PHOTONICS21

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PARALIA

Photonic Multi-beam Beamforming Technology enabling **Radar/LiDAR** Multi-sensor Fusion platforms for **Aerospace** and **Automated Driving** applications

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THE CHALLENGE

The impressive milestones achieved in the on-going global race for highly automated or autonomous vehicles set the stage for major transformations across the transportation industry, primary led by:

(i) The expected wide adoption of Level 2 and Level 3 automated driving systems in next-generation automotive vehicles.

(ii) The forward-looking roadmaps of major technology vendors, predicting next generation consumer-centric fleets of robo-taxis.

(iii) The growing maturity and expected proliferation of autonomous or Enchanted Flight Vision System (EFVS)-augmented Urban Air Mobility (UAM) scenarios that have proven their credentials as a safe, secure and efficient aviation transportation systems for passengers and cargo at low altitudes within urban and suburban areas.

Transforming however, these technological concepts into reality has been more challenging than originally anticipated. Recent studies urgently call for a new-generation of integrated, cost-effective and multi-domain sensory systems, capable of providing to Machine Learning (ML)-based algorithms the required heterogenous environmental information in a low-energy envelope. In this context, Silicon Photonics based LiDAR and microwave-photonic RADAR implementations have been identified as key enabling technologies for next generation sensing systems, due to their cost, size and energy advantages, as well as their increased frequency operational bandwidth, which translates into high range resolution and light's inherent diffractive capabilities. Delving deeper, however, into the recent photonic-assisted LiDAR and RADAR prototypes reveals some fundamental shortcomings in their pathways towards next-generation high-performance yet cost- and power-efficient sensor solutions:

- The need for multi-beam beamforming capabilities in LiDAR and RADAR implementations is still lacking a solid development roadmap.
- Distinct Sensor deployments are still dominating the photonic sensor-based landscape, despite the well-known synergies and complementarity of LiDAR and RADAR sensory data that can offer fail-safe and weather condition agnostic operation.
- Data acquisition through photonic-assisted LiDARs and RADARs is still lacking a tight synergy with the data processing and interpretation domain.

MISSION STATEMENT

PARALIA will enable an agile, low-cost, and energy-efficient multi-sensor platform combining RADAR and LiDAR technologies and will re-architect the sensors ecosystem, upgrading their capabilities in terms of ultra-high resolution at ultra-long distances crucial for current and futuristic automotive and aerospace applications. Within **PARALIA** project, a common LiDAR/RADAR optical multibeam beamforming platform will be developed based on the best-in-class multi-port linear optical architecture. For its implementation, **PARALIA** will utilize hybrid InP-SiN integration while leveraging a tight integration of InP components in multielement arrays and the advances in SiN PZT optical phase shifters (Fig.1) with μs-reconfiguration time, and low power consumption < 1μW.

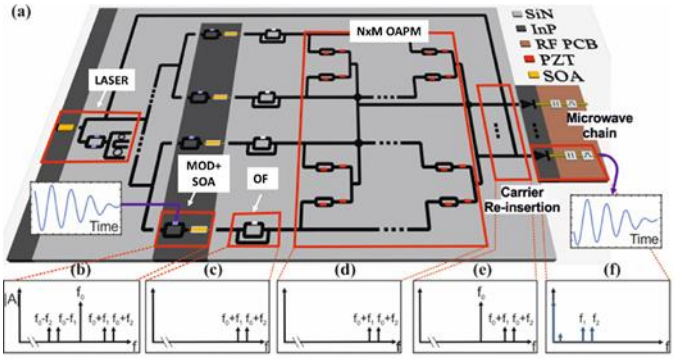

Fig. 1 (α)The NxM InP-TriPleX MBFN PIC with insets at every circuit block (b)-(f) indicating the respective signal spectrum

To demonstrate the universality of the developed optical multi-beam platform **PARALIA** will demonstrate:

- Two multibeam LiDAR modules featuring 120 degrees horizontal field of view (FOV) and 30 degrees vertical FOV that support 8 and 64 independent beams with 64 independent beams generated by utilizing 8λ-WDM signals (Fig. 2).

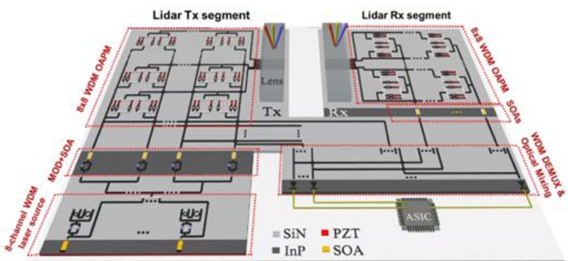

Fig. 2 PARALIA's 8-beam 2D scanning LiDAR, depicting both its Tx and Rx segments along with their constituent functional circuit blocks

- Two multibeam RADAR modules operating at K- and E-band for aerospace and automotive industries, respectively. Both RADAR modules feature 120 degrees Vertical and Horizontal FOVs and support 8 independent beams (Fig. 3).

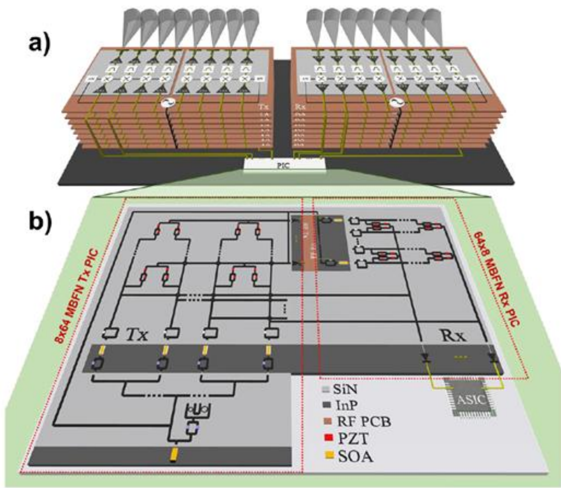

Fig. 3 PARALIA's RF chain together with its 8x8 multi-element antenna PCB

- A multi-sensor module combining the RADAR and LiDAR modules with a processing unit that employs a fusion ML algorithm developed to acquire and process the information coming from the multiple beams of the multisensory system enhancing its range and resolution (Fig. 4).

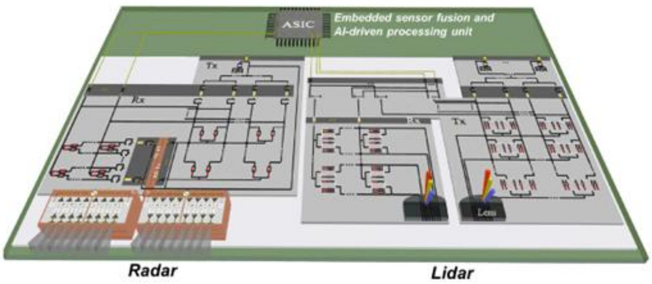

Fig. 4 PARALIA's multisensory RADAR/LiDAR fusion hardware complex employing embedded heterogeneous data fusion and AI-driven processing

TARGET TECHNOLOGY BREAKTHROUGHS

A novel optical multi-beam beamformer technology through the synergy of the best-in-class linear optical circuit architecture with the low-loss TriPleX waveguide platform and low-power PZT phase shifters.

PARALIA will transfer the principles of the best-in-class multi-port linear optical circuit design in the design and development of low-loss and low-power integrated photonic multibeam beamformer.

Develop a 64-channel (8-chx8x8) LiDAR PIC prototype for both horizontal/vertical scanning.

PARALIA will utilize its WDM Xbar-based beamformer towards deploying and demonstrating a pioneering low-loss Frequency Modulated Continuous Wave (FMCW) LiDAR photonic integrated chip prototype that will support 64 simultaneous beams, being capable of simultaneously scanning with 8 different beams in the horizontal direction and with 8 different wavelengths in the vertical direction.

Develop 8beam x 64 antennas microwave (K-band) and mm-Wave (E-band) RADAR prototypes.

PARALIA will combine its multibeam beamformer technology with the optical carrier re-insertion technique towards releasing a pioneering and power-efficient multibeam RADAR technology via the demonstration of two different RADAR prototypes:

i) A microwave 8x64 RADAR that targets operation in the K-band for aerospace safety and security applications and comprises a single-wavelength InP-TriPleX photonic beamformer chip assembled together with an optically interfaced 8x8 K-band multi-element Tx/Rx antenna pair.

ii) A 8x64 mm-Wave E-band RADAR that targets automated driving applications and comprises a single-wavelength InP-TriPleX photonic beamformer chip assembled together with an optically interfaced 8x8 multielement Tx/Rx antenna pair in E-band.

Deploy a co-integrated LiDAR and RADAR multi-sensor fusion platform based on application-driven machine intelligence algorithms.

PARALIA aims to design and develop a multi-sensor fusion platform incorporating a series of hardware-based mechanisms for heterogeneous data acquisition, preprocessing and ML, introducing in this way the key enabling technology for jointly exploiting RADAR and LiDAR signals by i) utilizing low-latency, high-availability data processing techniques, ii) targeting specialized filtering mechanisms that will overcome multi-sensor integration nonlinearities, adapting to different data sampling times, and iii) realizing a series of ML-flavored approaches based on real-time classification and regression algorithms.

Experimentally validate of the multisensory fusion complex in aerospace and automated driving applications (Fig.5), (Fig.6)**.**

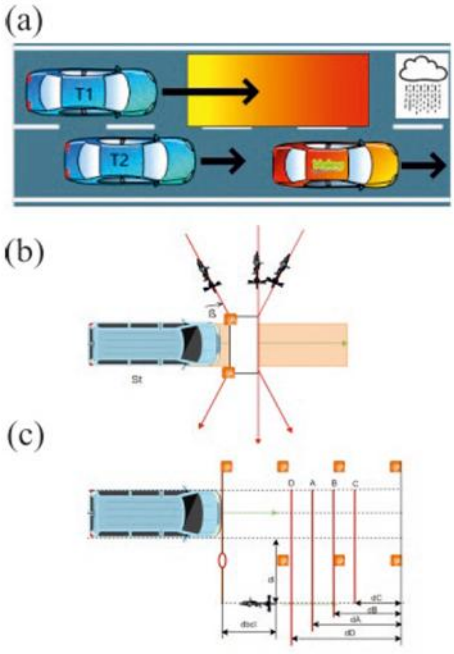

Fig. 5 Automated Driving Application Scenarios including (a) LCDAS, (b) MOIS, (c) BSIS

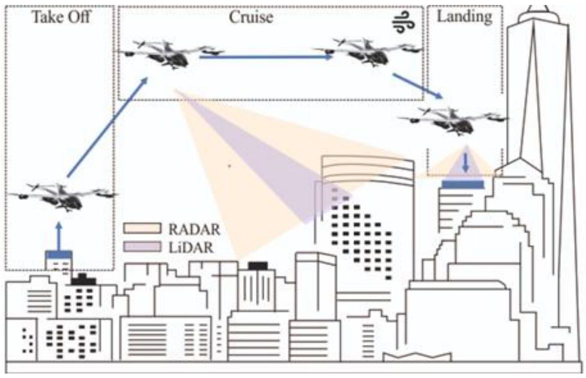

Fig. 6 UAV application scenarios including i) Vertical Take Off, ii) Cruise iii) Landing