Exceptional service in the national interest

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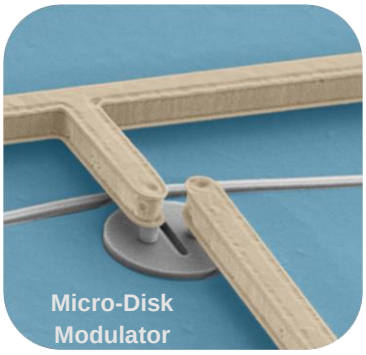
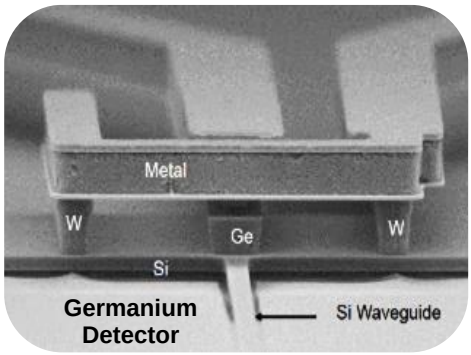
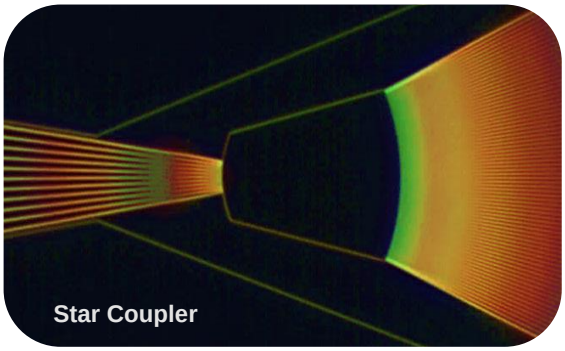






Silicon Photonics *Low-energy High-speed Optical Communication and Signal Processing*

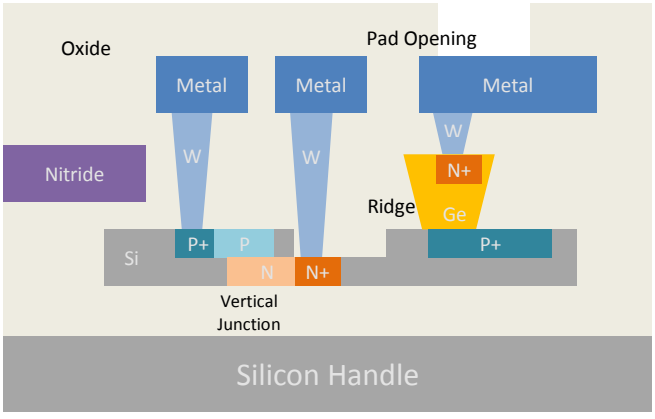
To support next generation computing, communication, and sensing needs, Sandia researchers have successfully developed a Silicon Photonics platform that leverages the semiconductor and nanotechnology capabilities of Sandia's Microsystems and Engineering Sciences Applications (MESA) complex to create optical components for multiple applications.

Computing Challenges

As integrated circuit chips now incorporate over a billion transistors, and single boards provide multi-teraflop (10^{12}) computing capacity, the bandwidth and energy required to communicate data within and between integrated circuits are becoming a primary performance bottleneck. Silicon photonics offers a potential breakthrough in optical interconnection performance, not only for supercomputer applications, but also for data communication and other applications.

Power Saving and Speed

Silicon photonics devices are comprised of silicon nanowire waveguides clad in silicon dioxide (SiO_2). The large refractive index contrast between the silicon waveguide and the oxide cladding allows light to be routed in the waveguide. Optical modulation may be achieved using micro-disk resonators with just a few microns of diameter. These resonant electrically controlled optical modulators can have capacitances as low as 20 femtofarads, and can operate with an electrical power usage of 3.2 femtojoules (fJ) per bit or lower, or 40 µW for 12.5 gigabits per second of information. This power saving is critical in high performance computing, satellite communications, and high output sensors like cooled focal plane arrays. In addition to the optical resonant modulator, Sandia has demonstrated many leading-edge silicon photonics devices, from integrated avalanche photodetectors, to transceivers and optical switching building blocks for low-energy optical networks.



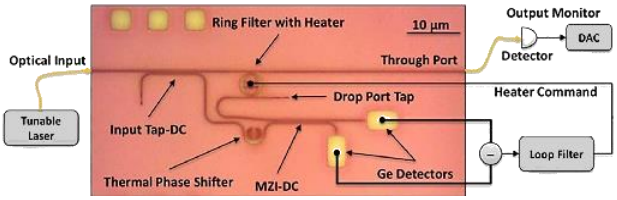
Cross-section of Sandia's Silicon Photonics Platform

Non-traditional Applications

Optical systems offer some inherent benefits over electrical systems due to their insensitivity to electromagnetic interference. Thus silicon photonics offers potential unique advantages over electronics for harsh environments. With promising results, Sandia researchers are actively exploring technology applications from cryogenic temperatures to high radiation environments.

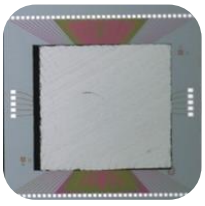
Silicon photonics also provides advantages beyond traditional digital applications. For RF systems that are computationally intensive and require high frequency operation, silicon photonics may be used for analog signal processing with power saving and frequency agility. Sandia has developed optical components including filters, modulators, and channelizers that enable next-generation compact, high-performance spectrum analysis and communication systems.

Micro-resonator Wavelength Control via Balanced Homodyne Locking

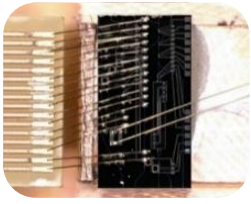


Commercialization Path

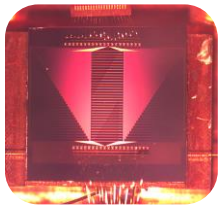
Sandia continues to advance its silicon photonics platform with integration of new materials and to develop new devices and systems for a variety of applications. We are utilizing heterogeneous integration technology to create microsystems with CMOS, silicon photonics, and III-V materials. We are actively seeking collaborators on photonics projects ranging from fundamental research to commercialization of technologies in areas related to low-energy optical communication and computing, as well as other areas of importance for national security such as RF signal processing, quantum information system, secure communication, sensing, and imaging.



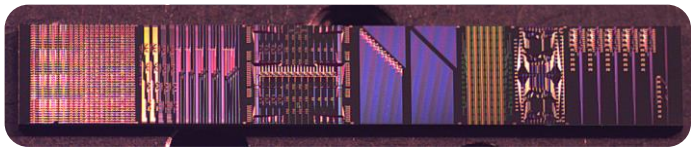
CMOS on Silicon Photonics



Quantum Key Distribution Transceiver



AWG Channelizer



Fabricated chip from multi-project wafer (MPW) run

We welcome discussions with academic and commercial entities interested in Sandia's Si photonics (SiP) multi-project wafer (MPW) and custom fabrication runs for research, device prototyping, and low-volume product manufacturing using our unique fabrication capabilities. Participants may leverage Sandia's SiP Process Design Kit (PDK) and device library while collaborating with our team to customize these designs or to co-develop novel concepts for their requirements. Interested parties may collaborate with Sandia through Cooperative Research and Development Agreement (CRADA) and Strategic Partnership Projects (SPP). Sandia also supports the American Institute for Manufacturing Integrated Photonics (AIM Photonics).

Intellectual Property Licensing

Sandia's broad portfolio of intellectual property in silicon photonics, with 29 issued and 14 pending patents, is available for licensing through Commercial License Agreements. This portfolio includes several essential technologies for building low-power high-speed optical networks: low-voltage, high-speed resonant modulators (with integrated heater for wavelength tuning), scalable methods for wavelength stabilization of resonant devices, high-speed Mach-Zehnder devices (including depletion-mode vertical p-n junction phase-modulator in MZ configuration, traveling wave carrier depletion MZ modulator, and avalanche photodetector, etc.

For additional information, visit our website at: **www.sandia.gov/mstc**

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U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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