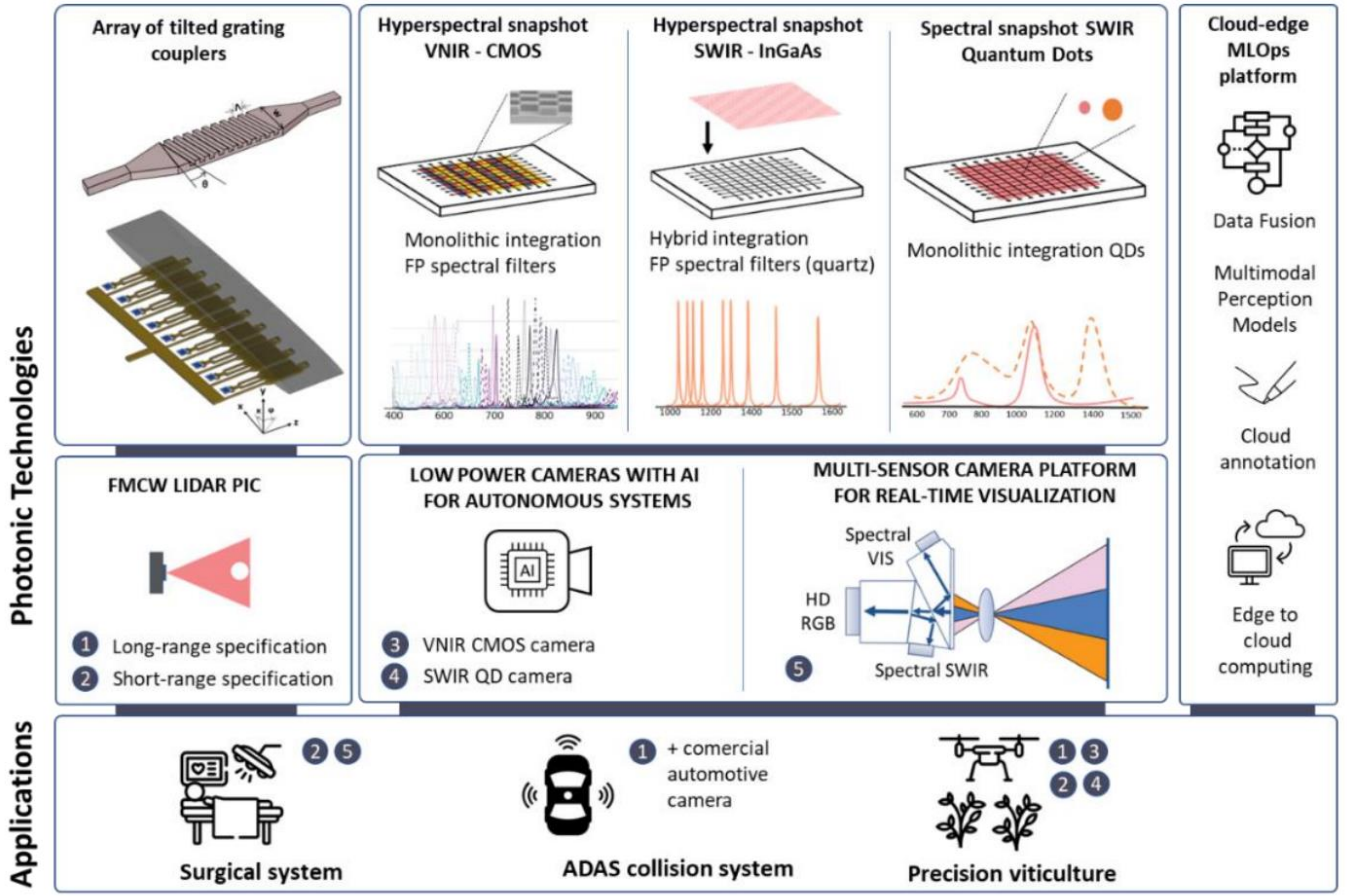
RETINA: Multimodal Photonics Sensor Systems

Dr. Ivan Nikitski, Technology Expert, EPIC – European Photonics Industry Consortium

RETINA: On-chip LiDAR and snapshot spectral imagers combined for smart multimodal perception in precision applications



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Quest medical imaging

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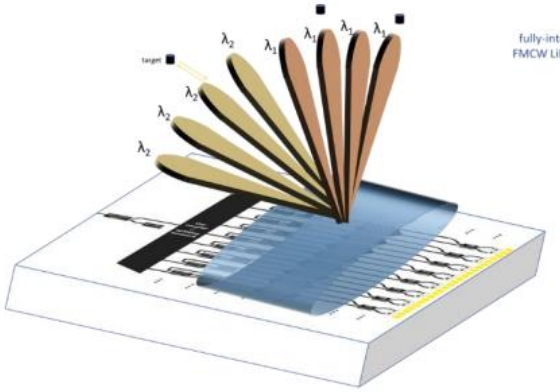
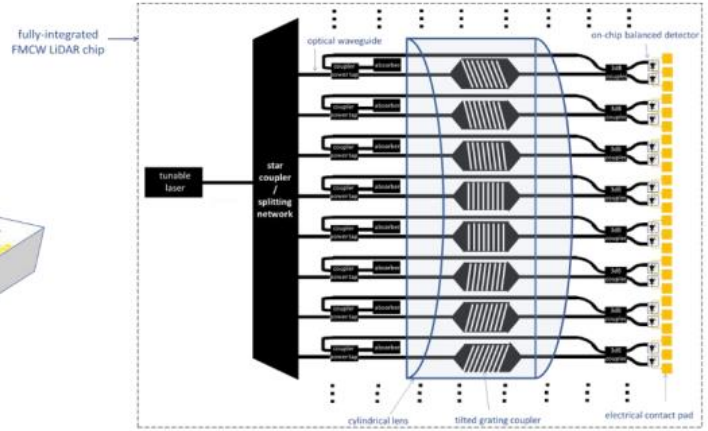
PIC-based LiDAR

- Tilted grating coupler array for beam steering
- Modulation: Frequency Modulated Continuous Wave (FMCW)
- Fabricated on an InP substrate
- Different packaging approaches will be studied
- Two specifications: long and short-range
- Several design-fabrication interactions





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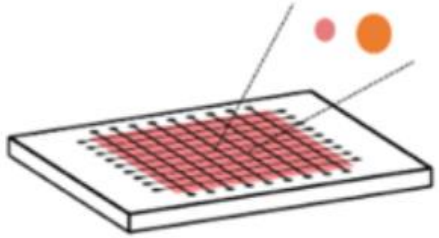
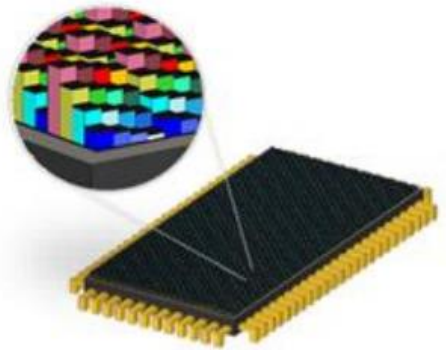
- # Snapshot spectral sensors
  - Several approaches:
    - Q-Dot based SWIR sensor
    - Pixel level band-pass optical filters integrated in new generation imagers:
      - CMOS for VNIR
      - InGaAs for SWIR
  - These sensors will be integrated in two different modules:
    - Multi-sensor camera platform
    - Ultra low-power for spectral imaging





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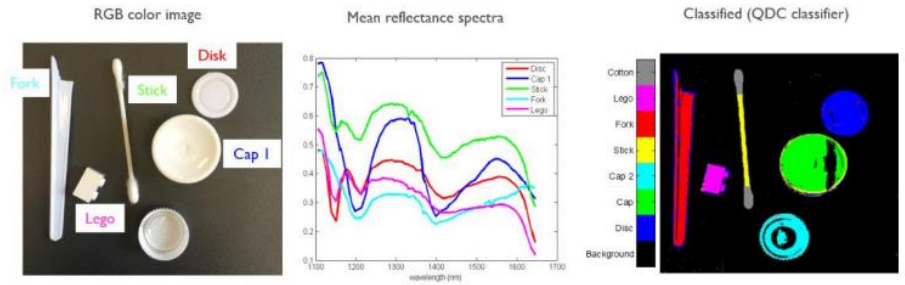
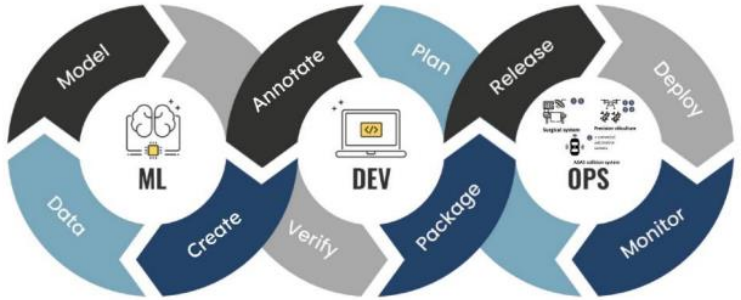
Machine-learning algorithms

- Cloud-based MLOps platform for data ingestion, data annotation and model prototyping, training and validation
- Specific data elaboration techniques, data fusion and ML models
- Edge deployment of the ML models





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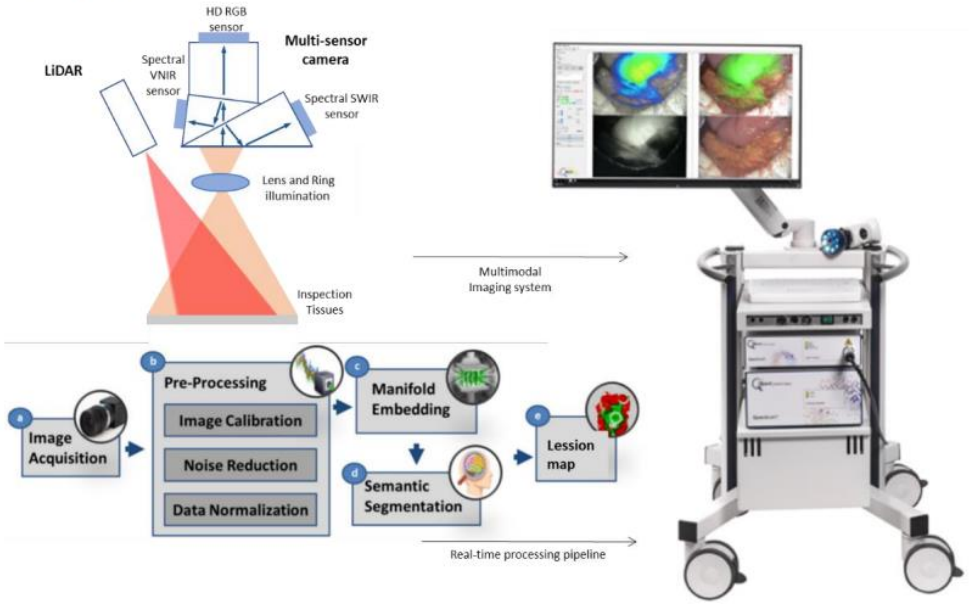
Use Case #1: Multimodal surgery support system for tissues lesions visualization

- Detect and measure tissue lesions' position, size and shape even in the presence of obscurants such as blood
- Sensors:
  - Short-range LIDAR
  - SWIR & VNIR spectral Imagers
  - Commercial RGB camera



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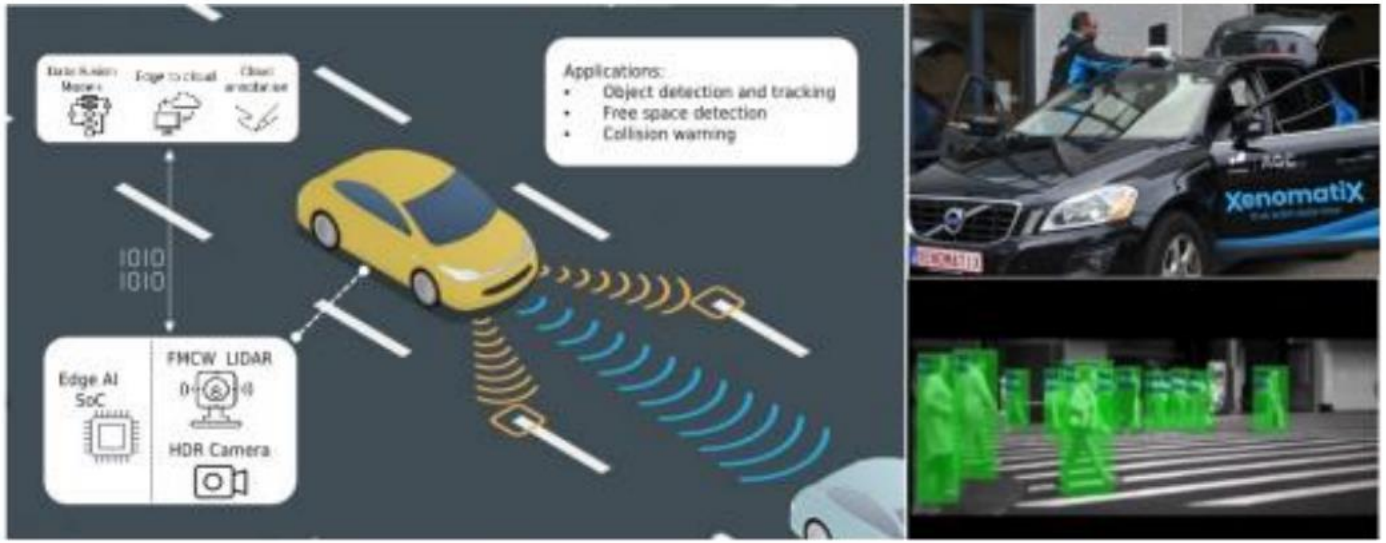
Use Case #2: Multimodal sensing for obstacles and collision detection under complex weathering conditions

- Collision avoidance will require to detect and measure people and objects' position, size and shape, as well as distance and motion ahead of and around a vehicle in any weather and light conditions.
- Sensors:
  - Long-range LIDAR
  - Commercial camera



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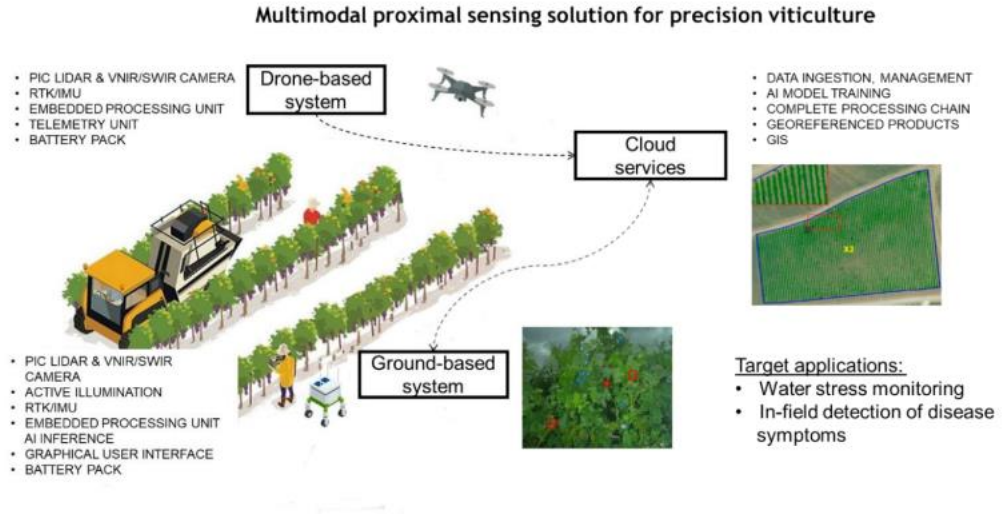
Use Case #3: Multimodal proximal sensing solution for estimating critical parameters in viticulture

- RETINA will provide a tailored multi-modal monitoring solution to support the implementation of precision viticulture programs. Thev demonstration in the project will be focused on supporting the following three:
  - Water stress monitoring: a novel methodology for assessing vineyard water status;
  - Early detection of disease: in field detection grapevine trunk diseases (GTD);
  - Productivity forecast: real time estimation of harvest quantity.
- Sensors:
  - Ground-based system:
    - Short-range LIDAR
    - SWIR & VNIR spectral Imagers
  - Drone-based system:
    - Long-range LIDAR
    - SWIR & VNIR spectral Imagers



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Summary

OBJ 1. To develop a novel concept of highly scalable PIC-based LIDAR

OBJ 2. To develop snapshot spectral imagers for high resolution and cost-efficient sensory systems

OBJ 3. To set up innovative software techniques and digital services for the deployment of reliable and accurate application-driven sensing platform

OBJ 4.- To support the technology leadership of EU photonic-based ecosystem by boosting growth in strategic industries

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OBJ 1. To develop a novel concept of highly scalable PIC-based LIDAR

a) Solid state passive optical beamforming -based on a Tilted Grating Coupler Array approach

b) Frequency Modulated Continuous Wave LIDAR chips

c) Customised optics and components packaging

KPIs: *PIC-based LIDAR with angle resolution (0.1º), field of view (at least 100ºx30º), rate(20Hz), range (250m for targets with 10% reflectivity), distance precision measurement (< 0.5 cm), size (300cm 3), weight (40g), power consumption (<10W) and industrialised production cost (<150€).*

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OBJ 2. To develop snapshot spectral imagers for high resolution and cost-efficient sensory systems

a) Quantum Dot detectors (QDs)

b) Monolithic and hybrid integrated optical microfilters

c) Ultra low-power camera modules for spectral imaging

d) Multi-sensor VNIR/SWIR imaging module for real time visualisation

KPIs: *Snapshot VIS-NIR camera with higher spatial resolution(>5Mpx), up to factor 3 increase in the SNR, and increased wavelength range with 31 bands in 450-850 nm. Snapshot imaging medical system covering visual to infrared range (400-1700 nm) with 9 relevant bands in 1.1-1.7µm range for medical application. Drone and autonomous systems ready low power (<3W) with AI inference capabilities and cost-effective QD camera of at least 1.5 Mpx, maximum pixel size of 2.5 µm and spectrum adapted for viticulture in SWIR range (1-1.7um).*

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OBJ 3. To set up innovative software techniques and digital services for the deployment of reliable and accurate application-driven sensing platform

a) Application-driven multimodal sensing strategies
   a) Tissues identification for surgical applications
   b) ADAS vehicle collision detection system
   c) Precision viticulture solutions for hydric status management and prediction of pathogens infections

b) Cloud-edge MLOps platform for end-to-end machine learning pipelines based on RETINA sensor systems

KPIs: *Tissues lesions identification (95% of damaged tissues properly identified, <1s latency time). ADAS vehicle collision detection (<0.15 sec latency time, 200m of monitoring distance, <1000€ L3 ADAS). Precision viticulture solutions (90% of damaged vineyards properly identified, 1m accuracy for geographical localisation). Data processing cloud platform (<5s latency for near real-time ingest of multimodal image data from edge to cloud, and 1 day iteration cycles of continuous model re-training and deployment).*

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Photonic integrated LIDAR and snapshot spectral imagers for scaling up multimodal perception in precision applications

- Two new technologies proposed:
  - Novel LIDAR based on PICs
  - QDs and optical microfilters for spectral imagers
- Coupled with a digital infrastructure for ML algorithms development for multimodal sensing applications.
- Validation of customised sensory systems for these sectors:
  - Healthcare -> tissue lesions visualisation supporting surgery
  - Automotive -> Autonomous vehicle safety system
  - Agriculture -> precision viticulture ground and drone-mounted platforms
- TRL 3 -> 6-7

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