Radiation Testing of Silicon Photonics Modulators

Results and plans

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Opto Working Group Mini Workshop

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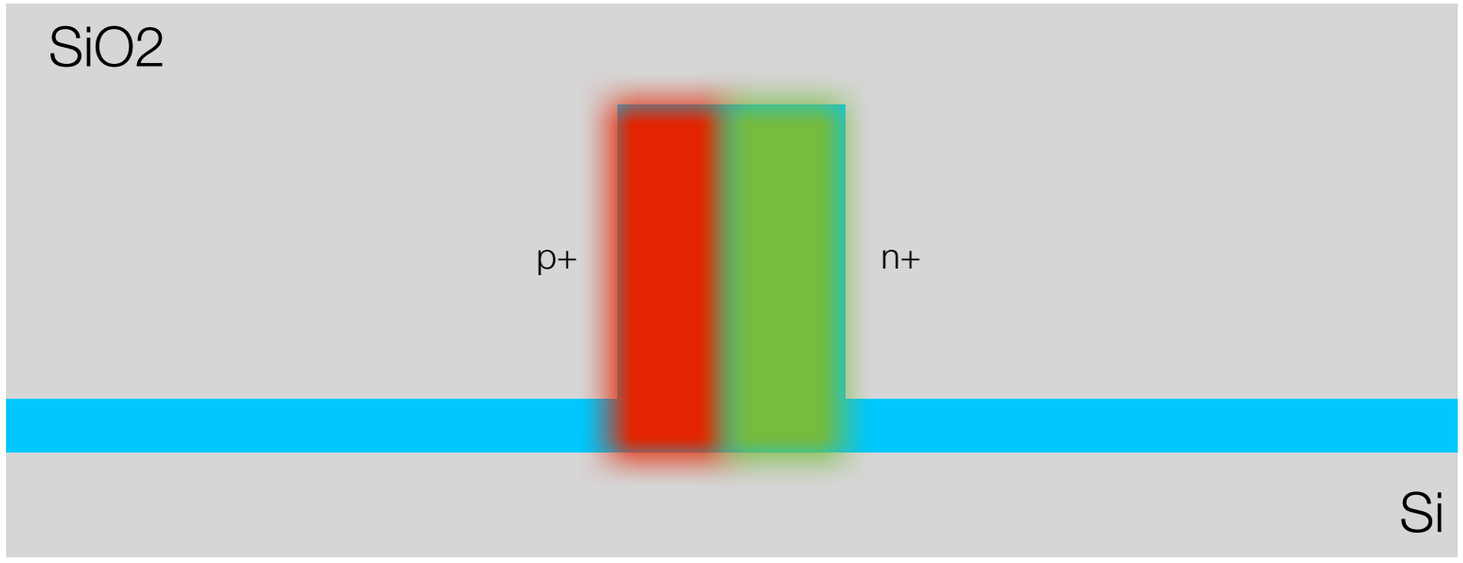
Outline

- Introduction
- Results from radiation test
- Conclusions & Future Work

Silicon Optical Modulator

- **Refractive index of silicon depends on the number of free carriers available in the material**
  - as an example take a simple pn junction built in-to silicon waveguide



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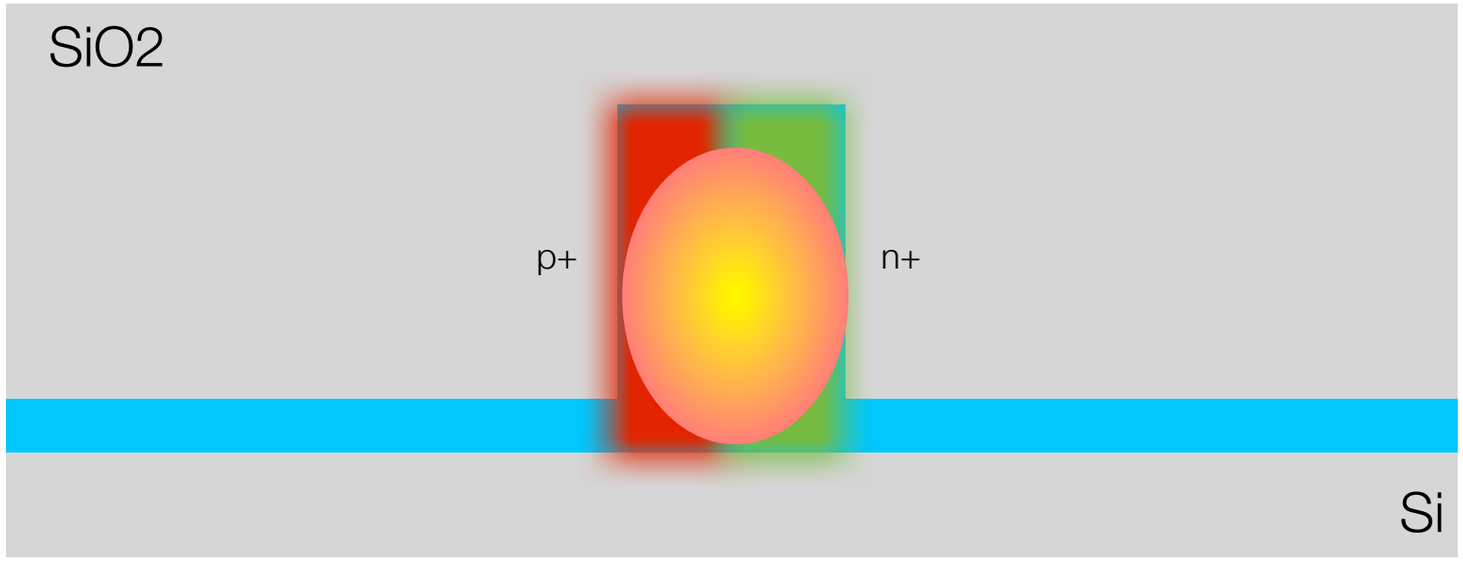

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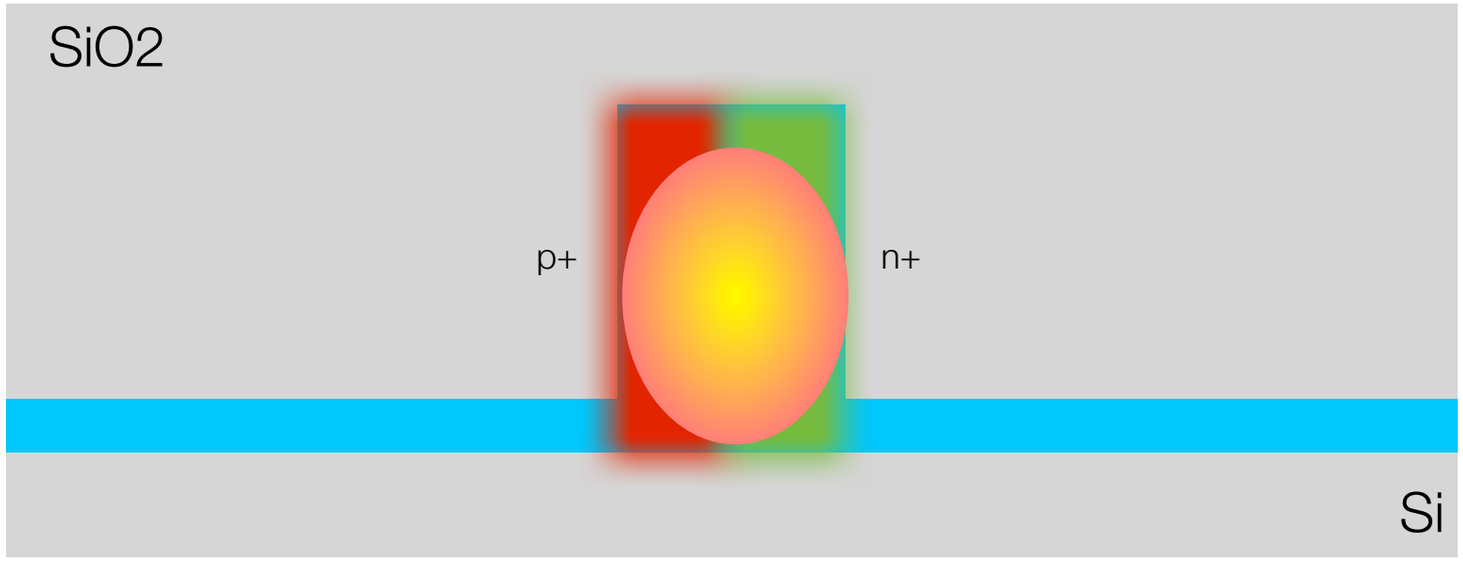

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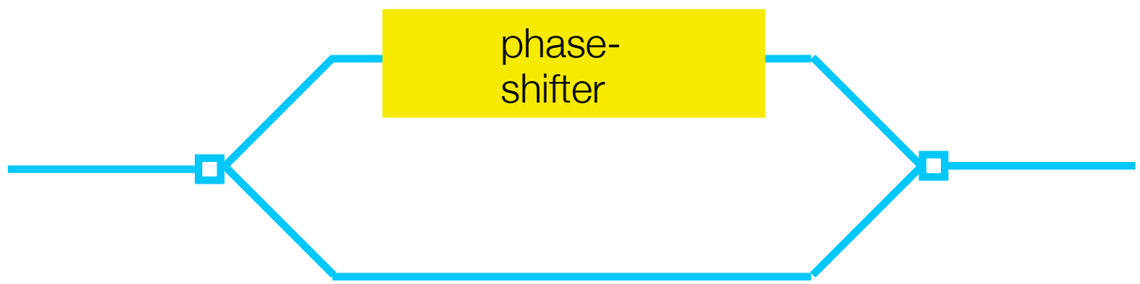
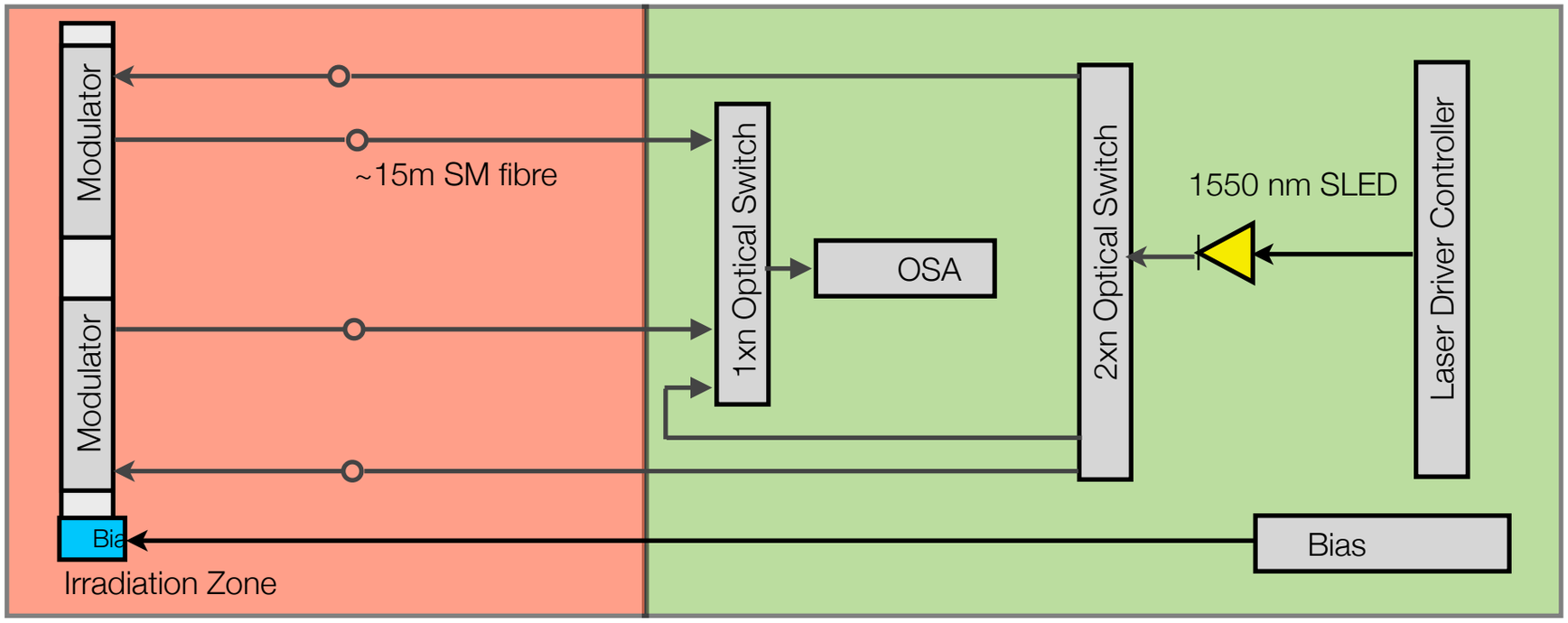
  - change in carriers is converted in a change in the effective refractive index of an optical mode traveling in the waveguide (i.e. a change in phase)
  - change in phase is converted to a change in amplitude
    - e.g place the junction in an arm of a Mach-Zehnder interferometer

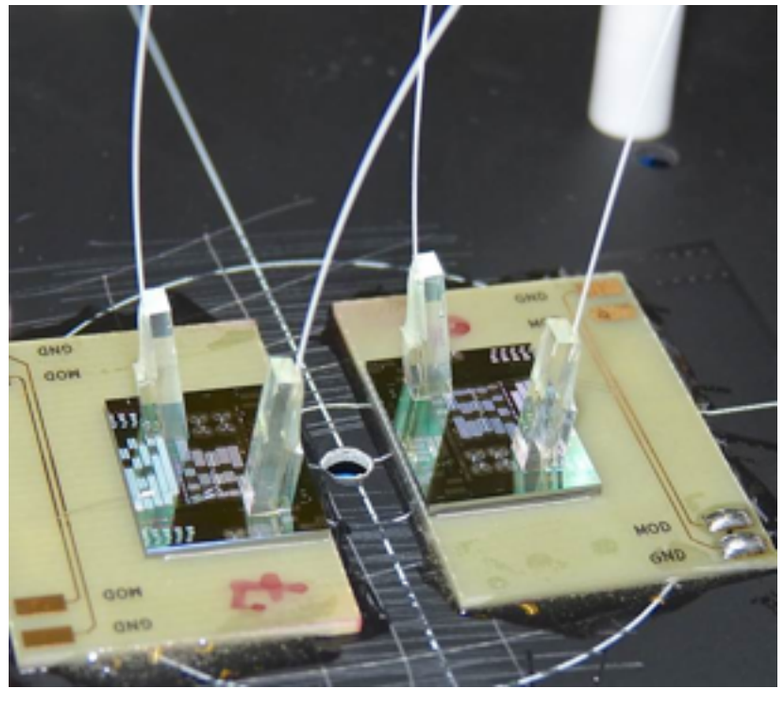


Radiation Test on Mach-Zehnder Silicon Optical Modulator

- **Radiation test carried out on Mach-Zehnder silicon optical modulators**
  - 20 MeV neutron beam at Louvain-La-Neuve to a fluence of 0.8×10^{15} n/cm^2



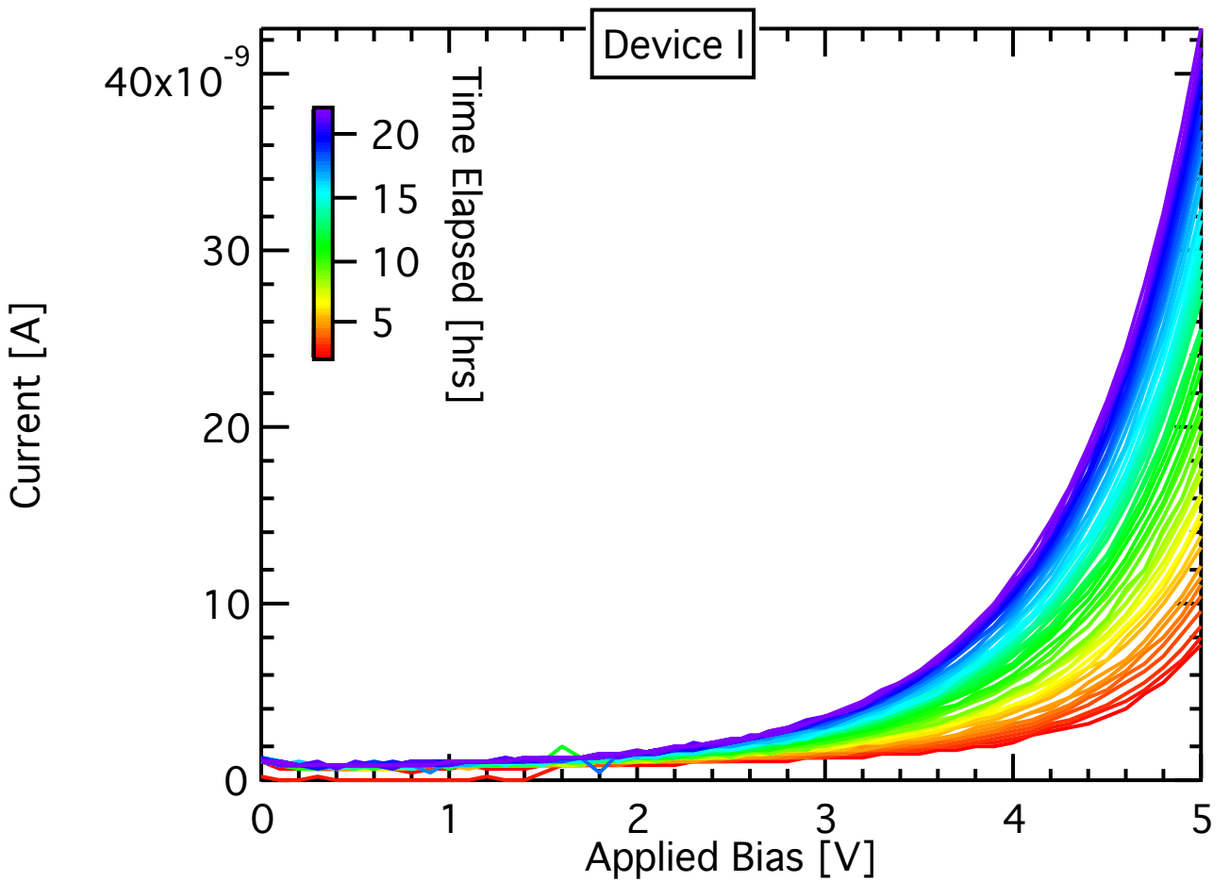
- **Test set-up used to measure**
  - modulation efficiency of the 2 DUTs during the test
  - reverse current of the DUTs during the test

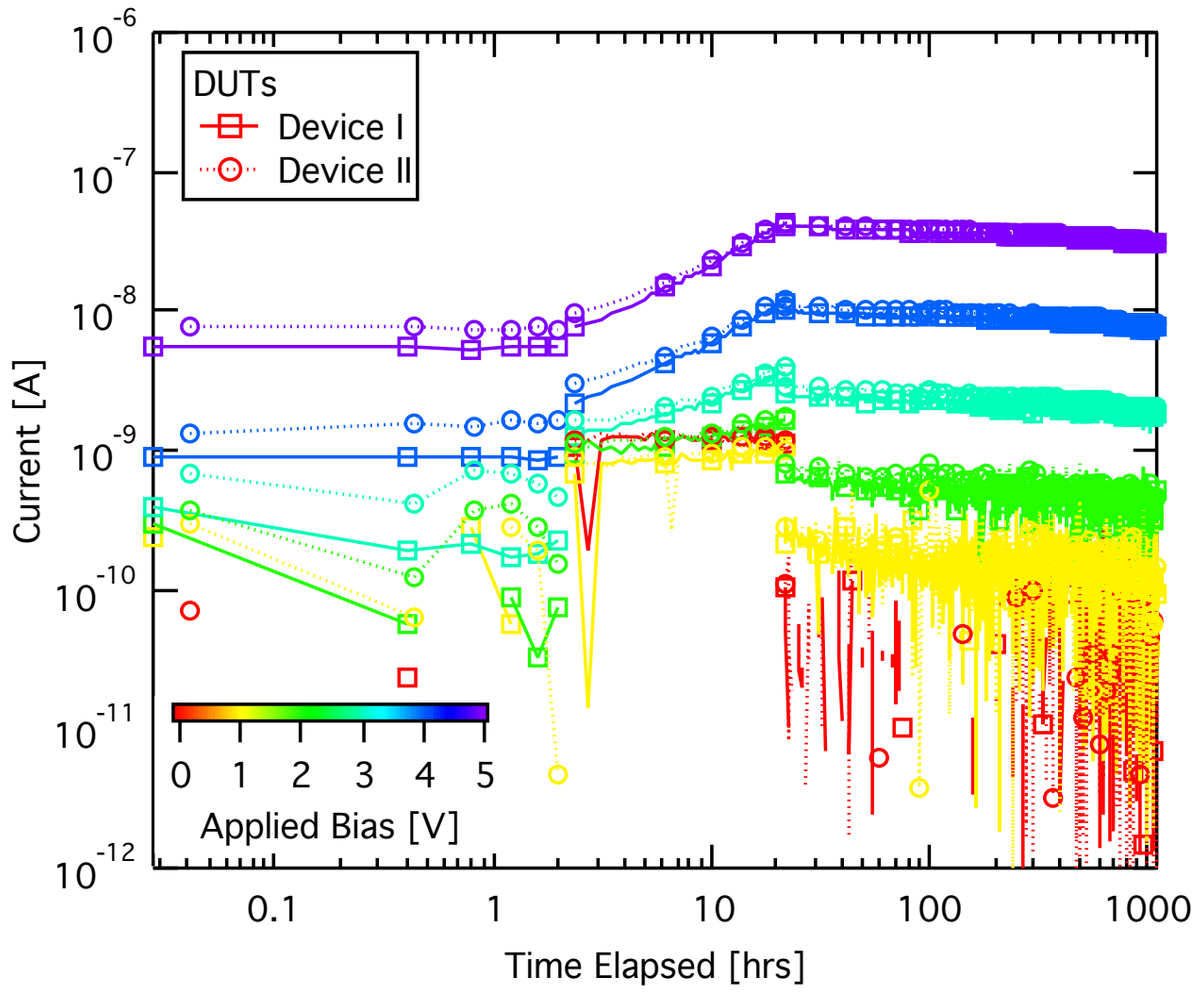


test-chip with one pigtailed sample on each prepared on irradiation PCB

Effect of radiation on IV

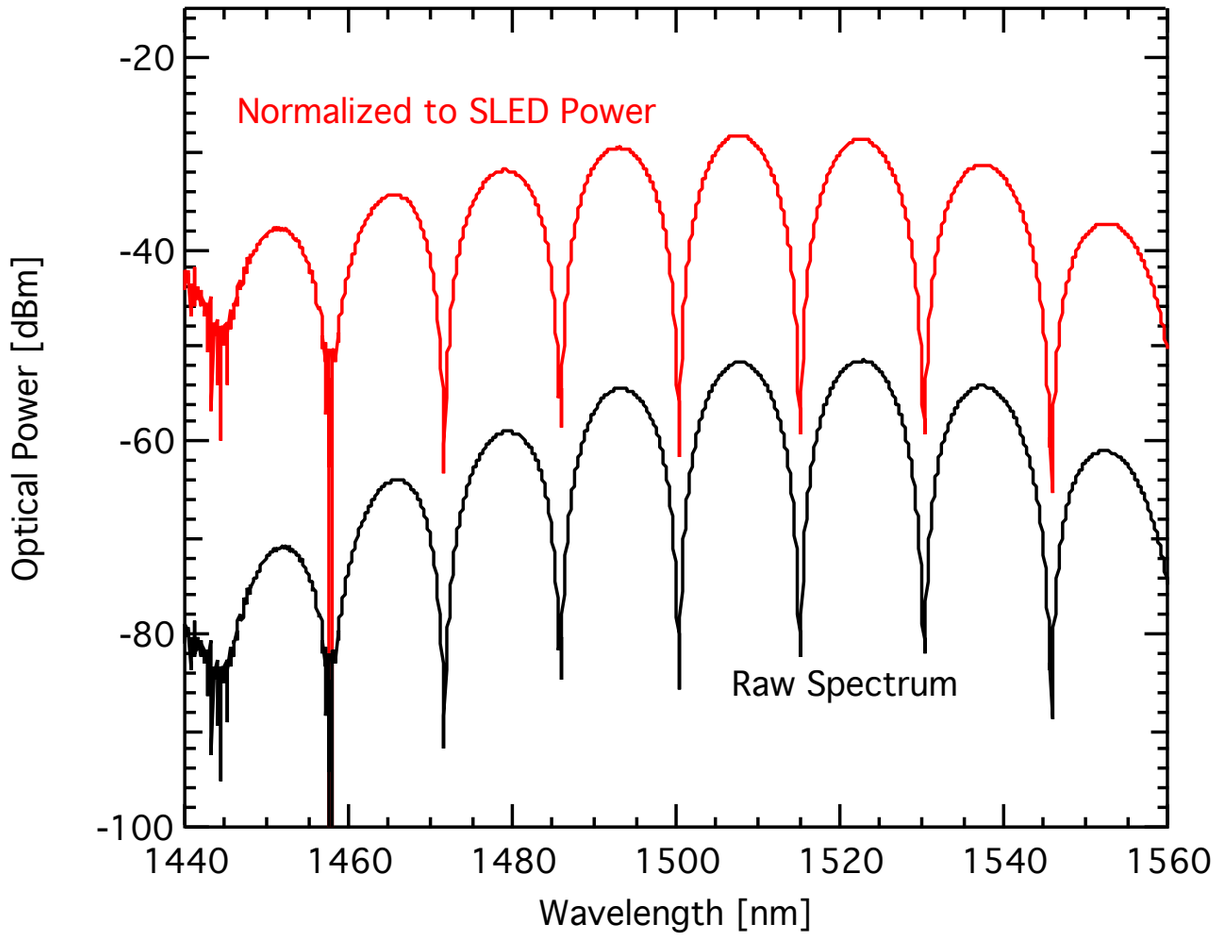
- **IV curves of irradiated modulator**
  - reverse current increases during irradiation
  - increase is linear with fluence
  - modulator reverse I-V behaves as you would expect from an irradiated diode





Extracting the modulation efficiency of the MZIs

- **Optical spectra collected during test used to calculate the modulation efficiency of the devices under test**
  - all transmission spectra normalized to SLED output power



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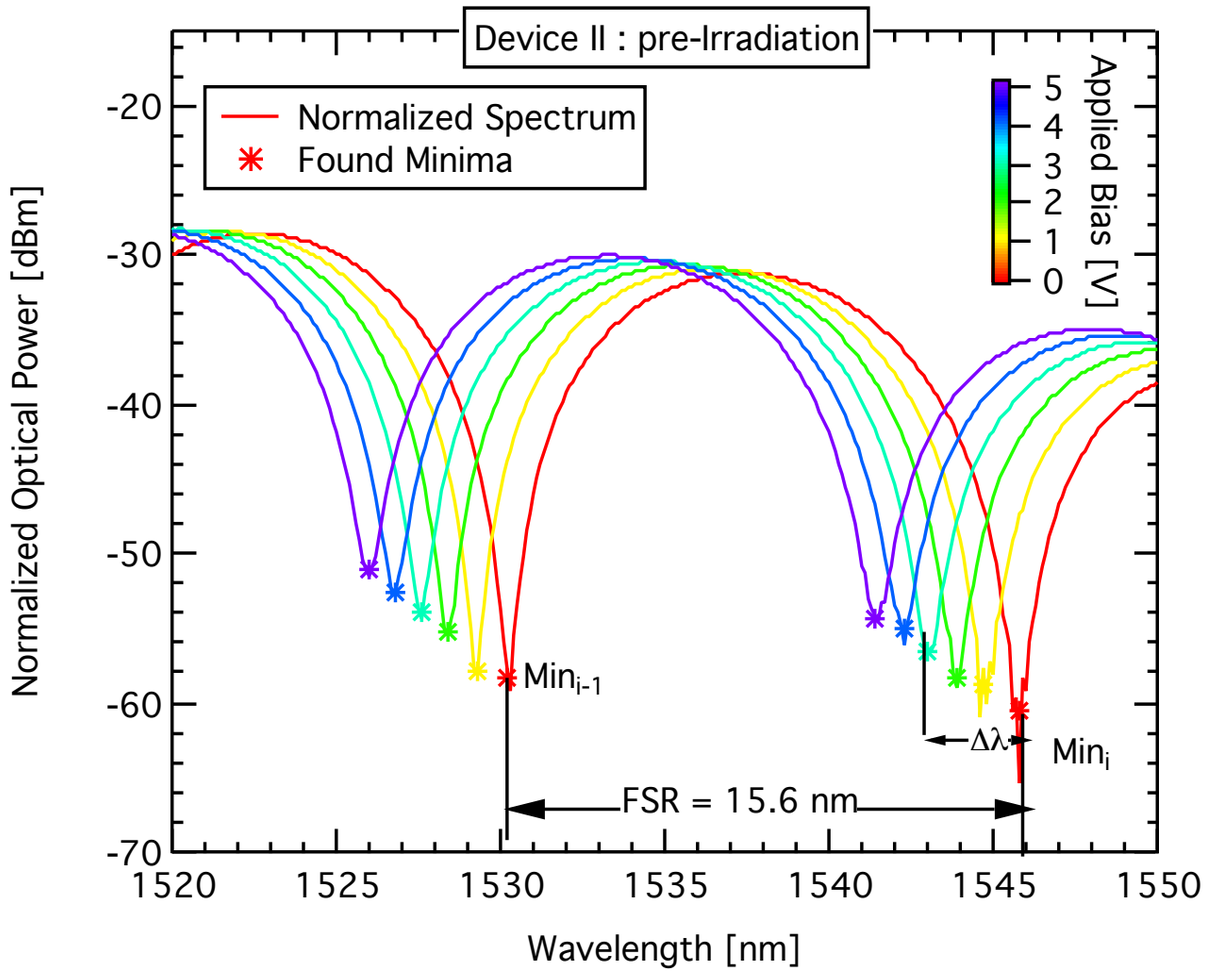


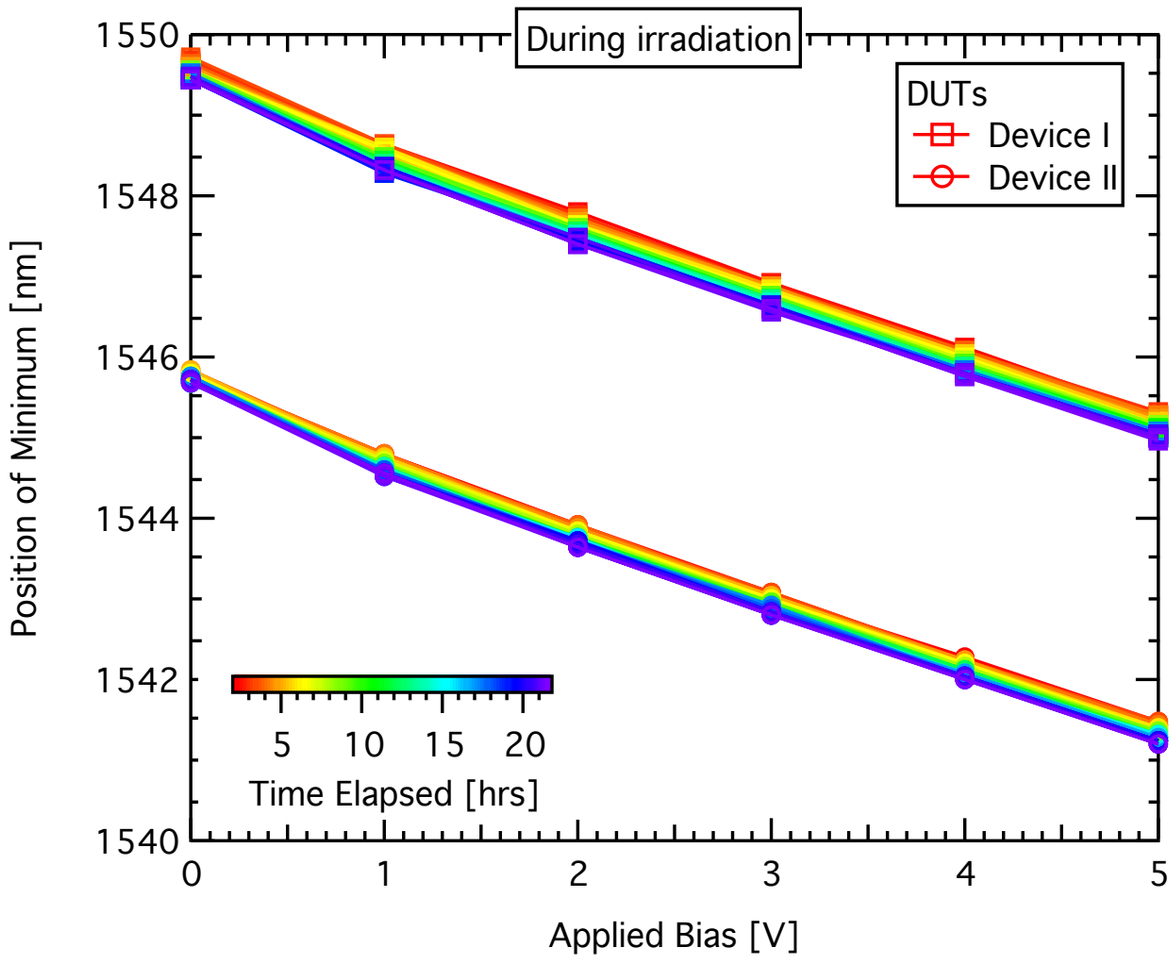
$$\Delta\phi = \frac{2\pi\Delta\lambda}{FSR}$$

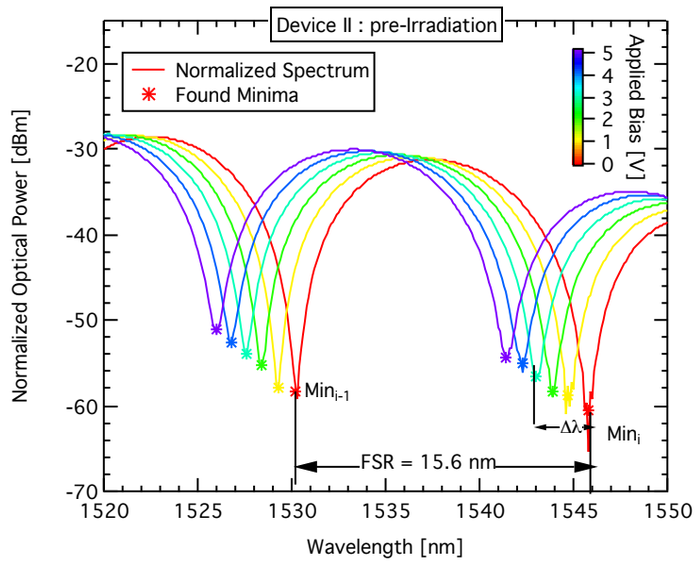
- transmission spectra used to locate minima closest to 1550 nm
- figure of merit used to characterize performance of modulator : $V_\pi L_\pi$ (the smaller the better)

$$V_\pi L_\pi = V_{applied} L_\pi = V_{applied} \frac{L}{\Delta\phi}$$

Extracting the modulation efficiency of the devices

- **Transmission spectra of devices shift during irradiation**
  - track position of minimum closest to 1550 nm during the irradiation

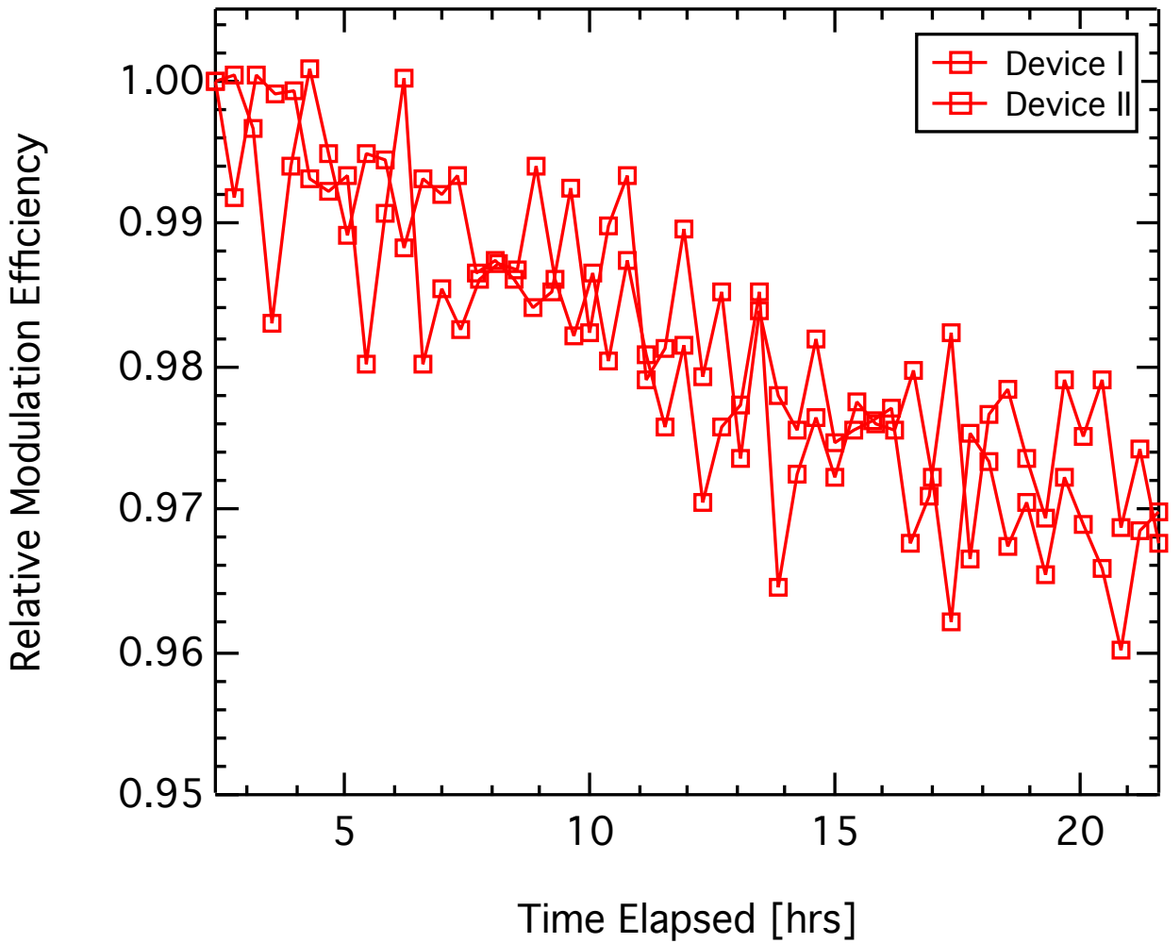


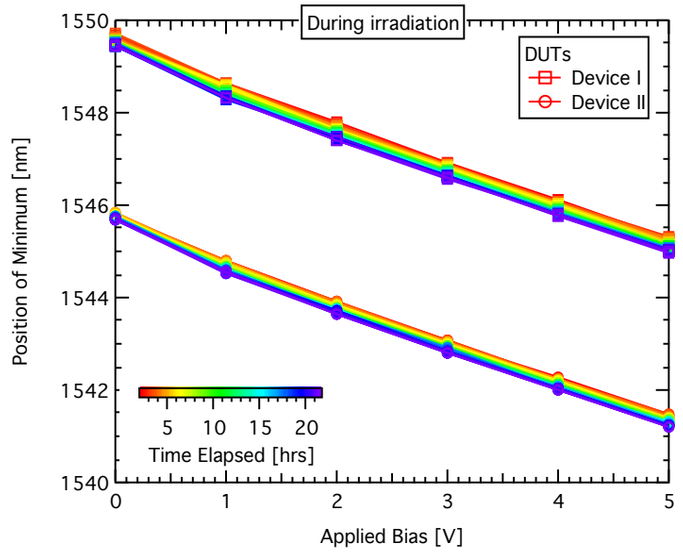


- **Device still working at the end of the test**
  - applying a bias still results in a change in the spectrum
  - how does this affect $V_\pi L_\pi$

Extracting the modulation efficiency of the devices

- Evolution of $V_\pi L_\pi$ during irradiation





Modulation efficiency during test normalized to pre-irradiation value

- **Change in device very small!**
  - few percent difference change in the modulation efficiency of the device
  - actually improving the device slightly

Conclusions & Future Work

- **First report on the effect of radiation on the performance of a silicon based MZI optical modulator**
  - devices irradiated to a fluence of 0.8×10^{15} n/cm^2 with 20 MeV neutrons
  - modulation efficiency and IV characteristic of devices measured on-line during the irradiation
  - very small change observed in the performance of the devices
    - small increase in leakage current
    - small (~3%) change in the modulation efficiency

- **Future work**
  - another irradiation to higher fluence
  - X-ray testing to figure out impact of TID
  - device simulation of the radiation induced damage in the devices