



## PHOTONIQUE ET PROCESEURS QUANTIQUES DE L'ELECTRONIQUE A LA LUMIERE

FIEEC #InnovTech | Laurent Fulbert | 16 Juin 2022

- **Introduction à la photonique intégrée sur silicium**

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- **Valorisation industrielle**

Yannick Paillard

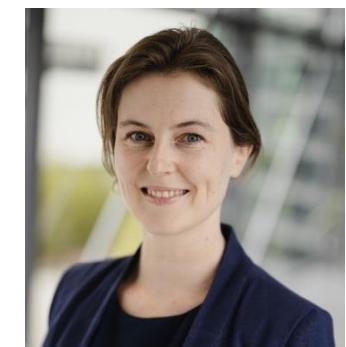
Directeur commercial et marketing  
Scintil Photonics

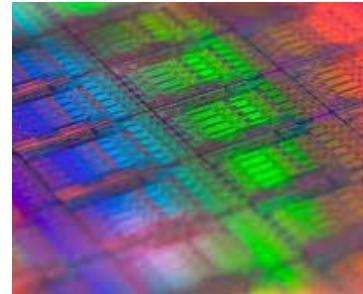


- **Applications émergentes**

Eléonore Hardy

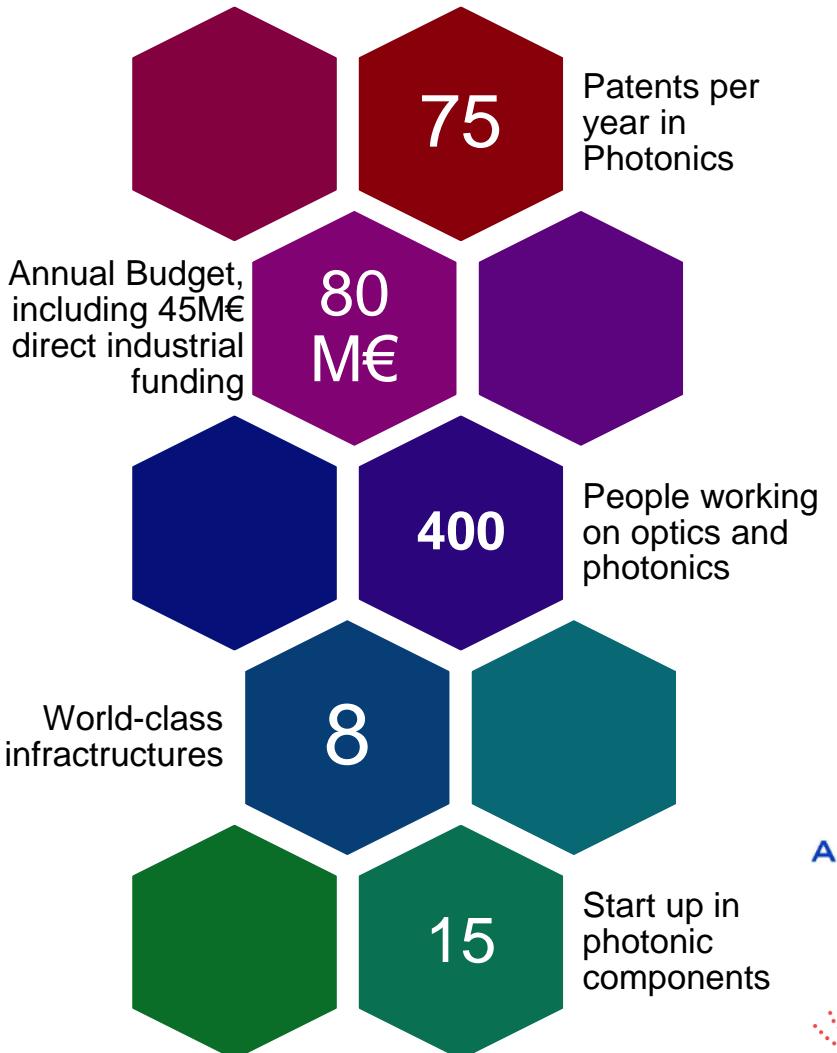
Responsable des partenariats en photonique silicium  
CEA-Leti





## INTRODUCTION À LA PHOTONIQUE INTÉGRÉE SUR SILICIUM

# PHOTONICS @LETI IN A FEW KEY FIGURES



## QUELQUES DÉFINITIONS

***“Photonics is the science of the harnessing of light. Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation and amplification and, most importantly, its utilization for the benefit of mankind”***

Pierre Aigrain

**“The 21<sup>st</sup> century will depend as much on photonics as the 20<sup>th</sup> century depended on electronics”**

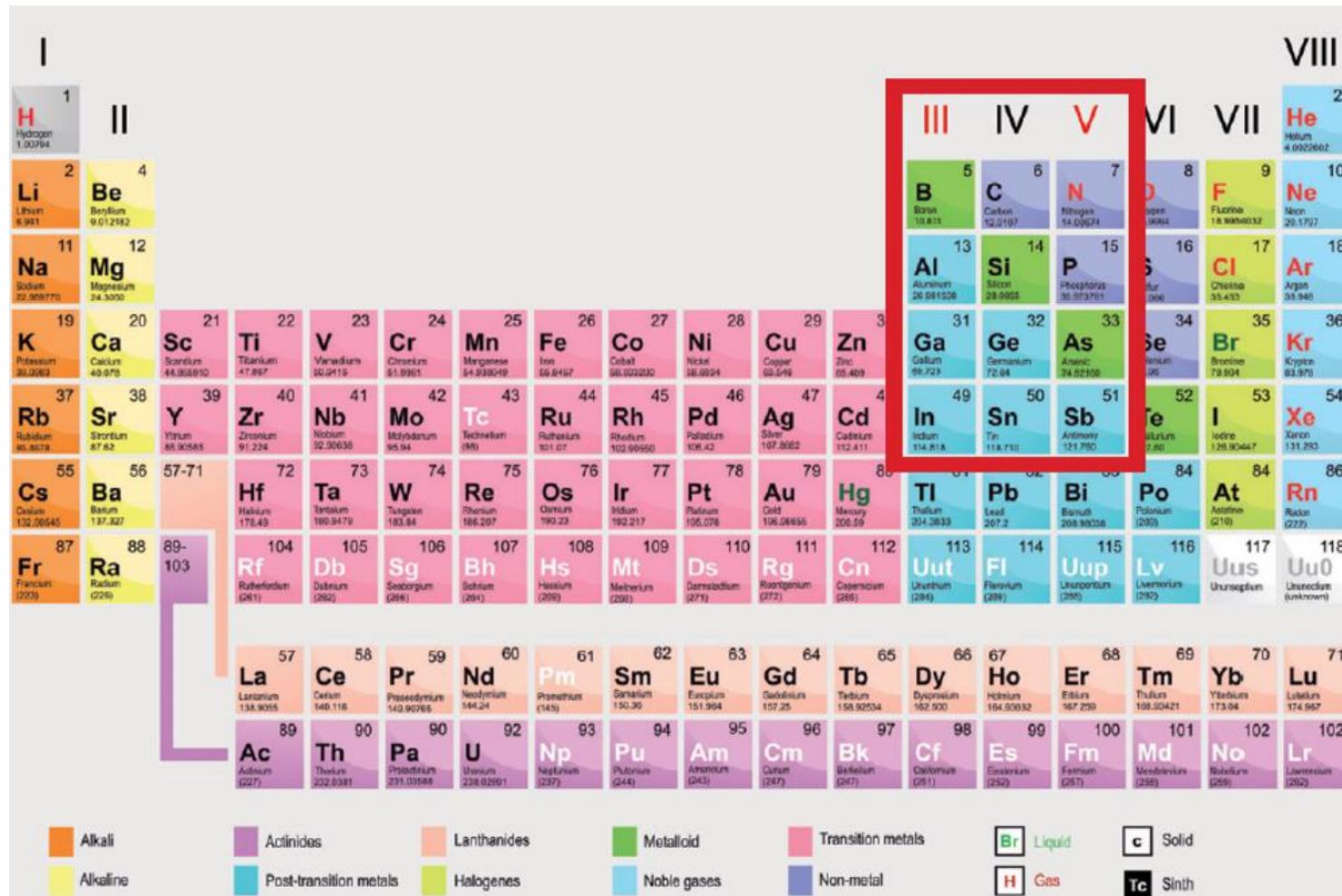
UNESCO

- **La photonique est partout, mais mal reconnue**
  - Optique
  - Optoélectronique
  - Optronique

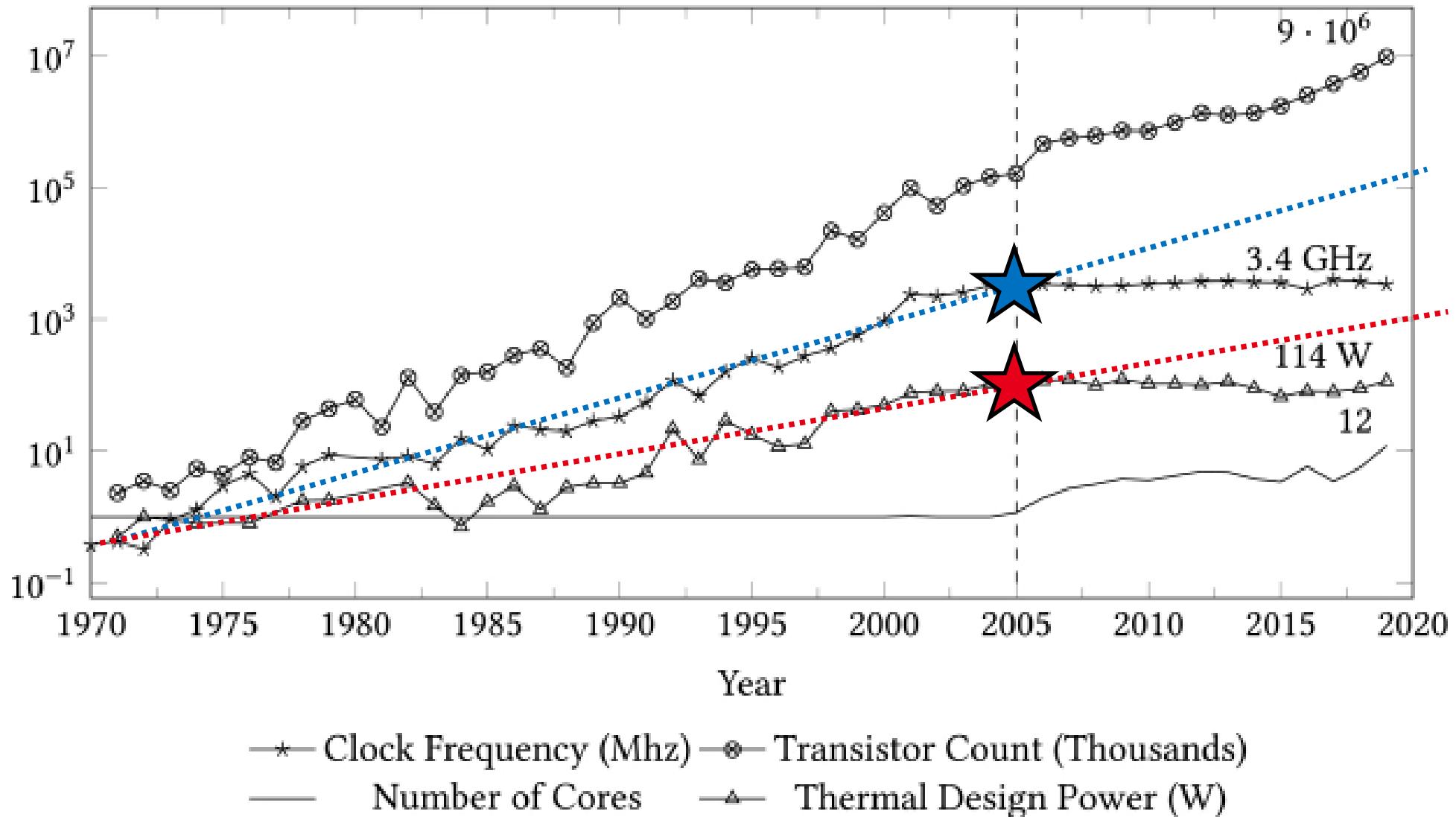
# QUELQUES PROPRIÉTÉS

- Familles de matériaux

- Silicium
- III-V
- II-V
- Verre
- Organique



## CPU TRENDS



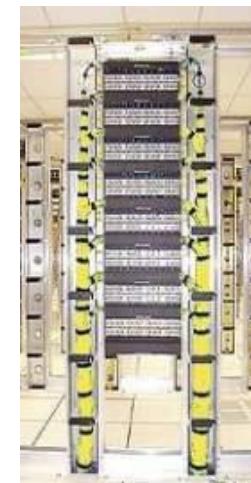
## WHAT ABOUT OPTICS ?

- **Benefits of optical links:**

- (almost) unlimited capacity: bandwidth x distance 1 million times larger than copper
- Low latency, excellent signal integrity
- Insensitive to EMI
- (Lower) power consumption, lower footprint
- Scalability through WDM

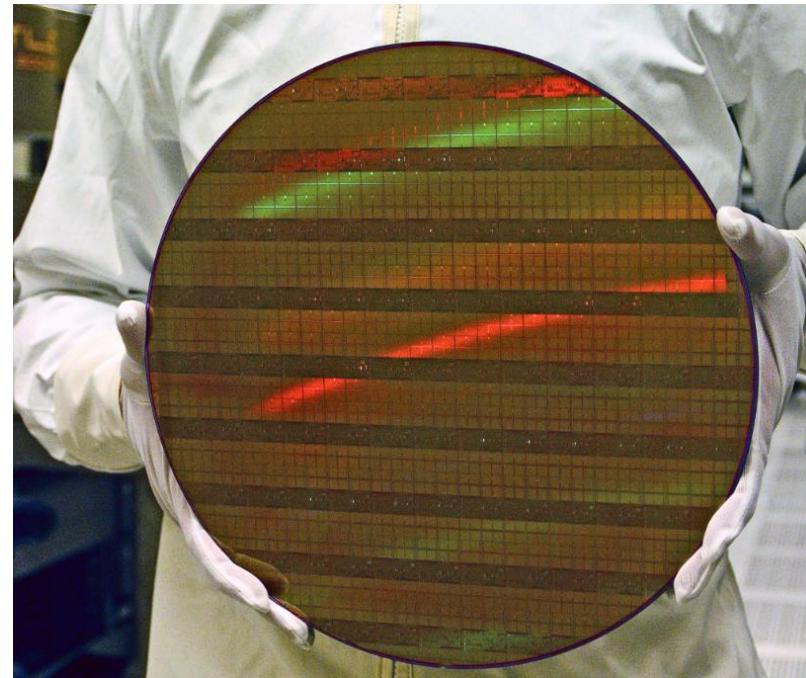


*Courtesy of IBM*



## WHY SILICON PHOTONICS ?

- **Silicon photonics aims at integrating in the silicon microelectronic CMOS technology optical functions initially based on other technologies (InP, InGaAs, LiNbO<sub>3</sub>, SiO<sub>2</sub>, ...)**
- **Need for integration is driven by:**
  - Miniaturization: cost&size reduction, power consumption
  - Increased complexity and functionnality

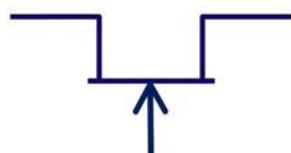


*300mm Si wafer*

# PHOTONIC INTEGRATED CIRCUITS

	Electronics	Photonics
Invention of key component (transistor/ semiconductor laser)	1947	1969
Semiconductor integration technology	1958	1987
Generic integration technology (MPWs)	1979	2008
Killer random defect densities reported $<1 \text{ cm}^{-2}$	1987	2010

## Electronic Building Blocks



Transistor



Resistor



Capacitor

## Electrical Connection

## Photonic Building Blocks



Optical Amplifier



Phase Shifter



Polarisation Converter

## Waveguide

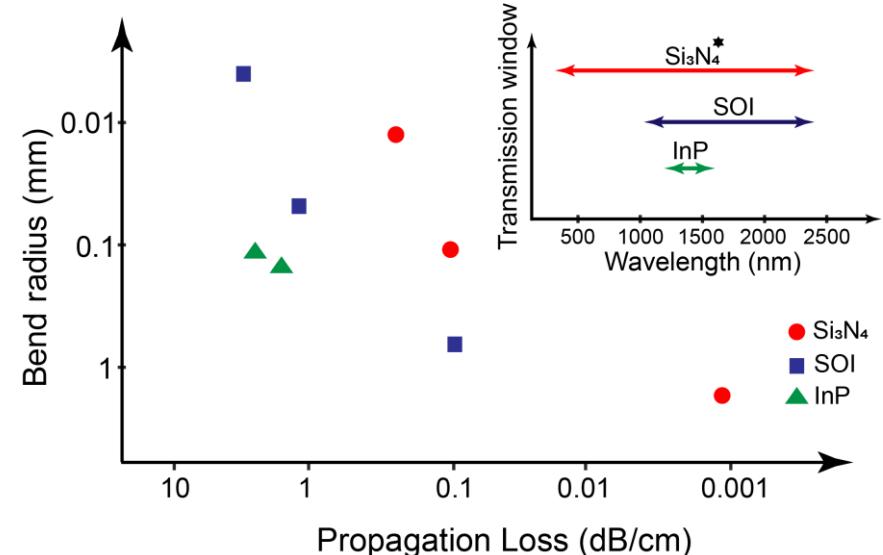
# OPTICS WITH SILICON ?

## • Pros

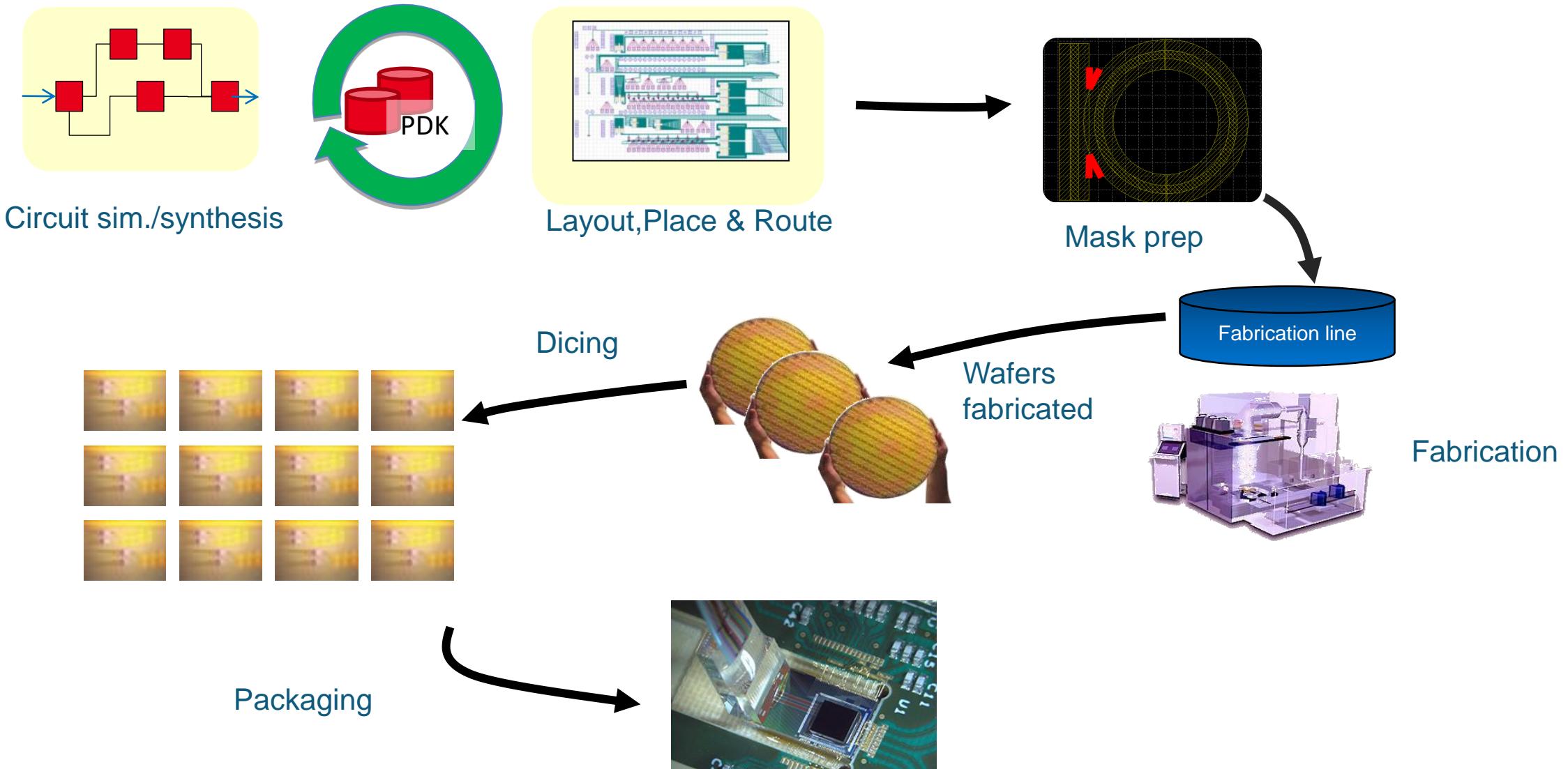
- Transparent in the near IR
- High index contrast = miniaturisation
- CMOS compatible
- Low cost

## • Cons

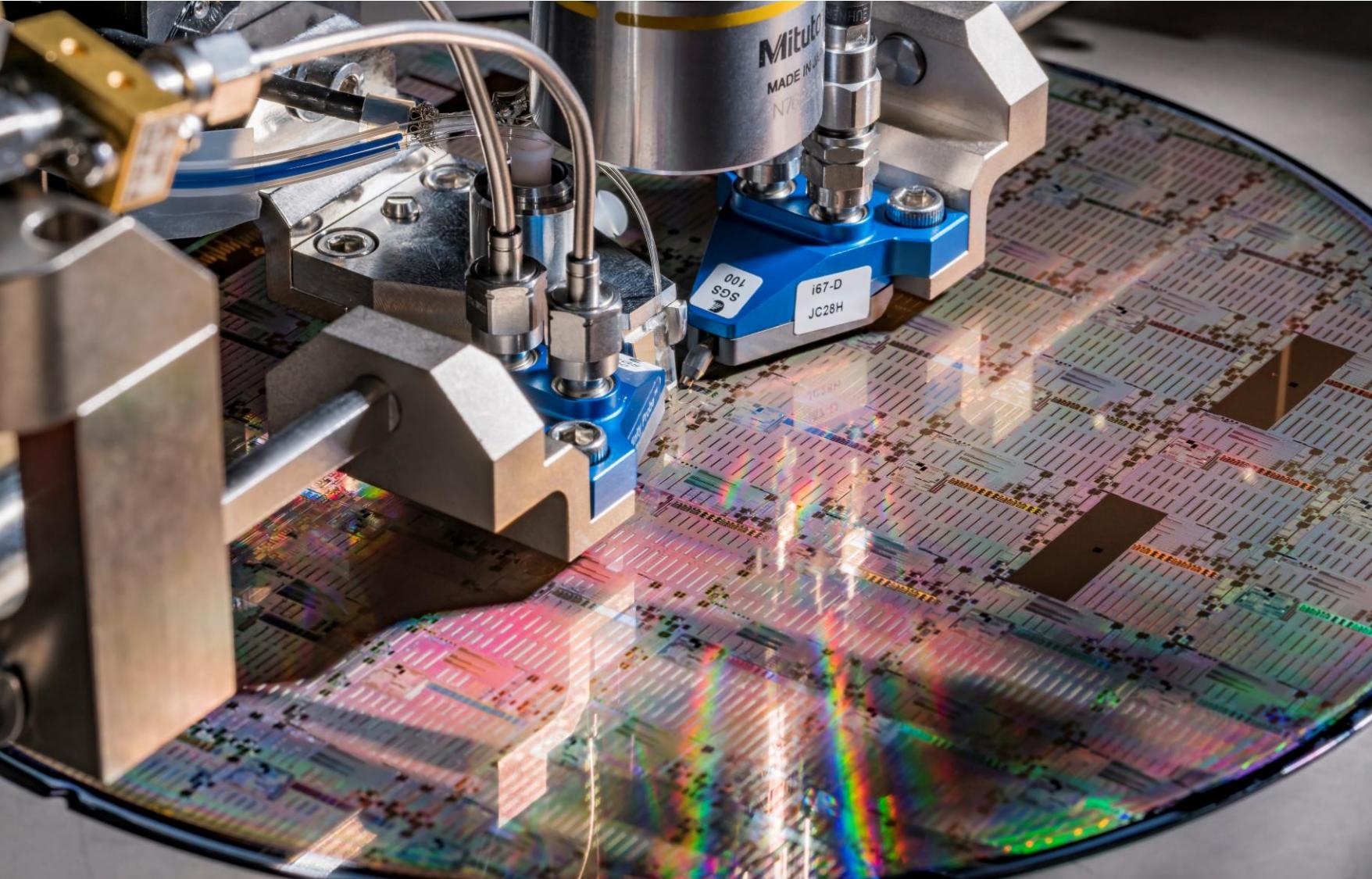
- No photodetection in  $1.2\mu\text{m}$  to  $1.6\mu\text{m}$  → Ge photodiodes
- High index contrast= coupling with fiber difficult
- No electro-optic effect → free carrier induced dispersion modulation
- No efficient light emission → external source or III-V/Si heterogeneous integration



# SUPPLY CHAIN SIMILAR TO MICROELECTRONICS

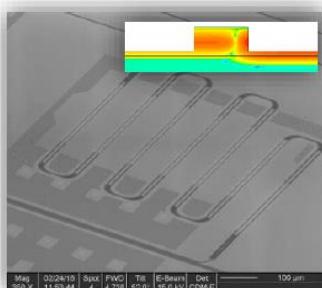
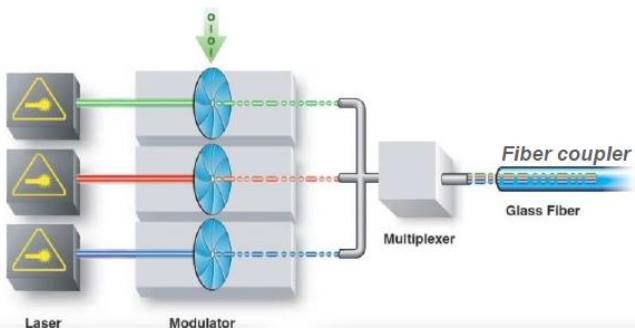


## WAFER LEVEL TESTING

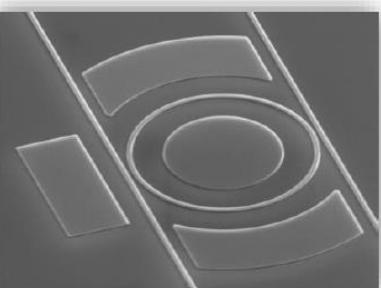


# KEY BUILDING BLOCKS AT 50GBPS

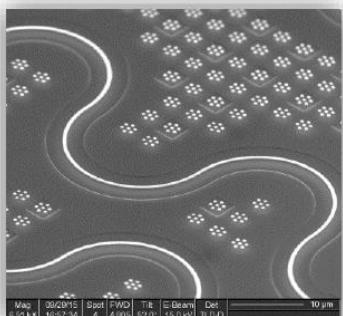
Emitter



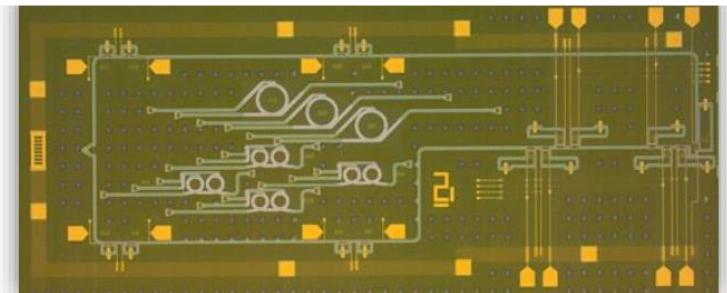
High speed modulator



Micro ring modulator

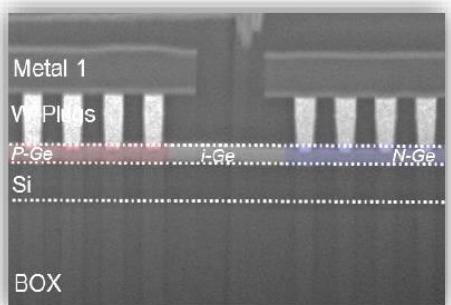
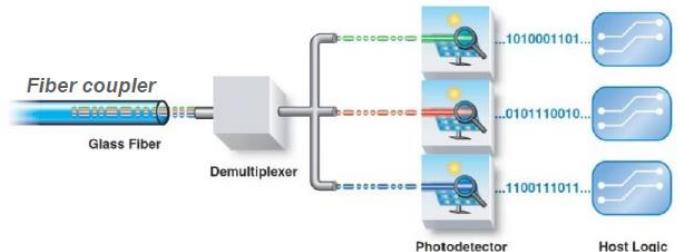


Highly confined waveguides

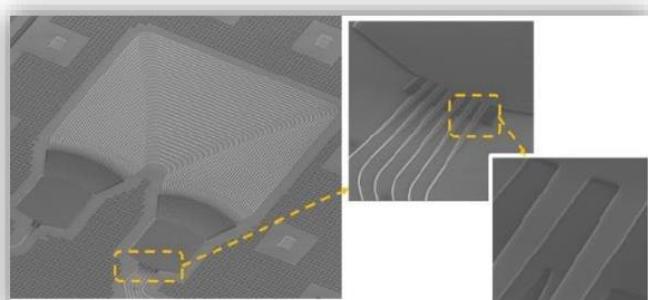


Optical transceiver circuit

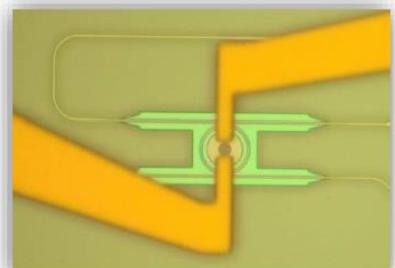
Receiver



High speed photodetector

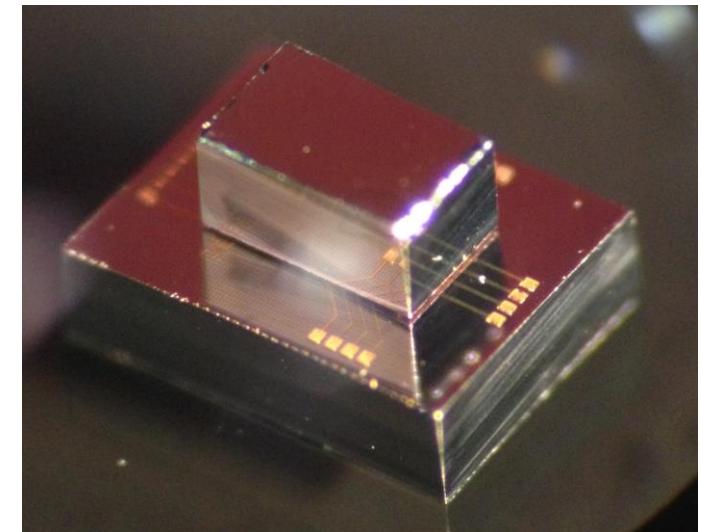
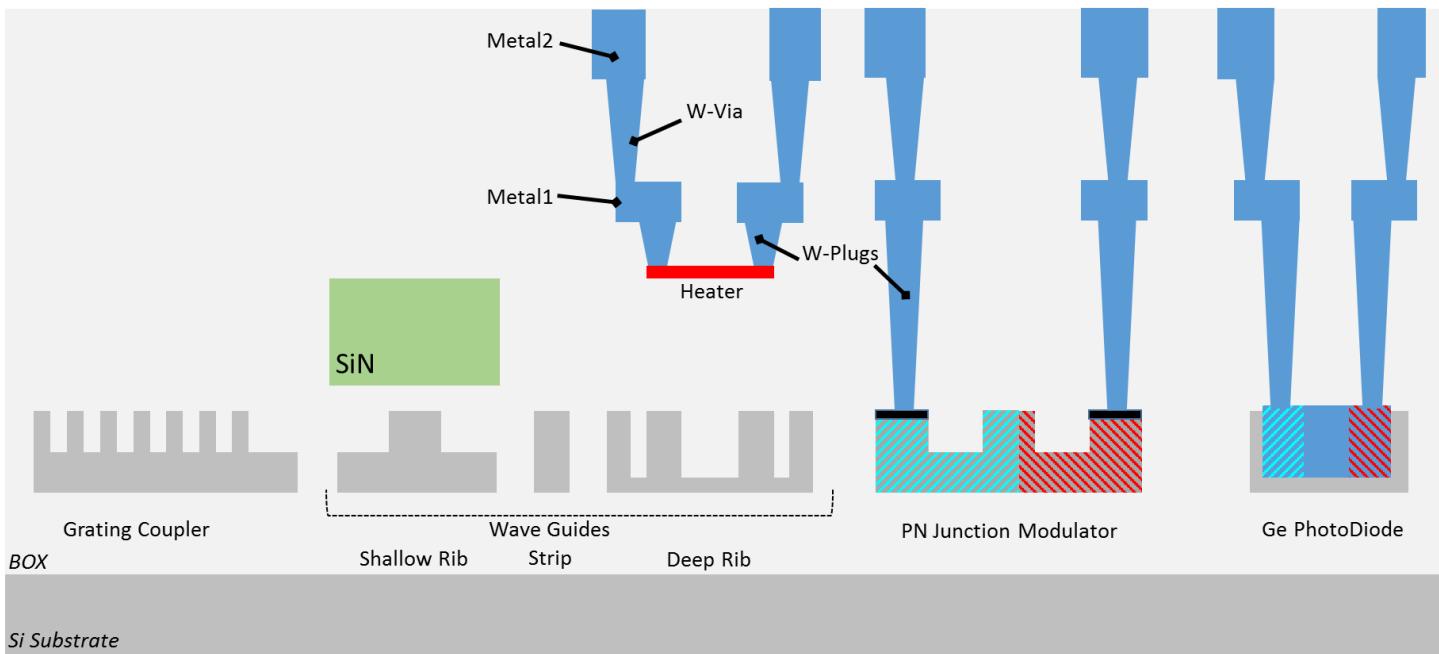


Wavelength multiplexer



Tunable filter

## TECHNOLOGY KEY PROCESS FEATURES



Low parasitics 3D  
Photonic/Electronic Integration

PDKs available (Cadence, Phoenix...)

Complete library with Models, Circuit simulation, Layout, Verification, Layout finishing

3D integration with electronics

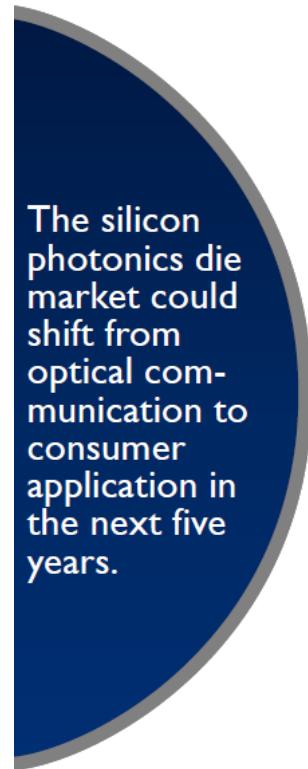
Compatibility with 300 mm industrial foundry

## SILICON PHOTONICS MARKETS

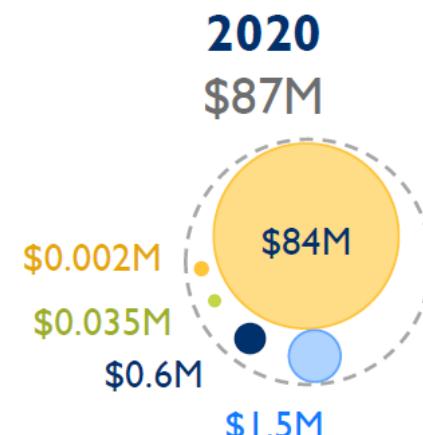


## SILICON PHOTONICS DIE FORECAST, BY APPLICATIONS

2020 - 2026 forecast



- Datacenter transceivers
- Long haul transceivers
- 5G transceivers
- Co-packaged engines
- Photonic computing
- Optical interconnects
- Immunoassay
- Consumer health
- Fiber-optic gyroscope
- Automotive LiDAR

CAGR<sub>2021-2026</sub> 49%