Pulsed Electron Beams for Radiation Effects Testing

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Radiation Effects

- The radiation hardness of an electronic component is critical to mission success

- Single Event Effects (SEE) are caused by single ions hitting spacecraft

- SEE can cause bits to flip, memory losses, or latch-up

- Imperative to have adequate testing infrastructure to characterize SEE resistance
Current Testing Infrastructure

- SEE testing takes place in heavy-ion facilities

- Current facilities are extremely oversubscribed

- Current heavy-ion sources don’t have variable Linear Energy Transfer (LETs), high penetration depth, and beam localization

- Alternatives to heavy-ion testing are required for the space missions of the future
Pulsed Electrons | An Alternative

- Ultrafast high-energy electron beams are a good candidate
- Electrons have deep penetration depths
- Short bunches can mimic ion tracks
- Bunch control allows for beam localization and variable LETs
Testing at PEGASUS

• Sought to correlate photodiode responses between existing heavy-ion data and pulsed electrons

Solenoid
z = 0.2895 m

Aperture
z = 3.191 m

Solenoid
z = 4.5618 m

Sample
z = 5.1317 m

Beam Parameters:
- 6 MeV
- < 100 um spot size
  (unclear due to jitter)
First Tests at PEGASUS

**Matched Transient Peak**

- Heavy Ion - LET 20.3
- Pulsed E Beam - Peak

**Matched Transient Collected Charge**

- Heavy Ion - LET 20.3
- Pulsed E-Beam - Collected Charge

Electron transients are faster and shorter
• Strong correlation was not achieved

• Saturating the sample with charge yielded better correlation at similar spot size

• Same deposited charge over larger area collects more efficiently (than heavy ion)

• Looking towards generating high fidelity smaller spots to better mimic charge collection physics
Achieving Small Spot Sizes

- Simulations in GPT
- Pinhole to sample simulations shown

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>$\sigma_x$</td>
<td>200 um</td>
</tr>
<tr>
<td>$\sigma_t$</td>
<td>150 fs</td>
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<tr>
<td>$\gamma$</td>
<td>7.28</td>
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<tr>
<td>MTE</td>
<td>0.5 eV</td>
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No pinhole

20 um at sample with 500 fC

10 um pinhole

940 nm at sample with 500 fC
Current Work

• Building a single-shot spot size diagnostic
Moving Forward

• Moving towards DARPA objectives for ASSERT - higher energies, thicker targets

• Work with Yttrium photocathodes is underway to reduce emittance at photoemission

• Planning to run experiments in the next few months with smaller spot sizes

• Looking to test out the single-shot spot size diagnostic

• Making sample chamber upgrades for better in-vacuum alignment

• Presenting further research results at IPAC ‘24