

Priority research topics from the perspective of silicon photonics

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Multifunctional integration

including Integrated Photonics and Flexible Electronics

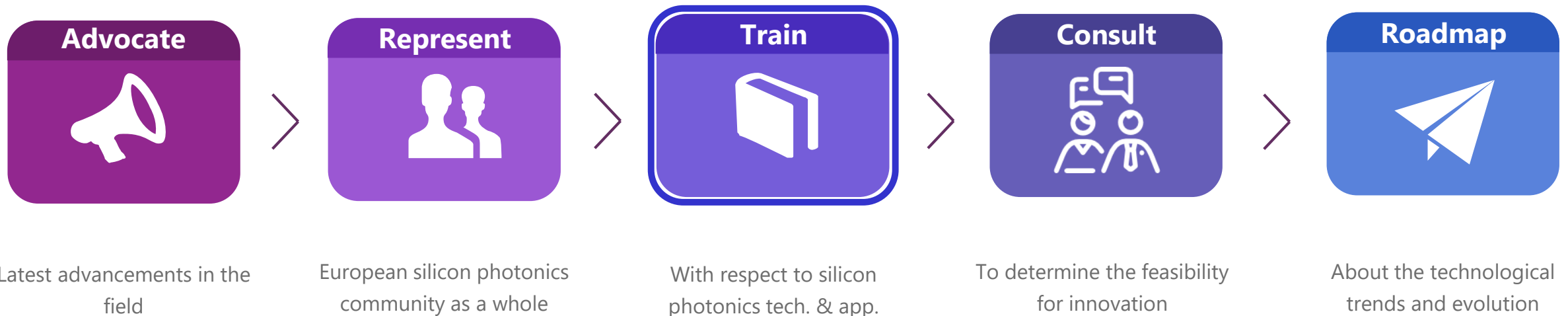


ePIXfab

The European
Silicon Photonics Alliance

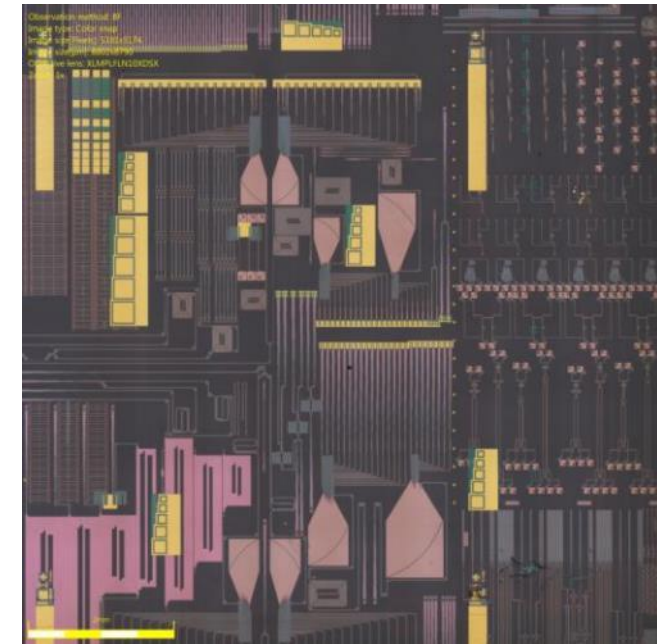
EPIXFAB: THE EUROPEAN SILICON PHOTONICS ALLIANCE

ePIXfab is an open alliance of organizations that promotes silicon photonics science, technology and applications



WHAT IS SILICON PHOTONICS?

The implementation of high density photonic integrated circuits by means of CMOS process technology in a CMOS fab

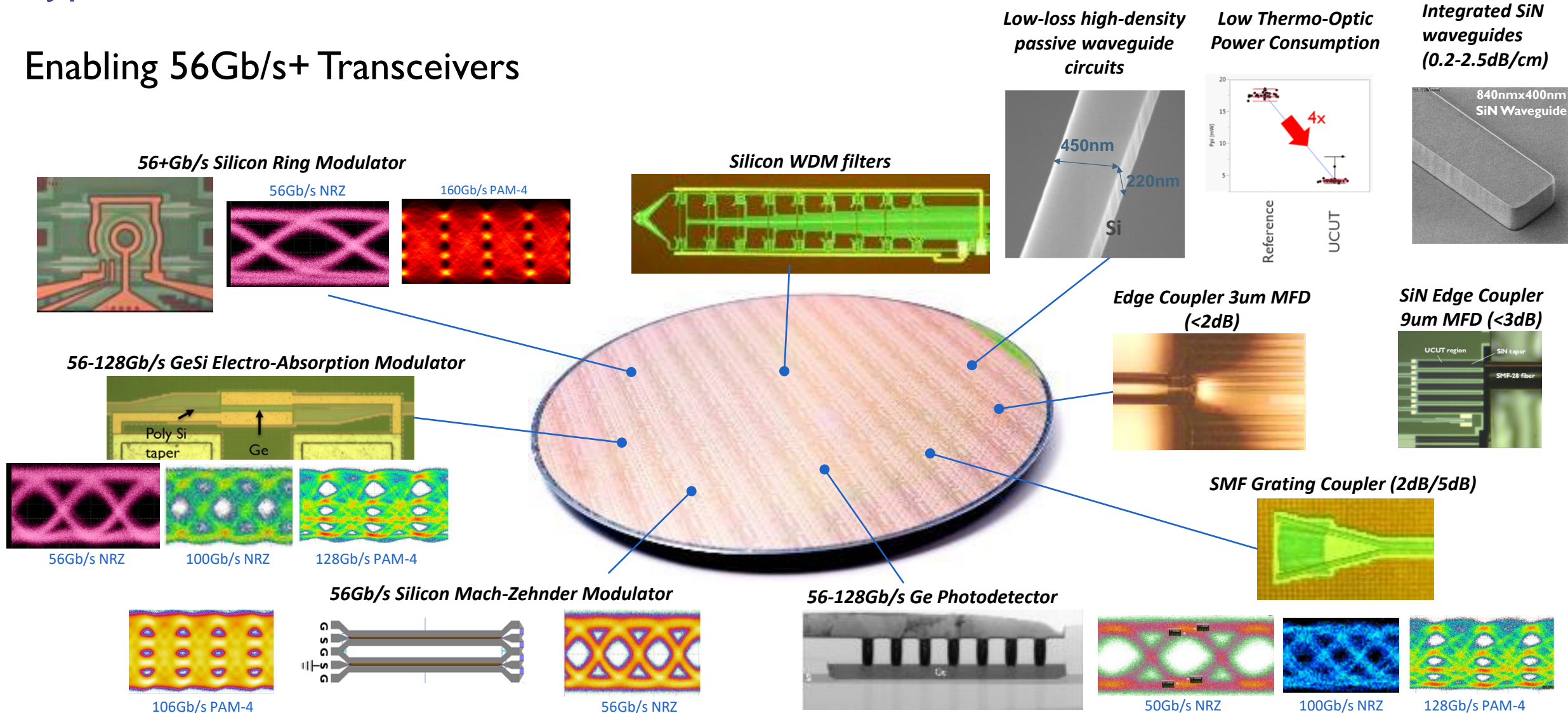


Pictures, courtesy of imec

Enabling complex optical functionality on a compact chip at low cost

Typical Silicon Photonics Platform

Enabling 56Gb/s+ Transceivers



EUROPE'S (OPEN ACCESS) SILICON PHOTONICS ECOSYSTEM (2021)

SOI Manufacturing



SiN Manufacturing



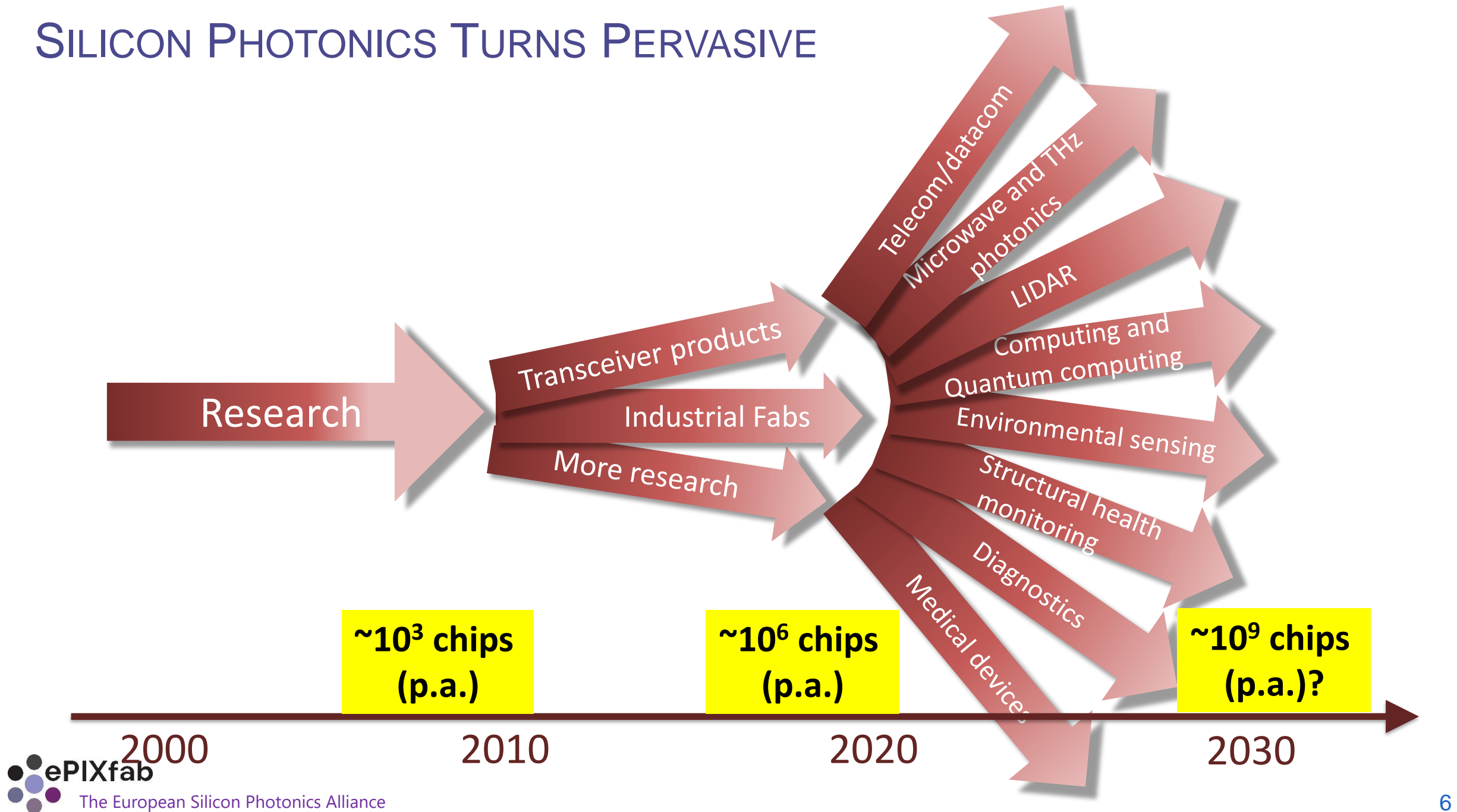
Rapid prototyping



EUROPE	SME	Large	RTO
Provider	15+	5+	10+
User	10+	5+	10+

Design tools and services
Test tools and services
Packaging tools and services
Wafer manufacturers

SILICON PHOTONICS TURNS PERVASIVE



2021-2030: KEY ROADBLOCKS AND SOLUTIONS

Roadblock 1

Performance and/or functionalities as needed for new innovative products are not enabled by current manufacturing platforms.

Solution

Wafer-level heterogeneous integration modules added to the supply and value chain (from low-volume to high-volume).

LIMITATIONS OF CURRENT SOI AND SiN (OPEN ACCESS) PIC PLATFORMS

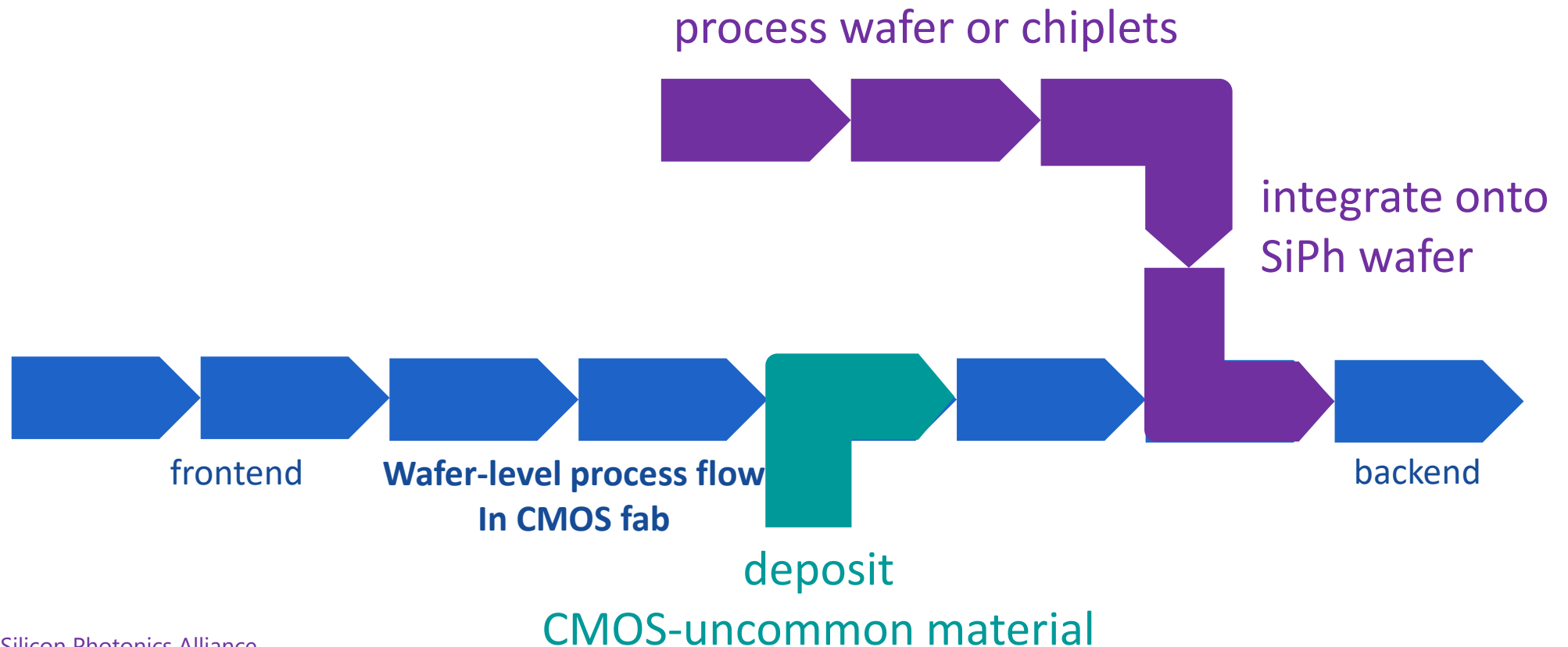
Feature/function	SOI	SiN
Light source integration	Not established	Not established
Phase modulation (electronic)	Spurious AM Bandwidth limitations	Not established
Phase modulation (thermal)	Power hungry	Very power hungry
Linear waveguide loss	Good	Superb
Nonlinear waveguide loss	Problematic at high power	Superb
Integrated detectors	Good	Not established
Optical isolators/circulators	Not established	Not established
Non-volatile programmable functions	Not established	Not established
Integration with electronics	Limited options (for SMEs)	Not established

CAPABILITIES OF FUTURE SOI AND SiN (OPEN ACCESS) PIC PLATFORMS

Feature/function	SOI	SiN
Light source integration	Superb	Superb
Phase modulation (electronic)	Superb	Superb
Phase modulation (thermal)	Superb	Superb
Linear waveguide loss	Superb	Superb
Nonlinear waveguide loss	Less problematic	Superb
Integrated detectors	Superb	Superb
Optical isolators/circulators	Superb	Superb
Non-volatile programmable functions	Superb	Superb
Integration with electronics	Superb	Superb

THE SOLUTION: WAFER-LEVEL HETEROGENEOUS INTEGRATION

Heterogeneous Integration refers to the **integration of separately manufactured components OR CMOS-uncommon materials onto silicon photonics wafers** that, in the aggregate, provides enhanced functionality and improved operating characteristics



WAFER-SCALE HETEROGENEOUS INTEGRATION: A STORY OF MANY MATERIALS

III-V on silicon (InP, GaAs, GaN, GaSb,...)

Colloidal quantum dots on silicon

Liquid crystals on silicon

Dielectric materials ($\text{Si}_x\text{O}_y\text{N}_z$, Ta_2O_5 ,...)

Electro-optic materials on silicon (LiNbO_3 , BTO, PZT, polymers, ...)

Rare-earth-doped materials

2D-materials (graphene, WSe_2 , WS_2 , MoS_2 ...)

Magneto-optic garnets

Phase change materials

... AND MANY TECHNIQUES

Epitaxy, LPCVD, PECVD, PLD, sputtering, wafer-to-wafer bonding...

Die-to-wafer bonding, flip-chip, micro-transfer-printing, ...

THE CAVEAT

High NRE cost

Adding a heterogeneous integration module to a process flow is challenging

Thermal budgets, contamination

Risk of dilution

Many options: materials x approaches x platforms

Away from 'unified platform'

Loosing critical mass



PRIORITY 1

Identify multiple markets that can benefit from a given heterogeneous silicon photonics platform

Due diligence on business cases: critical mass?

Technical and financial due diligence on materials and methods: select

DEVELOP HETEROGENEOUS SILICON PHOTONICS MANUFACTURING PLATFORM

Develop associated PDK, wafer-level-test and -packaging

Develop product prototypes

Manufacture and Go To Market

2021-2030: KEY ROADBLOCKS AND SOLUTIONS

Roadblock 1

Performance and/or functionalities as needed for new innovative products are not enabled by current manufacturing platforms.

Solution

Wafer-level heterogeneous integration modules added to the supply and value chain (from low-volume to high-volume).

Roadblock 2

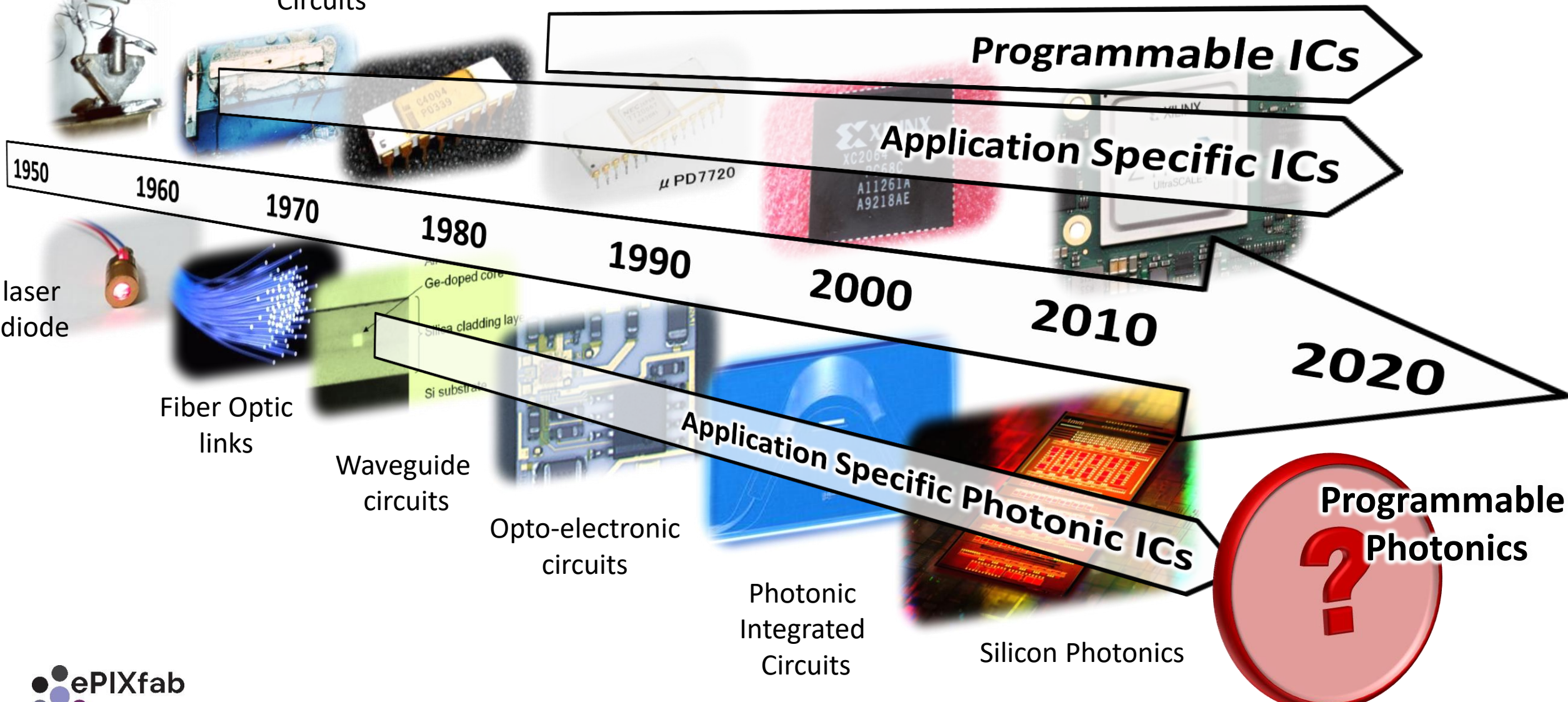
Prototyping and low-volume manufacturing hampered by large turn-around-time and large initial cost. A major burden for SMEs.

Solution

Software-defined functions in off-the-shelf **programmable photonic ICs** (“photonic FPGAs”).

FROM ASIC TO GENERAL-PURPOSE FPGAs

Transistors Integrated Circuits Microprocessors DSP FPGA SOC with FPGA



PRIORITY 2

Identify multiple functions that can be implemented by a given programmable PIC

Due diligence on business cases: critical mass?

Technical and financial due diligence on programmable PIC technology: select

DEVELOP PROGRAMMABLE SILICON PHOTONICS MANUFACTURING PLATFORM

Develop associated PDK, wafer-level-test and -packaging

Develop software environments for programming the PICs

Manufacture and Go To Market

PRIORITY RESEARCH TOPICS FROM THE PERSPECTIVE OF SILICON PHOTONICS

1. Establish value chains for wafer-scale heterogeneous silicon photonics

- for a wide range of innovative products
- in high-value markets
- with associated PDKs, wafer-level-test and -packaging tools and services

2. Establish value chains for silicon photonic FPGAs

- programmable for multiple high-value products and markets
- enabling a disruptive supply chain (off-the-shelf)
- with associated PDKs, wafer-level-test, -packaging tools and programming environments