Custom Silicon Photonics Process for Standalone Switches

Article Overview

Custom silicon photonics processes enable the design and fabrication of standalone optical switches using PDKs, MEMS or interferometric switch engines, and scalable integration strategies.

Process Design Kits (PDKs) and Foundry Support

Designing standalone silicon photonic switches typically begins with Process Design Kits (PDKs) provided by foundries. PDKs include compact models, layout rules, and building blocks for photonic integrated circuits (PICs), enabling designers to create devices compatible with specific fabrication processes. Leading foundries supporting silicon photonics include AIM Photonics, CEA-Leti, Fraunhofer-HHI, imec, SMART Photonics, Tower Semiconductor, and others. PDKs can be integrated into design platforms like Synopsys OptoDesigner to facilitate layout, simulation, and verification of custom switch designs .

Switch Architectures

Standalone silicon photonic switches are built using several fundamental switch engines:

o Mach-Zehnder Interferometer (MZI): Broadband interferometric switches suitable for WDM systems. Phase shifters based on thermo-optic or electro-optic effects control the interference between two arms, enabling signal routing with low insertion loss and fast switching times .
o Micro-Ring Resonators (MRR): Compact resonant structures that allow wavelength-selective switching. They are highly scalable for dense switch fabrics but require precise thermal or electrical tuning .
o MEMS-actuated Waveguide Couplers: Vertically movable couplers controlled by micro-electromechanical actuators provide sub-microsecond switching with low crosstalk and low optical loss, suitable for large-scale non-blocking switch fabrics .

Large-Scale Integration

For standalone switches, scalable architectures are critical. Techniques include:

o Crossbar and multi-level bus waveguides: Reduce in-plane waveguide crossings, minimizing crosstalk and optical loss while maintaining broadband performance .
o Modular building blocks: Using 2x2 or 1x8 microring-based switch units allows piecewise assembly of larger fabrics (e.g., 8x8 or 32x32), simplifying fabrication, packaging, and control .
o Heterogeneous integration with driver electronics: Flip-chip bonding of high-voltage driver arrays to the photonic chip enables scalable electrical control and high-speed operation .

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Performance Considerations

Key specifications for standalone silicon photonic switches include:

o Insertion loss: Typically 1-5 dB per switch unit, depending on architecture and fabrication quality .
o Crosstalk: MEMS-based and modular designs can achieve < -80 dB in large-scale switches .
o Switching time: Thermo-optic MZI switches operate in microseconds, while MEMS-actuated switches can achieve sub-microsecond ON/OFF times .
o Footprint and power consumption: Silicon photonics allows compact layouts (square millimeters per port) with low energy per bit (picojoules), making them suitable for data center and telecommunication applications .

Fabrication and Customization

Custom processes may involve:

o Wafer bonding or heterogeneous integration for combining multiple materials or layers.
o Thermal or electro-optic tuning elements for precise control of phase and resonance.
o Advanced packaging to integrate optical I/O, electrical drivers, and thermal management. By leveraging PDKs, modular switch blocks, and MEMS or interferometric engines, designers can create standalone silicon photonic switches optimized for low loss, high-speed operation, and scalable deployment in optical networks or high-performance computing systems .

Marvell designs custom silicon tailored for any application and offers the industry"s most comprehensive

We review our recent results in multi-port strictly non-blocking optical switches based on silicon photonics. Silicon

Monolithic silicon photonics is a promising solution to meet the energy efficiency, sensitivity, and cost requirements of these

The investigated devices aim to expedite the transfer of silicon photonics from academia to industry by opening the

Featured Application The CORNERSTONE silicon photonics rapid prototyping service can be used by academic and

The design schemes and associated physical principles for enabling switching functionalities are delineated,

along with the important

The optical circuit switch presented here is an integrated, non-blocking, switch built on a scalable silicon photonics

By using our 45-nm CMOS process, we have recently demonstrated a low loss 32 × $times$ 32 silicon photonics

The Nature photonic processor uses an organic substrate for heterogeneous integration, while Passage uses a

In this paper, we systematically discuss the state of art of the silicon photonic switch engine, for example, MZI, MRR

NVIDIA"s Spectrum-X (Ethernet) and Quantum-X (InfiniBand) photonic switches also incorporate multiple 1.6Tbps

The switch configurations based on hybrid integration of various materials with silicon are also discussed, especially the

One such emerging technology is the optical circuit switch, which can increase the performance, flexibility, and power

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What will the next generation of silicon photonics look like? What are the common threads in the integration and

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