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Partially depleted GaAs photodiodes degrade with square root of fluence

Elizabeth Auden, Barney Doyle, Gyorgy Vizkelethy, Darwin Serkland, Dave Bossert

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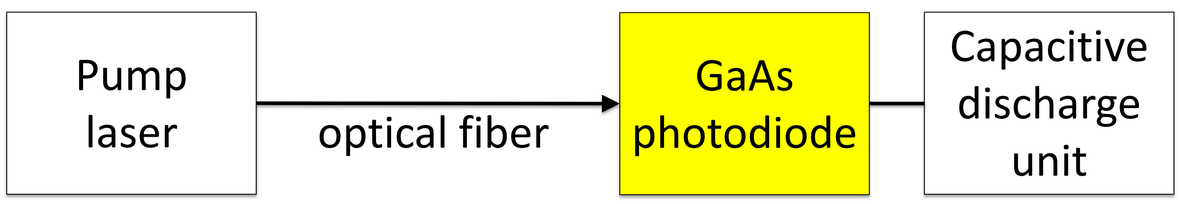
Application:
Optical firing sets exposed to mixed radiation (γ, n_0)

The Sandia IBL is developing optical firing set components that are hardened against gammas and neutron radiation. All-optical firing sets are safer than electric circuits subject to accidental initiation caused by

- Lightning strikes
- Electromagnetic pulses
- Electromagnetic interference
- High voltage breakdown



Optical firing set components

Physics:
Damage reduces diffusion length and average drift distance

Normalized charge collection efficiency (CCE):

$$\frac{photocurrent(\Phi)}{photocurrent(no\ damage)}$$

Laser-generated carriers in depletion and field-free regions:

Carriers drifting in the depletion region contribute to photocurrent:
- Electrons and holes generated in depletion region
- Holes that diffuse from field-free region into depletion region

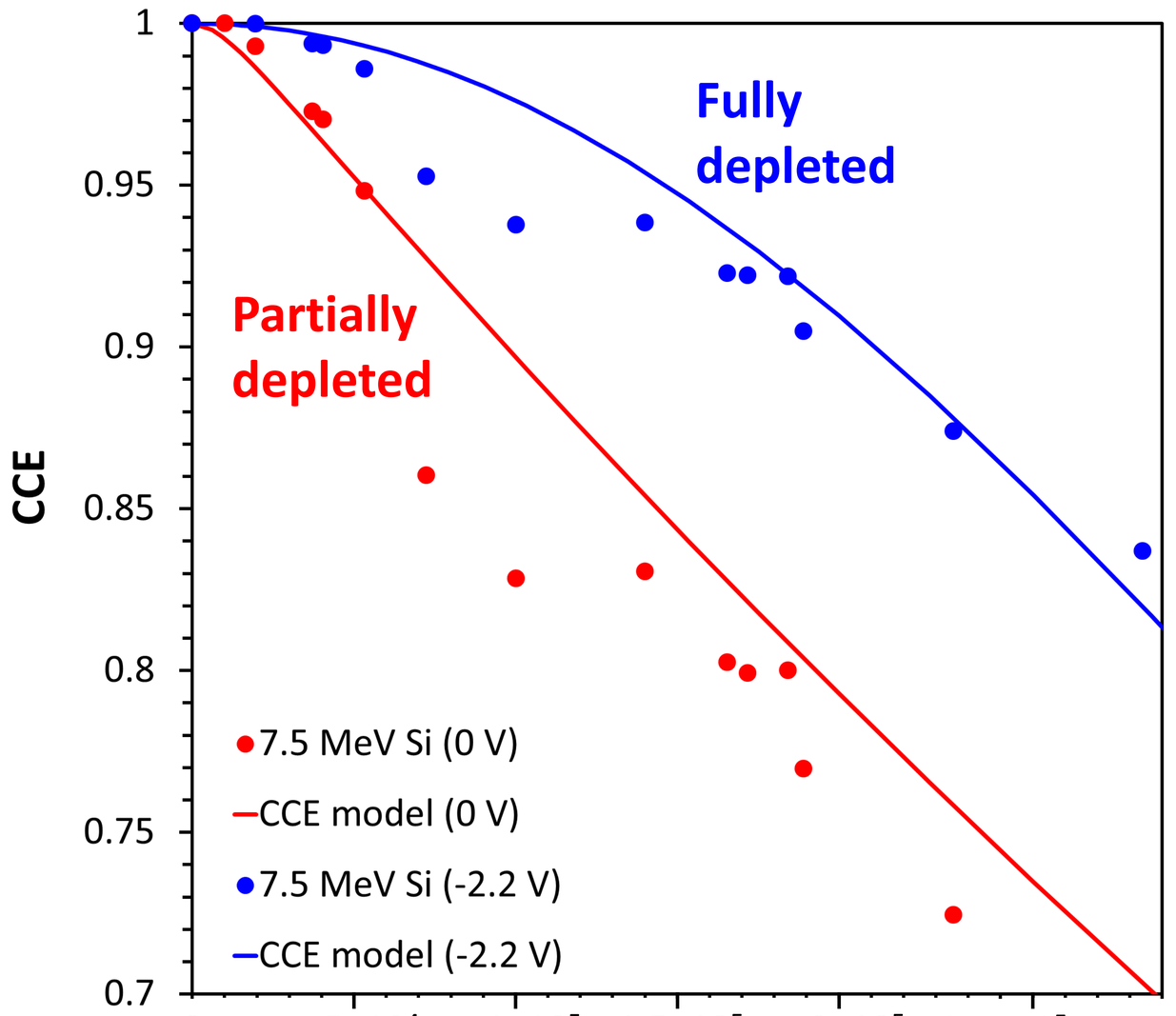
CCE degradation with fluence:

Displacement damage creates lattice defects. Electrons and holes stop contributing to photocurrent once they recombine at midgap defects.

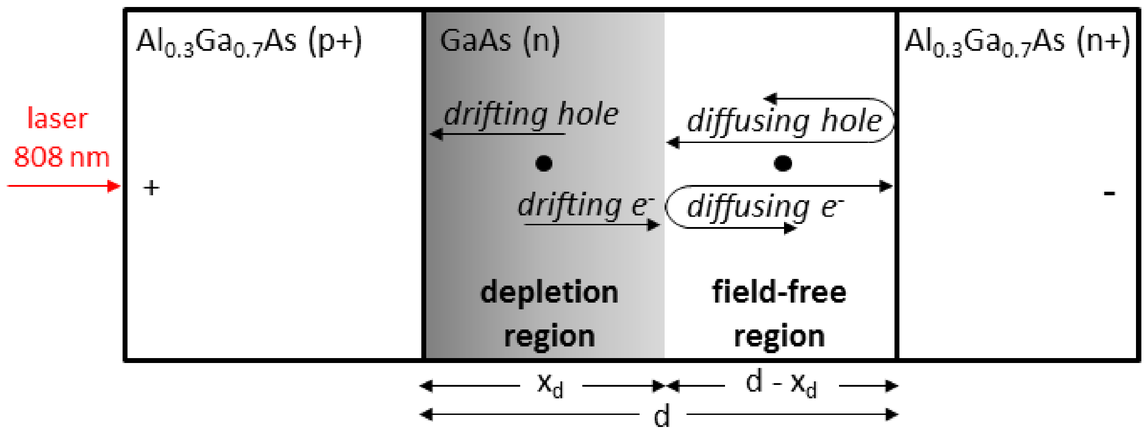
Theoretically models show that CCD degrades when
- Diffusion length L is shorter than the field-free region width
- Average drift distance λ is shorter than depletion region width

$$L = \sqrt{\tau D} \approx \sqrt{\frac{D}{k\Phi}} \qquad \lambda = \tau \times v_{drift} \approx \frac{v_{drift}}{k\Phi}$$

Result:
At low fluences, CCE scales with √Φin partially depleted devices

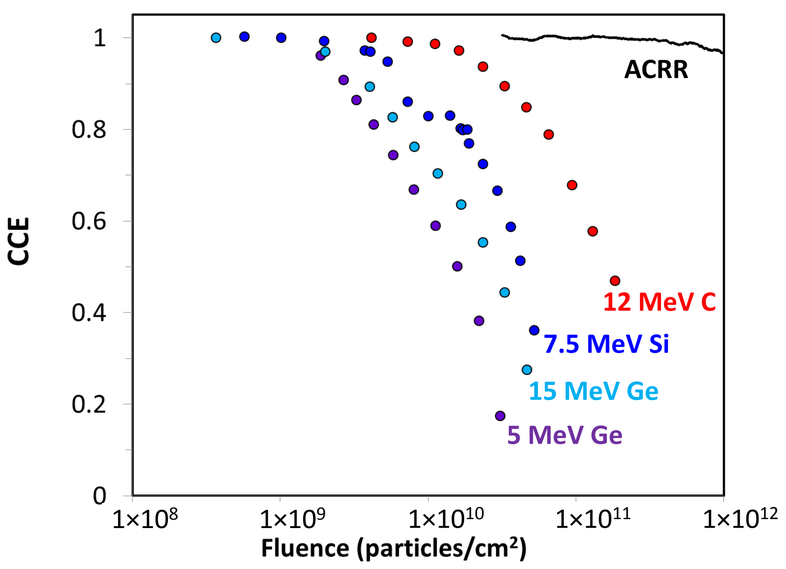


At low fluences, CCE degrades linearly with √Φ in a partially depleted device.

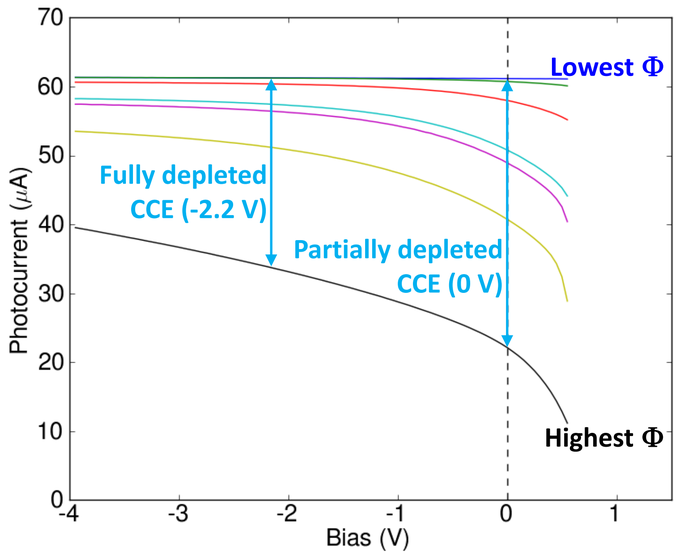


Carrier movement in partially depleted GaAs photodiode

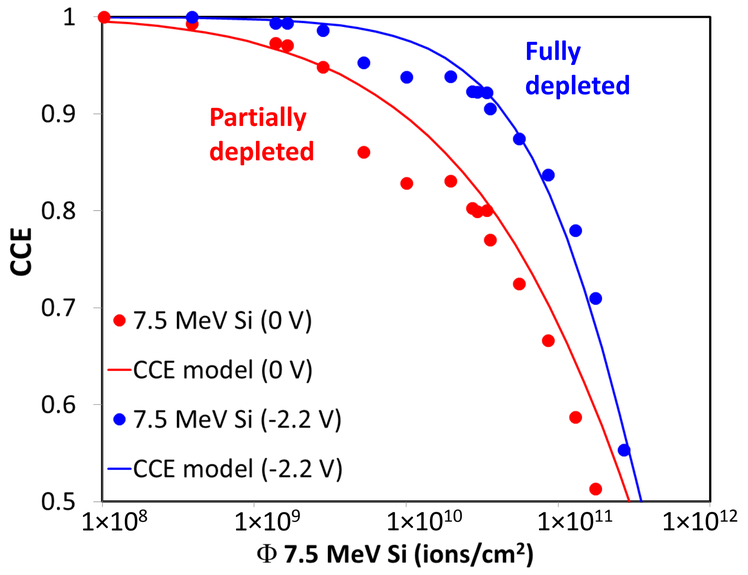
Experiment:
Measure and model CCE in ion and neutron-irradiated GaAs photodiodes



CCE vs. fluence in partially depleted photodiodes irradiated with neutrons and heavy ions.



Fully depleted photodiodes are more rad-hard than partially depleted photodiodes.



CCE degrades faster in a partially depleted device due to hole recombination in the field-free region.

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