Radiation-Hardness of VCSEL/PIN Arrays

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March 4, 2010

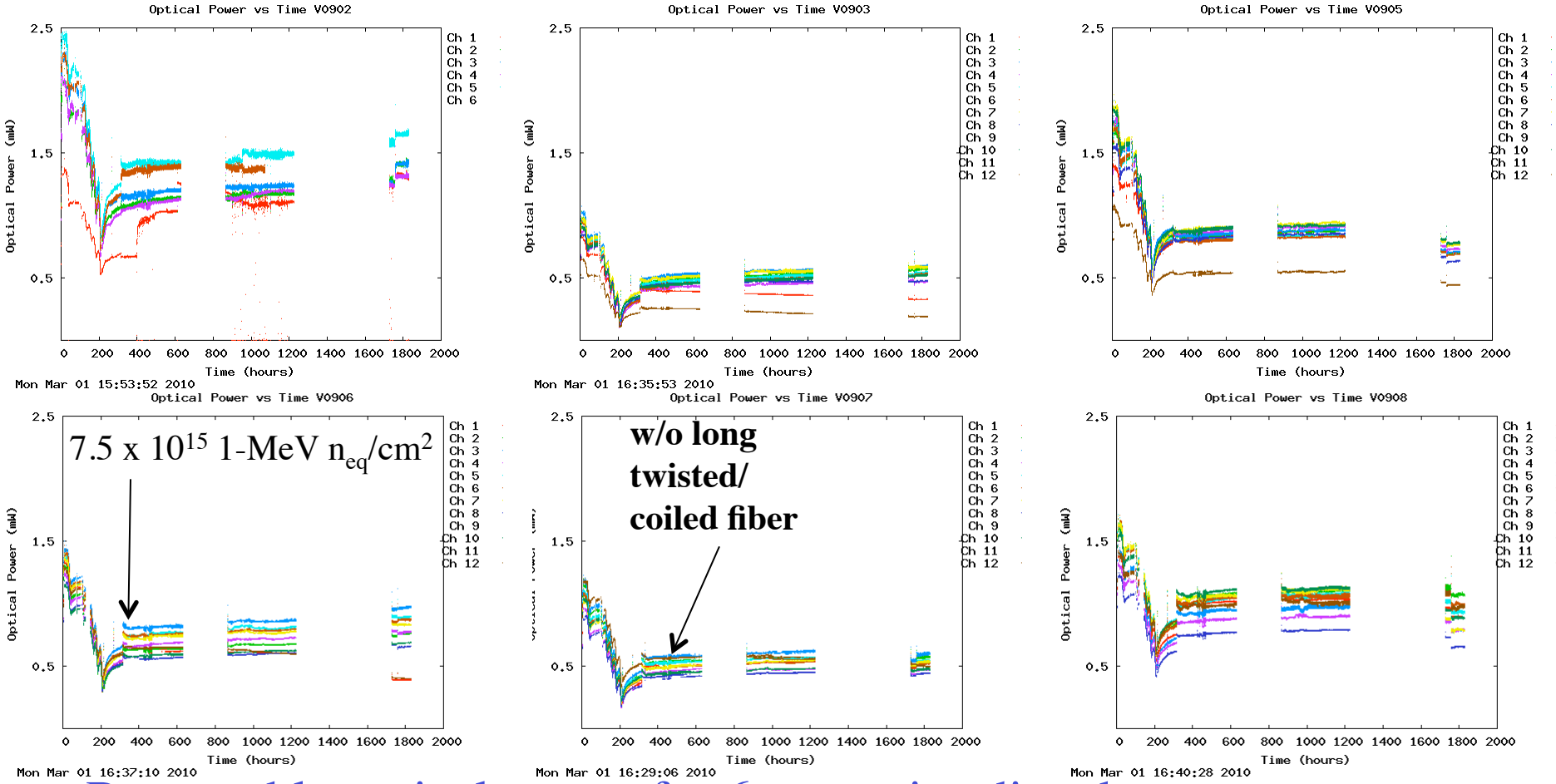
Outline

- Introduction
- Radiation hardness of VCSELs
- Radiation hardness of PINs
- Summary

2009 Irradiation

- After 3 years of irradiating ~2 samples/device with 24 GeV protons at CERN, the following arrays are identified as most promising:
  - 10 Gb/s AOC VCSEL array
    - ⇨ irradiate 6 AOC arrays in 2009 (limited by vendor problem)
  - Optowell PIN array
    - ⇨ irradiate 20 Optowell arrays in 2009

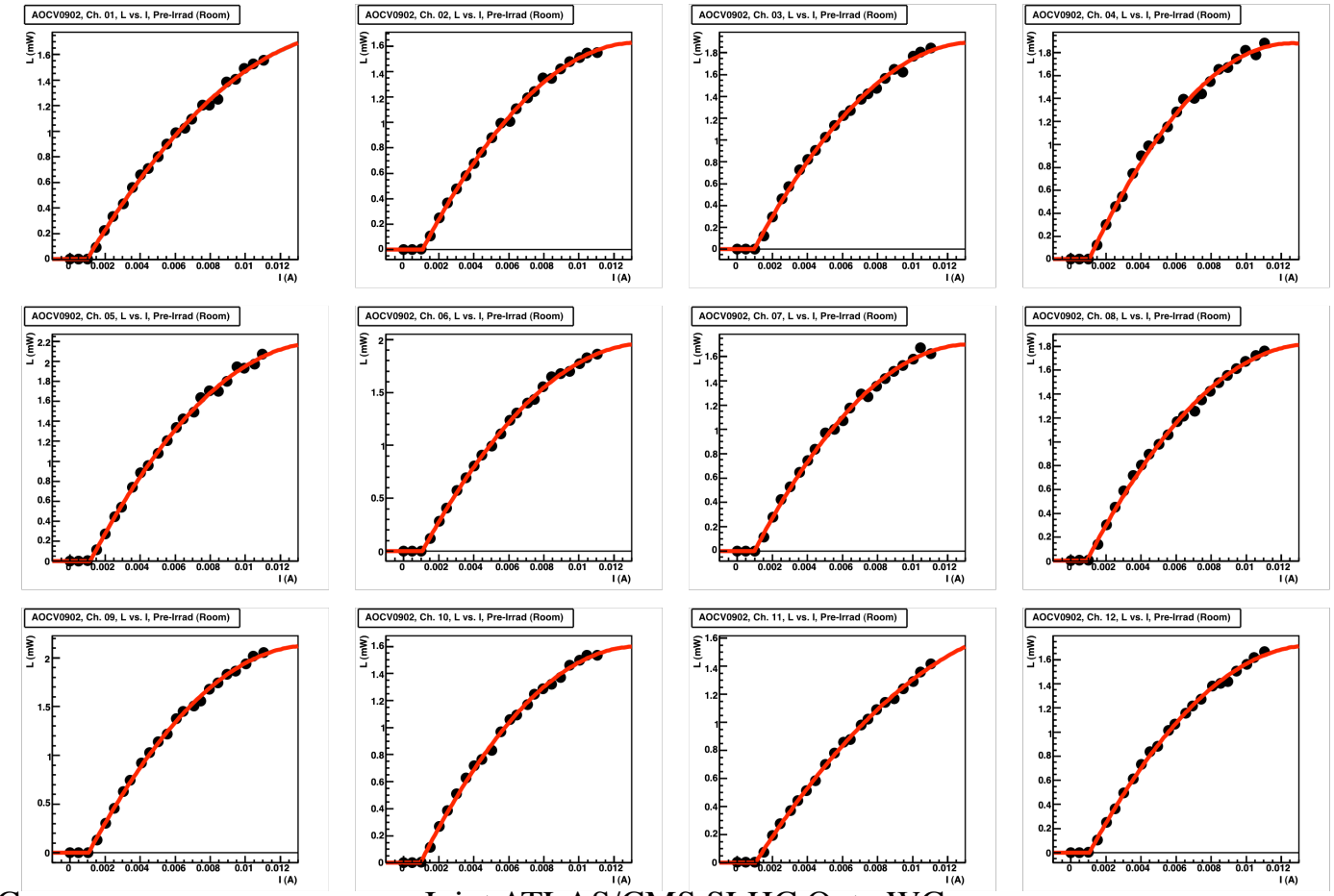
AOC 10 Gb/s VCSEL



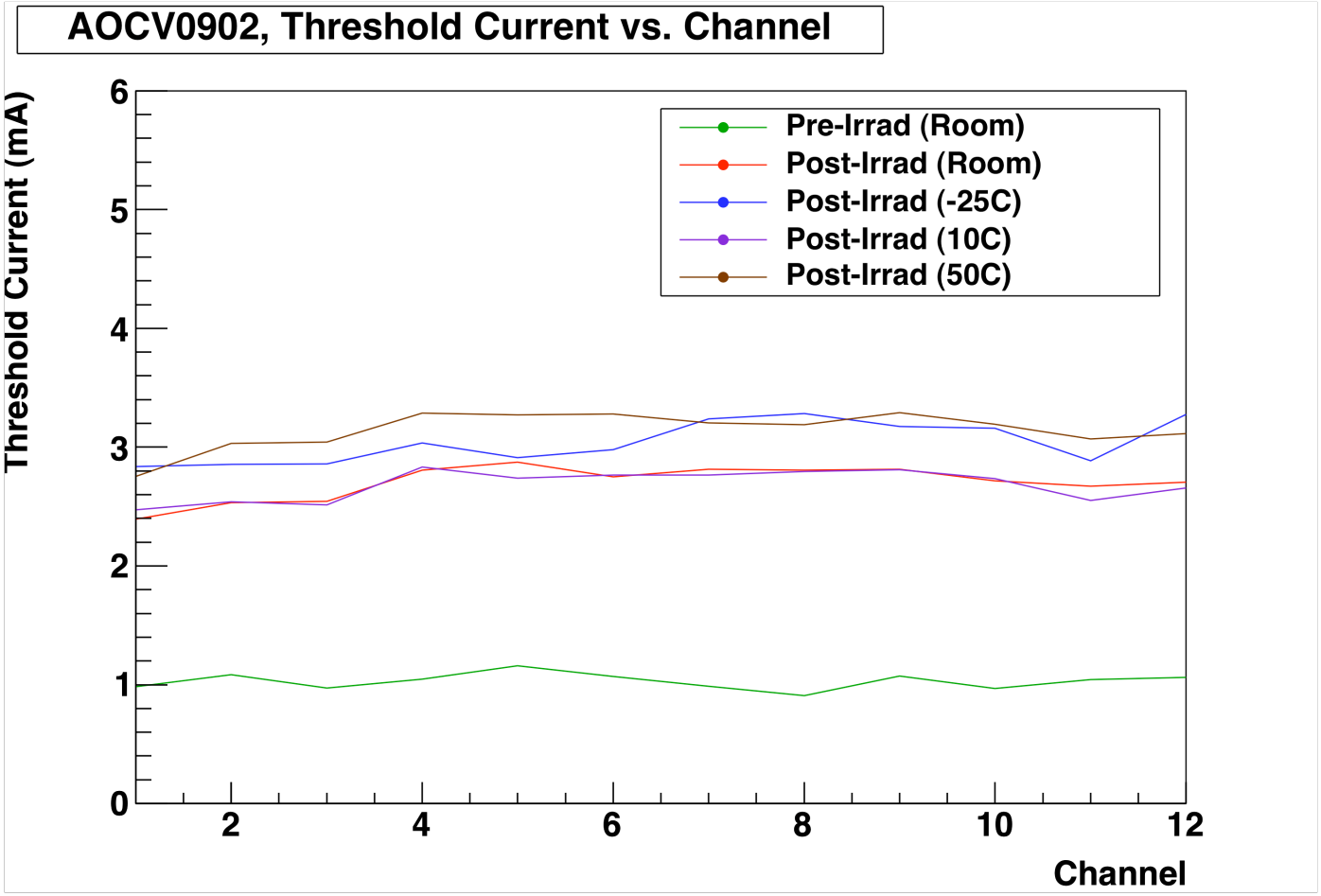
- Reasonable optical power for 6 arrays irradiated
  - slow recovery of optical power during annealing
  - ⇨ need to irradiate a sample of 20 arrays in 2010

VCSEL Threshold/Slope Fitting

- Fit LI curve to 2nd order polynomials
  - compare threshold and slope (1st order) vs dosage etc.

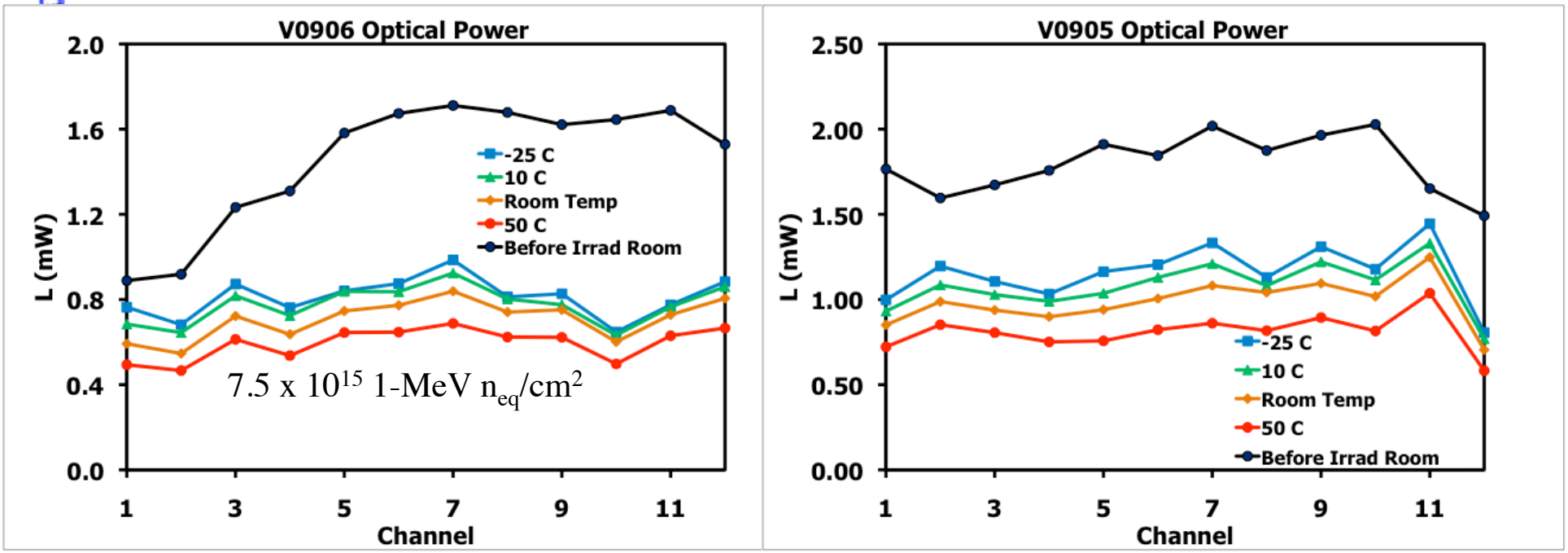


VCSEL Thresholds



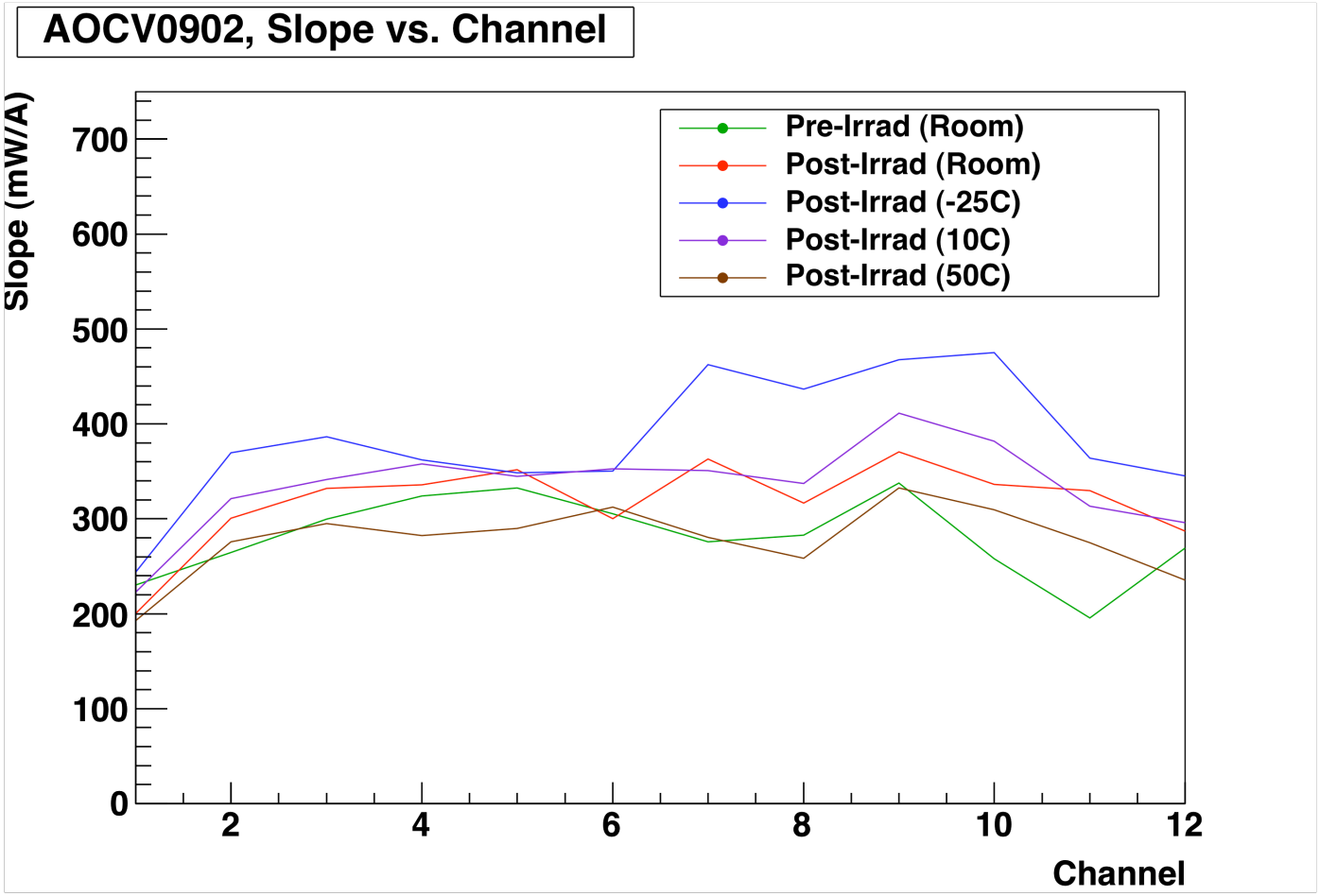
- Thresholds increase after irradiation as expected

VCSEL Power vs Temperature



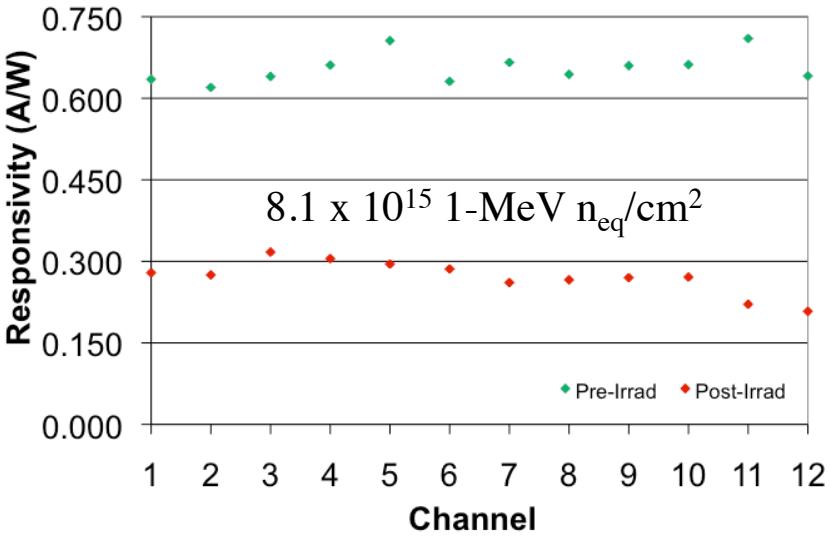
- Cooler VCSEL produces more optical power

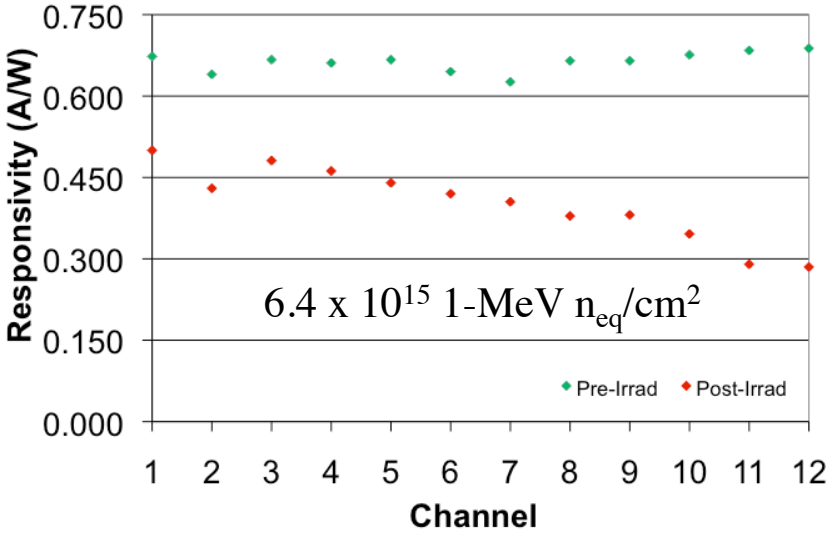
VCSEL Slope



- Slopes of irradiated VCSEL is similar to non-irradiated VCSEL
- Slopes decrease with increasing temperature

PIN Responsivity after Irradiation

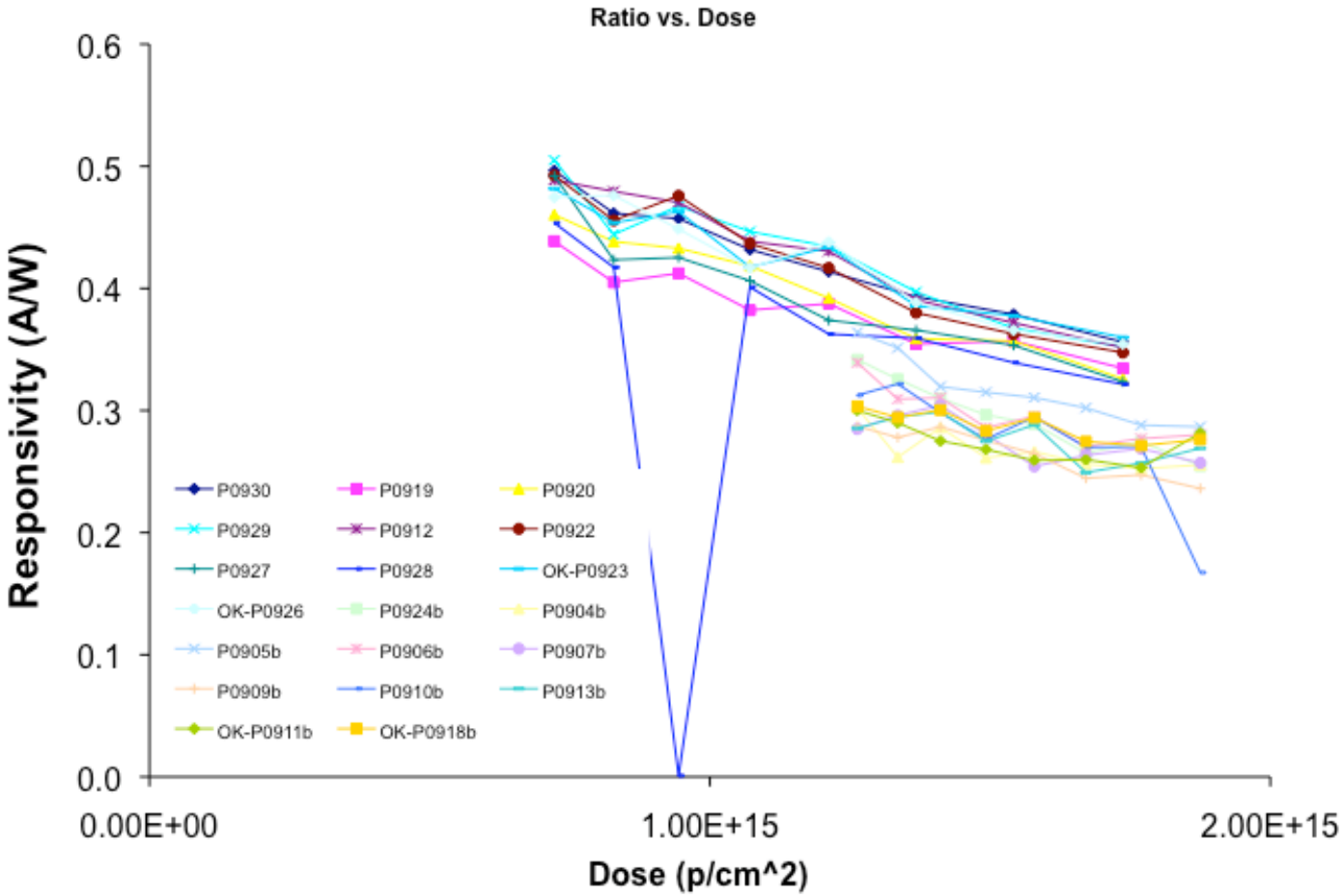




- PIN arrays were irradiated in two batches of 10 arrays each
- Beam alignments were different for the two batches

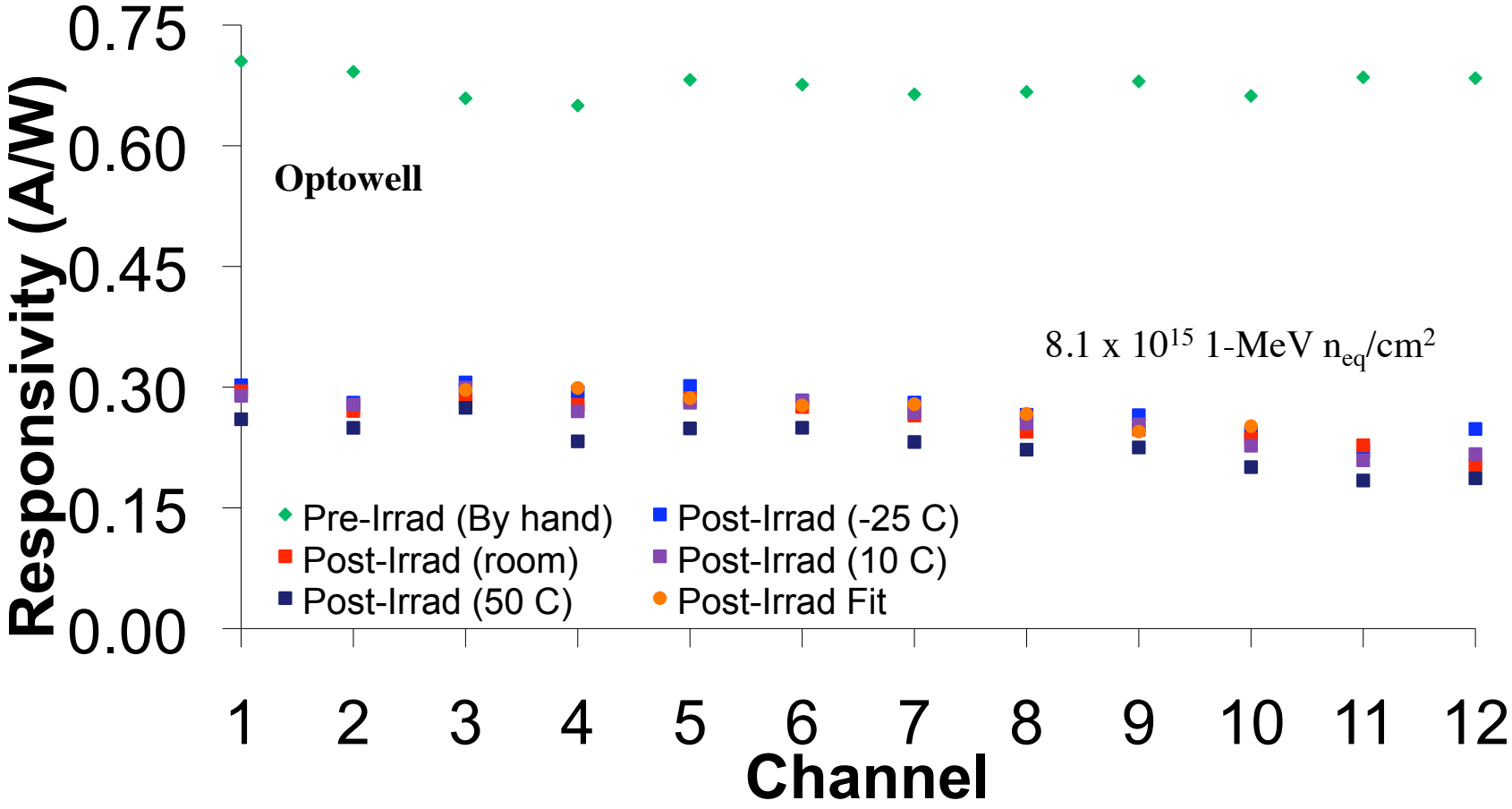
⇨ Different degradation in responsivity for the two batches

PIN Responsivity vs Dosage



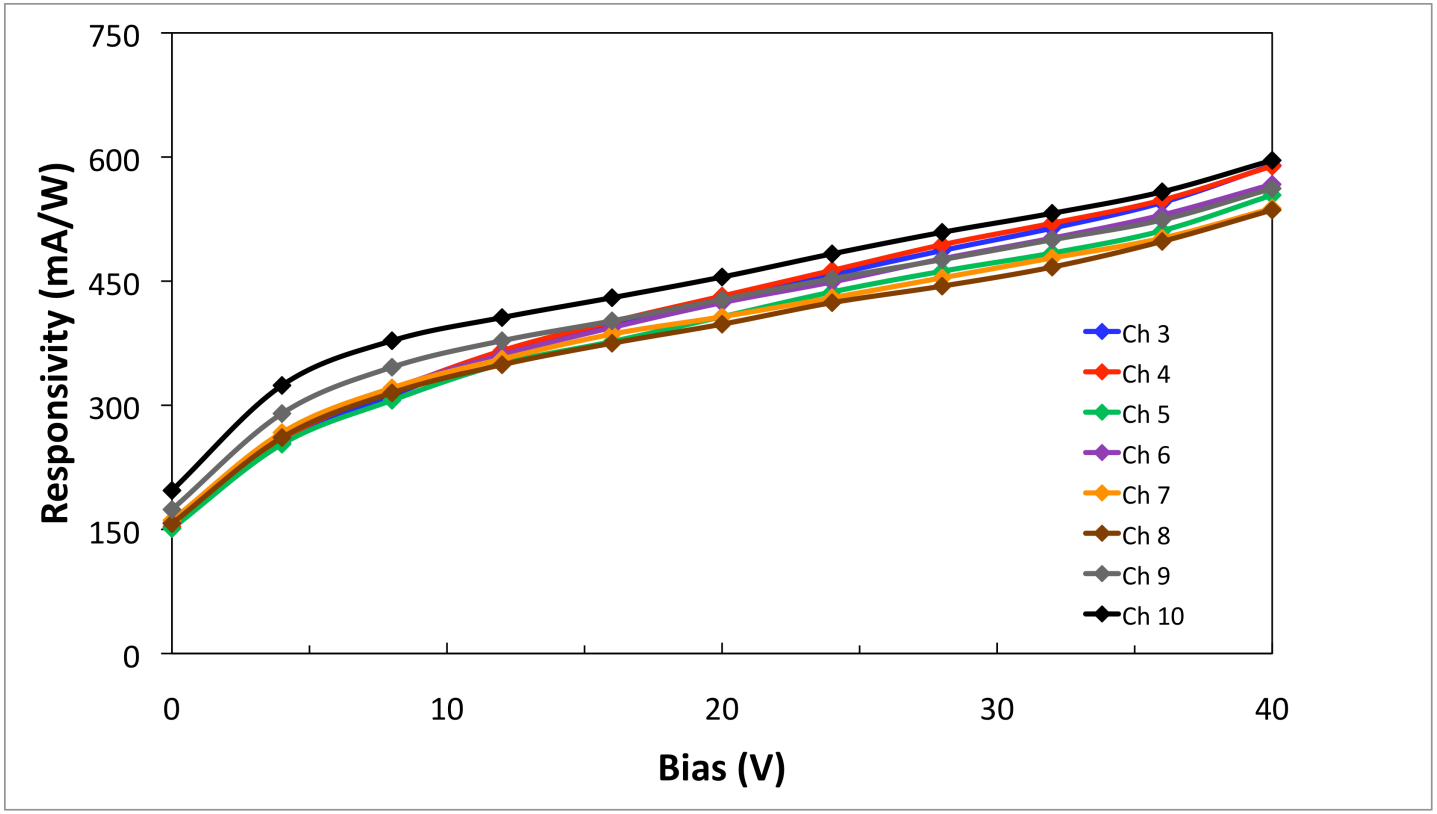
- the two batches have different responsivity vs dosage based on naive assumption of linear proton flux vs channel number

PIN Responsivity vs Temperature



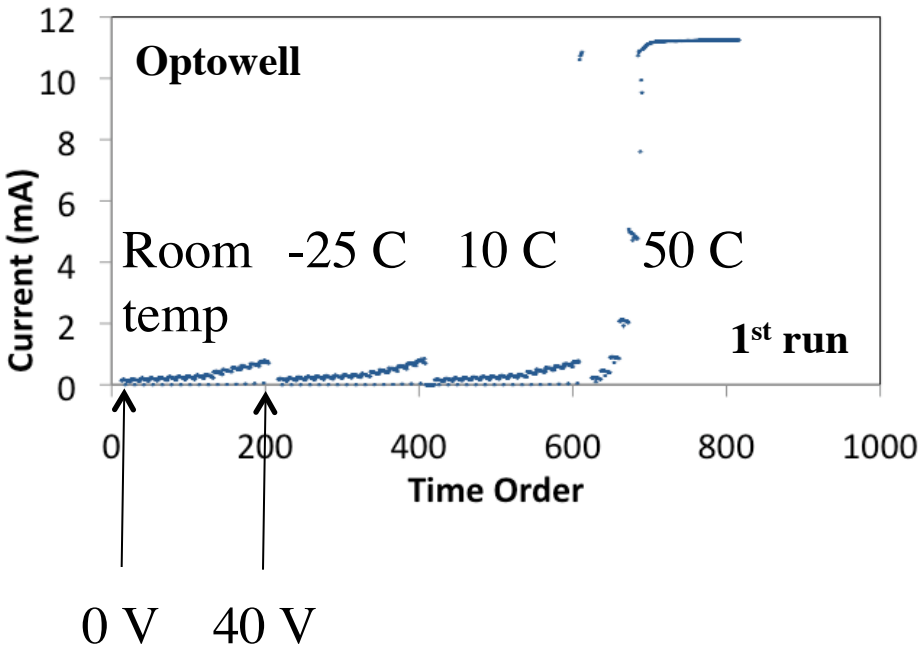
- Responsivity is slightly higher at lower temperature
- VCSEL and PIN have similar temperature dependence

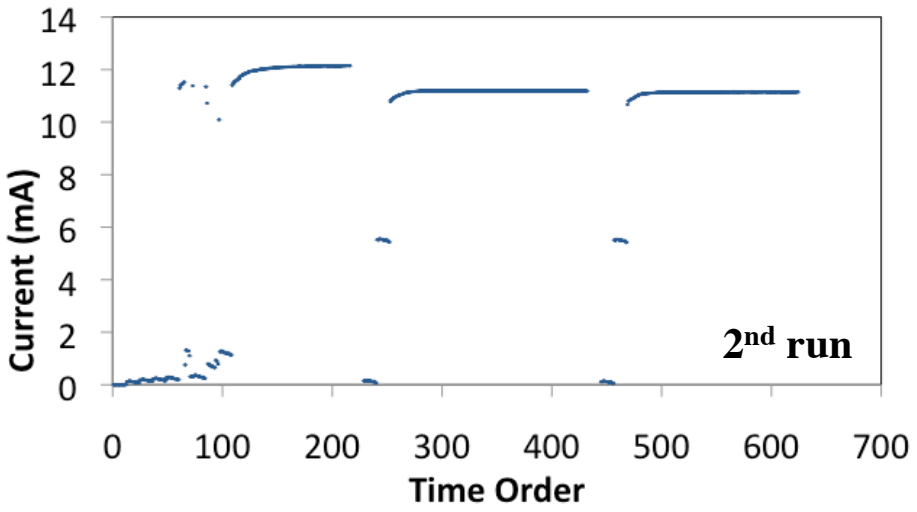
PIN Responsivity vs Bias Voltage



- can fully recover pre-irradiation responsivity with high bias voltage

PIN Current vs Bias Voltage





- Sudden breakdown in PIN current during ramping of bias voltage
- Once broken, entire array has high leakage current even at low voltages

PIN Leakage Current Problem

- Three out of 20 irradiated Optowell PIN arrays are now inoperable due to high leakage current
- Cause of breakdown unknown:
  - devices are not actually capable of operation at 40V as claimed by vendor?
  - did radiation damage reduce the operation voltage?
- Recovery plan:
  - need to purchase/package a large sample of Optowell arrays (> 20) for bias current study followed by irradiation in summer 2010
    - communicate with vendor
  - need to purchase/package a large sample of arrays (> 20) from a second vendor (ULM) for irradiation in summer 2010

Summary

- AOC VCSEL arrays have reasonable power after irradiation
  - plan to irradiate 20 arrays in 2010
- Optowell PIN arrays have good responsivity after irradiation
  - 3 out of 20 Optowell PIN arrays broken
  - need further investigation and second vendor
- VCSEL and PIN have similar temperature dependence
  - good to operate the devices at room temperature or lower