실리콘 포토닉스 및 포토닉 집적회로 2025-2035: 기술, 시장, 전망

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개요

실리콘 포토닉스와 포토닉 집적회로(PIC)는 반도체와 광학이 융합된 혁신적 기술로, 실리콘 칩 위에서 빛을 제어함으로써 데이터 전송 속도, 전력 효율, 연산 성능을 획기적으로 향상시키면서도 기존 반도체 제조공정의 경제성과 대규모 생산성을 동시에 실현하고 있다. 이러한 기술은 데이터센터, 고성능 컴퓨팅, 5G/6G 통신, 센싱, 인공지능(AI), 양자컴퓨팅 등 다양한 첨단 분야에서 핵심 인프라로 자리 잡고 있다.

시장 성장 동인 및 주요 트렌드

- **AI 및 데이터센터의 폭발적 성장**

  AI와 머신러닝의 급격한 확산, 대규모 데이터센터의 등장, 클라우드 컴퓨팅의 고도화로 인해 초고속·저전력·고대역폭 데이터 전송이 필수적이다. 기존 전자식 인터커넥트는 물리적 한계에 직면해 있으며, 실리콘 포토닉스와 PIC가 이를 대체하는 차세대 솔루션으로 부상하고 있다. 예를 들어, AI 데이터센터 내 GPU 간 대규모 데이터 이동을 위해 1.6Tbps 이상의 PIC 기반 트랜시버가 요구되고 있으며, 2026년에는 3.2Tbps급 트랜시버도 상용화될 전망이다.

- **통신 인프라의 진화**

  5G/6G 네트워크 및 장거리·도시권 통신망에서 실리콘 포토닉스 기반 광통신이 대역폭과 에너지 효율 측면에서 기존 솔루션을 빠르게 대체하고 있다.

- **센싱·LiDAR·바이오포토닉스**

  자율주행차용 LiDAR, 의료 진단, 환경 센서 등 다양한 센싱 분야에서 PIC의 소형화·고성능화가 시장 확대를 이끌고 있다.

- **양자컴퓨팅 및 신경모방 컴퓨팅**

  양자정보처리, 암호, 신소재 개발 등 미래산업의 핵심인 양자컴퓨팅에서 PIC는 광 큐비트

의 정밀 제어와 확장성 확보에 필수적이다. 신경모방 컴퓨팅, AI 가속기 등 신개념 컴퓨팅에도 적용이 확대되고 있다.

기술 및 소재 혁신

- **기존 실리콘 기반 외에도**

  인듐인산(InP), 실리카, 실리콘 나이트라이드(SiN) 등 다양한 소재가 활용되고 있으며, 최근에는 박막 리튬 나이오베이트(TFLN), 바륨 타이타네이트(BTO), 희토류계 신소재 등 차세대 소재 연구가 활발하다. 이는 고성능 변조, 양자 시스템, 차세대 트랜시버 등에서 주목받고 있다.

- **집적화와 패키징**

  단일 칩 내에서 다양한 광소자(레이저, 변조기, 검출기 등)를 통합하는 고집적화, 첨단 패키징(Co-Packaged Optics 등), 자동화 테스트 및 대량생산 기술이 시장 확대의 핵심이다.

시장 전망 및 주요 수치

- **시장 규모 및 성장률**

  글로벌 실리콘 포토닉스 및 포토닉 집적회로 시장은 2025년 약 22억~20억 달러에서 2035년 260억~540억 달러까지 성장할 전망이며, 연평균 성장률(CAGR)은 20~25%에 달한다.

- **적용 분야별 확장**

  데이터통신, 고성능 컴퓨팅, 통신 인프라, 센싱·LiDAR, AI/머신러닝, 양자컴퓨팅, 바이오포토닉스, 의료진단 등으로 시장이 다각화되고 있다.

산업 구조 및 주요 기업

- **주요 기업**

  Intel/Jabil, Coherent, Infinera, Innolight 등 글로벌 선도 기업들이 PIC 기반 트랜시버 및 고성능 광소자 개발에 주력하고 있다1.

- **공급망 및 생태계**

  소재, 부품, 패키징, 테스트, 시스템 통합 등 전 밸류체인에서 혁신과 협력이 이루어지고 있다.

미래 전망 및 과제

- **AI와 양자컴퓨팅 등 신시장 주도**

  AI 데이터센터, 양자컴퓨팅, 자율주행, 바이오센서 등에서 실리콘 포토닉스와 PIC가 핵심 인프라로 자리매김할 전망이다.

- **기술적 과제**

  소재 한계, 집적화 난이도, 생산 비용, 대량생산 리드타임, 신뢰성 확보 등은 여전히 극복해야 할 과제로 남아 있다.

보고서 주요 내용

- 2025~2035년 10년간 시장 전망 및 수요 예측
- 주요 응용 분야별 분석(데이터센터, 통신, 센싱, AI, 양자컴퓨팅 등)
- 소재·부품·패키징·공급망 심층 평가
- 180여 개 주요 기업 프로필 및 산업 동향
- 차세대 소재·기술·응용에 대한 전략적 인사이트 제공

실리콘 포토닉스와 포토닉 집적회로는 차세대 데이터·통신·컴퓨팅·센싱 패러다임을 주도할 핵심 기술로, AI와 양자컴퓨팅 시대의 글로벌 ICT 혁신을 이끌 기반으로 평가된다.

목차

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Silicon Photonics and Photonic Integrated Circuits 2025-2035: Technologies, Market, Forecasts

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Summary

IDTechEx's report "Silicon Photonics and Photonic Integrated Circuits 2025-2035: Technologies, Market, Forecasts" categorizes the photonic integrated circuit industry, including silicon photonics. It outlines key market players, emerging materials (such as TFLN, and BTO), and key applications such as AI, to forecast the growth of the Silicon Photonics and Photonic Integrated Circuit (PIC) market. IDTechEx also discusses emerging technologies, including Programmable Photonics, Photonic Quantum Computers, and Co-Packaged Optics.

What are the benefits and challenges for Silicon Photonics and Photonic Integrated Circuits?

Photonic Integrated Circuits (PICs) are tiny optical systems made out of materials such as Silica (Glass), Silicon, or Indium Phosphide. PICs enable everything from complex optical designs that allow billions of bits of information to be sent and received in a package the size of a candy bar to artificial noses that can detect different compounds and molecules in the air around them. Their importance in high-speed communication within AI data centers is leading to rapid growth in demand for PIC-enabled transceivers to help machine learning models grow ever larger.

By leveraging the billions of dollars in investment in CMOS chip manufacturing, PICs can unlock new processing scaling potential beyond Moore's law. However, there are still significant challenges for the PIC market, such as material limitations, integration complexity, and cost management. Large demand volumes are required to offset the initial cost of designing and manufacturing PICs, and production lead times can take months. IDTechEx's new PIC report thoroughly investigates the PIC market and has identified Photonic Transceivers for AI as an emerging segment that is soon to be the largest source of demand for PICs.

What are the PIC materials of the future?

There is a wide variety of future PIC materials. Most of the current market uses Silicon and Silica-based PICs for light propagation. However, as an indirect bandgap semiconductor, silicon is not a practical light source or photodetector. Therefore, silicon is usually combined with III-V materials for light sources and photodetection. Leveraging the enormous existing integrated circuit manufacturing industry and generally taking advantage of mature node processes, silicon's market dominance is set to continue.

However, Thin Film Lithium Niobate (TFLN), with its moderate Pockels effect and low material loss, is emerging as a strong contender for applications that require high-performance modulation such as quantum systems or potentially high-performance transceivers in the future. Monolithic Indium

Phosphide (InP) continues to be a major player due to its ability to detect and emit light. Additionally, innovative materials like Barium Titanite (BTO) and rare-earth metals are being explored for their potential in quantum computing and other cutting-edge applications.

How AI is changing the demand for Silicon Photonics and PICs

The rise of Artificial Intelligence (AI) has spurred an unprecedented demand for high-performance transceivers capable of supporting the massive data rates required by AI accelerators and data centers. Silicon Photonics and PICs are at the forefront of this revolution, with their ability to transmit data at speeds of 1.6Tbps and beyond. As shown by Nvidia's latest H200 server units, which according to IDTechEx's research, require approximately 2.5 800G transceivers per GPU, the need for efficient, high-bandwidth communication is becoming more critical for AI, positioning Silicon Photonics and PICs as essential components in the AI-driven future. The biggest driver of the development of PIC transceivers is AI, as higher-performance AI accelerators will require higher-performance transceivers, with 3.2Tbps transceivers expected to arrive by 2026.

What are the future applications?

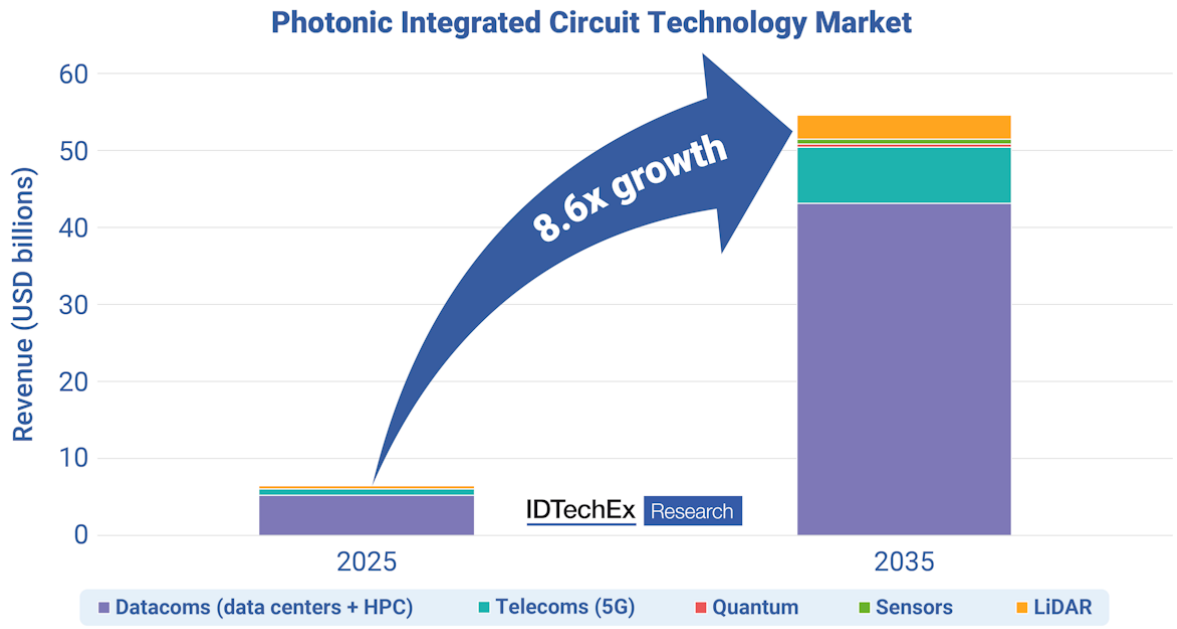
Other applications for Silicon Photonics and PICs vary - from high-bandwidth chip-to-chip interconnects to advanced packaging and co-packaged optics, these technologies are paving the way for next-generation computing.

Photonic Engines and Accelerators: Using certain photonic components such as Mach-Zehnder Interferometers, and controlling these components through electro-optical interconnects, high-performance processors and programmable PIC devices can be designed and manufactured, unlocking higher performance than what is possible with electronic accelerators alone.

PIC-based Sensors: Certain PIC materials, such as Silicon Nitride, can used for a range of different sensors, from gas sensors to 'artificial noses'. The healthcare sensor industry may be able to take advantage of the miniaturization of optical components into PIC devices, which could see applications in Point-of-Care diagnostics or wearables.

PIC-based FMCW LiDAR has the potential to transform the automotive and agricultural industries with applications in drones and autonomous vehicles.

Quantum Systems: Companies investing in Trapped Ion and Photon-based Quantum Computing are looking to PICs for more stable and scalable quantum systems. The challenge lies in achieving the precise control of photons necessary for quantum computation.



Source: IDTechEx Research

The market for Silicon Photonics and PICs is experiencing robust growth, driven by the surge in AI and datacom transceiver demand. Key players in the industry such as Intel/Jabil, Coherent, and Infinera are actively using PICs within their transceivers. Innolight, a China-based transceiver company, hit 1.6Tbps of transfer speed in their latest transceivers in late 2023. Coherent, which has its own InP wafer fab facilities, is also developing higher-performance transceivers for 1.6T+ applications. Intel Silicon Photonics, which has transferred its transceiver business to Jabil, announced it had shipped over 8 million PICs since 2016, showing the maturity of the technology. IDTechEx forecasts that PIC technology is to continue to dominate the high-performance transceiver market, further solidifying its position as a critical component in the modern technological landscape.

What is in this report?

This report includes a detailed examination of the latest innovations in Silicon Photonics and Photonic Integrated Circuits, key technical trends, analysis across the value chain, major player analysis, and granular market forecasts.

The report covers the following topics:

- Key Player Analysis for the High-Performance PIC-based Transceiver Market.
- A breakdown of Co-Packaged Optics and its key concepts.
- Analysis of Photonic Integrated Circuits for Quantum Systems.
- Benchmarks and comparisons of photonic materials, with an industry breakdown by material. It also includes an insight into emerging materials such as Thin-Film Lithium Niobate (TFLN) and Barium Titanite (BTO).

- Photonic Integrated Circuit Fundamentals and Key Concepts, including important components, and underlying principles.
- An analysis of how AI is changing demand for PIC-based transceivers, with a look at how Nvidia's recommended server architecture requires large numbers of transceivers.
- An overview of PIC manufacturing techniques.
- A look into future applications of PICs such as interconnects, LiDAR, biosensors, and gas sensors.

The report is based on extensive research and interviews with industry experts and provides valuable insights for anyone interested in the future of photonic integrated circuits. It includes 32 company profiles, many from first-hand interviews, and summaries from events including SPIE Photonex 2024 and SPIE Photonics West 2024.

Market Forecasts:

- 10-year Total Photonic Integrated Circuit Market Forecast.
- 10-year PIC Transceivers for AI, Data Centers and HPC (Datacom) Unit Shipments Forecast
- 10-year PIC Transceivers for Datacom Cost per Gbps Forecast
- 10-year PIC Transceivers for Datacom Market Forecast
- 10-year AI Accelerator Unit Shipments Forecast
- 10-year PIC Transceivers for 5G Market Forecast
- 10-year PIC Transceivers for 5G Unit Shipments Forecast
- 10-year Quantum PIC Market Forecast
- 10-year PIC-based LiDAR Market Forecast
- 10-year PIC-based Sensor Market Forecast

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