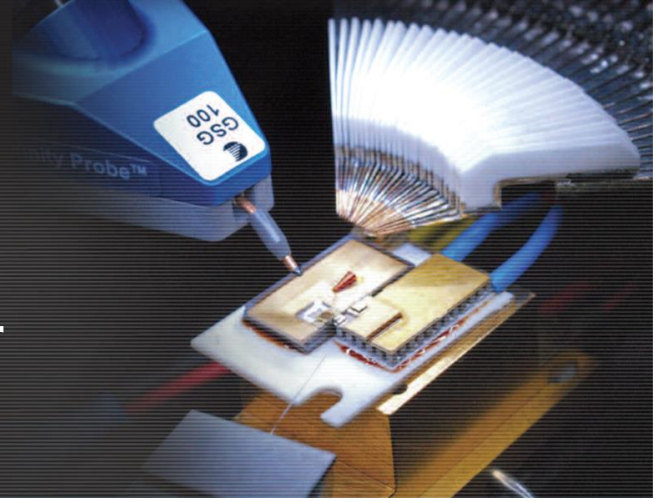
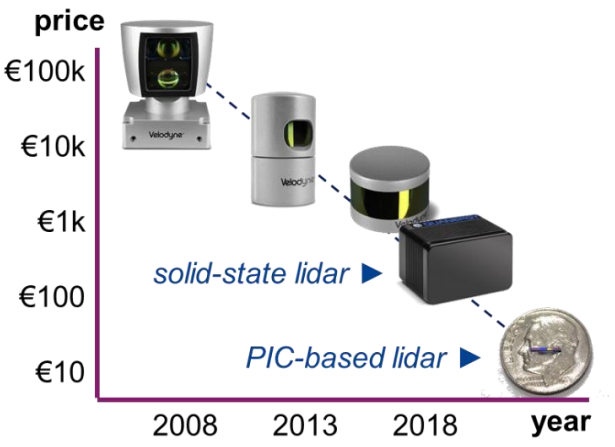


Photonic Integrated Circuits for LIDAR

Lidar, short for light detection and ranging or "light radar", is used to measure distances with high resolution and precision. This is achieved by illuminating the object with a scanning laser beam, and consequently measuring the reflections. Complete three-dimensional mappings can be made. Various techniques are used, such as pulsed, flash and frequency-modulated Lidar.

The opportunities for using Lidar are plenty, most notably in automotive, where it is used in advanced driver-assistance systems (ADAS) and in autonomous driving, providing a better resolution than radar. It is furthermore used in wind farms, to monitor wind speeds, and in remote sensing, mapping the environment and atmosphere.

A Lidar consists of a laser source, a laser beam scanner, and the detection optics. Traditionally, such systems were bulky and costly (see figure below). Over the last decade, pushed by the automotive market, the price of Lidar systems has come down by more than an order of magnitude. Solid-state Lidars are promising in bringing the cost down by another order of magnitude. Moreover, these Lidars are more robust, with no moving parts, and compact.

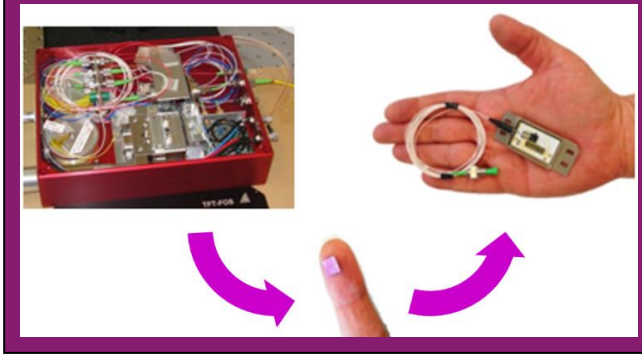


Evolution of the Lidar cost, including forecast. Source data: Velodyne, Quanergy and Massachusetts Institute of Technology.

Photonic Integrated Circuits (PICs)

Also known as optical chips, PICs can contain tens to hundreds of optical components. While electronic ICs consist of transistors, capacitors and resistors, a PIC consists of, for example, lasers, modulators, photodetectors and filters, all integrated on a single substrate. These PICs are nowadays extensively used commercially, mainly in datacom and telecom.

PIC technology has now become accessible to users without a cleanroom, through so-called multi-project wafer runs and open foundries. Indium phosphide based technology is commercially available through SMART Photonics and Heinrich Hertz Institute. Access is coordinated by the JePPIX platform: http://www.jeppix.eu/.



The opportunity for photonic integration

PICs offer some very concrete opportunities for Lidar. In solid-state Lidars, PICs can be used as the laser source. When combined with the on-chip components typically used in communications technology, pulsed lasers and frequency-modulated lasers can be realized. As an example, Blackmore[1] is bringing a frequency-modulated continuous-wave (FMCW) Lidar to the market, based on PICs. Such a Lidar provides both range and velocity measurements, through the Doppler effect. Coherent detection allows for highly-sensitive measurements, with high dynamic range. An added advantage is that PICs are designed for operation

[1] https://blackmoreinc.com/

around wavelengths of 1550 nm, which is a sweet spot for Lidar due to eye-safety requirements. This allows the range to be extended significantly, to over 200 m, as argued by, e.g., Luminar[2].

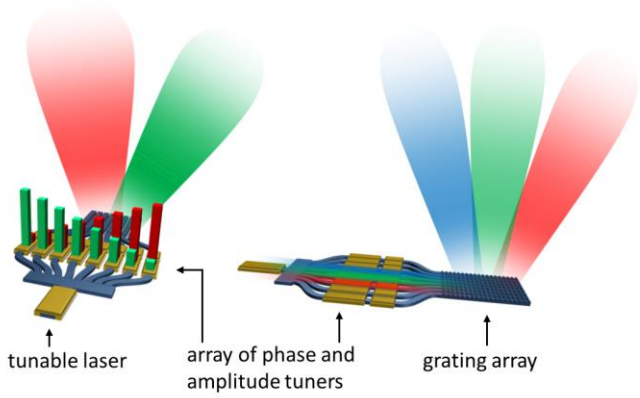
PICs can also be used to replace the beam-steering part of the Lidar, through the use of optical phased arrays, as shown in the figure to the right. Much like phased-array antennas in wireless communications, such optical phased arrays can shape the laser beam and steer it fast for video-rate three-dimensional imaging[3]. The system has no moving components, as compared to using mechanical and micro-mechanical (MEMS) scanning devices, making it robust, and is lens-free. Laboratory-based implementations have already shown the feasibility, and the technology is now moving to the market, e.g., by Analog Photonics[4]. Initial feasibility studies have shown these optical phased arrays can reach output powers up to 10 W [3]. Sources and detectors can be integrated on the PIC, with the potential of realizing a fully integrated, single-chip Lidar, and allowing unprecedented high volumes at low cost. Moreover, this technology allows for close integration with electronics.

Current technical developments

The PIC and overall system need to be carefully designed for the target application. Although the PIC technology platforms are mature now, they have been developed mostly for telecom and datacom applications. Lidars require a different design of basic components.

There are application-specific operational parameters that are different from the communications field. For example, for automotive applications, a target operating temperature range of −40 °C to 125 °C is often required. The PICs need to be designed for that.

Packaging of the PIC with electronics and, potentially, with fiber or free-space coupling, is also a challenge. However, commercial packaging solutions are now available, e.g., as offered by PHIX Photonics Assembly, Technobis IPPS and Linkra, and by the PIXAPP Photonic Packaging Pilot Line[5]. Specifically for optical phased arrays, the electronics for fast beam-steering into the



Schematic of an optical phased array, using optical phase control (left) and wavelength control (right) for beam steering[3].

10s of MHz range, with many closely-integrated channels, pose a challenge. Side-lobe suppression and beam width are design trade-offs for optical phased arrays[3].

Discuss your application with us

If you are interested to know more about the use of PIC technology for Lidar applications, please contact Martijn Heck, coordinator of the PICs4All Application Support Center (ASC) at Aarhus University, Denmark. We have experience with pulsed and frequency-modulated lasers, as well as with optical phased arrays. We are set up to help you do a feasibility study for the use of PICs for Lidar applications.

The PICs4All consortium[6] is funded under the Horizon 2020 framework and brings together expertise to support end-users, like academia, research institutes and industry, with PIC technology. The ASCs can help you connect to the eco-system of designers, foundries, packaging and test services.

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[5] http://pixapp.eu/
[6] http://pics4all.jeppix.eu/