Photonic Integrated Circuits for Ultrafast Optical Logic

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Sponsorship: DARPA

With an increasing demand for higher speed switching technologies in optical telecommunications networks, interest in both all-optical switching schemes and monolithic integration of photonic components is increasing. Reducing or eliminating optical-electronic-optical (OEO) conversions offers advantages of higher bit rates, lower power consumption, and reductions in size and weight.

The current study aims to demonstrate an optical gate consisting of semiconductor optical amplifiers (SOAs) integrated into a Mach-Zehnder interferometer on InP substrates. The optical gate is capable of basic Boolean functionality, wavelength conversion, and other important switching operations. Prior to fabrication, the design of the components such as the InGaAsP quaternary dilute waveguide, the multi-mode interferometers, and the adiabatic taper geometry has been optimized using standard optical simulation techniques.

To integrate the active SOA devices with the passive components, an asymmetric twin waveguide approach, which eliminates the need for regrowth at the expense of additional processing steps, is employed. The first-generation design contained two separate die: one consisting of basic isolated components and the other consisting of integrated components (Figure 1). Upon the completion of the processing and testing, further optimizations of the design and fabrication process were incorporated into a second-generation design that is currently undergoing fabrication on campus and in collaboration with Lincoln Laboratory. The second-generation design combines both the active and passive devices into single die suitable for a step-and-repeat mask set, allowing for sharper tapers and smoother waveguide bends. Processing improvements include depositing the base metal for the top-side contact prior to any III-V etching, minimizing the amount of InP-based etching through the use of trenches, and using a dedicated CH
\[4\]/H\[2\] etcher at Lincoln Laboratory. Figure 2 shows the tips of the upper active waveguide and the trench in which the passive waveguides will be centered.

Figure 1: A photograph of the first-generation fabricated dies on a quarter of a 2” InP wafer.

Figure 2: A photograph of the beginning of the second-generation Mach Zehnder interferometer.