PHOTONICS Market & Technologies

Joël THOMÉ, CEO PISÉO

YOLE Group

EPIC Annual General Meeting 2023

EPIC
EUROPEAN PHOTONICS INDUSTRY CONSORTIUM

AGENDA

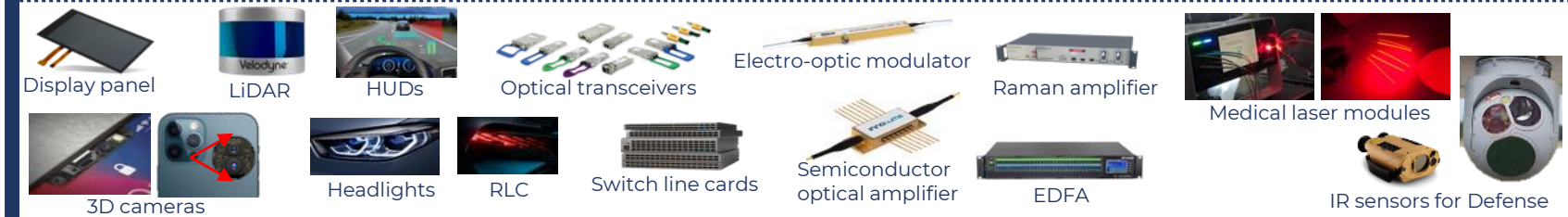
- Overview of original photonics technologies and applications
- Focus on market évolutions and technology roadmap of selected photonic technologies and systems:
  - LIDAR for automotive
  - AR/VR headsets
  - Optical telecommunications
  - Quantum technologies and photonics
- General conclusion
- Presentation of PISÉO

PHOTONICS
Original Photonics Technologies

Primary discrete photonics components based on original technology

VERTICAL

System
(non exhaustive)



Module
(non exhaustive)

ACTIVE

Wafer level	IR imagers
EEL	Amplifiers
VCSEL	Modulators
LED (UV/VIS/IR)	**Panel level**
APD/PIN photodiodes	OLEDs
CIS	LCD
	LCOS

PASSIVE

Wafer level	WLO/Lenses	Micro structured fibre
Couplers/splitters	**Panel level**	Speciality fibers
Waveguides	Waveguides	
Mux/Demux	Connectors	
Attenuators	**Fiber**	
Isolators	Multimode fibre	
Circulators	Single-mode fibre	

Component

Wafer

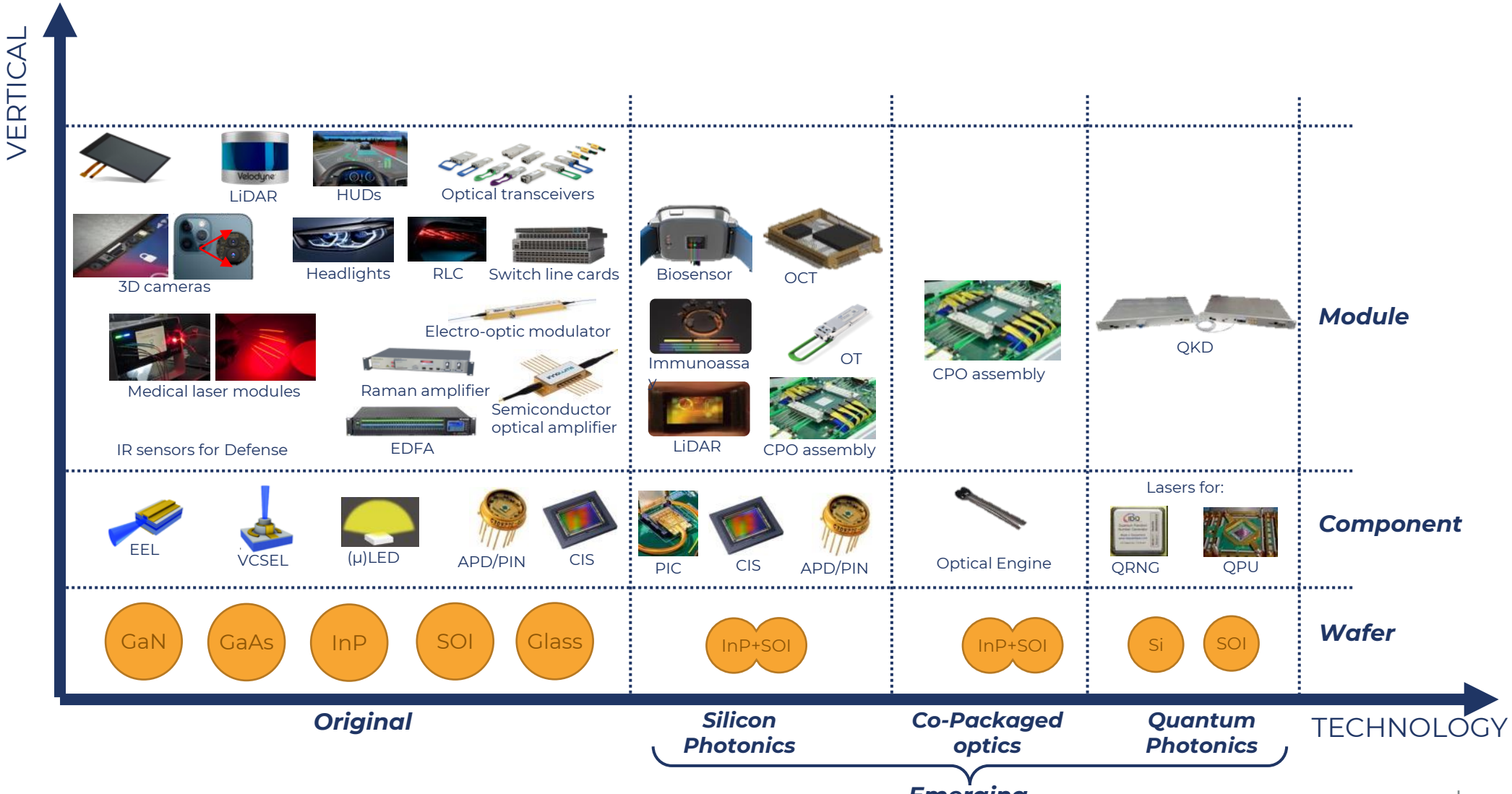
- *Mobile and consumer*
- *Auto & Mobility*
- *Communication*
- *Medical*
- *Industrial*
- *Defense & Aeronautics*

ALL MARKET SEGMENTS

PHOTONICS

Segmentation of Photonics – Yole's expertise

The emerging technology is not new but gaining traction in the respective markets



PHOTONICS

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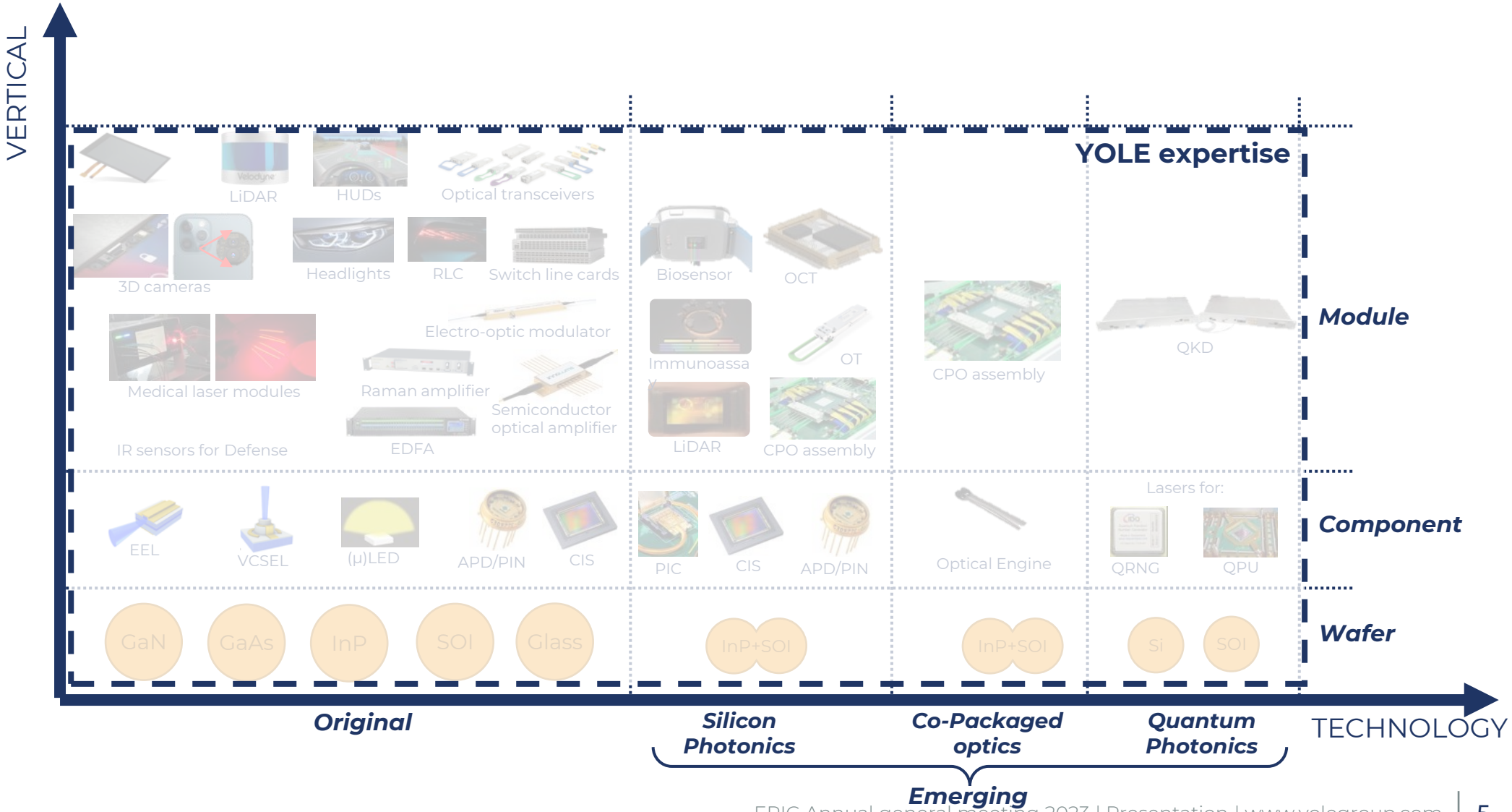

PHOTONICS

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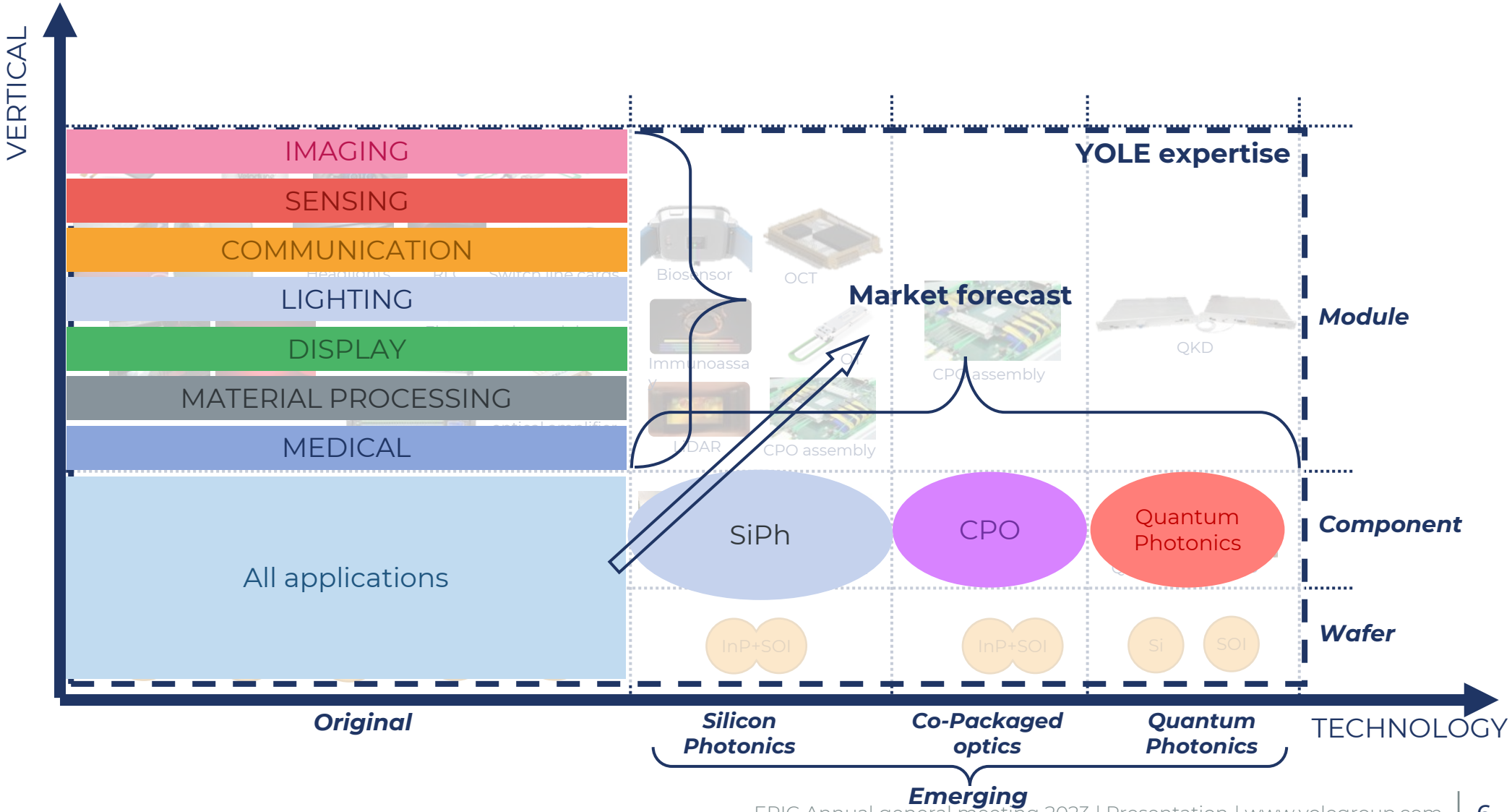

YOLE GROUP RELATED PRODUCTS

Reports **Imaging**

Contact our Sales Team for more information

SWIR Imaging 2023

Imaging for Automotive 2022

3D Imaging and Sensing 2022

Status of the Camera Module Industry 2022

Imaging for Security 2022

Status of the CMOS Image Sensor Industry 2022

Digital X-Ray Imaging 2022

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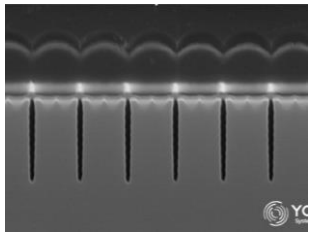
[Smartphones Camera Module & CIS Comparison 2022 - Xiaomi]

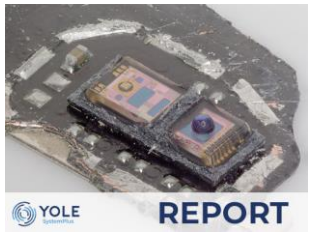
[Camera Module Comparison 2022 – Vol. 1 – Apple iPhone Evolution]

[Smartphones Camera Module & CIS Comparison 2022 - Samsung]

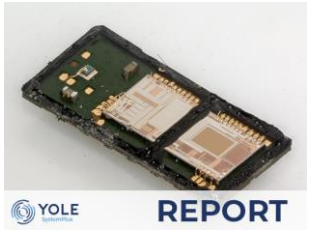


[Sony's Latest generation NIR CIS Sensor]

[Automotive CIS Comparison 2022]



[ams' dToF laser autofocus in the Honor Magic3 Pro]

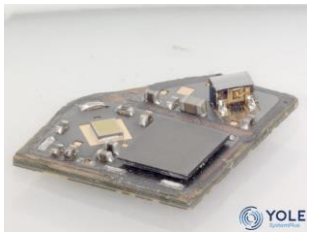


[STMicroel ectronics' VL53L5 dToF Laser Autofocus]

[Smartphone Camera Module & CIS Comparison 2023, Vol 1: iPhone Evolution]

YOLE GROUP RELATED PRODUCTS

Reports **Imaging**



iPhone 14 Pro Under-Display Proximity Sensor

Four Thermal Cameras: Performance Analysis

SWIR Light Sources – Product offer, technology and market structure analyses

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YOLE GROUP RELATED PRODUCTS

Reports **Photonics & Lighting**

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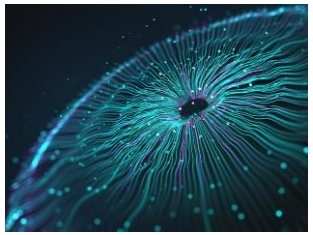
Lighting for Automotive 2022

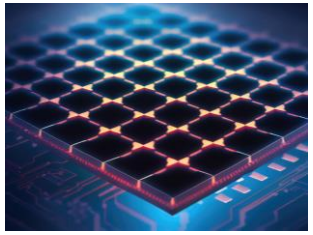
LiDAR 2022 - Focus Automotive and Industrial

VCSEL 2022

Edge Emitting Lasers



Optical Transceivers for Datacom & Telecom 2022



Co-packaged Optics for Datacenter 2023

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Reports **Photonics & Lighting**

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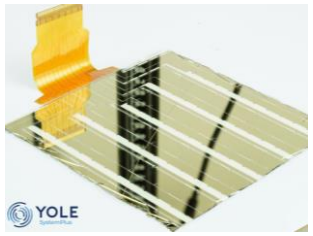
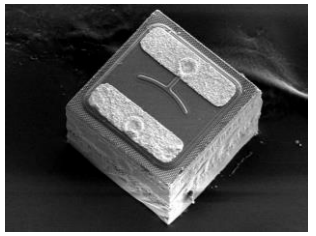
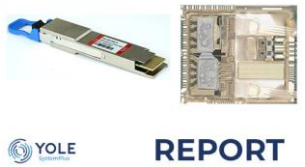


Skyworth – Chip-on-Glass miniLED Q72 TV 75”



MiniLED Backlight Unit in the 2021 Apple iPad Pro



Acacia/Cisco Silicon Photonic die in 400G QSFP-DD

Sony MicroLED Display

VW ID3 headlamps construction and performance analysis

YOLE GROUP RELATED PRODUCTS

Reports **MiniLED Displays Teardown and Performance Analysis Comparison**

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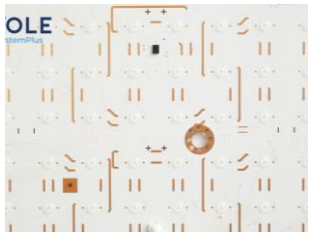
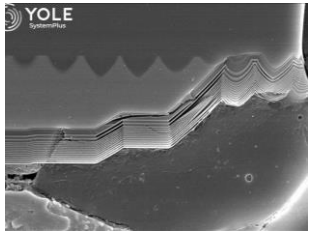
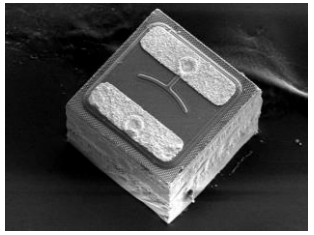


Mini-LED Backlight Unit in neo QLED TV Samsung

Mini-LED backlight unit in Odyssey Neo G9 49” Samsung Monitor



TCL MiniLED X9 85” TV BLU



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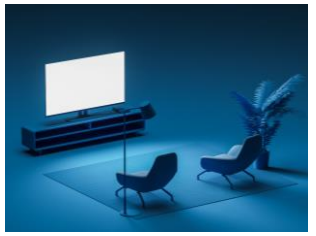


Samsung NEO QLED 65QN900A TV visual performance and optical construction analysis

Samsung Monitor MiniLED Odyssey Neo G9 visual performance and optical construction analysis

TCL TV 85X925 Pro 85” MiniLED 8K visual performance and optical construction analysis

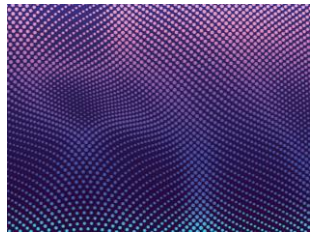
Apple iPad Pro MiniLED 12.9” visual performance and optical construction analysis

YOLE GROUP RELATED PRODUCTS

Reports **Displays**

MiniLED 2022: LCD Backlights and Direct View LED Displays

Display and Optics for AR/VR 2022



MicroLED 2022

Contact our Sales Team for more information

INTELLIGENCE TO SHAPE YOUR TOMORROW

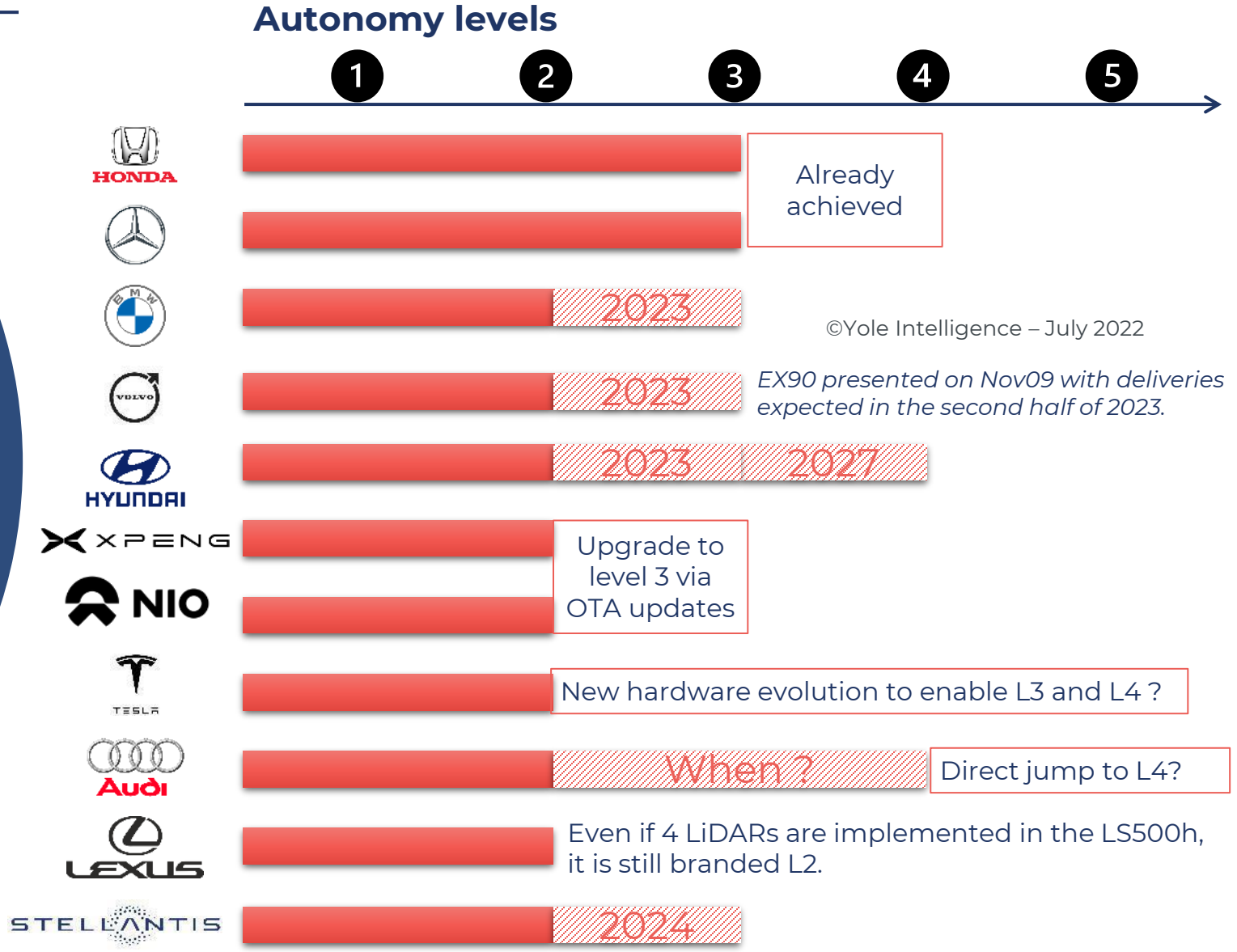
Focus on Automotive LiDAR ecosystem and market

YOLE Intelligence

CONTEXT

OEM achievements on automated driving (non-exhaustive list)

As of Q2-2022, only two OEMs have officially released cars with L3 capability.



On the road to autonomy levels, Audi was the first one to implement a LiDAR to target level 3 applications in 2018 but stepped back a few time after due to a lack of regulation and the fear of liabilities in case of accident.

New EV OEMs like Xpeng or Nio are embedding the necessary hardware to enable level 3 applications, but it is not yet activated. This will be the case using OTA updates.

Big players like VW or Toyota are still not delivering cars with L3 features.

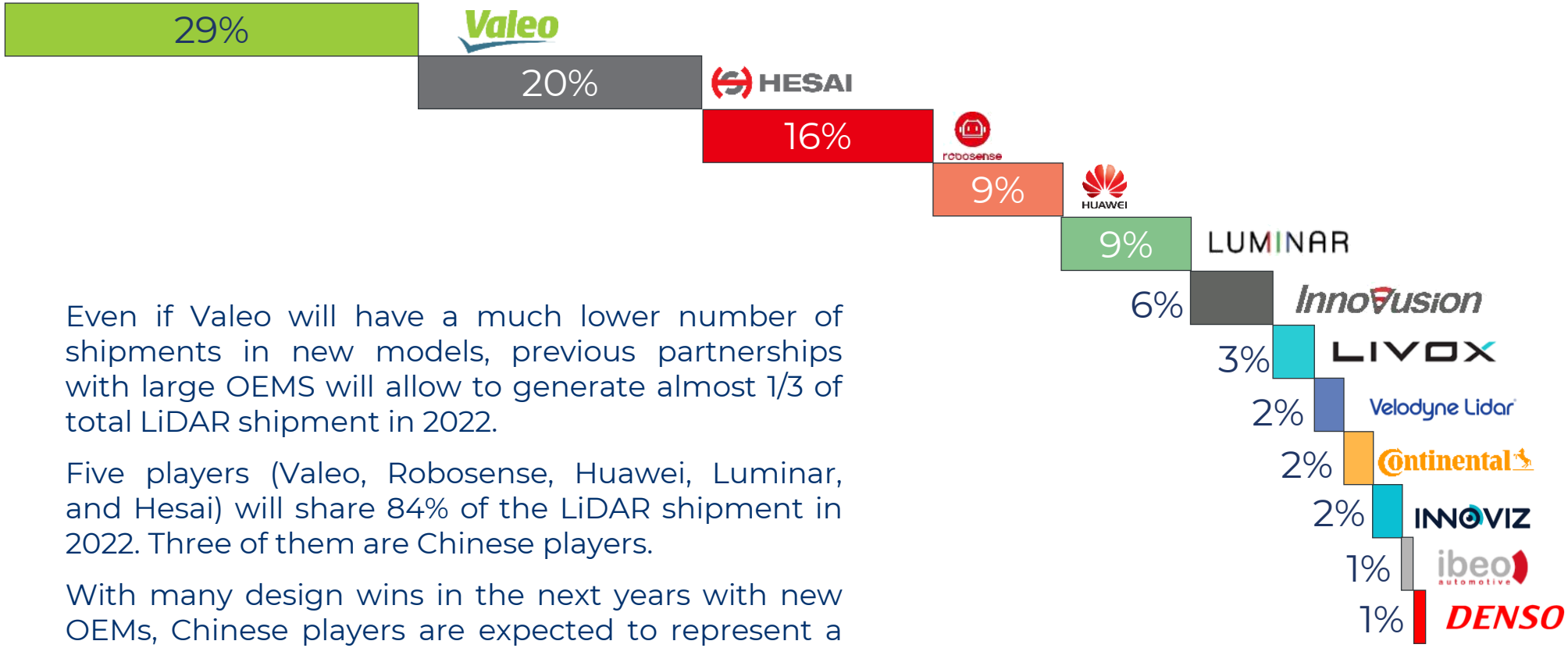
Stellantis has recently partnered with Valeo to develop L3 functionalities.

AUTOMOTIVE LIDAR MARKET

LiDAR shipments expected for 2022

Valeo is expected to remain leader, but competition is increasing, especially from Chinese players.

~221,000 LiDARs are expected to be shipped in ADAS cars in 2022



Even if Valeo will have a much lower number of shipments in new models, previous partnerships with large OEMS will allow to generate almost 1/3 of total LiDAR shipment in 2022.

Five players (Valeo, Robosense, Huawei, Luminar, and Hesai) will share 84% of the LiDAR shipment in 2022. Three of them are Chinese players.

With many design wins in the next years with new OEMs, Chinese players are expected to represent a significant part of the LiDAR market.

AUTOMOTIVE LIDAR TECHNOLOGY

Technology roadmap (1/2)

APD (Discrete)

EEL (Discrete)

FPGA (250 MHz)

Manual

High

Photodetector (1D in 2022)

Laser (1D in 2022)

Processing (FPGA at 1.2GHz in 2022)

Assembly

Cost of production

SPAD / SiPM (array)

VCSEL (array)

Custom ASIC

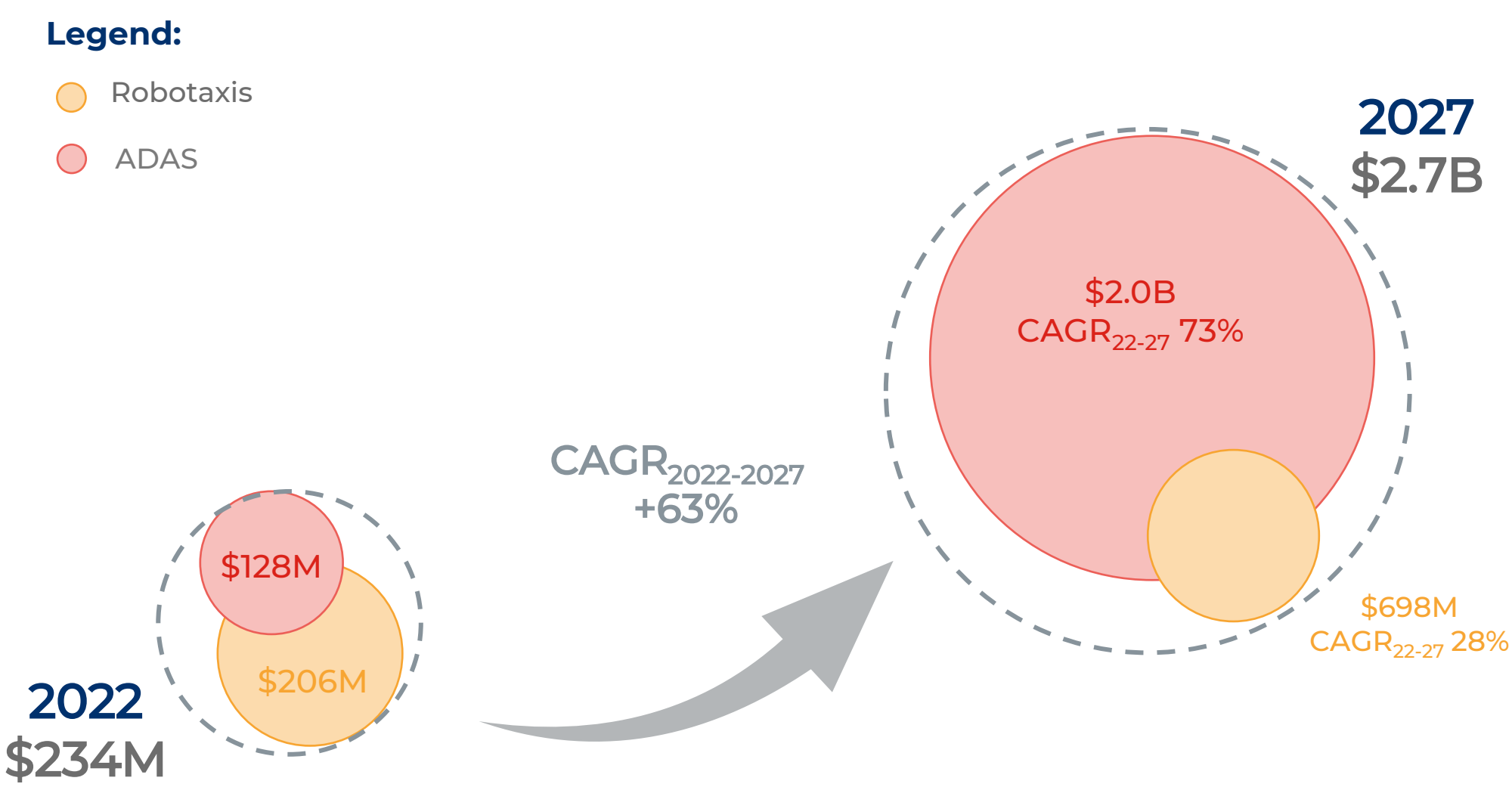
Highly automated

Low

Better semiconductor integration

AUTOMOTIVE LIDAR MARKET

ADAS market is expected to have a major impact on the LiDAR market.



Focus on AR/VR headsets

FOCUS ON AR/VR HEADSETS

Definitions – two different systems

Visual presence of the environment

Augmented Reality (AR)

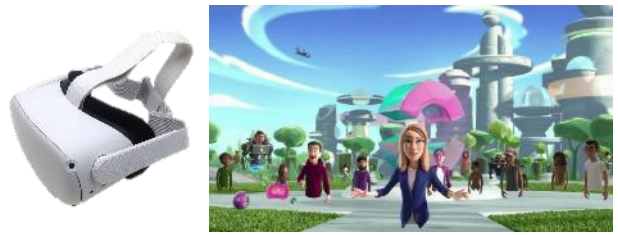
- Overlays simple information and computer-generated (CG) images onto the real world.
- There is little to no interaction between the CG content and the user's environment.
- The display must not obstruct the real world. It must compete with ambient light to generate digital information with similar brightness as that seen in the real world. Resolution and field of view requirements (FOV) vary with the application.

Mixed Reality (MR)

- Overlays complex, often 3D computer-generated (CG) images onto the real world.
- The CG content can interact with the environment (objects in the room, wall, vehicle, etc.). The system uses multiple sensors to create a real-time 3D model of the environment, and the CG content adapts in real-time to any change.
- Display requirement is like AR. A larger FOV is usually desirable. Improved resolution and brightness are likewise expected.

Virtual Reality (VR)

- A 100% artificial, computer-generated simulation or display of a real-life environment that immerses the users by making them feel like they are experiencing the simulated reality firsthand.
- VR requires a fully enclosed head-mounted display (HMD) that visually isolates the user from the outside world. For a realistic and immersive experience, the system should offer a field of view and resolution closely matching the capabilities of the human eye.



Quantity of information displayed

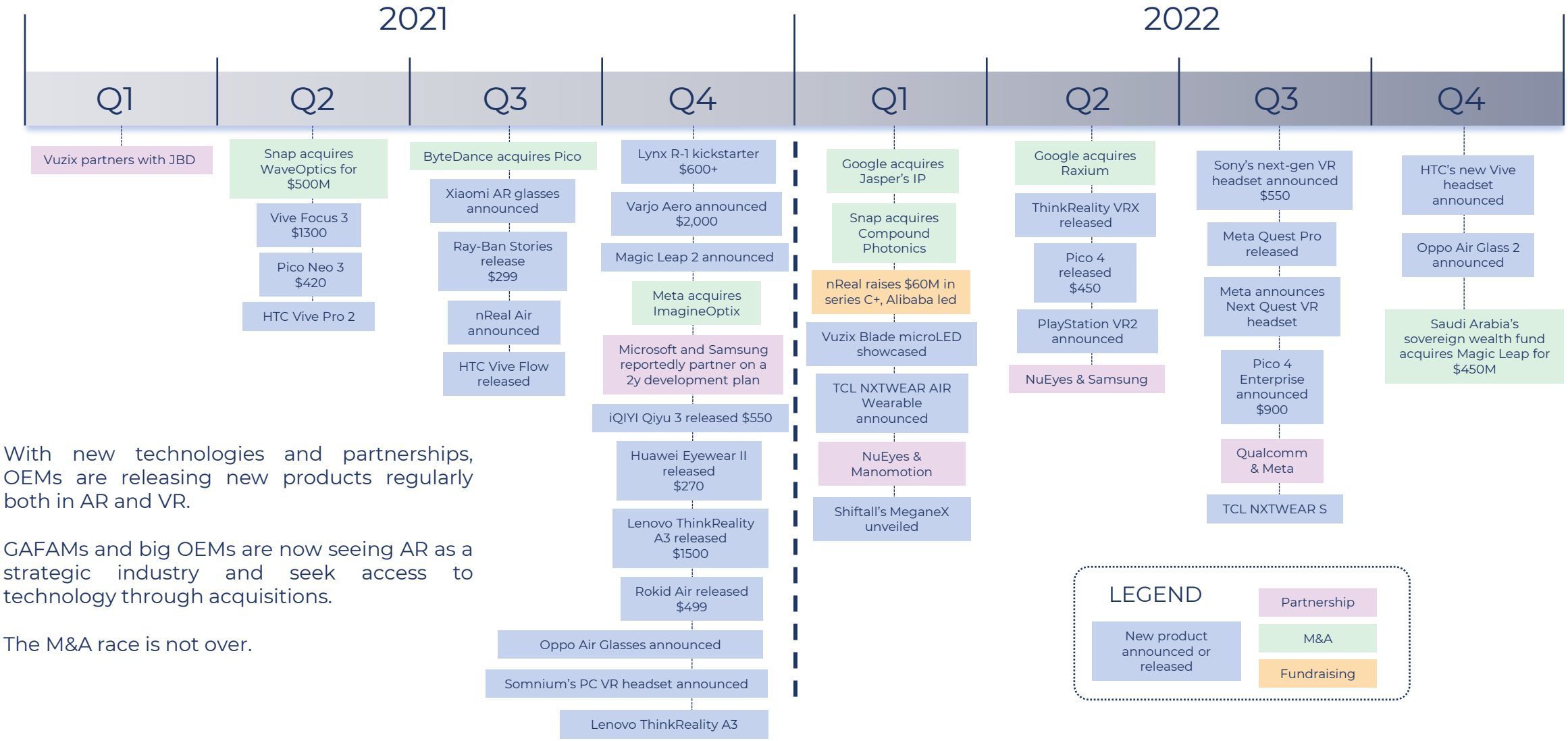
FOCUS ON AR/VR HEADSETS

Different applications for headsets

	VR	AR
Industrial		
Education	• Distance learning • Job training • Medical education	• Job training • Medical education • Astronomy • Defense
Industry	• Engineering • Design • Marketing	• Assembly • Maintenance • Repair • Safety • Inspection
Healthcare	• Physical therapy • Pain management • Treatment of phobia • Cognitive recovery	• Patient communication • Surgery • Health treatments
Logistics		• Optimized picking • Warehouse planning • Completeness check • International trade
Consumer		
Entertainment	• Video games • Theater • Museums • Immersive documentaries • Tourism • Amusement parks • Art-work • Personal coach • Galleries • Music concerts	• Sports statistics? • Tourist guide? • Food calorie scanning? • Cooking instructions? • Personal trainer? • Movie subtitles?
?		

FOCUS ON AR/VR HEADSETS

Significant OEM developments since 2021



- With new technologies and partnerships, OEMs are releasing new products regularly both in AR and VR.
- GAFAMs and big OEMs are now seeing AR as a strategic industry and seek access to technology through acquisitions.
- The M&A race is not over.

FOCUS ON AR/VR HEADSETS

Consumer, Medical and industrial markets trends

Main applications

- Video games
- Social networks
- Health monitoring
- Phone functions

Consumer

In the consumer market, creating a use case is required. Gaming and well-being are well-established for VR systems but need a major consumer electronics player to jump in for AR. Today, AR is mainly used through smartphones rather than bulky, expensive AR headsets.

- Surgery
- Medical education
- Pain management
- Teleconsultation

Medical

The use cases for medical professionals are clearly defined. The use of AR headsets for training, treatment, and education is a possible new solution being investigated to help surgical procedures. VR headsets are finding interest in depression, cognitive recovery, phobia, and post-traumatic stress disorder (PTSD) of soldiers.

- Logistics
- Maintenance
- Labor operation
- Training
- Meetings

Industrial

More and more companies are developing AR/VR systems for the industrial market. They were mainly used for military and security applications in the past and are now widely used for training and maintenance operations.

- In the consumer market, the goal would be to convince the consumer that there is a reason for them to acquire AR smart glasses. Big consumer OEM companies, such as Apple, Samsung, Oppo, have been quite dynamic in the field for a few years.
- AR/VR headsets for the medical market continue to evolve. They are now connected to robots able to operate on patients at a distance. In the coming years, the functions will continue to be improved thanks to the 5G connectivity.
- AR/VR systems for the industrial market are now well established; the use cases for professionals are clearly defined and have been known for years: logistics, safety, repair, training, treatment, education, etc.

FOCUS ON AR/VR HEADSETS

Two different markets and dynamics

VR

→ Job training
→ Distance learning
→ ...

→ Gaming
→ Entertainment

→ Future killer app?

LEGEND

DEFENSE

INDUSTRIAL

CONSUMER

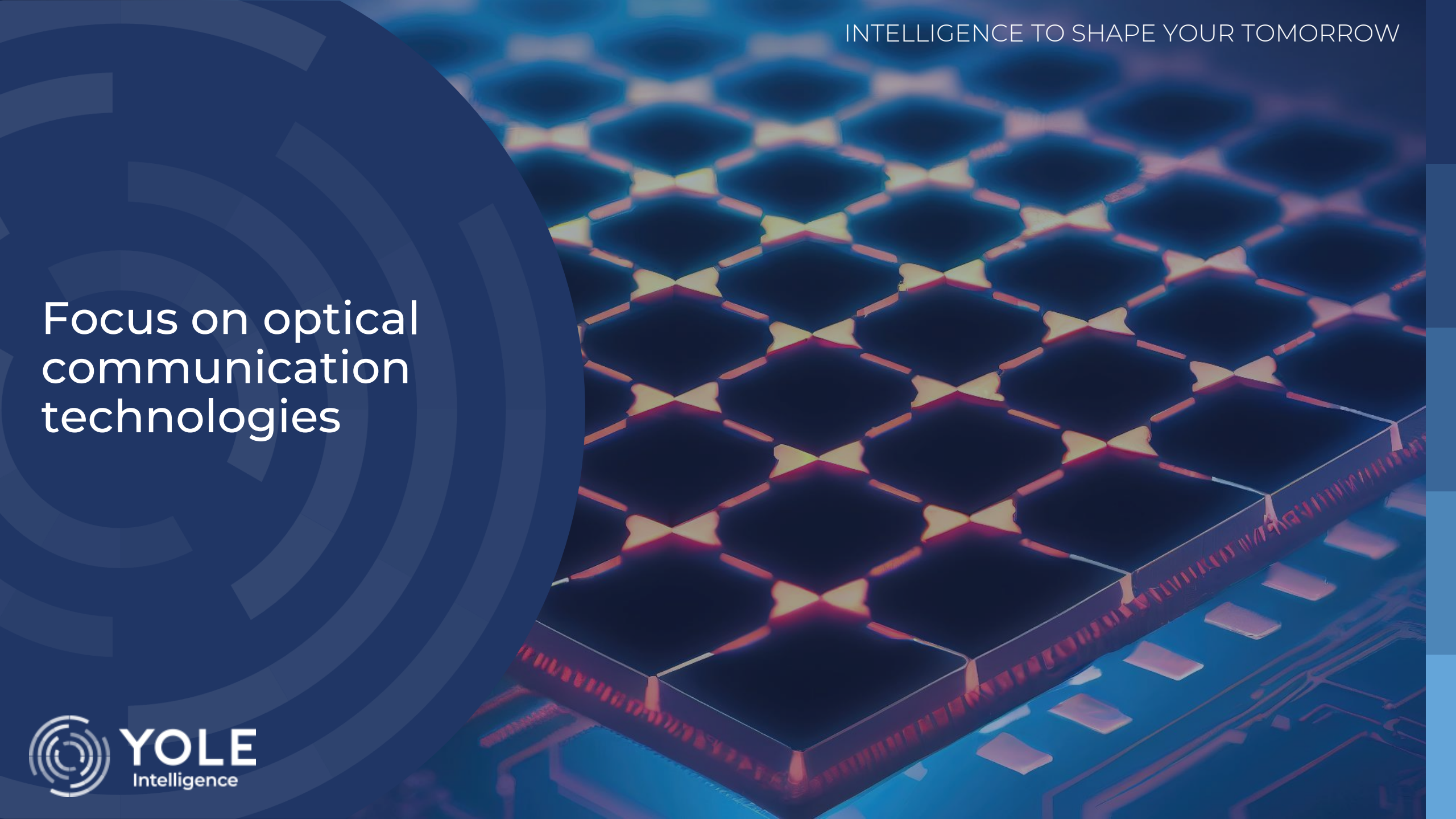
AR

→ Soldier AR HUD

→ Job training
→ Assembly assistance
→ ...

→ Consumer smart glasses

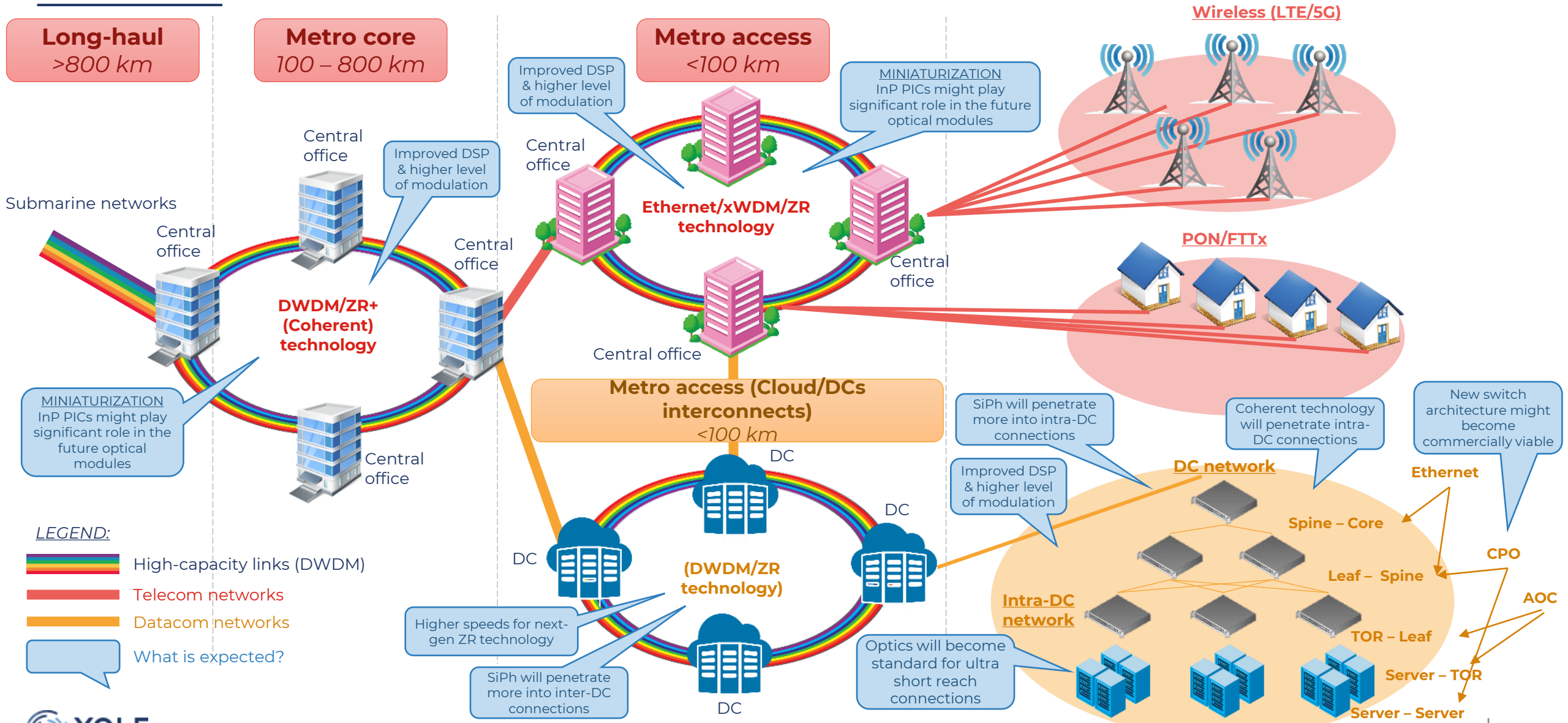
Focus on optical communication technologies



YOLE Intelligence

FIBER-OPTIC COMMUNICATION APPLICATION TRENDS

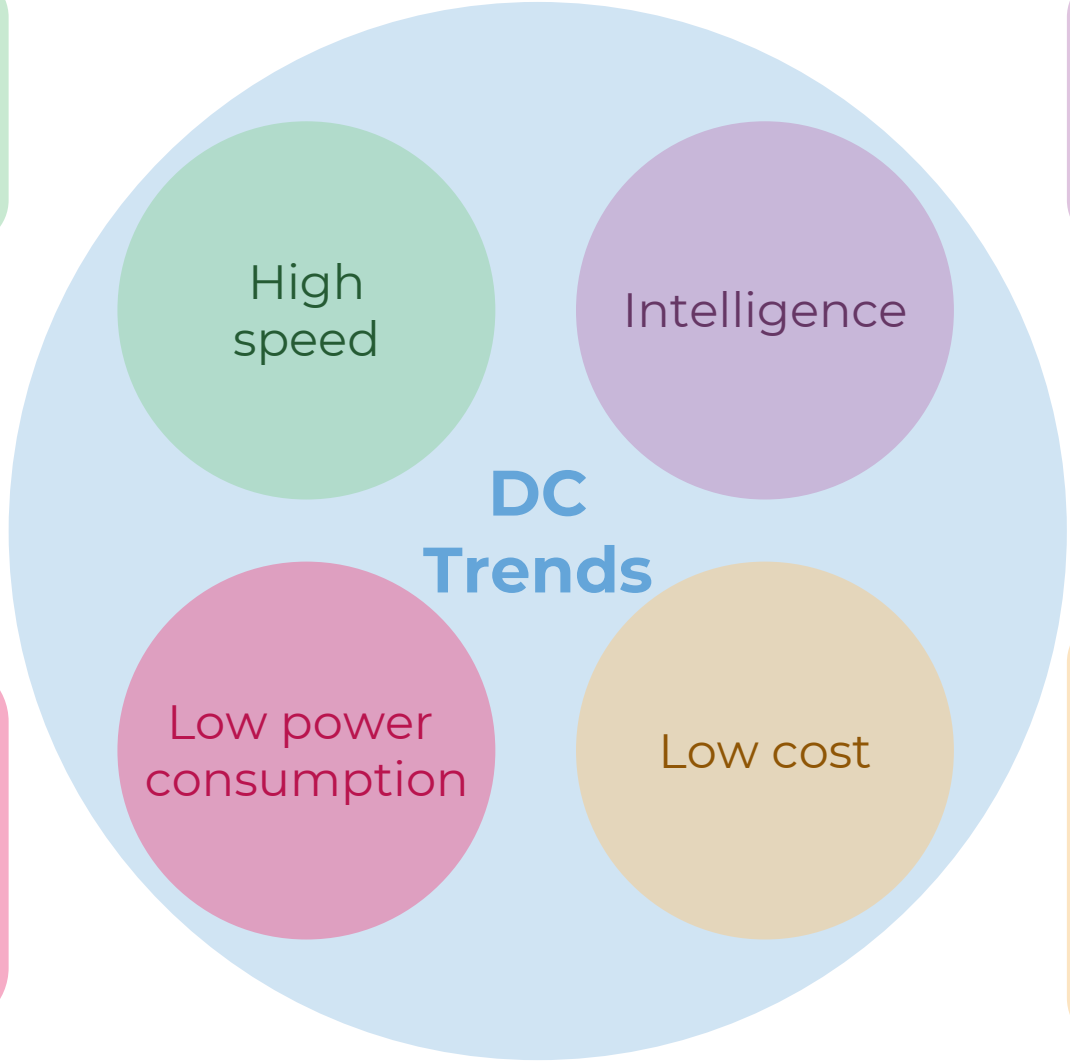
Mapping of optical interconnections – What is expected over next 5 years?



DATACOM

Trends in data center in terms of technology

- Commercial deployment of 400G in volume has begun
- Transition from 100G to 400G
- Throughput switch ASIC 51.2Tb/s early 2023, and 102.4Tb/s after 2025
- Migration to higher data rate 800G and 1.6T next three years



- New requirements on capabilities of the operation and maintenance due to new DC applications
- AI/ML applications: automated logistics/manufacturing, health monitoring

- Power contribution of optical interconnects starts to exceed that of switch ASIC
- 400G (Initially 10-12W, future 8-10W) | 800G (16W)
- Electrical interface also has significant impact
- Solutions: low power modulators or deep integration → co-packaging optical engines and switch ASIC

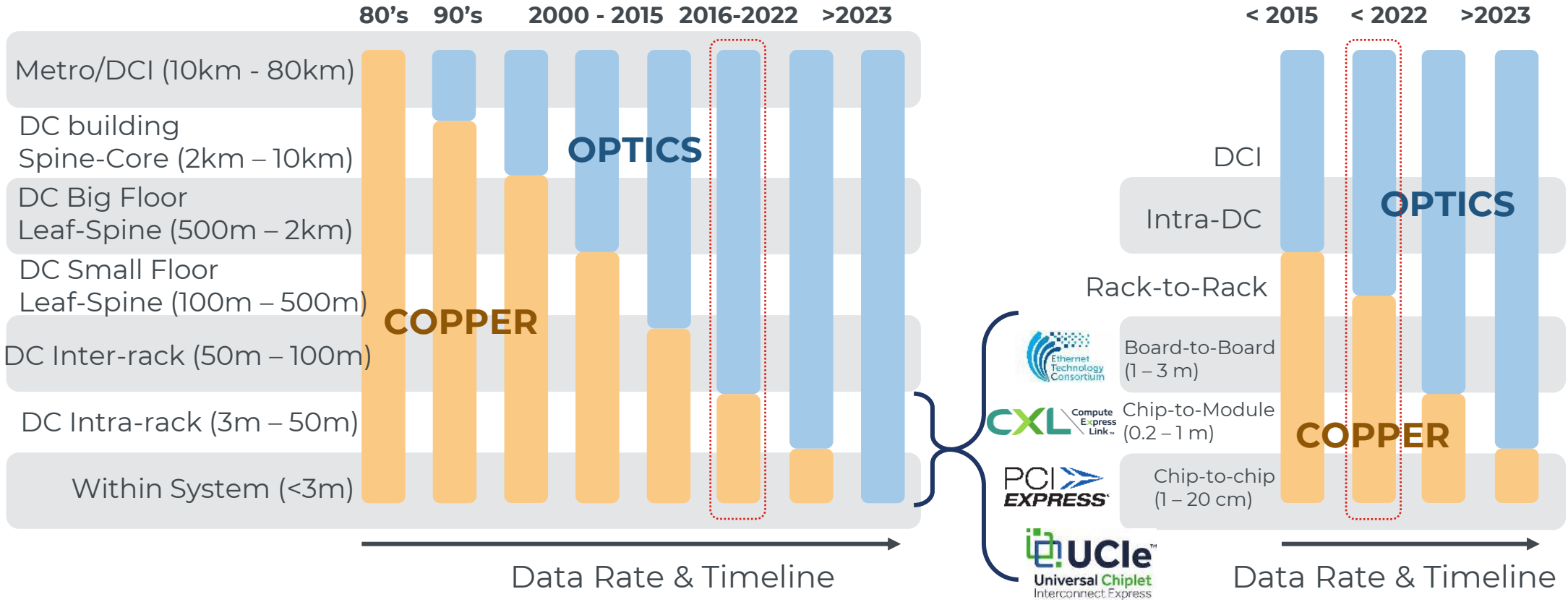
- High volume of module adoption forces the operators to carefully choose the right technology for each application (transmission distance)
- Server-TOR: Copper cables dominate, but with a data rate increase, the transmission distance reduces.
  - A new rack layout is needed, or optical fiber will replace DACs
- Flexibility and longevity of the switch systems remain essential – rapid modules replacement, low-temperature environment to save cost

FIBER-OPTIC COMMUNICATION APPLICATION TRENDS

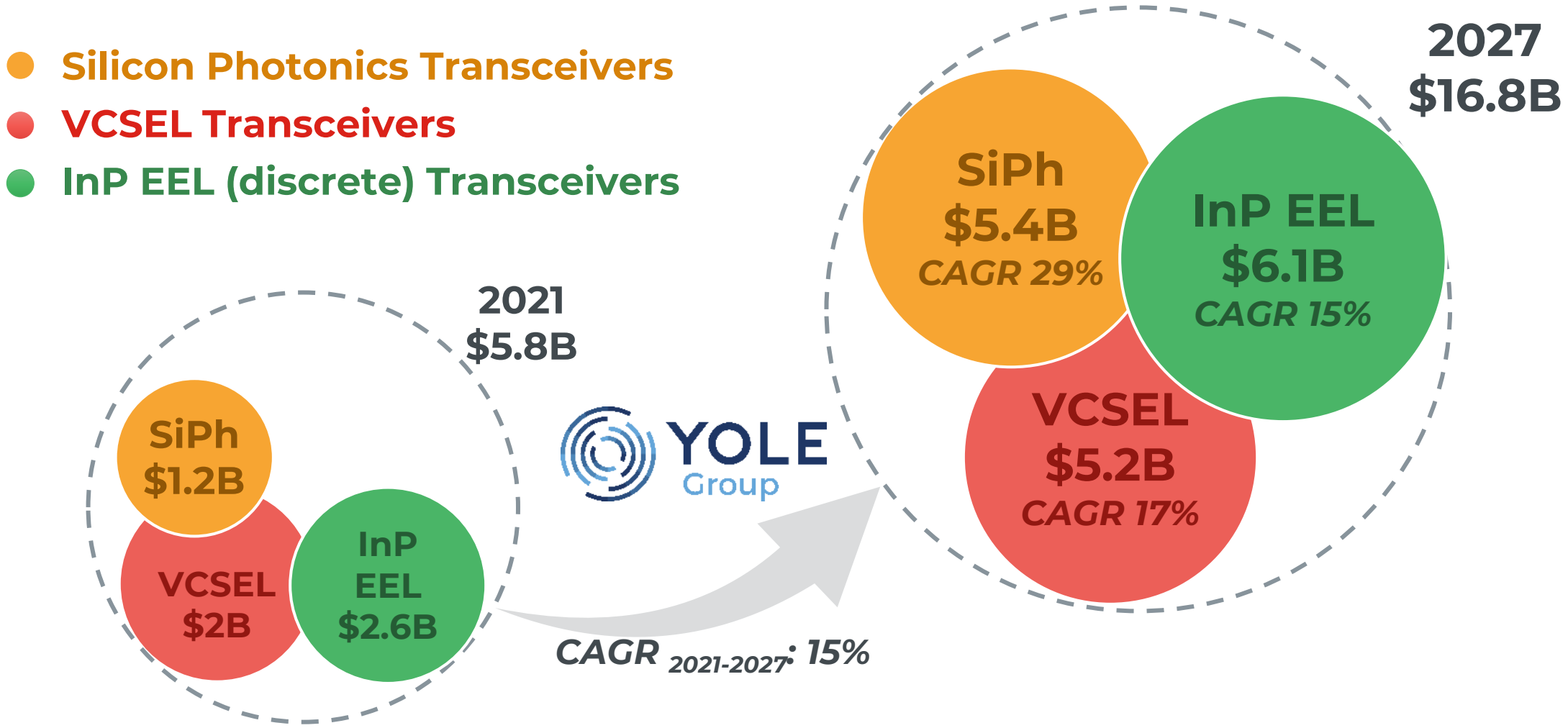
Pluggable optics evolution – Moving from copper to optics

TREND:

Optical interconnects tend to penetrate the rack and computing systems.



OPTICAL TRANSCEIVER REVENUE GROWTH FORECAST (2021 VS. 2027) IN DATACOM SPLIT BY TECHNOLOGY

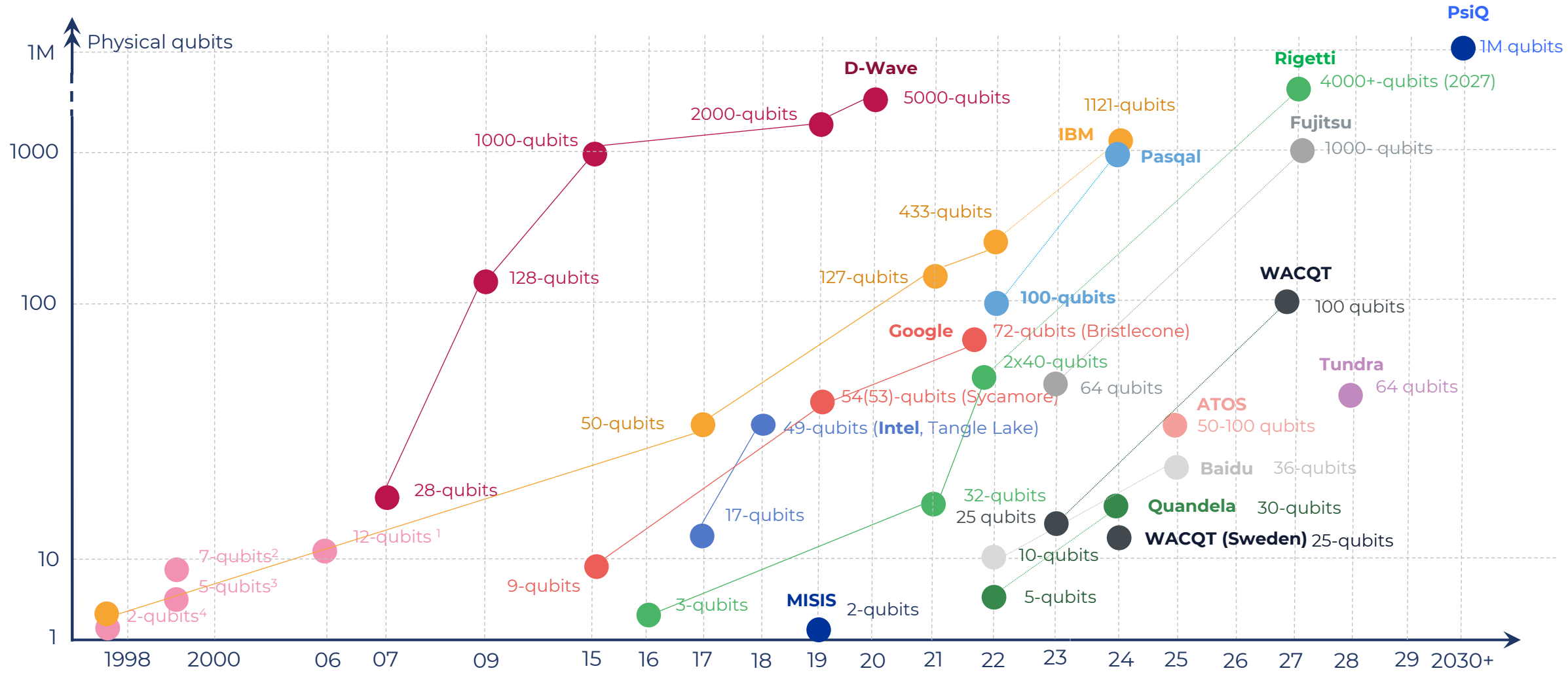


Focus on Quantum Technologies

A photonic perspective

YOLE Intelligence

QUBIT R&D EFFORT AND ROADMAP (1/2)

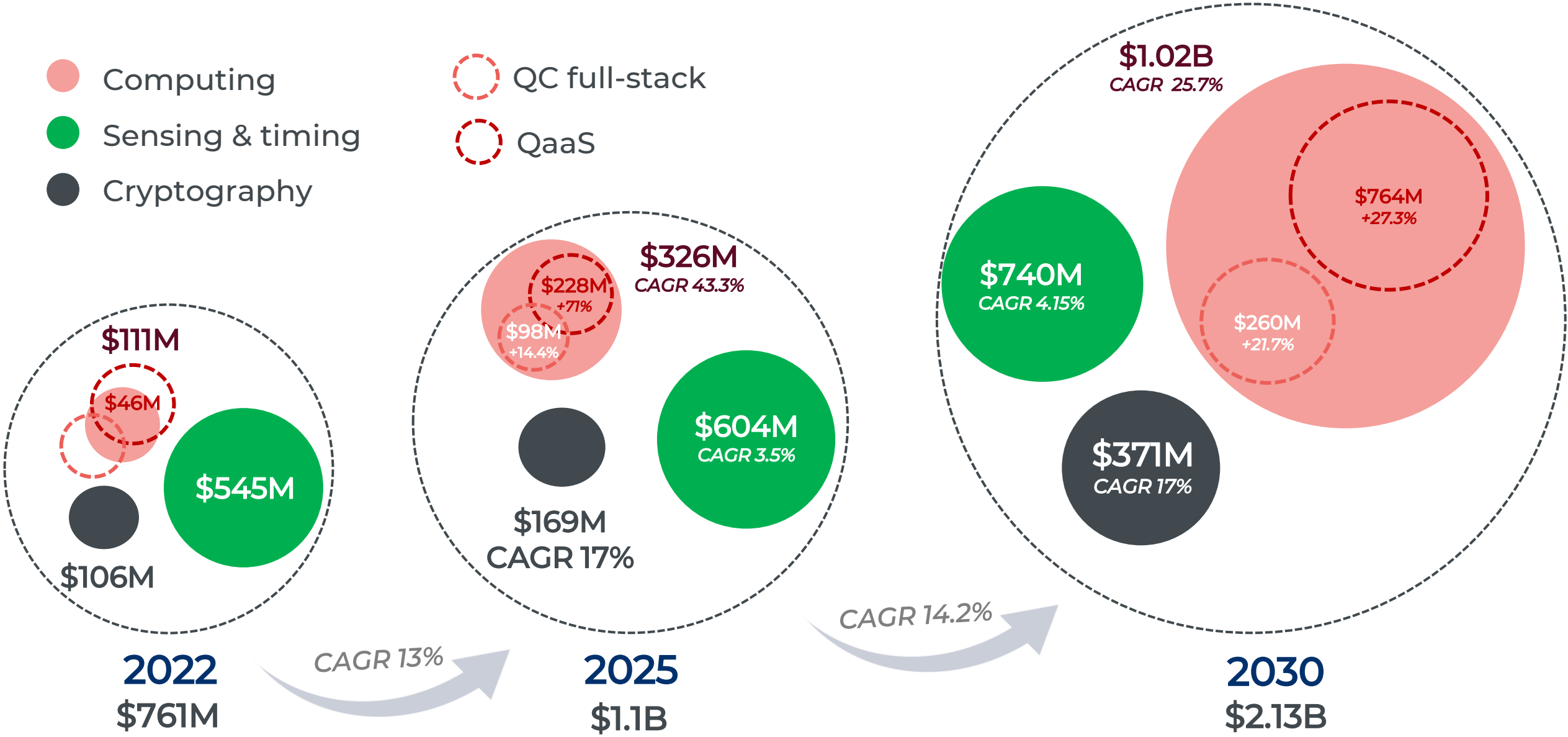


[1] (Institute for Quantum Computing, Perimeter Institute for Theoretical Physics, MIT)
[2] (Los Alamos National lab)
[3] (TU Munich)
[4] (Oxford University, IBM, UC Berkeley, Stanford, MIT)

*** Intel stopped superconducting qubits and is today focusing on spin QD**

MISIS (RU) · IBM · Fujitsu · Tundra · D-Wave · ATOS · Google · Rigetti · Quandela · Baidu · Intel* · PsiQ · WACQT (Sweden) · Pasqal · R&D

2022 - 2025 - 2030 QUANTUM TECHNOLOGIES FORECAST



PHOTONICS AND QUANTUM COMPUTING NEED EACH OTHER

Except for Si spin / QD and topological qubits (they are very early-stage), all others will require optics and photonics elements.

Photonic devices

- Lasers
- Single photon source
- Photo detectors
- Fiber optics (if networked)
- Modulators
- Collection and imaging optics
- Switches
- Waveguides
- Couplers and filters

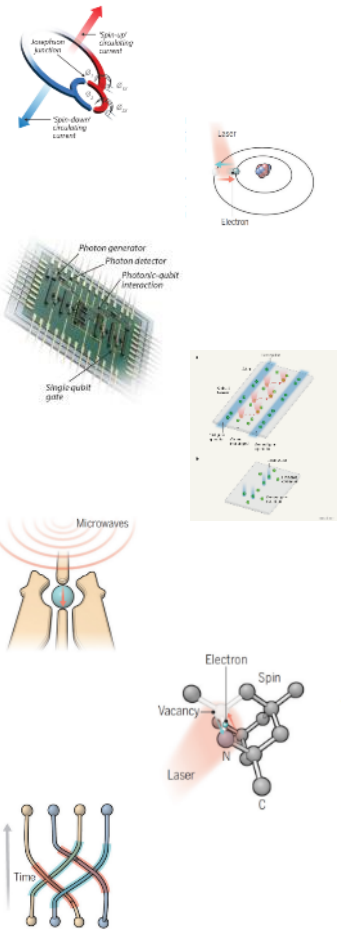
Unlikely?

Unlikely?

Photonics will be of great importance to the development of quantum technologies, as lasers and other photonic devices are used for trapped ion / photon /neutral atom technologies.

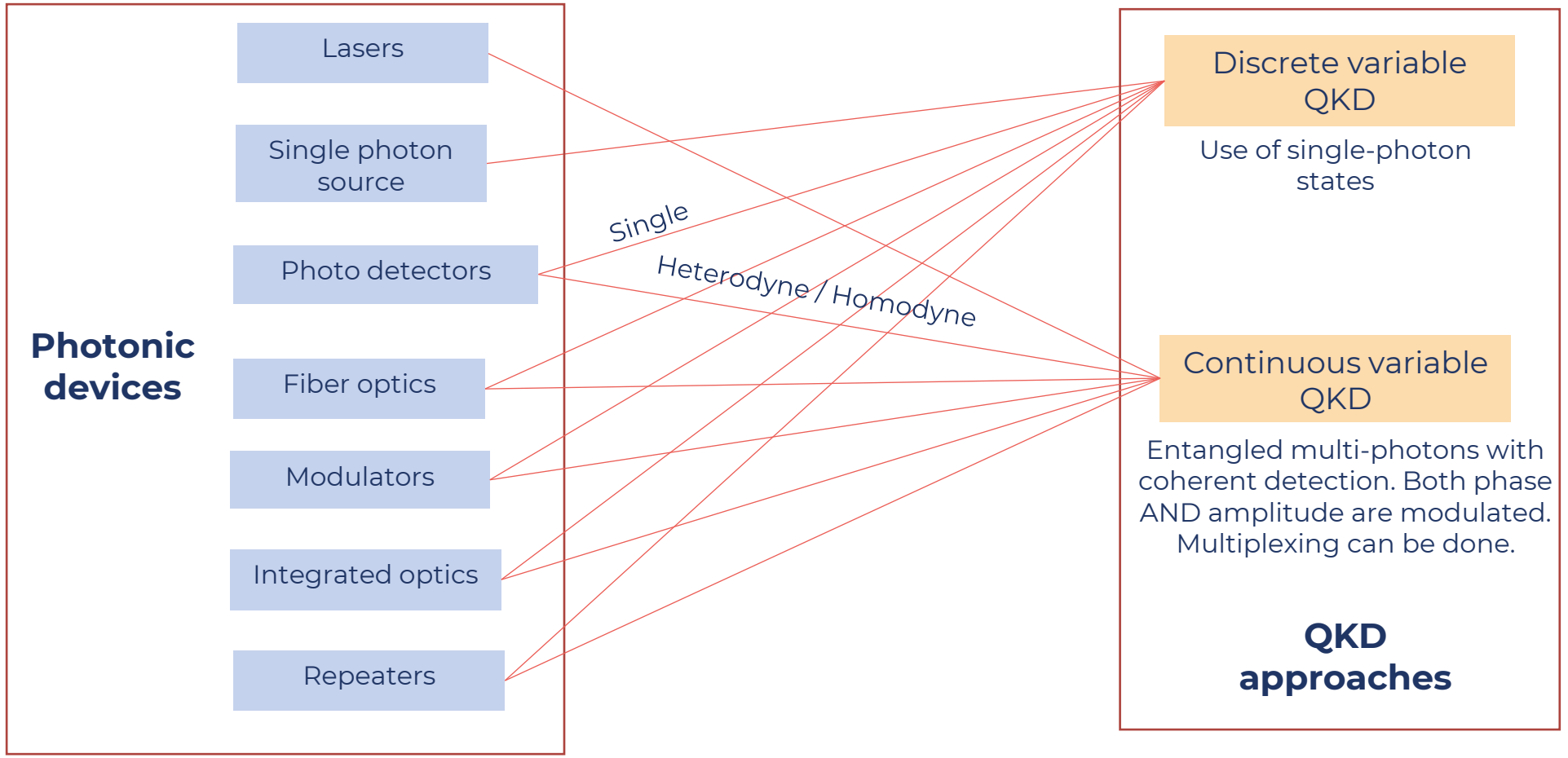
Qubit approaches

- Superconducting
- Trapped ions
- Photons
- Neutral / cold atoms
- Si spin / QD
- NV centres
- Topological



PHOTONICS AND QUANTUM COMMUNICATION NEED EACH OTHER

D-QKD requires single photon detectors (since they use single photon source) while CV QKD requires heterodyne or homodyne photon detectors (since they use laser source).



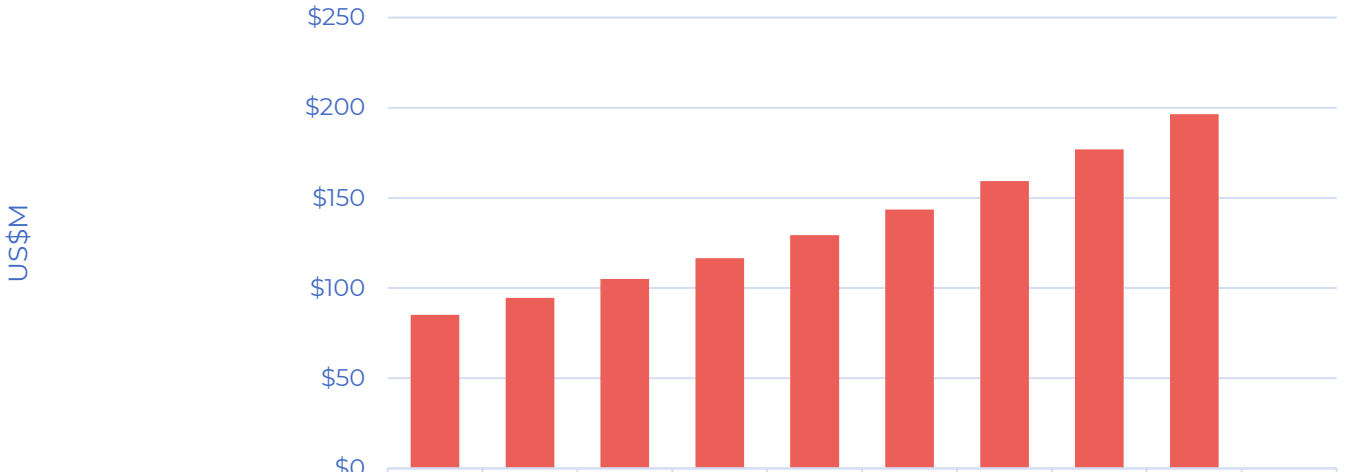
LASERS SYSTEMS FOR QUANTUM APPLICATIONS MARKET FORECAST

A $200M market in 2030.

Graph below shows the market forecast for lasers for quantum applications. It includes revenues from shipment to industrial quantum companies and R&D labs.

If we considered a US$300k price for a complete laser system for quantum computers, it will be 650 systems that will be shipped in 2030 (a complete quantum computers will need several laser systems).

Lasers systems for quantum solutions 2022-2030 forecast



	2022	2023	2024	2025	2026	2027	2028	2029	2030	CAGR 2022-30
Lasers systems for quantum solutions	$85	$95	$105	$117	$129	$144	$159	$177	$196	11%

CONCLUSIONS

Quantum is the new Gold Rush!

Today quantum technologies are like the Gold Rush. Although in the long term, the companies that will success are the ones that will develop a full-stack QC, in the short term, the companies making money are the ones that will provide the tools (lasers, cryogenics …).

Developing a set of toolboxes (such as photonic systems) is a good way to have revenue in the 3-5 years term while reassuring investors.

XIX century

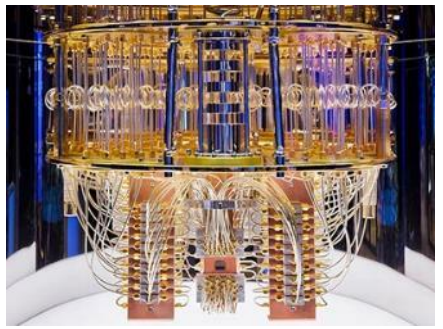
XXI century

Immediate recurrent revenue

Long-term revenue – strong R&D effort required

IBM

Google



Silicon Quantum Computing

阿里云

rigetti

intel

Honeywell

IONQ

GENERAL CONCLUSION

- Photonic technologies abounds
- New photonic technologies emerge
- Lots of innovation will continue to happen at sub-system and system levels for all sort of applications

PISÉO, INDEPENDENT INNOVATION PLATFORM

A UNIQUE COMBINATION OF EXPERTISE AND TECHNICAL MEANS DEDICATED TO THE INTEGRATION OF UV-VIS-IR PHOTONIC TECHNOLOGIES: LED, LASER, PHOTODIODS, IMAGE SENSORS, MATERIALS…

CONSULTING & ENGINEERING

- System pre-development and feasibility studies
- Optical design and simulations
- System design and industrialization: products & test benches
- Scouting & analyses: technologies, markets, standards and regulation
- Optical risk assesment and prevention

TEST LAB (ACCREDITED ISO 17025)

- Radiometry, photometry, luminancemetry & colorimetry
- Image quality of VIS and IR imaging systems
- Optical properties of materials

Markets: Automotive, Healthcare, Defence, Lighting, Industries…

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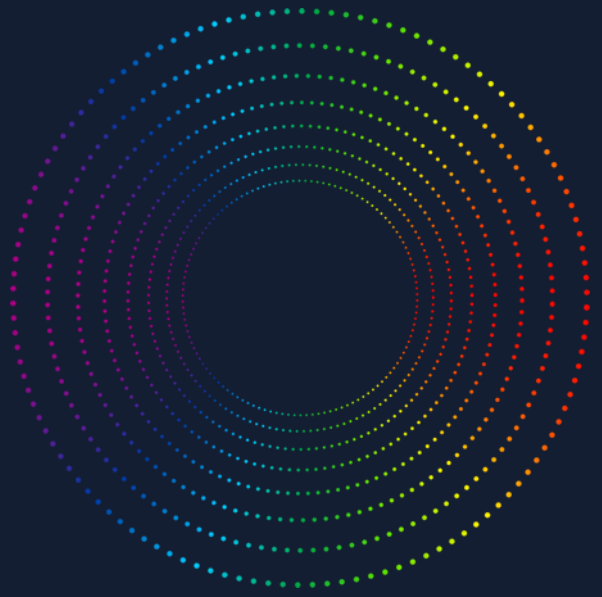
YOLE Group

THANK YOU



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