



PhotonDelta

Gateway to Integrated Photonics

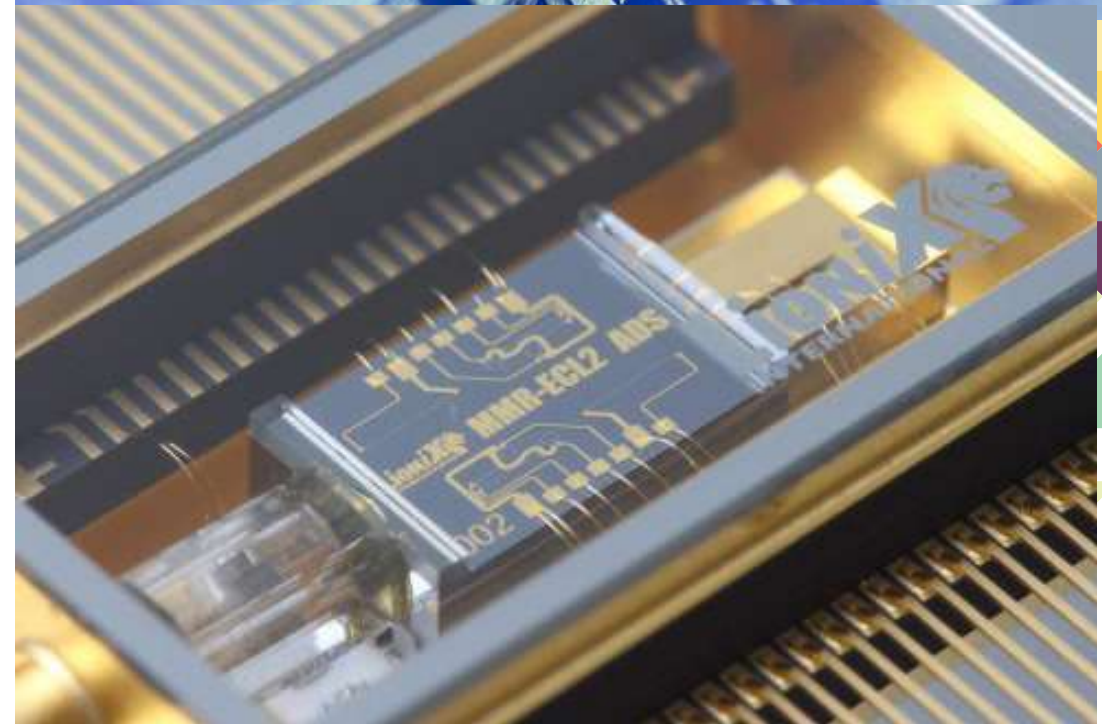
Integrated photonic biosensors

leading the path to point-of-care
diagnostics

Maarten Buijs

Program Manager Biosensors

PhotonDelta



Integrated Photonics is a highly promising key enabling technology for disruptive solutions in multiple markets

▶ Integration of **multiple** photonics **functions** on a Photonic Integrated Circuit (PIC) fabricated using automated **wafer-scale** generic integration **technology** over e.g. silicon, silica or InP substrates

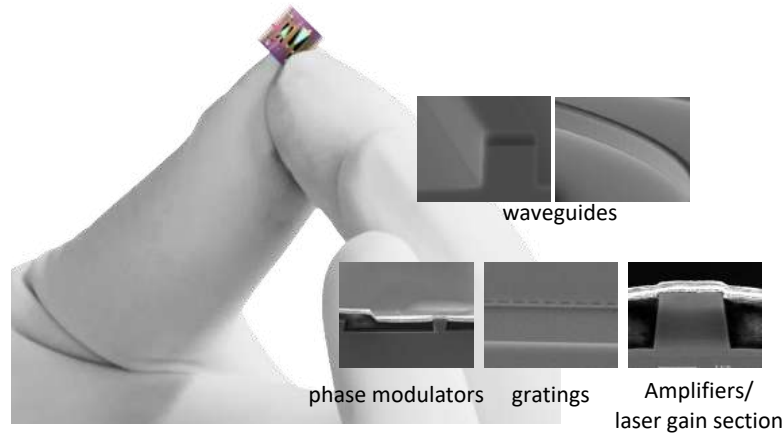
▶ Significant **reduction*** of **size and weight**, manufacturing **costs**, power consumption

▶ **Improved*** **thermal/vibration stability, reliability**

*compared to assembling and packaging of discrete photonics components and bulk-optics

▶ **Supply chain** matured and ready to **scale-up its production capabilities**

▶ Enabler of a **rich** diverse range of **products** and **applications** in **multiple markets**



Datacom and Telecom



Medical Devices and Life Sciences

Infrastructure and Transportation



Food and Agriculture



Integrated photonics will grow through focus on dedicated product-market areas

INFORMATION TRANSPORTING



Datacom and Telecom

- ▶ Optical transceivers for ultra-high data transfer for short-haul/metro telecom fiber-based access networks/data centers
- ▶ Optical transceivers and components for high-throughput, secure, (long-haul) free-space communications links
- ▶ Optical-domain RF beamforming and optical phased arrays modules for satellite, mobile and wireless communications

INFORMATION SENSING



Life Science and Health

- ▶ Optical modules and components for low-cost (portable) Optical Coherence Tomography (OCT) devices for point-of-care/home diagnostics and monitoring
- ▶ Low cost label-free biosensing disposables/readers for point-of-care diagnostics
- ▶ (Fiber-based) Sensor systems and components for multi-point multi-parameter guidance and monitoring



Infrastructure & Transportation

- ▶ Optical front-end modules and key components (e.g. tunable lasers, optical phased arrays) for coherent solid-state LIDARs in decision support/ autonomous control systems
- ▶ (Fiber-based) Sensor systems for real-time accurate distributed structural health monitoring in (large)/high-duty objects and structures



Food and Agriculture

- ▶ NIR spectral sensing modules and components for analysis of fruit and vegetables nutrients, taste and structure insights
- ▶ VIS/UV absorption and Raman spectroscopy sensing modules for e.g. nitrate/phosphate monitoring in water and soil

Highest Volume Markets

PhotonDelta acts as the driver of accelerated growth for the Dutch Integrated Photonics industry cluster

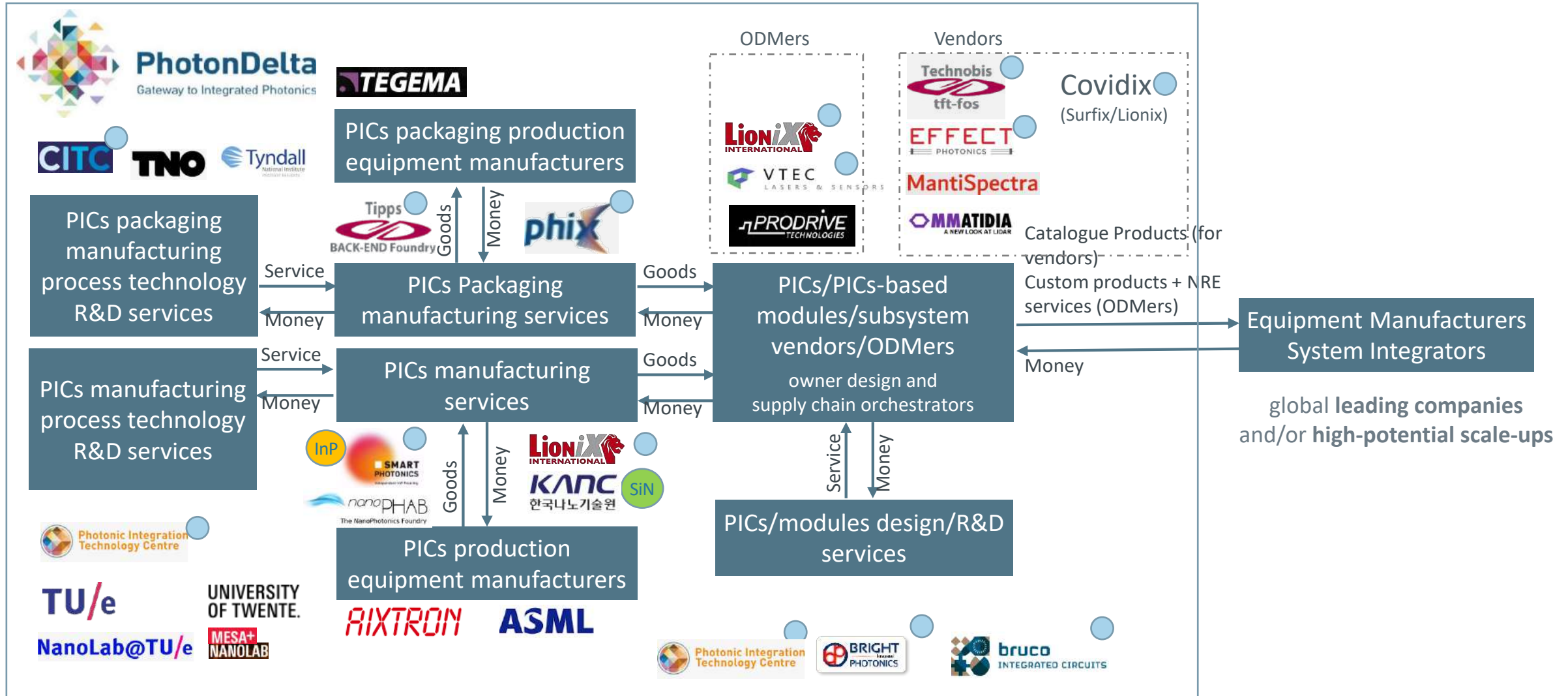
- ▶ Leveraging funds from Dutch Public (national/regional) investors to deliver on ambitious strategic goals
- ▶ Managing a range of investment models and a thorough decision-making process for high-return/high-leverage investments allocation
- ▶ Driving the creation and growth of a strong portfolio of companies and partners by
 - ▶ identifying and prioritizing most promising product-market and technology opportunities for strategic/sustainable business growth,
 - ▶ driving and promoting roadmap-driven synergies and co-operations,
 - ▶ initiating and establishing trustworthy relations with key strategic customers,
 - ▶ leveraging a wide network of structural contacts with key stakeholders and other key similar European/global initiatives



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Integrated Photonics supply chain and PhotonDelta footprint at present



All partner of PhotonDelta in collaborative projects or other R&D/business dev. PhotonDelta activities

● Also beneficiary of PhotonDelta equity, loan and/or co-financing investments

PhotonDelta technology leadership based on monolithically integrated InP and (hybrid) SiN-based technology platforms

- ▶ InP excels at **light generation, amplification, modulation and detection** in the **IR** region

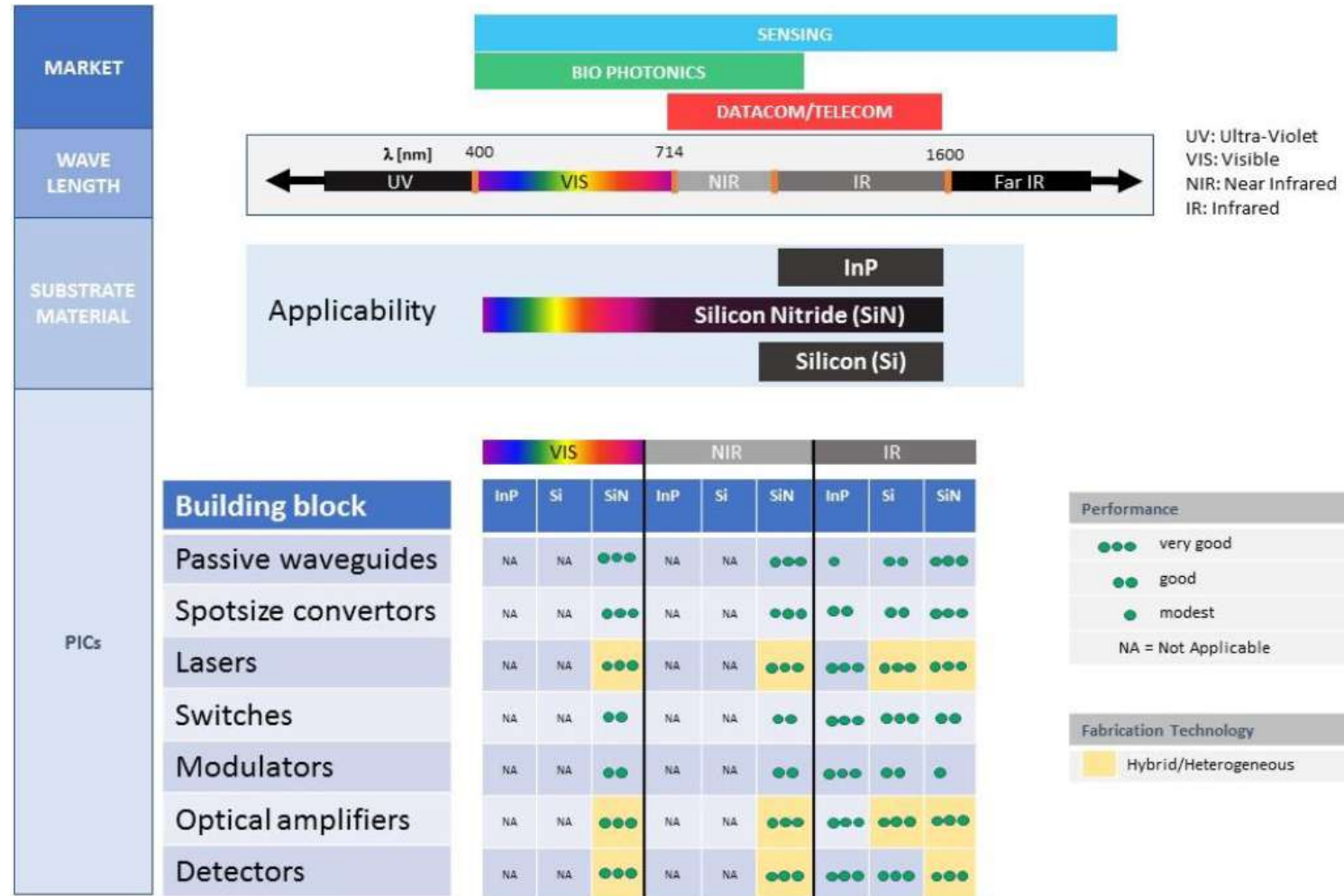


- ▶ High performance low-cost photonics **System-on-Chip** devices in this range via effective **monolithic** integration of multiple **active** and **passive** components

- ▶ SiN excels at **passive** light processing in the **visible, NIR** and **IR** range thanks to a.o. its very low channel attenuation, adjustable polarization, small bend radii



- ▶ High performance low-cost photonics **System-on-Chip** devices in this range via effective **monolithic** integration of multiple **passive** components
- ▶ High performance photonics **Systems-in-Package** devices in this range via **scalable (wafer-scale) hybrid** integration with active components (e.g. InP, GaN, GaAs based PICs)



The landscape of the life science and health market is changing

in the heavily regulated markets

Healthcare

Drivers

- ▶ Severe cost pressure as a result of ageing populations
- ▶ Reduce impact of deadliest diseases

Trends

- ▶ Shift to lower cost settings (Point of Care, GPs)
- ▶ Remote/outpatient monitoring
- ▶ Prevention, early screening/diagnostics
- ▶ Treatment Effectiveness
- ▶ Easier and faster regulatory approval for new devices

Life Sciences

Drivers

- ▶ Unbearable drug development costs
- ▶ Effective treatments with minimum risks

Trends

- ▶ Personalized/Precision Medicine
- ▶ Digital/innovative approaches to drug discovery/development
- ▶ Smart pill treatments (pill + device/services)

in the professional/consumer healthcare markets

Personal Health

Drivers

- ▶ Disease Prevention/postponing

Trends

- ▶ Prevention and early diagnostics propositions in consumer products
- ▶ Monitoring physical/mental status and impact from improvement activities*

Personal Care

Drivers

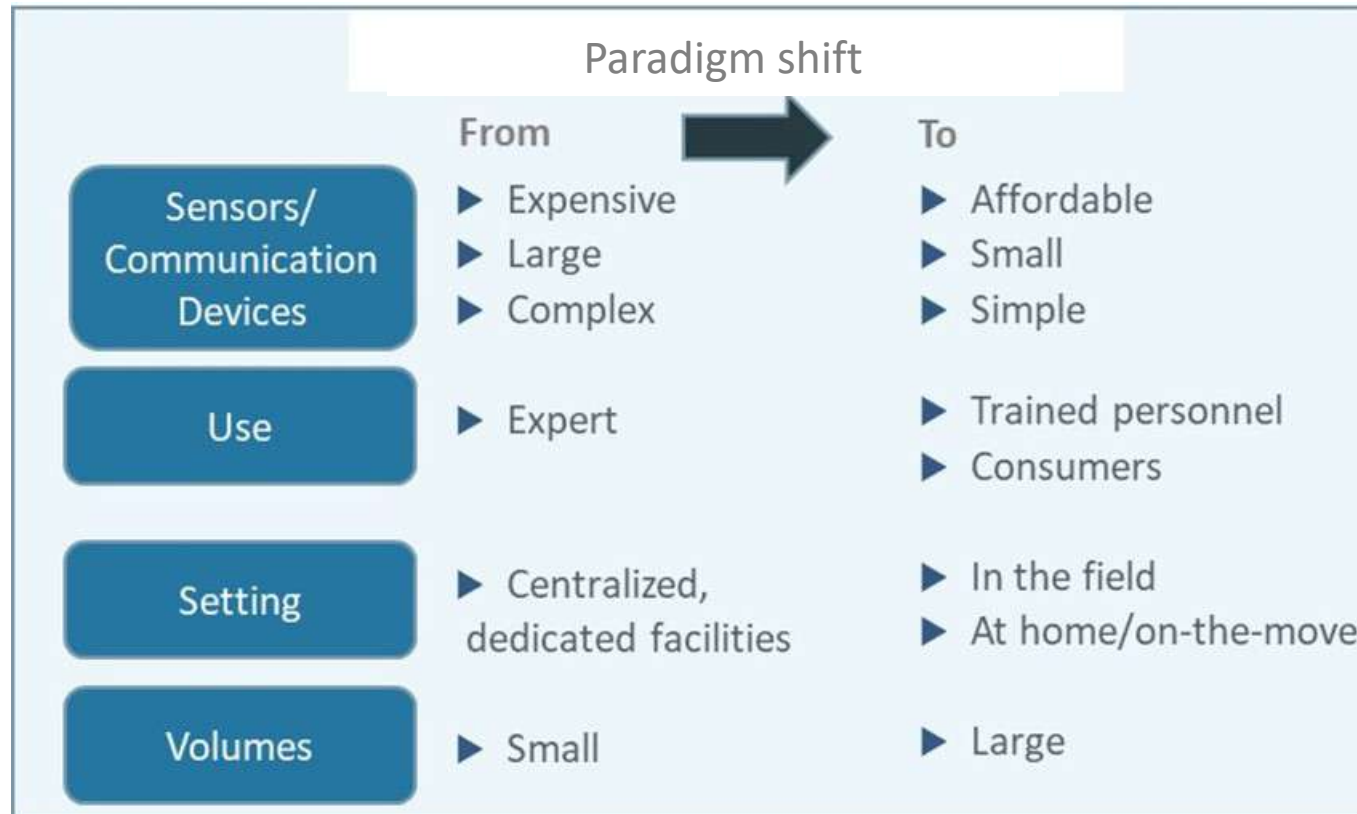
- ▶ (Full) body appearance
- ▶ Healthy environments

Trends

- ▶ Growth of spending for appearance* improvements and/or monitoring products in both professional and consumer segments
- ▶ Skin Evaluation and Personalization tools
- ▶ Healthy environments, healthy nutrition*

* driven disruptively by the likes of Apple and Google

A paradigm shift is occurring, accelerated by integration of photonics



**Biosensors for
point-of-care testing**

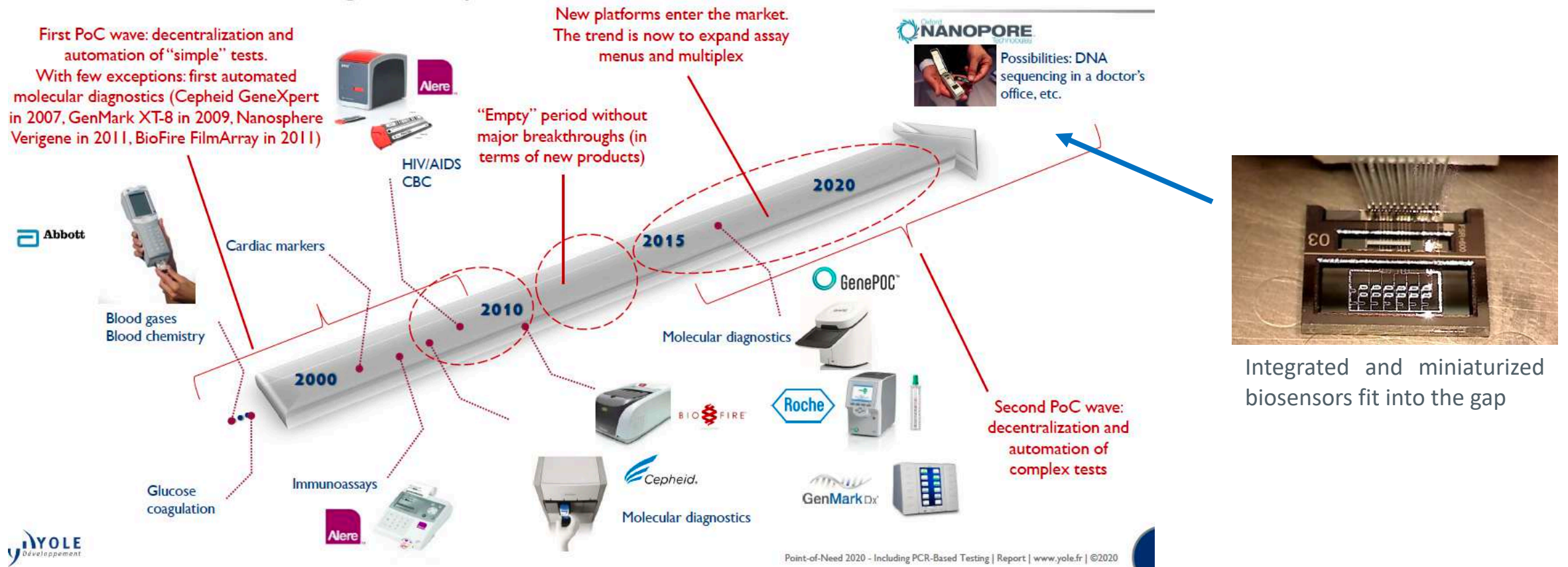
- Integration of multiple photonics functions in medical devices supports this by
 - significantly reducing size, weight, and power consumption;
 - significantly reducing manufacturing costs
 - provided a matured supply chain ready to scale up its production capabilities

The market (growth) for Point-of-care (or -need) testing is there

- 2019: 400M CAGR 2019-2025 of 7.0%.
- In value: growth from \$4.8B in 2019 to \$10.1B in 2025, at a CAGR of 13.0%.
- Associated biosensor device market (microfluidic chips): \$500M in 2019, \$777M by 2025 at CAGR of 7.7%.
- The market is largely dominated by human testing, non-human testing applications are emerging
- Largest market segment is by far hospital tests, both in volume and value, followed by emergency testing (in value).
- Major growth drivers:
 - tests performed in decentralized healthcare settings (clinics and doctors' offices),
 - developing world infections (remote area testing).
- Market is mostly focused on clinical chemistry and electrolytes, as well as cytometry and haematology tests.
- Number of Molecular Diagnostics tests is increasing rapidly and will approach 25% of the units in 2025; already now dominating in value because of complexity and price
- Covid-19 underscores the need for the availability of large quantities of fast high-throughput point-of-need tests

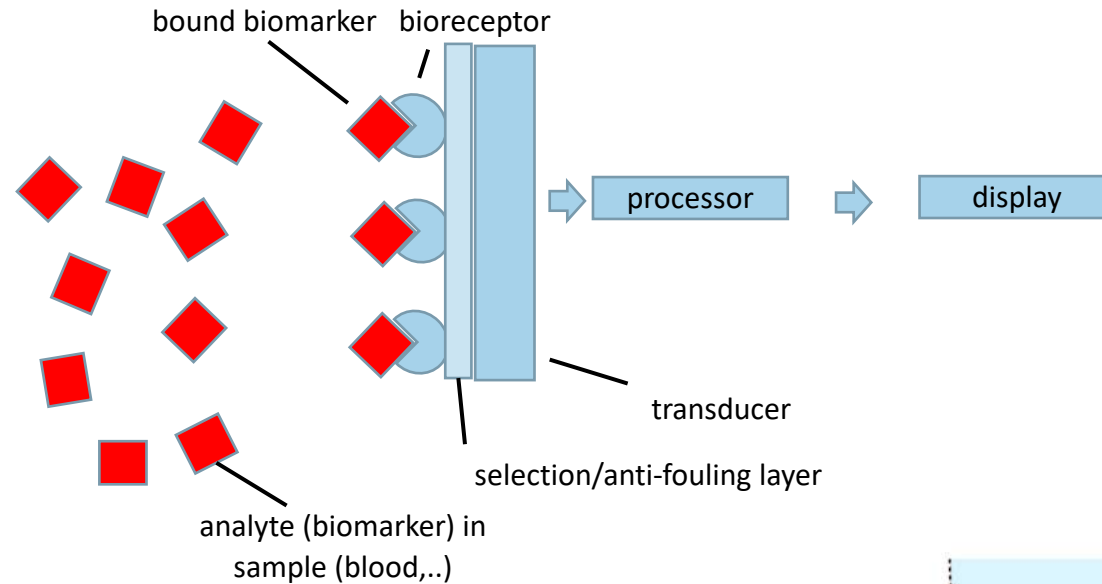
The market now asks for fast tests with a large degree of multiplexing

Point-of-care testing roadmap



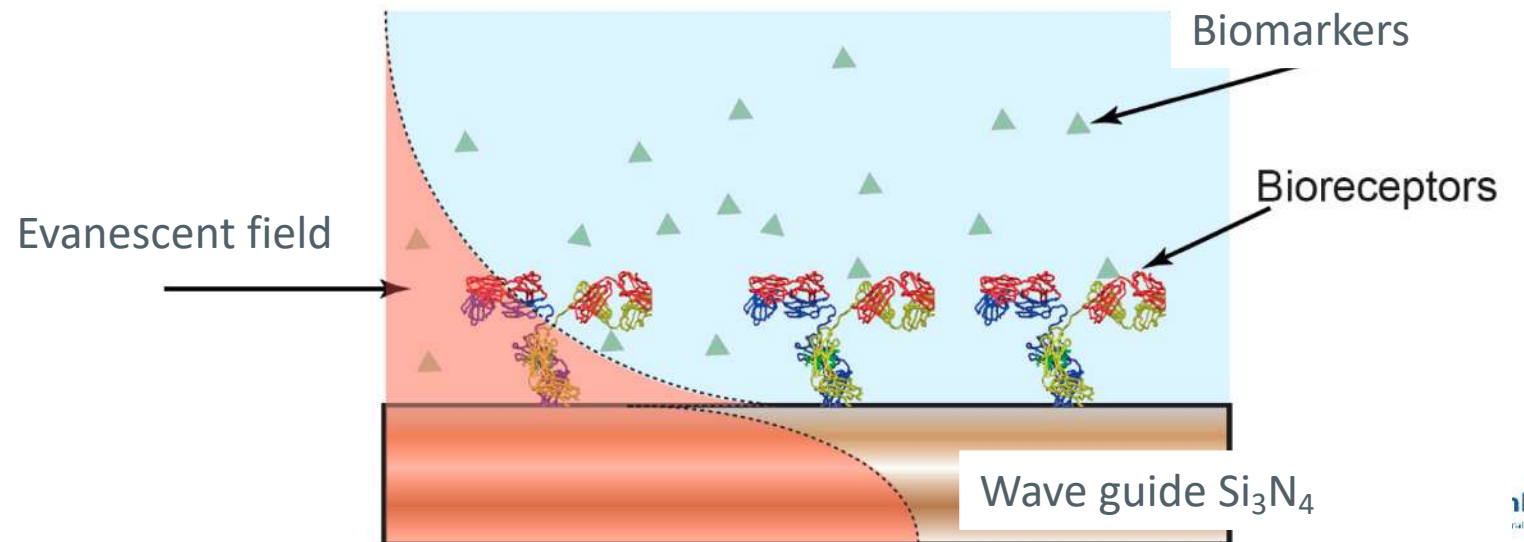
- A large opportunity exists in the zone of fast time to results and large degree of multiplexing (number of pathogens detected/parameters measured in a single test)
- DNA sequencing at Point-of-need becomes increasingly important; PCR is cumbersome and time consuming

Label-free miniaturized and integrated biosensors depend on the same (microfluidic) principle



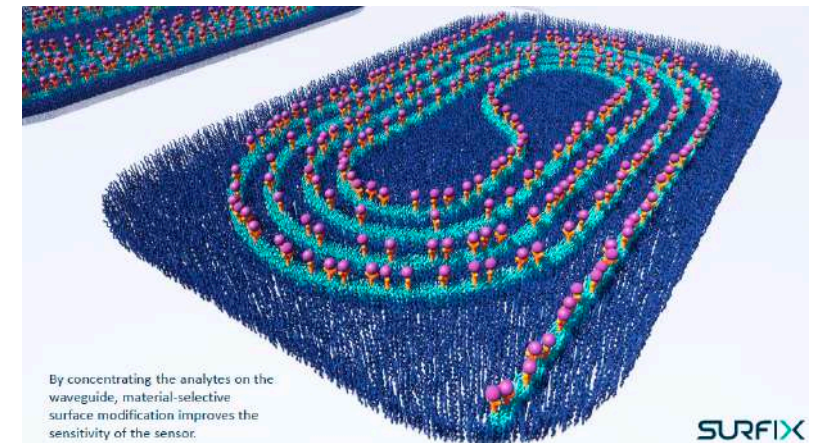
Transducer detection principles

- surface plasmon resonance
- electronic, electrochemical
- surface/bulk acoustic wave
- optical (evanescent field)



Integrated optical transducers have strong advantages over other types

- Except for SPR, all can be mass manufactured in wafer-scale processes, leading to very low cost and small footprint
- Strong miniaturization allows a large degree of multiplexing for all transducer types
- For all, the specificity and selectivity is determined by the assay and biochemistry in relation to the surface properties of the transducer
- Optical transducers have strong advantages in terms of
 - insensitivity to electromagnetic interference
 - wide bandwidth
 - robustness,
 - sensitivity
- Different integrated optical nanostructures exist
 - interferometer
 - ring resonator
 - photonic crystal
 - bimodal waveguide
- The aMZI interferometer in Si_3N_4 -technology has proven to be extremely sensitive
 - Surfix and Lionix are actively pursuing a Covid-19 biosensor based on this technology



The PhotonDelta biosensor roadmap points the way to commercial success

- The product cycle in the medical industry is long: > 10 years between company inception and recurring revenue
 - regulatory approval, clinical trials, reimbursement
- The whole industrial manufacturing supply chain, according to medical standards, still needs to be established
- There are many more economic than technological reasons for market failure; having enough cash is key
- PhotonDelta is working on a roadmap to chart all challenges, technological and otherwise, and plans to overcome these



Key takeaways

- ▶ Integrated Photonics is a highly promising key technology enabling the paradigm shifts required in the life sciences and health
- ▶ The PhotonDelta cluster is a global leader in supplying customized PICs and PICs-based modules/subsystems and/or relevant design and (volume) manufacturing services
- ▶ PhotonDelta is keen to drive the application of integrated photonics towards point-of-care testing by developing the roadmap for targeting the most promising market entry points





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