-house developed first-time-right design algorithms, in combination with state-of-the-art commercial tools for non-sequential ray tracing (ASAP, OpticStudio – Zemax, Code V, …) and wave optics simulations (Lumerical MODE Solutions, Lumerical FDTD Solutions, VirtualLab Fusion).

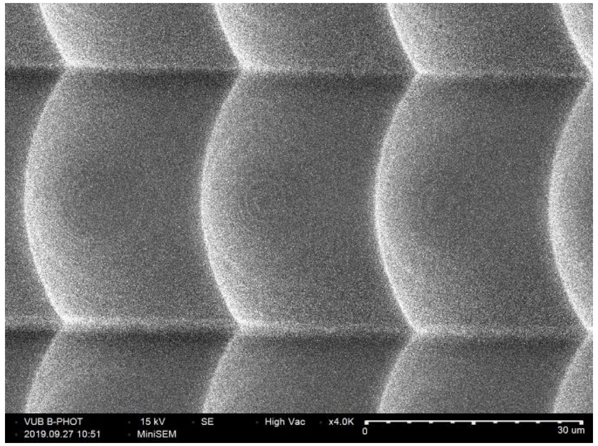
For the fabrication, we offer different routes:

- Direct prototyping in polymers, or specialty materials (CaF2, ZnS, GaAs, …) using **ultraprecision diamond tooling**
- Replication in polymers by mould machining via **high-precision 5-axis milling**, which is then used as a shim in a **(micro-) injection moulding** process, or a **hot embossing** process (up to 350 °C)
- Direct fabrication in glass by grinding and **ultraprecision bonnet and fluid jet polishing**
- Replication in glass by mould machining using **high-precision 5-axis grinding** and ultraprecision polishing and subsequent replication in a **glass press moulding** process (up to 800 °C)
- Direct prototyping of very small optics arrays in polymer photoresist using **two-photon polymerization-based 3D nanoprinting**
- Direct prototyping of micro-optics in glass using **femtosecond laser machining**, followed by fluid jet polishing

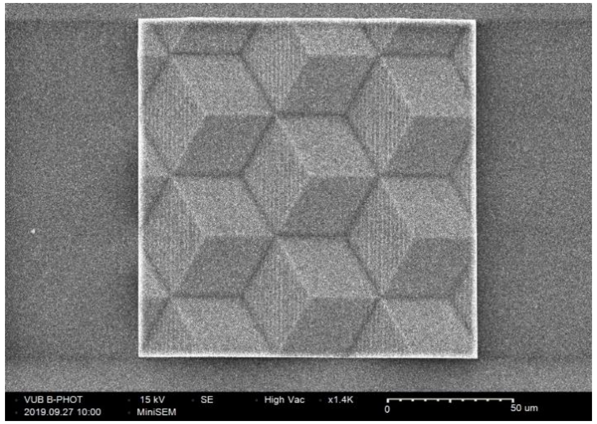
(2) PIC to free-space coupling using micro-optics:
Refractive micro-optics

Top: Top and bottom mould for 6-channel freeform optic component fabricated by high-precision 5-axis milling and ultraprecision diamond tooling.

Right: polymer replica obtained using the above mould inserts in a hot embossing process.



Microlens array with square footprint (30um size) and 100% fill factor prototyped using two-photon polymerization-based 3D nanoprinting.

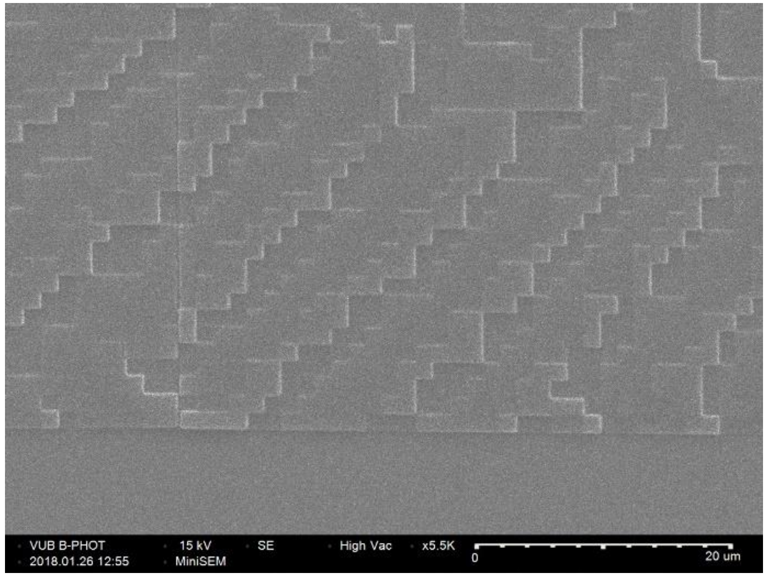


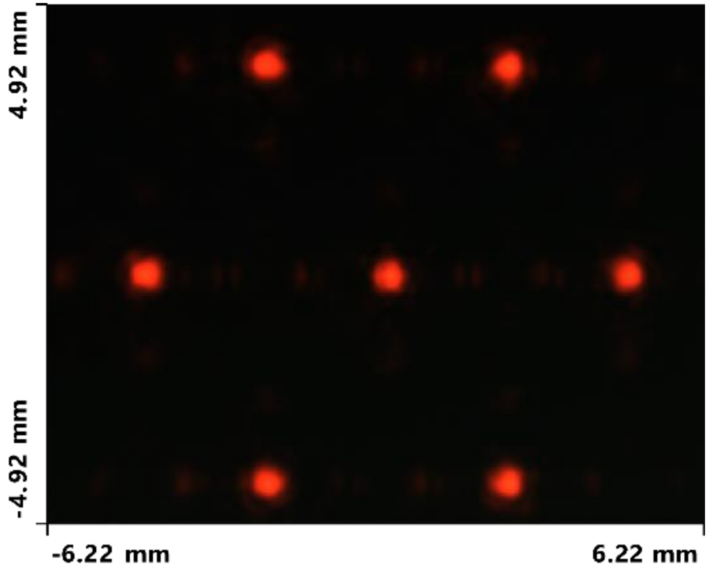
Microreflector array prototyped using two-photon polymerization-based 3D nanoprinting (scalebar = 50um).

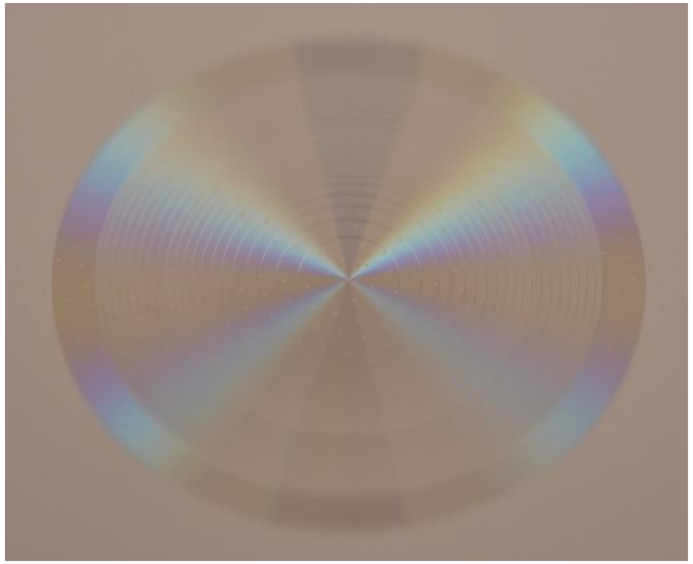
(2) PIC to free-space coupling using micro-optics:
Diffractive optical elements

The high resolution of the two-photon polymerization technology also allows us to fabricate diffractive optical elements (left figure). These structures can be very useful to achieve functionalities such as optical beam fan-out, e.g. to split an incoming light beam into N beams (middle picture).

B-PHOT has all the expertise in house to do the optical design of the DOE as well as their fabrication. Blazed gratings and Fresnel zone plates can also be fabricated using ultraprecision diamond tooling (right picture).







(3) Microfluidics for PIC-based sensing:

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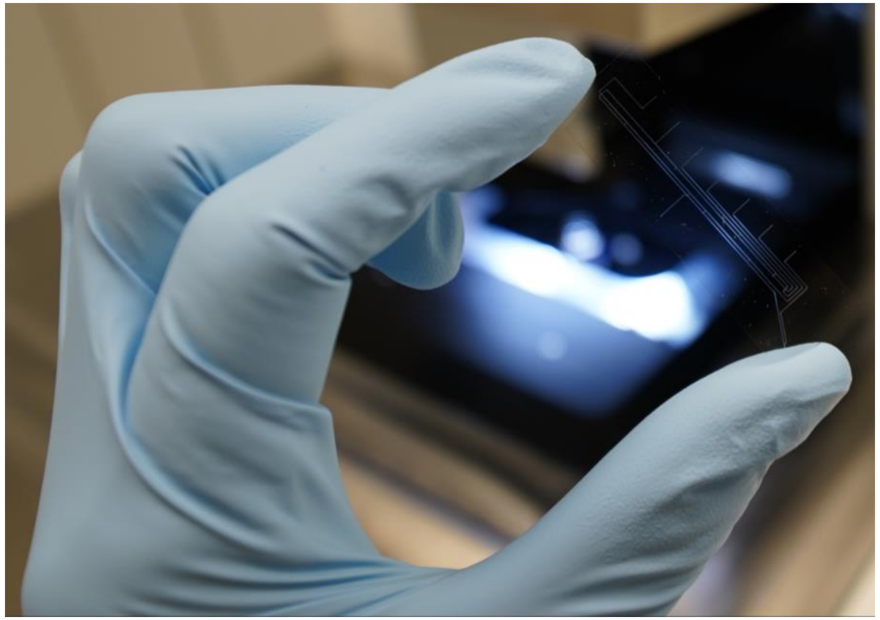
Microfluidics devices can be fabricated at VUB B-PHOT making use of one of the following routes:

- Direct prototyping in polymers using **high-precision 5-axis milling**
- Replication in polymers by mould machining using 5-axis milling or ultraprecision diamond tooling, which is then used as a shim in a **(micro-)injection moulding process**, or a **hot embossing process**
- Direct fabrication in glass by **femtosecond laser micromachining**, if needed followed by fluid jet polishing (if surface roughness reduction is required)

Optical components can potentially be directly integrated into the microfluidic devices to ensure optimal coupling to the PIC. Post-processing of laser micromachined glass samples for surface roughness reduction is a process under development.



Contact info

For more details on the technical specifications and capabilities, contact:

Jürgen Van Erps
jurgen.van.erps@vub.be
www.b-phot.org
Mobile: +32 497 80 07 94

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http://www.oip4nwe.eu

Thank you!

Presentation

Integrated Photonics Packaging

Donal Behal

Tyndall National Institute

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European Regional Development Fund

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Open Innovation PIC Pilot

Open-Innovation Photonics pilot for North West Europe

Integrated Photonics Packaging

10.02.2021

Integrated Photonic Packaging

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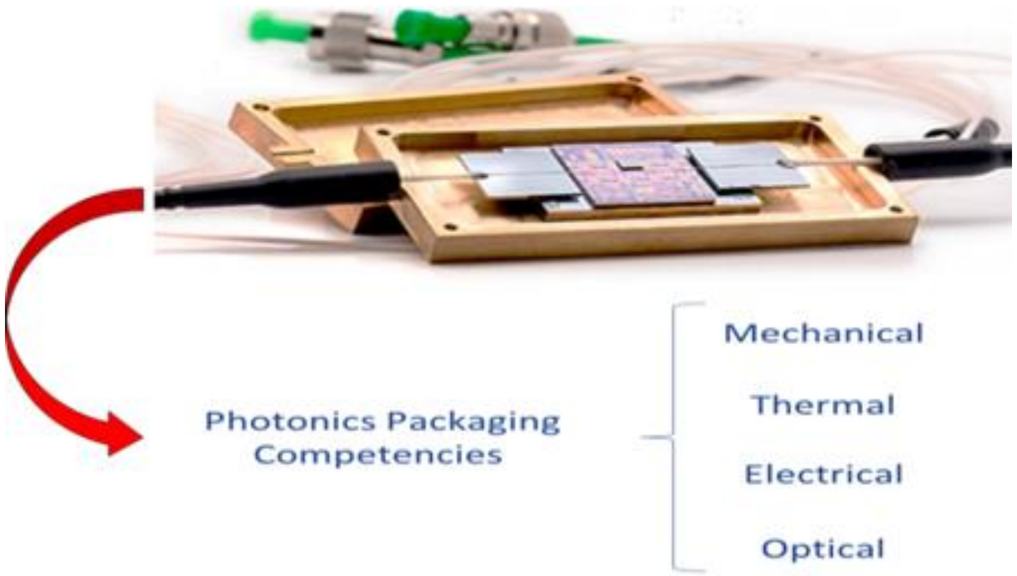
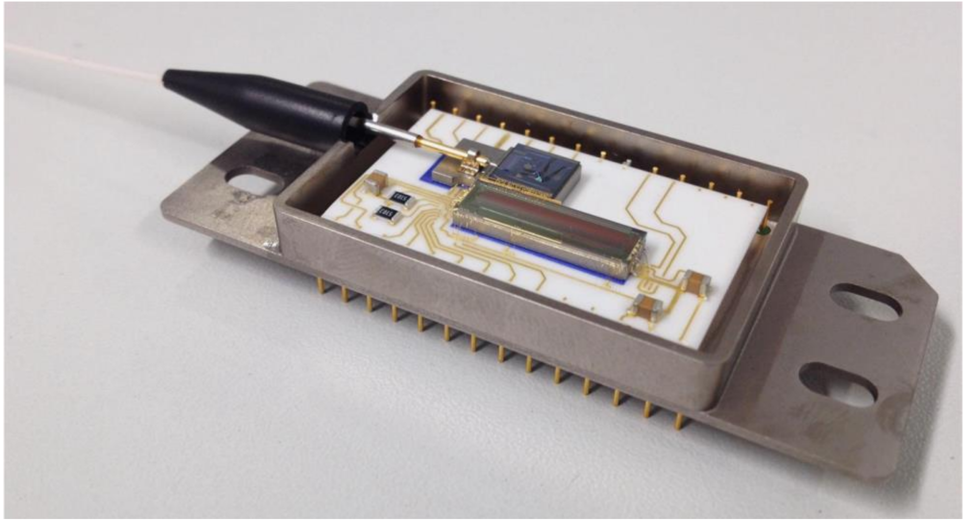
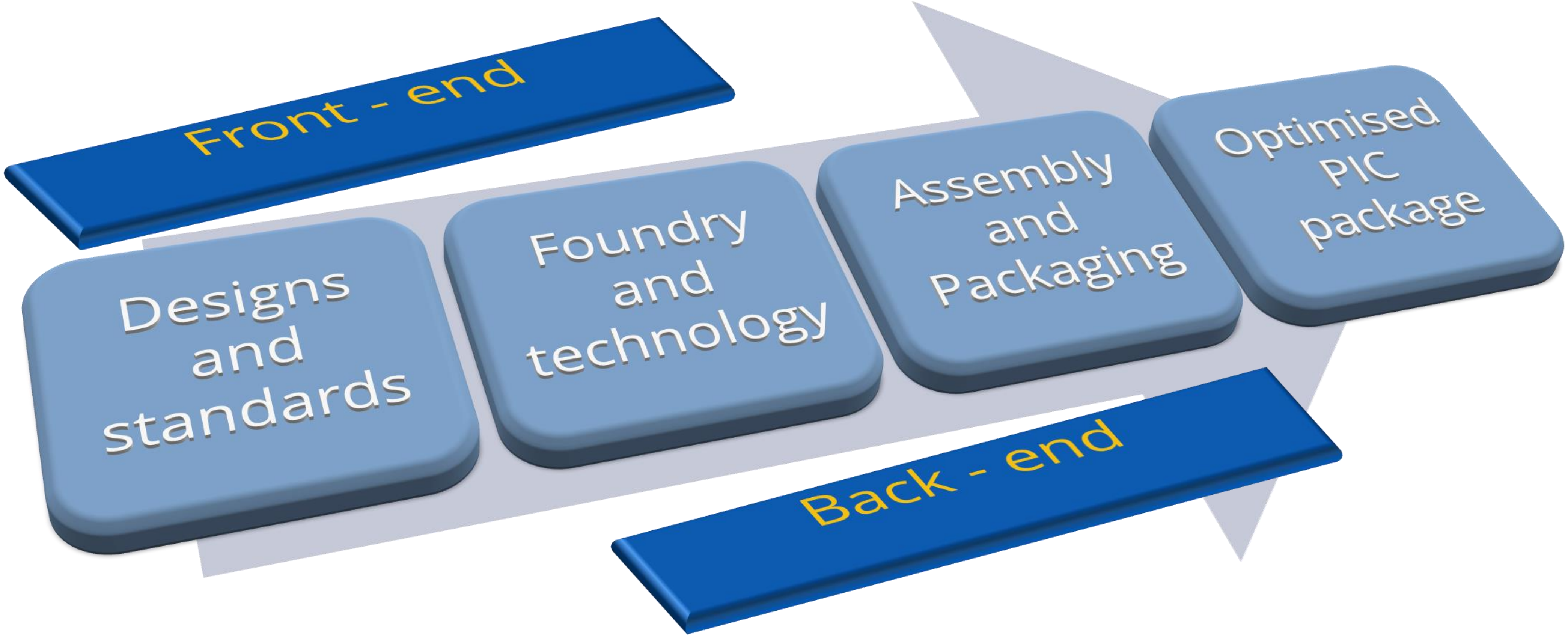
Photonic packaging is the catch-all term used to describe the range of techniques and technical competencies needed to make the optical, electrical, thermal, mechanical (and sometimes chemical) connections between a PIC and the outside world.





OIP4NWE Front-end and back-end



The challenges with Photonic Packaging

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1. PIC packaging on average can account for 60%~80% of the costs of the photonic product manufacturing costs and a barrier of entry in scaling up operations.

2. Photonics supply chain has a limited ‘off-the-shelf’ components and most packages require a high level of customisation.

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What can OIP4NWE do for SMEs in the region and the integrated photonics community?

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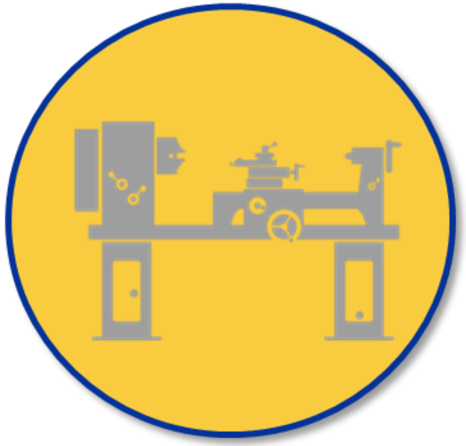
1. Offer validated and scalable packaging assembly processes & technologies

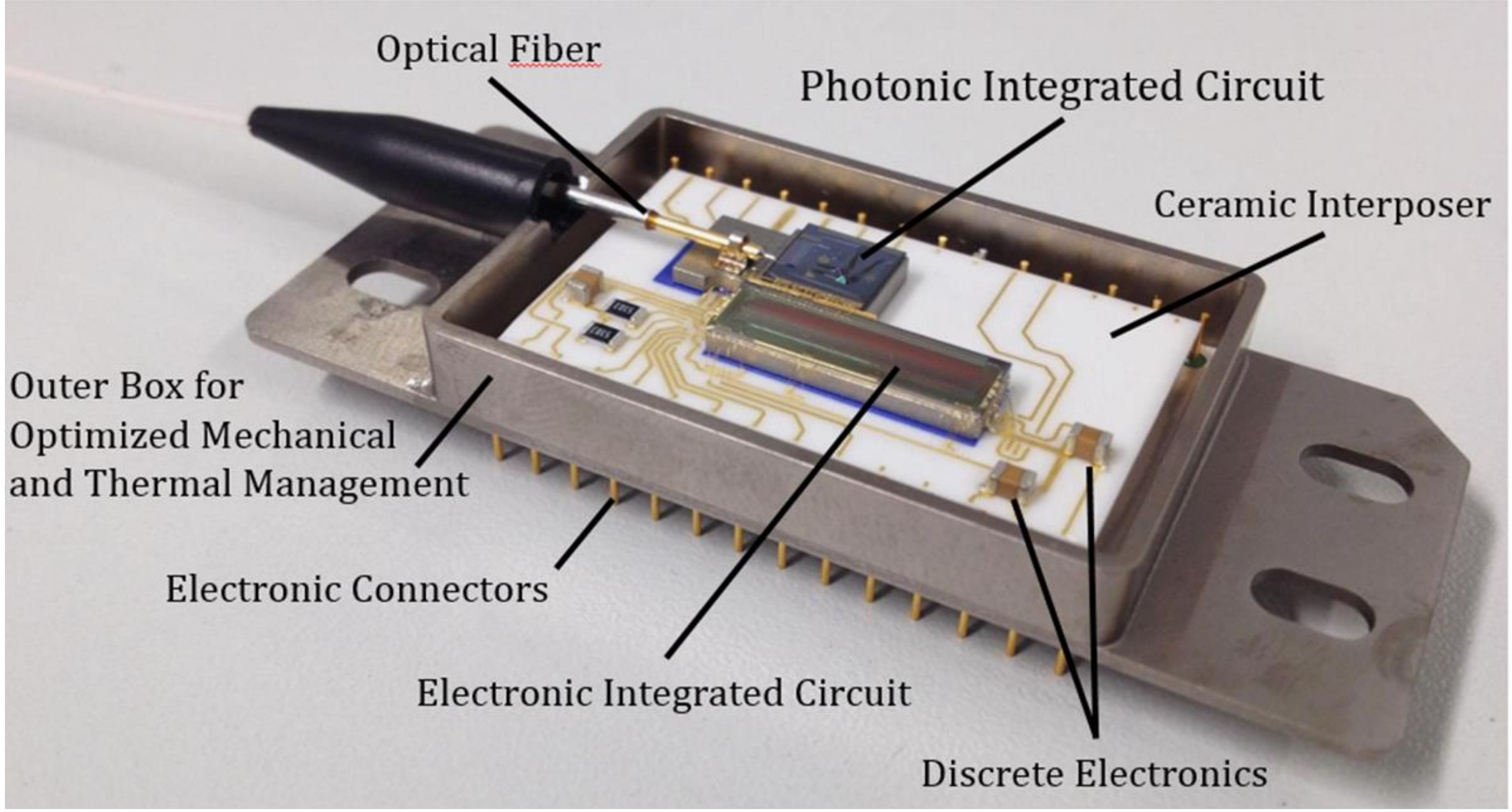
2. Access to MPW runs & prototyping photonic solutions

3. Offer access to European Pilot Lines for scaling up projects.



OIP4NWE
Open Innovation PIC Pilot

Offer validated and scalable packaging assembly processes & technologies



Tyndall offer in OIP4NWE

Optical connections:
-Fiber to Edge Coupler
- Single mode
- Pitch 127 µm 250 µm
- Max channels 20
- MFD 3µm – 10µm

Electrical connections:
-Flip Chip Bonding
- ASICs gold stud bumping and solder sphere jetting

Thermal management
- Thermo-electrical coolers

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EUROPEAN UNION
OIP4NWE Open Innovation PIC Pilot

What can OIP4NWE do for SMEs in the region and the integrated photonics community?

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Access to MPW runs & prototyping photonic solutions

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SMART PHOTONICS
Independent InP Foundry

VUB
VRIJE UNIVERSITEIT BRUSSEL

TU/e
Technische Universiteit
Eindhoven
University of Technology

Tyndall
National Institute
Institiúid Náisiúnta

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What can OIP4NWE do for SMEs in the region and the integrated photonics community?

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1. Offer validated and scalable packaging assembly processes & technologies

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Offer access to European Pilot Lines for scaling up projects.

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PIXAPP Photonic Packaging Pilot Line

MIRPHAB ENABLING CHEMICAL SENSING

JePPIX Pilot Line

MedPhab Photonic Medical Devices

EUROPRACTICE IC SERVICE

ACT PHAST 4.0

PHOTONICS21
PHOTONICS PUBLIC PRIVATE PARTNERSHIP

OIP4NWE Open Innovation PIC Pilot

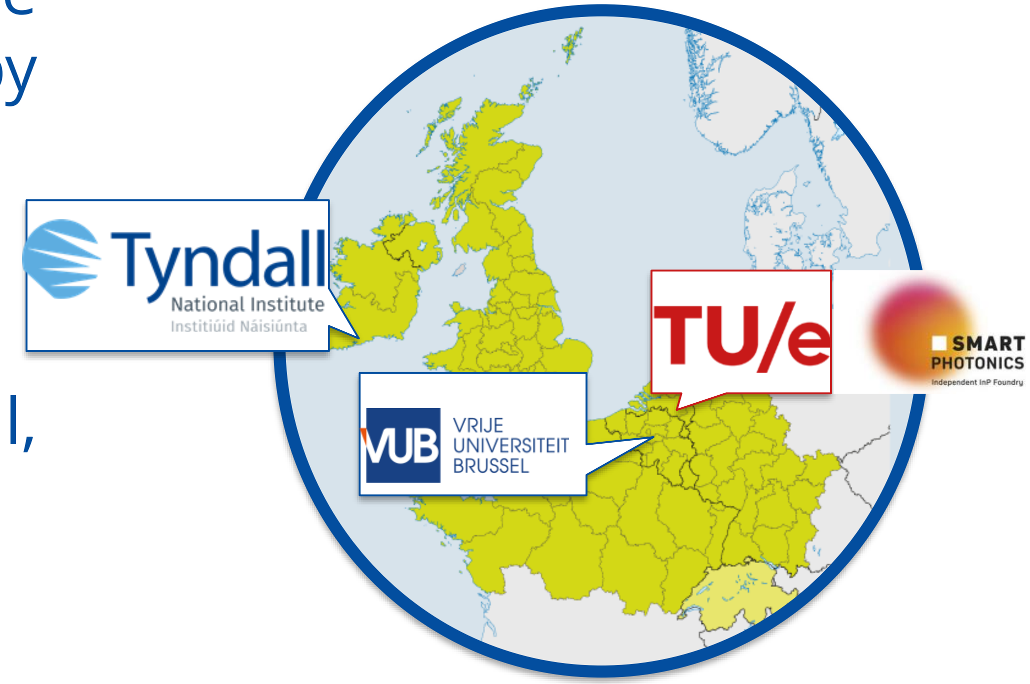
Summary

OIP4NWE supports the growth of the photonic ecosystem in the region by providing:

-Access to InP MPW runs (SMART photonics)

-Access to global leaders expertise (Tyndall, VUB, Tyndall, TU/E)

-Access to EU Pilot Lines and ACTPHAST



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Thank you!

Presentation

Introduction of the Innovation Support Fund and how to apply

Prof. Jürgen van Erps

Vrije Universiteit Brussel

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European Regional Development Fund

OIP4NWE Open Innovation PIC Pilot

Open-Innovation Photonics pilot for North West Europe

Innovation Support Fund – Call for applications

Jürgen Van Erps, VUB

Innovation Support Fund - Call for applications

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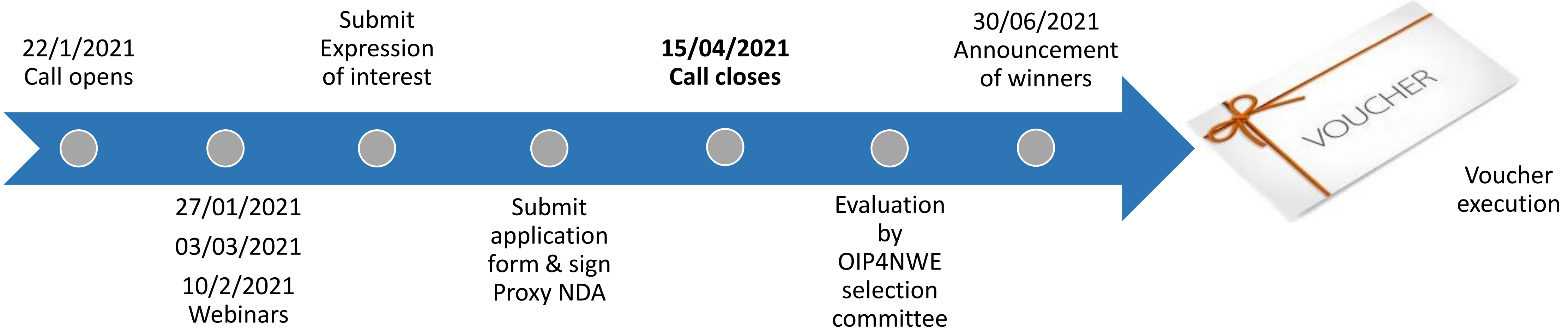
Are you an SME in the NWE region wanting to scale up production of PICs to a trial series beyond proof-of-concept demonstration?

Apply now to receive 1 of 7 vouchers providing you with up to 50k€* support and access to the OIP4NWE open innovation pilot line, covering

1) Design verification to check compatibility of the PIC design with the OIP4NWE pilot line
2) Manufacturing of the PICs, external optics and packaging



For more information, visit www.oip4nwe.eu/vouchers

* A financial contribution of 20% will be required from the SME on the total project cost and of 100% for anything above the 50k€ max support.

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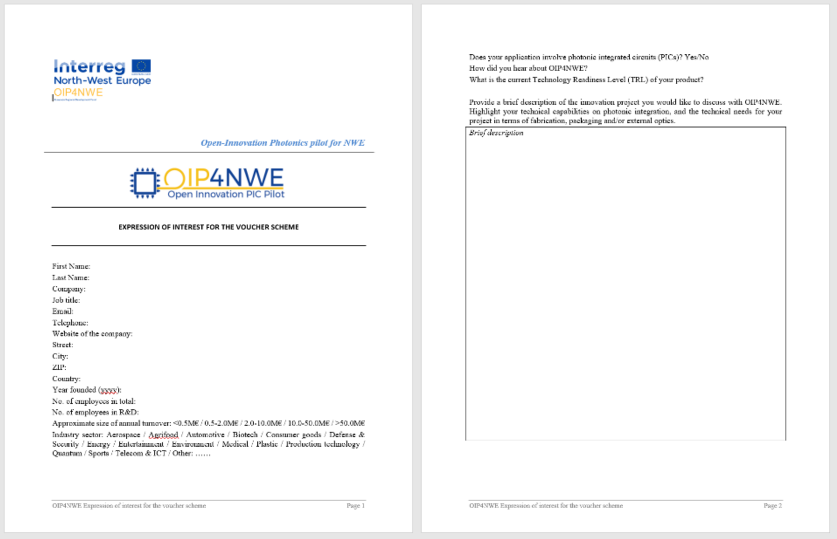
Open Innovation PIC Pilot

Requirements for application

1. The applicant should be a **small or medium-sized entreprise (SME)**, according to the European definition, which can be found at https://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition
2. The applicant should be **based in the North-West Europe** region, as defined on https://www.nweurope.eu/about-the-programme/the-nwe-area/
3. The applicant should have demonstrated the technical feasibility of their application proposal, i.e. the applicant should have a PIC design ready and preferably a validated prototype. This means that the technology readiness level **(TRL) of their current PIC should be 4 or higher**. Proposals for proof-of-concept type demonstrators are not eligible.
4. The applicant should **demonstrate a business case** for scale-up to volume production and/or how the funded project will positively **impact** their future business, either through increased revenues or through the creation of new jobs.
5. The applicant should **comply with the minimis criterion for state aid** and provide a self-declaration to that end. A "De Minimis" award letter will be issued by the OIP4NWE consortium when complying.
6. The applicant should **submit a fully completed "Voucher application form"** and should **sign a "Proxy NDA"** to allow evaluation of the proposal by the OIP4NWE voucher selection committee.
7. Voucher recipients should **agree to collaborate on documenting their use case**. This is to be used as dissemination material to attract other users of the pilot line, during as well as after the project.

Application procedure

→ Fill out a pre-registration “**expression of interest**” form to allow early follow-up and eligibility check prior to preparing a full proposal. Send the form to voucher@oip4nwe.eu


Open-Innovation Photonics pilot for NWE

EXPRESSION OF INTEREST FOR THE VOUCHER SCHEME

First Name:
Last Name:
Company:
Job title:
Email:
Telephone:
Website of the company:
Street:
City:
ZIP:
Country:
Year founded (yyyy):
No. of employees in total:
No. of employees in R&D:
Approximate size of annual turnover: <0.5M€ / 0.5-2.0M€ / 2.0-10.0M€ / 10.0-50.0M€ / >50.0M€
Industry sector: Aerospace / Agrifood / Automotive / Biotech / Consumer goods / Defense & Security / Energy / Entertainment / Environment / Medical / Plastic / Production technology / Quantum / Sports / Telecom & ICT / Other: ……

OIP4NWE Expression of interest for the voucher scheme — Page 1

Does your application involve photonic integrated circuits (PICs)? Yes/No
How did you hear about OIP4NWE?
What is the current Technology Readiness Level (TRL) of your product?

Provide a brief description of the innovation project you would like to discuss with OIP4NWE. Highlight your technical capabilities on photonic integration, and the technical needs for your project in terms of fabrication, packaging and/or external optics.

Brief description

OIP4NWE Expression of interest for the voucher scheme — Page 2

→ Fill out application form and send it to voucher@oip4nwe.eu before the call closure (15/04/2021)


1 2 3 4 5 6 7

Application form

Open-Innovation Photonics pilot for NWE

VOUCHER APPLICATION FORM

Note that fields marked with an asterisk (*) will be used in public communications about OIP4NWE and the company should be aware of this in advance.

Company Information *

Company name:
Company type:
Main industry sector of the company:
Street:
City:
ZIP:
Country:
Website:
Year founded (yyyy):
No. of employees in total:
No. of employees in R&D:
Size of annual turnover:
First time photonics innovation with PICs? Yes/No
Is there any cause for concern over potential conflicts of interest between the company and any of the OIP4NWE partners or individuals? Yes/No (If yes, please explain)

Are there any current or previous technical or commercial relationships between the company and any of the OIP4NWE partners or individuals involved? Yes/No (If yes, please provide details)

Company contact person

Title*:
First Name*:
Last Name*:
Position in the company (e.g. CEO, CTO, etc.)*:
Department:
Email:
Mobile:
Telephone:

General project information

Application field*: Aerospace / Agrifood / Automotive / Biotech / Consumer goods / Defense & Security / Energy / Entertainment / Environment / Medical / Plastic / Production technology / Quantum / Sports / Telecom & ICT / Other: ……
What is the current technology readiness level (TRL) stage of this innovation project?
What is the targeted TRL stage?
What is the current TRL stage of the end product?
Has the company participated before in any EU funded project? Yes/No (If yes, please provide details)

Part A - Project description

Abstract *

Provide a short overview of the scope/objective of the project

Context of the innovation project

Describe the overall system/application for which the innovation project will be conducted

Application form

General description of the innovation approach

Describe how the scope of the project will be reached

Major challenges

Describe in specific terms the major innovation challenges and why support is needed to solve them

Target specifications

Quantify the target specifications of the innovation outcome

Detailed project description

Provide further details

Application form

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Part B - Impact on company's business

Summary of the key points relating to the business impact of the proposed innovation for the company. Please answer ALL questions below.

I. Target Market

What is the target market application for this innovation? What does the market evolution (growth projection) look like for this innovation? What major societal challenges does it address?

II. Market Validation

What gives the company confidence that there is a good opportunity for its innovation within this market? Does the company have an existing foothold in this market? Does the company have a track record of similar business activities or customers in this market? Has the company already spoken with target customers for this innovation? Please describe. If this is a new market for the company, please explain the track record of the company management in other businesses or markets.

III. Route-To-Market

How does the company plan to commercialize this innovation? What will the route-to-market be for the company (product sales, licensing, services...)? How will the manufacturing / production be organized (where, who, ...)? Which sales channels will be used and in which geographic areas will the product be sold?

IV. Competitive Positioning

What is the current state-of-the-art in the application domain being targeted by this innovation? What is the state of the competitive environment for this innovation? What are the main competing products for this innovation?

V. Unique Competitive Advantage

Why will this innovation offer superior benefits to target customers over the current state-of-the-art? What are the key points relating to the unique selling points of the targeted product for this project?

VI. Financial Business Plan

What will need to be done to realize this new business once the project is finished? Does the company have a clear, strong and realistic business plan for the steps it will take to compete successfully in this market? How will the company finance bringing the product to market? The business case MUST include a description of the estimated cost & pricing of the target end product and its attractiveness to the target market when compared to the cost-value proposition of existing alternative solutions. In case it is the intention to attract new Venture Capital to realize the business, explain these plans in more detail including: amount of investment needed, timing, potential candidates, current status, etc...

New Business and EU Jobs expected from this project

Only direct revenues and direct jobs created by the company within the EU should be considered. Revenues and jobs created by partners or subcontractors should not be included.

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Application form

Forecast figures must be realistic to the company's starting position and the target market application, and must be justified by the company's business plan which has been summarized earlier in the proposal.

Please specify year 1 (ex: 2021)

Note: Year 1 starts at the end of this OIP4NWE voucher project.

	Year 1	Year 2	Year 3	Year 4	Year 5
New revenues in k€					
Additional number of Full Time Equivalent jobs in the EU (cumulative)					

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Selection criteria

Evaluation criteria and associated weight:

1. **The innovative character of the project (weight 1)**:
   Is the proposed solution new to the marked?
   Is the project creating valuable knowhow?
   Are PICs key enabling elements in this project?
2. **Technical feasibility and quality of the project plan (weight 1)**:
   Compatibility with the OIP4NWE pilot line?
   Current TRL level of the PIC?
   How should the PIC be interfaced with the outside world?
   Is the proposed technological approach in line with the project goals?
3. **Credibility and level of commitment of the company (weight 2)**:
   Level of financial commitment?
   Does the company have a proven track record of bringing new products/solutions to the market?
   Does the company have a proven track record of successfully completing public or public-private funded project?
4. **Added value on the business case and potential impact (weight 2)**:
   The target market (target customers/segments, purchasing decision-makers, …)?
   The market validation (experience and relationship of the company with these customers; is the target market an existing one or a new one?)?
   The route to market (what channels will the company use to sell and deliver its products to its target customers?)?
   The value proposition (competitive positioning and unique selling point)?
   Financial aspects of the business plan (increase in revenues or new jobs created)?

Each criterion is scored with a value from 0 (strongly underperforming) to 5 (excellent).
The score is multiplied with the weight.
The individual score of each criterion should be at least 2,5/5.
The total score should be at least 20/30.

The selection committee will take into account **geographical distribution in the NWE region** as well as **distribution over different application sectors** of the voucher grantees.

Need more information?

→ Visit our website: www.oip4nwe.eu/vouchers
→ Contact voucher@oip4nwe.eu

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Thank you!