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Compound Semiconductor Photonic Integrated Circuits at Sandia National Laboratories

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ABSTRACT

This talk will review compound semiconductor photonic integrated circuit research and development activities at Sandia and highlight the unique capabilities of the technology.

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Monolithic photonic integrated circuits (PICs) have a long history reaching back more than 40 years. During that time, and particularly in the past 15 years, the technology has matured and the application space grown to span sophisticated tunable diode lasers, 40 Gb/s electrical-to-optical signal converters with complex data formats, wavelength multiplexors and routers, as well as RF and other sensors. Sandia National Laboratories (SNL) has developed a complete InGaAsP PIC capability supporting the needs of U.S. government that may be of interest to industry. This talk will review the Sandia PIC capability and highlight the unique strengths and applications. Examples will be provided from recent R&D activity.

SNL PICs monolithically integrate tunable diode lasers of various wavelengths, with modulators, amplifiers photodiodes and interconnection optical waveguides on InP substrates for operation at telecom wavelengths. This capability rests on a foundation of state-of-the-art III-V semiconductor crystal growth and regrowth using metal-organic chemical vapor deposition (MOCVD) and post-growth quantum-well band-gap modification using quantum-well intermixing (QWI) methods to achieve the multiple band-edges and optical confinement needed for highly-functional PICs.

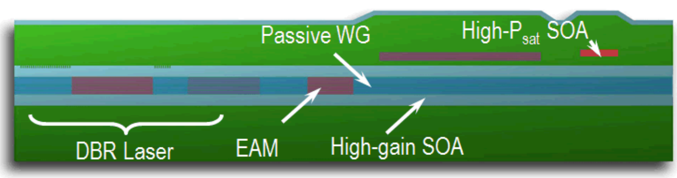

Figure 1: Illustration of active and passive elements integration inside a PIC.

Figure (1) illustrates integration of passive waveguide photonics elements (such as waveguides, modulators, and switches) as well as active photonics elements including lasers, optical amplifiers, photodetectors onto a single PIC. The approach enables compact high-performance PIC functions of integrated transmitter lasers and modulators, coherent optical receivers, and advanced telecom optical modulation formats such as Differential Quadrature Phase Shift Keying (DQPSK) in single-chip platforms.

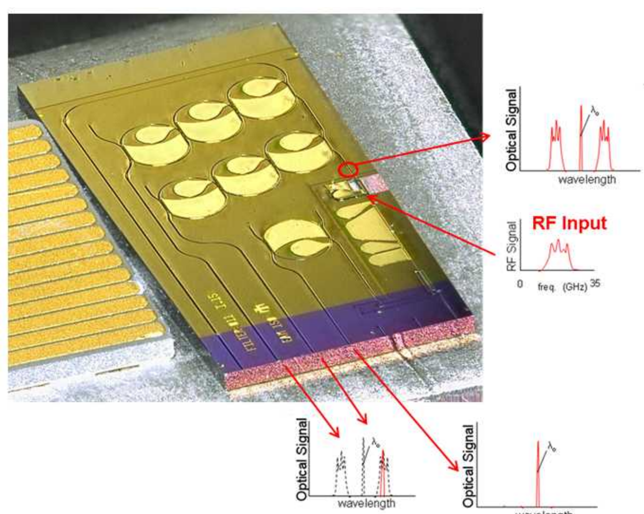

Figure 2: RF-optical channelizing PIC.

Recent SNL activity in high-speed digital optical datacom includes an all-optical logic PIC performing a logical NOT and AND function at 40 Gb/s. On this PIC a data stream is input from optical fiber and then optically amplified and the inverse data (NOT output) transferred to an output optical beam sourced from an on-chip Distributed Bragg Deflection (DBR) laser. This all-optical logic approach[1] is extensible to NAND, XOR and other gate functions at bit rates exceeding 80 Gb/s.

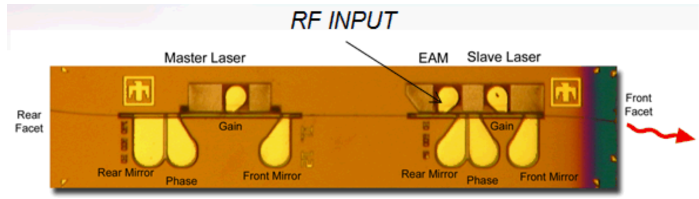

Figure 3: PIC more mutual injection locking of diode lasers.

Another SNL PIC development project demonstrated channelization of wideband RF signals.[2] Figure (2) shows the PIC with illustrated input RF and output optical signals. This monolithic InP PIC integrates low-loss optical ring resonator filters[3] with an on-chip wavelength tunable DBR laser to achieve parallel notch filtering (channelizing) in the optical domain of an input RF signal. Filters are 1-3 GHz wide.

A third example, Figure (3), is a PIC using mutual injection locking of monolithically integrated coupled-cavity DBR lasers and modulators to exploit on-chip optical coupling to push the data modulation bandwidth of coupled lasers well beyond the fundamental limits of individual lasers. In this case[4], the coupled laser PIC is capable of modulation beyond 40 GHz where the individual lasers function only to ~ 3 GHz.

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