Radiation-Hardness of VCSEL/PIN

W. Fernando, K.K. Gan, H.P. Kagan, R.D. Kass, H.D. Merritt, J. Moore,
A. Nagarkar, D.T. Pignotti, J. Smith, S. Smith, M. Strang
The Ohio State University

M.R.M. Lebbai, P.L. Skubic
University of Oklahoma

B. Abi, F. Rizatdinova
Oklahoma State University

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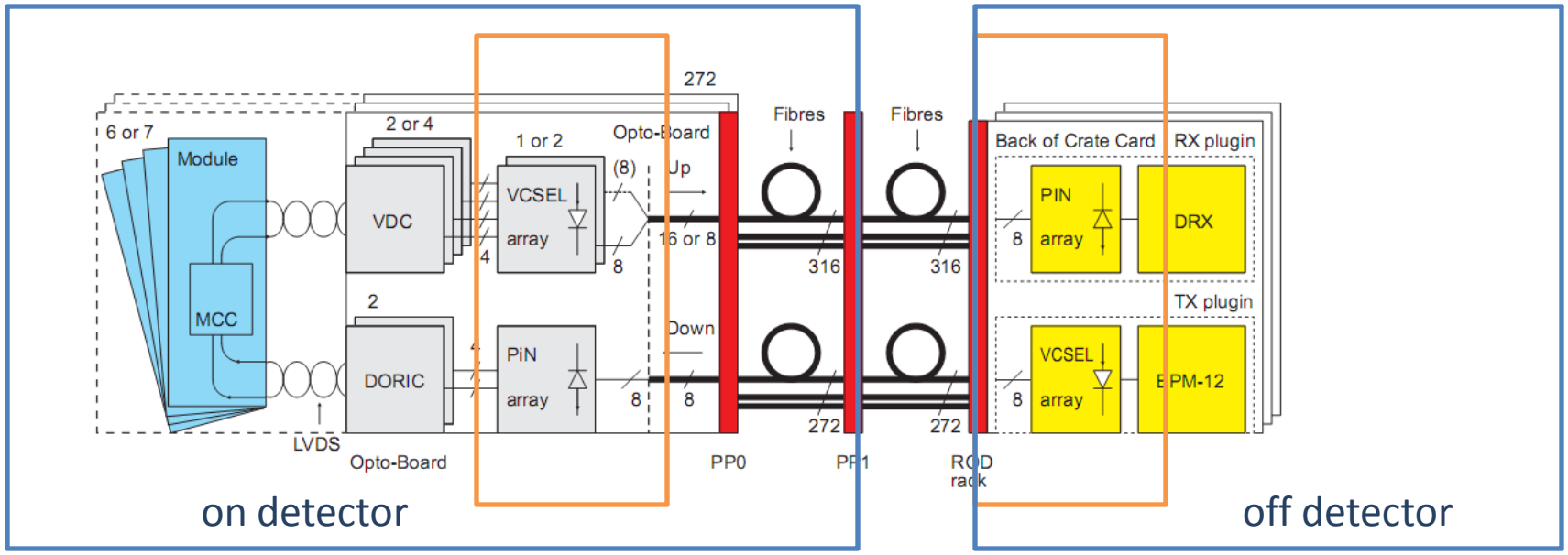
Outline

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

VCSEL/PIN Location of ATLAS Pixel Detector



- VCSEL : Vertical-Cavity Surface-Emitting Laser
- VCSEL/PIN mounted on patch panel PP0 at LHC
- Expected to be mounted at a location no closer than PP0 to the interaction region at SLHC

Radiation Dosage at SLHC

- Luminosity of SLHC: 10^{35} $cm^{-2}s^{-1}$
  - 10 x the luminosity of LHC
- Study degradation of VCSEL/PIN at "PP0"
- Irradiate Si and GaAs PINs; GaAs VCSELs
- Expected dosage at 3,000 fb^{-1} with 50% safety factor
  - Silicon: 1.5 x 10^{15} 1-MeV n_{eq}/cm^2
  - GaAs: 8.2 x 10^{15} 1-MeV n_{eq}/cm^2

Assuming radiation damage scales with Non Ionizing Energy Loss (NIEL)

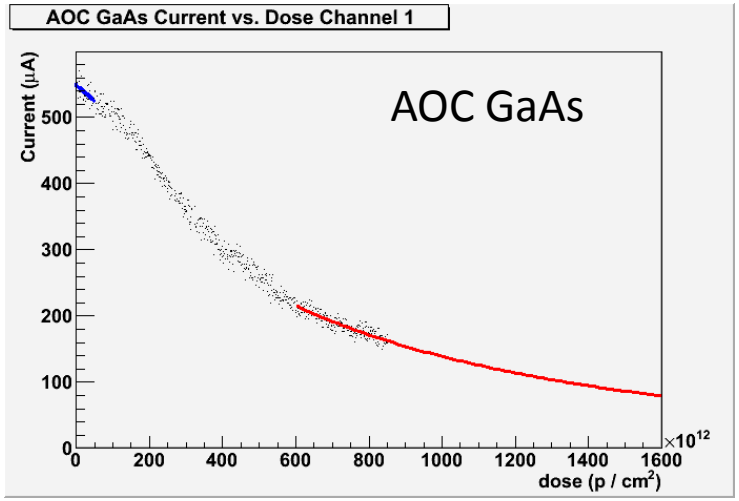
Irradiation Program in 2008

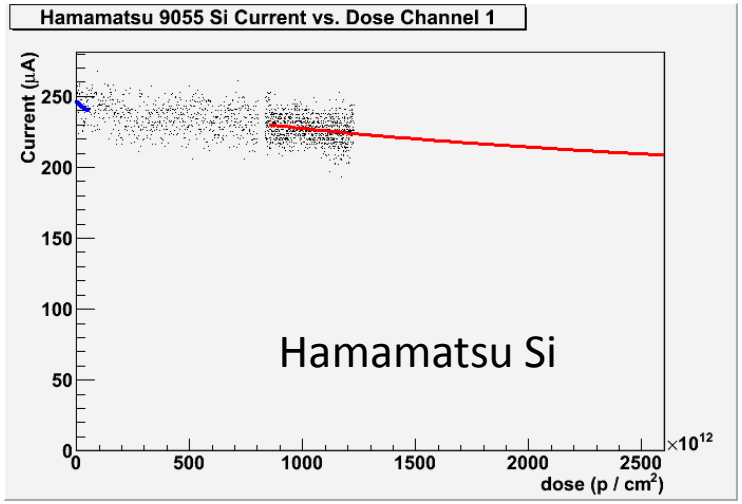
- Devices irradiated:
  - Si PINs :
    - 2 x Taiwan arrays
    - Single-channel silicon diodes from Hamamatsu (5 x S5973 and 6 x S9055)
  - GaAs PINs:
    - AOC, Optowell, ULM Photonics, and Hamamatsu G8921
  - GaAs VCSELs:
    - 2 x Optowell, AOC 5 Gb/s and 10 Gb/s array

Irradiation Program in 2008

- Irradiated to "official" 3,000 fb^{-1} with 50% safety factor
  - Beam profile changed after initial calibration for PINs
    - Dosage from initial calibration incorrect
  - Received ½ of the target dosage
  - Degradation has to be extrapolated

Degradation extrapolatation

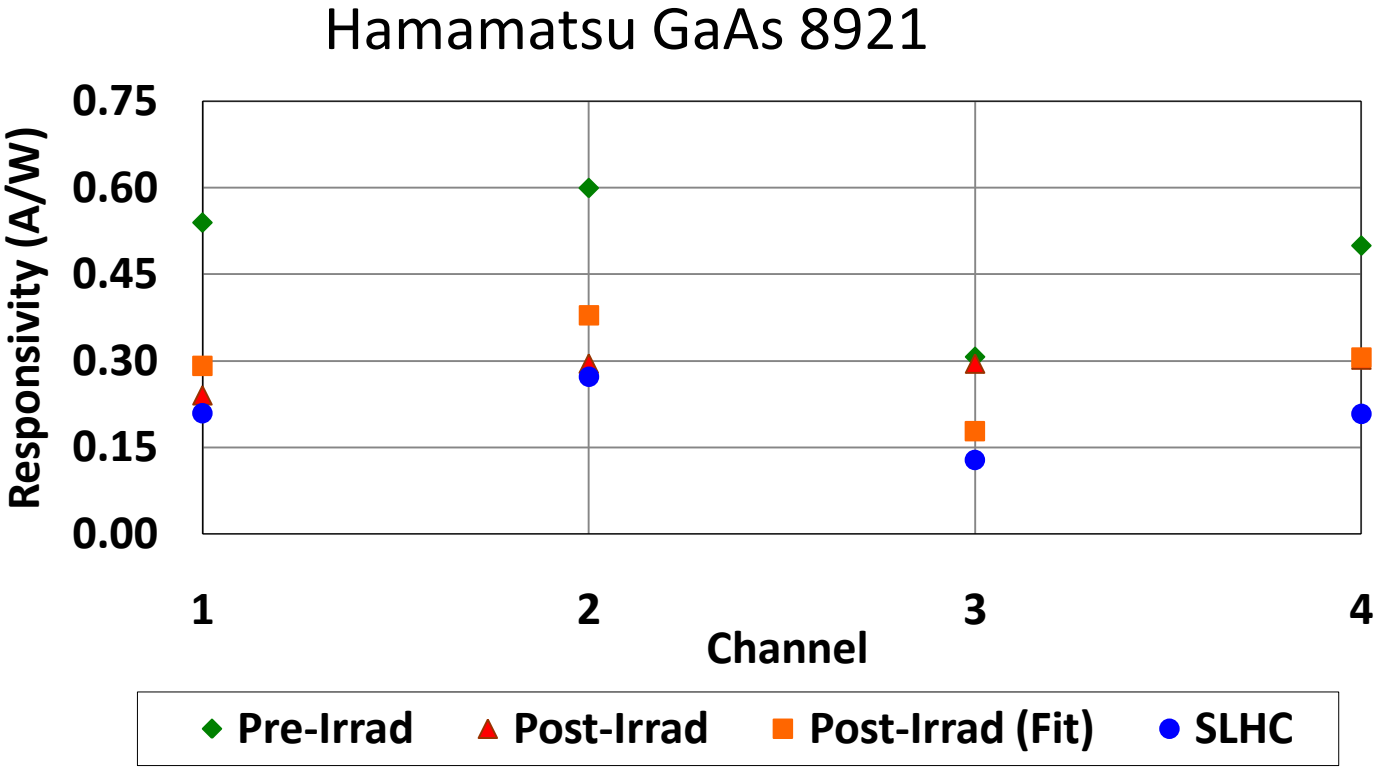




- The tail of the distribution fitted to extrapolate (Red)

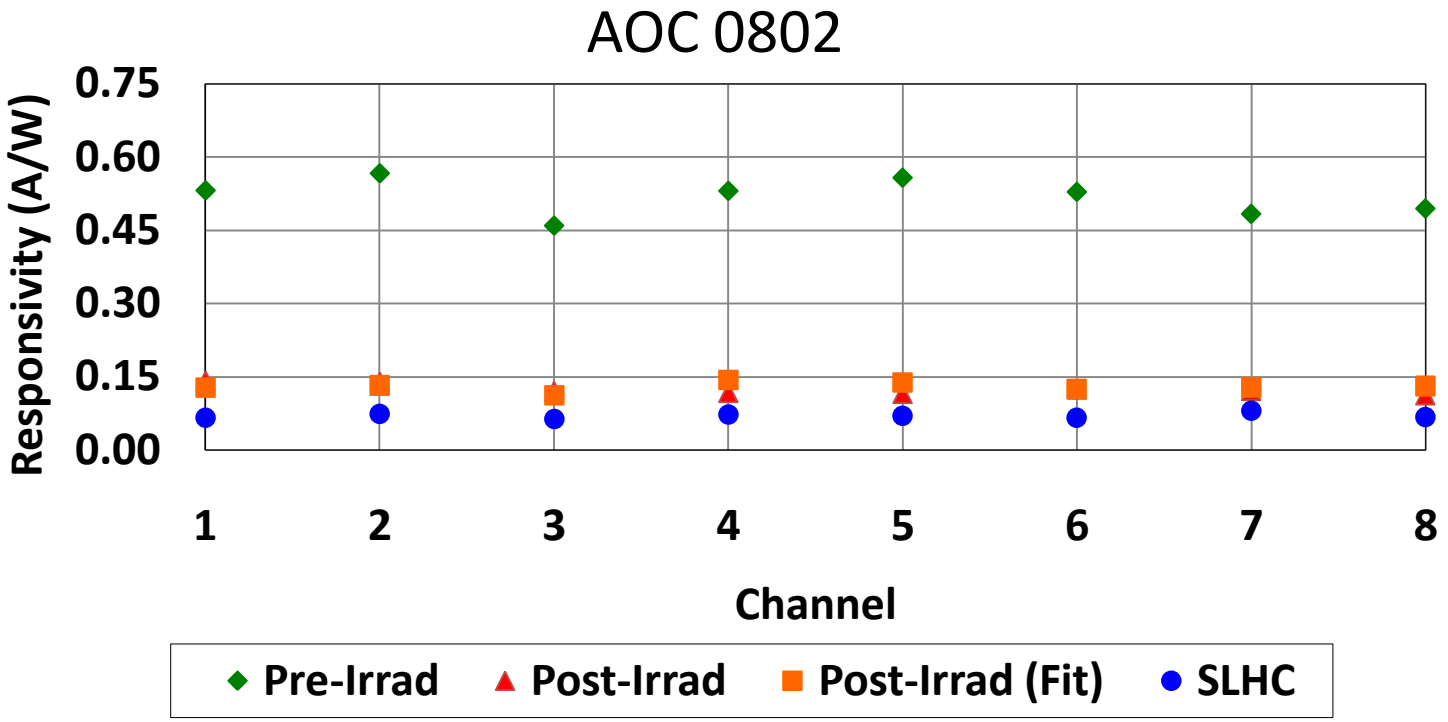
$$\frac{A}{(1 + B \times dose)^C}$$

Radiation-Hardness of PINs



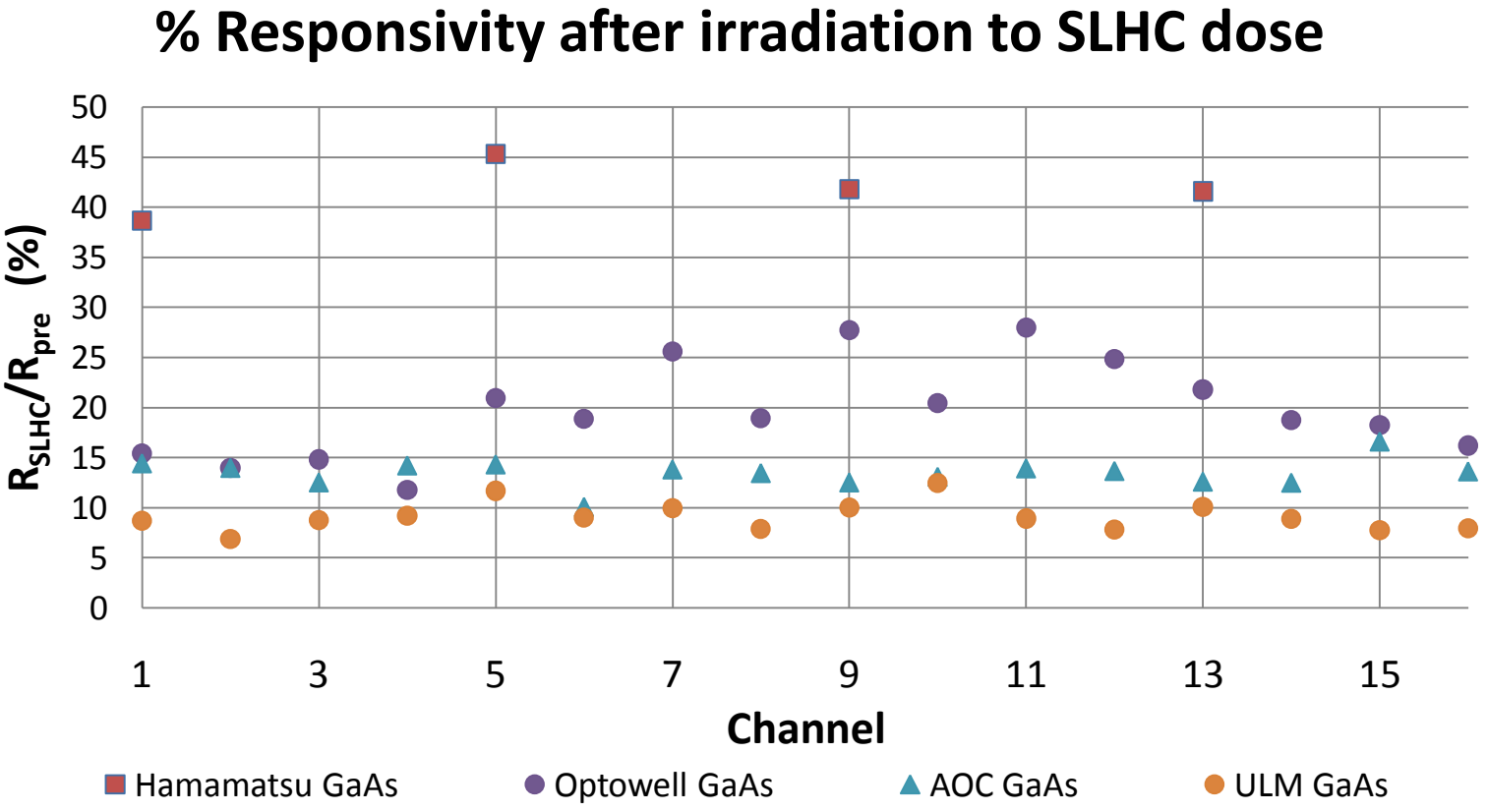
- Responsivity change : ~0.5 → ~0.2 A/W @ SLHC
- Radiation-hard @ SLHC

Radiation-Hardness of PINs



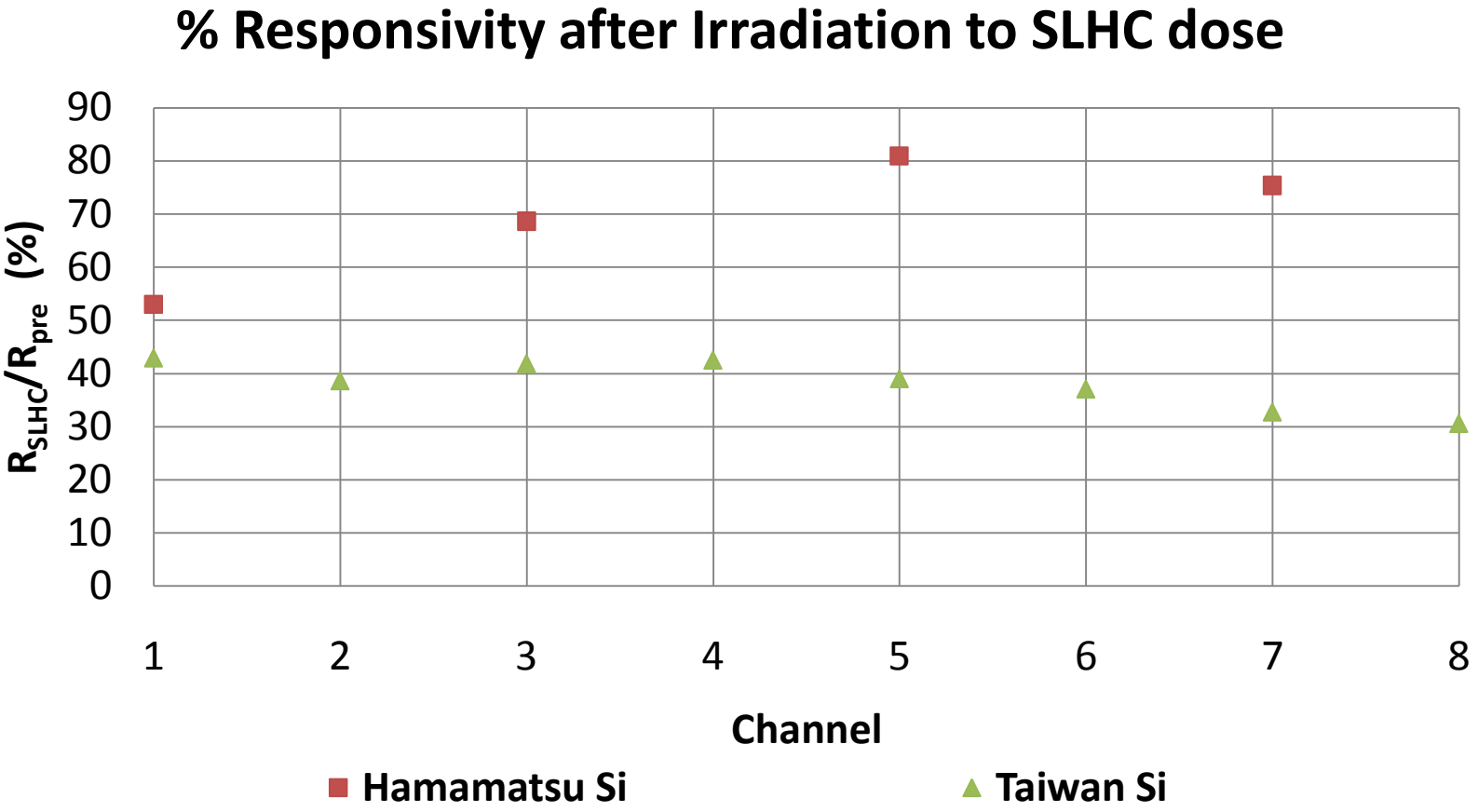
- Responsivity change : ~0.50 → ~0.04 A/W @ SLHC
- Not sufficiently radiation-hard @ SLHC

Responsivity after radiation : GaAs PINs



- Hamamatsu devices are more radiation hard
- ULM and AOC PINs are not quite radiation-hard

Responsivity after radiation: Si PINs



- Hamamatsu devices are more radiation hard
- Silicon PINs are quite radiation-hard as expected

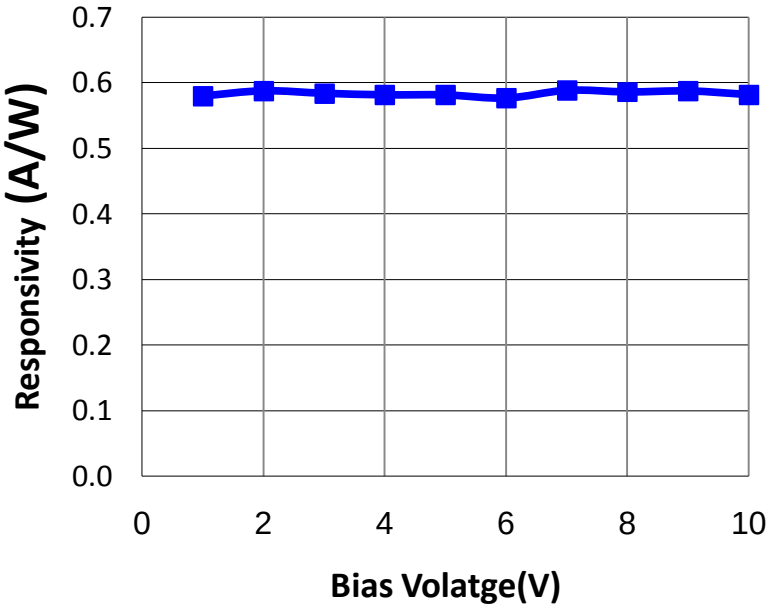
Degradation of PIN @ SLHC-summary

Type	Device	Gb/s	Responsivity (A/W)	
			Pre	Post
GaAs	ULM	4.25	0.48	0.04
	AOC	5.0	0.51	0.07
	Optowell	3.125	0.57	0.11
	Hamamatsu G8921	2.5	0.50	0.20
Si	Taiwan	1.0	0.55	0.20
	Hamamatsu S5973	1.0	0.47	0.33
	Hamamatsu S9055	1.5/2.0	0.25	0.19

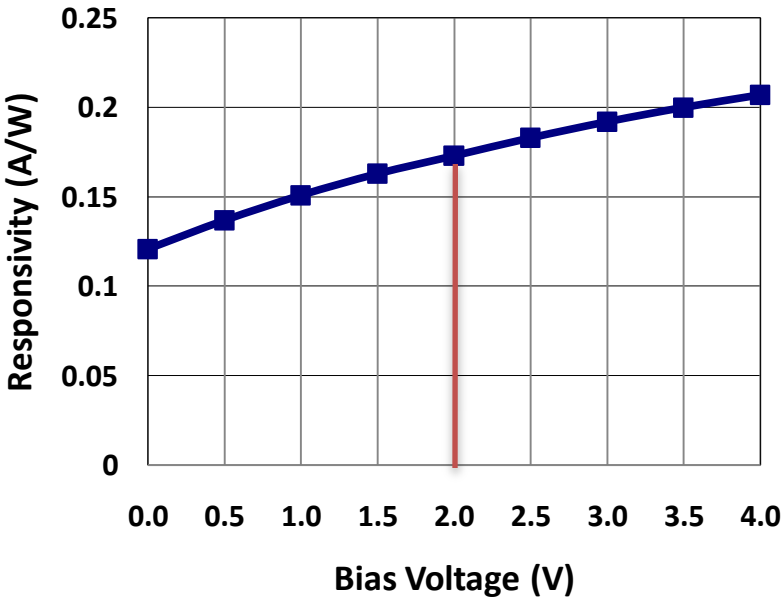
- Hamamatsu G8921 radiation hard + fast
- Optowell radiation hard + very fast +array

Responsivity vs bias voltage

Optowell PIN responsivity vs bias voltage pre irradiation



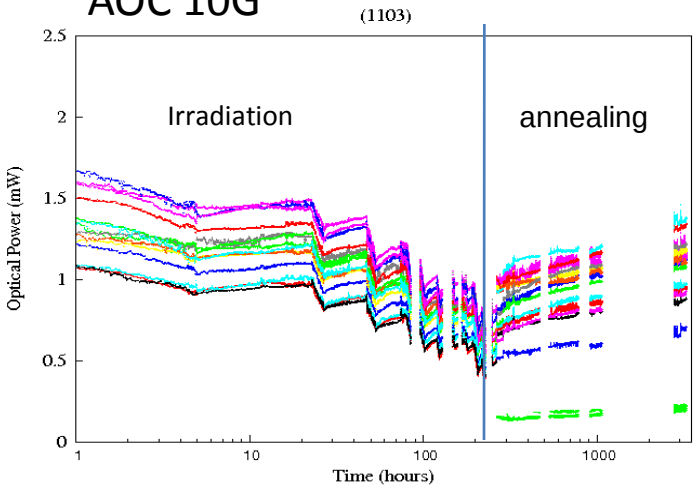
Optowell PIN responsivity vs bias voltage post irradiation



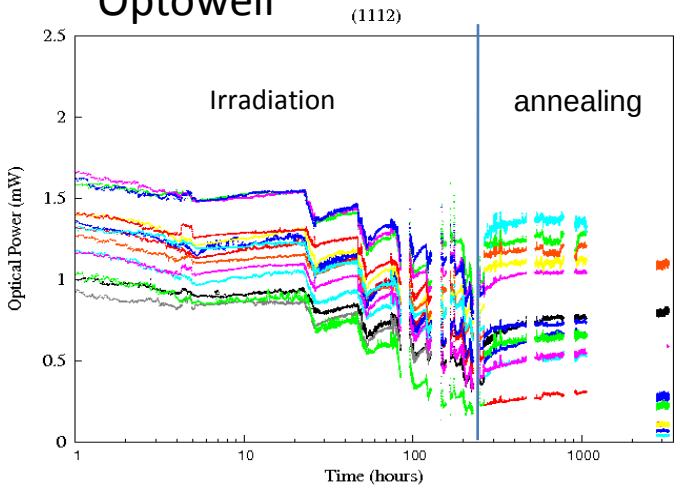
➢ Responsivity can be partially recovered after the irradiation by increasing the bias voltage

VCSEL Power vs Dosage

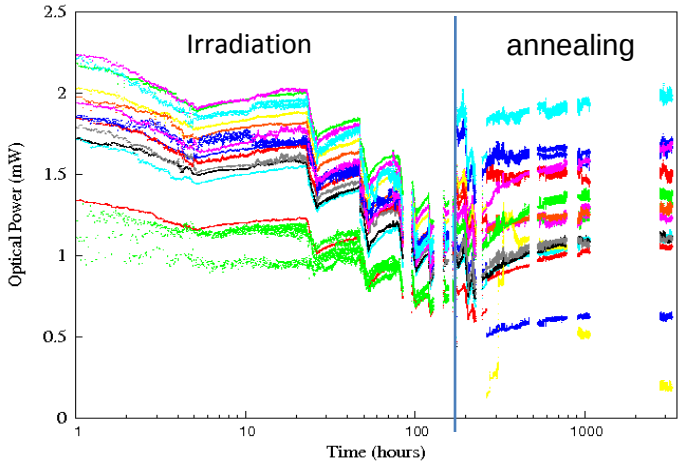
AOC 10G



Optowell



AOC 5G



- AOC has good powers at SLHC dosage
- Insufficient time for annealing

Summary

- Hamamatsu and Optowell PINs are more radiation hard
  - Responsivity can be partially recovered by increasing the bias voltage
  - Will irradiate 20 Optowell 12-channel PIN arrays to SLHC dose in August
- AOC VCSEL arrays have good power after SLHC dose
  - Manufacturer encountered technical difficulty in current production
    - Will irradiate ~6 devices in August