

Application of Optoelectronic Fusion Integration Technology



Overview

Micromachines | Special Issue : Optoelectronic Fusion Technology It will allow for the multi-functional integration of communications, sensing, and computing.

Key Takeaways

An optoelectronic fusion integration solution combines optical and electronic computing to achieve high-speed, low-power, and reconfigurable processing for AI, communications, and sensing applications.

Optoelectronic fusion integration merges microelectronics and optoelectronics, leveraging the mature processing capabilities of electronics with the ultra-wideband, high-speed, and low-power advantages of optical systems. This integration enables multi-functional chips that combine communications, sensing, and computing, supporting innovations in ultrabroadband optical networks, satellite communications, and artificial intelligence .

Core Technologies

- Hybrid Computing Modules Modern solutions employ optical analog computing modules for feature extraction and dimensionality reduction, paired with electrical analog computing modules for further computation. This hybrid approach overcomes the limitations of purely optical neural networks or digital processors, offering high speed, low energy consumption, robustness, and reconfigurability .



- **Ultrabroadband Optoelectronic Chips** Recent breakthroughs include on-chip photonics for full-spectrum wireless communications, integrating broadband wireless-to-optical signal conversion, tunable low-noise carrier generation, and digital baseband modulation. These chips support adaptive, reconfigurable, and high-speed wireless communications across frequencies from 0.5 GHz to 115 GHz, enabling 6G and beyond applications .

- **Optical Connectivity Solutions** Technologies like Co-Packaged Optics (CPO), On-Board Optics (OBO), and Ceramic Multifiber Ferrules (CMF®) enhance optical interconnect performance in data centers and AI clusters, addressing high-density wiring, heat resistance, and high-speed data transfer .

Applications

- **Artificial Intelligence and Machine Learning:** Accelerates neural network computations with low-latency optical processing, reducing energy consumption compared to conventional digital processors .

- **Autonomous Systems:** Vision fusion systems integrate optical sensing with edge extraction and decision-making, achieving high recognition accuracy in complex environments .

- **Next-Generation Communications:** Supports ultrabroadband, full-spectrum wireless networks, enabling dynamic spectrum utilization and high-speed data transmission for 6G, XR, and remote medical applications .

Advantages

- **High Throughput and Low Latency:** Optical processing allows near-light-speed computation.

- **Energy Efficiency:** Reduces power consumption compared to traditional electronic-only systems.

- **Reconfigurability:** Systems can adapt to different tasks or frequency bands in real time.

- **Integration Potential:** Combines sensing, computing, and communication on a single chip, enabling compact and multifunctional devices .

Future Prospects

Optoelectronic fusion integration is expected to reshape AI hardware, optical networks, and wireless communications, providing scalable solutions for data-intensive applications. Ongoing research focuses on heterogeneous multi-dimensional integration, wafer-level chip preparation, and intelligent optoelectronic information processing, which will further enhance performance and versatility .

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