Cornell University
Center for Technology Enterprise and Commercialization

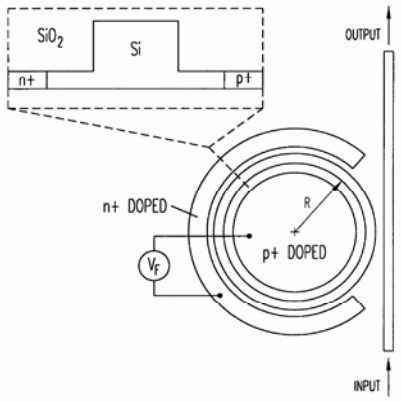
395 Pine Tree Road, Suite 310
Ithaca, NY 14850
Phone: 607-254-4698
Fax: 607-254-5454
www.cctec.cornell.edu

NONCONFIDENTIAL TECHNOLOGY BRIEF

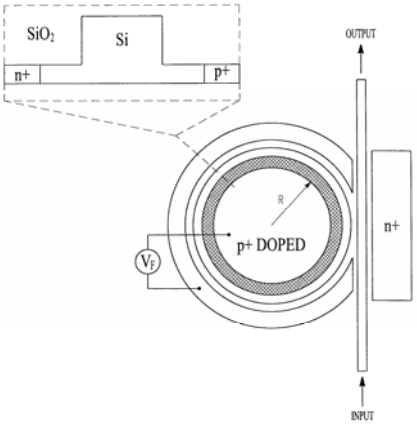
Cornell's Photonics Technology

Professor Michal Lipson and a team of Cornell researchers have invented small (~20 µm), fast (up to 40 Gbits/sec or Gbps), CMOS compatible optical and electro-optical switching devices. Cornell's switches can be used to build silicon photonic devices for different applications, including optical logic and multiplexers.

In its basic configuration, the device is an electro-optical switch (EOS) which uses a ring resonator to modulate an optical signal in an adjacent waveguide. **This is the first EOS based on a ring resonator.** This novel design exploits an electro-optic effect (plasma dispersion) in the resonator cavity to modulate light transmission; a bias applied across the resonator injects carriers which changes its refractive index and therefore its resonance frequency.



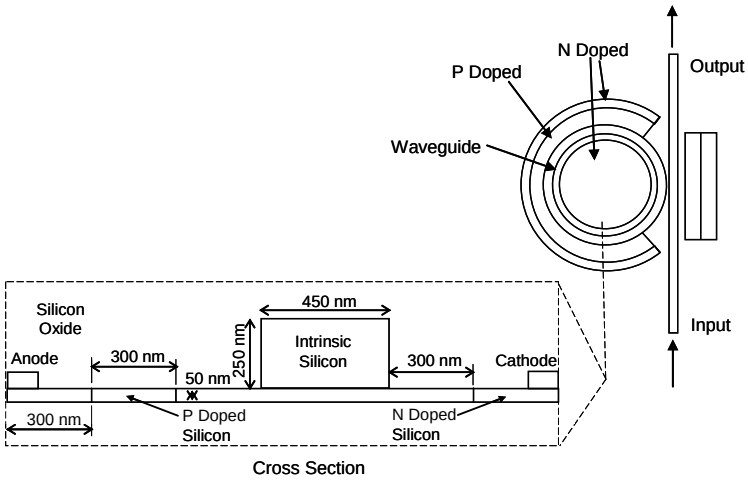
This configuration has a very high modulation depth at a drive power of as low as 20 mW and low dissipated power (Pd). In device prototypes, a maximum modulation depth of 53% was obtained at Pd = 20 mW with I = 5.4 mA. Switching speeds of at least 5 GHz at low power with high modulation depths have been demonstrated.



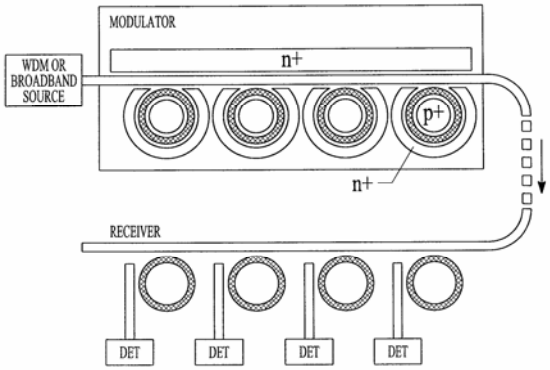
The ring EOS structure was improved by extending the n-doped region to create a nearly closed P-I-N junction thereby increasing the efficiency with which injected carriers are extracted. High quality modulation signal has been obtained at 4 Gbps with modulation as high as 10+ Gbps expected.

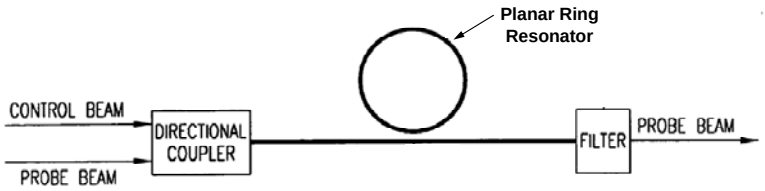
Further improvements involved employing a novel electrical driving system to increase the initial rate of carrier injection. The latest results show 18 Gbps electro-optic modulation speeds. Future improvements expected to reach speeds of 40 Gbps and higher.

A second design for an ultra-fast EOS uses a novel structure to significantly improve the modulator's performance. Also based on a resonating structure, this device exhibits a data rate of 40 Gbps in Non Return to Zero modulation using a silicon ring of 10 µm diameter embedded in a novel N-P-I-N device. The silicon ring is manufactured on silicon on insulator wafers using CMOS compatible technology.



In addition to the obvious application of Cornell's ultrafast EOSs to modulate a single signal in a waveguide, these devices can be cascaded to form the key components of a wavelength division multiplexing (WDM) interconnection system such as that shown at right. Experimental results show clean eye diagrams when each of four 10 micron diameter ring modulators is modulated at 4 Gbps with no inter-channel crosstalk. Terabit per second data transfer rates can be achieved by multiplexing twenty-five 40 Gbps EOSs.





A further application is in optical logic. The refractive index in silicon can be changed by optical as well as by electrical means. Cornell's optical logic exploits two-photon absorption (TPA) in silicon to modulate the signal (probe) beam. The energy of the control beam and the probe beam are each kept below the threshold at which TPA will induce change in the ring resonator's resonance frequency, but if both beams are present, the threshold is surpassed and the ring's resonance frequency is altered sufficiently to either stop the probe beam (a NAND gate – see figure above) or to allow the probe beam to pass (an AND gate). Both NAND and AND operations have been demonstrated at 310 Mbps. Because NAND gates have the property of functional completeness, which means that any logic structure (AND, NOR, XOR, etc.) can be created using only NAND gates, Cornell's all-optical logic device is sufficient to enable the construction of a complete integrated circuit.

INVENTORS: Michal Lipson et al.

PATENTS PENDING AND PUBLICATIONS:

US-2006-0215949-A1
US-2006-0023997-A1
US-2005-0089257-A1
US-60/908,004
US-60/846,530
US-60/839,975
US-60/839,970
US-60/839,919
US-60/574,293
US-60/461,705

Xu, Q. and Lipson, M., *All-optical logic based on silicon micro-ring resonators*, Optics Express, Vol. 15, No. 3, 924, 02 Feb. 2007.

Xu, Q., Schmidt, B., Shakya, J. and Lipson, M., *Cascaded silicon micro-ring modulators for WDM optical interconnection*, Optics Express, Vol. 14, 9430, 02 Oct. 2006.

Lipson, M., *Compact Electro-Optic Modulators on a Silicon Chip*, IEEE J. Sel. Top. Quant., Vol. 12, No. 6, Nov.-Dec. 2006, p. 1520-6. (invited)

Preble, S. F., Xu, Q., Schmidt, B. S. and Lipson, M., *Ultrafast all-optical modulation on a silicon chip*, Optics Letters, Vol. 30, No. 21, 2891-2893, 01 Nov. 2005.

CONTACT: Scott Macfarlane, Senior Technology Commercialization & Liaison Officer
E-mail: ssm8@cornell.edu Phone: (607) 254-2330