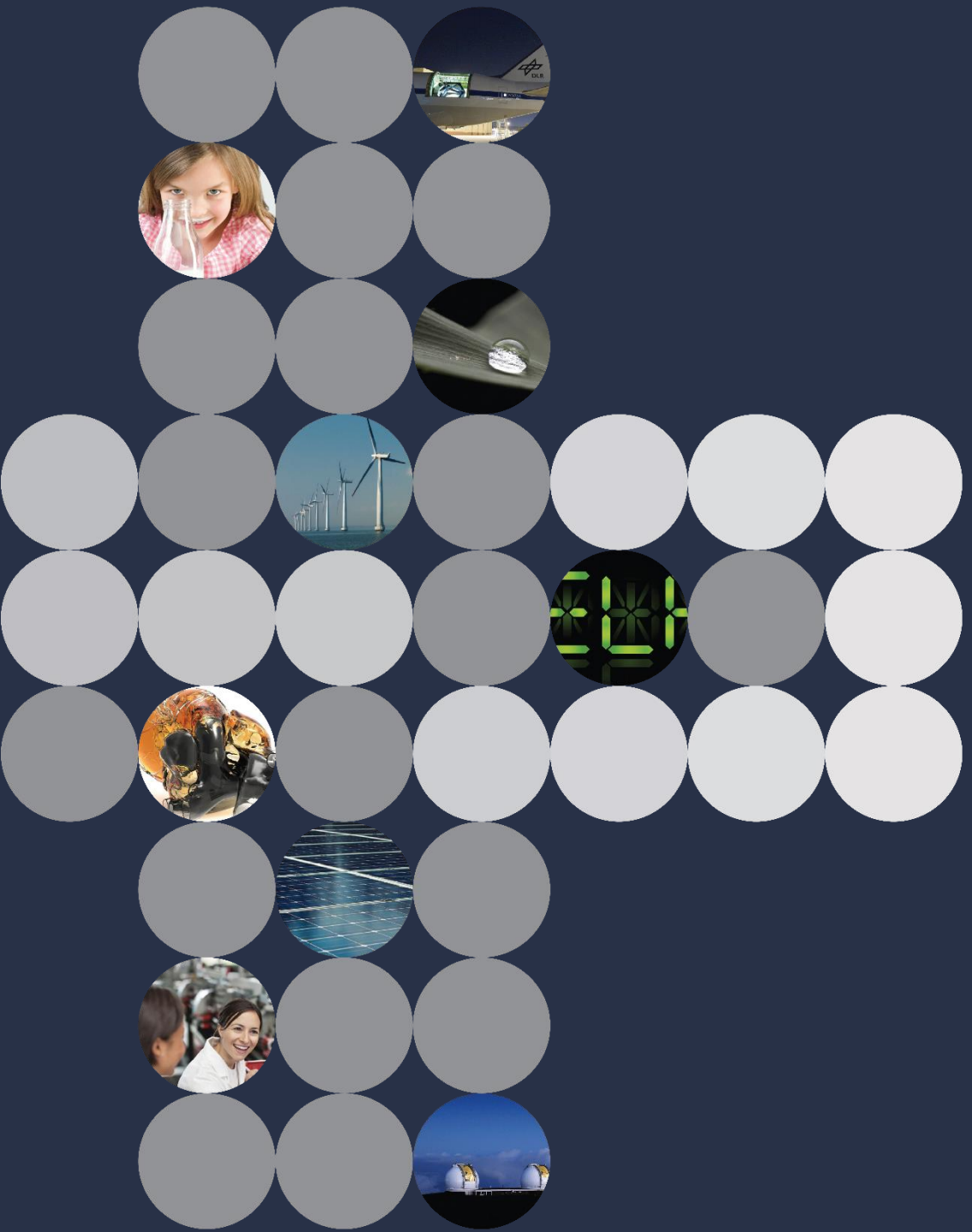

Development of PIC based systems

Davide Grassani
PIC System Manager

Swissphotonics PIC Convention,
Polariton Technologies AG, Adliswil 21/06/2024

CSEM AT A GLANCE

We are a public-private, non-profit, Swiss technology innovation center.

We enable competitiveness through innovation by developing and transferring world-class technologies to industry.

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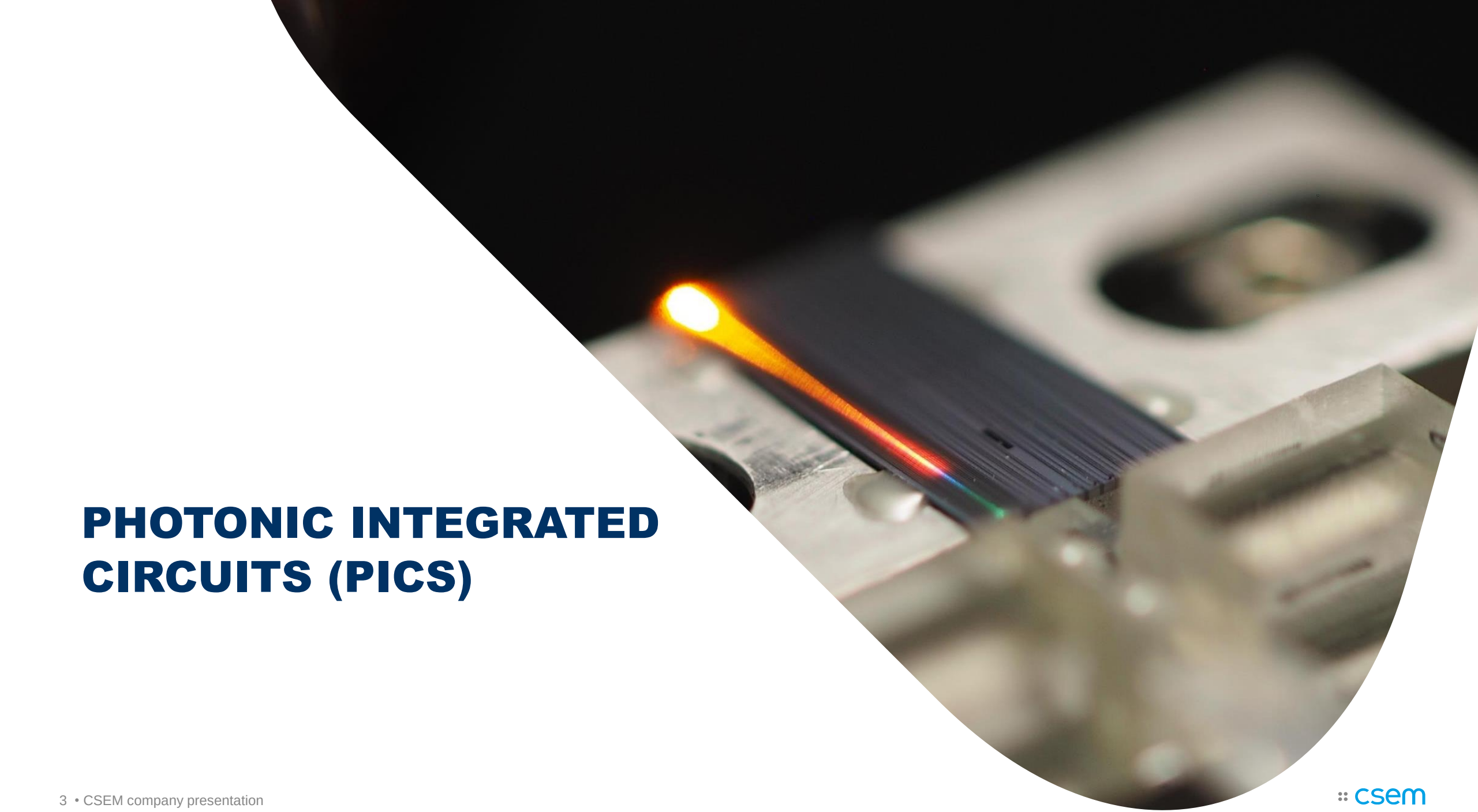

PHOTONIC INTEGRATED CIRCUITS (PICS)

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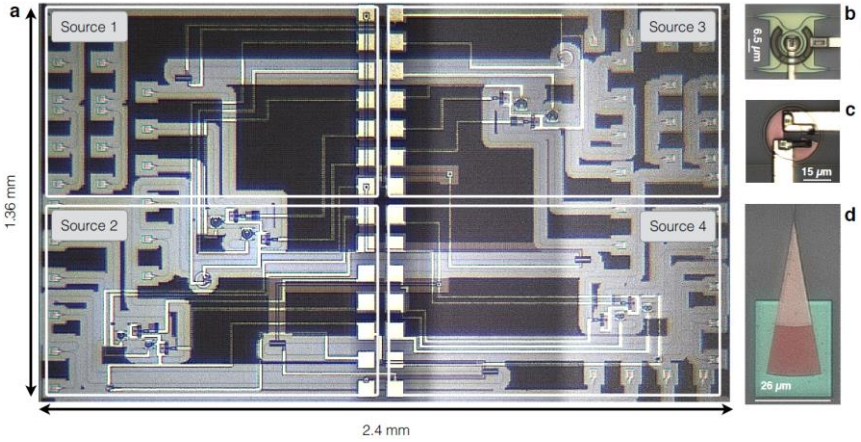
PIC

Definition

A microchip containing two or more photonic components that form a functioning circuit. This technology detects, generates, transports, and processes light. (Wikipedia)

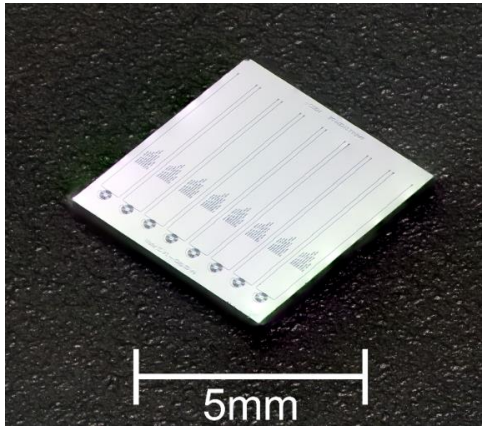


Motivation

Reduce SWaP of optical systems

Enable scalability/large volume production

Unlock new/better functionalities



Bring your optical system on-chip!

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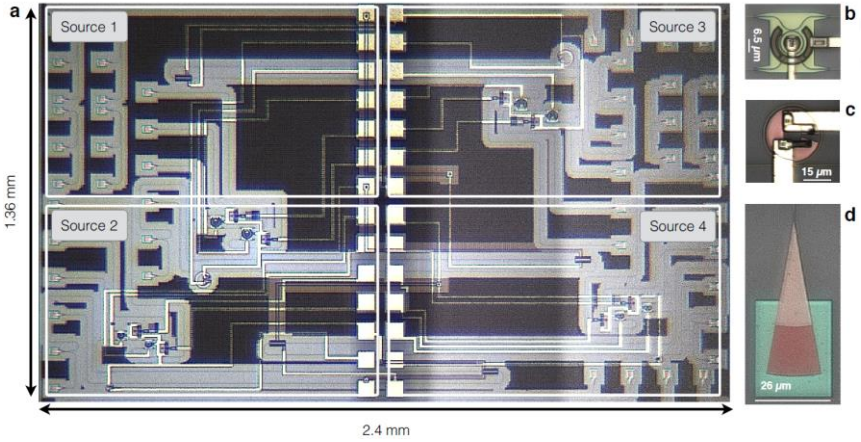

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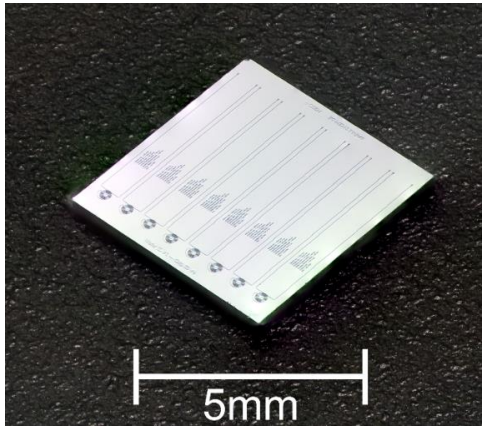

Bring your optical system on-chip!

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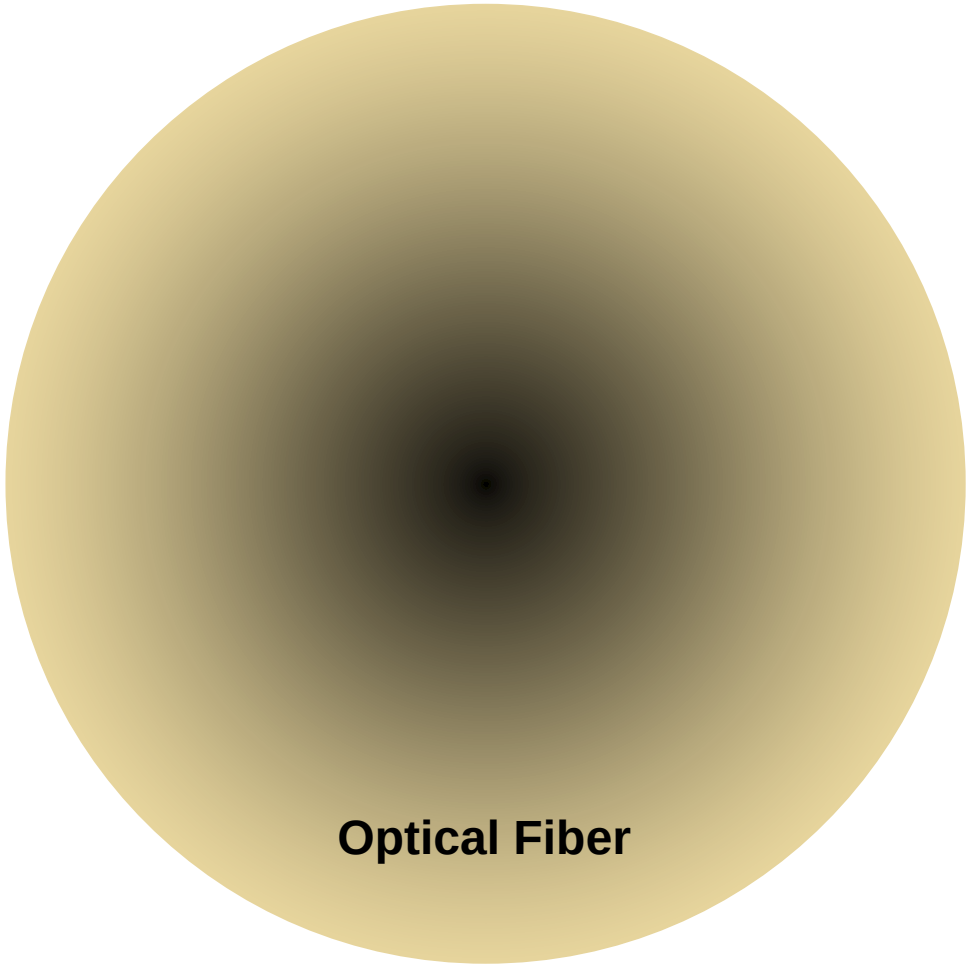
PIC key component: the waveguide



> 10x MFD

PIC waveguide

Benefits

- Planar topology
- Lithographic precision
- Strong mode confinement
- Tight bend
- Efficient nonlinear processes
- Dispersion engineering

Challenges

- Losses (propagation / coupling)
- Tolerance robust designs

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Choosing the PIC platform

Generate, Transport, Process, and Detect light → No single material can do everything!

Famous PIC platforms / Property	InP	Si	SiN	LNOI	Polymers
Transparency window	0.9 – 2 µm	1.1 – 8 µm	0.25 – 8 µm	0.3 – 5.5 µm	0.5 – 2 µm
Propagation losses	1.5 to 3 dB/cm	0.1 to 3 dB/cm	0.01 to 0.1 dB/cm	<0.1 dB/cm	<0.5 dB/cm
Two-photon absoprtion	high	high	Very low	Very low	low
Electro-optic coefficient (Modulators)	not intrinsic	not intrinsic	-	High (31pm/v)	Some polymers
Optical gain (lasers, amplifiers)	Yes	-	-	-	-
Detectors	Yes	Yes (<1µm)	-	-	-
Industry Status	Ramping up	High Volume	Low Volume	No Foundry	R&D Qualification

+ ongoing development in: AlN, GaAs, GaN, ChG, LiTO, BTO etc…

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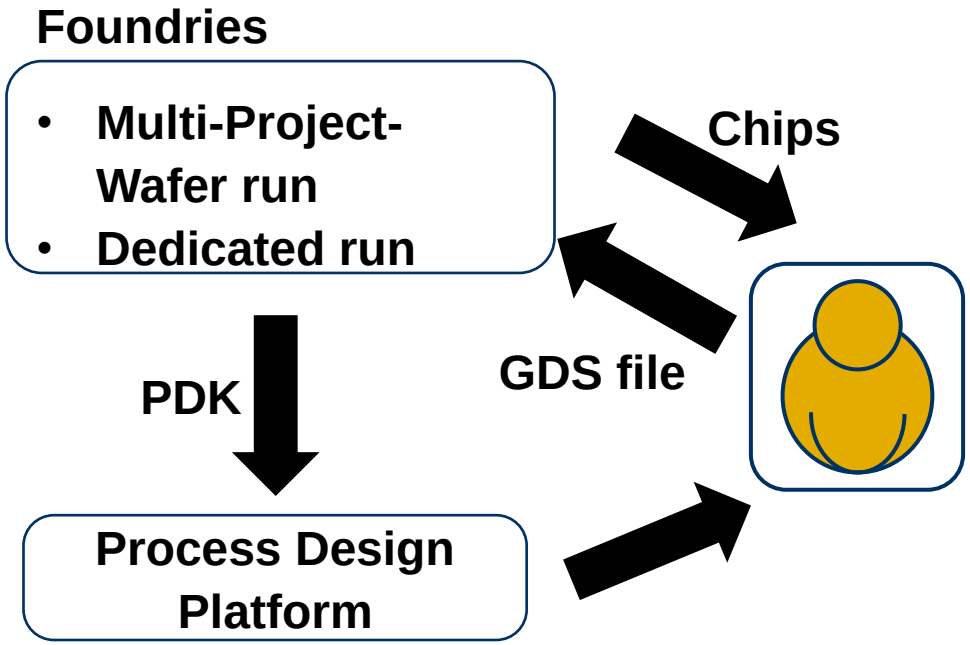
PIC value chain



PIC value chain

Foundries

- Multi-Project-Wafer run
- Dedicated run

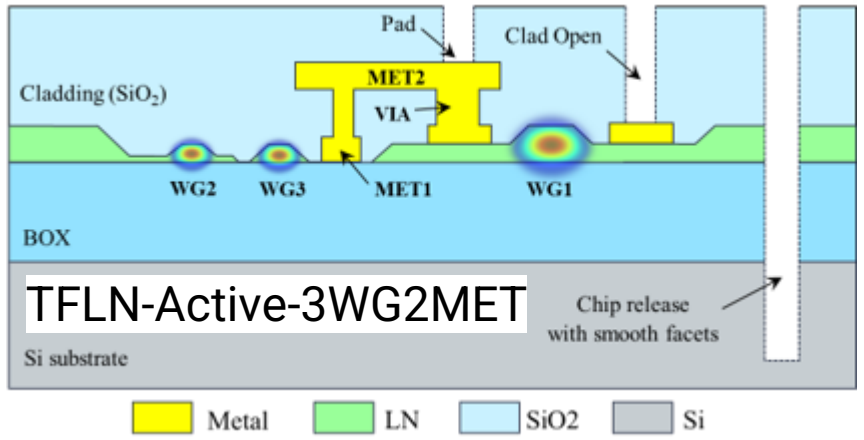
Chips

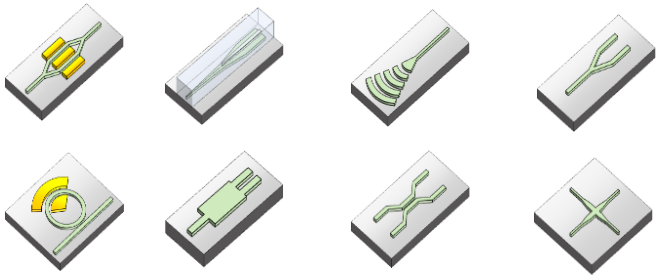
GDS file

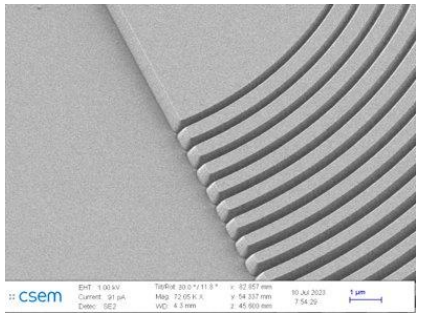
PDK

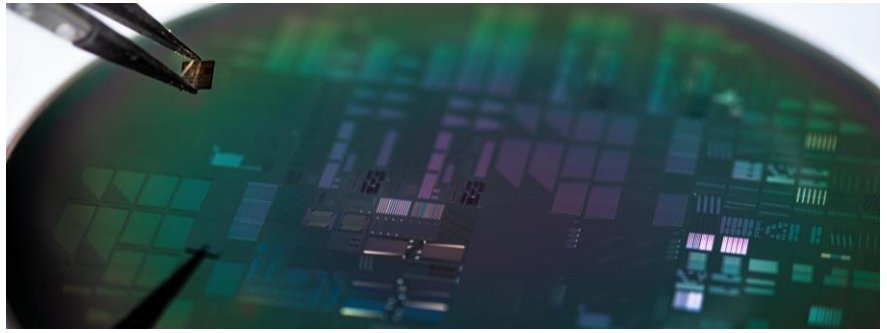
Process Design Platform

LNOI Open access foundry









PIC value chain

Foundries

- **Multi-Project-Wafer run**
- **Dedicated run**

PDK

Process Design Platform

Chips

GDS file

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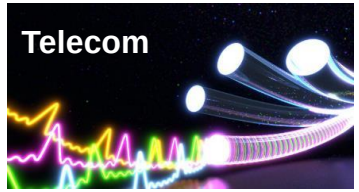
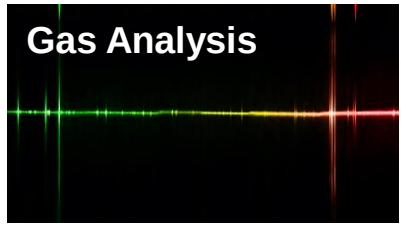
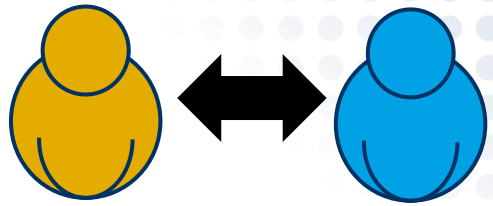
Laser Systems for





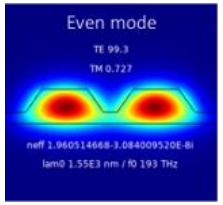


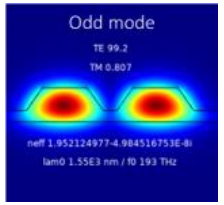
Consultancy

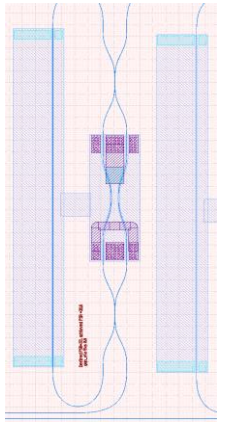
- Identify critical system parameters
- what can (and should) be put on a chip
- PIC platform

Design

- Physical simulation
- Layouting

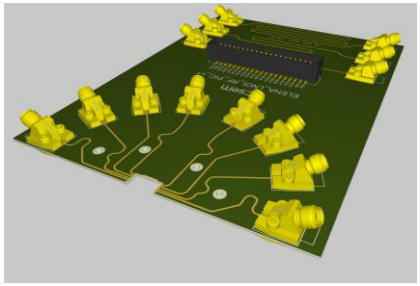


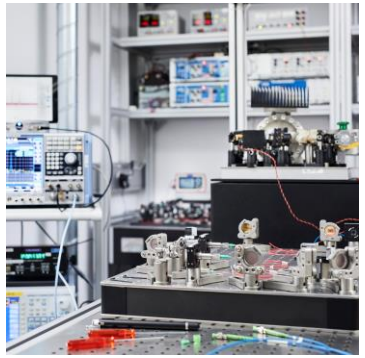


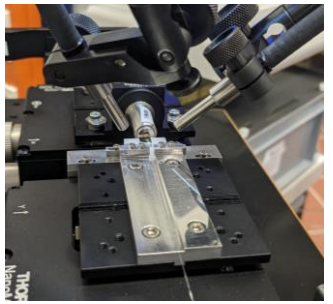


Prototyping & Testing

- Linear & non-linear Optics (VIS - MIR)
- RF & Electro-Optic testing (up to 50 GHz)
- Laser metrology







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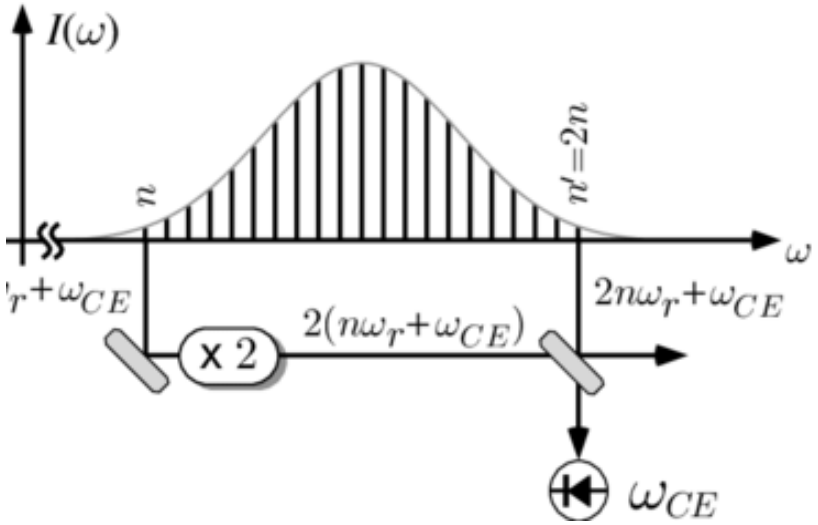
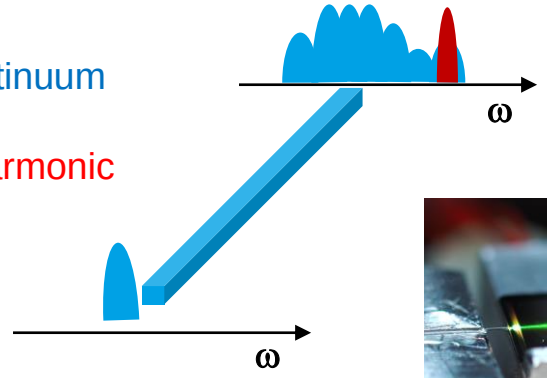
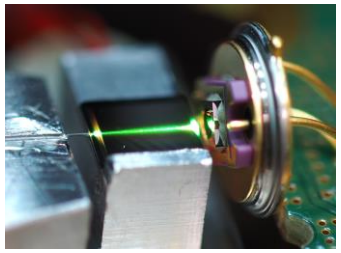
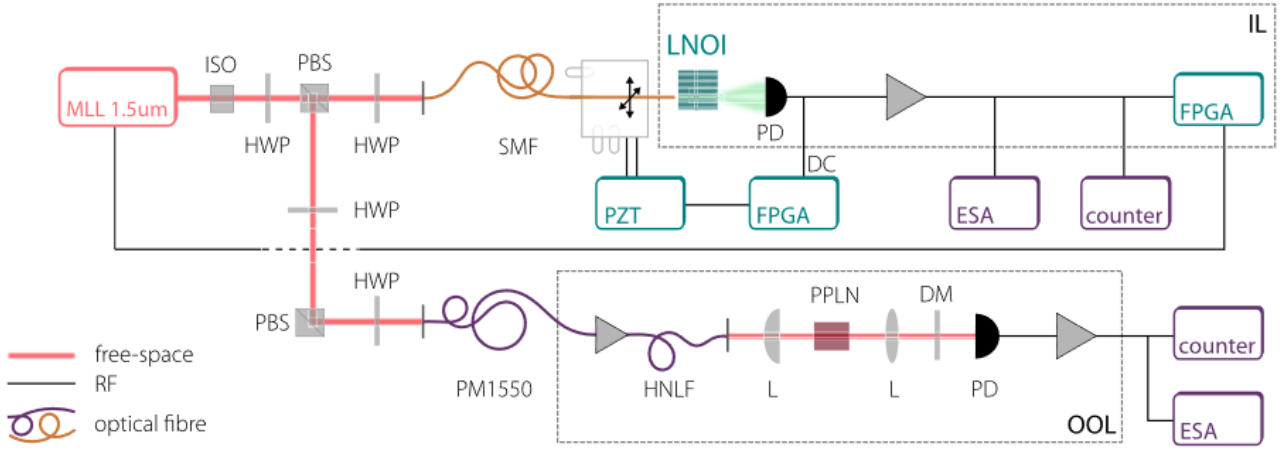
Self-referencing of Optical Frequency Combs

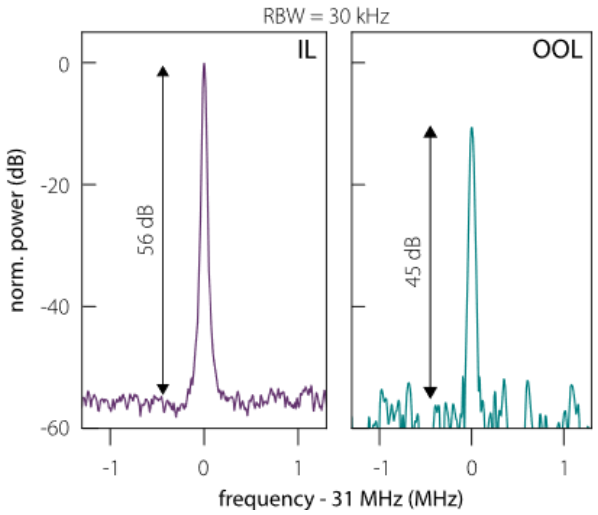


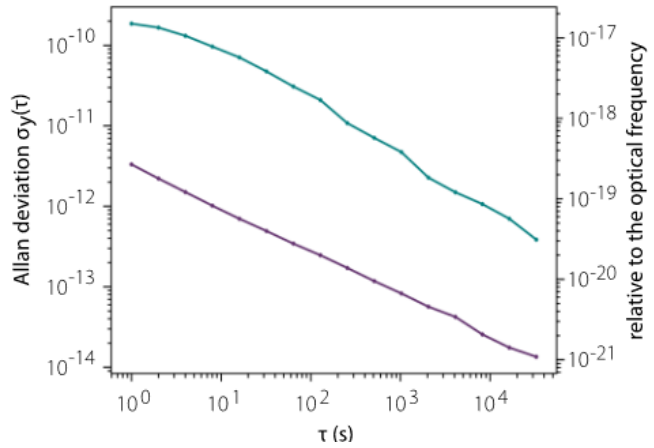
Supercontinuum
+
Second harmonic











Obrzud, E. *et al. APL Photonics* **6**, 121303 (2021)

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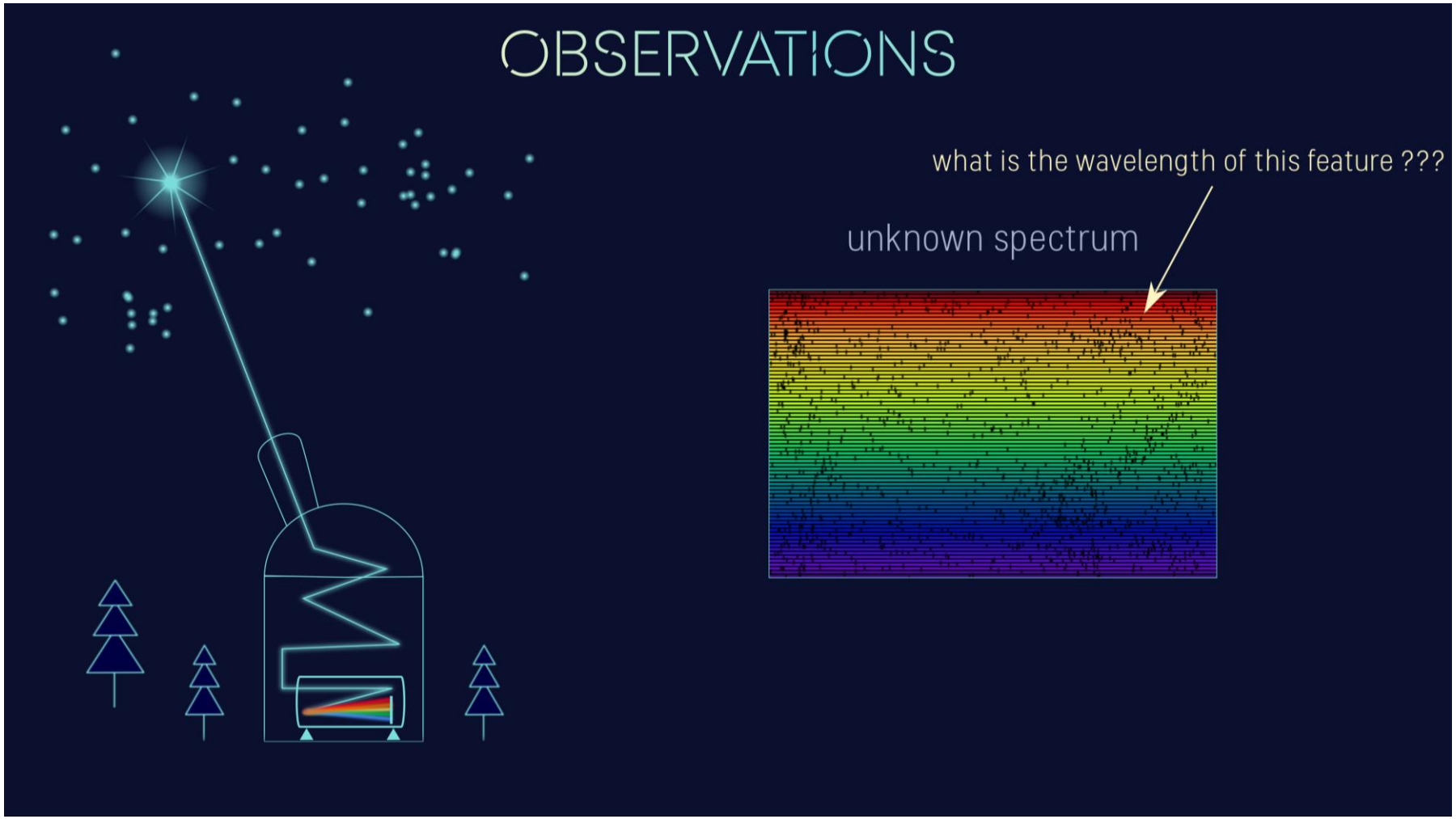
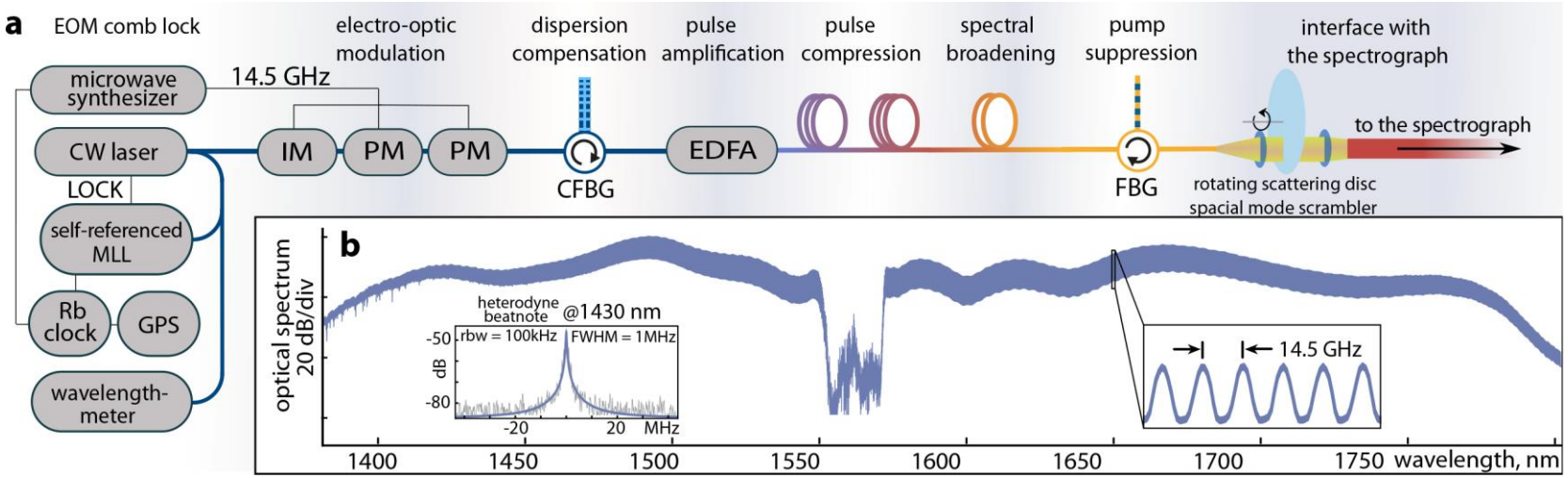
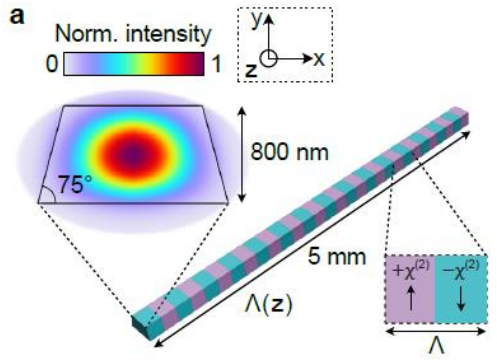
Astrocombs towards VIS-UV

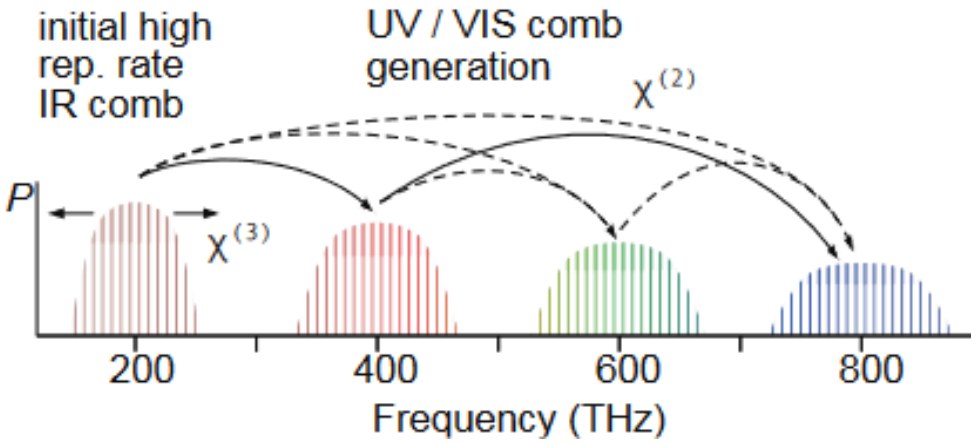


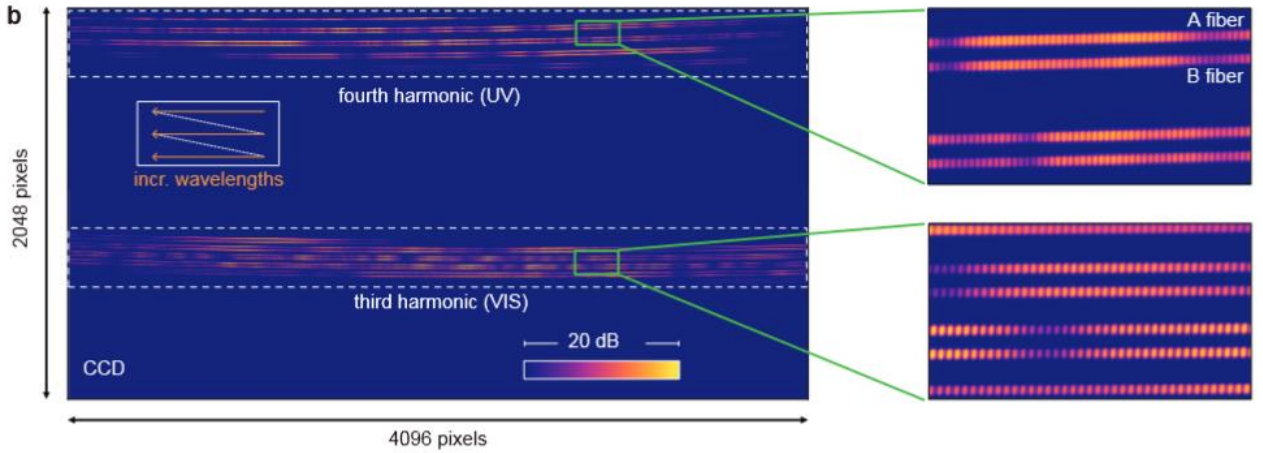
Astrocombs towards VIS-UV





E. Obrzud et al., " Opt. Express **26,** 34830-34841 (2018)

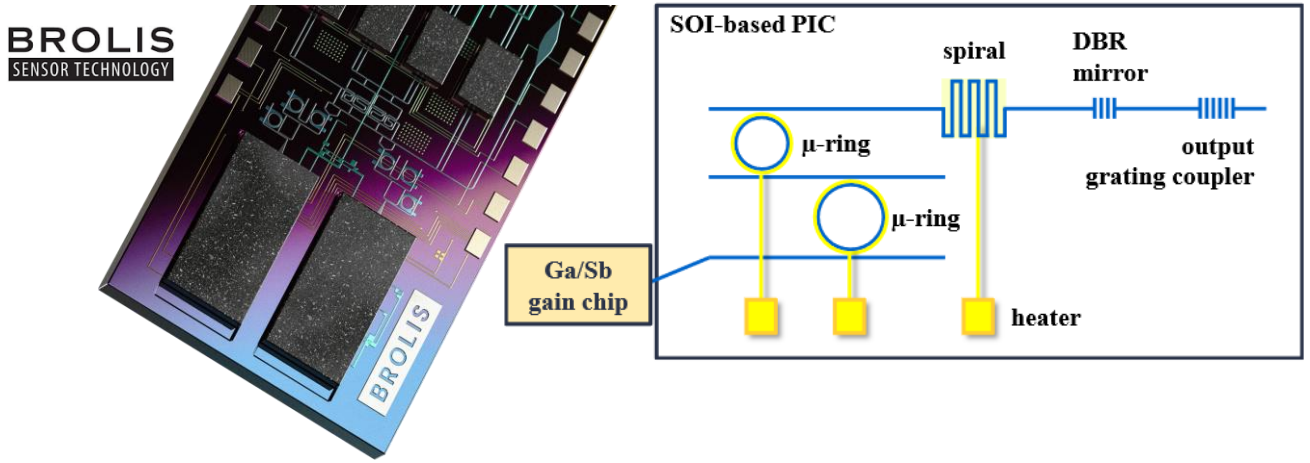


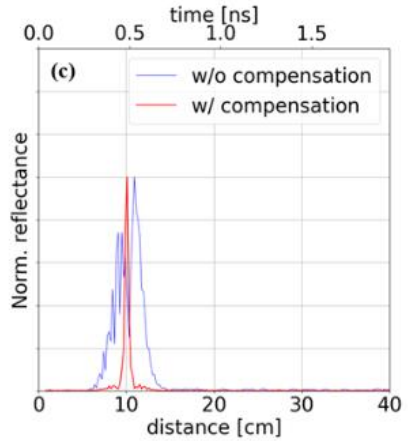


M. Ludwig *et al.*, arXiv, Jun. 23, 2023.

On-Chip Laser for LIDARs

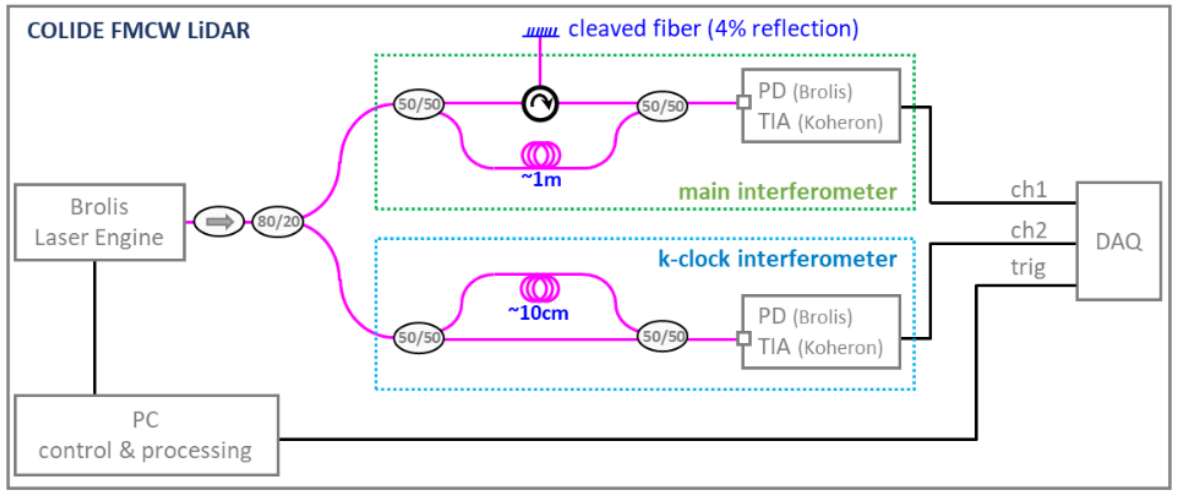
Laser characterization and performance evaluation in a FMCW Lidar system

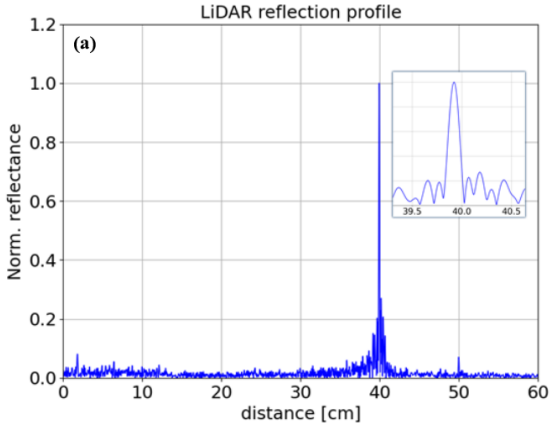


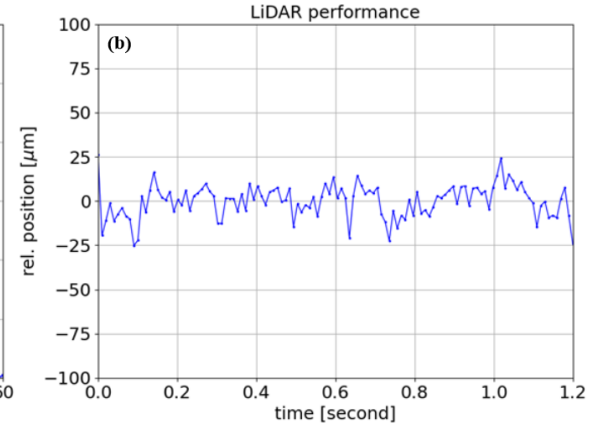


Characterization

- Laser linewidth
- Lidar Axial Resolution
- Lidar Ranging precision







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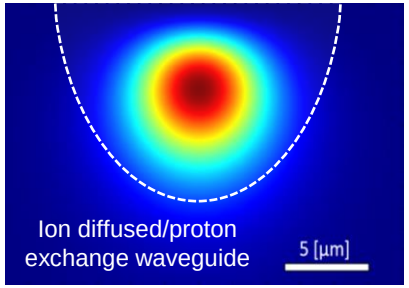
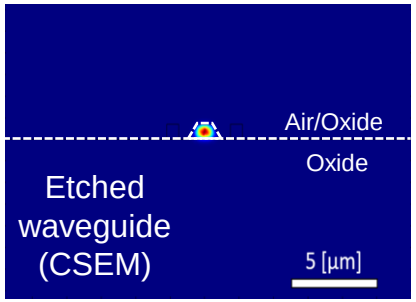
UNDER DEVELOPMENT

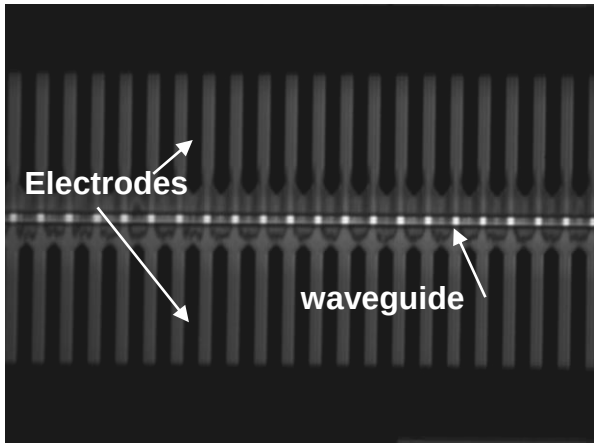
Periodically poled TFLN waveguides
→ Laser frequency conversion

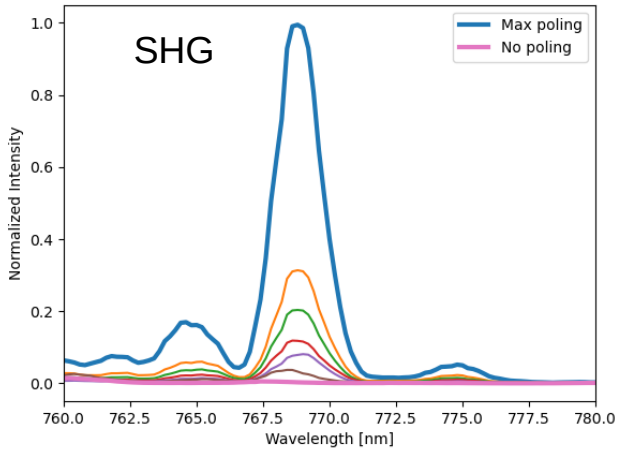
- Quantum sensors
- Nonclassical state-of-light
- Spectroscopy/Sensing

PPLN Type	Internal SHG efficiency @ 1550 nm [%/W cm²]
Bulk crystal	~ 5
RPE waveguide	~ 15
Ridge waveguide	~ 80
LNOI waveguide	~ 500 (CSEM) (> 4000 (Theory))



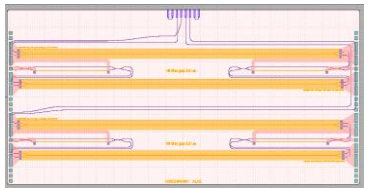


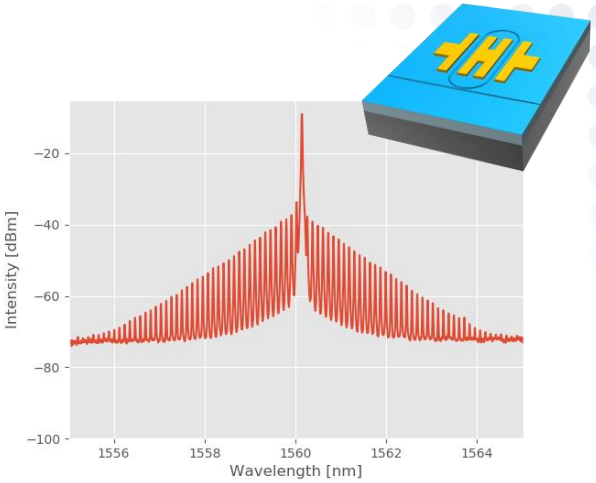




Electro-optic frequency combs on TFLN

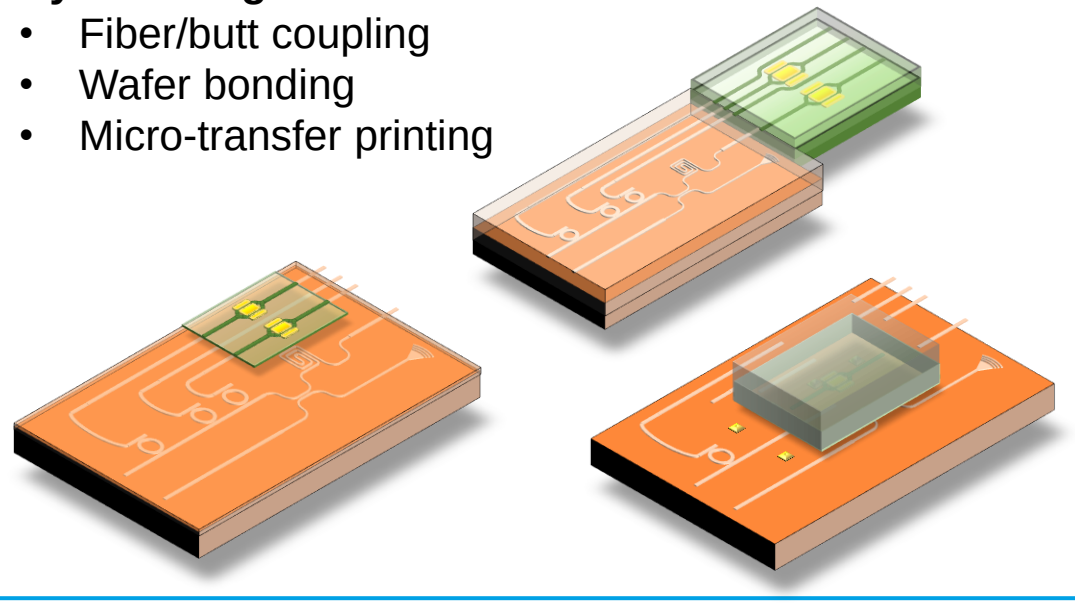
- Astrocombs
- Telecom laser sources
- Spectroscopy/Sensing





Hybrid integration

- Fiber/butt coupling
- Wafer bonding
- Micro-transfer printing



RUNNING PROJECTS & PARTNERS

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CONCLUSIONS

- Careful understanding of which part of a system makes sense to put on a PIC
  - Nonlinear processes
  - Dense integration
- Simply translating the system geometry and components into a PIC is (often) not the best solution
- Account for additional tunability and/or insensitive designs to compensate tolerances
- No one single PIC platform can do everything → hybrid integration & packaging

FUNDING AND CONTRIBUTIONS

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FACING THE CHALLENGES OF OUR TIME

esa

European Commission

FNSNF
FONDS NATIONAL SUISSE
SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

Contacts:
davide.grassani@csem.ch