

## 17. Photonic Integrated Circuits for Ultrafast Optical Logic

### Sponsors:

DARPA

### Project Staff:

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The aim of this project is to model and to produce a modular monolithically integrated all-optical unit cell capable of performing a complete set of Boolean operations at speeds of 100s of gigabits per second. The basic structure consists of a balanced Mach-Zehnder interferometer with an (In, Ga)(As,P)-based semiconductor optical amplifier (SOA) in each arm as shown schematically in Figure 1.

Modeling is used to develop the design rules, to identify tradeoffs, to determine fabrication tolerances and to estimate the effects of imperfections in semiconductor processing on the device performance. The Beam Propagation Method is used to model passive waveguides, multimode interference couplers, and asymmetric twin waveguide structures. Finite Difference Time Domain technique is employed for simulations involving interfaces between the various components. Custom MATLAB scripts are developed to assess tradeoffs in SOA performance and to work toward design rules that specifically address the design of the SOAs for switching applications. The challenge is to optimize the performance of each component even when all of the components are monolithically integrated together on a photonic integrated circuit.

Fabrication processes are being developed to create the all-optical logic unit cell. The waveguide design calls for vertical integration of passive waveguides and active amplifiers. This integration is achieved by employing a taper coupler to transfer the optical mode between the lower passive waveguide and the upper active waveguide of the twin-waveguide structure. In addition to the optical logic unit cell, isolated components are being fabricated and tested to confirm the device design and the computer simulation results.

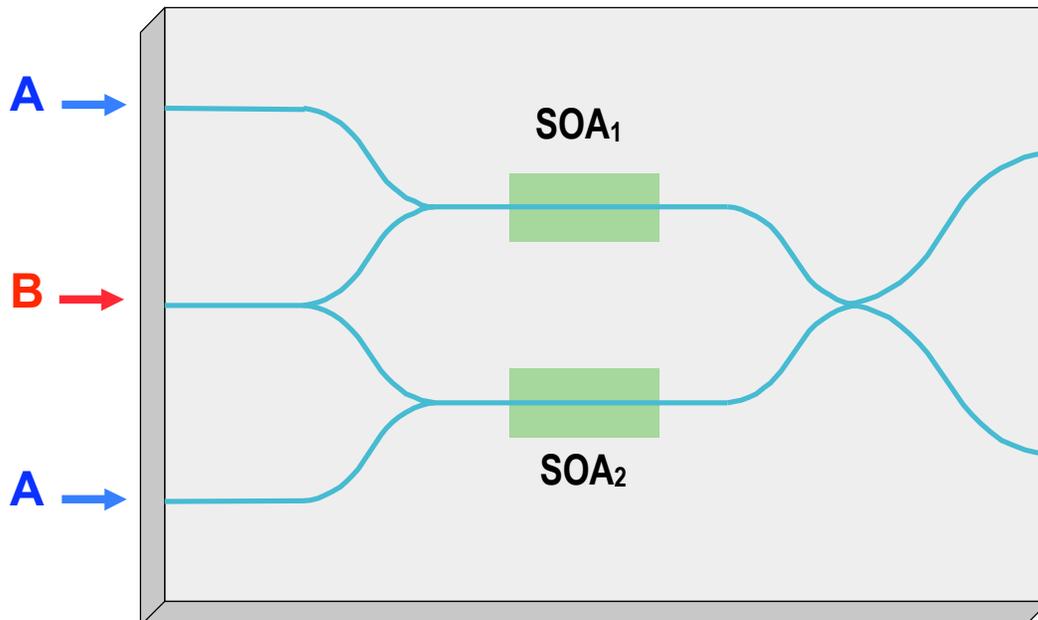


Figure 1: The optical logic unit cell. A balanced Mach-Zehnder interferometer composed of SOAs, multimode interference couplers, phase shifters, and time delays.