T1-L4

Integrated Photonic Circuits: Enabling a New Era of Photonics

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Photonic integrated circuits (PICs) mark a pivotal stage in the evolution of optical wave routing, continuing the trend toward increased modal confinement seen in the transition from free-space benchtop setups to optical fiber circuits. Integration of multiple optical functions - such as waveguides, modulators, detectors, lasers, and nonlinear materials - on a single chip offer a path analogous to that of electronic integrated circuits, drastically reducing size, cost, and power consumption while improving reliability, robustness, and enabling new functionality.

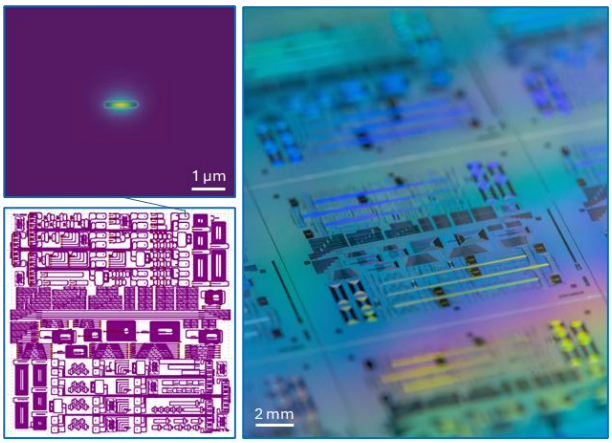

Fig. 1 SiN PIC workflow steps: mode simulation, circuit design, fabricated chip.

This tutorial introduces the principles, technologies, and applications of integrated photonics. Starting by laying out the case for PICs relative to alternative platforms, it will provide a concise summary of the platforms, including silicon [1], silicon nitride [2], III-V and piezoelectric material platforms [3], as well as emerging heterogeneous approaches. The tutorial will follow a representative photonic circuit path and introduce its key components – interfaces, couplers, modulators, and resonators, highlighting how well-defined primitives underlie the scalability of the PIC approach. It will also discuss the typical workflows for simulation, design, fabrication, and packaging of such devices.

A major focus will be on the role of integrated photonics in augmenting application areas, including communication systems, optical frequency metrology, and radio-over-fiber transmission. It will also survey emerging applications, such as integrated LiDAR for autonomous systems, biosensing platforms for healthcare diagnostics, frequency synthesis, and photonic processors for neuromorphic and quantum information processing.

Challenges such as optical losses, thermal effects, operation beyond the telecommunication wavelength region, packaging, and scalability will be discussed alongside recent advances in addressing these limitations. Finally, the tutorial will provide a forward-looking perspective on the emerging trends in integrated photonics, and how they are expected to shape the technological landscape across multiple domains.

REFERENCES

[1] Y. Yuan et al; *APL Photonics* **10** (2025) pp. 060901.
[2] K. A. Buzaverov et al; *Laser & Photonics Revie*ws **18** (2024) pp. 2400508.
[3] D. Zhu et al; *Advances in Optics and Photonics* **13** (2021) pp. 242-352.