Optical Sensors in Automotive
disruption on its way

NB Photonics Doctoral school seminar

Dr. ir. Joris Roels 6th April, 2018

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About the speaker

- Electrical engineering Master at Ghent University 2005
- PhD research INTEC Photonics Research Group
- Melexis business unit (optical) Sensors in 2010
  - Responsible for “far infrared” temperature sensors since 2013
- Business unit mission
  - Key decision makers on business strategy, product & technology development
  - Key partners: R&D, sales (and operations, quality)

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INTRODUCTION TO MELEXIS

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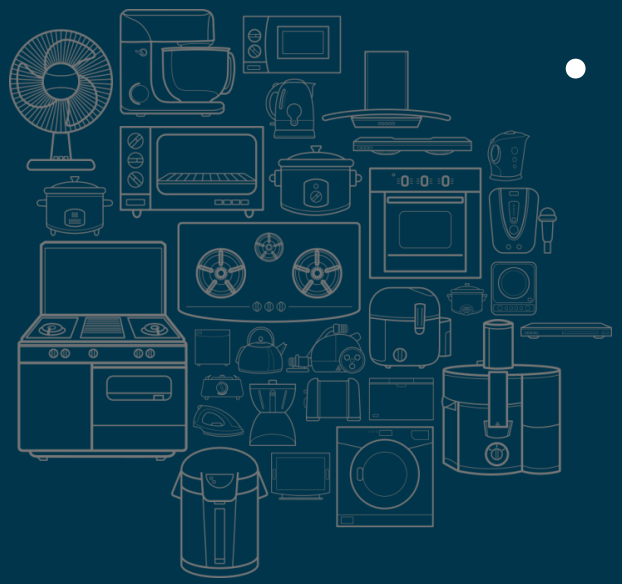
Melexis supplies worldwide **> 1.3 billion** ICs with an average of **10 ICs / car**

Sensing

- Speed
- Position
- Current
- Pressure
- Temperature
- Light

Communicating

- Wired SW CAN, SENT and LIN
- Wireless RF & RFID/NFC



Driving

- BLDC/DC Motor Drivers
- Smart Drivers
- LIN RGB Drivers
- Fan Drivers

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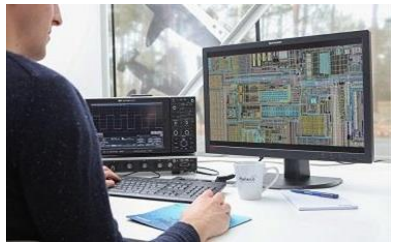
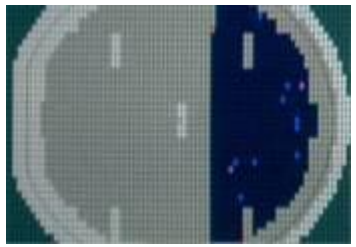
Typical process flow

Chip design



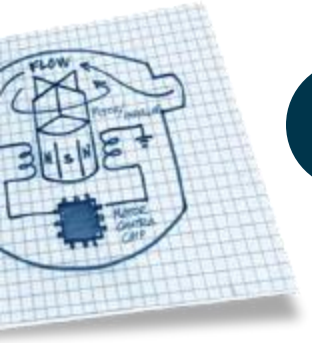
Wafer probe



Final test

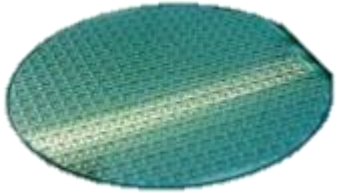
Customer

1



Idea

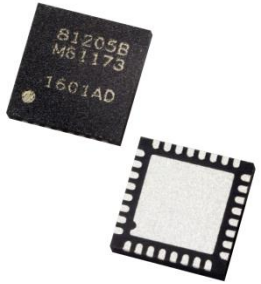
2



Wafer fab

3

4



Assembly

5

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Facilities and locations

Sales & Applications

Belgium - Tessenderlo

Greater China - Shanghai, Shenzhen, Taipei

France - Paris

Germany - Erfurt

Italy

Japan - Yokohama

South Korea - Seoul

USA - Detroit, Nashua

Manufacturing

Belgium - Ieper

Bulgaria - Sofia

France - Corbeil-Essonnes

Germany - Erfurt

Malaysia - Kuching

Research & Development

Belgium - Tessenderlo

Bulgaria - Sofia

France - Grasse, Paris

Germany - Erfurt

Philippines - Manila

Switzerland - Bevaix

Ukraine - Kiev

USA - Nashua

1500 employees world wide, >50% engineers

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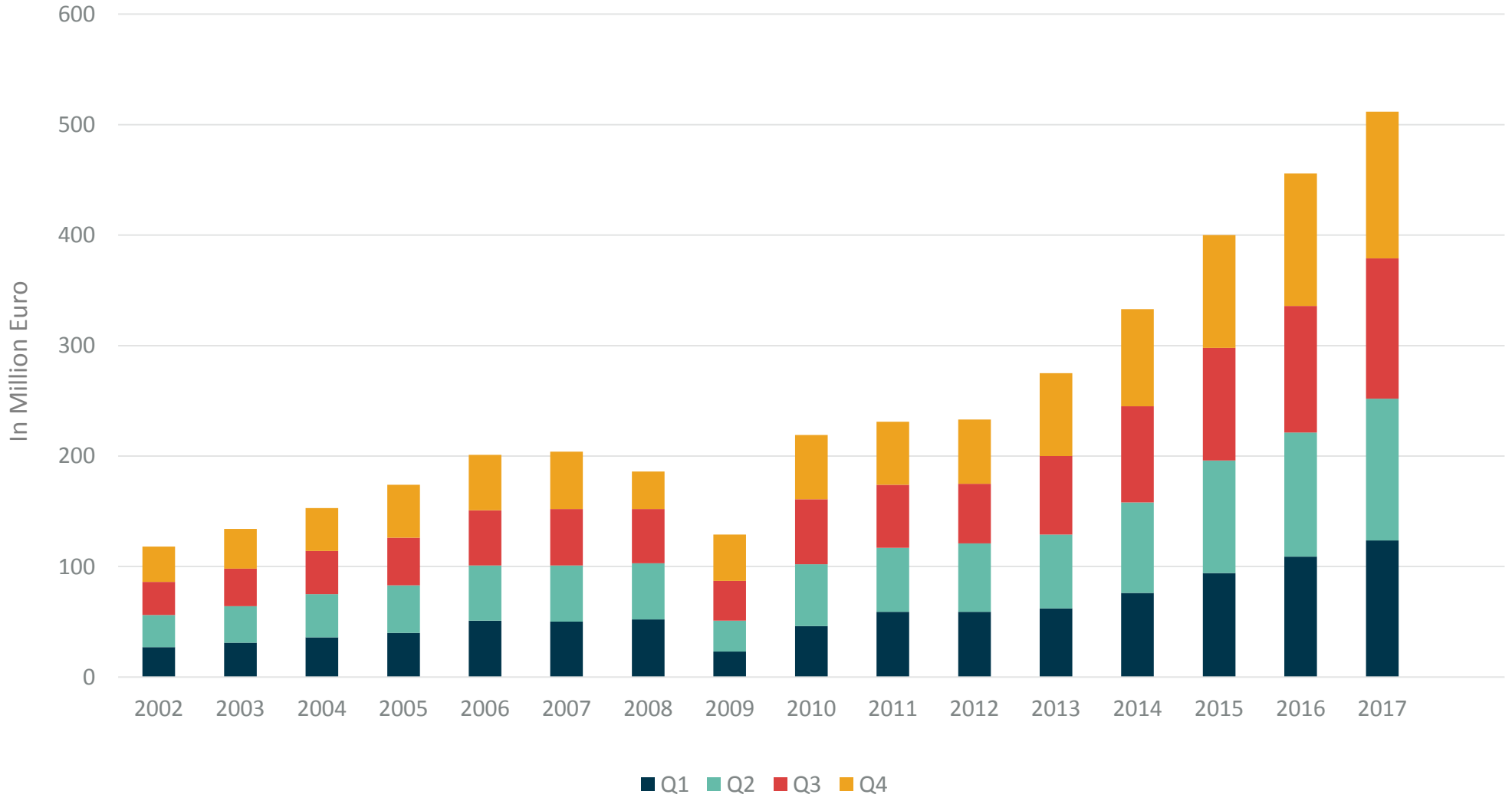
Melexis revenue



Innovation, innovation, innovation… 15% re-invested as R&D

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Megatrends in automotive

The Auto Industry will change more in the next 5 years than prior 50

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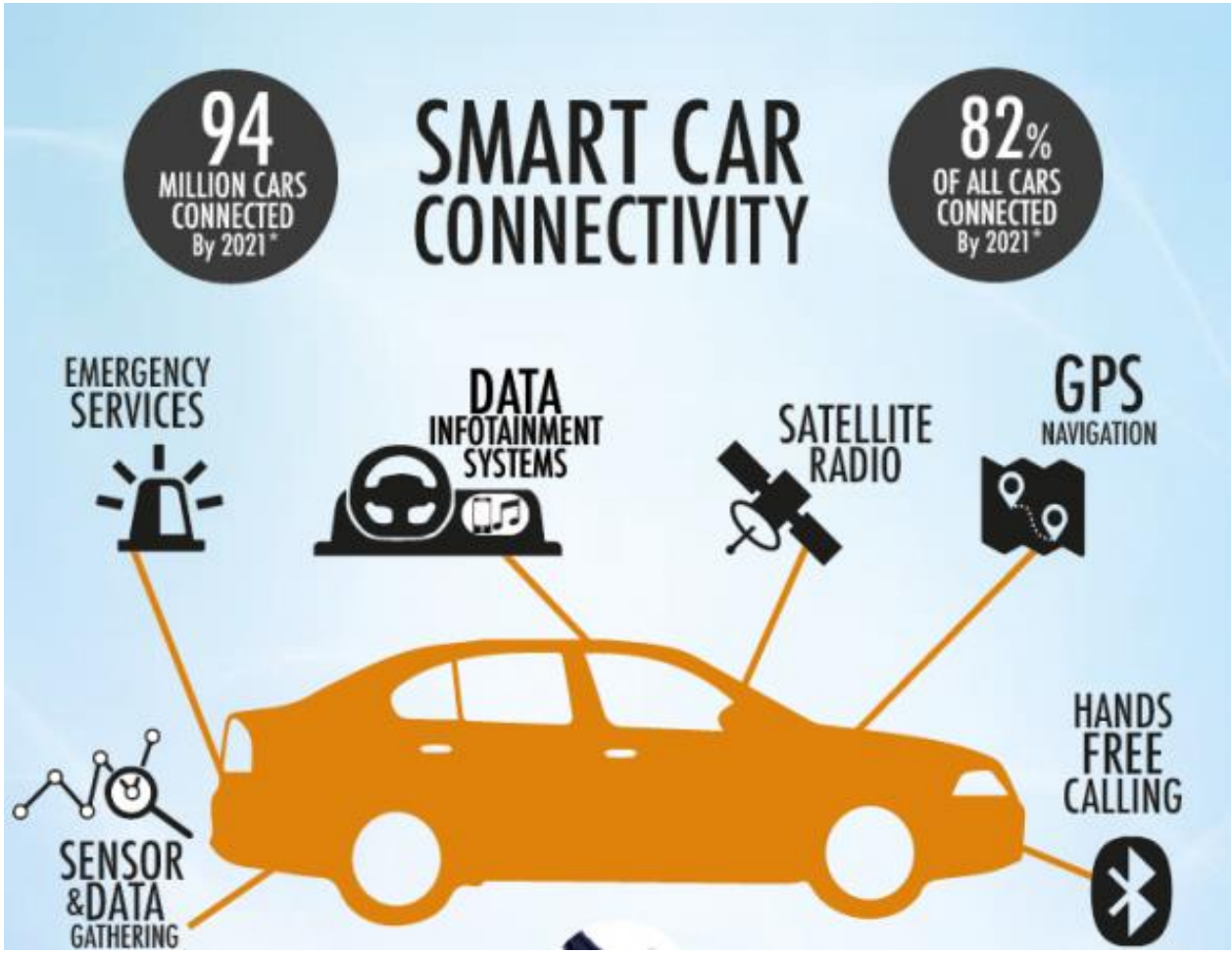
Connectivity

- Intra Car
- Car to car
- Car to portable
- Car to infrastructure/cloud



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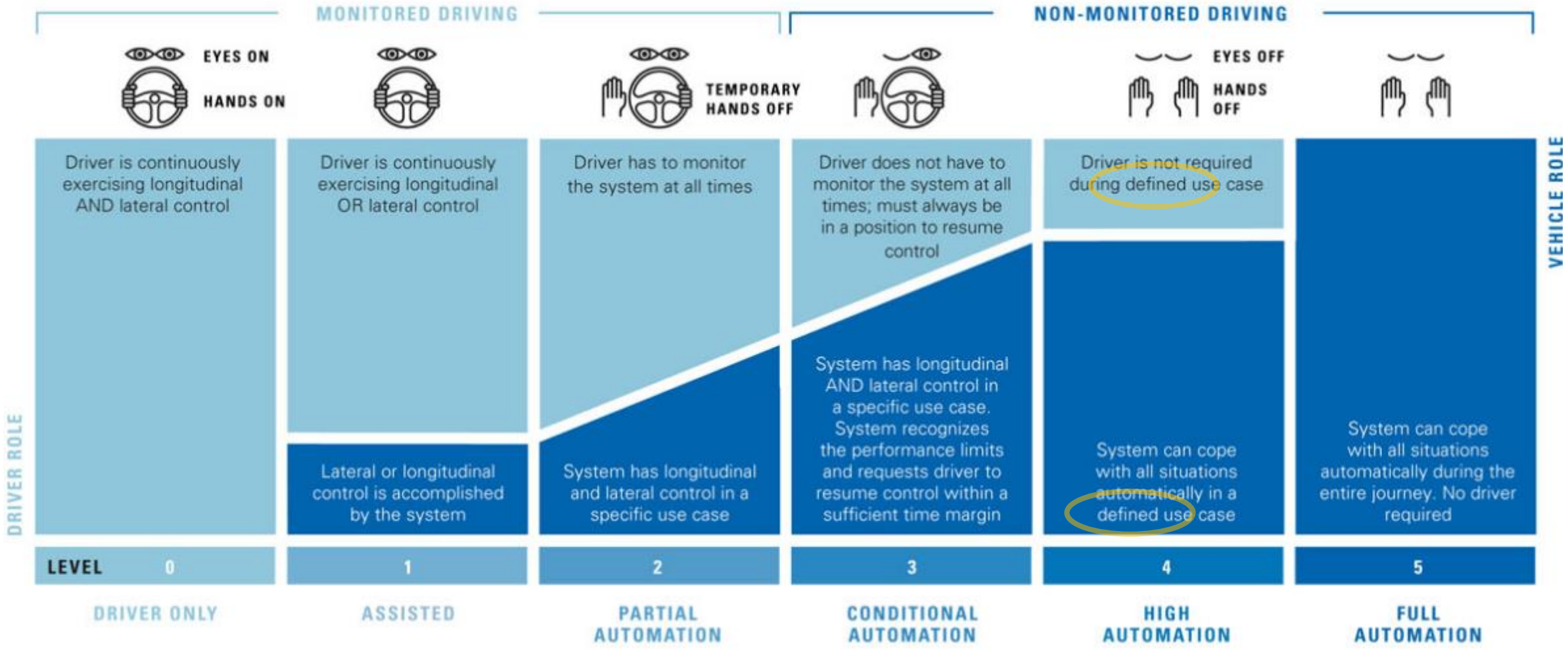
Autonomous driving

SAE LEVELS



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Autonomous Driving

- Low cost, reliable (optical) sensors are key (level 1-5)
- Software maturity/data processing/testing/ethics
- Urban, limited domain “campus” deployments happening today.
- “True level 5 may never be achieved in our life!”
- Advanced driver-Assistance Systems (ADAS) are booming today
- Tech giants vs. automotive giants

THE UBER CRASH WON'T BE THE LAST SHOCKING SELF-DRIVING DEATH

TRANSPORTATION \ UBER \ RIDE-SHARING

Uber scaled back the number of sensors on its self-driving cars: report

Sustainability

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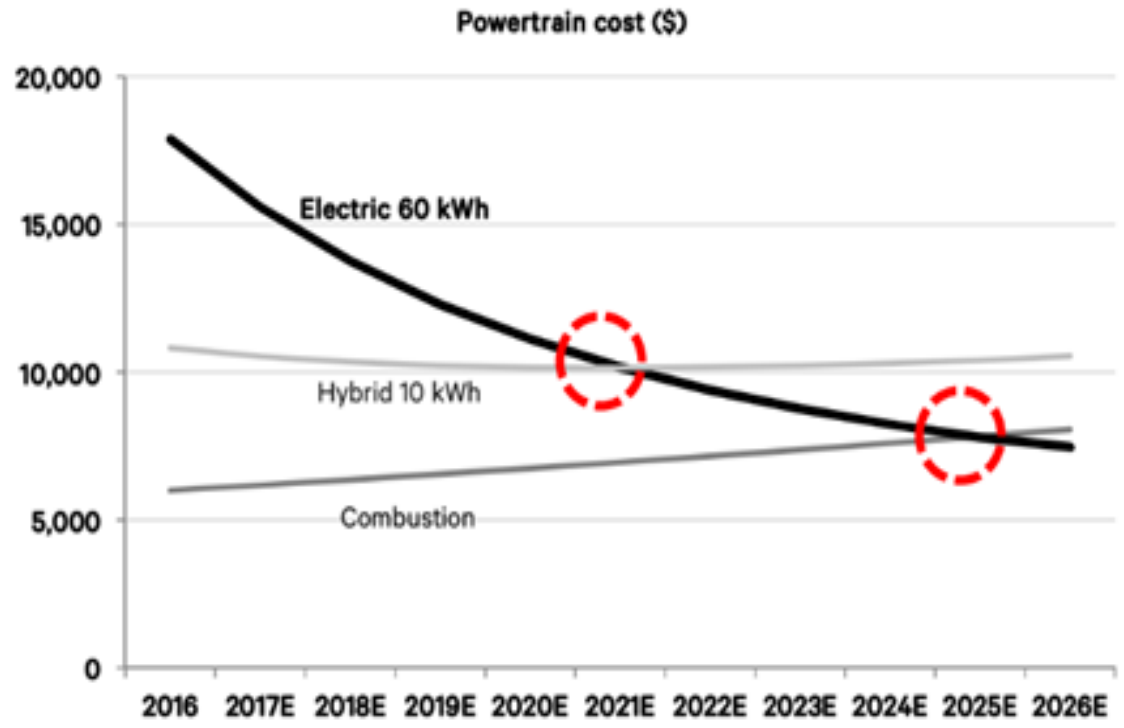
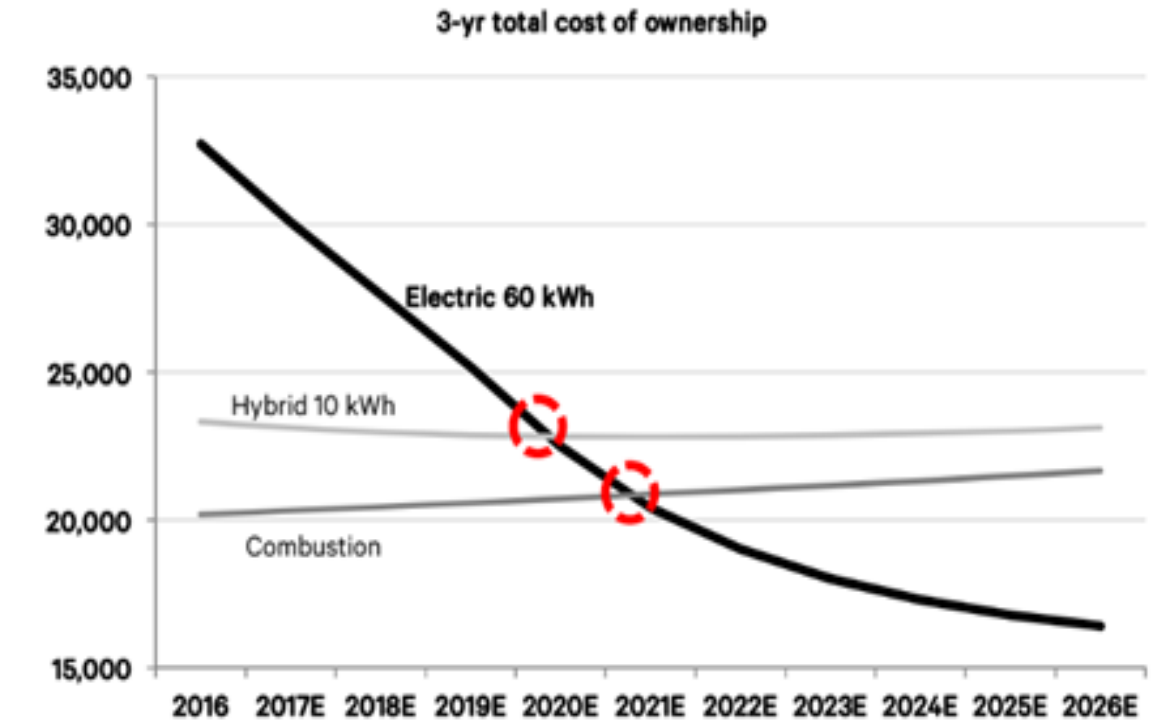
Electrification: tipping point ahead!

Pure electric powertrain cost could reach parity with hybrid powertrains by 2021, and with combustion by 2025



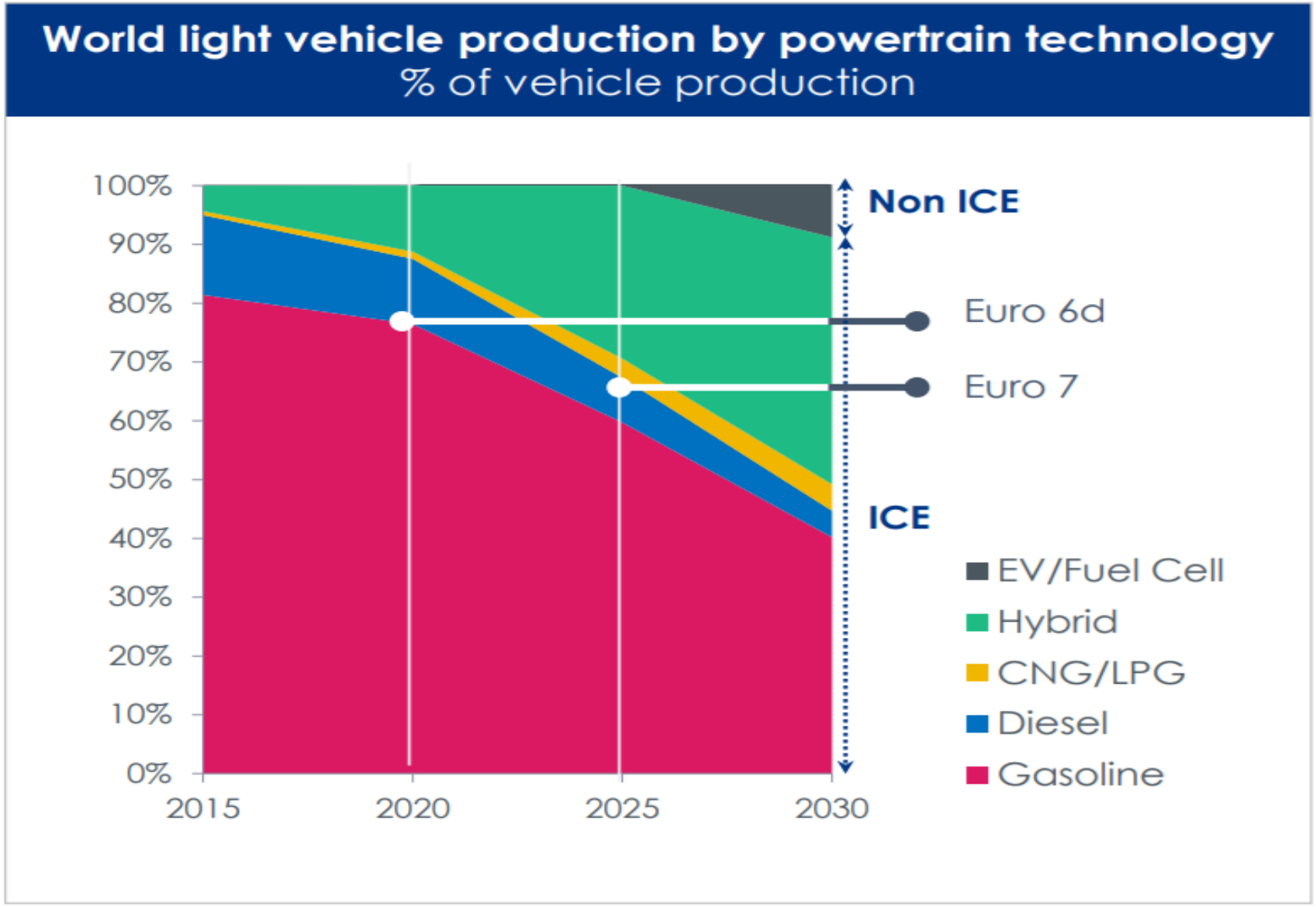
Source: Berenberg estimates
Note: Electric based on 60kWh battery; hybrid based on 10kWh battery

On a three-year TCO basis, we estimate parity with hybrids in 2020 and with combustion in 2021. Taking longer ownership timespans would lead to even earlier intersections



Source: Berenberg estimates

Sustainability (electrification)



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Some Alternative Quotes…….

"I think there is a world market for maybe five computers"

Thomas Watson, Chairman of IBM, 1943

Nokia's CEO Stephen Elop ended his speech with the following words:

"We didn't do anything wrong, but somehow, we lost."

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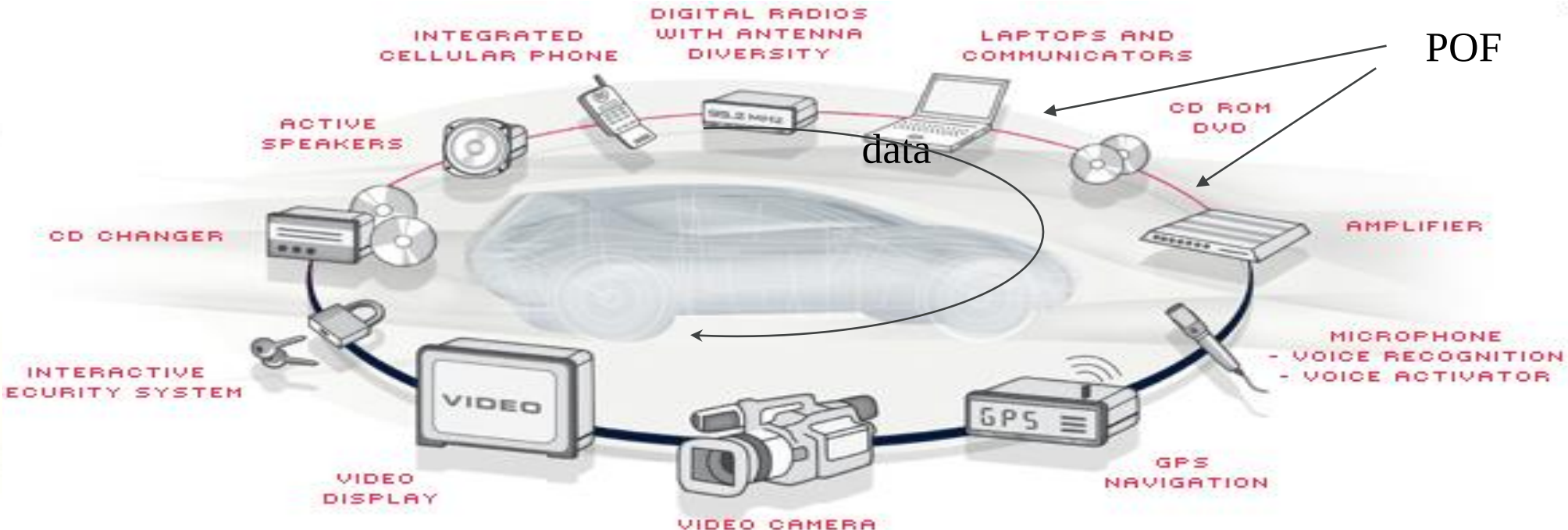
Optical sensors in automotive: Connectivity

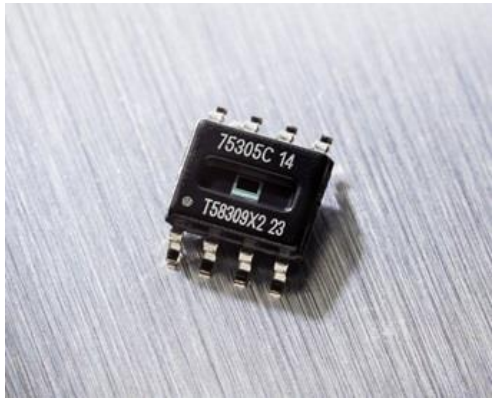
Datacom

- Currently mainly infotainment (rear seat entertainment, GPS, audio)
- Visible light (red) over Plastic Optical Fiber (300Mb/s with LED)
- Competitor 100Mb/s Ethernet over UTP cable (good enough)
- Autonomous driving might push back momentum to optical technology

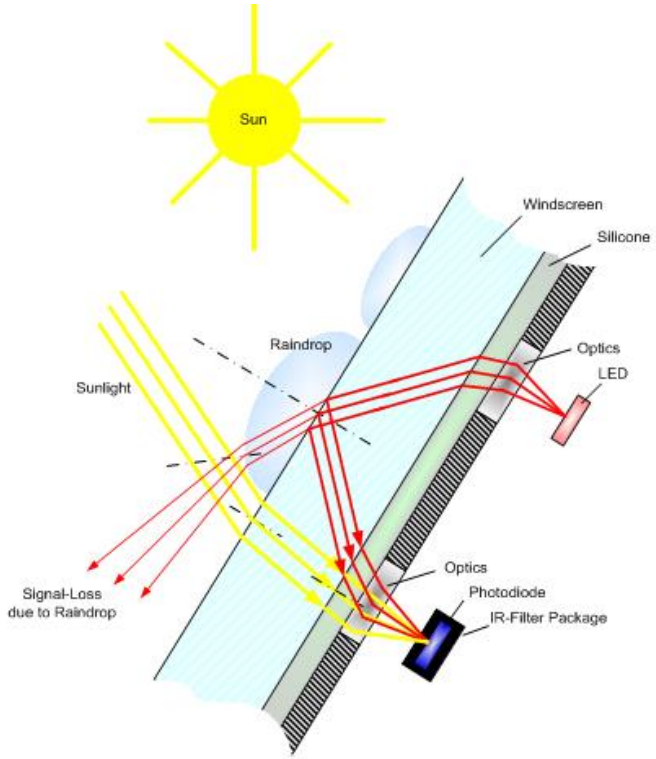


Optical sensors in automotive: Autonomous driving cars & ADAS

Si photodiode sensor technology



- “Simple” Si photodiode
- Day/night detection
- Electrochrome mirror (automated dimming)
- Sun load for HVAC control
- Ambient light (V-lambda) luminosity for head light control
- Rain sensing with Total Internal Reflection modulation



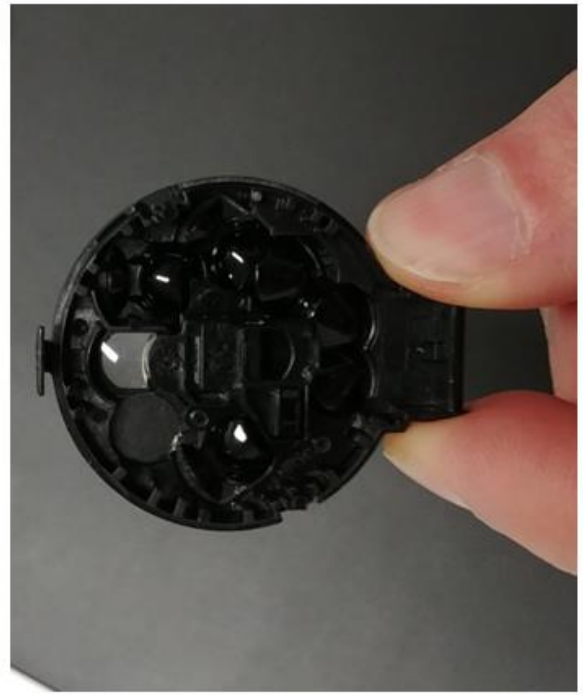
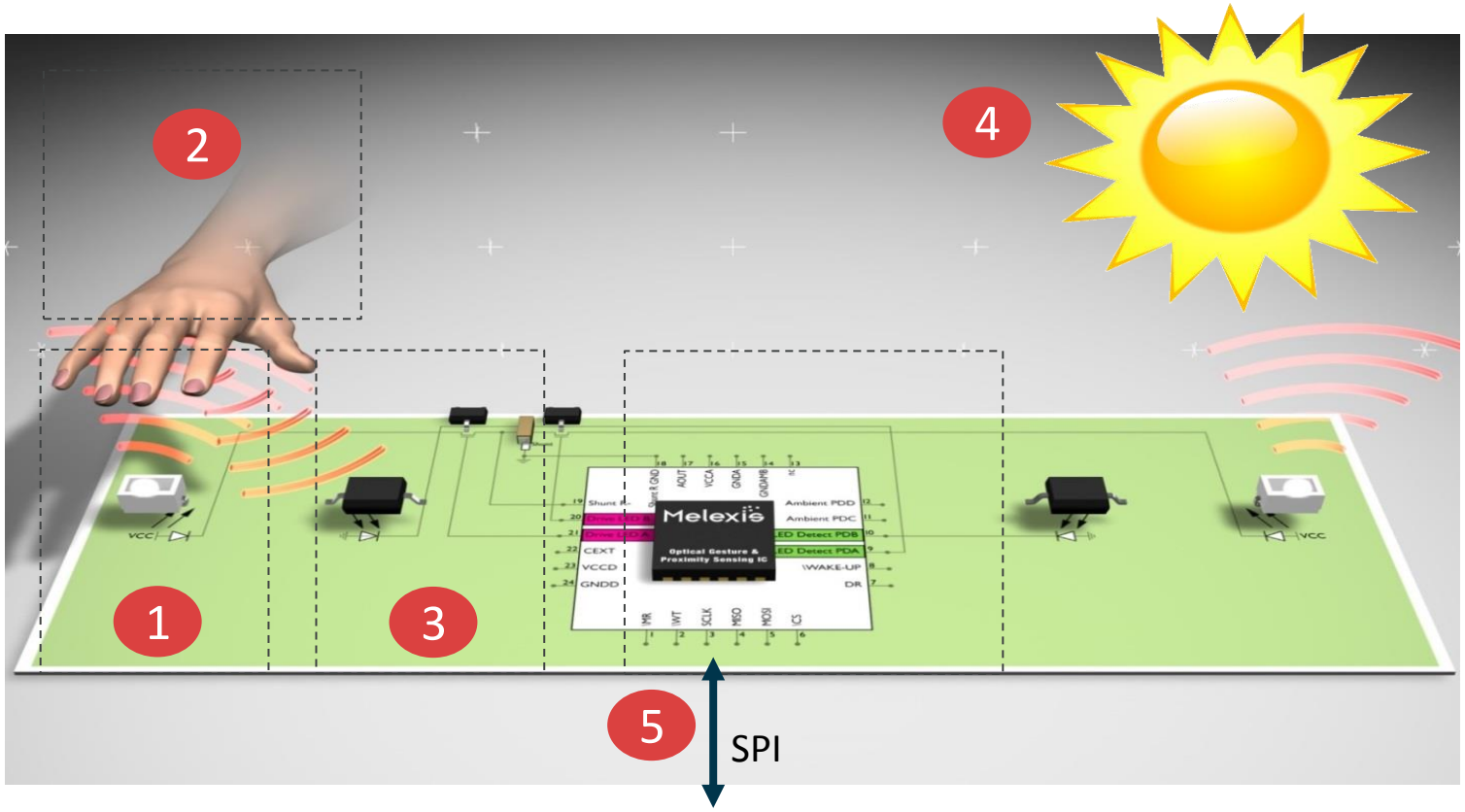


Figure 2. Left: Rain measurement principle.
Right: Rain channel NIR light-guide optics and transparent global sun optics

ActiveLight Technology: human machine interface

for Proximity & Simple Gesture Sensing



For each channel:

1. LED emits short pulse train
2. Light reflects from object
3. Photodiode detects reflected light
4. ActiveLight IC rejects ambient (sun) light
5. ActiveLight IC outputs detected light over SPI

Applications:
** Approach/Swipe detection*
** Automated trunk opening*

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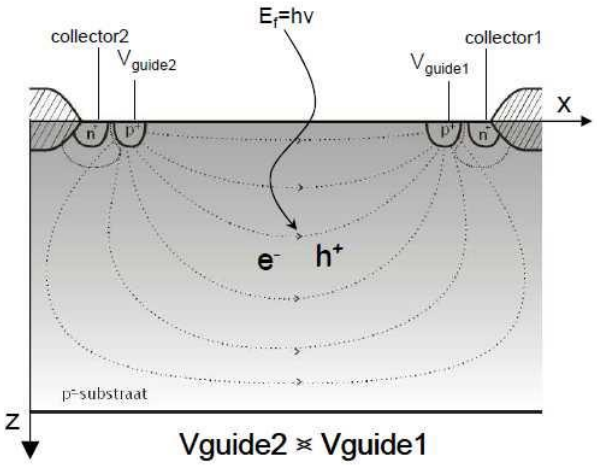
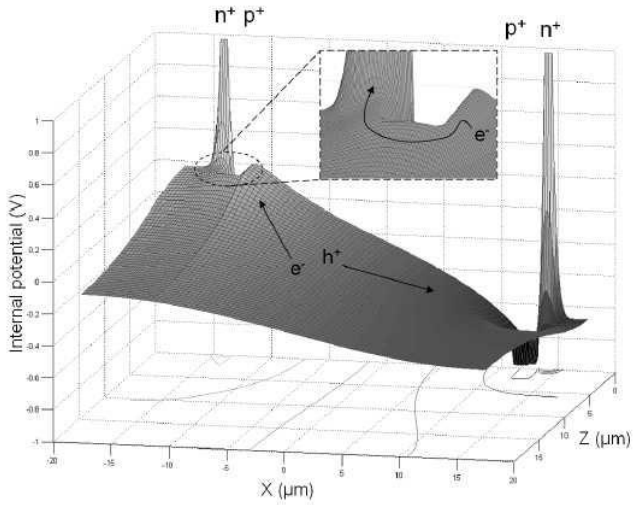
Time of flight Technology

- Current Assisted Photonic Demodulator (CAPD)
- It’s like a pixel with 2 taps and a built-in mixer to 100 MHz





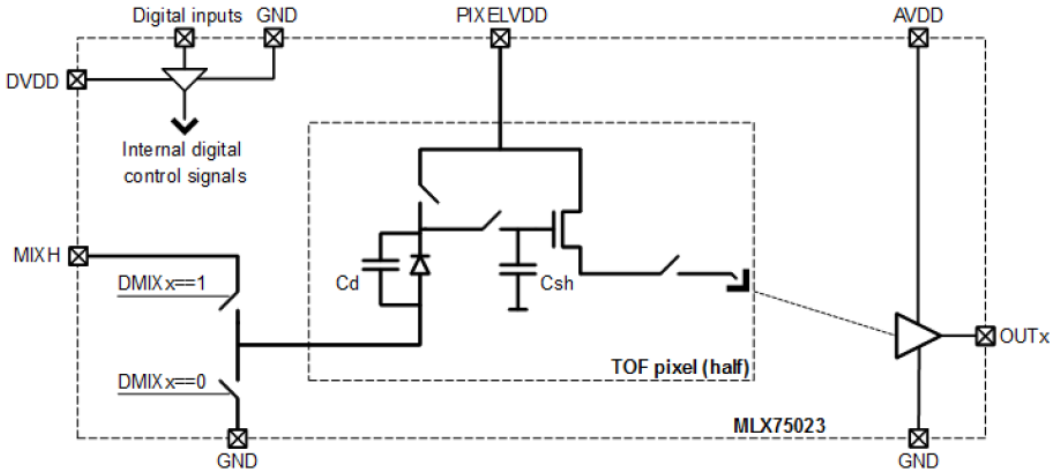


Figure 10: Electrical model of one phase output of the pseudo differential TOF pixel

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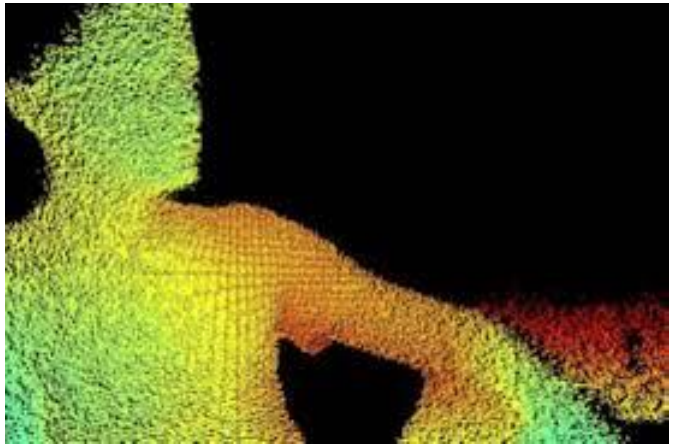
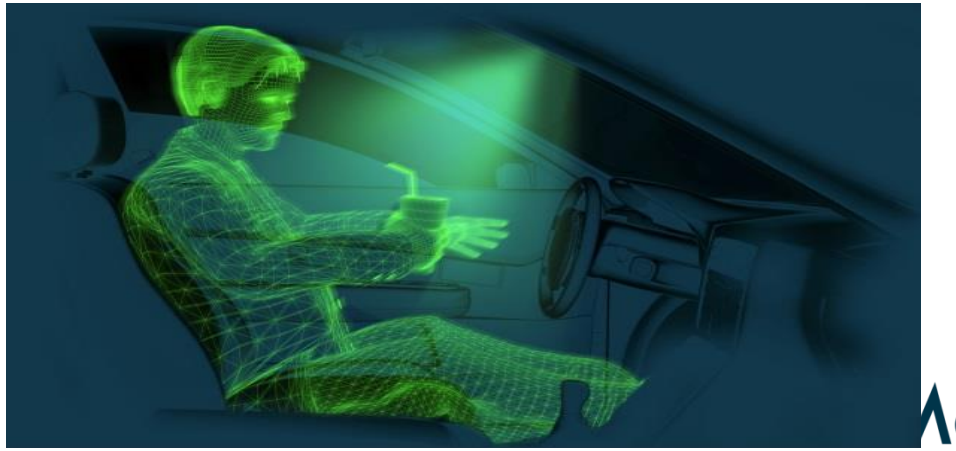
3D Time of Flight Sensing for Automotive

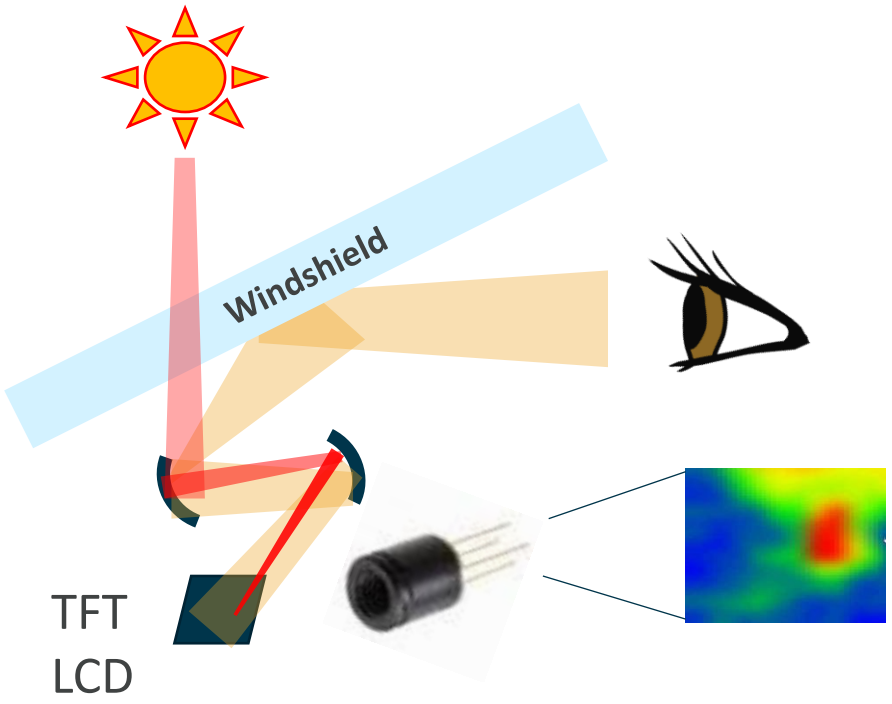
- Gesture recognition
  - robust 3D sensing
    - Sunlight rejection
  - Focus on center console
    - In production for BMW





Head up display systems

- Project important info in driver's viewing cone (e.g. on windscreen)
- Trend toward more info, larger FoV, augmented reality?
- Wider FoV might create issues with solar heating
  - Monitoring with small thermal camera?



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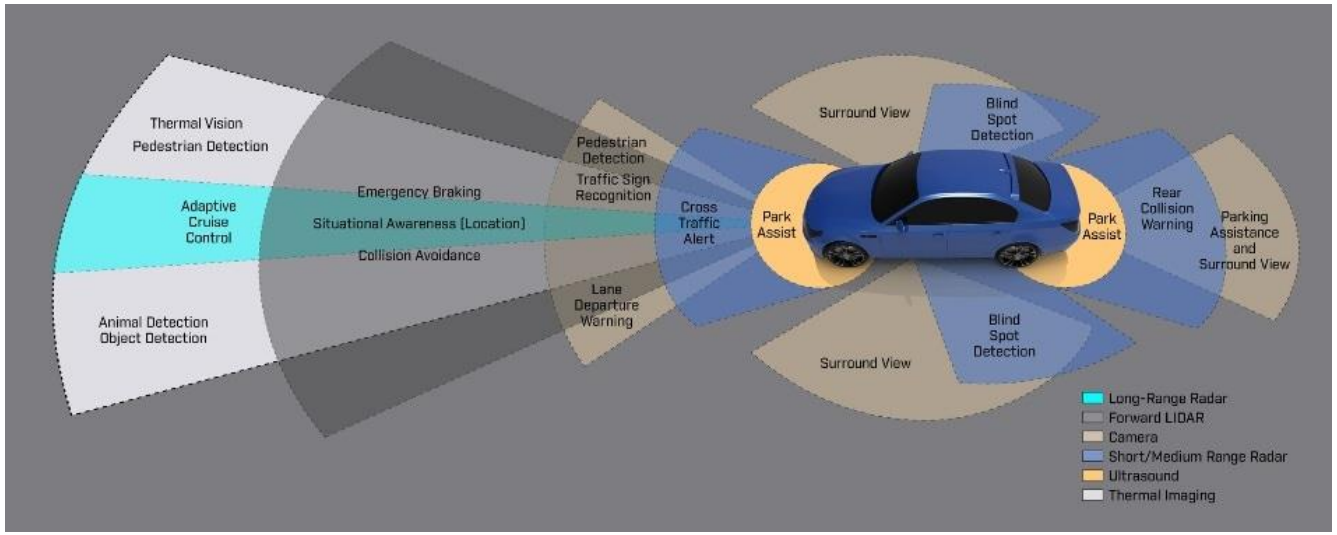
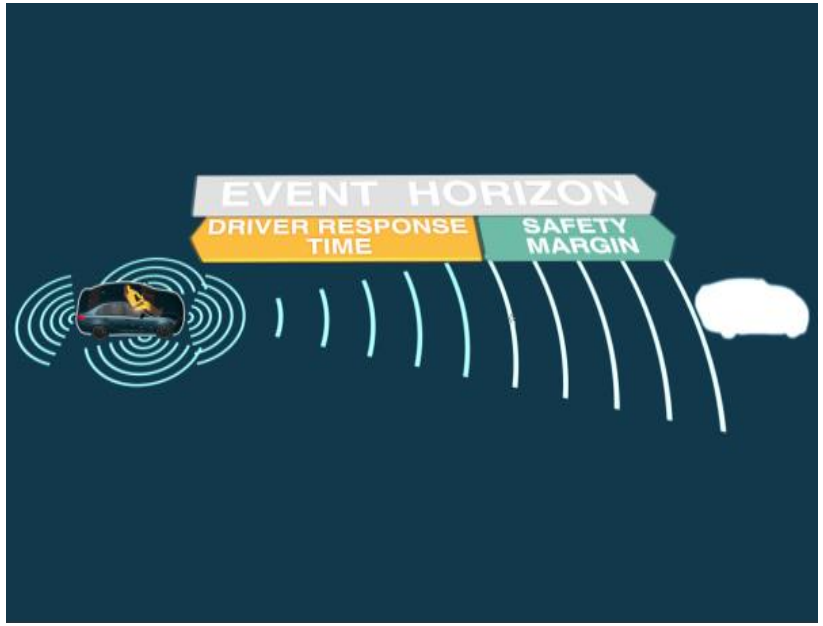
ADAS: Camera, LIDAR, SWIR (MIR, FIR?)





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CMOS Camera Imagers

- Extended High Dynamic Range (HDR) and good low light performance with a resolution of 1024x512 pixels and maximum framerate of 72fps.

- ADAS (advanced driver assistance systems)
  - Lane departure warning
  - Forward Collision warning
  - Night Vision
  - Truck Blind Spot cameras

No HDR

HDR MLX75412 “Avocet”

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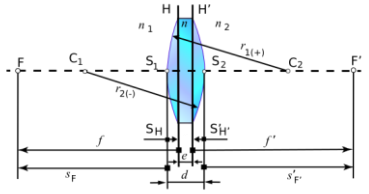
LIDAR System & Key Technologies

Light Detection And Ranging (LIDAR) System

Emitting

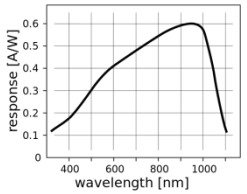
- Laser
- LED
- VCSEL
- VECSEL

Projecting & Viewing

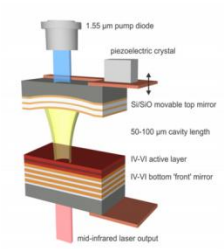


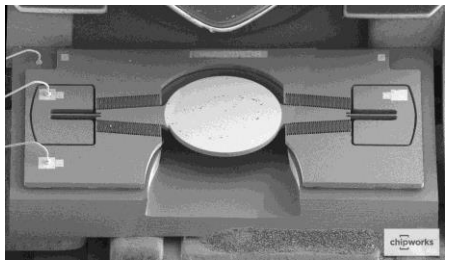
- Scanning
  - Mirror
  - OPA
  - Rotating
  - μ-Mirror
- Non-scanning (Flash)

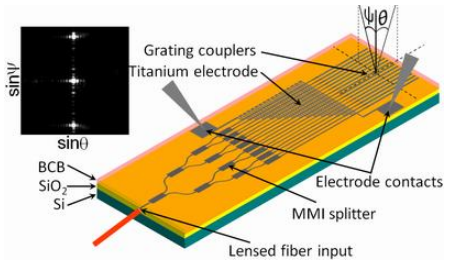
Sensing

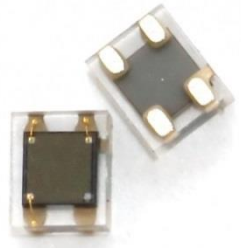


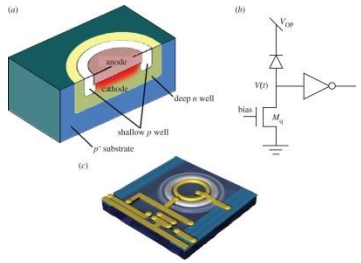
- APD
- PIN
- SPAD
- SiPM











Picture sources: web

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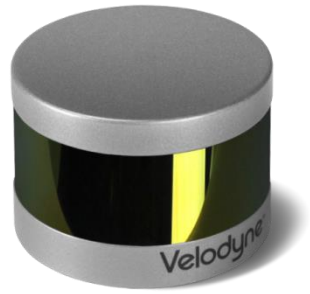
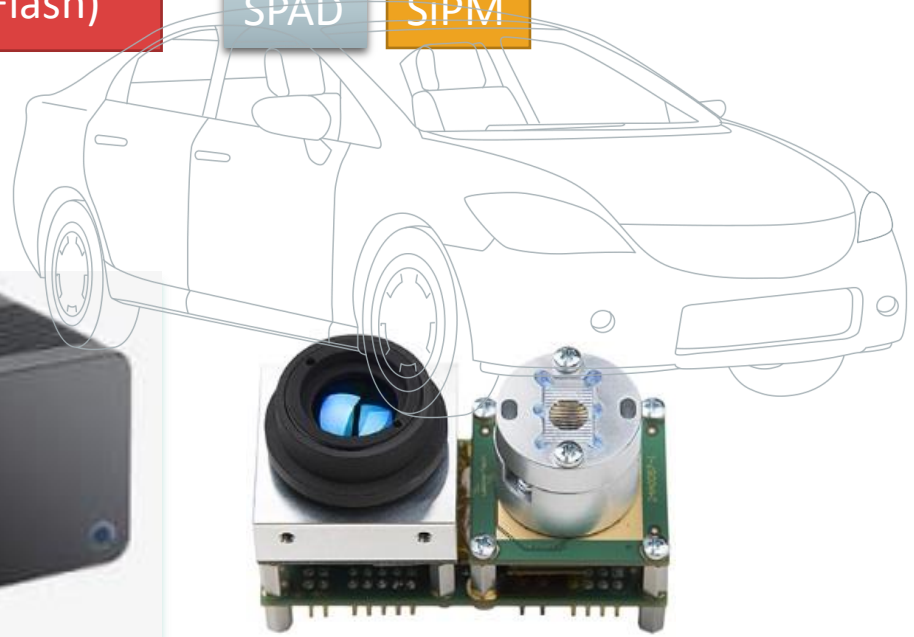
OPA technology

Light Detection And Ranging (LIDAR) System

- **Emitting**
  - Laser
    - VCSEL
    - VECSEL
  - LED
- **Projecting & Viewing**
  - Scanning
    - Mirror
      - μ-Mirror
    - OPA
    - Rotating
  - Non-scanning (Flash)
- **Sensing**
  - APD
    - SPAD
    - SiPM
  - PIN





Picture sources: web

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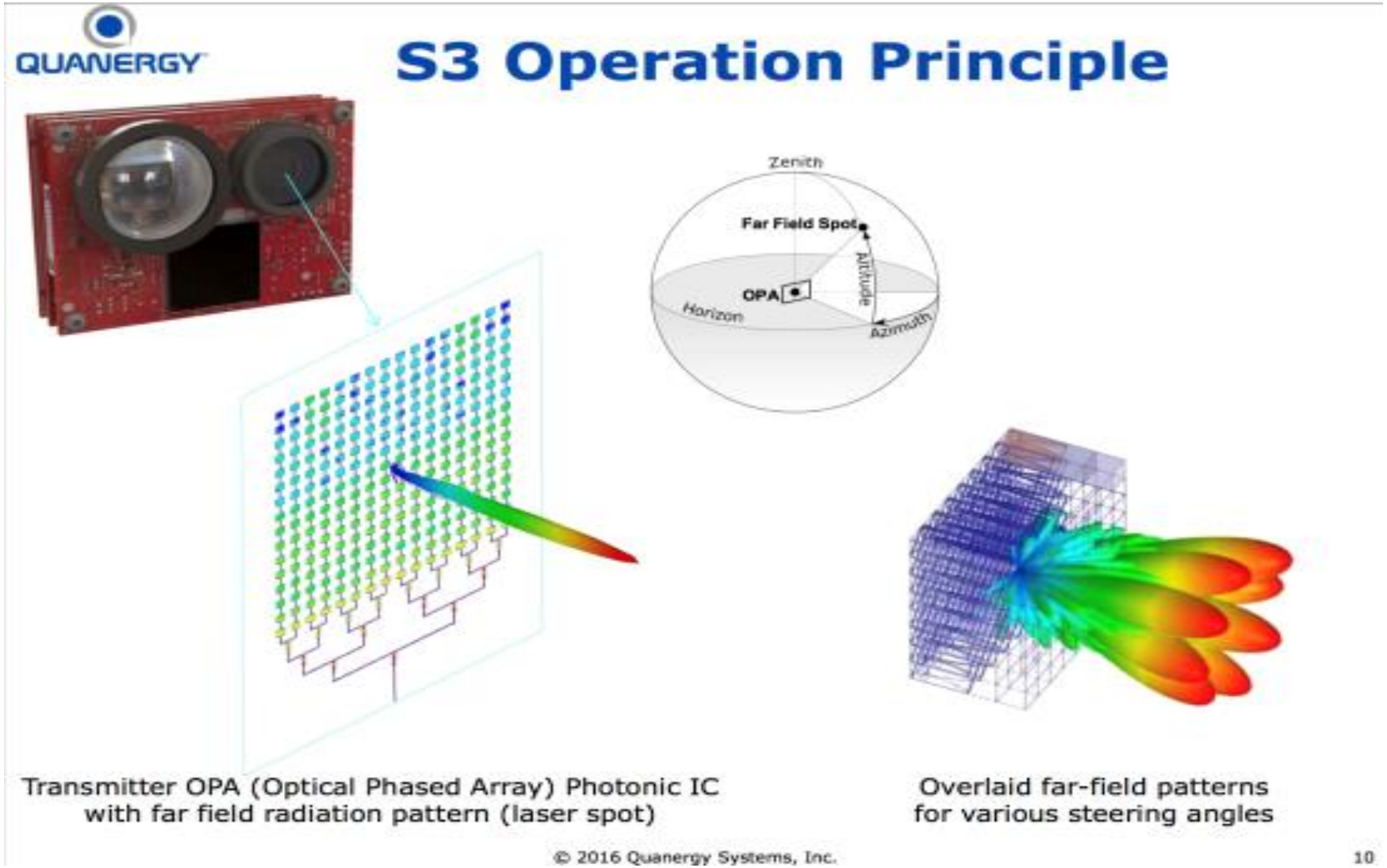
Optical Phase Array LIDAR



Optical sensors in automotive: Sustainability (electrification)

Fuel Quality sensor

Courtesy SP3H

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Fuel quality sensor

Unexpected events and (lack of) legislation can heavily influence market acceptance!

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Air quality and CO_2 leakage sensor

- CO_2 is emerging refrigerant in car airco
  - R134a: must be discontinued (1000x CO_2 global warming potential)
  - R1234yf: more expensive, might create toxic gases when burning
- CO_2 air quality
  - Indicator for indoor air quality
  - Driver drowsiness
- Big emerging market need for low cost automotive sensing solution!

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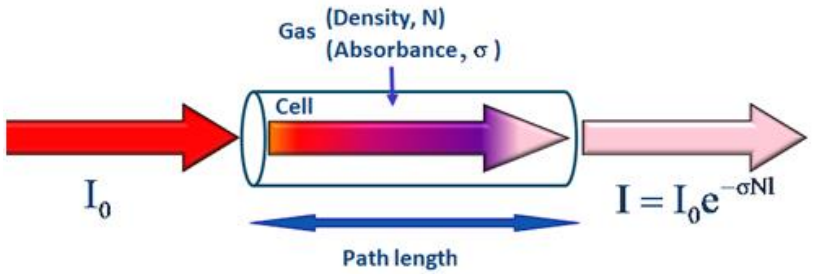
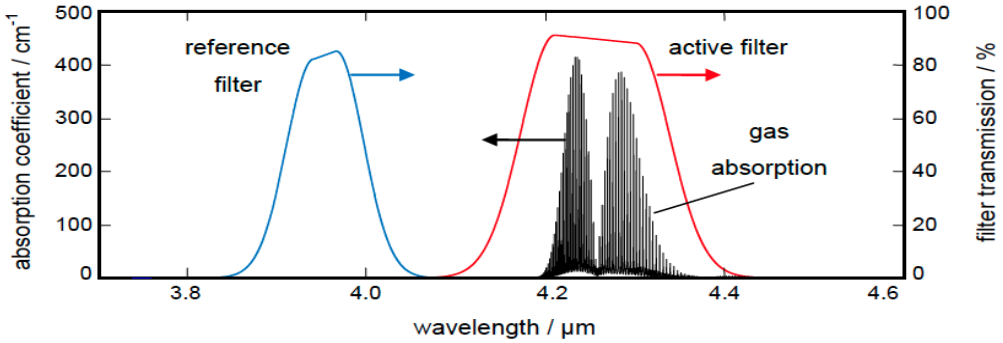
NDIR CO_2 detection principle

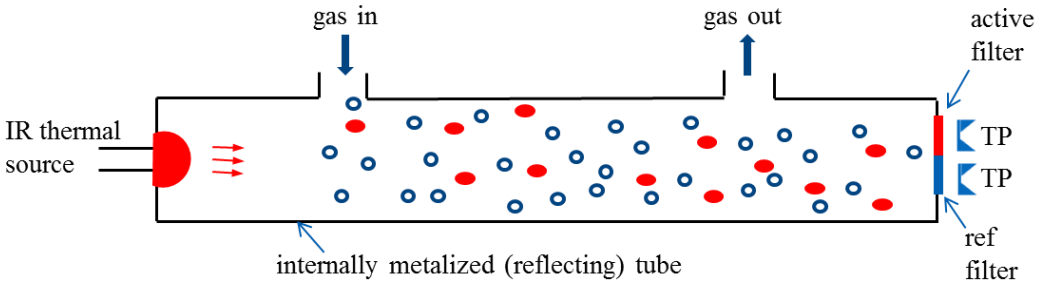
Beer-Lambert law:



CO2 absorption spectrum:



Current approach:



- Discrete optics
- Gas tube

⇒ Bulky (~10cm)
Expensive(~ 10 EURO)

Current products:

source: Edinburgh Instruments

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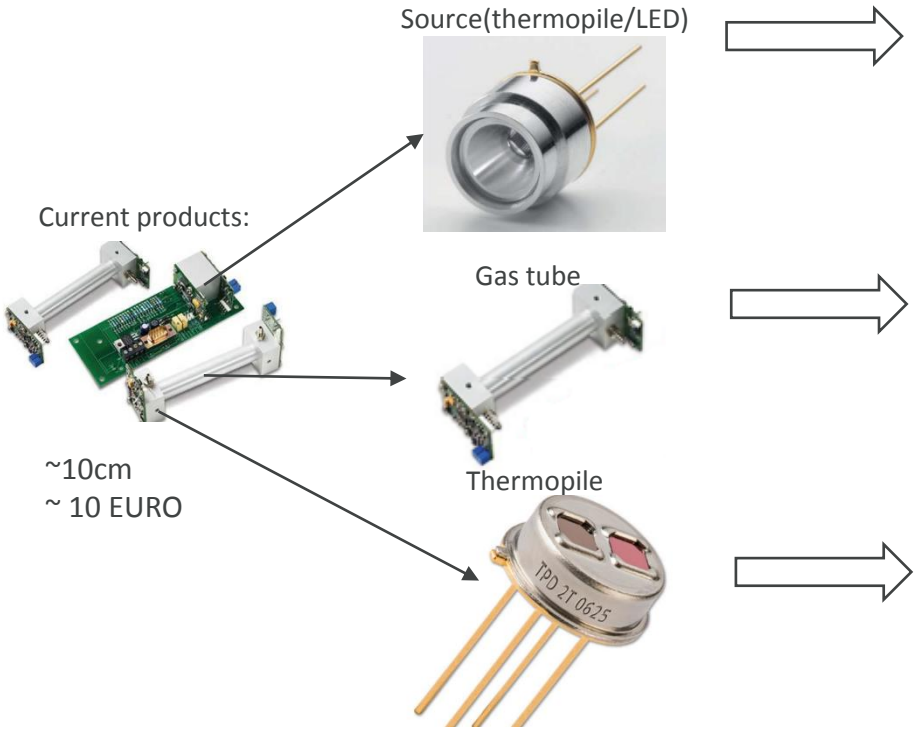
Low cost integrated miniaturized NDIR solution

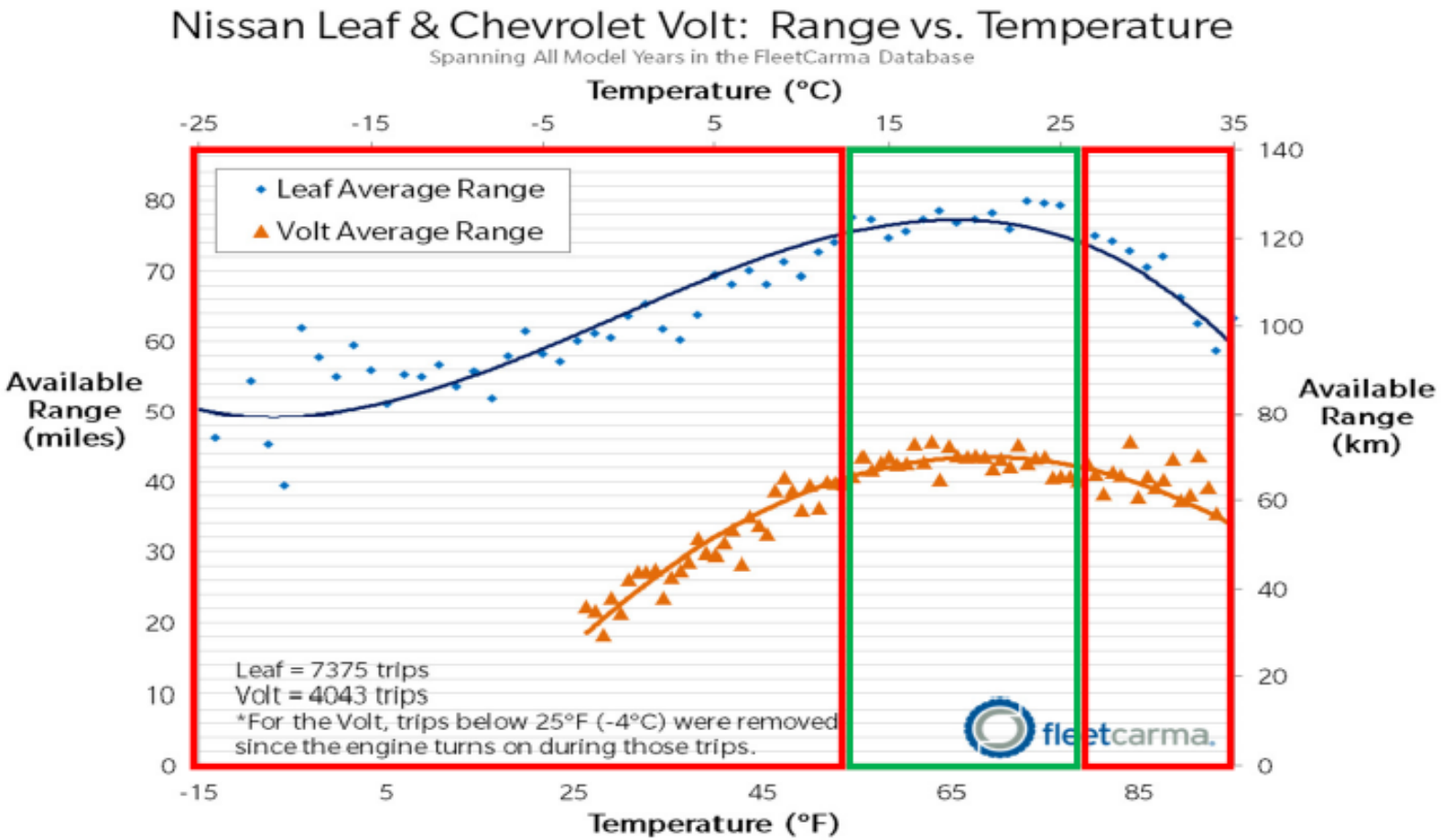


MELEXIS Technologies NV

Geminiaturiseerde geïntegreerde NDIR voor ultra lage kost CO2 sensing

Jia Xiaoning
UGent, Faculteit Ingenieurswetenschappen en Architectuur - Vakgroep Informatietechnologie (INTEC)

HVAC: the BEV range killer



Heat Ventilation AirCo consumption in hot/cold weather→
25-40% range reduction for battery electrical vehicle (BEV)

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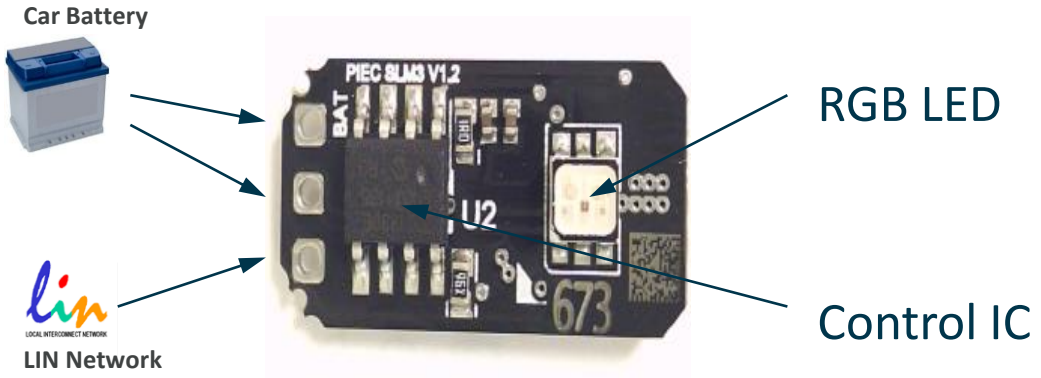
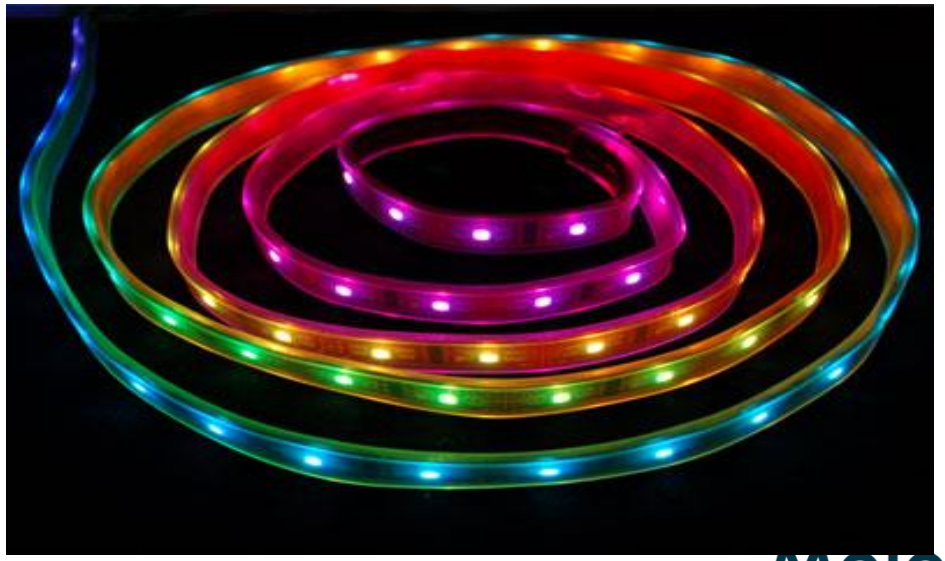
Ambient lighting with LIN RGB



- “Perceived temperature” can be increased/decreased 1-2C°
- Automotive harsh environment
  - Environmental influences to modules
  - High electromagnetic disturbances
- Wide Operating range
  - Battery voltage of 6V to 18V
  - Operating temperature -40 to 125°
- Smart Connectivity
  - Communication via LIN



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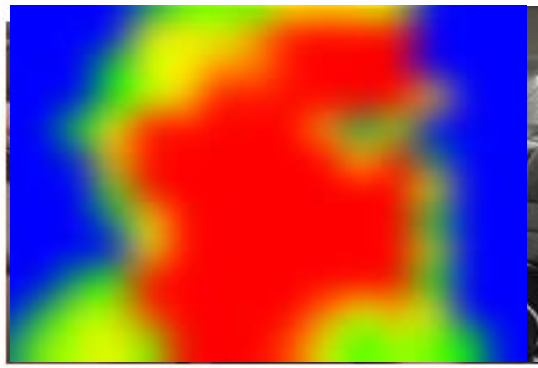
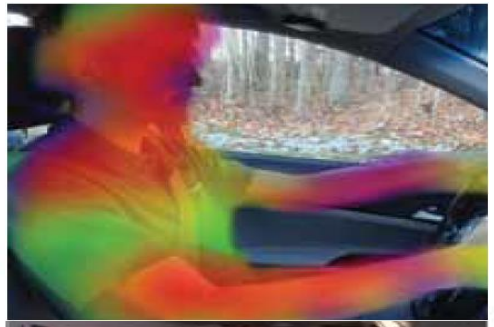
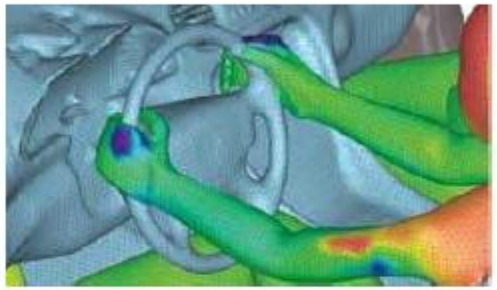
Thermal imaging: **the** ultimate HVAC control input

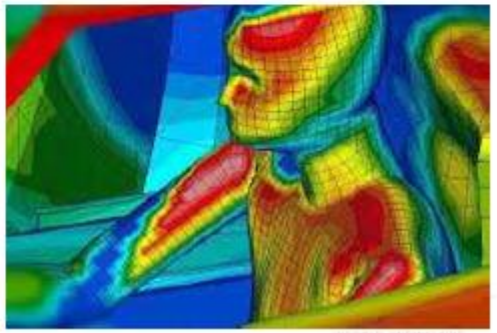
Move to Local Heating / Local Cooling creates the need for Sensors to understand Interior Awareness





Interior Awareness
- Driver Monitoring
- Passenger Classification
- Passenger Confort Understanding





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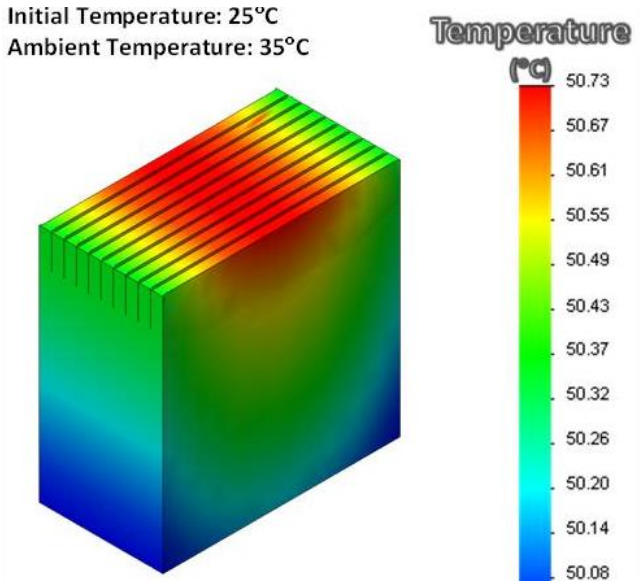
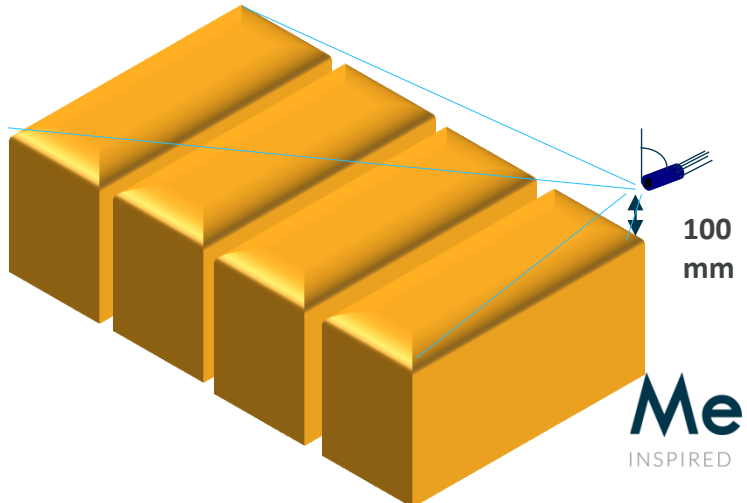
Thermal imaging: battery management

- Safety feature wireless charging
- Monitoring battery temperature





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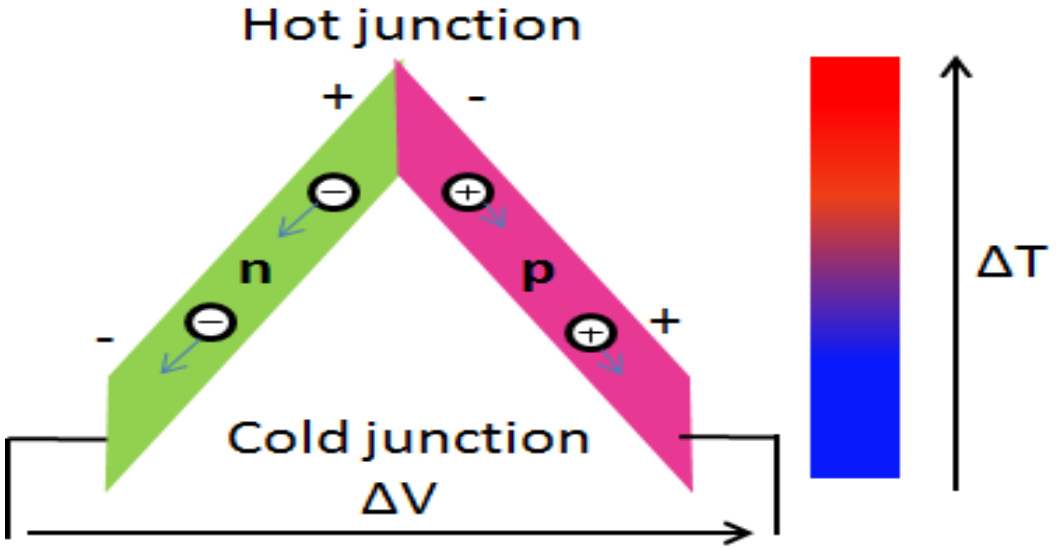
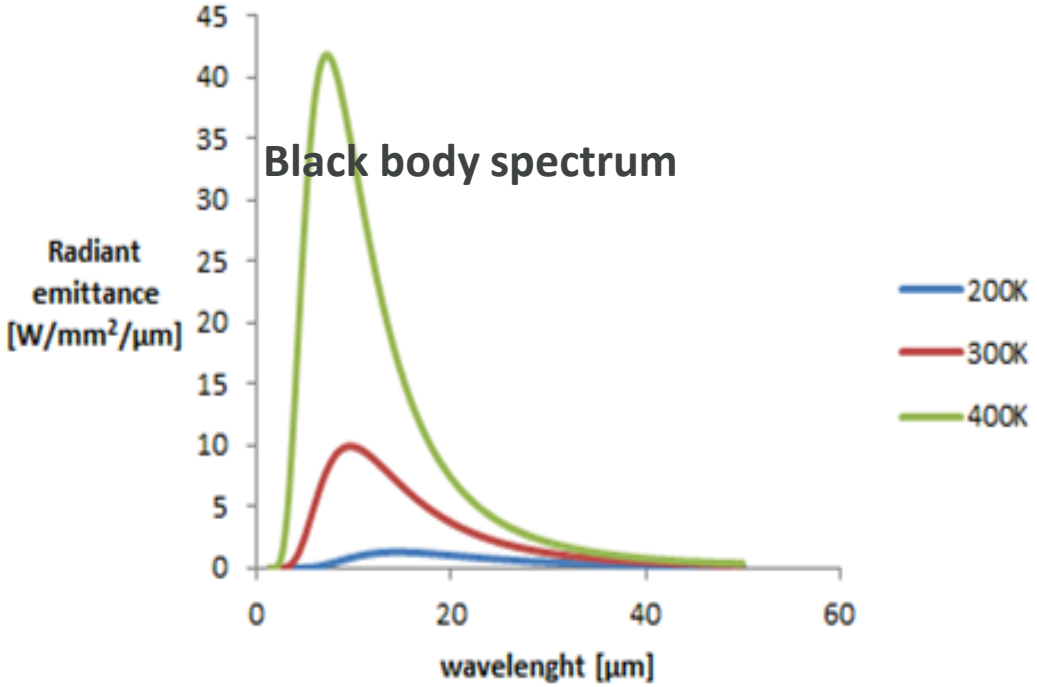
How it works: thermocouple principle

- Thermo-electric (Seebeck) effect
  - ΔT over p/n junction
  - charge carriers move (net) to cold junction
  - resulting EMF ΔV ~ ΔT
  - typical signal level µV



How it works: black body radiation

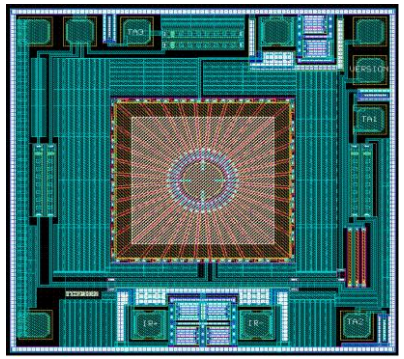
- Stefan Boltzmann law: integral over BB spectrum
- $j = \eta\sigma T^4$
  - j = radiant emittance [W/m^2]
  - η = emissivity (surface property)
  - σ=5.67e-8 [$W/m^2/K^4$]
  - T=absolute temperature [K]
- assumption η≈1 → surface temperature can be tied to emitted power

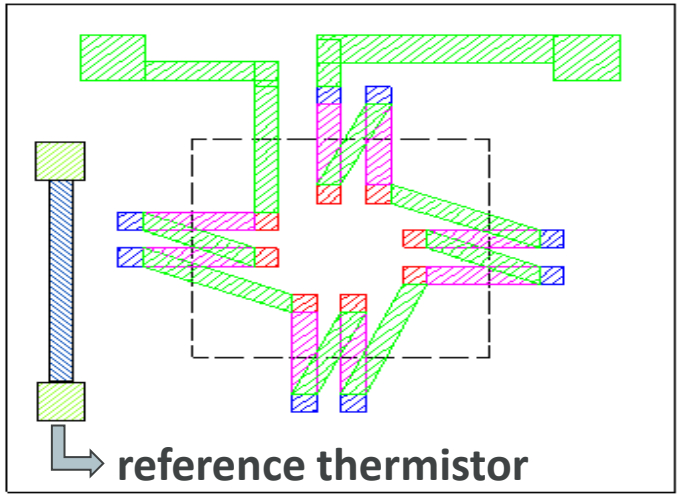


On chip MEMS thermopile technology

- Thin membrane
  - thermally isolated
  - low thermal mass
  - heated by incoming heat flux→ΔT

- Measure ΔT using thermocouples in series = thermopile
  - hot junction on membrane
  - cold junction on chip
  - (absolute) temp reference: thermistor





Conclusion

- Several megatrends are driving a never seen wave of innovation in automotive
- Optical sensor technologies are and will be of crucial importance

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Thank You
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