PhotonDelta
Gateway to Integrated Photonics

PhotonDelta Automotive Roadmap

Integrated Photonics for Automotive

Automotive in motion:
Grand challenges

2021

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Content

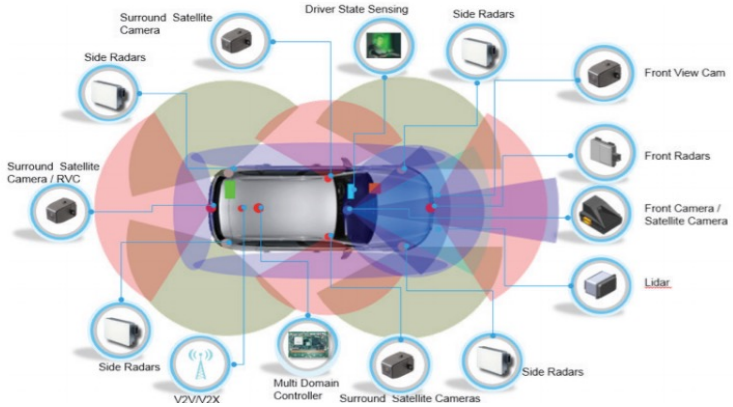
1.

Automotive in motion: Grand challenges

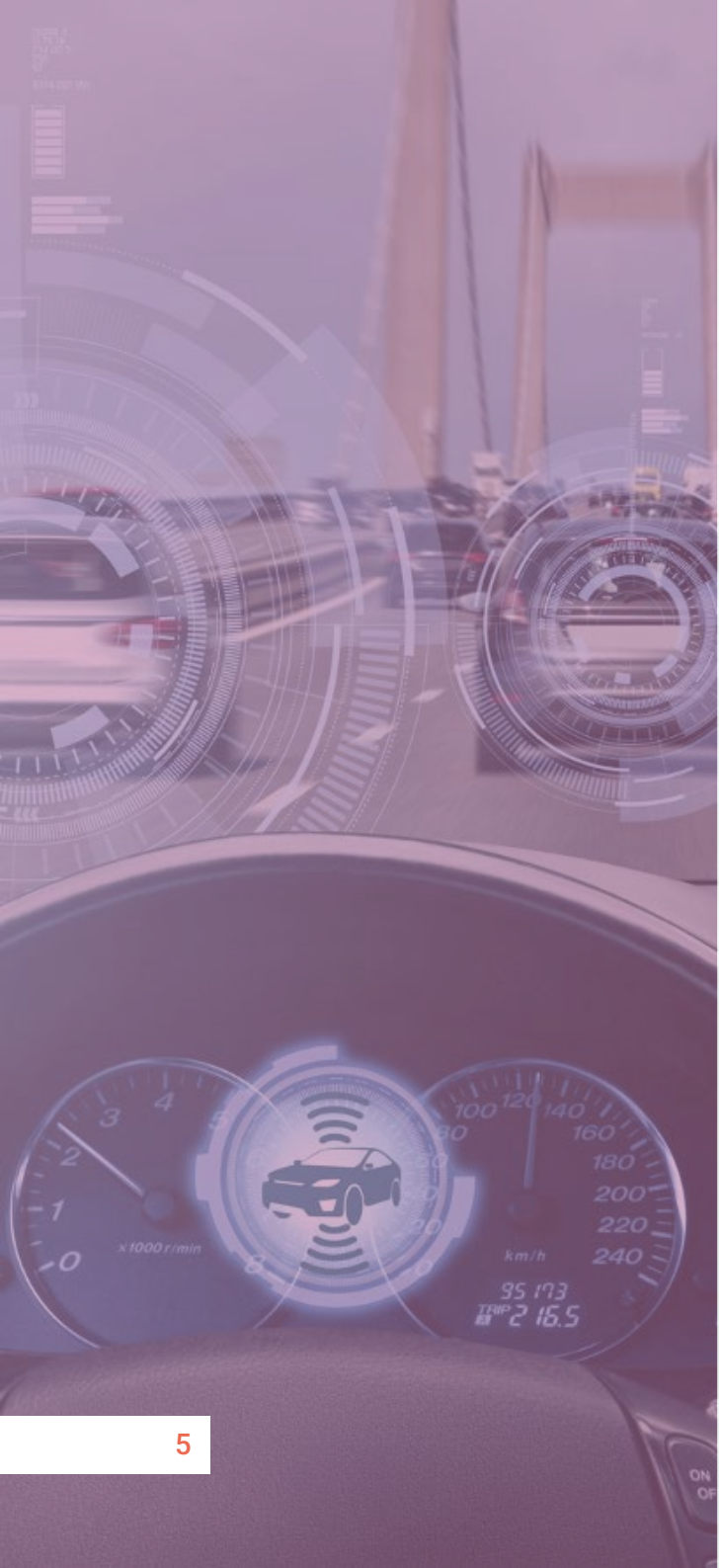
Automotive in motion: Grand challenges

- **The automotive industry is facing 3 revolutionary changes:**

1. Electrification
2. ADAS and the drive towards Autonomous vehicles
3. Mobility pattern changes,
   - different e-vehicles
   - robotaxis and transporters
   - “sustainable cities” influencing traffic patterns



- At the same time existing combustion engine vehicles are facing increasing headwinds
- All major car makers are moving strongly into Electric Vehicles (EV)
- This leads to accelated innovation and a very strong increase of electronics in vehicles
  - Power electronics and sensors in EV
  - Sensors and computing/networking for ADAS en autonomous vehicles
- The huge investments lead to reshaping of the automotive landscape,
  - cooperations between car makers,
  - New entrants, especially from China
  - Stopping investment in Combustion engines

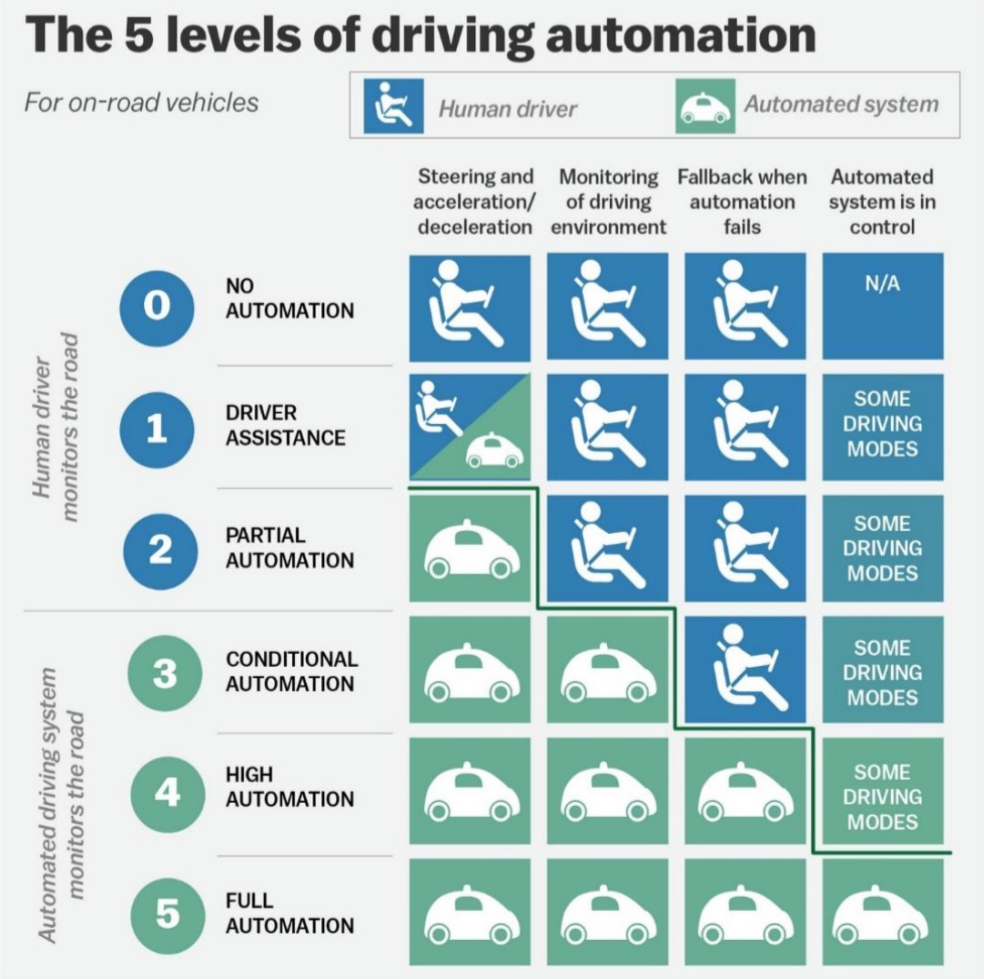


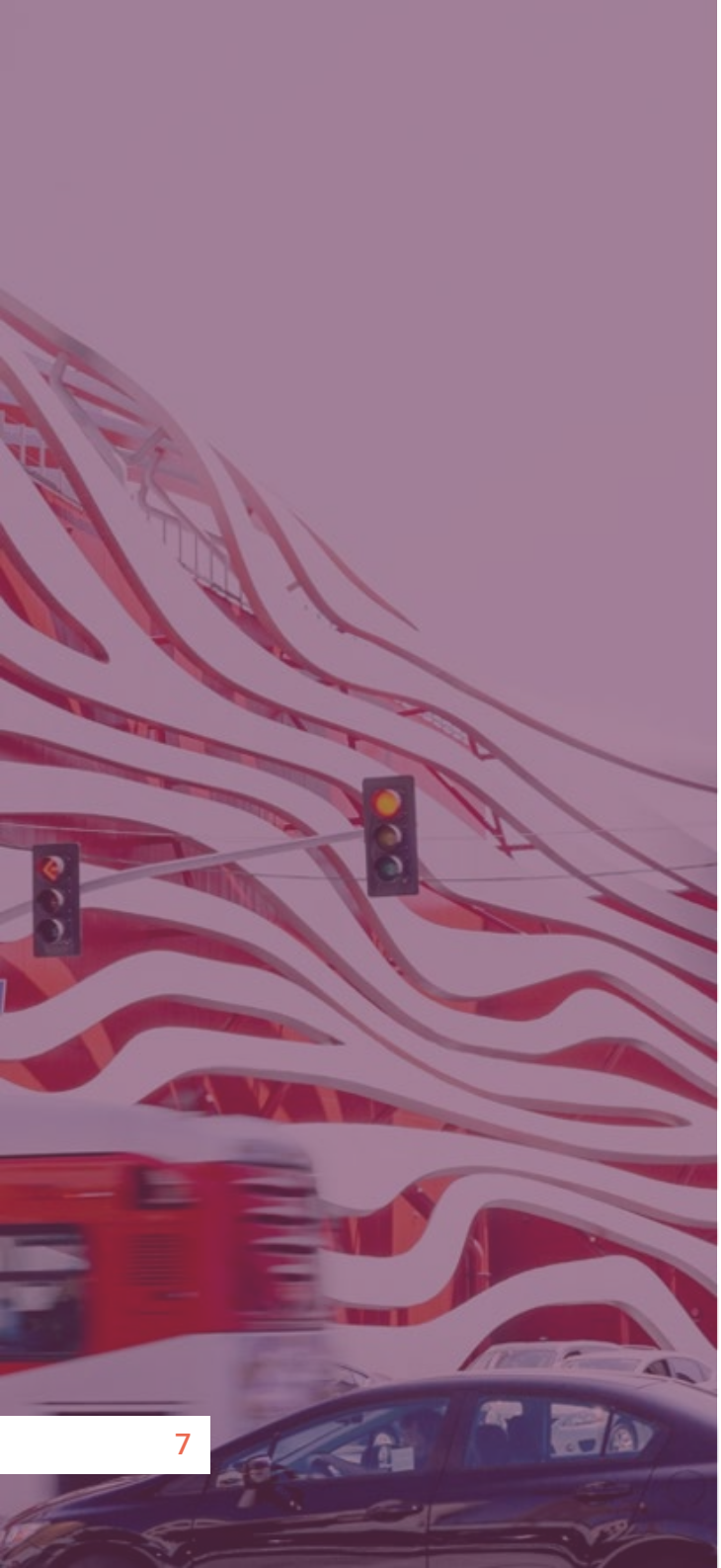
Electric vehicles are pushing out the combustion engine

- In the EU, car makers will have to manage the total emissions of their fleet or face huge penalties, so new strategies are needed.
- In the coming years, car makers will introduce hybrids (plug in, full , mild) for this reason.
- But full EVs are becoming rapidly more attractive as battery prices fall , supported by incentives and will total to > 30% share in new car sales by 2030 globally, after which the transition will go very fast in developed countries
- Some car makers have already announced that they will stop development of combustion engines.
- EVs have superior efficiency compared to Internal Combustion Engines (ICE). Cost parity on TCO (total cost of ownership) is expected before 2024 in some countries.
- Developing EVs and battery packs is very expensive. Only a few players will be able to keep this up.
  - E.g Tesla, VW spending 90B$, Daimler 60B$, Hyundai, Chinese conglomerates...
  - There are massive investments taking place in battery plants.
- Trucks will have their own dynamic, with short range delivery going first Hybrid and then EV. Long haul transport, has a number of options still open (H2/fuel cells, EVs or green Biogas).
- Buses are going electric rapidly.
- There is already a huge market for electric 2 wheelers and this will continue to grow.

Autonomous driving

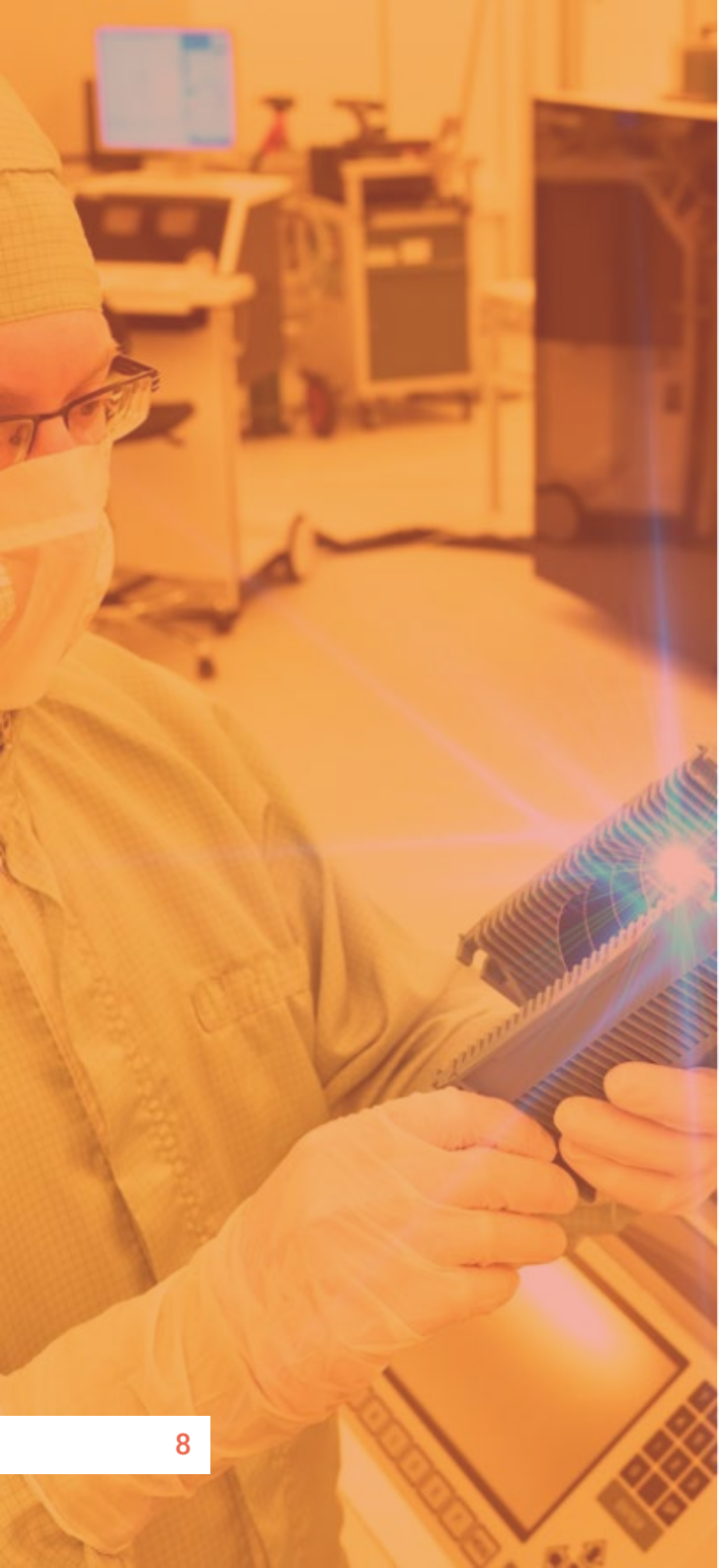
- Driving automation has gotten a lot of attention to improve driving safety and eventually create fully autonomous vehicles.
- Autonomous driving has been a huge hype in the past years, with several companies announcing level-5 cars in the coming years.
- After trials and some first experience, a sense of reality has come in, on open roads this will not happen before 2030 at best.
- Huge investments are still made, but most players now will first introduce improved ADAS (advanced driving assistance systems).
- There is a different business case for controlled environments (e.g. warehouses, industry) and robotransport and robotaxis
  - The first case is simpler to manage, and the second one can allow for much more expensive cars, because absence of the driver will create a strong business case





New mobility patterns, mobility as a service

- It is unlikely future cars will only look like electrified versions of cars we have today.
- Increasing urbanization (>70% of the world population in cities) will put pressure on the available space.
  - City centers will need more living space, greener and less roads.
  - Parking problems are huge, and very expensive for drivers and infrastructure.
- Alternative transportation has come up, enabled by electrification, like e-bikes, motors, steps, etc., mostly for the last (few) miles.
- As most cars stand still for >90% of the time, sharing services have become popular in cities
- Ubiquitous information access and increasing integration of service will allow for multimode transport, handled through your smartphone.
- In the future robotaxis can fullfill a large part of last miles transport as well.
- The same can hold for autonomous goods transport to city centers.
- This can lead to less roads with less cars and more mixed traffic patterns in cities.
- The cars that drive around will drive more kilometers and will recycle faster.
- It will mean a huge change in every aspect of the mobility chain.



Automotive suppliers will have to play by automotive rules

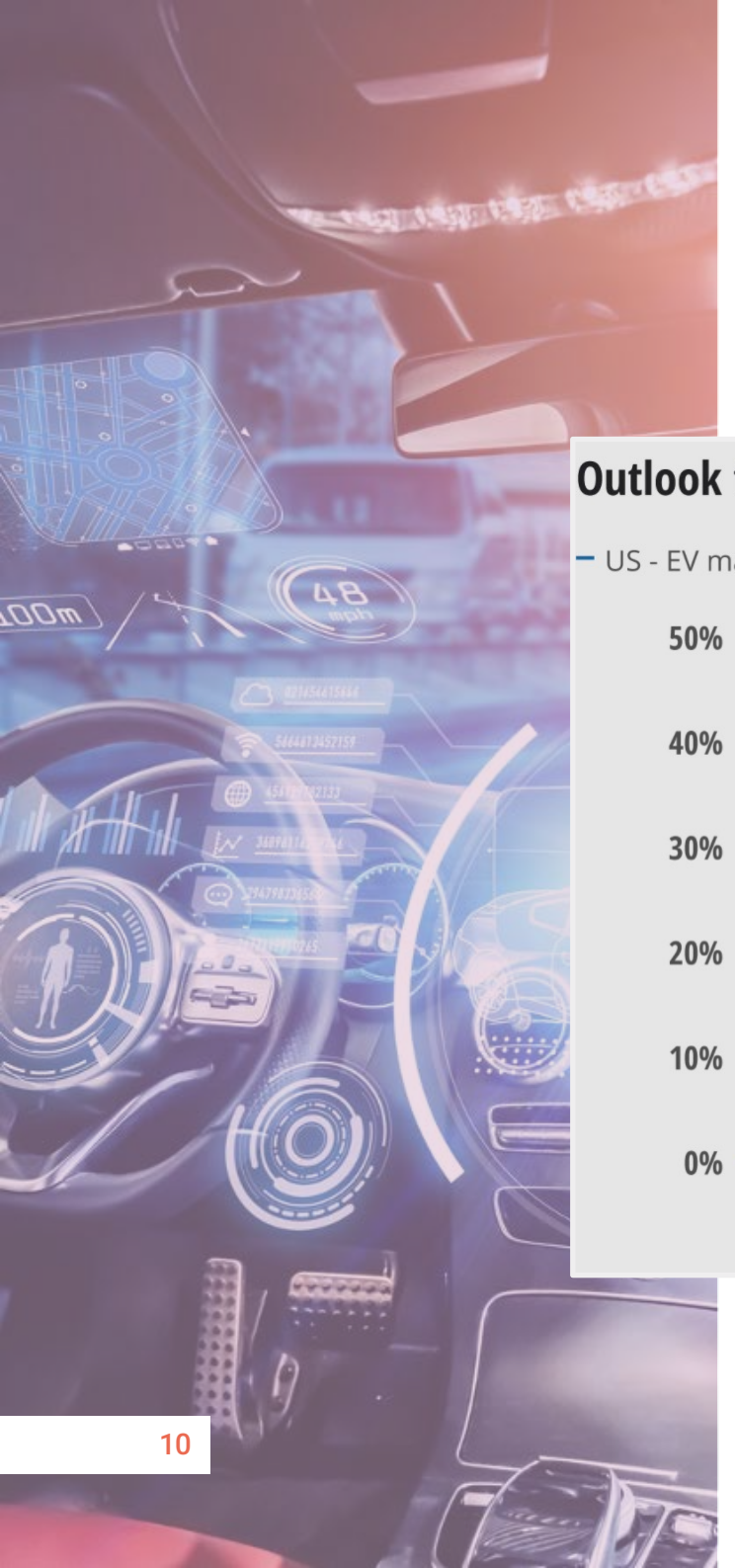
The automotive industry presents a specific combination of requirements:

- High volume production capability
  - No OEM will only develop key technology for a niche, 2nd sourcing is required.
  - You have to prove to be a trustworthy long-term supplier.
- Maturity of technology & supply reliability
  - Stopping a production line or product launch is sacrilege.
  - This means following automotive development & qualification (APQP) systems.
- Automotive quality and environmental conditions demands needs to be met
  - Single ppm (e.g. AEC Q100) failures, functional safety (ASIL) demands
  - Stringent temperature range, humidity, vibration/shock and dirt requirements
- Cost pressure
  - Cost roadmap
- Miniaturization and power consumption
  - There is limited space for electronics and design aesthetics are king
  - Power consumption drives cost (for cooling), and EV range.

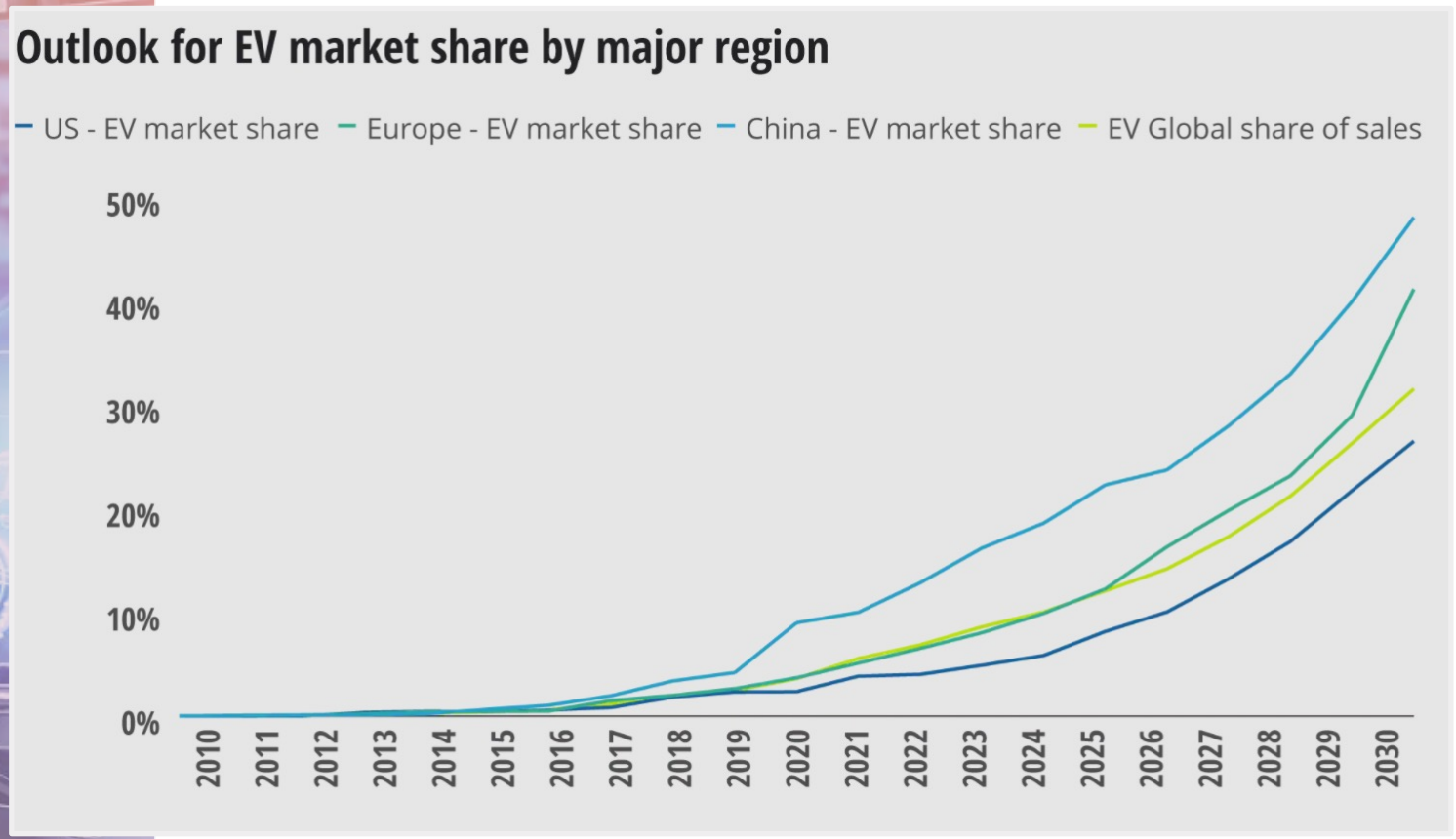
The automotive market

Overall conclusion:

- The automotive market is transitioning towards electric driving and more assisted driving.
- This is driving electronics and sensor content, which is positive for the market opportunities for (integrated) photonics as well.
- They also drive a strong increase in connectivity, which is another opportunity area.
- Besides traditional automobiles there will be a wide range of e-transport systems from 2 wheelers to robotaxis, autonomous transporters and drones , creating additional market opportunities

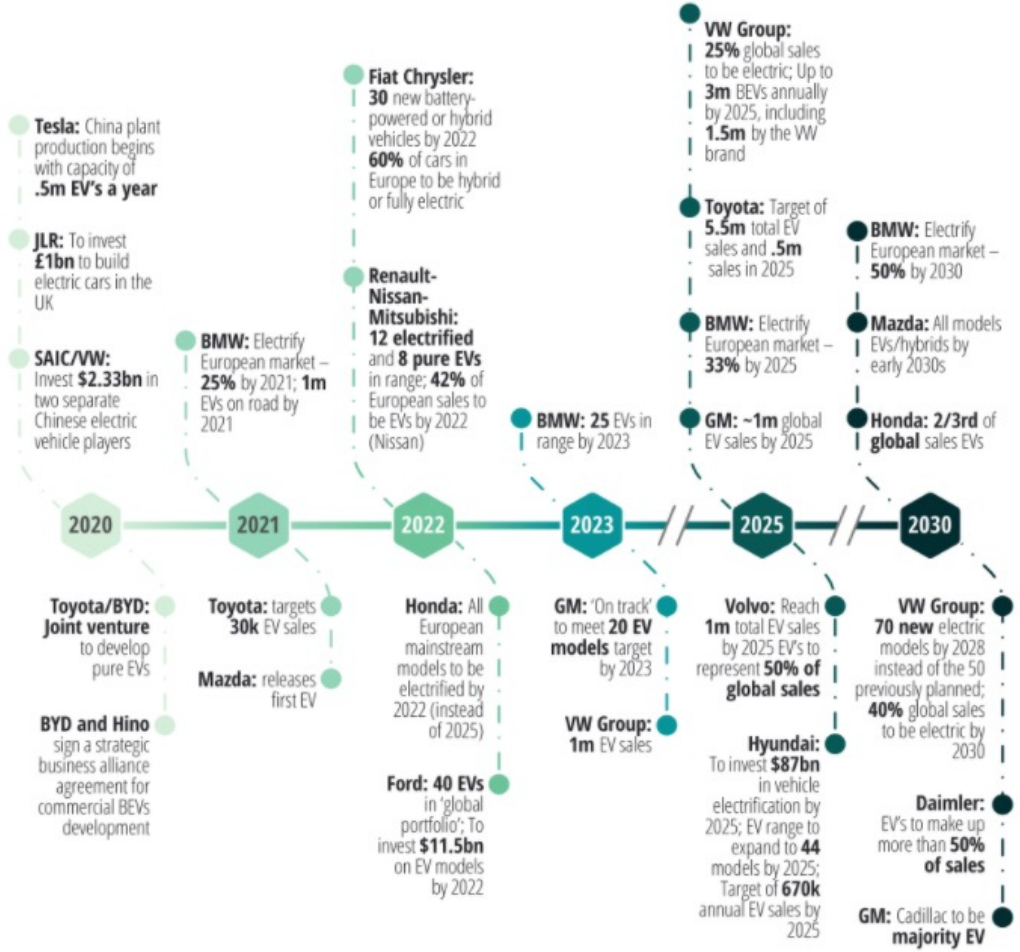


Global automotive market moving to EV



Sales trends are moving upwards faster (source: Deloitte Insights | deloitte.com/insights)

Global automotive market moving to EV



Timeline of strategic OEM targets for EVs (source: Deloitte Insights | deloitte.com/insights)

How autonomous driving can change the market

Fig. 9 Europe: Percentage of mobility forms (2017–2030)

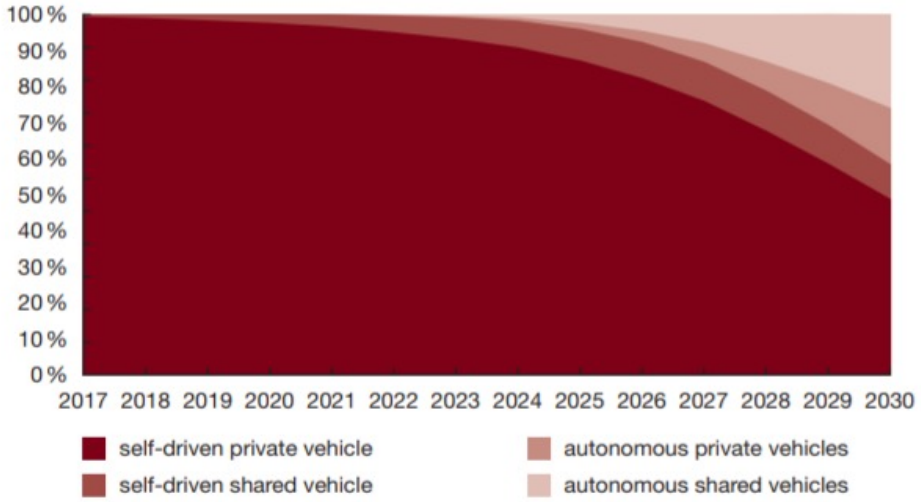
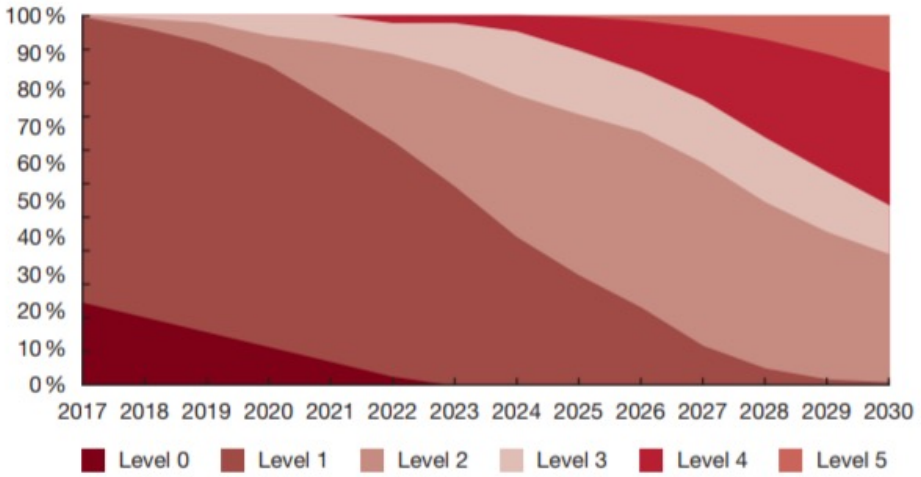


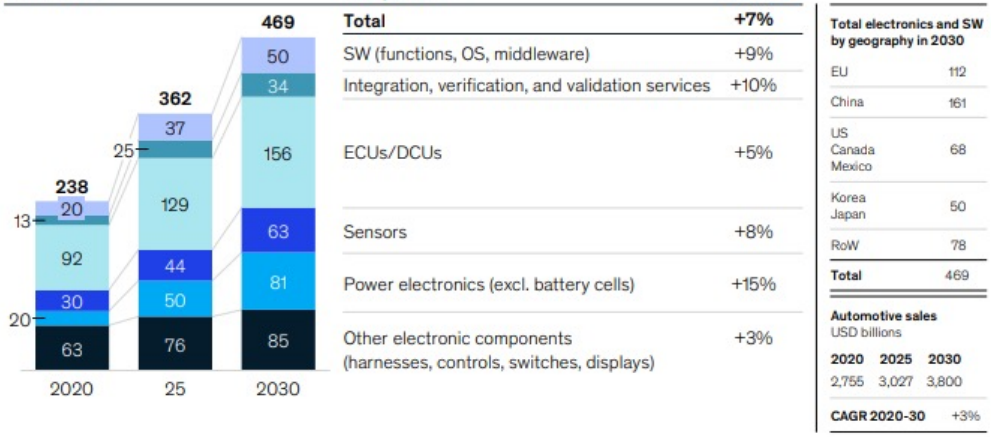
Fig. 26 Europe: Development of automation levels (2017–2030)



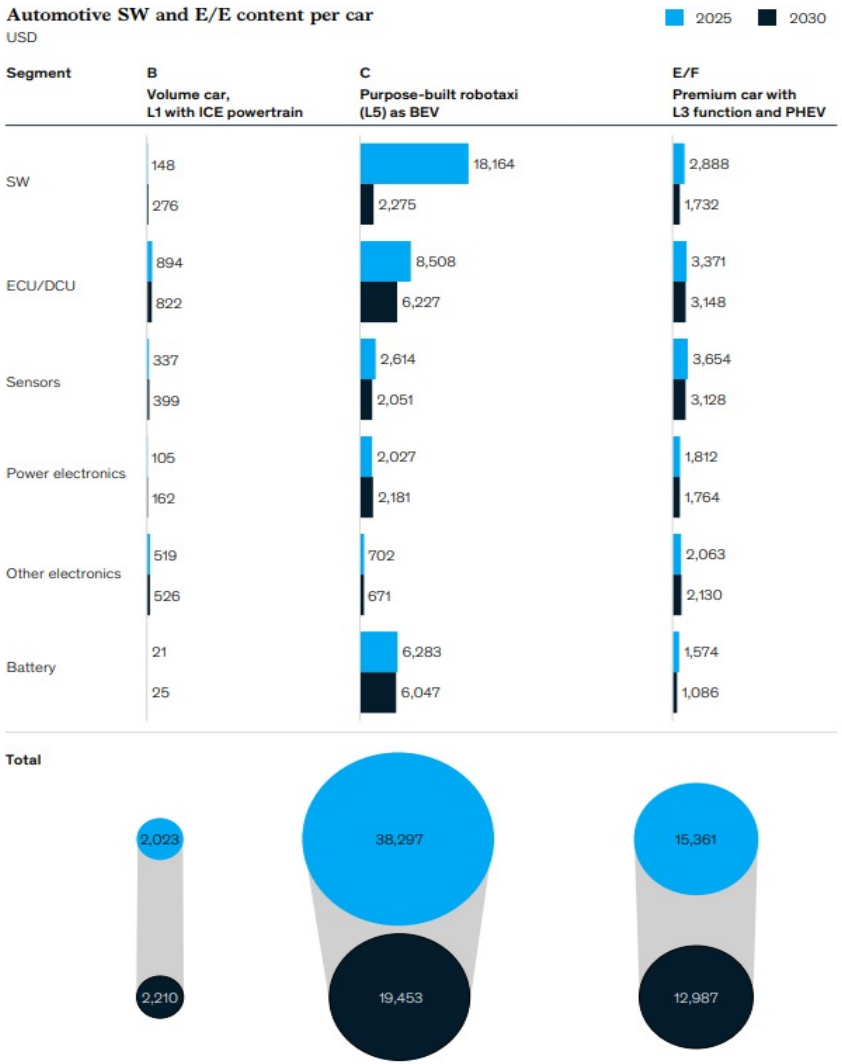
Source: PWC

Electronic content in cars is growing fast

Automotive SW and E/E market with a CAGR of 7% p.a. until 2030, largely driven by power electronics, SW, and ECUs/DCUs



Source: McKinsey analysis; revenue forecasts based on vehicle volumes from IHS Markit, Light Vehicle Production Forecast, October 2018, pull completed on November 6, 2018

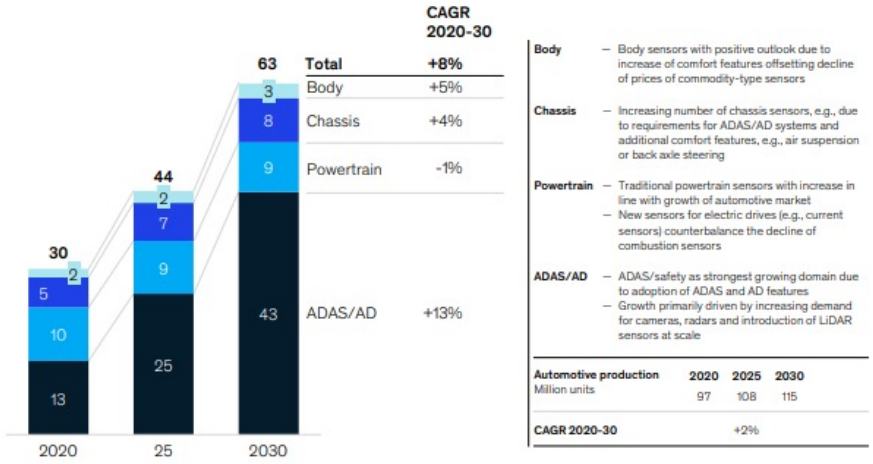


- Higher lever automated cars have much more electronic content
- Sensors are growing but the types are changing strongly in the transition from ICE to EV

ADAS systems show fastest growth

Total automotive sensor market will outgrow automotive sales primarily driven by strong growth in ADAS sensors

Total automotive sensor market, USD billions

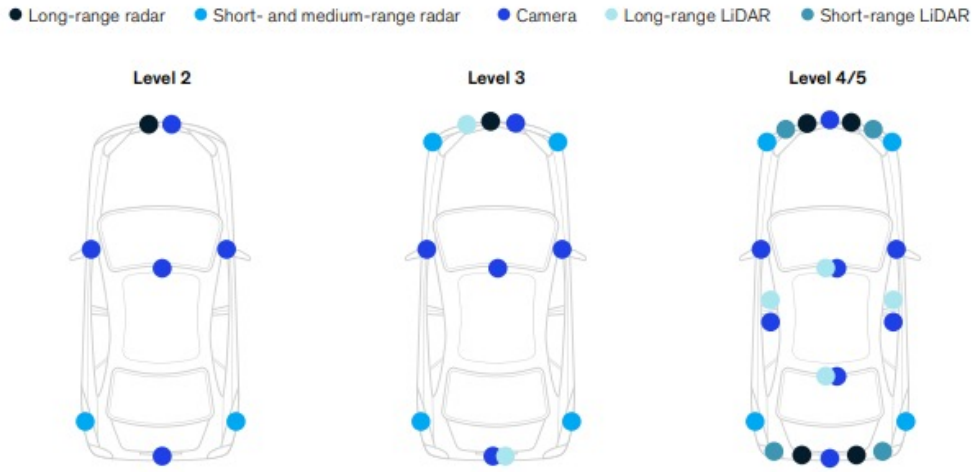


Body	– Body sensors with positive outlook due to increase of comfort features offsetting decline of prices of commodity-type sensors
Chassis	– Increasing number of chassis sensors, e.g., due to requirements for ADAS/AD systems and additional comfort features, e.g., air suspension or back axle steering
Powertrain	– Traditional powertrain sensors with increase in line with growth of automotive market – New sensors for electric drives (e.g., current sensors) counterbalance the decline of combustion sensors
ADAS/AD	– ADAS/safety as strongest growing domain due to adoption of ADAS and AD features – Growth primarily driven by increasing demand for cameras, radars and introduction of LiDAR sensors at scale

Automotive production Million units	**2020**	**2025**	**2030**
	97	108	115
CAGR 2020-30		+2%	

Source: McKinsey analysis

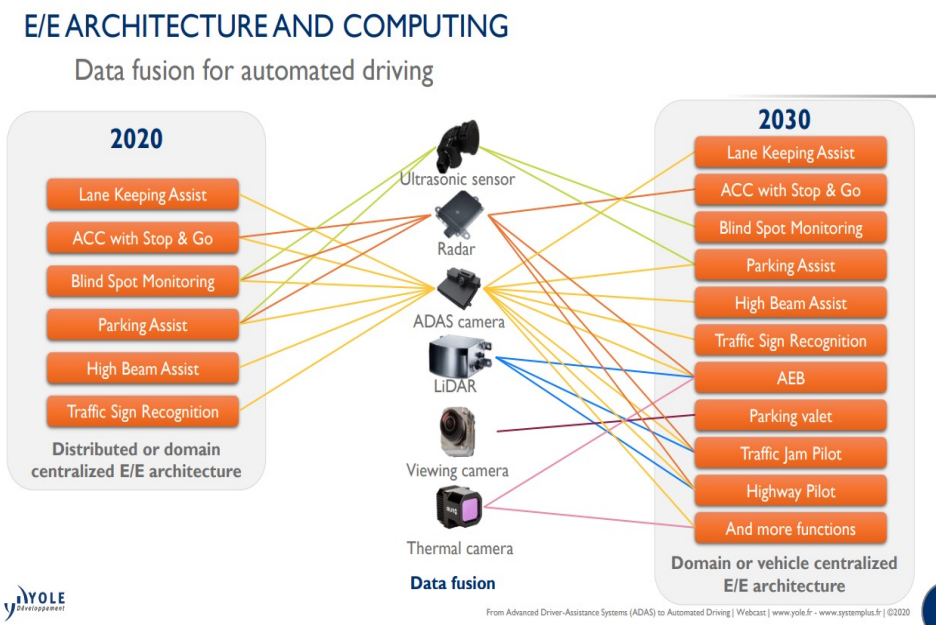
Sketch of a vehicle and its sensor setup for AD

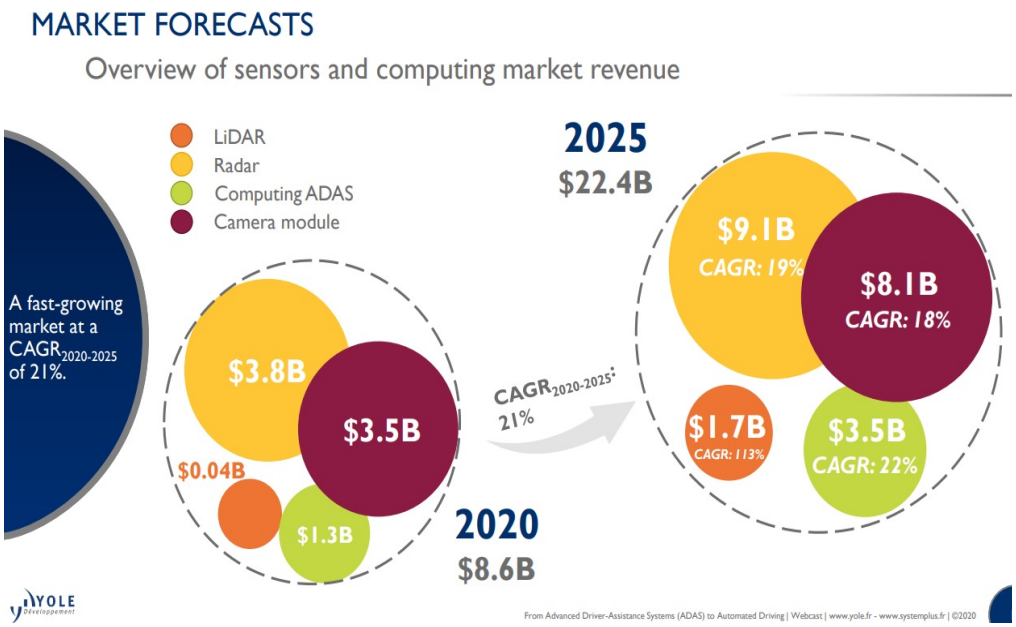


Source: Expert interviews, Waymo Safety Report, Audi press announcements, GM investor presentation

Sensor fusion and ADAS market development

- Multiple sensor types give better overall performance, lidar is the latest development
- Sensor fusion for autonomous driving requires much more complex processing and very high data rates





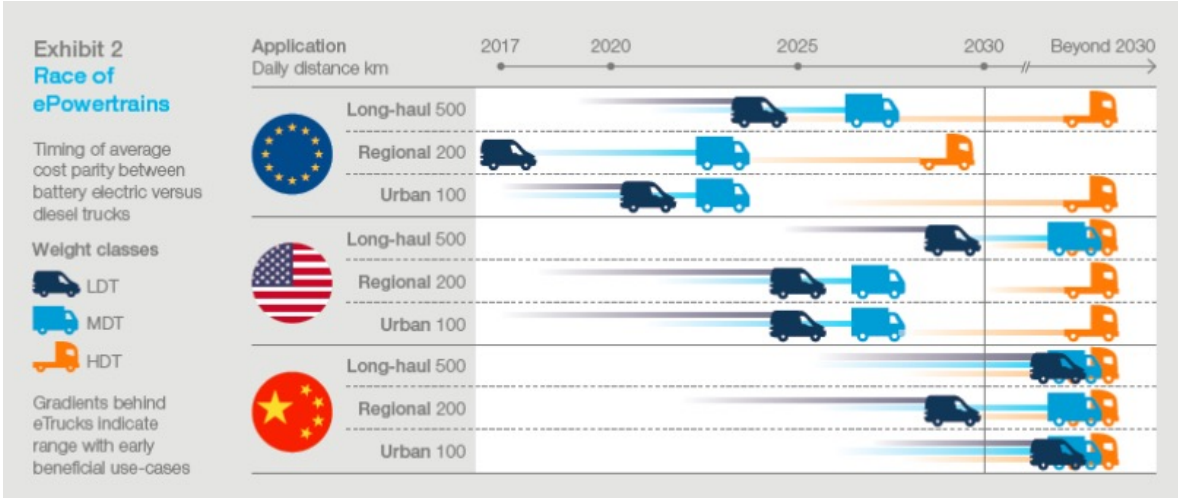
Source: From ADAS to Automated Driving | Webcast | www.yole.fr

The transport and bus sector is transitioning

- Many cities are already imposing emission requirements in city centers.
- Light commercial vehicles and short-haul trucks are moving towards EVs
- For long-haul transport the situation is not yet clear as biomethane, hydrogen and EV might be solutions.
- The availability of infrastructure is a key element in this.
- Buses are moving rapidly towards electric versions, especially in cities.

Attractive Opportunities in the Electric Bus Market

Source: Secondary Research, Expert Interviews, Company Presentations, and Markets and Markets Analysis



Source: McKinsey Energy Insights, McKinsey Center for Future Mobility

2.

Automotive and integrated photonics

PhotonDelta Automotive Roadmap

Mobility solutions:
What is in scope for Integrated Photonics applications?

CARS

TRUCKS

DRONES

ROBOTAXIS

AUTONOMOUS TRANSPORTERS

- They all have different development and growth trends.
- In general, electrification of all functions is happening.
- The value of electronics in automotive is increasing.
- There are specific areas where photonic solutions can make inroads.

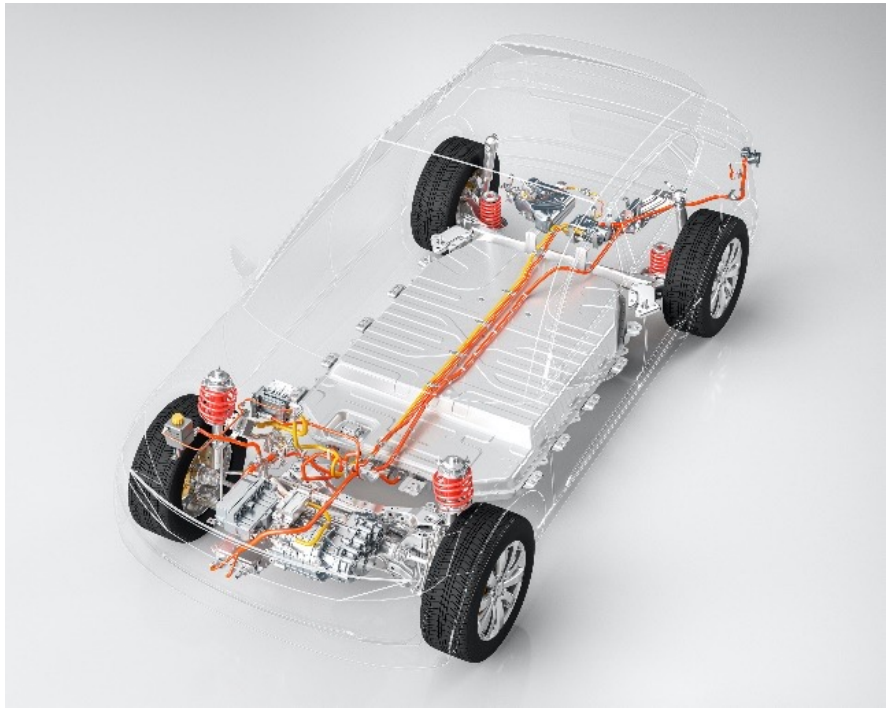
Automotive Market Segmentation

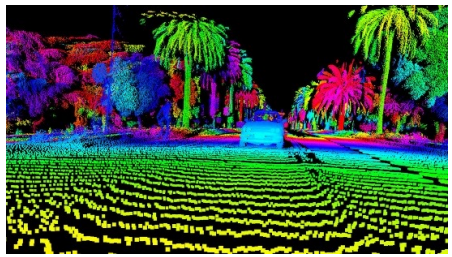
System function areas:

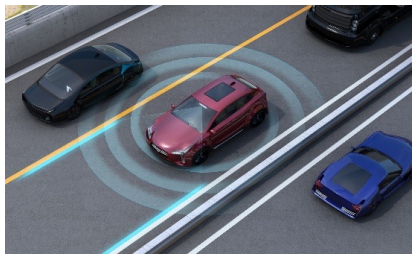
- **EV powertrain, battery**
  - Engine management, drive train
  - Battery management (SoF, SoH SoC), safety
- **Cabin & comfort**
  - Environment (airco, humidity, particles, seat)
  - Controls
  - Driver wellbeing
- **Infotainment**
  - Radio, movie, music , internet, smartphone
- **ADAS & autonomous driving**
  - Navigation, V2V, V2I
  - Traffic safety, driver support
  - Autonomous functions (cameras, radar , lidar)
- **Connectivity & networking**
  - In-car networks (CAN, Flexray, Ethernet, Wifi, optical)
  - External (Wifi, 4G, 5G, V2I, V2V)
- **Body & suspension**
  - Drive control systems (suspension, rollover , brakes, etc.)
  - Safety (precrash, airbag, ABS, TMS, loading, etc.)
  - Lighting (adaptive)

Applications with potential photonic content

- **EV powertrain**
  - Temperature, torque, strain sensing for engine
- **Battery**
  - Temperature, pressure, strain for cells sensing
- **ADAS & autonomous driving**
  - Lidar
  - Hyperspectral sensing and camera's







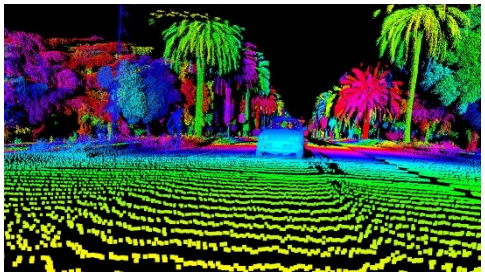
Applications with potential photonic content

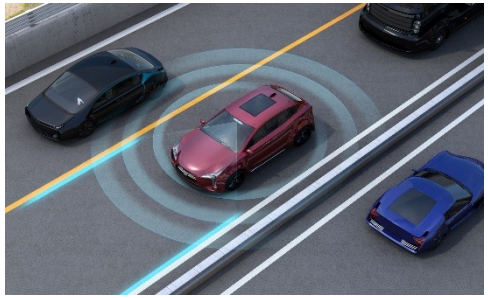
Connectivity & networking

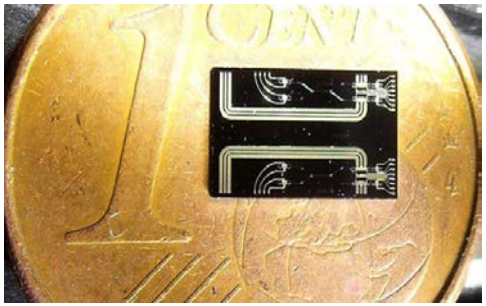
- **Optical communication**
  - Car to car , car to infrastructure
  - Between vehicles and planes, satellites etc
  - Inside vehicles (li-fi)
  - In-car optical network for sensor fusion, future ADAS systems require huge bandwidth and low latency

- **AI, quantum computing**
  - Artifical intelligence is entering cars, some of this could have photonics
  - Quantum computing for now is mostly aimed at design optimization of e.g batteries

- **Security (quantum keys, random number generators)**
  - Secure connections will become more important,
  - Nobody wants an (autonomous) vehicle hacked.



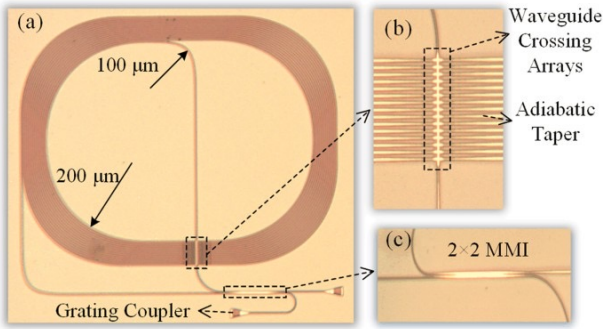




Applications with potential photonic content

- **Cabin & comfort**
  - Air quality (particles, gases)
  - Driver wellbeing (3D camera, IR, vital sign detection)
  - Attention detection

- **Body & suspension**
  - Gyroscope
  - Strain, load (trucks)
  - Lighting



3.

Integrated photonics options in detail

LIDAR (Light detection and ranging)

What is LiDAR?

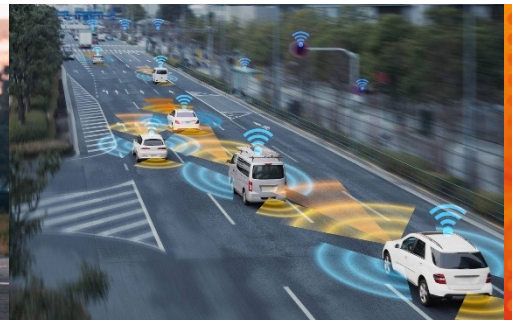
- A complementary sensor technology to radar and cameras for ADAS and autonomous vehicles.
- Actively scanning its environment with a laser beam and detecting the return signal to measure distance and speed (for some versions).
- Different operating principles (Time of Flight and FMCW) and many different technical solutions exist, developing rapidly.

Latest developments in LiDAR

- Historically large mechanical scanners were used, which were expensive and vulnerable.
- This is now getting replaced by solutions that are using MEMS mirrors for scanning or by scanning flash systems using VCSEL arrays, all using Time of Flight (ToF).
- The latest system gaining traction is FMCW lidar, because it can offer higher sensitivity and measure speed at the same time (very well suited for PICs)

The future of LiDAR

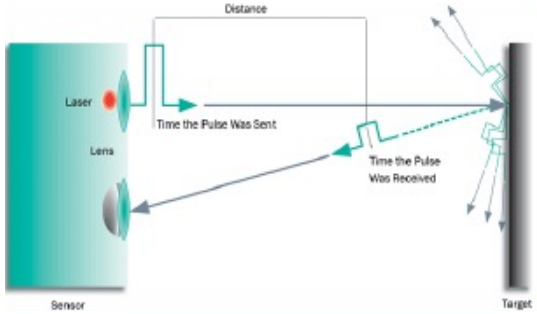
- Multiple lidars will be used in front and side; lower power, smaller size and a much lower cost are key to achieving this.
- Other applications are in robotics, warehouses, industry, drones.



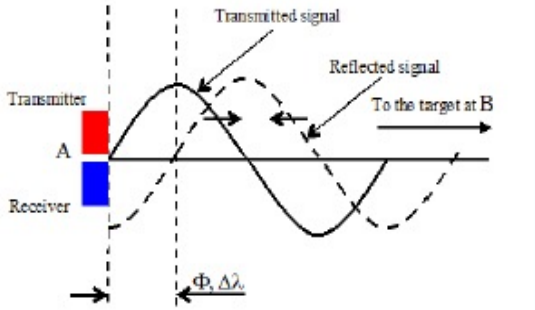
Lidar system architecture options are developing fast…

Ranging methods

Pulsed Time-of-Flight



Phase Shift



Frequency modulation

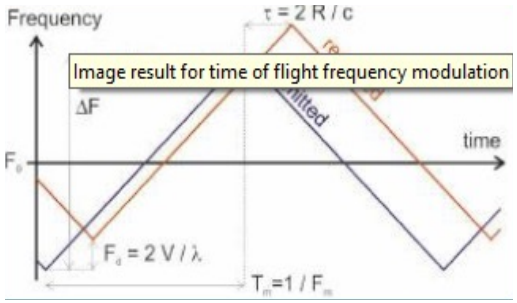
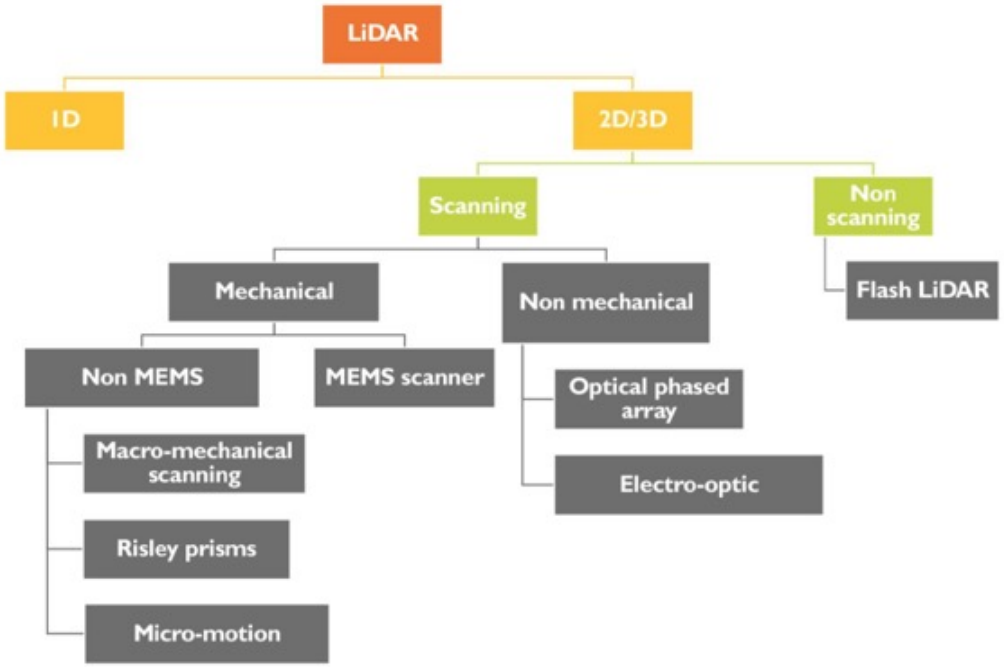
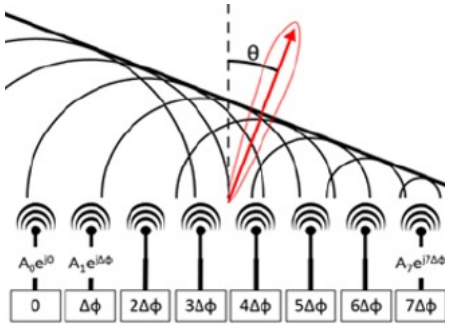


Image formation methods

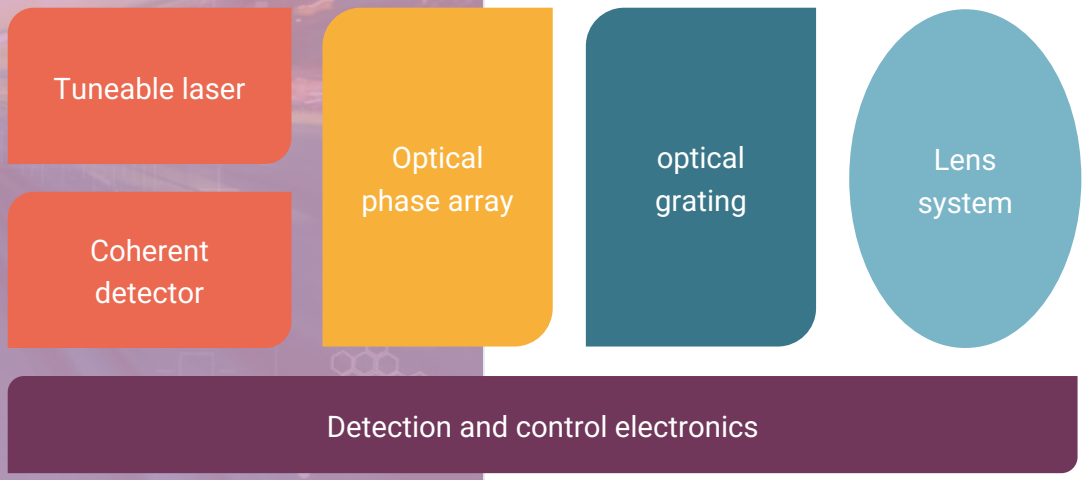


- Eye safety regulations determine use-case requirements (e.g. power, resolution). NIR 850-900nm (flash) and 1550nm (FMCW) are popular
- There is a strong drive for fully integrated solutions which are compact, have no moving parts and are low power

FMCW lidar using integrated photonics



Principle of optical phase array

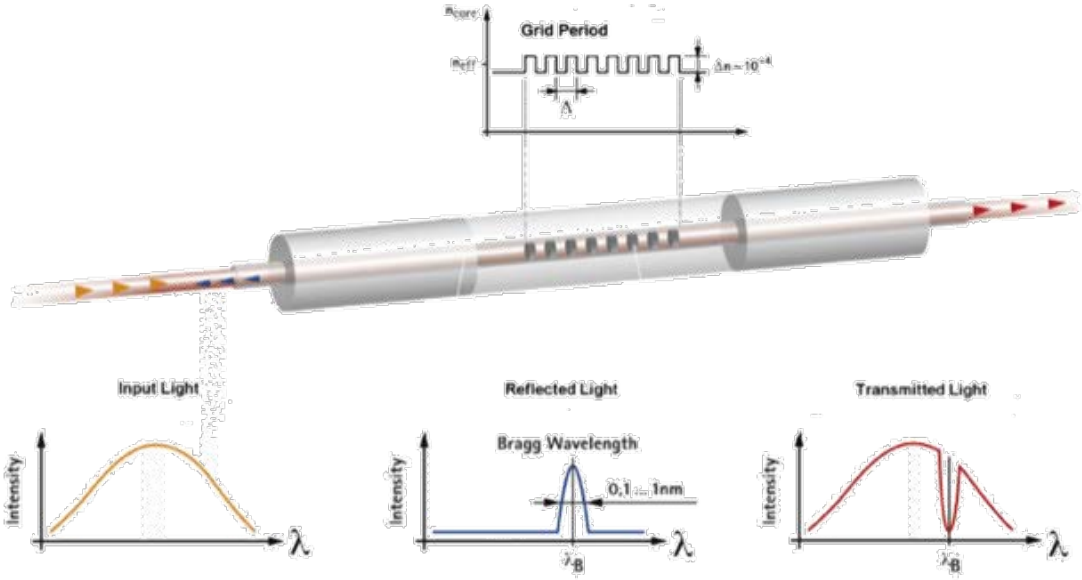


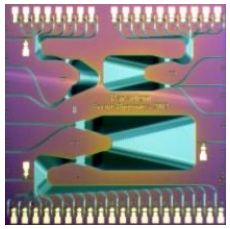
FMCW lidar building blocks

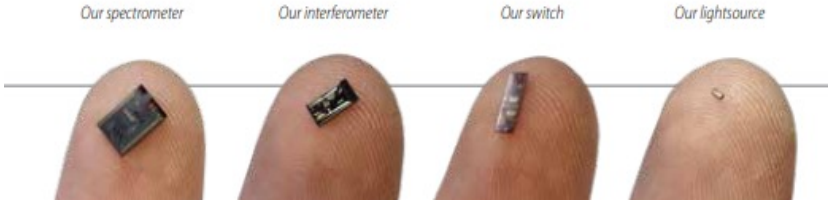
- FMCW lidar systems use many building blocks that can be integrated in a PIC.
  - Tuneable laser with high coherence
  - Coherent detector
  - Optical phase array
  - Grating
- This allows for a very compact low power solution
- A step by step evolutionary building block approach is also possible.
- Packaging solutions exist for heterogeneous integration.
- This allows for a true solid state solution.
- FMCW systems typically work at 1550 nm which is beneficial for eye safety and sensitivity.

Fiber Bragg Grating sensors using integrated photonics

- **FBG sensors**
  - light of a specific wavelength is reflected or absorbed in a fiber where, in specific positions, a frequency tuned grating is made.
  - This effect dependent on force, pressure, temperature and strain and can be measured with extreme accuracy simultaneously.
- **By using different wavelengths and gratings over FBG prepared optical fibers, many measurements are possible on one fiber**
- **These systems can be miniaturized using integrated photonics into very compact "interrogator" systems**







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Integrated Photonics Sensing

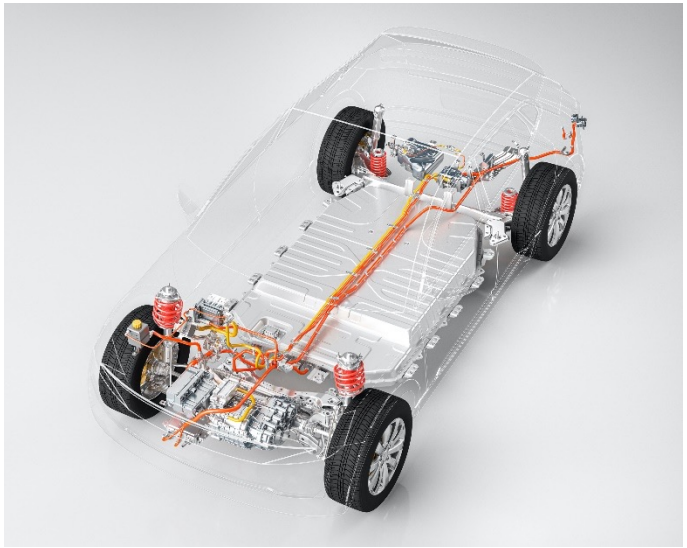
Fiber Bragg Grating sensors using integrated photonics

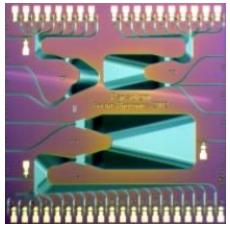
Advantages

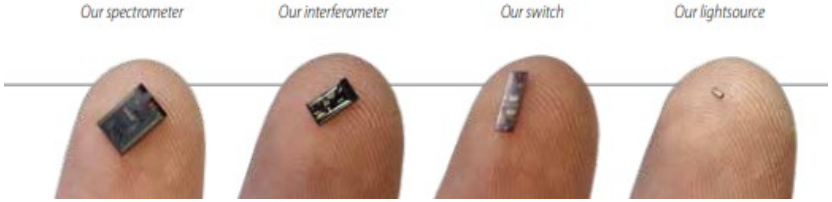
- Simultaneous distributed measurement of force, pressure, temperature and strain over single/multiple fibers
- Non-conductive/Immune to electromagnetic interference
- Chemically Inert, intrinsically safe

- High Accuracy
- High Acquisition Frequency
- Time division multiplexing over multiple fibers

- These systems are already used in aerospace and infrastructure (e.g., bridges)
- Very flexible due to fiber configuration
- Photonic integration allows for not only very compact systems, but also path to low-cost systems







PHOTONFIRST
Integrated Photonics Sensing

Let’s drive this revolution forward!

Discuss the content of the roadmap

- Contact Carol, our Program Manager and coordinator of the roadmap
- In-depth workshops will be organised on a later stage and communicated to all those who attended the event or downloaded the roadmap

Carol de Vries
Program Manager
at PhotonDelta

Carol@photondelta.com

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Let’s drive this revolution forward!

Connect with our ecosystem

- Engage with our ecosystem partners to help you design, develop and manufacture innovative products based on integrated photonics
- Discover our ecosystem on this page
- Contact Erik, our ecosystem manager

Erik van Oorschot
Ecosystem Manager
at PhotonDelta

Erik.vanOorschot@photondelta.com

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Let’s drive this revolution forward!

Get support in product development

- Get support in adopting integrated photonics in your organisation through the Photonic Integration Technology Center (PITC)
- Discover their services on their website
- Contact Jan-Laurens, PITC’s business development manager

Jan-Laurens van der Steen
BD Manager
at PITC

jan-laurens.vandersteen@pitc.nl

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Get EU support for your project

- Get in touch with Nilufar, our Program Manager
- Learn more about pan-European innovation support activities through PhotonHub Europe
- Discover funded support options for SME’s in North-West Europe for PIC manufacturing, external optics, and packaging through OIP4NWE

Nilufar Bulut
Program Manager
at PhotonDelta
Nilufar@photondelta.com

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Let’s drive this revolution forward!

Get support in funding

- Apply for our Startup Studio programme through High Tech XL
- Discover PhotonDelta’s funding programs for startups and scaleups
- Get in touch with Pieter, our Fund Manager

Pieter Klinkert
Fund Manager
at PhotonDelta
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