

# Development of PIC based systems

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PIC System Manager

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# PHOTONIC INTEGRATED CIRCUITS (PICS)

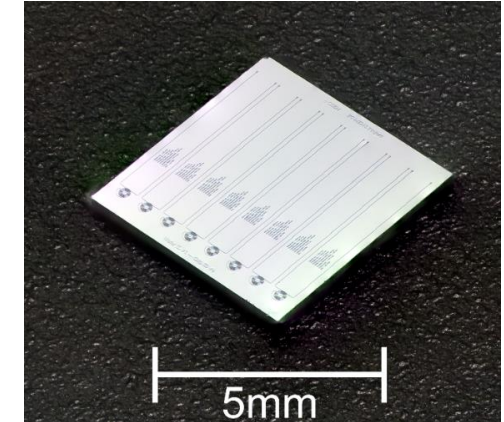
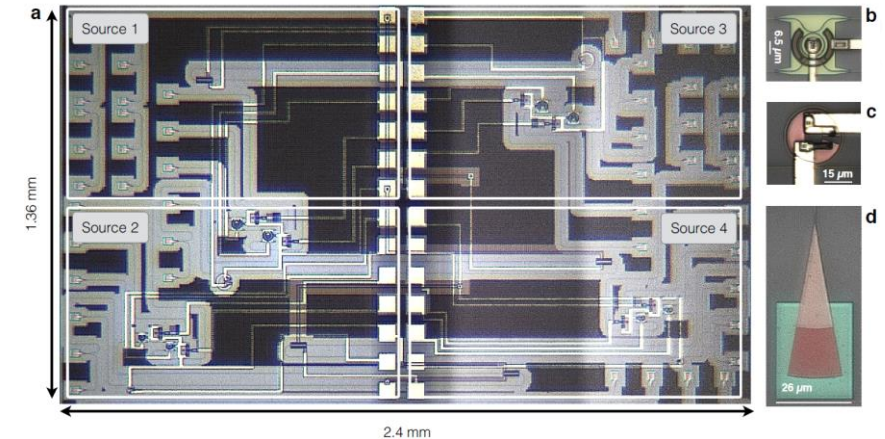
# PIC

## 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!**

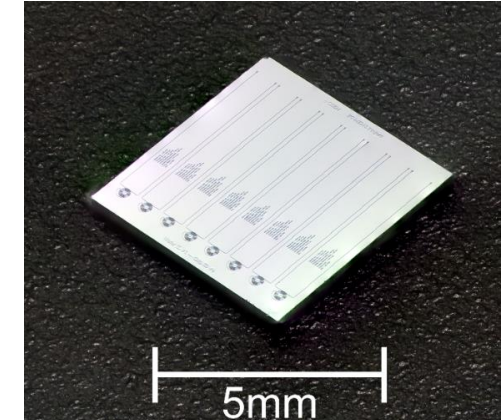
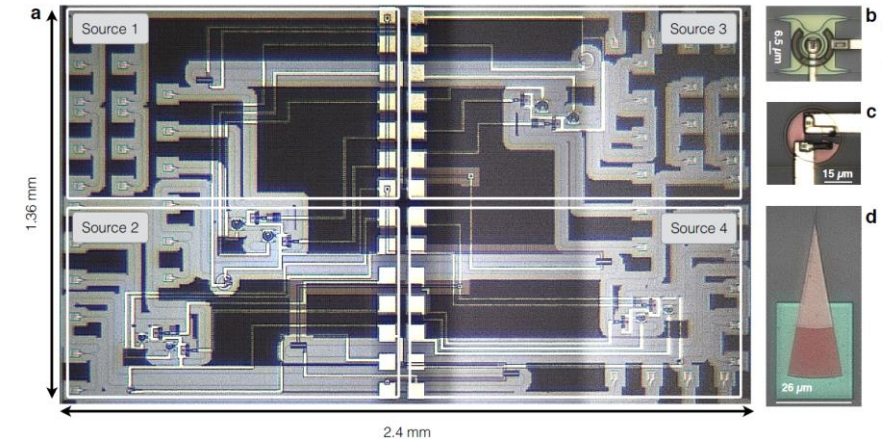
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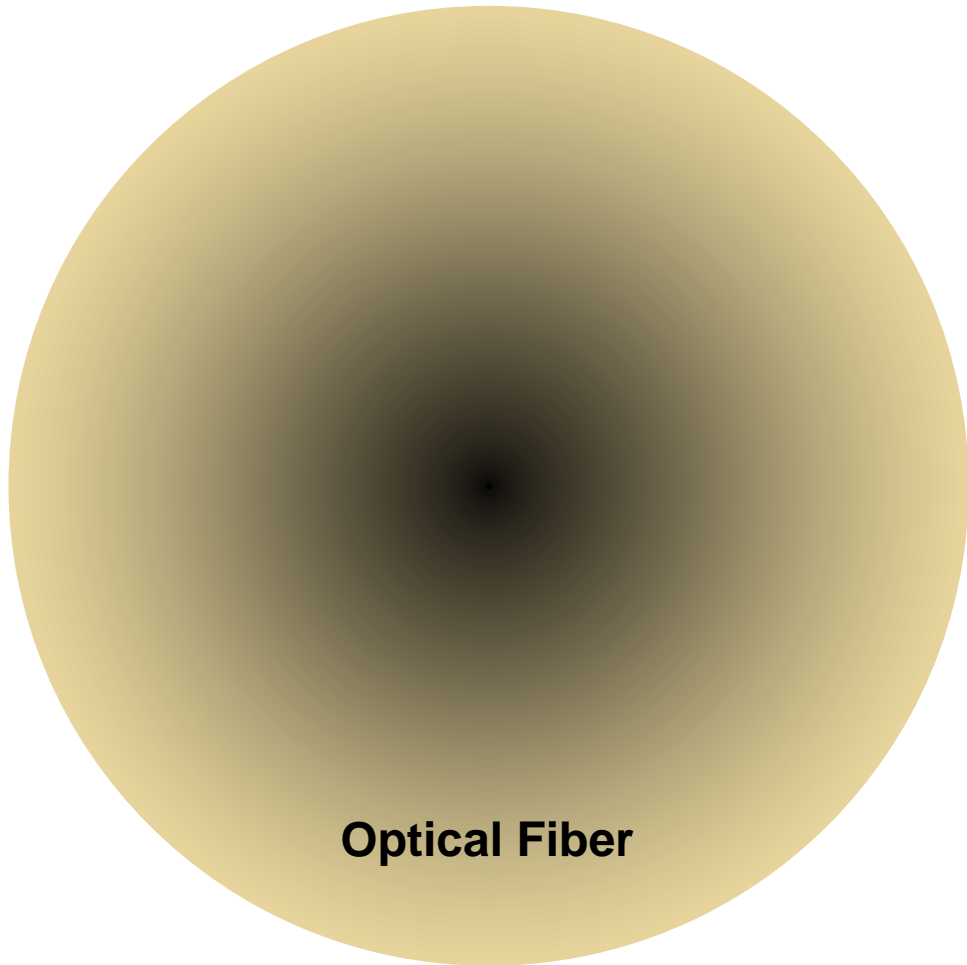
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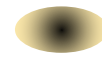
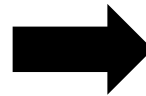


**Bring your optical system on-chip!**

# 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

# 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 absorption	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...

# PIC value chain

## Foundries

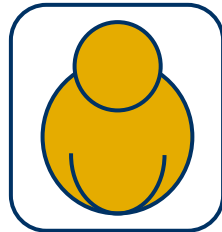
- Multi-Project-Wafer run
- Dedicated run

PDK

Process Design  
Platform

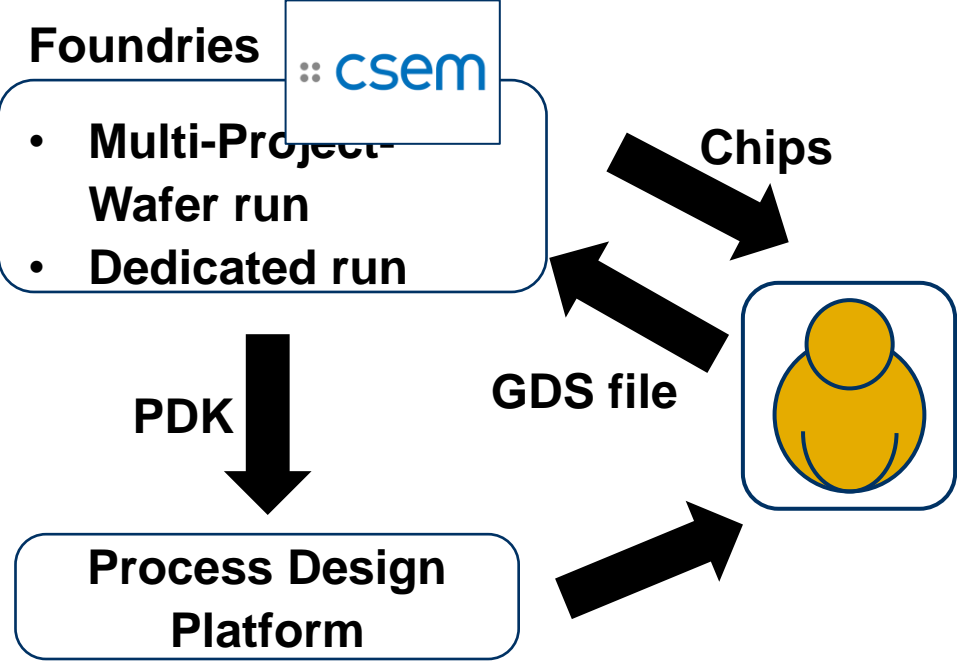
GDS file

Chips

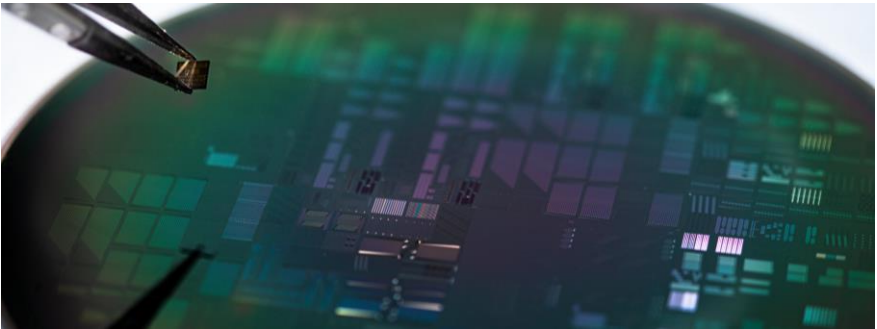
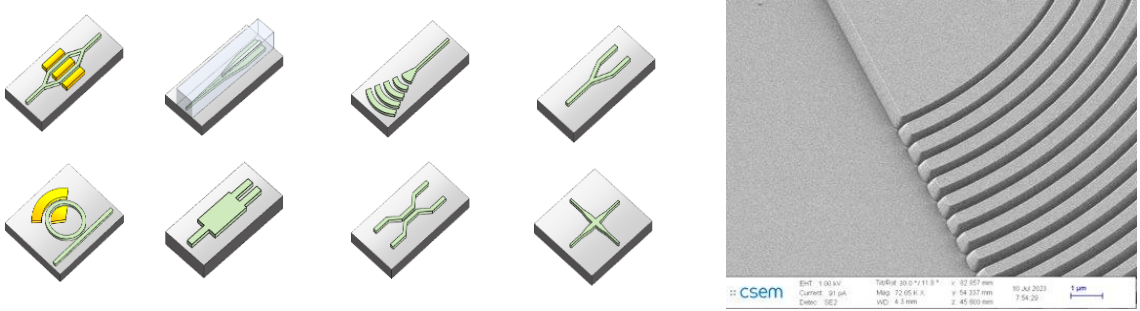
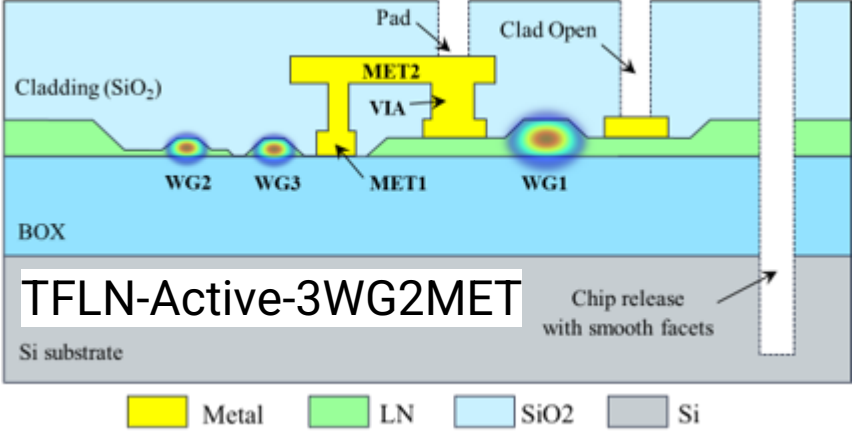




# PIC value chain



## LNOI Open access foundry



# PIC value chain

## Foundries

- Multi-Project-Wafer run
- Dedicated run

Chips

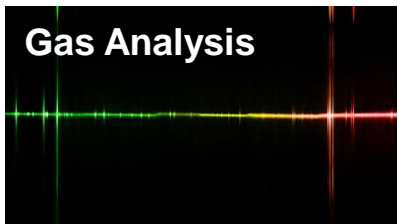
csem

GDS file

PDK

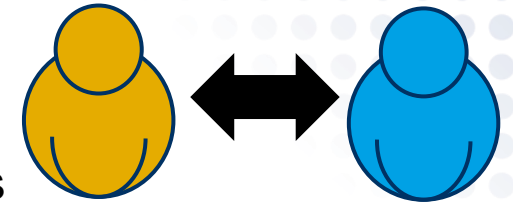
Process Design Platform

## Laser Systems for



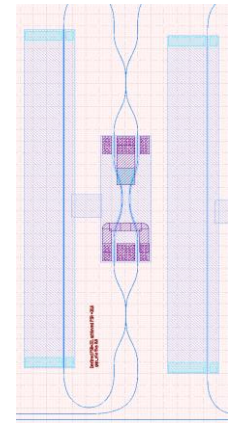
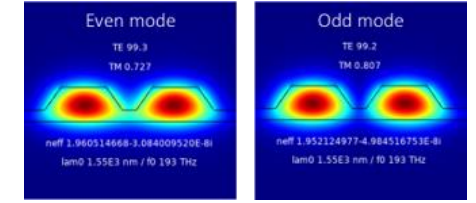
## Consultancy

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



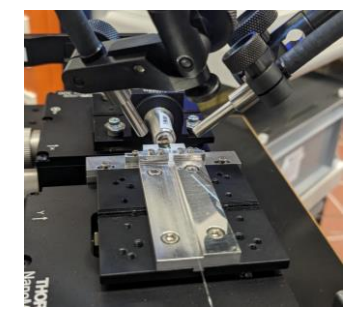
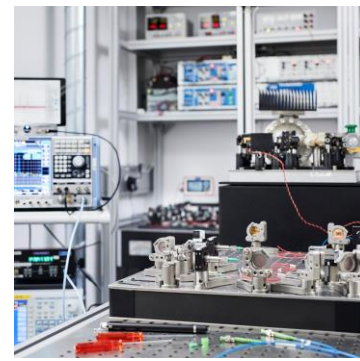
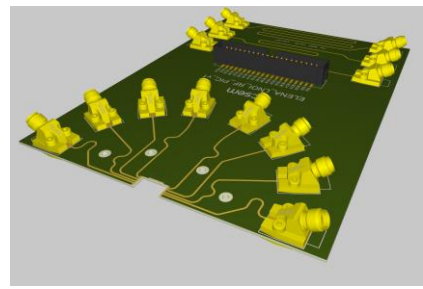
## Design

- Physical simulation
- Layouting

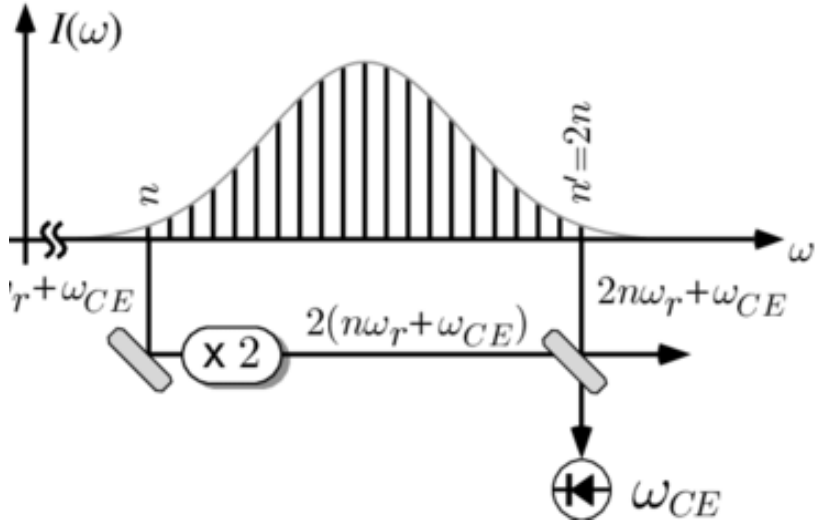


## Prototyping & Testing

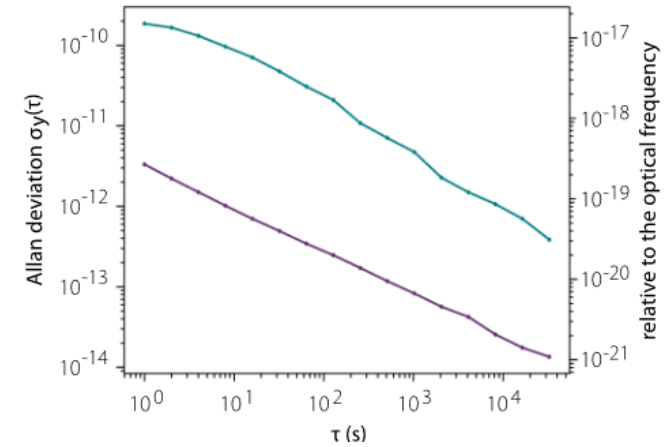
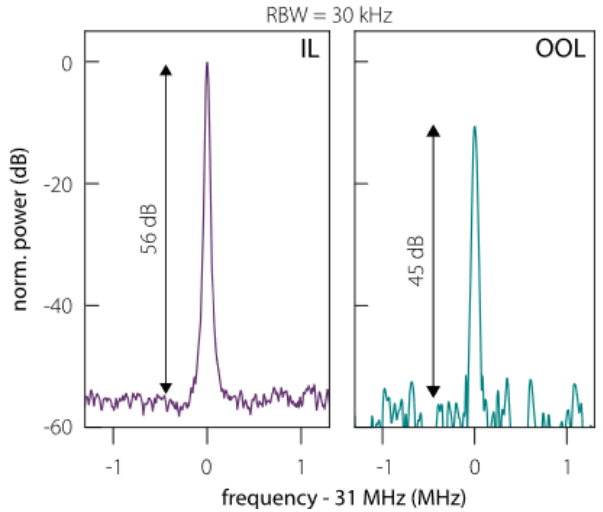
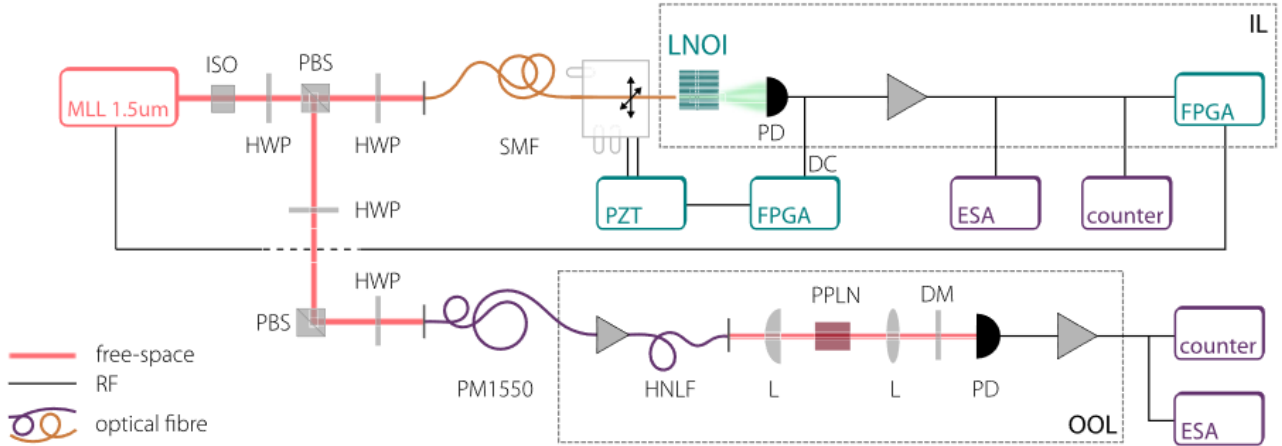
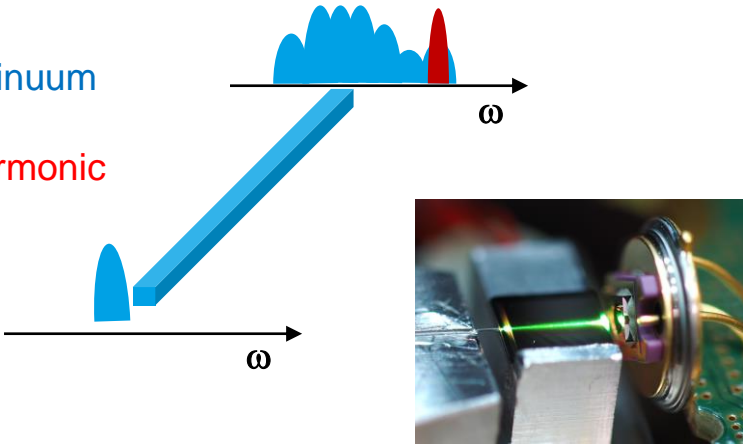
- Linear & non-linear Optics (VIS - MIR)
- RF & Electro-Optic testing (up to 50 GHz)
- Laser metrology



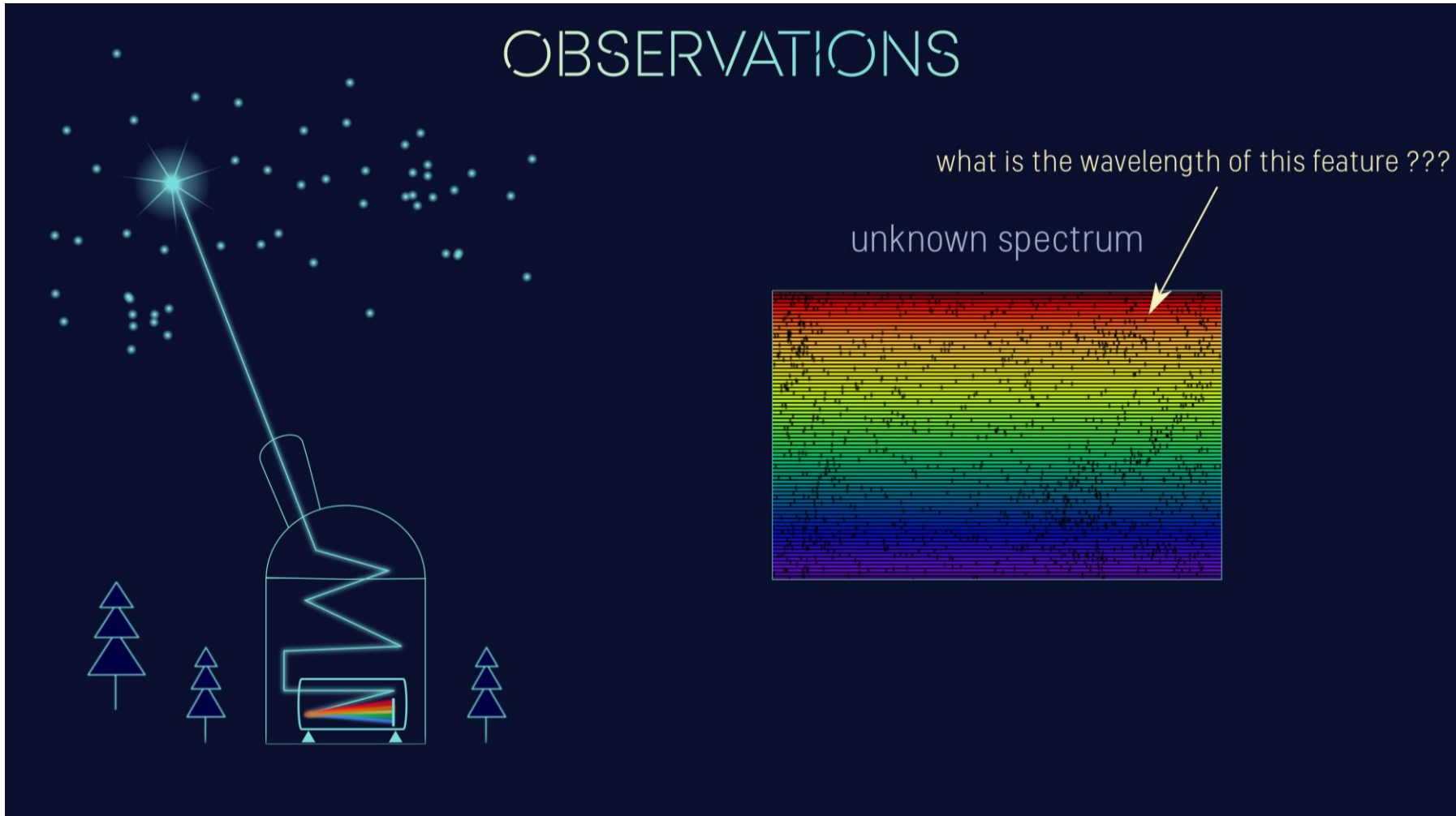
# Self-referencing of Optical Frequency Combs



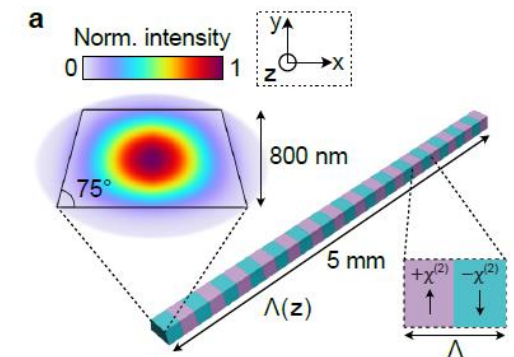
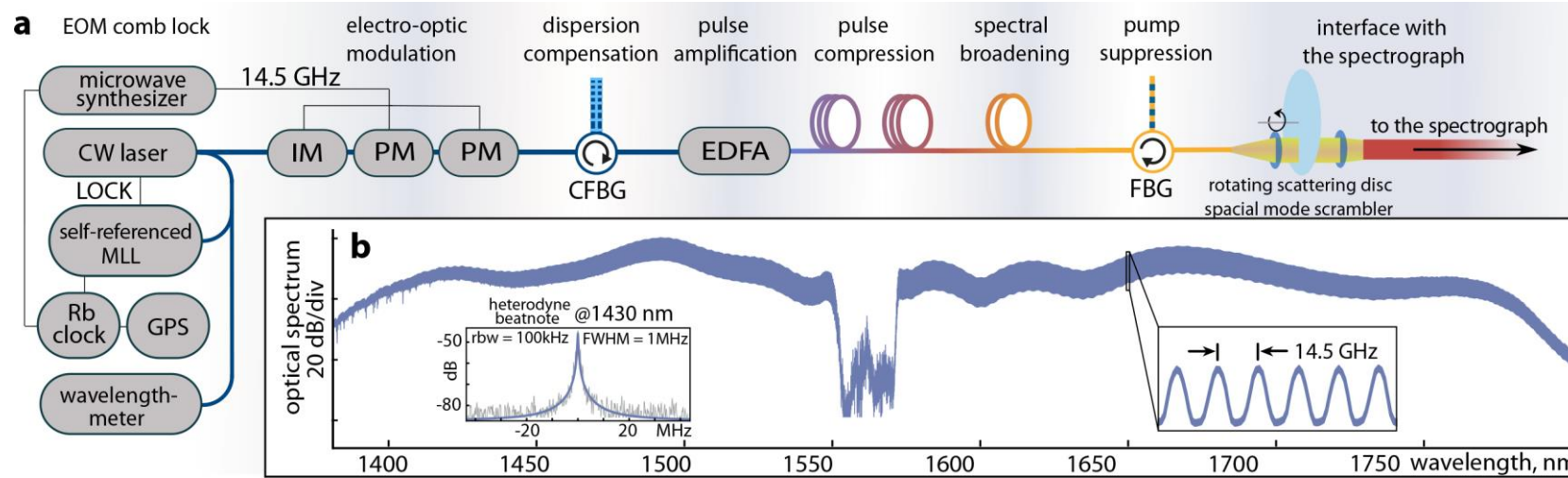
Supercontinuum  
+  
Second harmonic



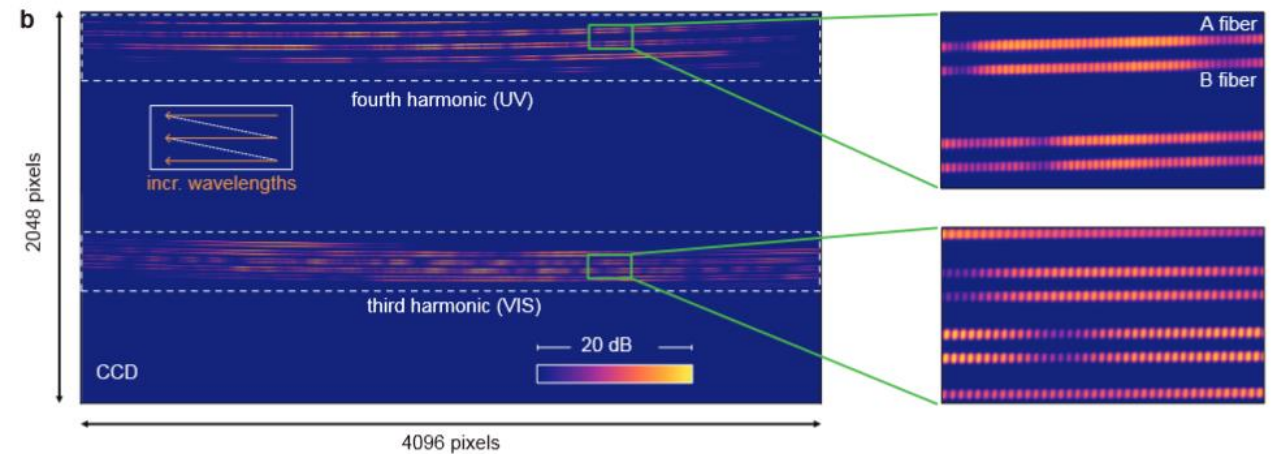
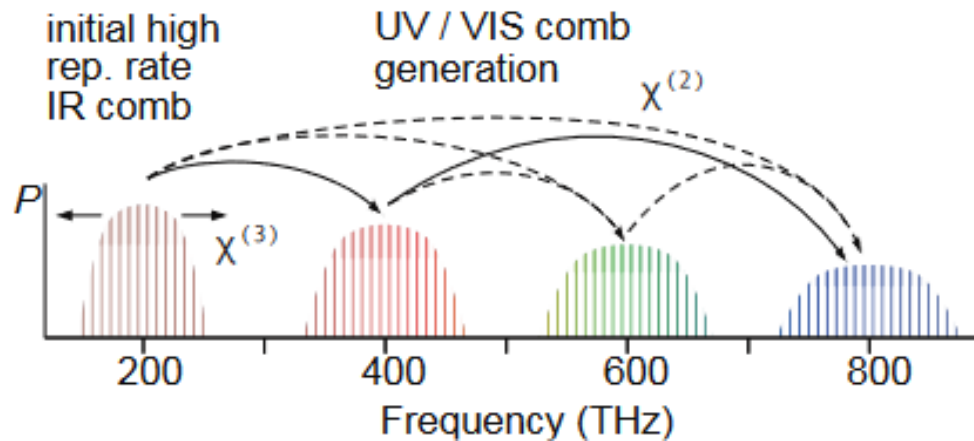
# Astrocombs towards VIS-UV



# Astrocombs towards VIS-UV



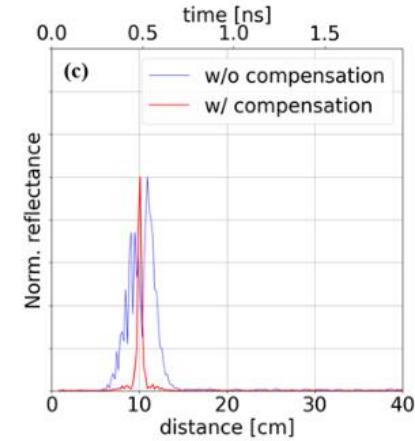
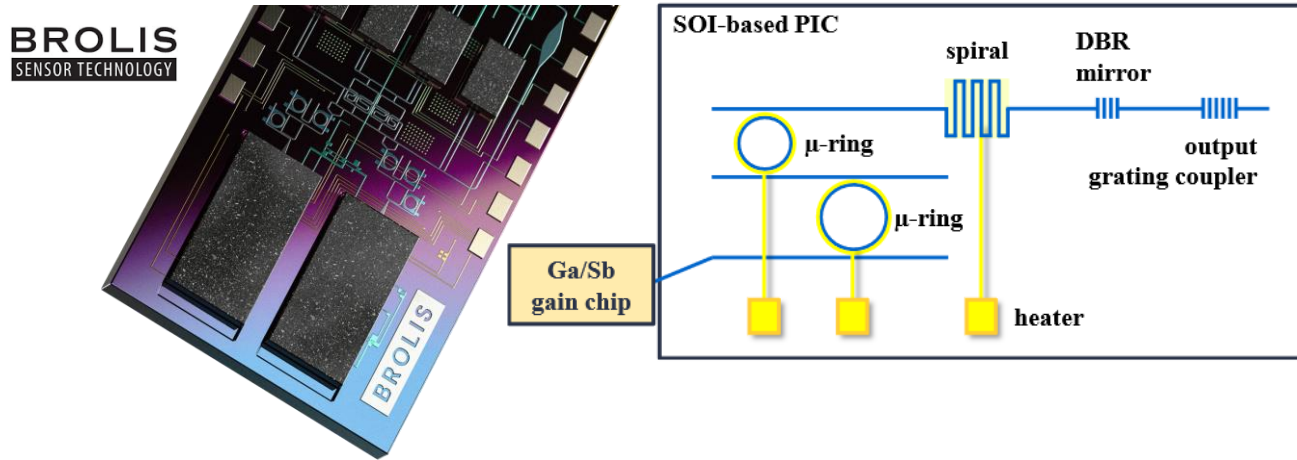
E. Obrzud et al., " Opt. Express **26**, 34830-34841 (2018)



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

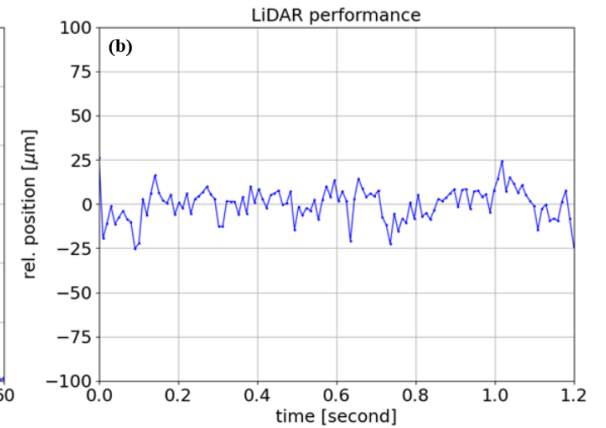
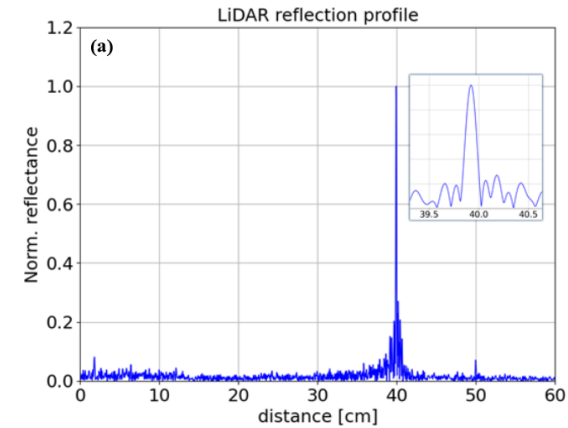
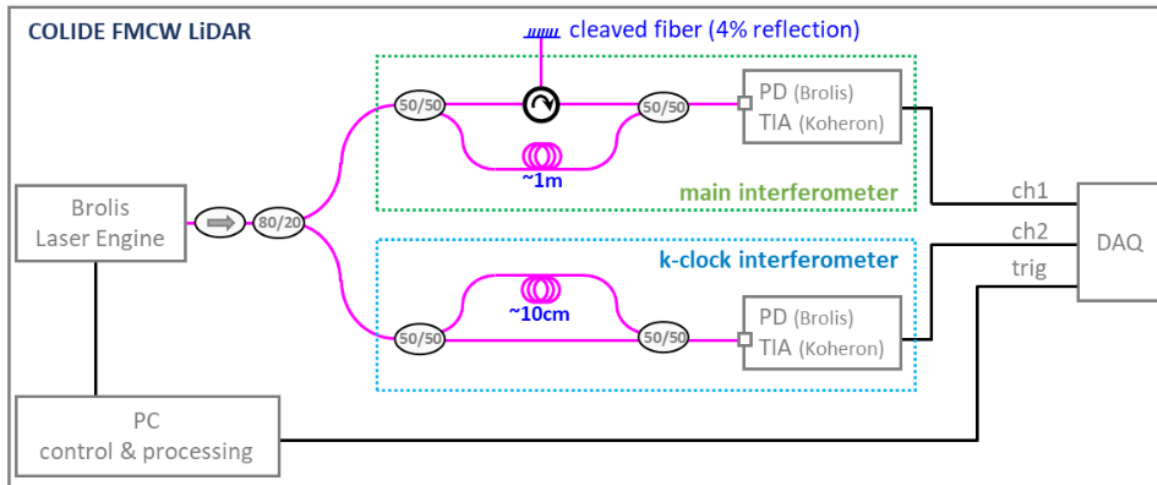
# On-Chip Laser for LIDARs

Laser characterization and performance evaluation in a FMCW Lidar system



## Characterization

- Laser linewidth
- Lidar Axial Resolution
- Lidar Ranging precision



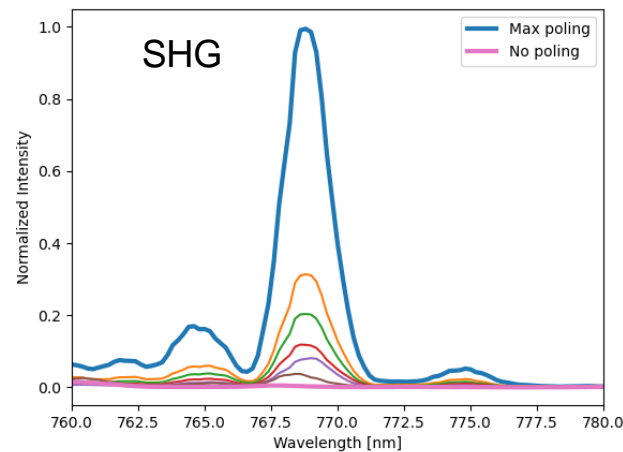
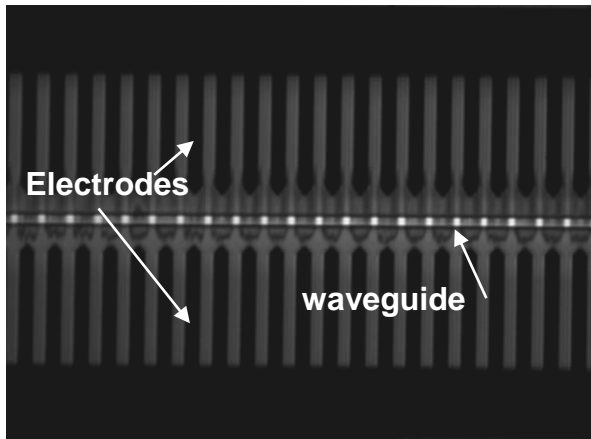
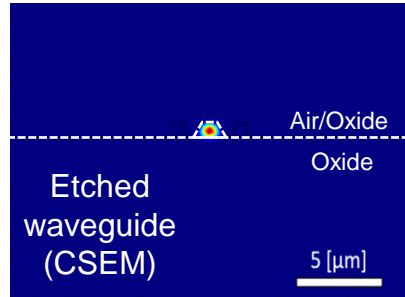
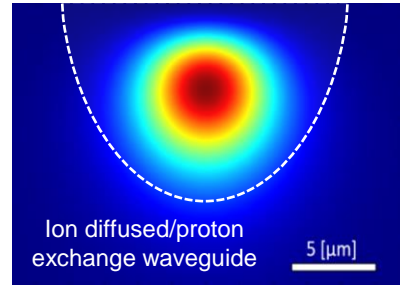
# UNDER DEVELOPMENT

## Periodically poled TFLN waveguides

### → Laser frequency conversion

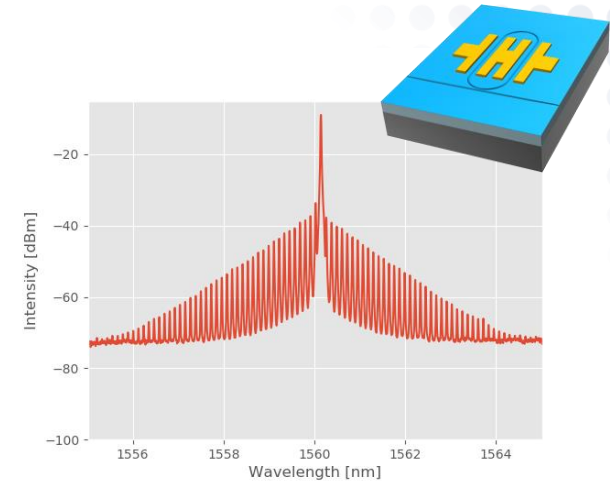
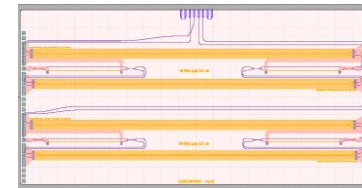
- Quantum sensors
- Nonclassical state-of-light
- Spectroscopy/Sensing

PPLN Type	Internal SHG efficiency @ 1550 nm [%/W cm <sup>2</sup> ]
Bulk crystal	~ 5
RPE waveguide	~ 15
Ridge waveguide	~ 80
LNOI waveguide	~ 500 (CSEM) (> 4000 (Theory))



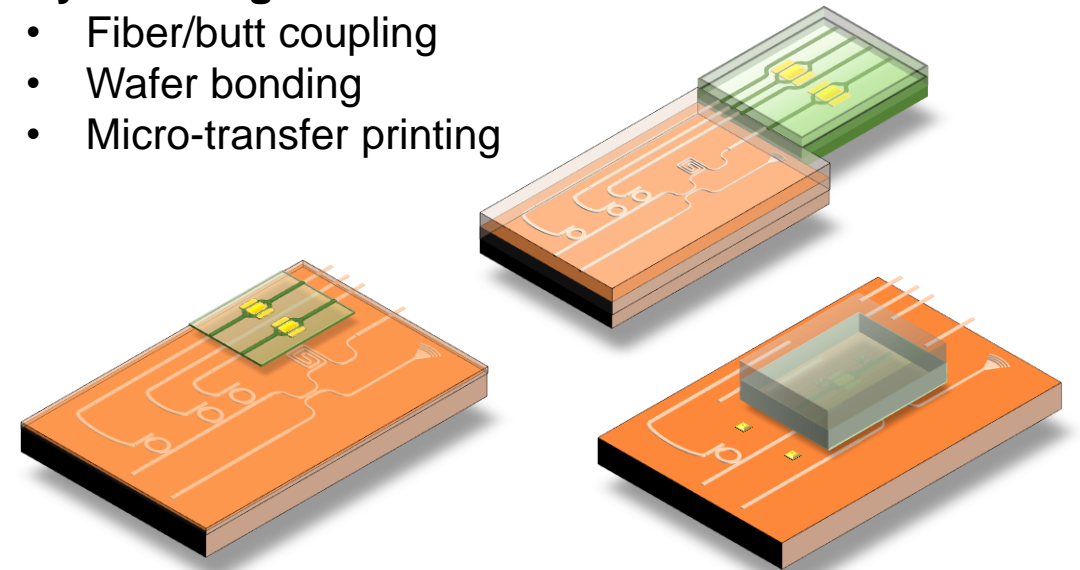
## Electro-optic frequency combs on TFLN

- Astrocombs
- Telecom laser sources
- Spectroscopy/Sensing



## Hybrid integration

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



# RUNNING PROJECTS & PARTNERS

TFLN Foundry	<b>ELENA<sup>IX</sup></b> Lithium Niobate PICs for Europe	:: csem	soitec	VPIphotonics	ETH zürich	vanguard AUTOMATION
		THALES Building a future we can all trust	III-V lab	Rosenberger	UP	leti OS2 Tech
LiDAR	<b>PATTERN</b>	:: csem	LUCEDA	phix	Fraunhofer HMI	imec GHEENT UNIVERSITY
		THALES Building a future we can all trust	cnrs	microwave PHOTONICS	UP	UCL
Telecom	<b>LOLIPOP</b>	ETIZEX IGCS	LionIX INTERNATIONAL	:: csem	phix	imec
		SUPERLUM	UNIVERSITY OF TWENTE.	Polytec	QUIX QUANTUM	IRIDA LABS
Quantum Technology	<b>sprinter</b>	ETIZEX IGCS	LionIX INTERNATIONAL	imec	uc3m Universidad Carlos III de Madrid	Fraunhofer HMI
		:: csem	ERICSSON	Fiil	Cumucore	INTRACOM INTECOM
Quantum Technology	<b>CLUSTEC</b>	DTU Technical University of Denmark	:: csem	Palacký University Olomouc	UNIVERSITÄT HEIDELBERG Zentrum für SIT 1286	
		Q.ANT	JOHANNES GUTENBERG UNIVERSITÄT MAGDEBURG	SDU University of Southern Denmark	SORBONNE UNIVERSITÉ	
Quantum Technology	<b>UTP4Q QUANTERA</b>	GHEENT UNIVERSITY	:: csem	UNIVERSITÄT DUISBURG ESSEN	Sparrow Quantum	UNIVERSITÄT ZÜRICH SIT 1286
					University of Jyväskylä	
Quantum Technology	<b>QUANTIFY</b>	INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA	ICFO	GHEENT UNIVERSITY	THALES Building a future we can all trust	le cnam
		:: csem	cnrs	LionIX INTERNATIONAL	SORBONNE UNIVERSITÉ	QUIX QUANTUM



# 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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SCHWEIZERISCHER NATIONALFONDS  
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