OPTICAL PHASED ARRAYS FOR AUTOMOTIVE SOLID-STATE LIDAR SYSTEMS

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Principal Member of Technical Staff
INTRODUCTION TO IMEC
ESTABLISHED IN 1984
35 YEARS EXPERIENCE IN TOP RESEARCH
IMEC (founded in 1984)

- World-leading R&D center in nanoelectronics & digital technologies

- **International top talent** in a unique >2B€ leading-edge fab infrastructure

- Delivering **industry relevant technology** solutions in ICT, Healthcare and Energy markets, serving 600+ companies

- >500 M€ R&D budget, 85% direct from industry

- >4000 people (from 90+ countries)

- HQ in Leuven (BE) + sites worldwide

- **24/7** operation (200 mm and 300 mm) cleanrooms (12,000 m²)
WORLD CLASS INFRASTRUCTURE

- Nerf lab
- 200 mm pilot line
- Organic solar cell line
- 300 mm pilot line
- Nano bio labs
- Silicon solar cell line
200 MM & 300 MM CLEANROOMS (24/7 OPERATION)
SOME AREAS OF EXPERTISE

Si and SiN Photonics
Life Sciences & Biophotonics
Radar Systems
CMOS and beyond CMOS
GaN
Lab-on-a-Chip
SI PHOTONICS PLATFORM @ IMEC
State-of-the-art mature and versatile platform

Philippe Absil et al., Optics Express 23(7), pp. 9369–78, 2015
A large library of experimentally verified components is available:

- Waveguides
- Ring Resonators
- Fiber-to-WG
- Low reflection
- Focusing
- Basic spectrometers
- Multi-mode interferometer
- Evanescent coupler
- Pseudo-random
AUTOMOTIVE LIDAR
TOWARDS SOLID-STATE LIDAR SYSTEMS

Low-cost integrated LiDAR chips

Source: http://velodynelidar.com

Building Blocks of the Autonomous Vehicle
Automotive LiDAR players
(Source: LiDARs for Automotive & Industrial Applications report, Yole Développement, Mai 2018)

Most automotive LiDAR players are considering pulse LiDAR.
## Automotive LiDAR players

<table>
<thead>
<tr>
<th>Type</th>
<th>Multi-channels</th>
<th>Other mechanical scanning</th>
<th>MEMS LiDAR</th>
<th>Optical phased array LiDAR</th>
<th>Flash LiDAR</th>
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<tbody>
<tr>
<td>Pulse LiDAR</td>
<td>Velodyne</td>
<td>Luminar 1550 nm</td>
<td>Valeo</td>
<td>Continental 1064 nm</td>
<td>superlum</td>
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<td>Phase shift</td>
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<td>CW LiDAR</td>
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<td>FMCW</td>
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A wide range of technologies are under consideration by LiDAR companies.
ILLUMINATION & DETECTION TECHNIQUES

Illumination techniques:

- No beam steering:
  - Flash LiDAR (uses ToF imaging arrays)
- Beam steering:
  - Bulky mechanical devices (large, heavy and costly)
  - MEMS mirrors (vibrations may be limitation)
  - Optical Phased Arrays (no-mechanical parts; can be integrated on a chip; 1D or 2D)

Main detection schemes:

- Direct Time of Flight (ToF) – High Laser power; eye safety issue (at 905nm); crosstalk/background light; noise limit
- Coherent Detection (FMCW: Frequency-Modulated CW) – Shot noise limited; better dynamic range; range+velocity measurements (Doppler); complex system
FMCW (COHERENT DETECTION)

MIT (2015)
AUTOMOTIVE LIDAR GENERAL TARGET SPECS

- Sensing depth: 3D mapping
- Range: >200 m
- Cost for high volume production: <<$1,000
- Field of view: >100° (H) × 10-30° (V)
- Angular resolution: <0.05°
- Power consumption: <50 W
- Weight: <0.5 kg
- Size: < 10 cm × 10 cm × 10 cm
- Samples per second: >>400k (frame rate: 10-30 Hz)
- Wavelength: 1550 nm (eye safe, less ambient noise)
- LiDAR engine: FMCW of TOF
- Beam delivery: Optical Phased Array (OPA)

Source: Hesai
OPTICAL PHASED ARRAYS
PHASED ARRAY

- A uniform phase difference $\Delta \phi$ between neighboring antennas results in beam steering
- Far-field radiation pattern is the product of the antenna radiation pattern and the array factor, assuming identical antennas

$$\alpha = \sin^{-1} \left( \frac{\Delta \phi \lambda}{2\pi d} \right)$$
\[ \alpha = \sin^{-1}\left(\frac{\Delta \phi \lambda}{2\pi d}\right) \]
1D & 2D STEERING DEMONSTRATION

OPA with binary tree architecture:
- SiN with low phase error for power routing
- Si antennas with high confinement for tight pitch
- 64 antennas at 3 μm pitch, at 1550 nm
- Wavelength tuning in the x direction
- Beam divergence: $0.47^\circ \times 0.4^\circ$
  
(S. Dwivedi et al., *IPR 2019*, IM4A.3)

OPA with binary tree architecture:
- Si for power routing and antennas
- 8 antennas
- Thermo-optic phase shifters for tuning in the y direction
- Tuning in the x direction with source wavelength
R&D OPPORTUNITIES

- Main challenges:
  - Insertion loss
  - Power consumption (for phase shifting)
  - Number of antennas (for large aperture size)
  - Electronics control for phase shifters (phase interrogators, ASIC)
  - Tight specs on tunable laser (linewidth, power, wavelength precision)
  - CMOS integration desired for complex electronics

- Main research activities @ imec:
  - Si and SiN hybrid platforms
  - Laser development and integration on Si/SiN
  - Chip packaging solutions
  - New materials for low-power phase shifters
IMEC R&D ECOSYSTEM

What you can do for us:
- Help us to better understand the LiDAR market dynamics
- Expose us to your key technology needs, problems and challenges
- Partner for system-level OPA LiDAR demonstrators
- Collaboration in R&D projects

What we can do for you:
emerging a better life
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