



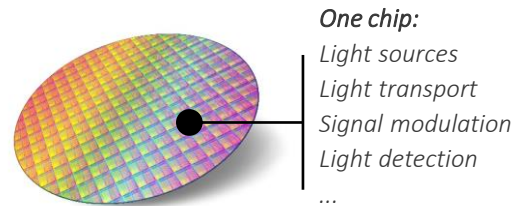
# PUTTING LIGHT INTO YOUR CHIPS: HETEROGENEOUS INTEGRATION OF INP PHOTONICS

Nov 14th 2023 – Ruud Vullers – Director R&D







# INTEGRATED PHOTONICS HELPS SOLVE MAJOR SOCIETAL ISSUES

## Integrated photonics will address issues

Photonic integrated circuit (PIC) integrate multiple photonic functions, like electronic ICs but **with light instead of electrons...**



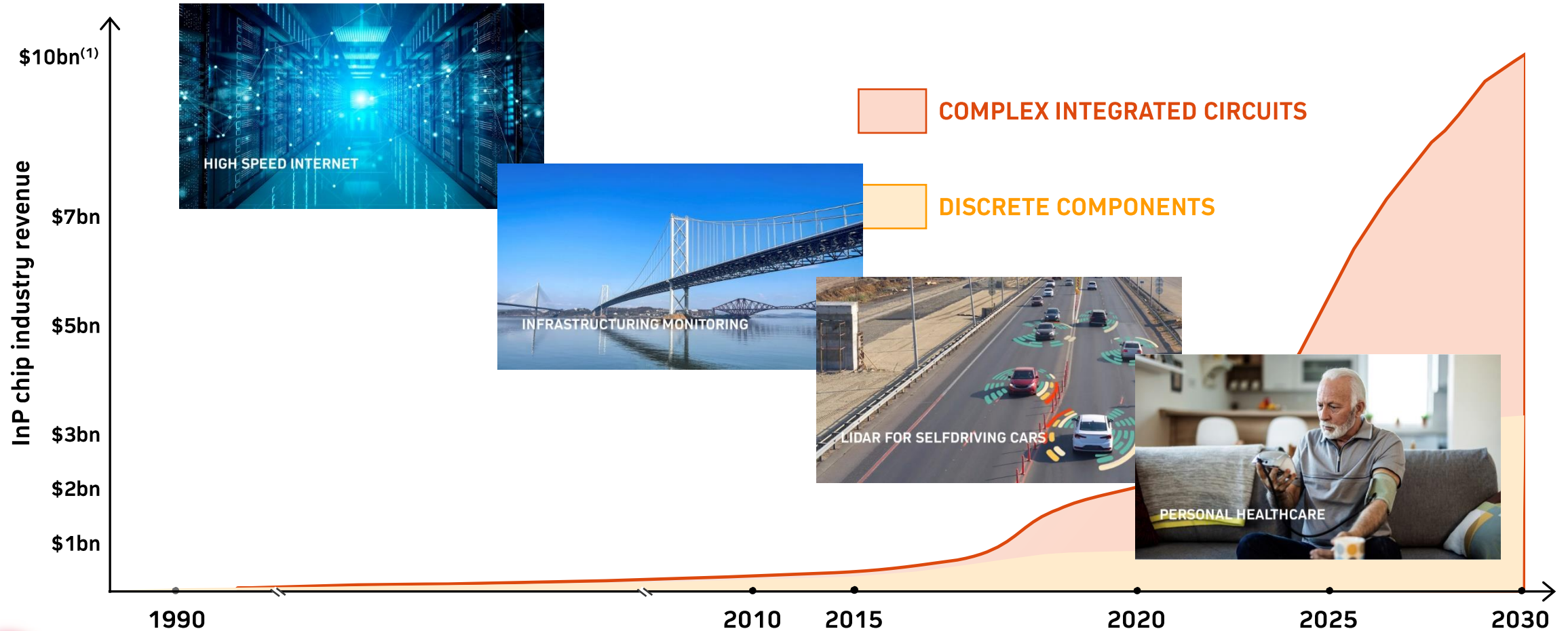
... which has many advantages over incumbents

 <b>More data</b>	 <b>Increased speed</b>	 <b>Increased reliability</b>
 <b>Less power consumption</b>	 <b>Lower cost</b>	 <b>Small form factor</b>

## In large and fast growing markets...



# GROWING MARKET AND GROWING COMPLEXITY



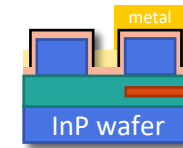
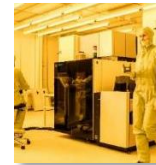
# MANY PARALLELS WITH ELECTRONICS

## 1 Integration enables new applications



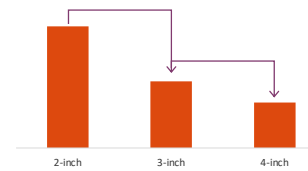
## 2 Manufacturing process

*Planar process and tool overlap*



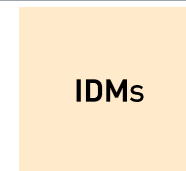
## 3 Economies of scale

*Cost reduction drives adoption*

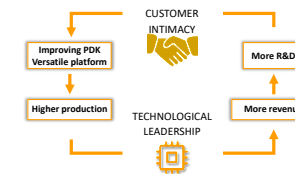


## 4 Industry structure

*Specialization within value chain*



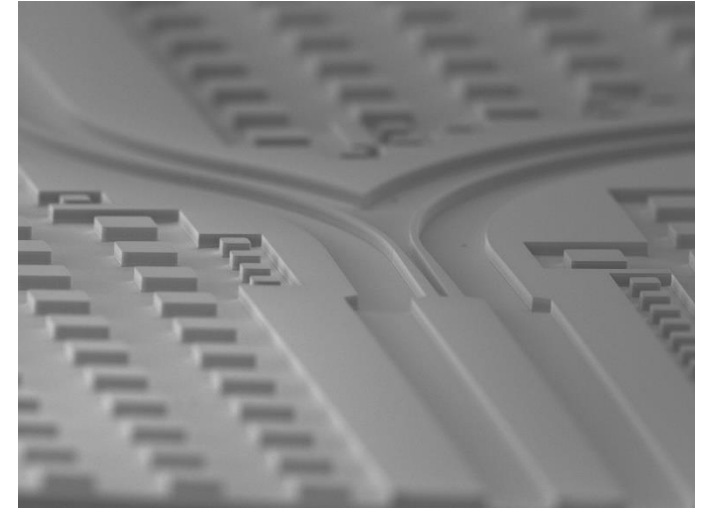
## 5 Foundry Technology/Customer flywheel





# SMART PHOTONICS: PURE PLAY FOUNDRY

## InP PIC Production Line and PDK



- Open Foundry – manufacturing services for InP wafers based on customers' designs
- Processes and capacity for supporting customers from prototype to volume

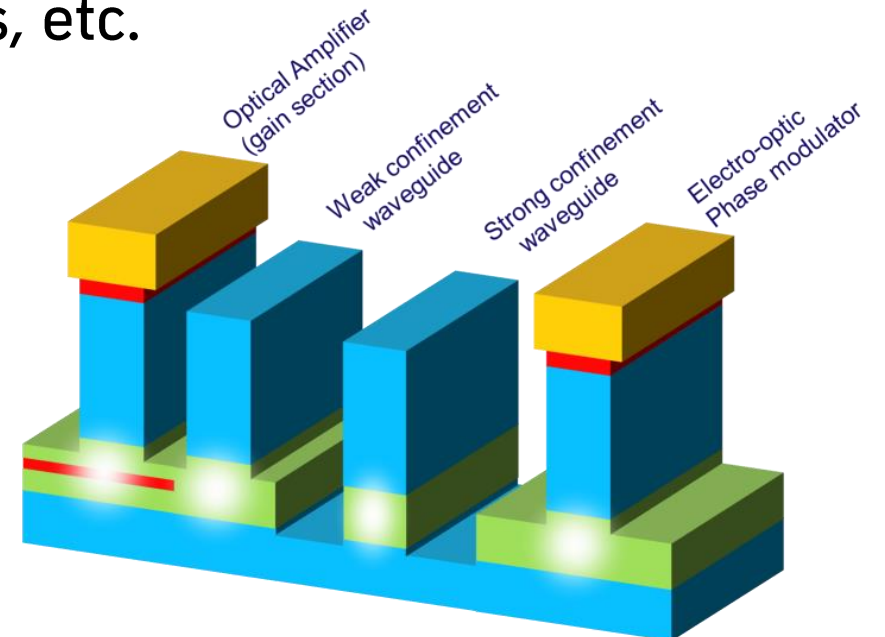
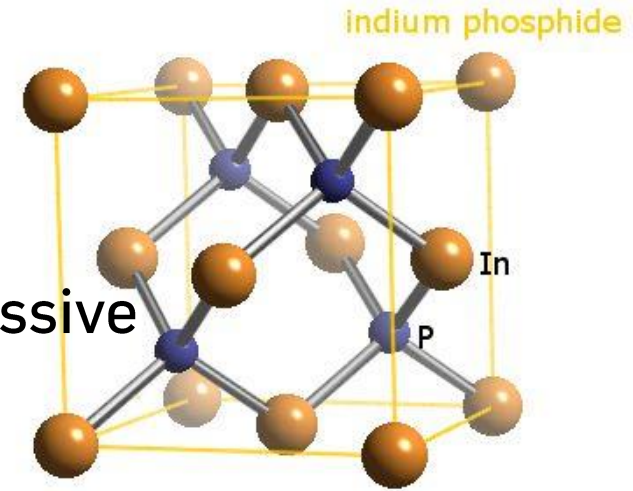
✓ **4" Volume  
Production**

✓ **Validated  
PDKs**

✓ **EU based**

# INP IS KEY TO SUCCESS!

- Only material suited for lasers and amplifiers
- Butt-joint integration: no compromise between active and passive components
  - Actives: lasers, amplifiers
  - Modulators: high speed phase and amplitude modulation
  - Passives: connecting waveguides, splitters, etc.
- Full on-wafer electrical testing
- Enabler for low-cost integrated circuits!



# MULTIPLE PLATFORMS WITH DIFFERENT STRENGTHS

CRITERIA	InP	Si Photonics	
		Si	SiN
Passive components	■ ■	■ ■	■ ■ ■
Active components	■ ■ ■	×	×
Modulator speed	■ ■ ■	■ ■	■ ■
Industrial infrastructure	■	■ ■ ■	■ ■
Current wafer size	3-4"	8"	4-8"
Standard equipment	■ ■ ■	■ ■ ■	■ ■ ■

**PERFORMANCE**

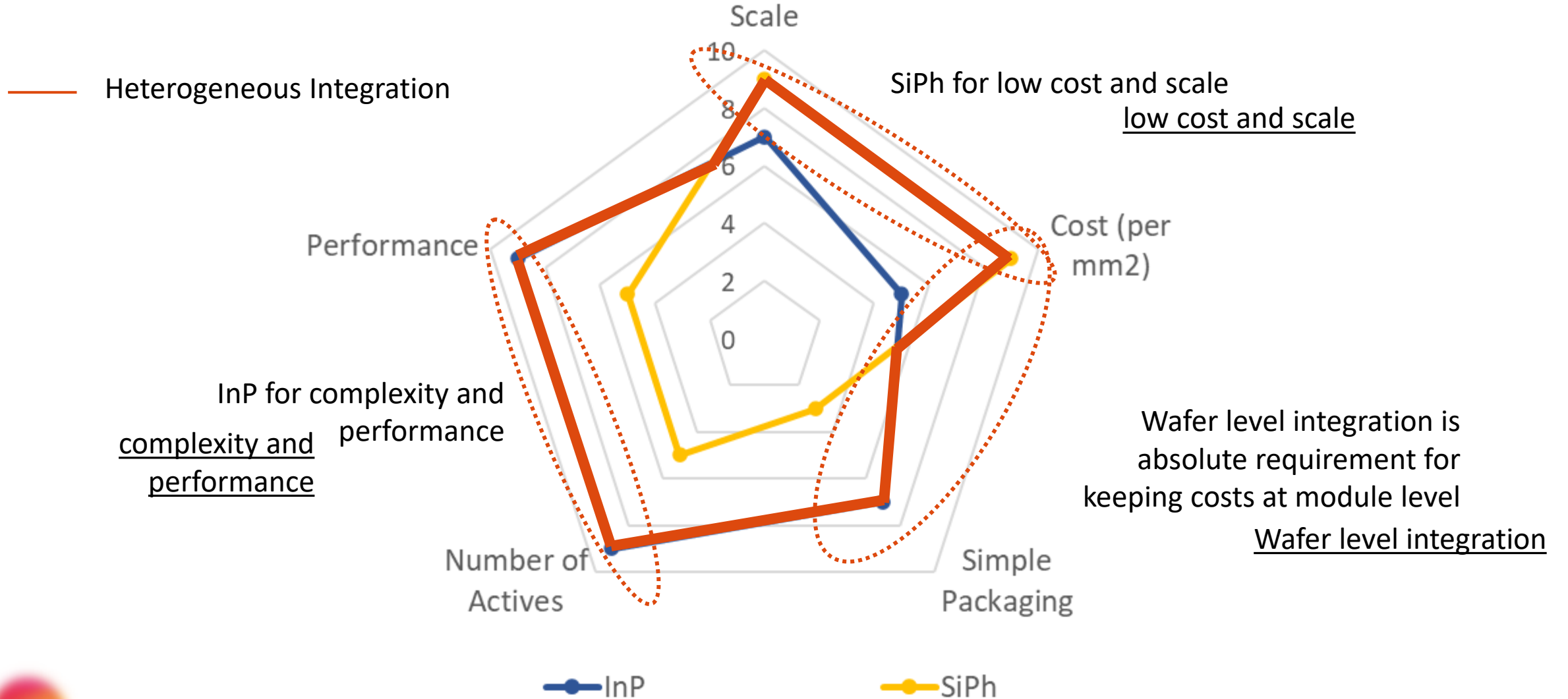
■ ■ ■ Very good

■ ■ Good

■ Modest

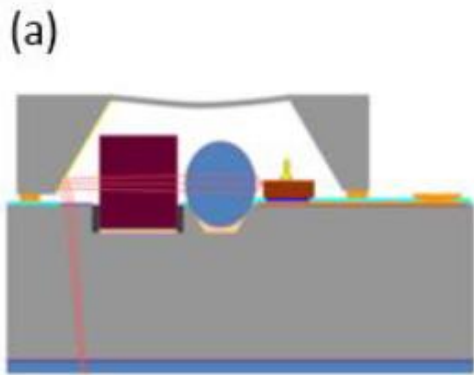
× Not possible

# COMPLIMENTARY PERFORMANCE

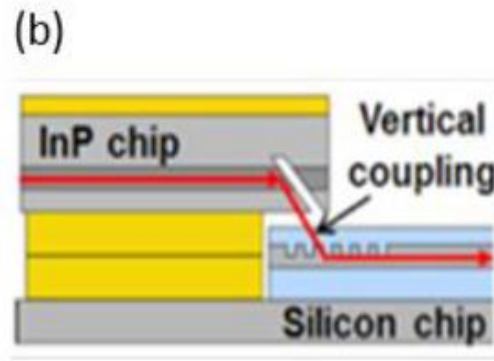




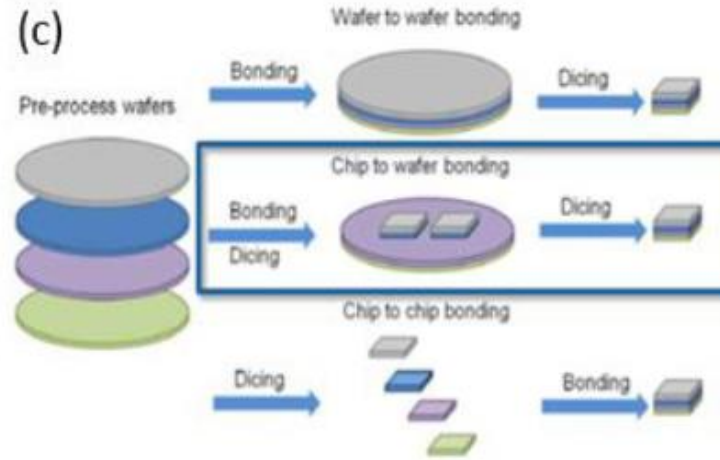
# METHODS FOR HETEROGENEOUS INTEGRATION



Laser micro package  
LAMP



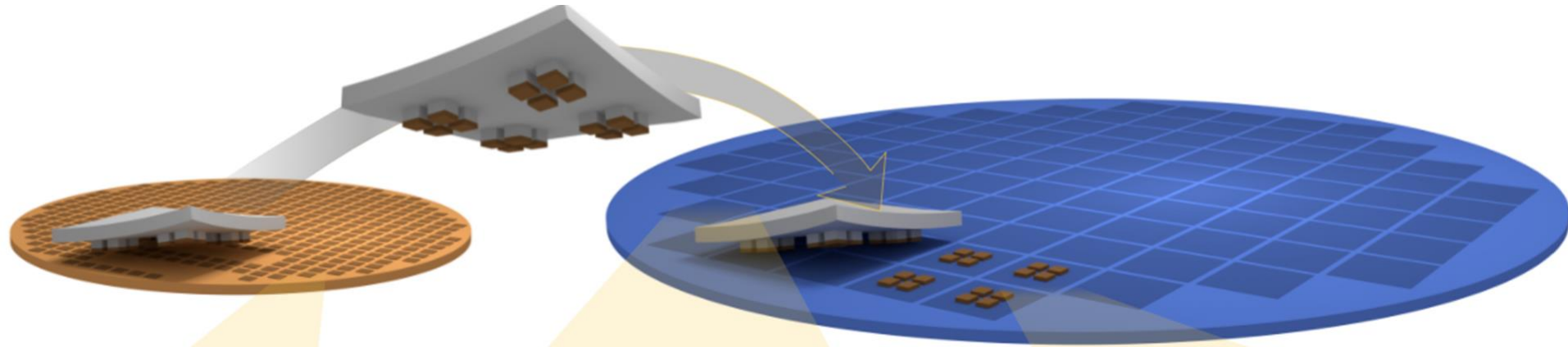
Flip-chip integration



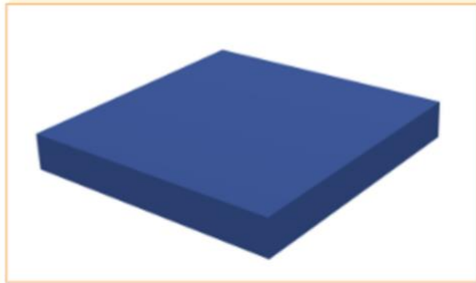
Wafer bonding

	LaMP	Flip-chip	Wafer-bond
InP PIC maturity	✓	✓	On target wafer
Optical coupling efficiency	✓	✓	✓
Waveguide in-out devices	None	✓	✓
Wafer level test and assembly	✓	✓	On target wafer
Burn in	✓	✓	On target wafer
Population of InP devices	Sequential	Sequential	✓
Laser performance	✓	✓	✓
Back end process integration	✓	✓	Substrate removal
Density and volume	Micro-optics	Solder pad limit	✓
Reduced barriers for new PICs	✓	✓	✓

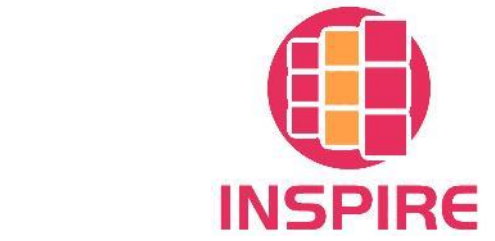
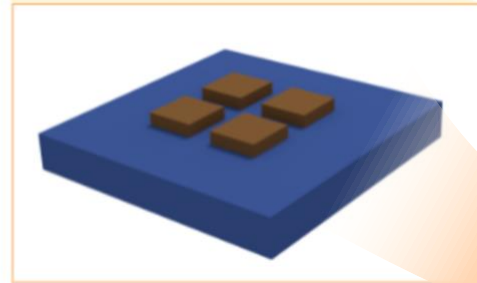
# INSPIRE: TECHNOLOGY DEVELOPMENT



InP PICs



Silicon Photonics wafer



AMIRÈS

THALES  
RESEARCH AND TECHNOLOGY



X-Celeprint



# TRANSFER PRINTING: COMBINING BEST OF ALL PLATFORMS



PIC platform attributes	Indium phosphide	Silicon Nitride	Silicon (CMOS) photonics	INSPIRE
Light sources and amplifiers	✓✓✓	✗	✗	✓✓✓
Electrical energy efficiency	✓✓	✗	✓✓	✓✓
Electro-optic speed	✓✓	✗	✓✓	✓✓✓
Optical connect efficiency	✓	✓✓✓	✓	✓✓✓
Optical signal integrity	✓✓	✓✓✓	✓	✓✓✓
Production scalability	✓	✓✓	✓✓✓	✓✓✓
Active device scaling	✓	✗	✗	✓✓
Passive device scaling	✓	✓	✓✓✓	✓✓
Hosting exotic materials	✓	✓✓✓	✗	✓✓✓
Route to 3D integration	✓	✓✓	✓✓✓	✓✓✓

Table 1.1: Attributes of established PIC platforms and the INSPIRE III-V/SiN platform. Red crosses ✗ indicate a platform deficiency, and single yellow ticks ✓ indicate a credible path is an active area of PIC development. Multiple green ticks ✓✓✓ indicate superior performance.

# NEXT STEP: PHOTONIXFAB



- Full EU-based photonics device value chain (started May 2023)
- Industrial manufacturing capabilities (3.5 Year, 48M€ budget)
- Path to high-volume manufacturing



See also EPIC presentations  
**X-fab** – *Enabling Photonics Product Innovation with a Path to High-volume Manufacturing* – Joni Mellin

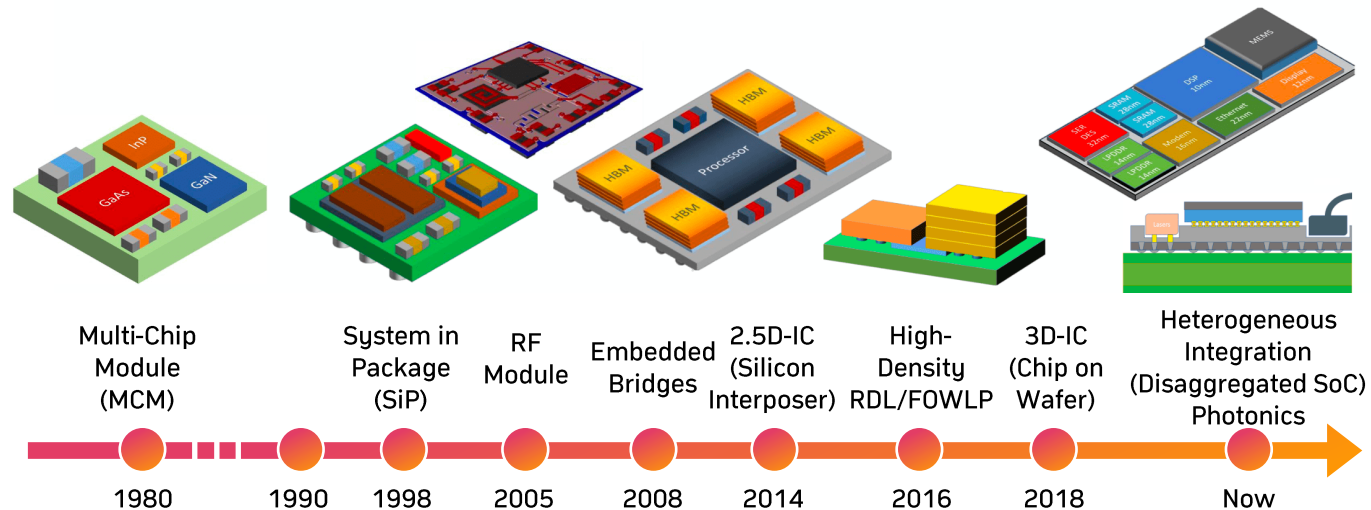
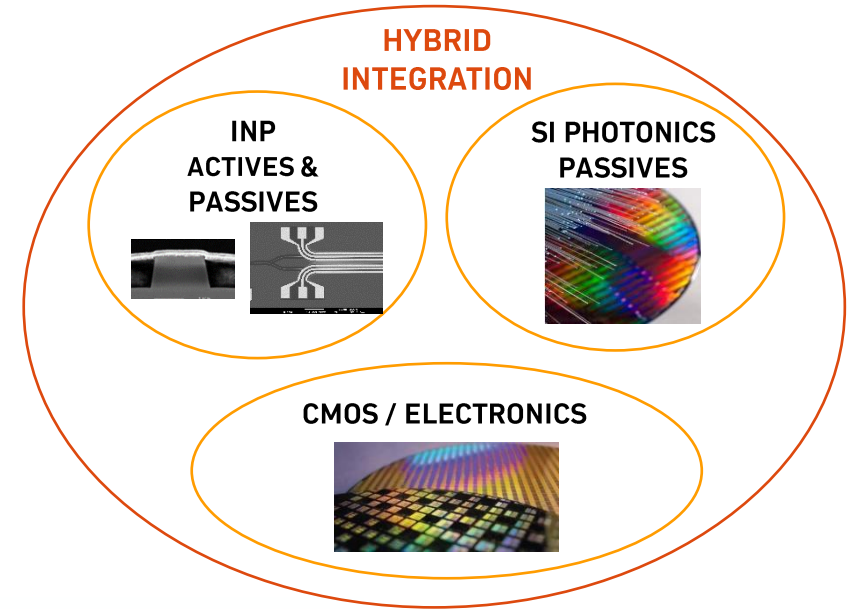


Co-funded by  
the European Union

<https://www.photonixfab.eu/>

# HYBRID INTEGRATION :PHOTONIC/ELECTRONIC

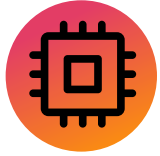
- Customers' demands drive improved performance
- Intimate integration needed
- Chiplet technology
- Multiple technologies in development for more intimate integration



Source: Cadence



# CONCLUSIONS



Integrated photonics: helps solving major worldwide challenges in large and high-growth markets



The industry has many parallels with electronics and is moving towards a horizontal value chain



Higher application demands drives the need for platform integration



SMART Photonics plays a key role in integrated photonics value chain



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