

PLAT4M silicon photonics supply-chain project develops three mature platforms

Four-year European Union FP7 project reaches mid-point.

Micro/nanotechnology R&D center CEA-Leti of Grenoble, France and its partners say that they have built three silicon photonics platforms, as they reach the mid-point of the four-year European Union Seventh

Framework Program (EU FP7) project PLAT4M (Photonic Libraries And Technology for Manufacturing, launched in 2013), which aims to build a European-based supply chain in silicon photonics, speeding industrialization of the technology. Funded by a European Commission (EC) grant of €10.2m and based in Grenoble, PLAT4M includes 15 European R&D institutes and CMOS companies, key industrial and research organizations in design and packaging, as well as end-users in different application fields, in order to build the complete supply chain.

The consortium has developed advanced technologies and tools by building a coherent design flow, demonstrating manufacturability of elementary devices and process integration, and developing a packaging toolkit. The supply chain is based on technology platforms of Leti, Imec and STMicroelectronics, supported by a unified design environment. The high level of maturity of the technology offered by these platforms makes them readily accessible to a broad circle of users in a fabless model, it is said.

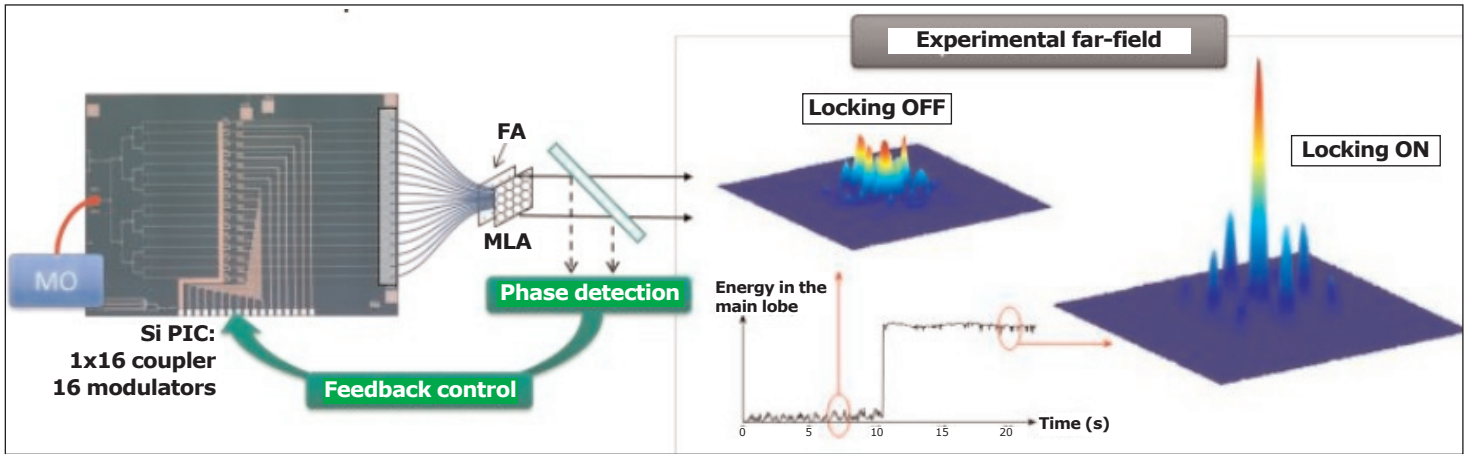
Imec's silicon photonics platform (based on 200mm substrates) has matured as a result of the PLAT4M project. The platform is based on silicon-on-insulator (SOI) substrates with 220nm crystalline silicon on a 2000nm buried oxide. During the project the existing fabrication processes and integration flow have been fine tuned to have stable and repeatable performance for all photonics building blocks (couplers, waveguides, phase shifters, photodetectors). This feeds the process design kit's robust performance specifications and guarantees quality and first-time-right designs for the platform's fabless users for high data-rate telecom and non-telecom applications, it is said. PLAT4M partners Thales, Polytec and TNO are already using the technology.

Beyond the 200mm platform, Imec has pushed the limits of silicon photonics, exploiting advanced optical lithography via its 193nm immersion lithography scanner. It has also demonstrated very low propagation

loss ($\sim 0.6\text{dB/cm}$) for fully etched waveguides, with excellent within-wafer linewidth control (standard deviation $< 3\text{nm}$ for 450nm-wide waveguides) and sub-100nm features. Deep sub-wavelength features can be made in a manufacturable process, avoiding the use of electron-beam lithography.

Using the Imec platform, Thales demonstrated a coherent combination of laser beams (CBC). Ultimately, this application aims to produce high-power, high-energy laser sources for sensing, industry or fundamental physics. The CBC rationale is to push the limits of single laser emitters (typically fiber amplifiers) by using a large number of amplifiers and coherently adding the output beams. The coherent addition requires locking the phase of all the amplifying channels. With the number of channels (potentially very large, from tens to thousands), an integrated technology is a major concern in terms of possible industrial products. The first-generation CBC demonstrator of PLAT4M, which was packaged by Tyndall UCC (University College Cork) in Ireland, included a 1-to-16 channel splitter tree, plus 16 independent thermal phase modulators. The CBC experiment has demonstrated the successful coherent addition of 16 laser beams at $1.55\mu\text{m}$.

Leti has developed a new photonic platform based on 200mm SOI wafers. This process offers multi-level silicon patterning that allows the design of various passive and active devices (e.g. a modulator and a photodiode) with thermal tuning capability. Two AlCu metal levels are available for routing. A process design kit (PDK) is available for circuit design and a multi-project wafer (MPW) service will be proposed in 2016. State-of-the-art performance has been demonstrated: insertion losses are below 2dB/cm for a mono-mode waveguide and below 0.2dB/cm for multimode devices. Germanium photodiode responsivity is $> 0.75\text{A/W}$ for a bandwidth $> 30\text{GHz}$. The Mach-Zehnder modulator $V_p L_p$ product is in the 2V.cm range for 2V operation with an E/O bandwidth of $> 25\text{GHz}$. Moreover, Leti and III-V Lab have developed integrated hybrid III-V lasers and electro-absorption modulators (EAMs) on silicon using a wafer-bonding technique. The hybrid lasers operate in the single-mode regime and the EAMs exhibit an extinction ratio higher than



(Left) Schematic of the CBC experiment layout with the PIC. MO: master oscillator; FA: fiber array; MLA: microlens array. (Right) Experimental measurement of the output combined beams in the far field, in closed loop and open-loop configurations. The plot shows the evolution in time of the energy encircled in the main central lobe.

20dB with a drive voltage lower than 2V. A clear eye-diagram has been achieved at a bit-rate of 25Gb/s, confirming the strong potential for telecom applications.

During the project, ST developed an additional silicon-photonics platform in 300nm technology to be used as an R&D tool for proof-of-concept purposes. Designed for evaluating new devices and subsystems for demonstration, DAPHNE (Datacom Advanced PHotonic Nanoscale Environment) is a flexible platform that fits R&D needs. While developing it, ST demonstrated wavelength division multiplexing (WDM) solutions using arrayed waveguide gratings (AWGs), echelle gratings, cascaded Mach-Zehnder interferometers and a side-coupled integrated spaced sequence of resonators. Some of the configurations are designed for the 100GBase-LR4 standard, and the experimental characterization results show insertion losses below 0.5dB and channel cross-talk above 25dB for a band flatness of 2nm. Furthermore, proper operation of receiver-and-transmitter blocks to be interfaced to optical devices above them has been demonstrated at 28Gbps, making use of 65nm-node technologies.

The PLAT4M WP2 work has led to a qualitative leap in the design flow for silicon photonics, allowing the photonics community to design more complex and more robust circuits. The electronics OpenAccess standard for data sharing between design-automation tools includes an extension for silicon photonics in a beta phase today. Simulation capabilities were leveraged thanks to an extensive characterization effort from the three partner fabs and the statistical data gathered for variability prediction. Paris-Sud University has studied theoretically the behavior of different phase shifters and photodetectors for time-efficient and precise modeling. The partners Mentor Graphics and Phoenix Software have improved phase-aware routing and tool interoperability. Verification and manufacturability have reached industry-requirement standards due to the development of new techniques based on the Mentor Graphics Calibre platform that delivers layout-versus-schematic comparison (Calibre nmLVS), photonic rule checks (PRC) and curvilinear-aware design-rule checks (Calibre nmDRC). Mask preparation is also improving, with better pattern-density control and mask correction.

www.leti.fr

PLAT4M consortium members

Coordinated by Leti, the PLAT4M consortium consists of technology providers, research institutes, end-users and small- and medium-size enterprises (SMEs) with track records in photonics technologies. At the design and process level, Leti and Imec have been the most prominent European players in silicon photonics for a decade. Together with University of Paris-Sud, III-V Lab and TNO, they have

demonstrated many scientific and technological breakthroughs. For building a complete design flow, electronic design automation (EDA) tool suppliers Mentor Graphics, Phoenix BV and Si2 have worked together to develop a common reference platform.

STMicroelectronics (of France and Italy) has been engaged for the past year in developing silicon photonics at the industrial level.

Tyndall-UCC and Aifotec are experts in opto-electronic packaging and work together on the implementation of packaging technologies developed within PLAT4M in a manufacturing environment.

End-users like Polytec and Thales Research & Technology are driving the demonstrators' development and assess the use of silicon photonics in their applications fields.

<http://plat4m-fp7.eu>