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# Silicon Photonics Platform for National Security Applications

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We review Sandia's silicon photonics platform for national security applications. Silicon photonics offers the potential for extensive SWaP-c reductions compared to existing III-V or electronics circuits. We will describe a variety of devices and subsystems that can enable future complex functionality in aerospace systems, principally focusing on communications technology in optical interconnects and optical networking.

The process consists of a thin silicon layer with a thick buried oxide layer to prevent absorption of the optical wave in the substrate. A silicon nitride layer is deposited above the silicon layer to aid in coupling to fibers and provide a crossover layer for optical signal routing. Active devices are made in the silicon layer by selective p-type and n-type doping. Our devices use vertical PN junctions, which gives a stronger carrier concentration change with applied voltage; thus our devices tend to operate at lower voltage compared to most devices in the research community at large. Germanium detectors are made using selective area growth on top of a silicon waveguide; the optical signal couples into the germanium region from the silicon waveguide below. A single layer of routing metal is generally used, although we have processed one run with as many as five layers; that same run included the monolithic integration of radiation-hardened CMOS electronics with a silicon photonic modulator. We have also developed a design kit that has enabled external collaborators to submit photonics designs.

We have demonstrated among the lowest energy resonant modulators to date with switching energies approaching 1 femtojoule per bit at 10 Gbps. When driven differentially, we can make use of the optimal charge transfer when biased slightly in forward bias while maintaining the speed of a reverse biased device and maintain compatibility with future low voltage CMOS drivers with power supply voltages below 0.5V. We have demonstrated the integration of CMOS drivers flip-chip bonded to these low voltage modulators. We have also demonstrated integrated heater-modulators with closed loop control sub-systems to stabilize the modulator wavelength to the incoming laser over temperature ranges of 55 degrees Celsius.

On the receiver side, we have demonstrated Germanium detectors with a 3 dB bandwidth of 45 GHz. When integrated with a simple high transimpedance amplifier, we have simulated 10 Gbps receivers generating logic level outputs with -

20dB average power inputs with energies below 10 femtojoules per bit. We are in the process of demonstrating these circuits.

We have also designed switching elements for constructing optical networks. We have developed broadband MZM switches and wavelength selective switches, either making use of thermal properties for compactness and broadly tunable devices and carrier effects for high-speed devices. We will describe switching networks that can be constructed from these devices for optical networking within aerospace applications.

We will provide references and greater detail on the devices and subsystems in the full paper. The authors would like to acknowledge the contributions of Professor Michael Watts, a former staff member now at MIT, for his contributions in designing many of the early devices while at Sandia.