

Latest industrial applications of Quantum sensing technologies

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SVP Quantum Sensing - ID Quantique

Quantum Tech Congress – Boston Sept. 10, 2019

ID Quantique company profile



Founded in 2001



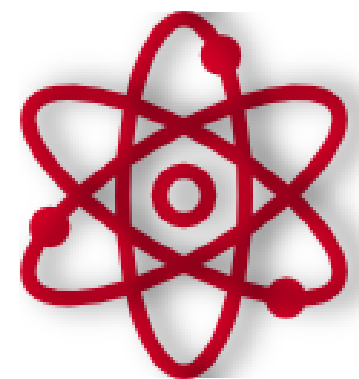
Geneva, Switzerland
Seoul, South Korea
Bristol, UK
Washington DC, Boston USA



By 4 quantum physicists from the University of Geneva



95 employees including 50 engineers/scientists



Develops technologies and products based on quantum physics & photonics within 2 business units:

- Quantum-Safe Security
- Quantum Sensing



Performs R&D, production, sales, professional services, integration, support

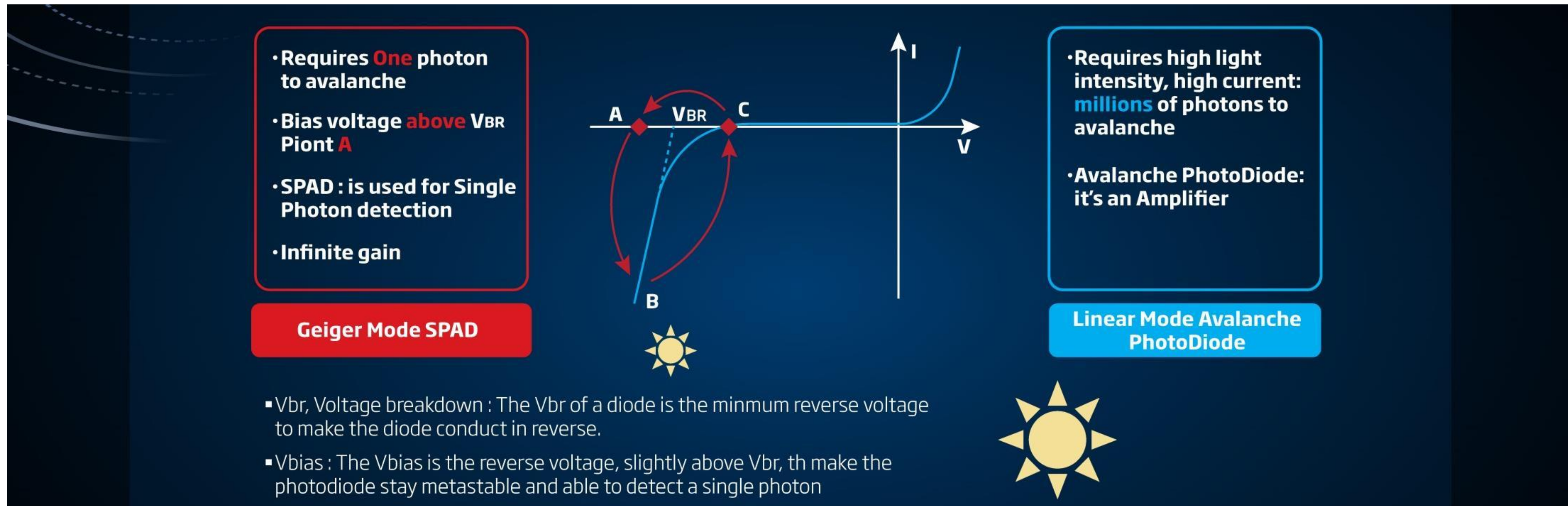


Clients: Governments / Banks / Gaming Industry / Universities / IT Security / O&G / Telecom

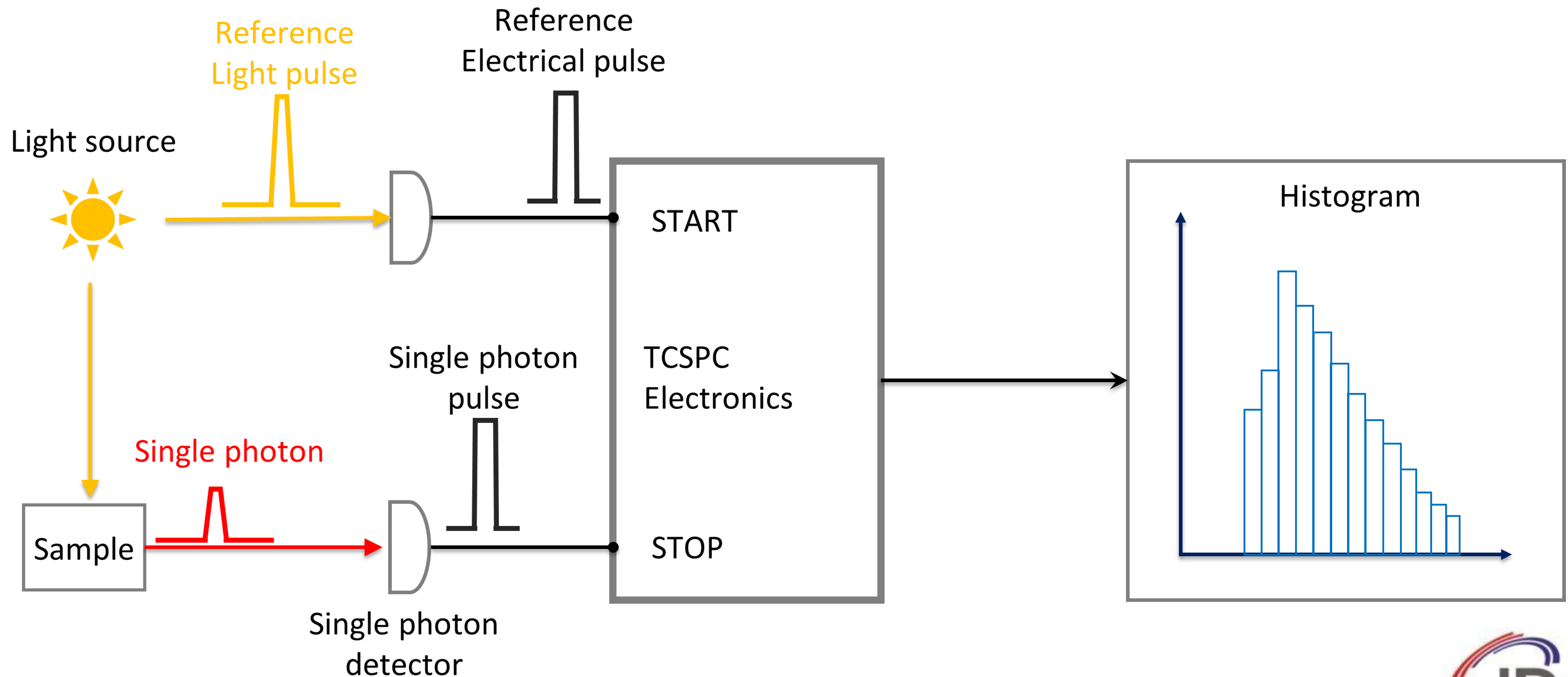


- Content
 - Quantum Sensing basics
 - Technology and applications
 - Asset integrity monitoring – Ariane6 case study
 - Quantum LiDAR and applications:
 - Autonomous driving
 - Gas sensing and leak detection
 - Conclusion

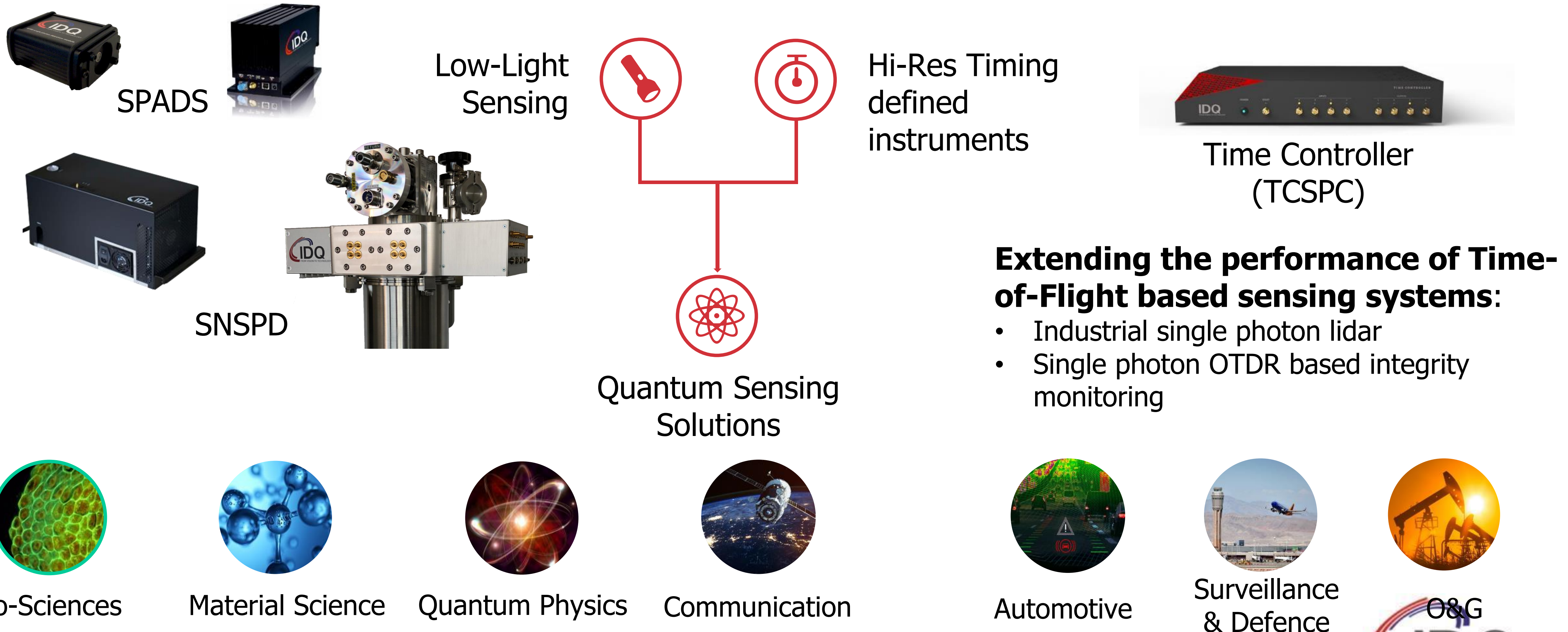
Technology APD - Single photon detection principle of operation



Technology TCSPC - Time correlated single photon counting



Quantum Technologies for sensing performance beyond conventional techniques





Ariane 6 launcher program

- Next-generation launcher
- Competitiveness
- Reduced production costs
- Reduced design-to-build lead times
- Maintain leadership



■ Ariane 6 Launcher program

- First space launcher using **Opto-Pyrotechnics**
- Pyrotechnic sub-systems: vital part of the avionics system – responsible for ignition, separation, passivation and neutralization
- Main advantages are:
 - immunity to electromagnetic interference,
 - simpler handling, shorter integration times,
 - mass, volume and **cost reductions**



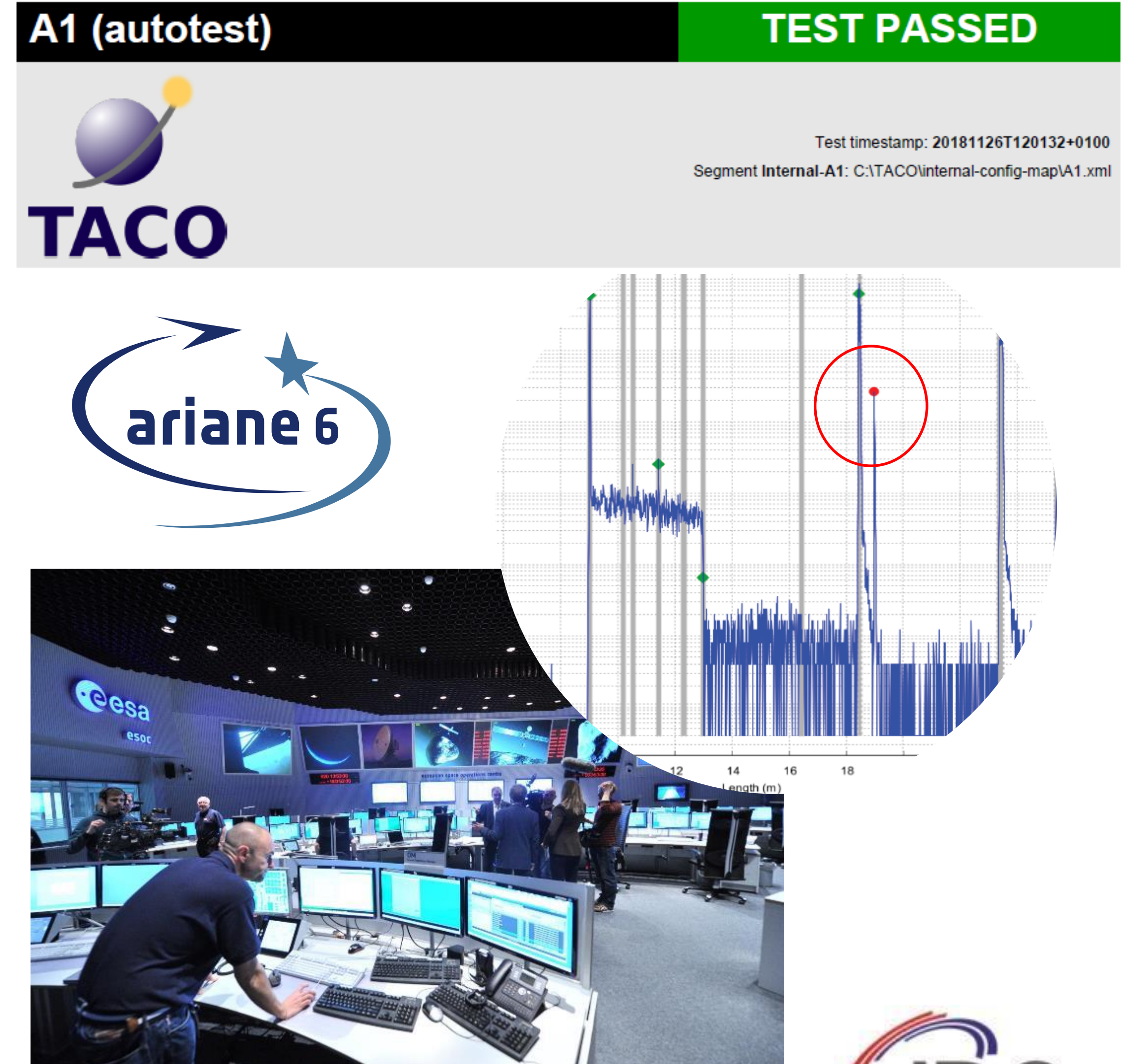
Ariane 6 future launcher Opto-Pyro system is composed of:

- High power Laser Diode combined with optical detonators connected through complex fiber optic network
 - >8 km of transmission line (fiber optic cables)
 - 82 pyrotechnical devices activating critical functions of the launch
- **Require system tests and verification from launcher assembly test and final validation before launch**

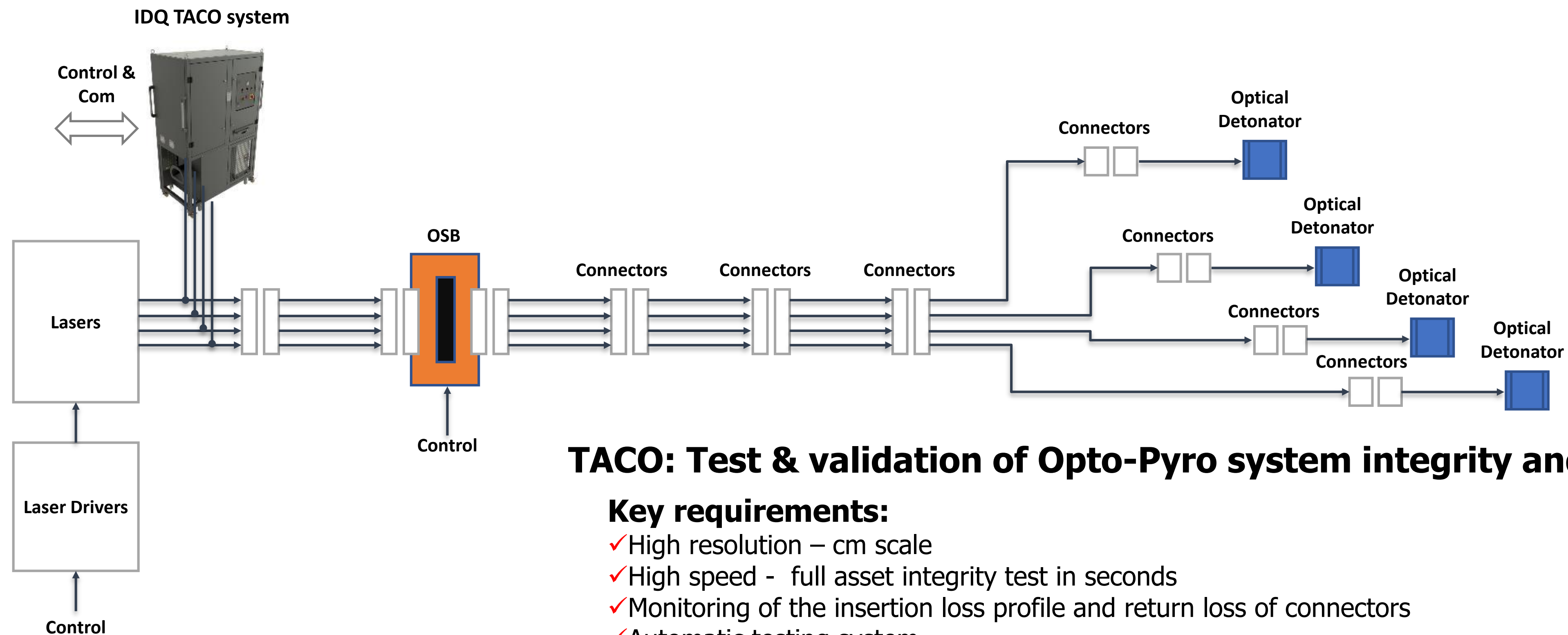


TACO – Automatic Test & Validation System

- ArianeGroup worked with IDQ to design a fiber optic integrity and performance monitoring for entire Opto-Pyro control system - “TACO”:
- High performance OTDR solution (Optical Time Domain Reflectometry)
- Capable to determine in real time whether opto-pyro chains are functional or not
- Provide real-time status information to ESA control room
- In case of abnormal condition, provide information about the type of issue and location in the opto-pyro chain



OPTO-PYROTECHNIC SYSTEM ARCHITECTURE



TACO: Test & validation of Opto-Pyro system integrity and performance

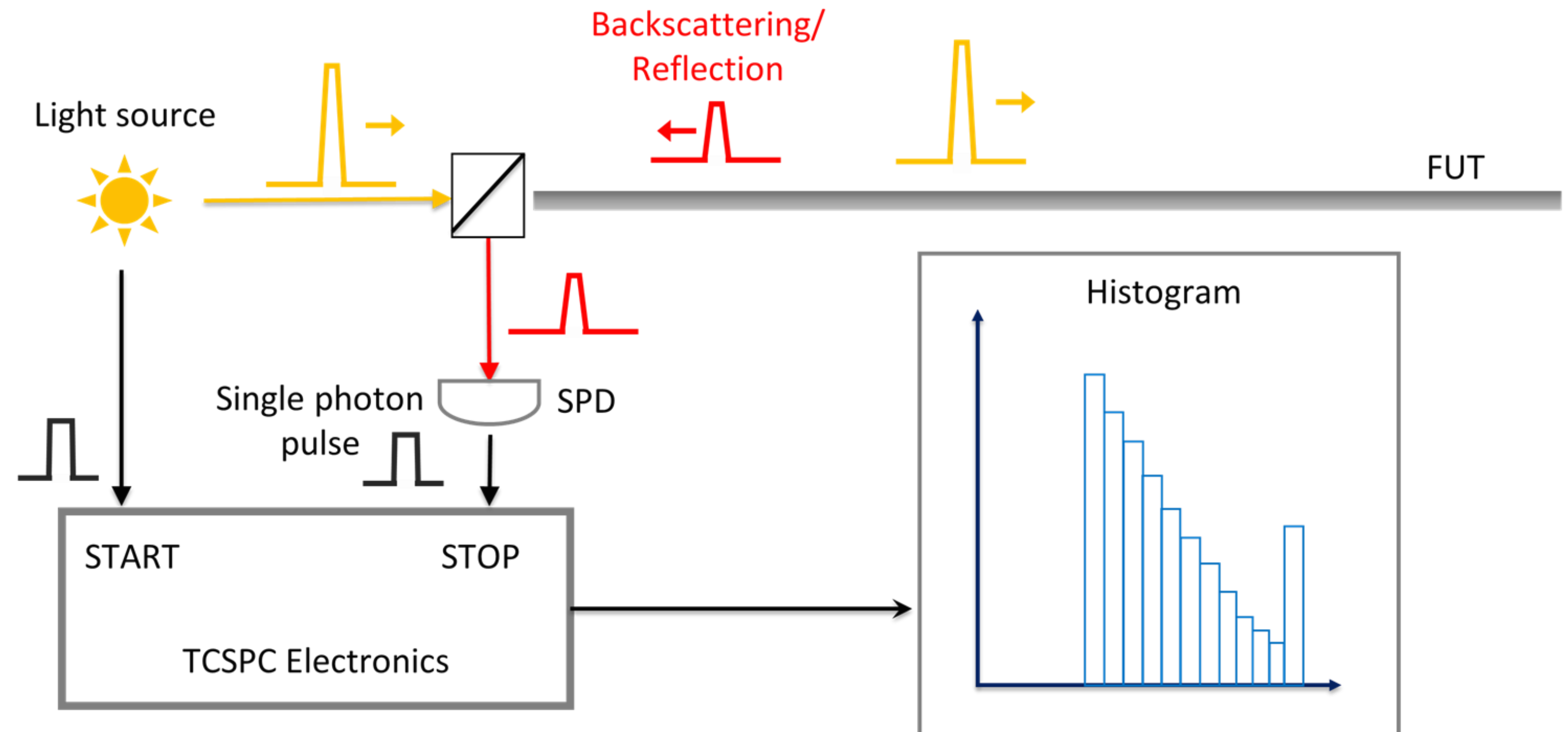
Key requirements:

- ✓ High resolution – cm scale
- ✓ High speed - full asset integrity test in seconds
- ✓ Monitoring of the insertion loss profile and return loss of connectors
- ✓ Automatic testing system
- ✓ Zero risk to affect the Opto-Pyro system

➡ Performance unachievable by traditional means

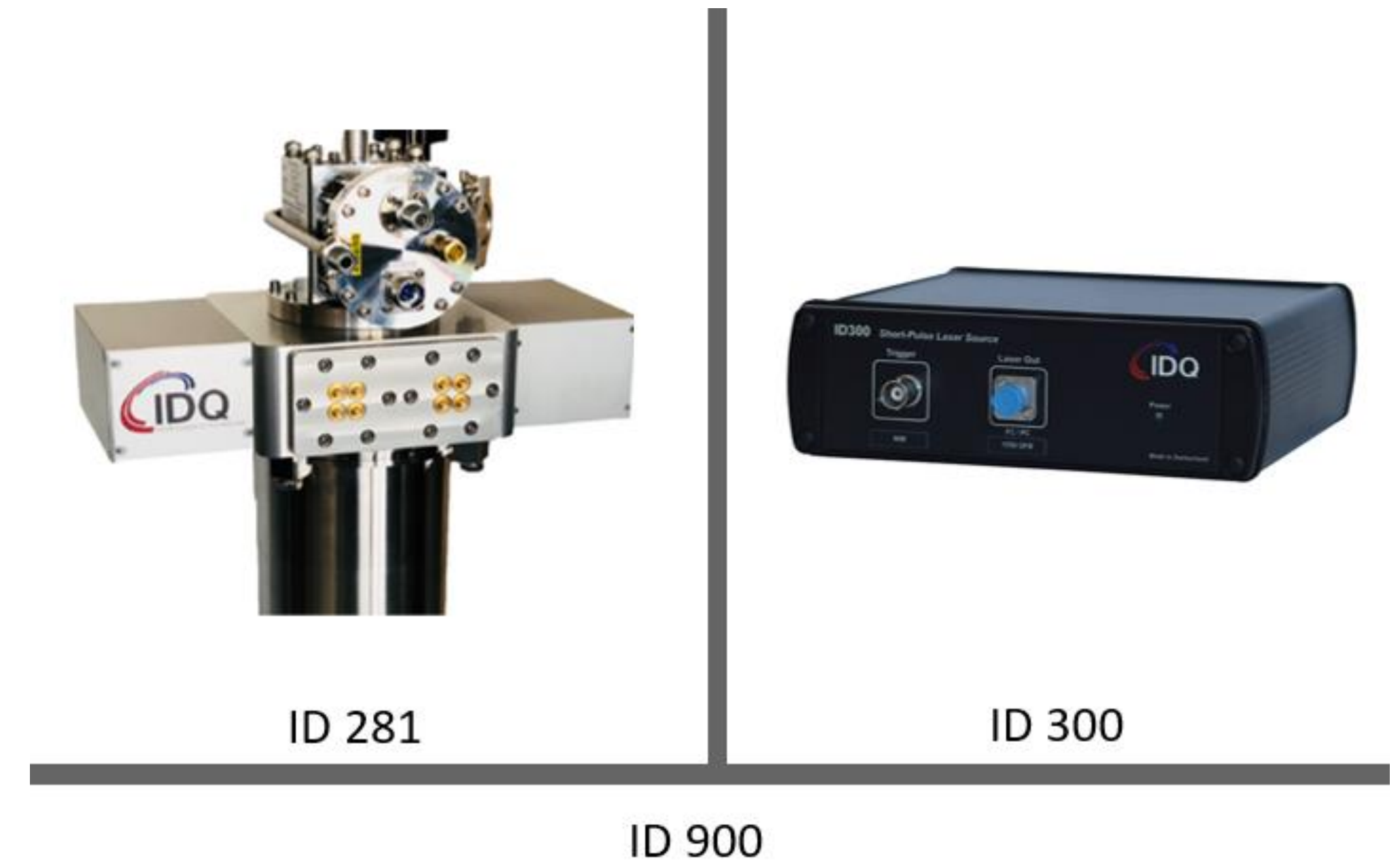
■ Principle of operation Single photon Optical Time Domain Reflectometer (OTDR) and benefits

- Single photon OTDR offers
- Operates with low optical power
- High sensitivity (photon counting)
- High dynamic range (>70dB)
- High spatial resolution (1.5cm)
- Virtually no dead zone
- Fast acquisition times (typ. 60 sec)

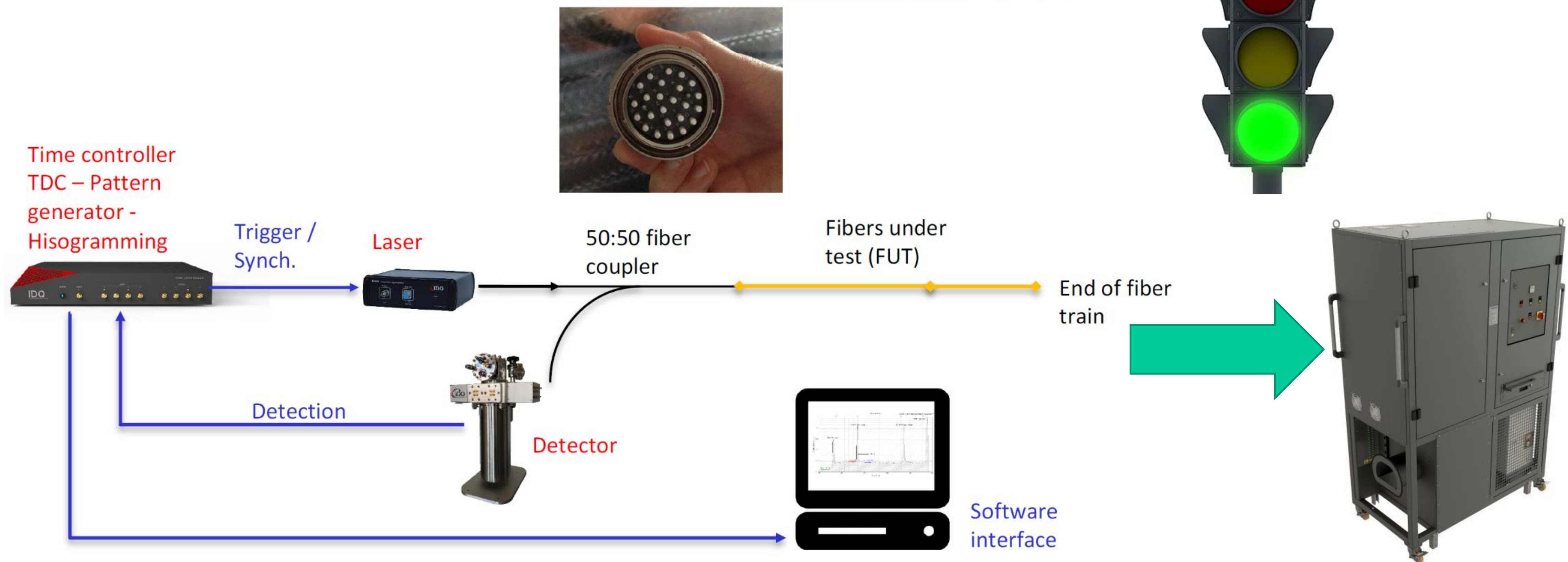


System components overview

- Complete multi-channel turnkey solution with control software
- ID300 Pulsed laser
 - Ultra low power laser requirement
 - No risk of impacting opto-pyro system
- ID281 Single Photon detection with high quantum efficiency
 - Cryogenic SNSPD solution
- ID900 Electronics for photon counting and timing
 - Real-time control of the measurements
 - Guaranteeing distance accuracy of +/- 1.5 cm of all fiber optic connectors and potential failures



TACO - architecture





- **Ariane 6 Launcher program**
 - ✓ Accuracy unachievable by traditional means
 - ✓ Ultra fast detection of integrity issues
 - ✓ Centimeter spatial resolution
 - ✓ Intrinsically safe solution

- ✓ Fully qualified by ArianeGroup (Airbus-Safran)
- ✓ First flight in October 2020
- ✓ 30 year program

- **Technique applicable to other distributed sensing – strain, temperature**



Quantum LiDAR Solutions

Single Photon LiDAR applications to:

- ✓ **autonomous driving,**
- ✓ **Security,**
- ✓ **gas sensing and leak detection**

LiDAR technology and applications

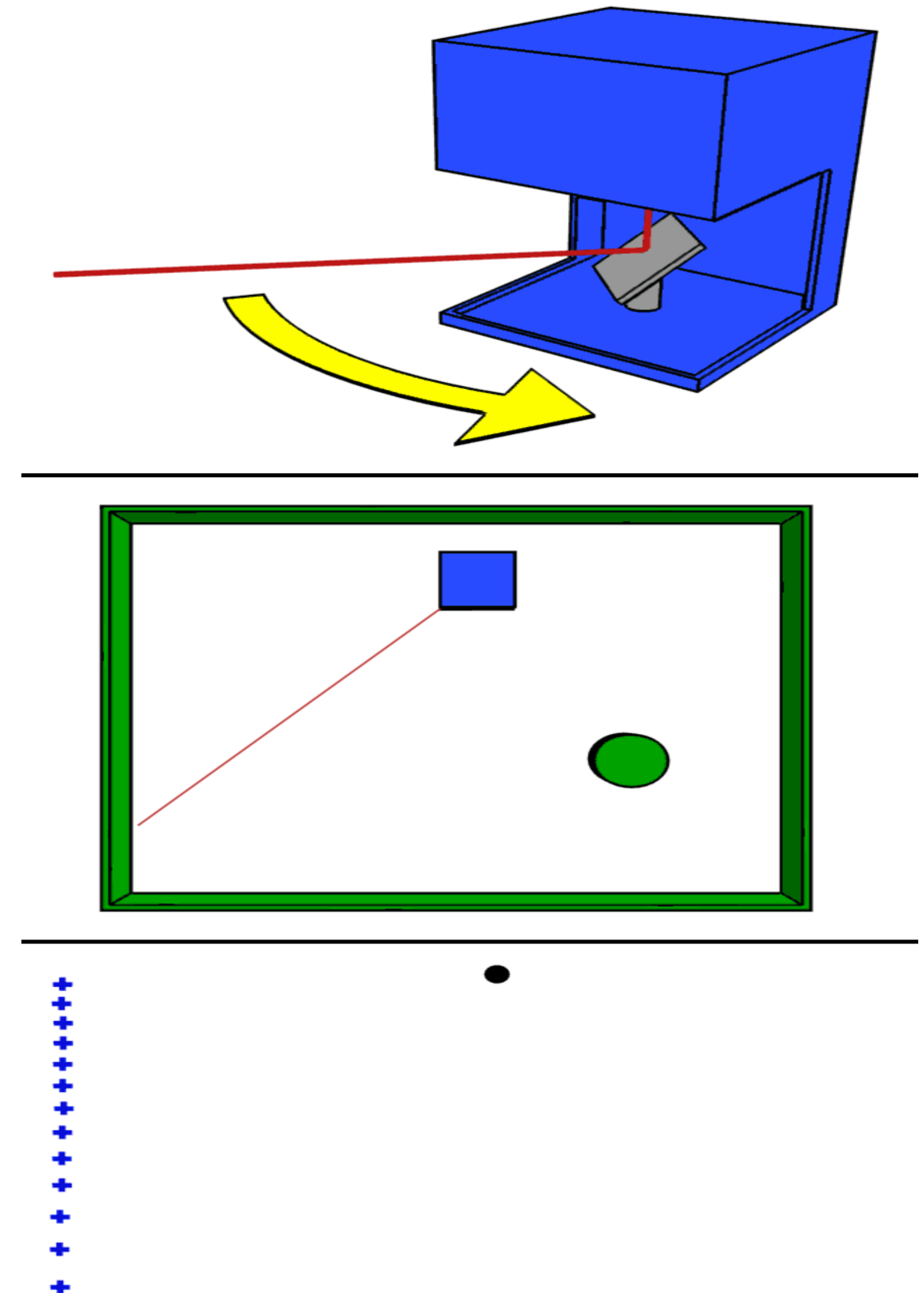
- **LiDAR** measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor.
- Differences in laser return times can then be used to make digital 3D representation of the target.

Time of flight measurement

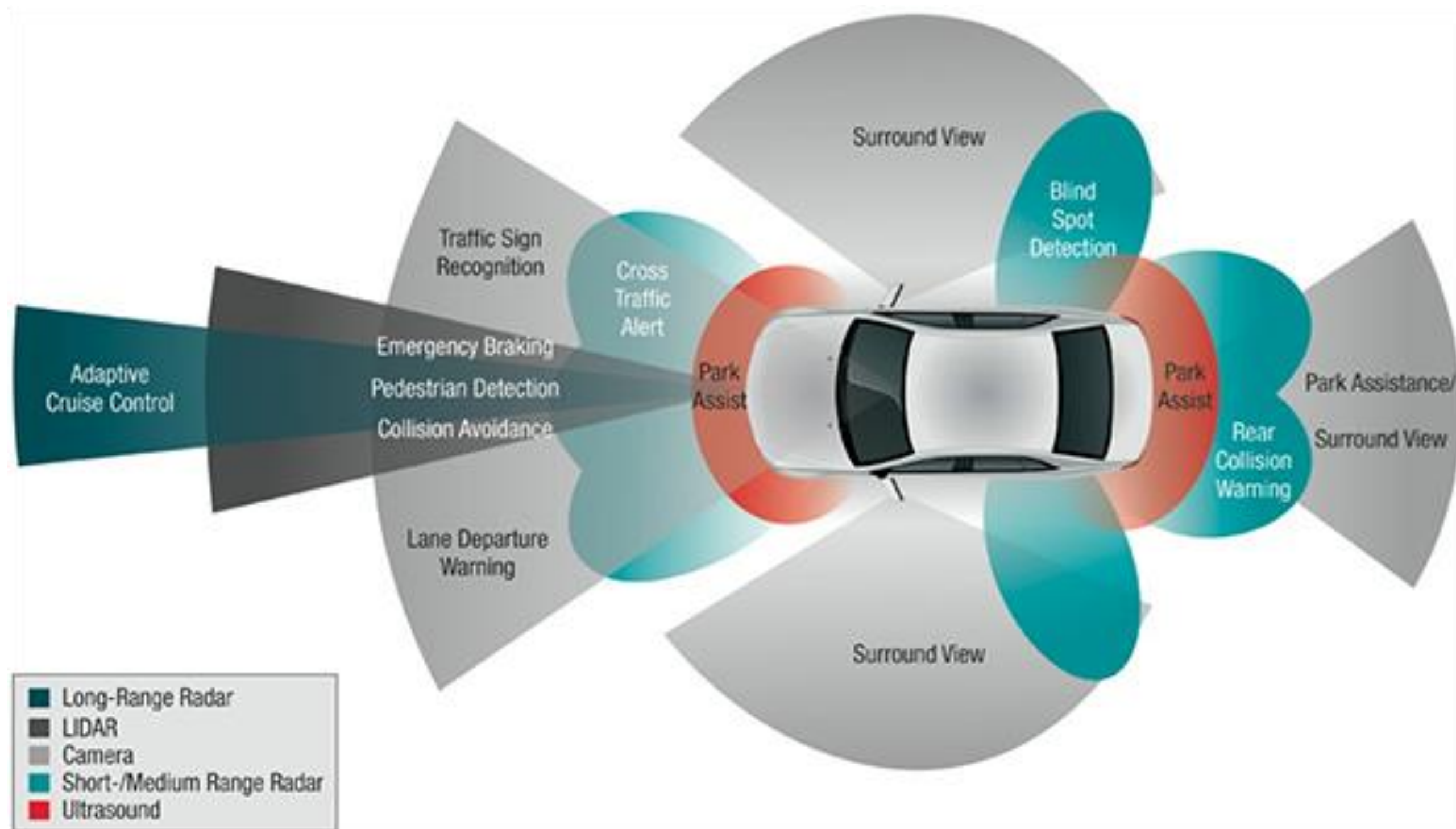
$$Distance = \frac{Velocity\ of\ Light \times Time\ of\ Flight}{2}$$

Key parameters and Limiting factors:

- Optical pulse power
- Detection system efficiency
- Scanning range



Autonomous vehicle sensors

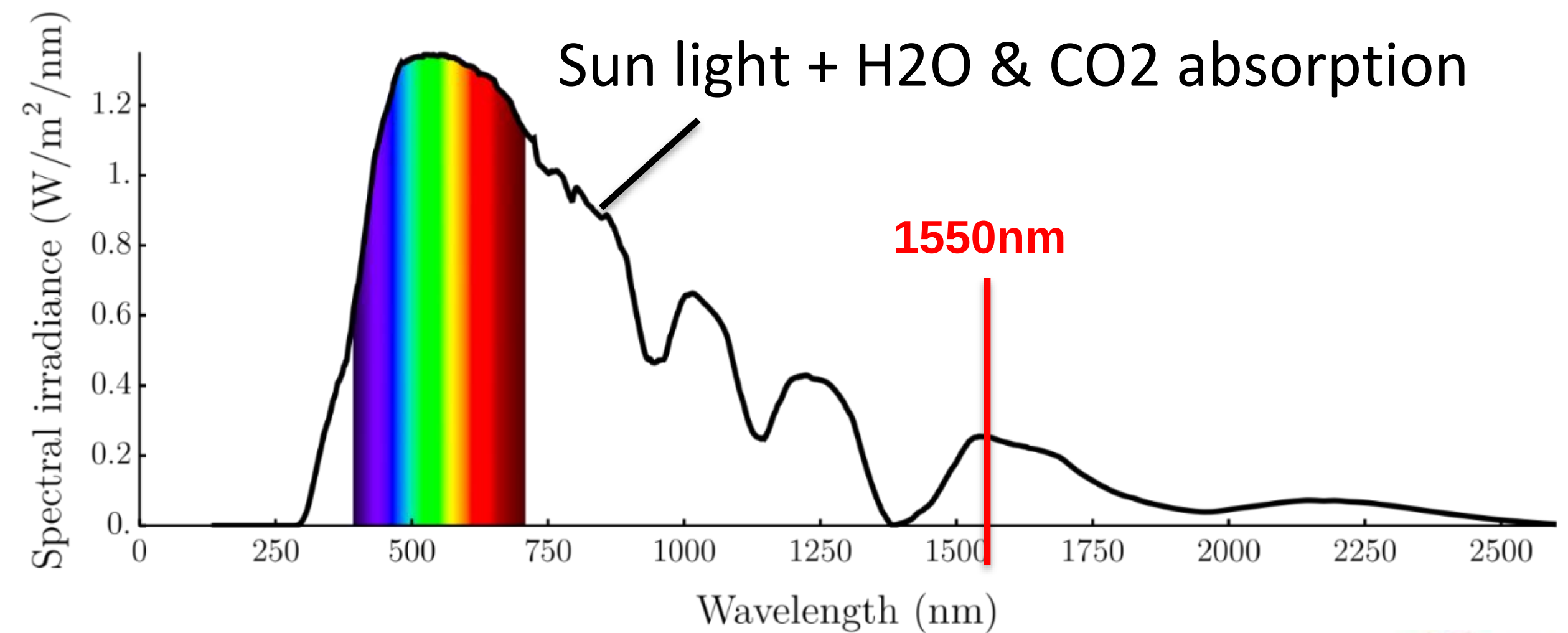


Lidar → distance and position measurement with high spatial and depth resolution

1550 nm, hybrid scanning +
flash LiDAR

1550 nm wavelength

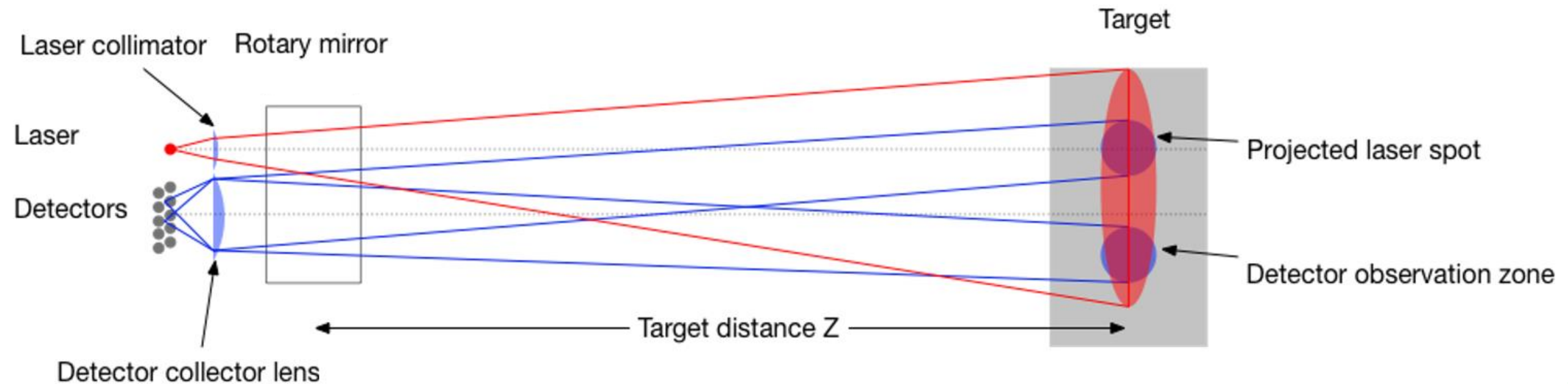
- Eye-safe at higher intensities
- Higher immunity to ambient light



1550 nm, hybrid scanning +
flash LiDAR

Hybrid imaging for high speed imaging

- Horizontal scanning
- Flash illumination in vertical with array detector



1550 nm, hybrid scanning +
flash LiDAR

WITH

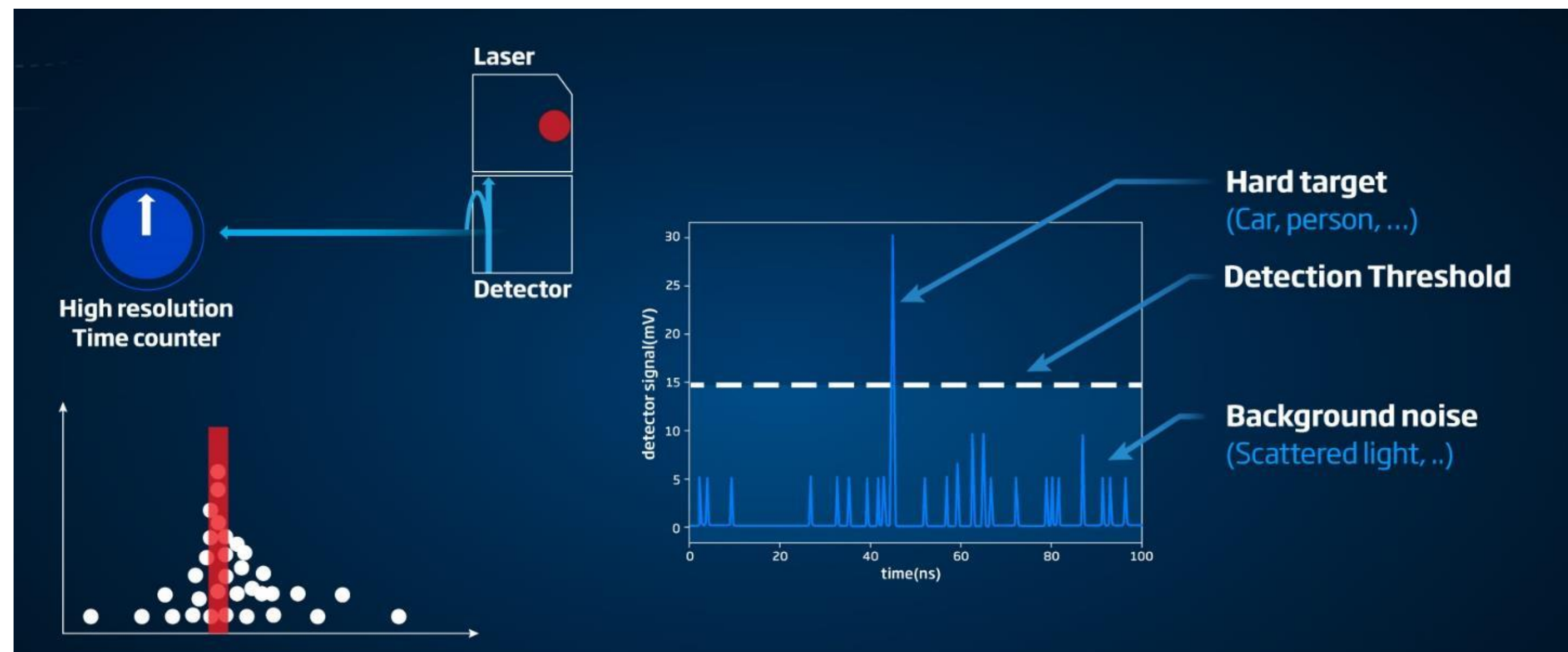
Single photon detection +
coincidence detection /
noise filtering signal processing

Single-photon detection

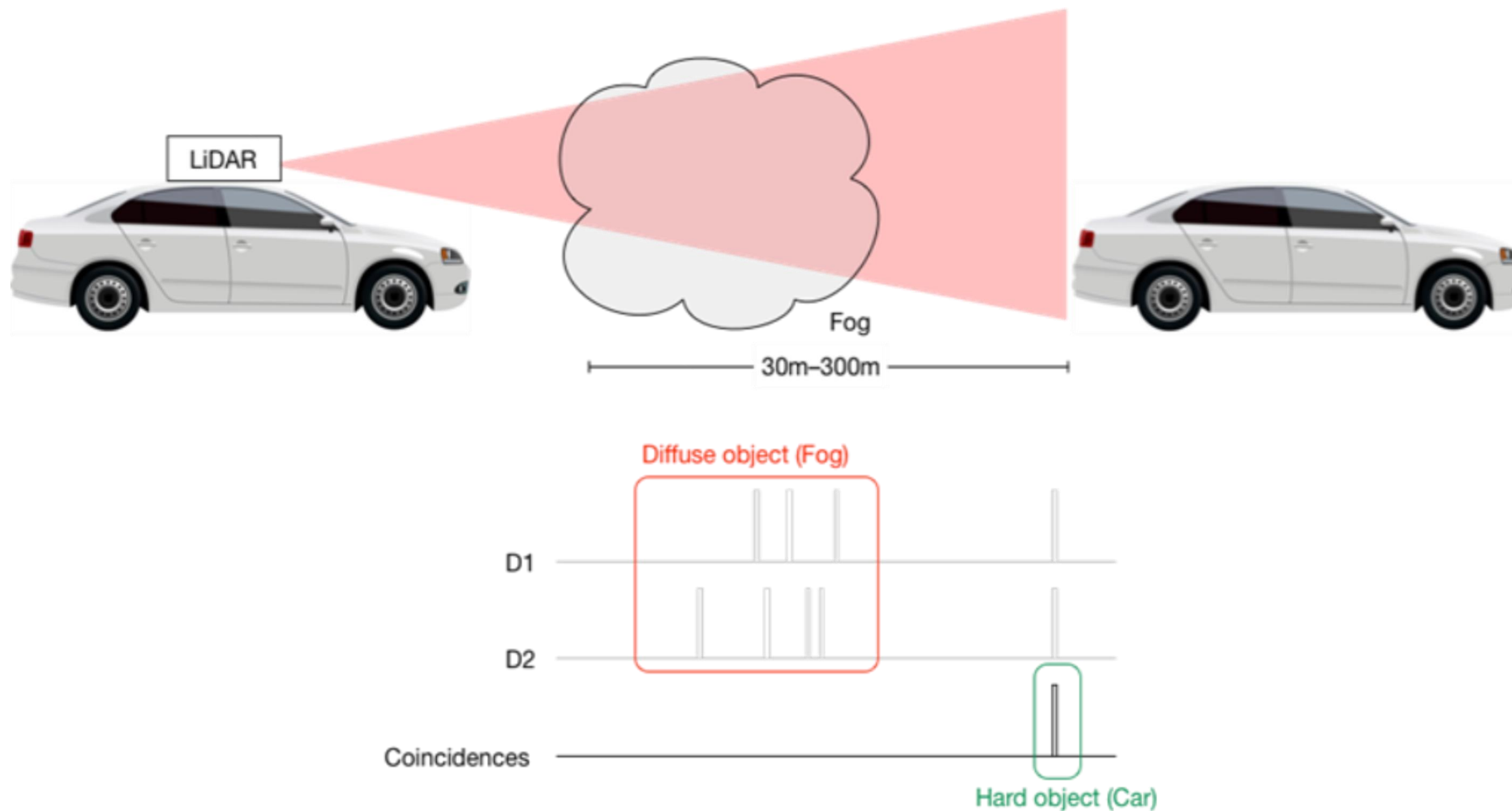
- High sensitivity
- Long range with low power

Photon counting - Coincidence detection

- Thresholding $\Leftrightarrow$ coincidence with SPADs
- Signal from hard target $\gg$ background noise



■ IDQ Quantum LiDAR Performance

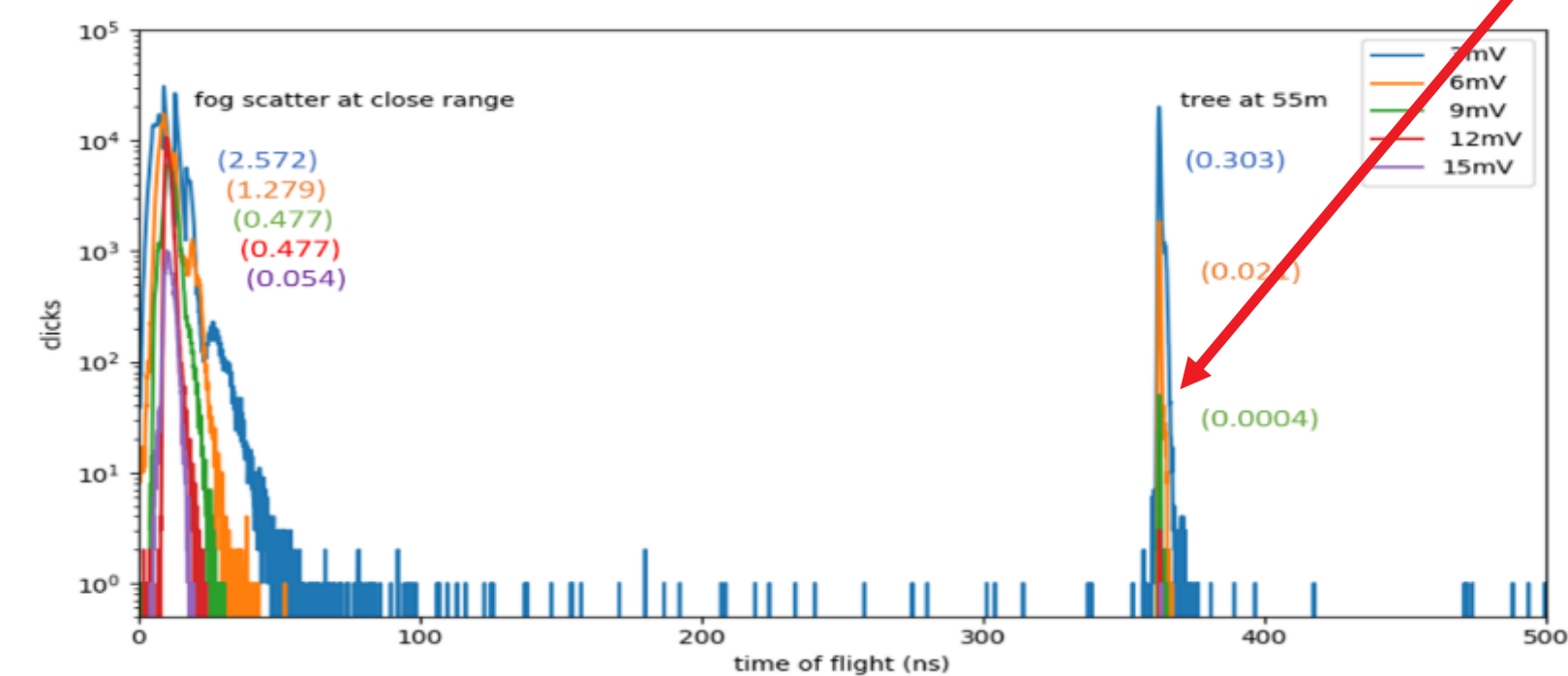


- >300m range @ 10% reflectivity (up to 500m capabilities)
- Pulse width: 1nsec
- Field of view: 110° (horizontal), 2-4° (vertical)
- Operation in poor visibility

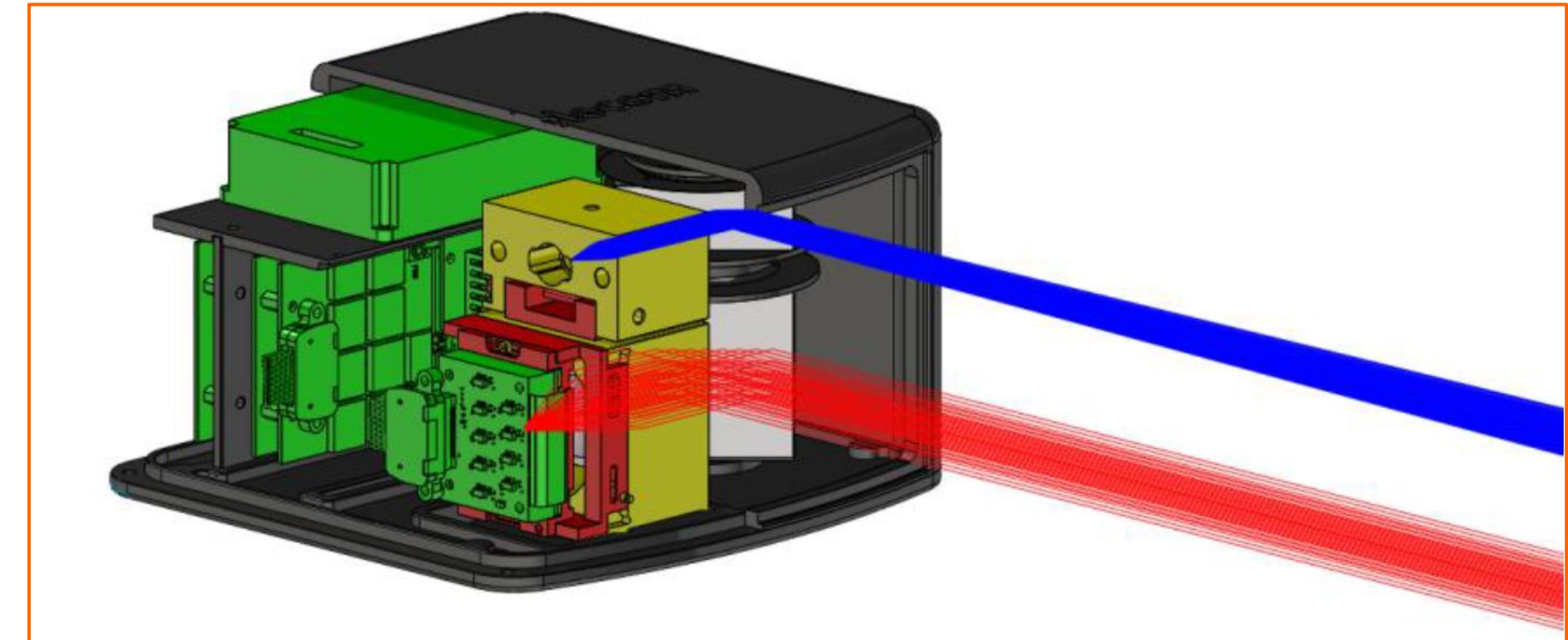
Vehicle at 515 m



Tree at 55m
clearly visible in
fog



Presented by SK Telecom at Las Vegas CES 2019 Seoul Autoshow 2019



A wide range of applications



Automotive



Surveillance
& Defence



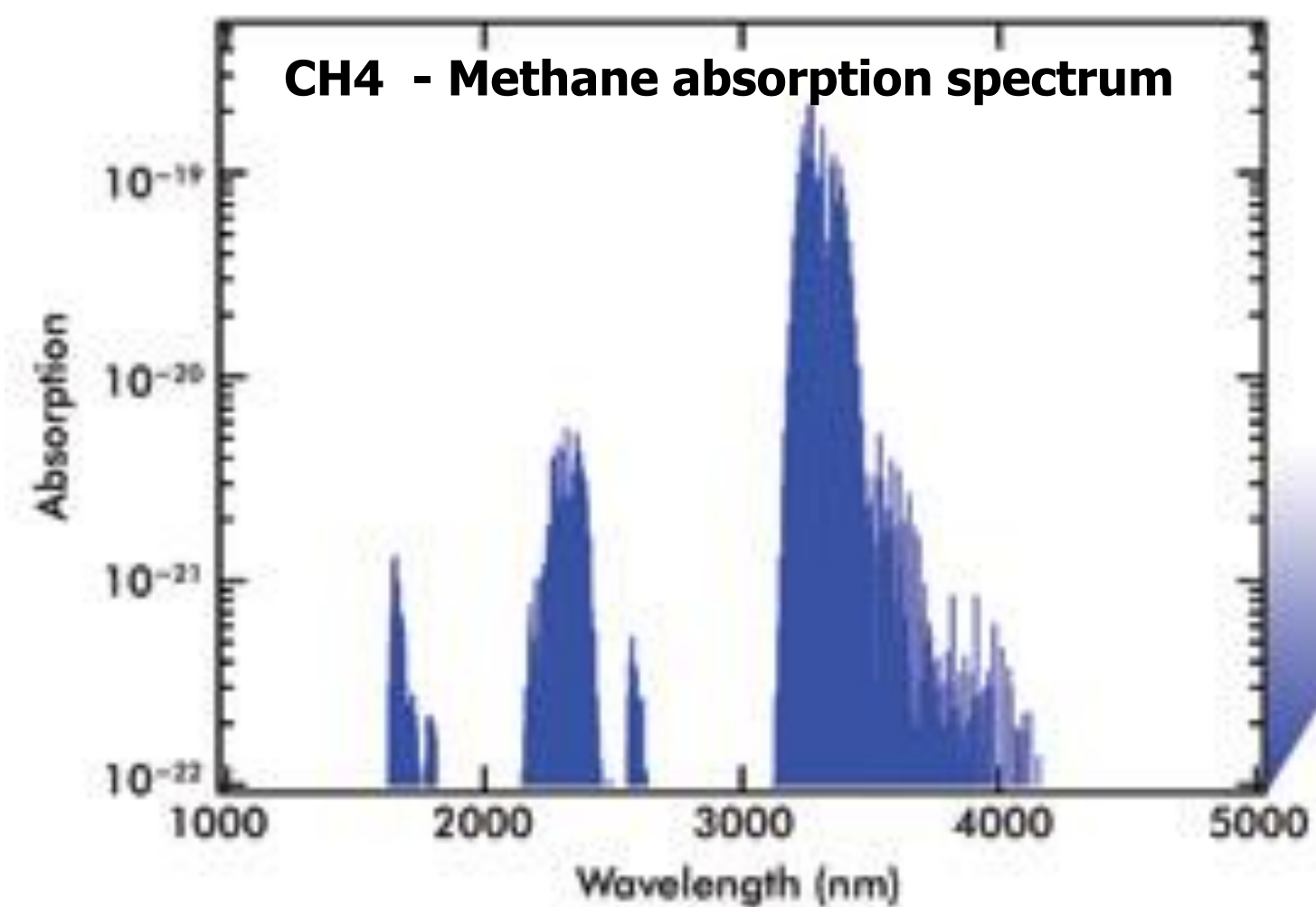
Aerospace

... but also Gas Sensing

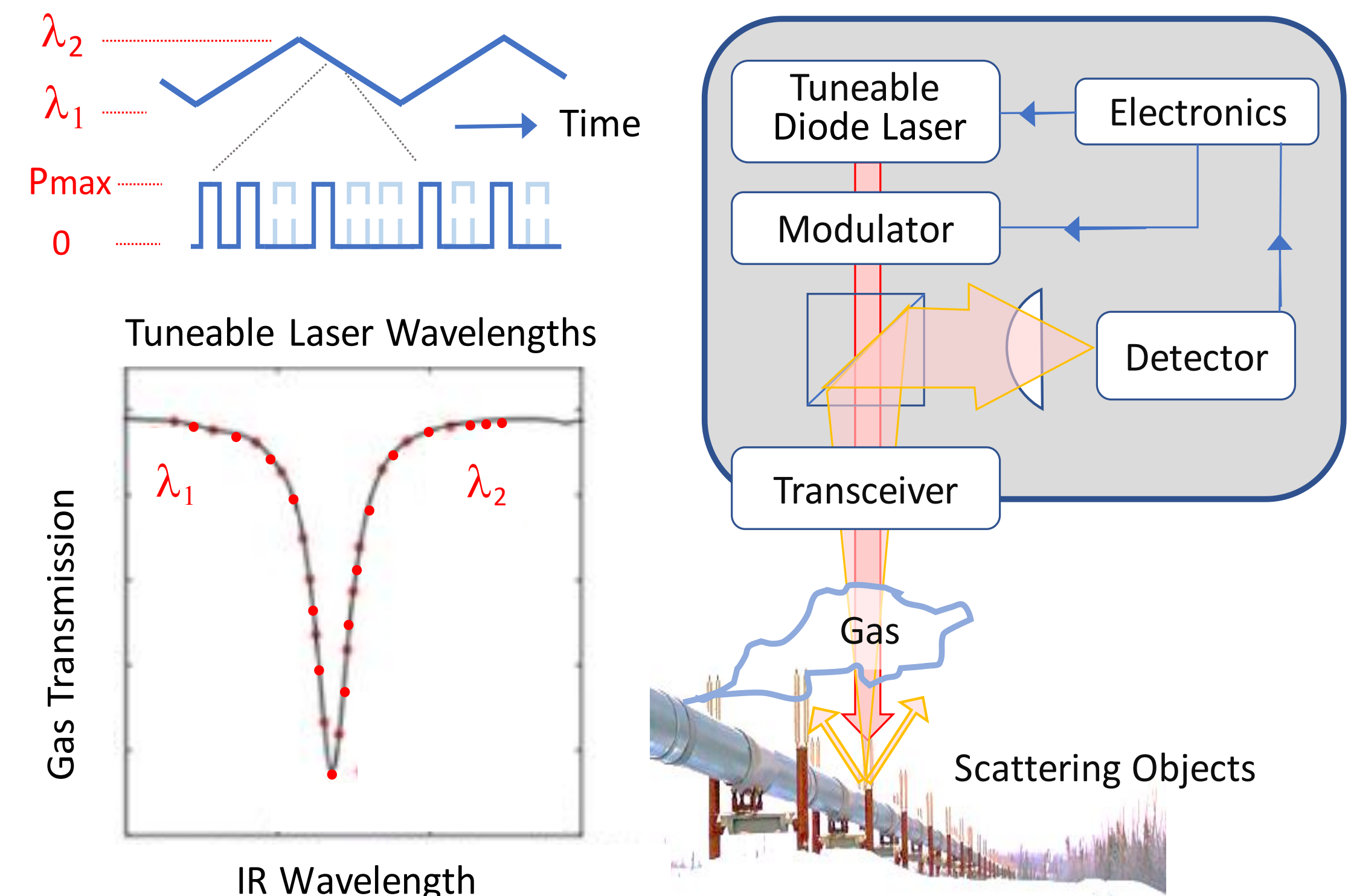


O&G

- **LiDAR-based gas sensing system**
- **Combining LiDAR technique with Tuneable Laser Spectroscopy**
 - Low power tuneable laser
 - Single-photon counting detector
 - Self-calibrating specific gas measurement
 - High-speed signal and digital data processing



Natural gas leak detection



Why monitor methane?

- World gas consumption: $>100,000 \text{ m}^3/\text{second}$ equivalent to $>20\%$ of the world total energy consumption
- Worldwide production: $1,050,000,000,000 \text{ m}^3/\text{year}$
- Natural gas composition
 - 95% Methane, 3% Ethane, 0.2% Propane, plus other traces...

Recent studies have shown that Natural Gas global warming potential is very high as Methane footprint is much larger than CO₂

- Methane is a potent Greenhouse Gas (GHG):
 - About 84 times more potent than CO₂ over a 20 year period (due to its capacity to absorb heat from light) and,
 - > 28 times more potent than CO₂ over a 100 years period
 - Methane lifetime in the atmosphere varies from 8 to 12 years and eventually transforms into CO₂ + H₂O
- $>3\%$ of the methane produced leaked out in the atmosphere (from wells to distribution, through undetected leaks)

- **LiDAR based gas imaging system**

- **Benefits**

- Low-Cost Quantitative Gas Imagers
- Leveraging telecom laser components
- Highest sensitivity (photon counting detector)
- Room temperature operation, no coolers
- Compact, low power, portable and eye-safe

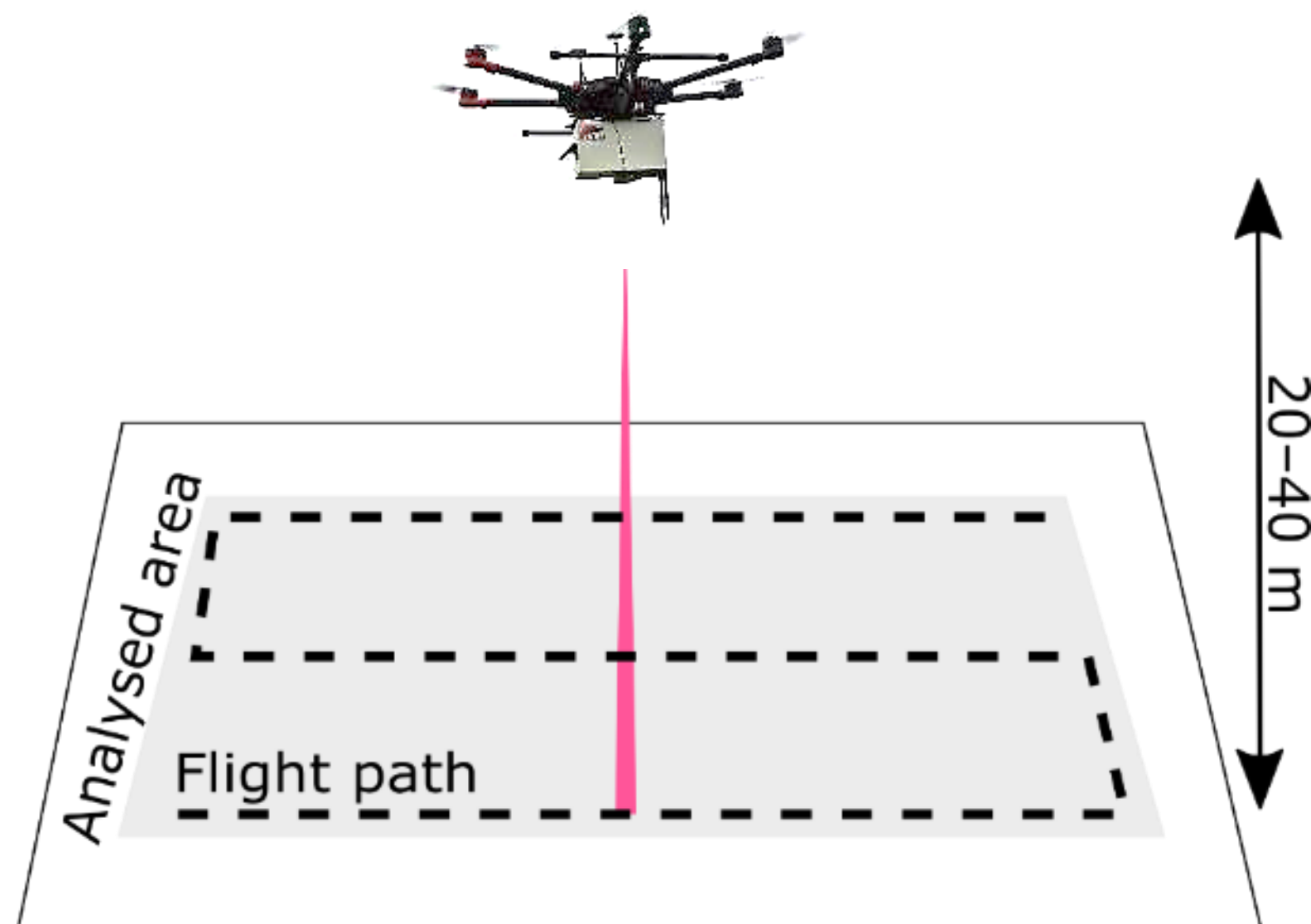


- **Capabilities**

- High-speed quantitative 3D imaging of specific gas concentration
- Precise mapping of gas leak locations
- Fixed, mobile, drone mounted options
- Solar or battery power

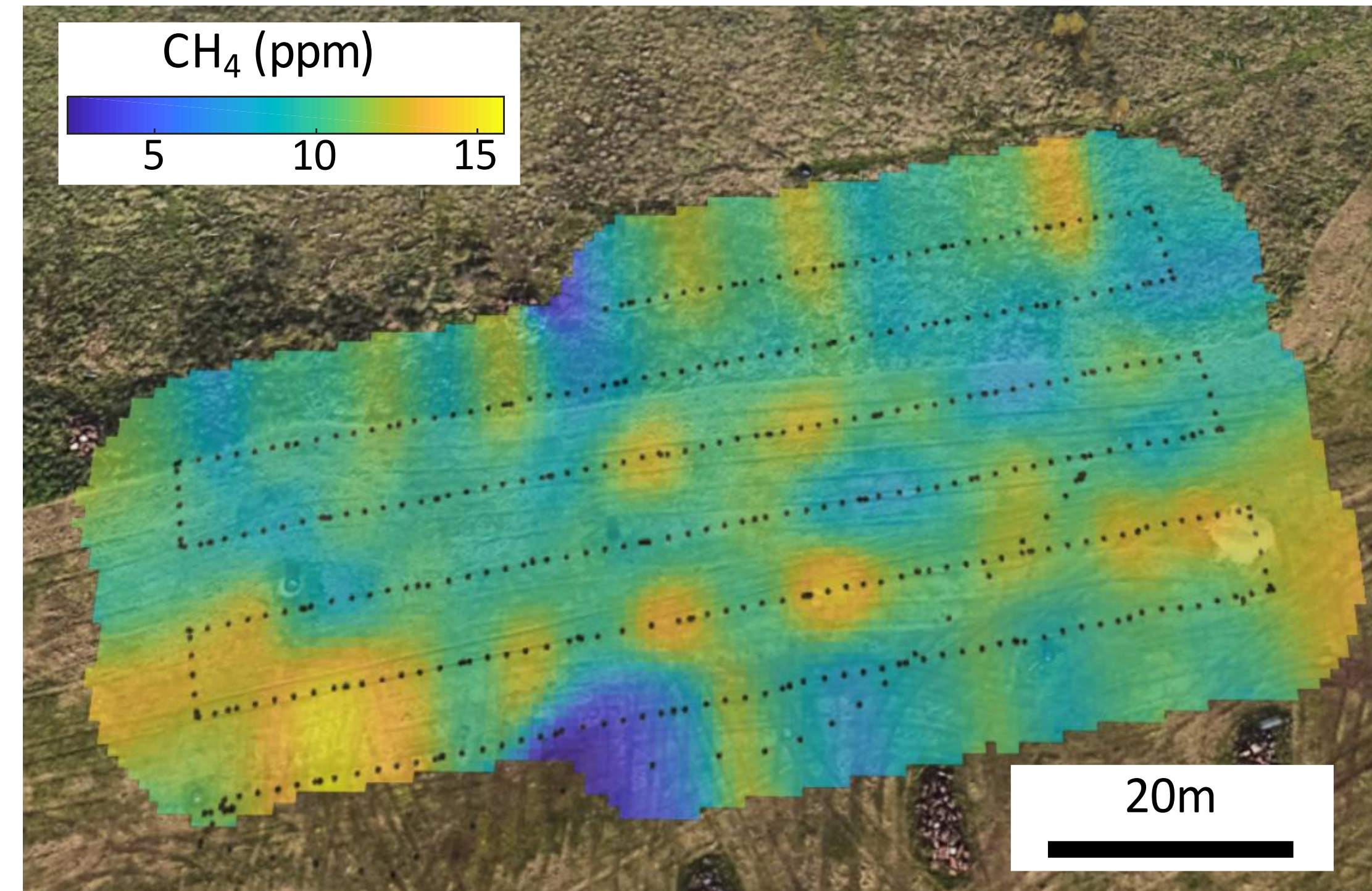
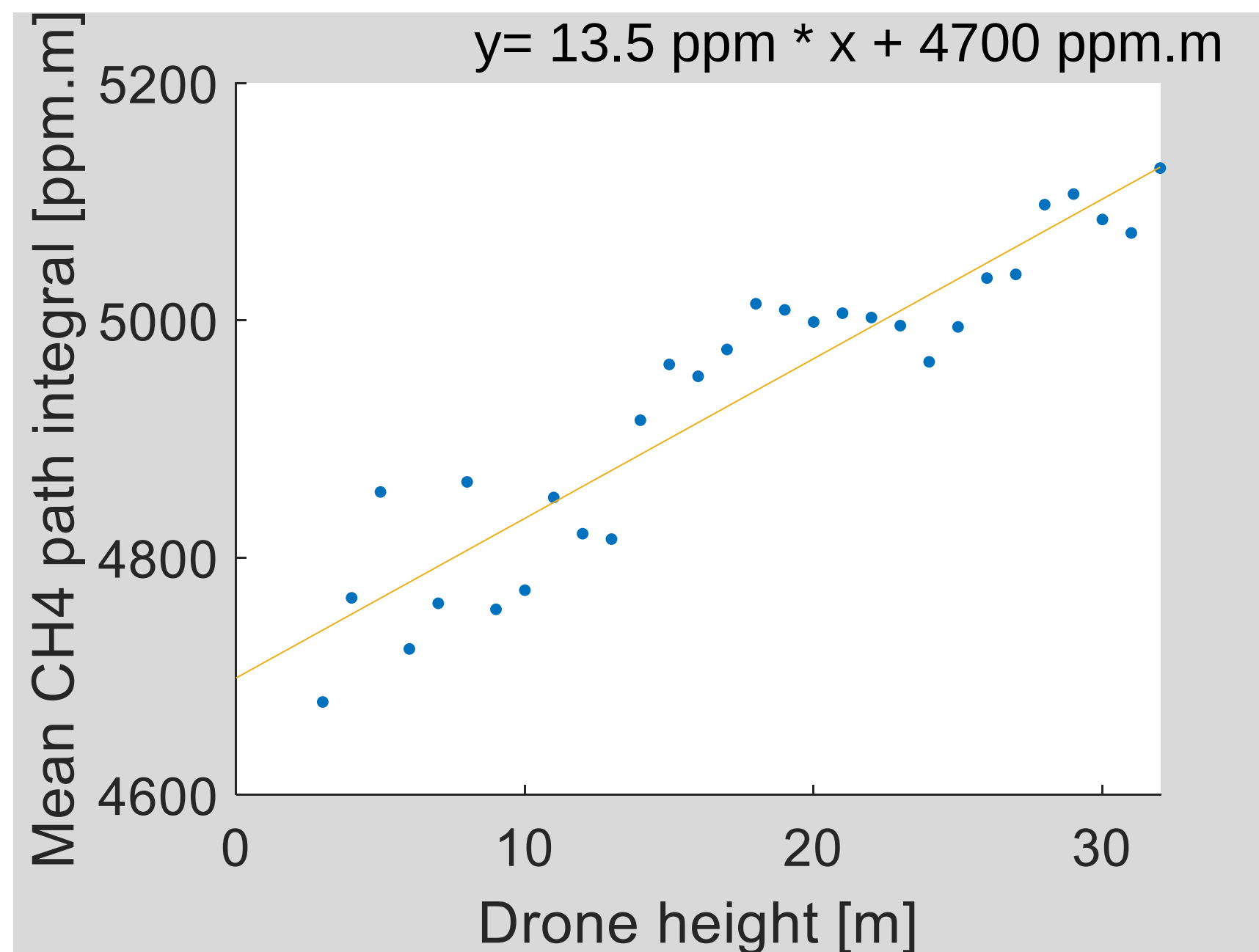
Drone Methane Mapping Trial

- Sensor Prototype mounted on industrial grade DJI M-600 drone.
- Flown over closed landfill site with high background methane



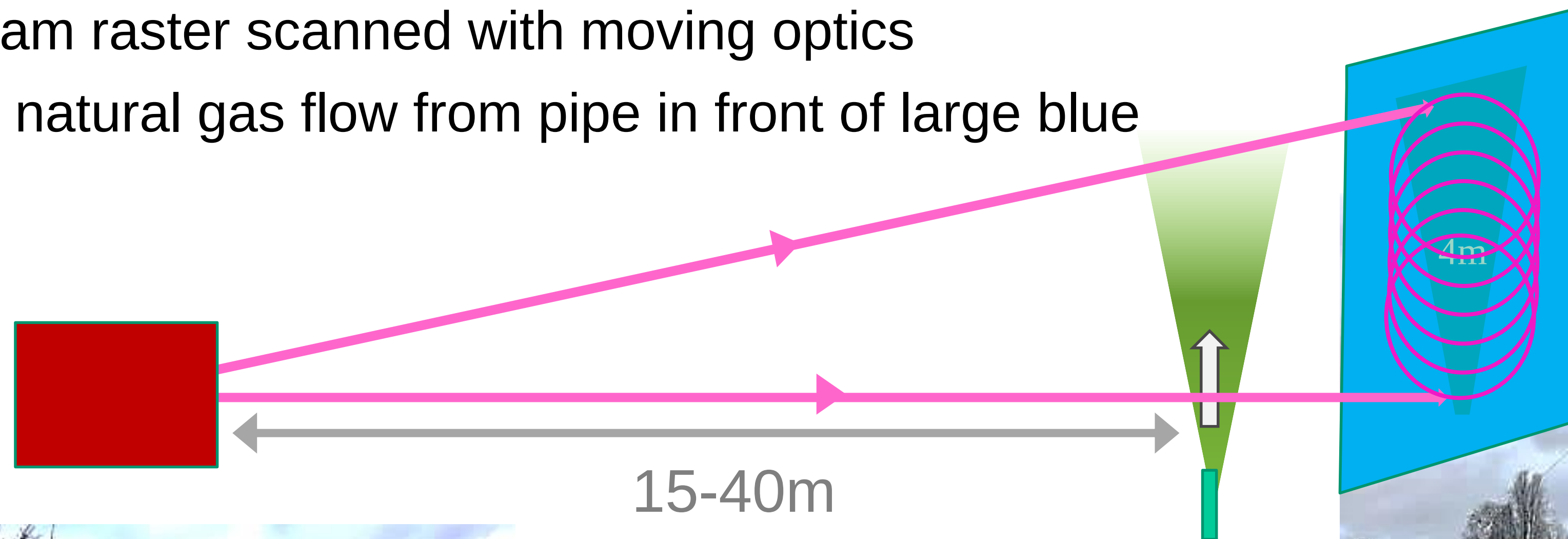
Drone Methane Mapping Results

- Remote high-speed surveying of methane levels
- Flying for ~5 min with speed ~1 m/s we covered a preprogrammed 60m x 30m grid



- Drone height versus concentration path length indicated 13.5 ppm CH₄ in good agreement with previously measured concentration ~15 ppm

- **Quantitative Gas Leak Imaging Trial**
- Sensor beam raster scanned with moving optics
- Calibrated natural gas flow from pipe in front of large blue tarpaulin

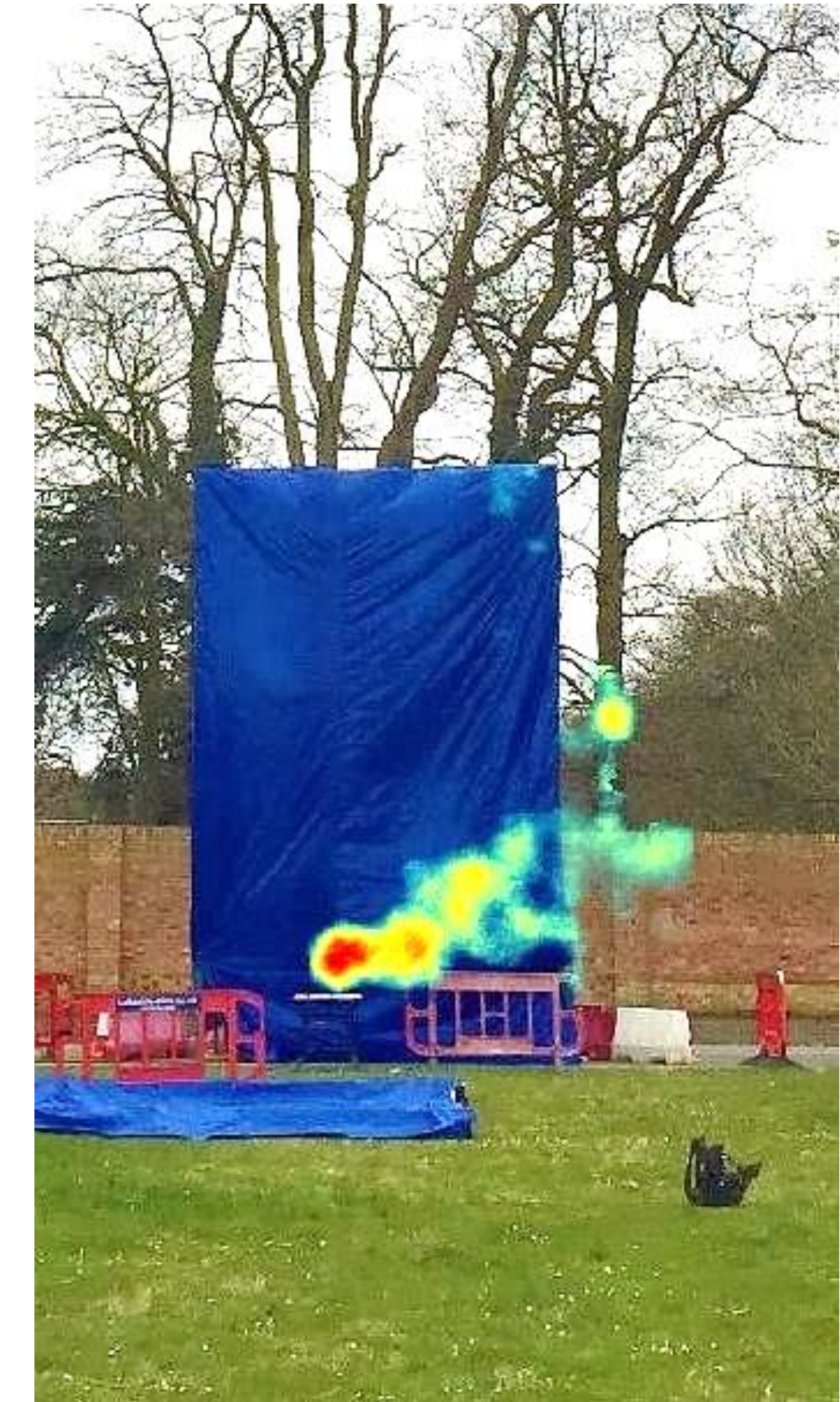
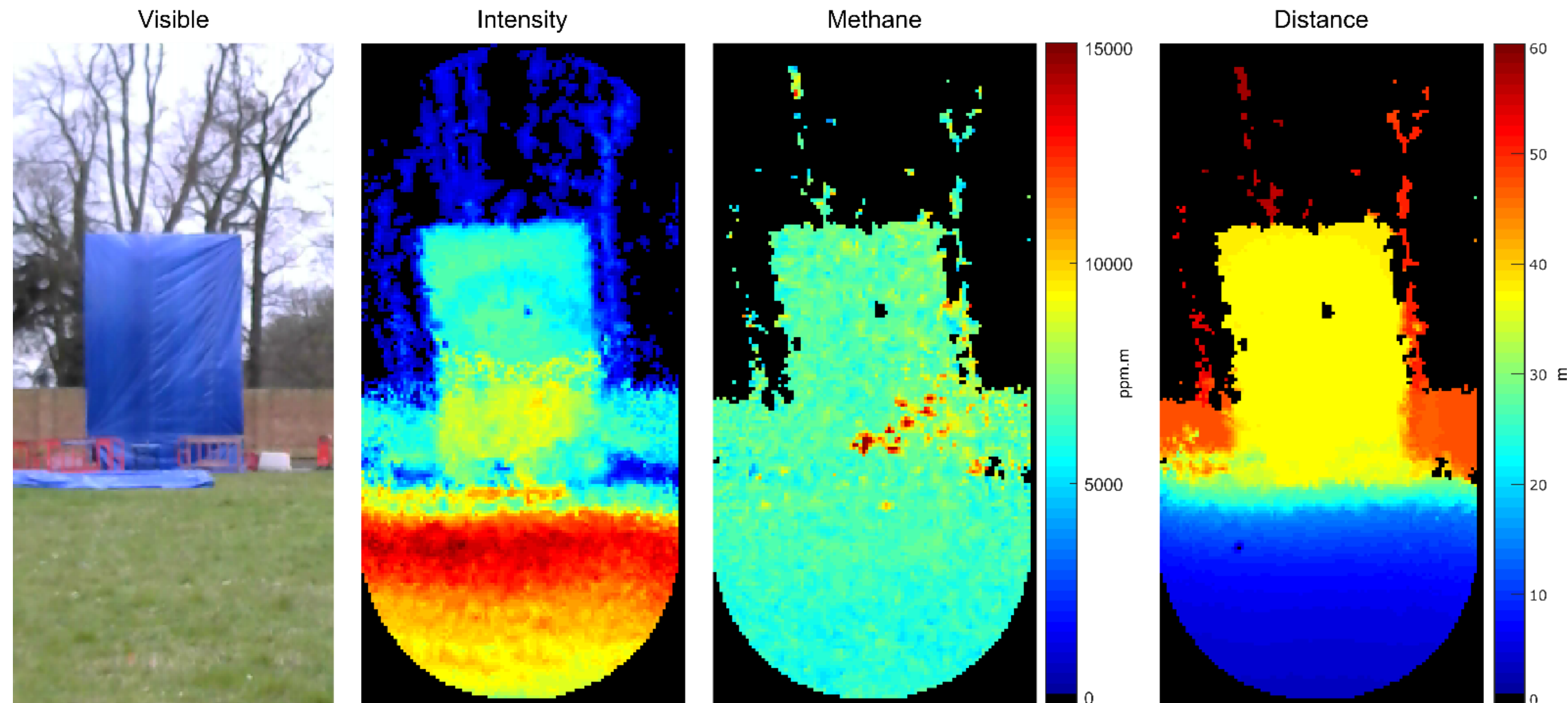


NPL
National Physical Laboratory



Quantitative Gas Leak Imaging Results

40 m, 75 l/min, blue tarp

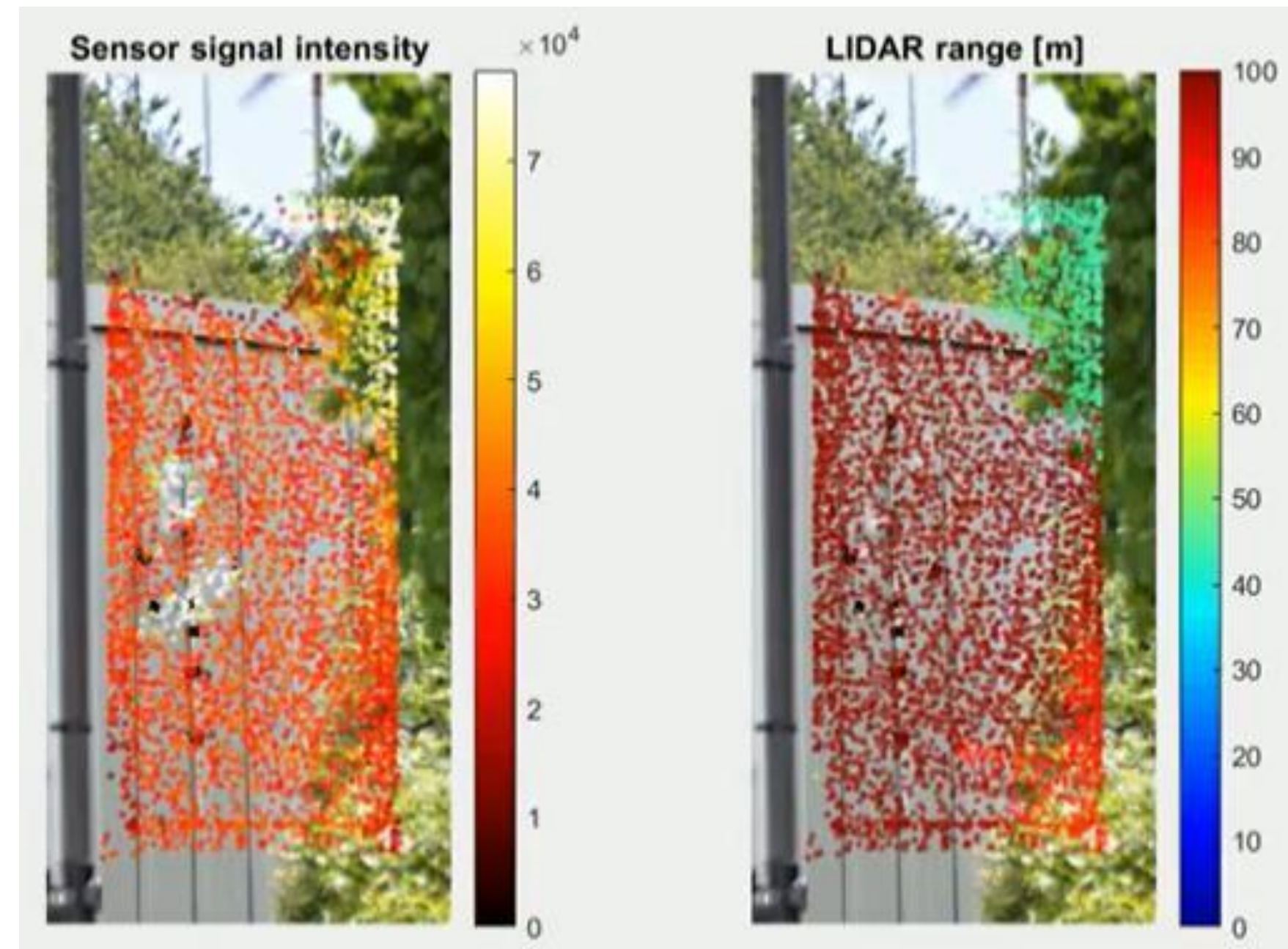


- **High resolution imaging of a leak's location and size**
- Imaged plumes of 10 litres/min and higher imaged at 40m
- Imaging in complex environments with multiple reflecting surfaces as Lidar unambiguously processes each data point

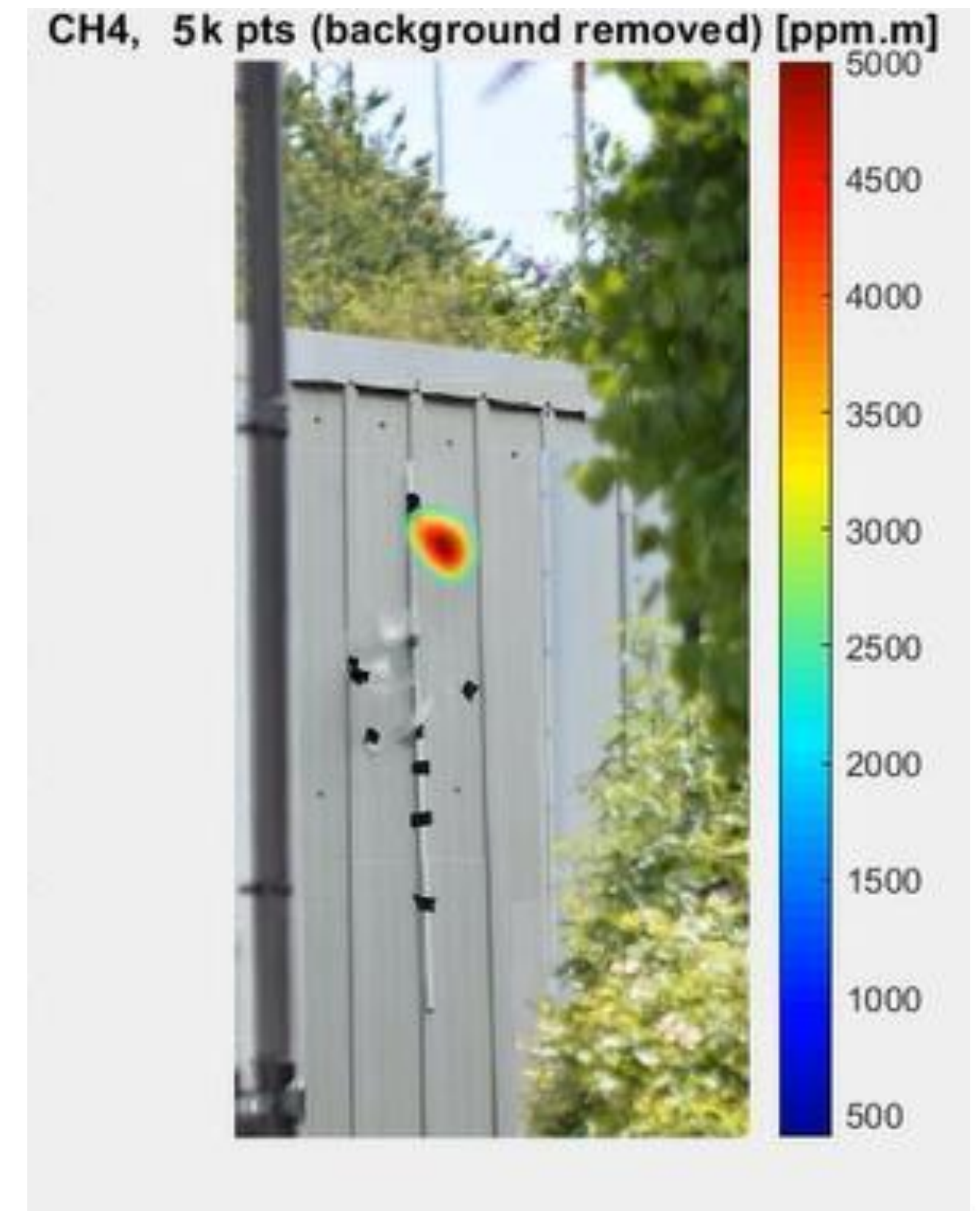
Quantitative Gas Leak Imaging Results

Methane overlay on camera image

96m , 23cm
balloon with
2.3% CH₄,
grey painted
wall



- **High resolution imaging of methane location and density**
- Imaged balloons with and without methane at 100m
- Total measurement: 5,000 points, ~ 1min at 100 Hz



Conclusion

- Quantum Sensing advantages
- New measurement methodologies
- Greatly improved sensitivity over conventional sensors
 - Seeing the invisible
 - Extended performance (distance range, sensitivity)
- Miniaturization and potential cost reduction
- Provably secure communications

- Industrial applications to high performance OTDR for asset integrity (Ariane6 space launcher program)
- LiDAR for autonomous driving
- 3D Gas imaging using LiDAR based gas sensing technique

About

ID Quantique

- ✓ World leader in Quantum sensing and secure communications, formed in 2002
- ✓ Leading provider of single-photon detectors and precision timing electronics
- ✓ First Quantum company to set up a solutions development group to take Quantum technology out of the lab and into the real world