A generic process platform for photonic integrated circuits

David J. Robbins, Katarzyna Lawniczuk, and Meint Smit

A generic integration platform, analogous to that used in microelectronics, may reduce the cost of photonic integrated circuits and make this technology accessible to new sectors.

Photonic integrated circuits (PICs) are used primarily in fiber-optic communications and telecommunications as signal encoders and decoders for systems operating at 100–400Gb/s. Furthermore, they have applications in fiber-based sensors as readout circuits, and in metrology and medicine (specifically, optical coherence tomography). PIC technology exploits light to achieve signal processing using predominantly indium phosphide (InP)-based materials (see Figure 1), which offer the required functionalities of emission, modulation, and detection.\(^1\)

InP-based PICs are not new, and for more than three decades developers have explored their application, design, and fabrication, as well as the optical and thermal crosstalk (interference) between integrated devices. Ideally, development of a generic integrated InP platform would enable simplified, reduced-cost access to a standardized technology. However, it is only relatively recently that InP growth and processing has matured sufficiently to enable such large-scale integration platforms. Their development is now underway, and the technology is nearing commercialization, particularly in Europe.\(^2\) Development is based on a range of calibrated parametrized building blocks using InP. This material is currently the only type that enables integration of optical gain (or amplification) blocks, an essential feature of on-chip integrated optical sources.

As with silicon and dielectric platforms, InP processing requires state-of-the-art equipment in a clean-room environment, like that used for metalorganic vapor phase epitaxy (chemical vapor deposition for producing thin films) and stepper-based lithography. Such facilities can cost $680 million (€500 million) to establish, placing them beyond the reach of many application areas. In microelectronics, however, there is a global-scale market served by a small set of integration processes, most of them CMOS-based. Using these, we can realize a broad range of functionalities from a small set of basic building blocks, such as transistors, resistors, and capacitors, all provided on a fixed process platform. By connecting these blocks in different numbers and topologies, we can develop a great variety of electronic circuits and systems. The method is called a ‘generic integration process,’ and we recently applied it in photonics, where the analogous basic building blocks of the circuit are passive waveguide optical wiring (which propagates light with minimal change to its original characteristics) and building blocks for gain and control of phase and polarization.

The generic foundry model for photonics shares the development cost between users, making it considerably lower for each participant. The availability of cheap multichannel sensors and readout circuits would benefit users outside the traditional telecoms sector, for example, in the use of fiber-based sensors for structural health monitoring. In this way, real-time analysis of structural status could become ubiquitous in avionics, bridges, buildings, and wind turbines.

We considered the particular applications of our system in novel laser development.\(^3\) Currently, only InP-based platforms

Continued on next page
allow the integration of optical gain blocks, which are essential in a semiconductor laser. The platform’s operation wavelength covers the whole of the electromagnetic spectrum’s C-band (in the range 1530–1565nm), but in the near future we expect to address other wavelengths of 1300–2000nm. For this we would use novel quantum wells, quantum dots, and selective area growth technology (an approach to integration using multistage crystalline deposition in selected areas of the InP wafer to enable specific building blocks).

For optical emitters, designers can build blocks such as amplifier sections and passive waveguides into integrated structures for a wide variety of lasers. This enables a range of applications, from fabrication of simple Fabry-Pérot lasers with novel reflectors, through tuneable distributed Bragg reflector, multi-wavelength comb, filtered feedback, picosecond pulse, ring, and fast-switching wavelength selectable lasers.

In summary, a generic platform offers a state-of-the-art InP process at a low entry cost. Users can access novel devices, such as integrated pulse sources, filtering, and multi-wavelength sources, employing a range of basic and circuit-level building blocks on a generic platform, at no extra development cost. Research is now underway not just in laser design, but also for applications in fiber-based sensing, telecoms, datacoms, and medicine.4

The basic platform technology for InP-based photonics is well established and nearing full commercialization. On the technical side, we now require qualification programs and the establishment of pilot lines for production. From a commercial perspective, we need to commence brokering operations and to cooperate with centers of expertise in design. Our near-term focus is on the development of lower cost packaging, capable of providing large numbers of electrical contacts and multifiber input/output at a reasonable cost. We are also developing second-generation technologies, offering 40Gb/s capability and alternative wavelength ranges.

Author Information

David J. Robbins
Willow Photonics Ltd.
Towcester, UK

David J. Robbins has worked in several branches of optoelectronics for more than three decades. Currently, he is involved in the setting up and commercialization of generic integration processes for photonics integrated circuits.

Katarzyna Lawniczuk and Meint Smit
Technische Universiteit Eindhoven
Eindhoven, The Netherlands

References