5/30/22

Silicon Photonics to 1 GRad

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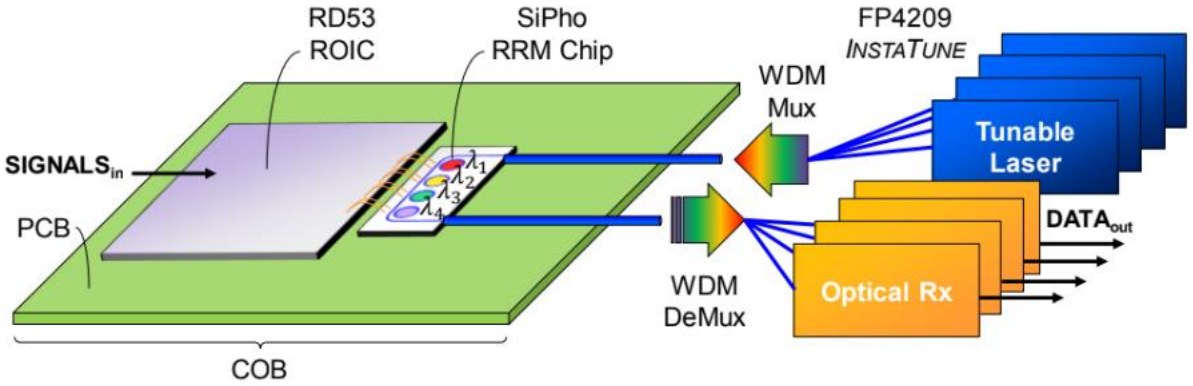
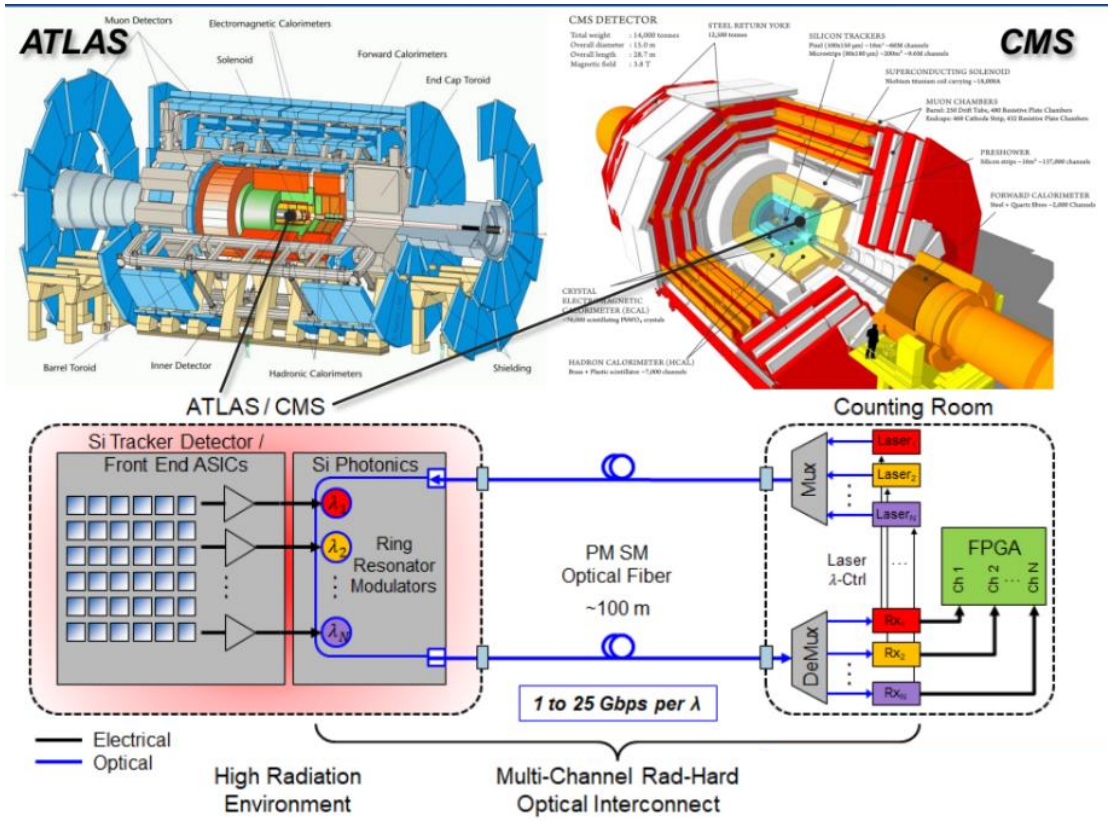
RadLink: Radiation Hard, High Bandwidth Optical Fiber Links for Detectors at High Energy Colliders

- Wavelength Division Multiplexing
  - Parallel readout on a single fiber
- External Optics
  - Lower mass, power, and complexity

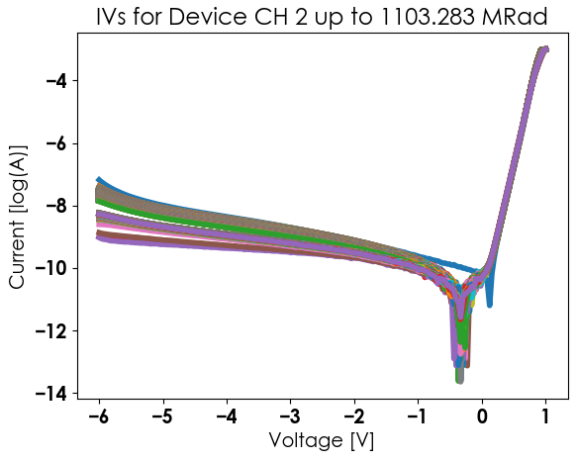


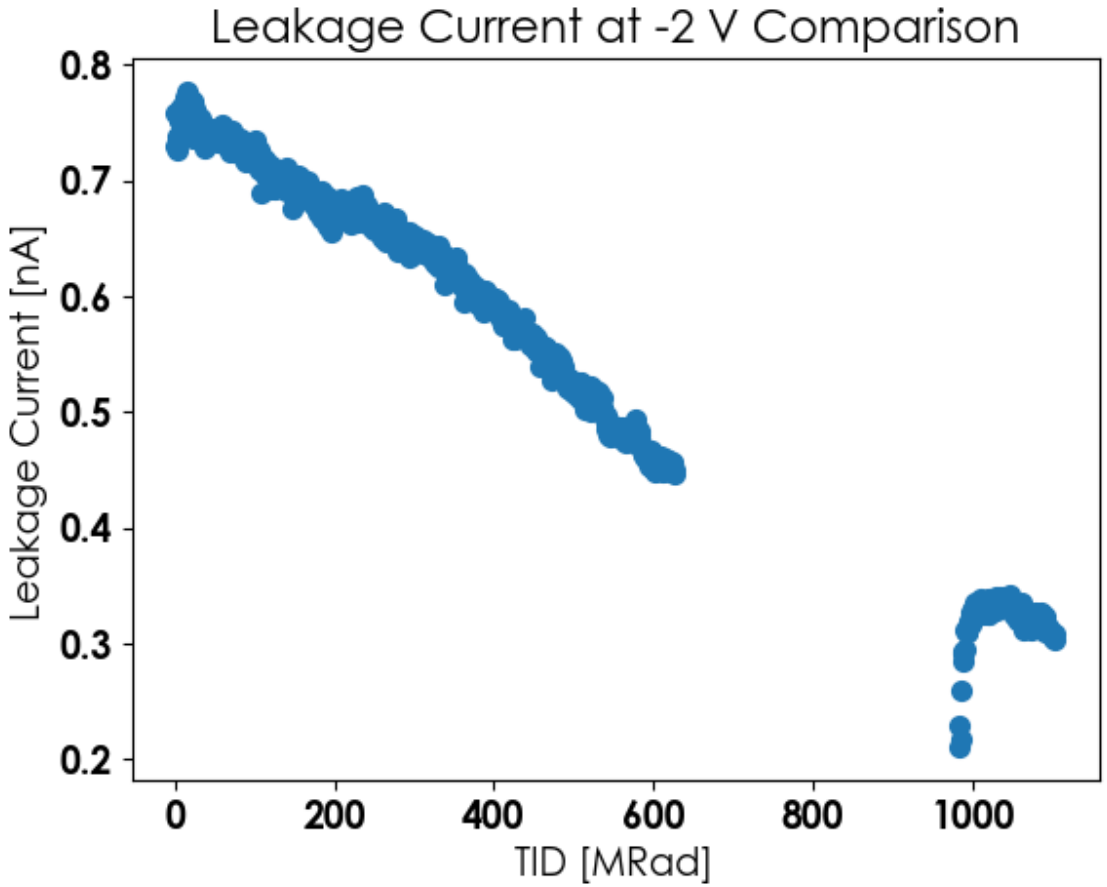


Current Irradiation

4C01 Nominally Doped Irradiation

- Nominally doped PDK MRM
- Biased at -2 V
- Xray dose at 1.95 MRad/hr
- Highly doped device has no change

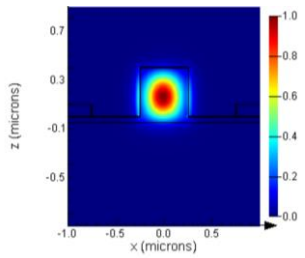




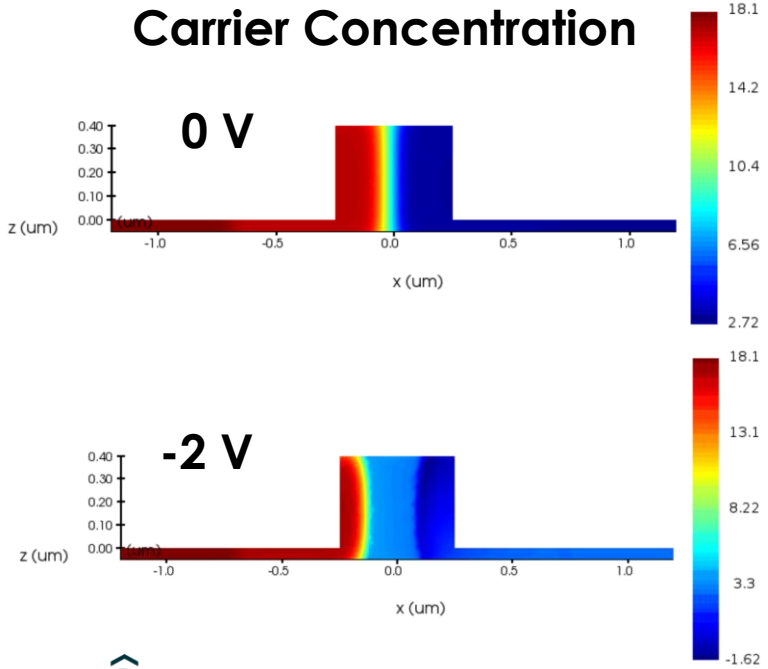
RRM Electro-Optic Conversion

Phase Shifter

Optical Mode



PN Junction
Carrier Concentration



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$$\Delta n = -\frac{e^2 \lambda^2}{8\pi^2 c^2 \varepsilon_0 n}\left(\frac{\Delta N_e}{m_e} + \frac{\Delta N_h}{m_h}\right)$$

electrons holes

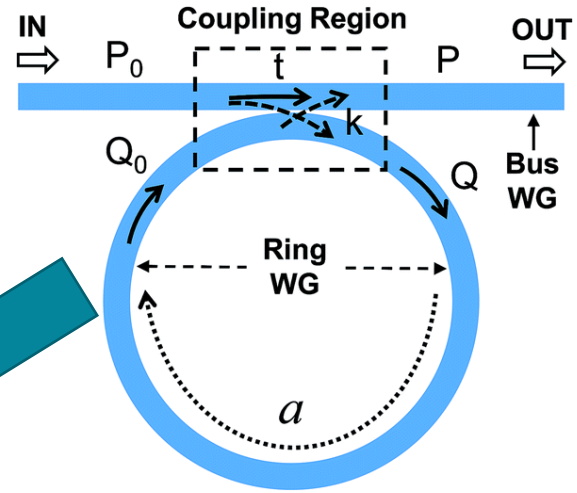
Loss

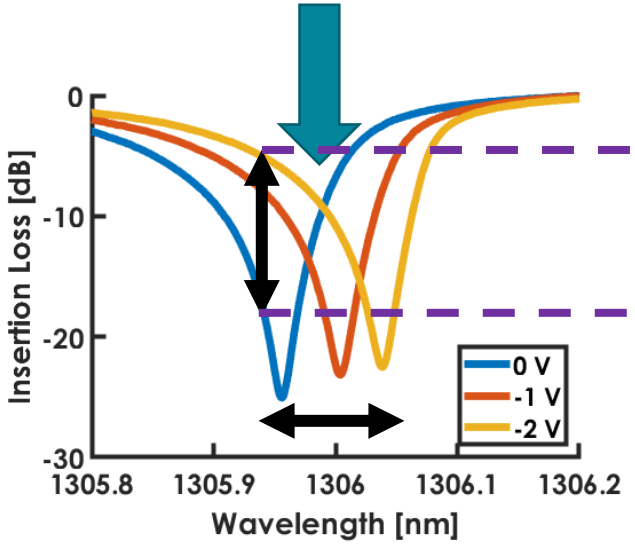
$$\Delta \alpha = -\frac{e^3 \lambda^2}{4\pi^2 c^3 \varepsilon_0 n}\left(\frac{\Delta N_e}{m_e^2 \mu_e} + \frac{\Delta N_h}{m_h^2 \mu_h}\right)$$

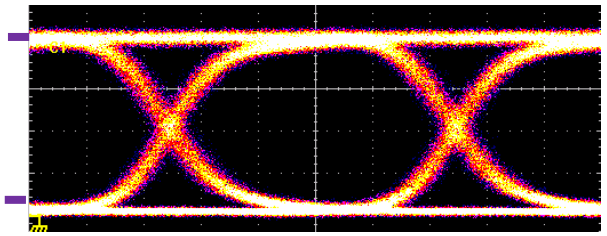
Power

$$P_{t1} = |E_{t1}|^2 = \frac{\alpha^2 + |t|^2 - 2\alpha |t| \cos(\theta + \varphi_t)}{1 + \alpha^2 |t|^2 - 2\alpha |t| \cos(\theta + \varphi_t)},$$

Resonator







Electrooptical Effects in Silicon – Soref-Bennet

- Absorption and loss depend upon the amount of free carriers that overlap with the optical mode

$$\Delta n = \left(\frac{-e^2\lambda^2}{8\pi^2 c^2 \epsilon_0 n}\right)\left[\frac{\Delta N_e}{m_{ce}^*} + \frac{\Delta N_h}{m_{ch}^*}\right] \qquad \Delta n = -(6.2\times10^{-22})\Delta N_e - (6.0\times10^{-18})(\Delta N_h)^{0.8}$$

$$\Delta \alpha = \left(\frac{e^3\lambda^2}{4\pi^2 c^3 \epsilon_0 n}\right)\left[\frac{\Delta N_e}{{m_{ce}^*}^2 \mu_e} + \frac{\Delta N_h}{{m_{ch}^*}^2 \mu_h}\right] \qquad \Delta \alpha = (6.0\times10^{-18})\Delta N_e + (4.0\times10^{-18})\Delta N_h$$

$$I_s = q\left[\mu_p N_p + \mu_n N_n\right]$$

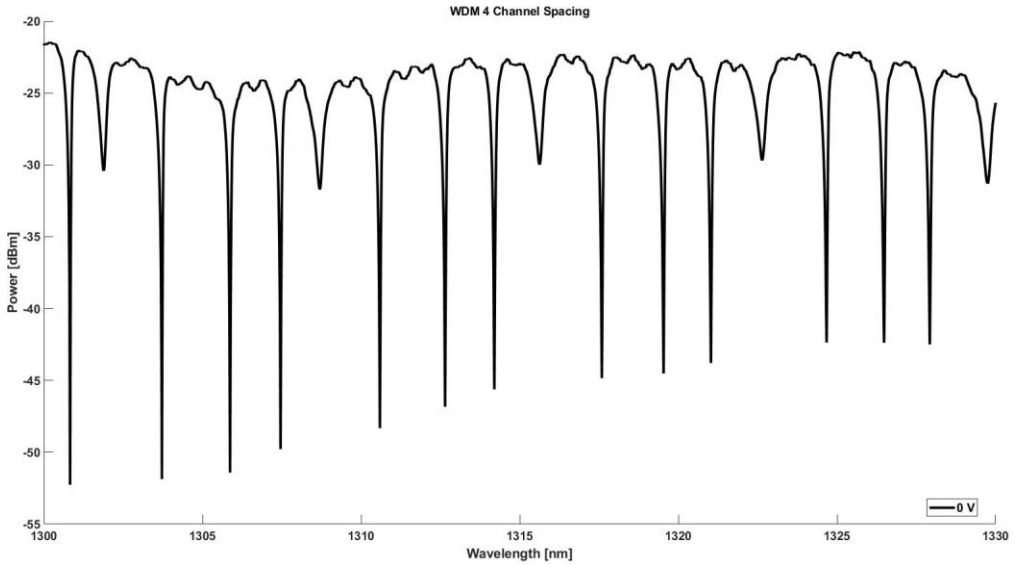
Soref, Richard & Bennett, Brian. (1987). Electrooptical effects in silicon. Quantum Electronics, IEEE Journal of. QE-23. 123 - 129. 10.1109/JQE.1987.1073206.

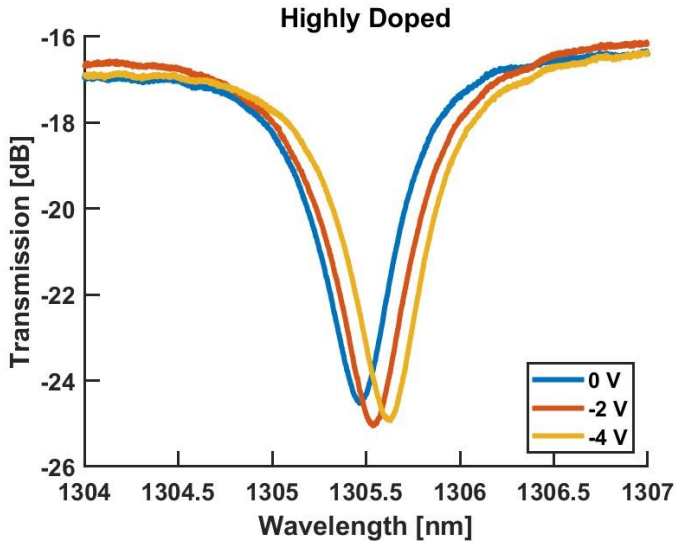
B. Wang et al., "A Compact Verilog-A Model of Silicon Carrier-Injection Ring Modulators for Optical Interconnect Transceiver Circuit Design," JLT, vol. 34, no. 12, pp. 2996-3005

New Devices

Previous Devices

- Nominally doped WDM 4 Ch
  - 9.9, 10.0, 10.1, 10.2 um MRMs
  - P/N doping forms junction
  - Design error on CH 3 caused anomaly
- Highly doped single channel
  - 10.0 um radius MRM
  - P+/N+ doping in the junction
  - Undercoupled device results in low extinction ra*tio





4C05 Highly Doped WDM

- 4 Highly Doped MRMs
- 9.9, 10.0, 10.1, 10.2 um radii
- 150 nm gap
- Designed to be evenly spaced in half of FSR
- Still pending active sweep for phase shift efficiency & ER