Indium Phosphide Photonic Integrated Circuits

M.K. Smit and K.A. Williams

Institute of Photonic Integration, Eindhoven University of Technology, P.O.Box 513, 5600 MB Eindhoven, The Netherlands Author e-mail address: m.k.smit@tue.nl

Abstract: Photonic integration is essential for high-performance communications and now becomes directly exploitable in sensing, metrology and imaging. InP PICs provide lasers, amplifiers, modulators and detectors in one platform, and a roadmap for higher density integration.

Photonic integration has long offered the promise of massive-bandwidth communications. It also offers the possibility to efficiently map temperature and strain across large surface areas with readout for fiber optic sensors (FOS), enable compact light based detection and ranging (LIDAR), and miniaturise free space optical (FSO) communication systems to name the most relevant to the future of optical communications. So far only a small number of businesses have been able to commercialise integrated photonic products though. This is attributable to the technical complexity of chip production and the challenges in integrating chips into mainstream manufacturing methods. However, two key breakthroughs have been made in the last decade: the establishment of open access foundry processes using Generic Photonic Integration and the integration of high-performance indium phosphide devices and circuits on silicon.

Generic Photonic Integration has been crucial to stimulating a new wave of product developments providing low-cost access to hundreds of researchers and innovators. This replicates the foundry model that has been so successful in microelectronics: Highly standardized fabrication processes are supporting the integration of a small set basic building blocks, with which a large variety of application specific circuits can be fabricated for a broad range of applications. This model was introduced in Europe in the first decade of the century in the FP6 Network of Excellence ePIXnet. ePIXnet established foundry platforms for silicon (ePIXfab) and InP (JePPIX), and later also for SiN (represented by both platforms). Significant investment has lead to increased technology maturity (HELIOS and PLAT4M for silicon photonics, EuroPIC and PARADIGM for InP and SiN). In the second decade, Asia and the US followed with Silicon Photonics foundry platforms further accelarating silicon PIC technology. In the prototyping phase, the foundry model allows early adopters to share costs of process design kit development and wafer production without needing to master PIC fabrication know-how or owning production infrastructure. Now JePPIX foundries are establishing a manufacturing pilot line [1]. Users will focus on circuit innovation with evermore accurate design tools, while foundries focus on producing high performance building blocks with accelerated yield-learning. PhotonDelta.eu provides a gateway to businesses developing the supply chains in the integrated photonic paradigm.

Embedding photonics within semicon manufacturing flows offers compelling opportunities for cost, size, weight and performance (c-SwaP). This has been important driver for the InP PIC membrane on silicon (IMOS) technology: IMOS combines superior material properties of InP with the advantages of silicon photonics: high-contrast waveguides. Compact active and passive components and circuits are created on a silicon substrate. Research currently uses 3" wafer processes but a number of new methods are in development for larger-substrate, wafer-scale processing and packaging. Electronic-photonic integration is now becoming essential in managing the electrical interfaces. Performance advantages are envisaged by moving the highest-speed electrical interconnects to within the precisely-controlled, wafer-scale process. The recent integration of InP PICs with co-designed BiCMOS drivers and amplifiers highlights the future potential [2]. Removing bond-pads and bond-wires not only removes parasitics, but releases chip area, enabling the exploitation of miniaturised, high-density photonic devices.

The next decade will provide technology solutions to very-high-density, electrical-photonic circuits, addressing thermal and optical connectivity challenges. This opens up new possibilities for massive-parallelism, wide-band sensing and communications. Additional new research lines are anticipated, with examples including neuromorphic chips for artificial intelligence systems [3] and quantum communications [4].

[1] inpulse.jeppix.eu
[2] K.A. Williams et al., "Indium phosphide photonic integrated circuits on silicon electronics", invited paper, OFC 2020.
[3] www.chipAI.eu
[4] www.quantum-uniqorn.eu