NEPP
NASA Electronic Parts and Packaging Program

Status Update on the Pulsed Laser Single Event Effects SEE Test Guideline Desk Reference - A NASA-NRL Collaboration

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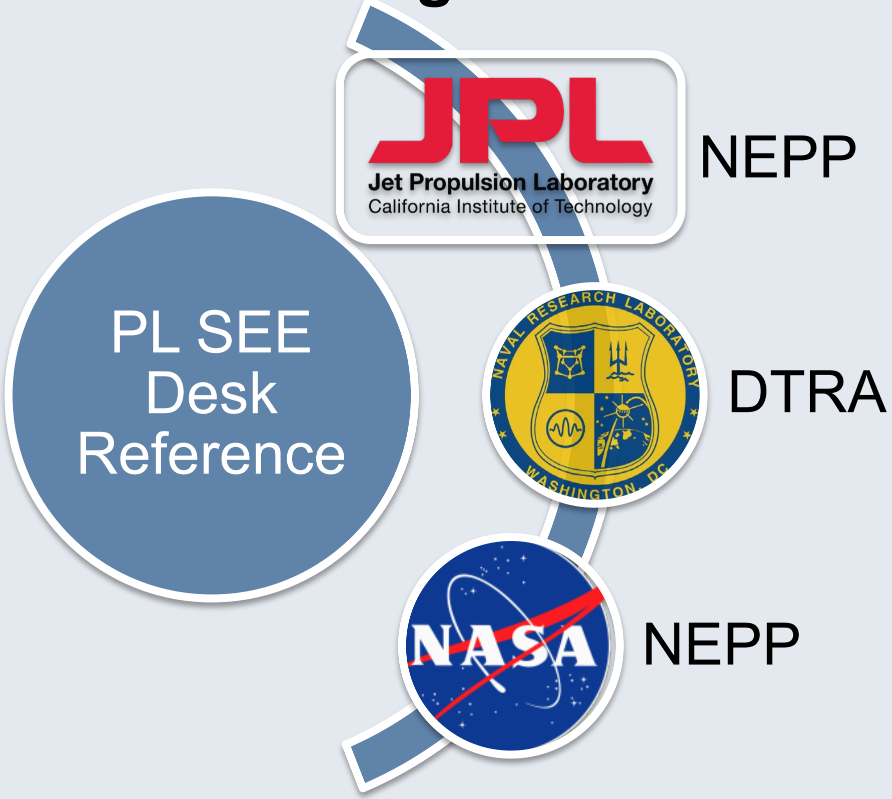
Collaboration and Acknowledgement



Why a PL SEE Test Guideline Document?

- Existing literature on PL SEE is extensive, but isn't focused on practical concerns
- GOAL: To provide the reader guidance in *test conception, development, and execution*, resulting in enhanced data acquisition and efficient use of facility time
- This is not a formal test method
- A comprehensive bibliography included

Why a PL SEE Test Guideline Document?

Existing Guidance Documents

- 2019 NSREC Short Course
  - "Laser-Based Testing for Single-Event Effects"
- SERESSA Course (multiple years)
  - "Fundamentals of the Pulsed-Laser Technique for Single-Event Effects Testing", Springer Chapter, 2007
  - "Characteristics and Applications of Pulsed Laser-Induced Single-Event Effects", Springer Chapter, 2019
- TNS 2013 Review Article
  - "Pulsed Laser Testing for Single-Event Effects Investigations"
- 30+ years of publications

Chapters

1. Purpose and Scope
2. Capabilities & Limitations of PL SEE
3. Experimental Design
4. PL SEE System and Parameters
5. DUT Considerations
6. Practical Guidance – Example Case Studies

Ch 1. Purpose and Scope

- **Primary goal:** to provide practical guidance to assist in planning for PL SEE test campaigns (including lessons learned)
- Intended for PL SEE users, rather than operators or those wishing to design or build a PL SEE system
- Guidance in both test development and execution
- Focused on test methodologies: how to test, rather than SEE mechanisms
- Discusses both the capabilities and limitations of the PL SEE approach
  - suggestions as to when, or if, PL SEE testing is appropriate
- Does not discuss: PL SEE modeling, dosimetry, data analysis, or laser-ion correlation

Chapter 2: Capabilities and Limitations

2.1 CAPABILITIES

- Sensitive node identification/mitigation
- Single-event upset (SEU) mapping of sensitive areas
- Logical-to-physical bit map generation
- Single-event latch-up (SEL) screening and mitigation
- Analog single-event transient (ASET) screening
- Digital single-event transient (DSET) characterization and mitigation
- Hardened circuit verification: radiation hardening by design (RHBD), radiation hardening by process (RHBP)
- Dynamic SEE testing
- Experimental test setup verification
- Software verification
- Complex circuit evaluation/error signature identification
- Basic mechanisms studies
- Model validation and calibration
- Fault injection studies

Chapter 2: Capabilities and Limitations

2.3 LIMITATIONS AND CHALLENGES

- *Optical Access*
- *Laser/Ion Correlation*
- *Dosimetry*
- *Cross-Section Determination*
- *Angle of Incidence*
- *Highly-Scaled Devices*

2.4 TARGET APPLICATIONS FOR PL SEE

- *Basic Mechanisms in Transistors and Simple Devices*
- *SEU/SET Mechanisms in Circuits*
- *RHBD/RHBP Evaluation*
- *ASET Screening*
- *SEL Screening*
- ***Pre-Accelerator Test Setup Verification and Optimization***
- ***Post-Accelerator Testing***
- *Complex Circuit Evaluation*

Chapter 2: Capabilities and Limitations

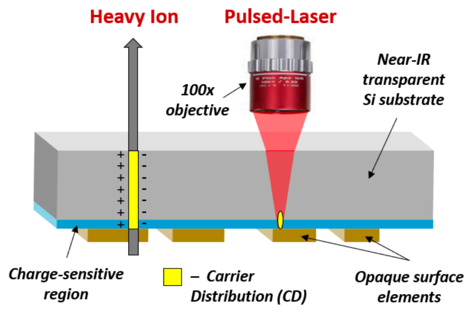
2.5 SHOULD YOU USE PL SEE?

Representative questions:

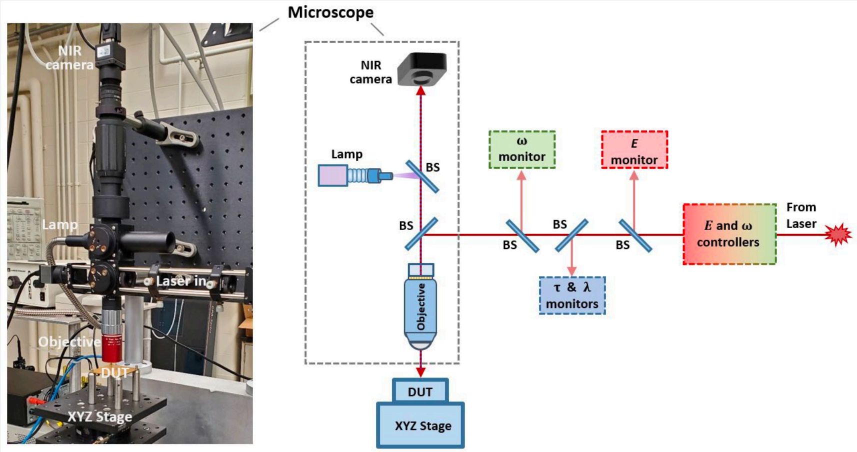
- What is the goal of your experiment?
- Does your experiment require spatial sensitivity? Do you have a need for generating a spatial map showing the locations of SEU or SET?
- Do you want/need to trouble-shoot your experimental setup prior to ion testing?
- Do you have a complex device that's expected to exhibit an array of error modes, such that it would be useful to map these out prior to heavy-ion beamtime?

Chapter 3: Experimental Design

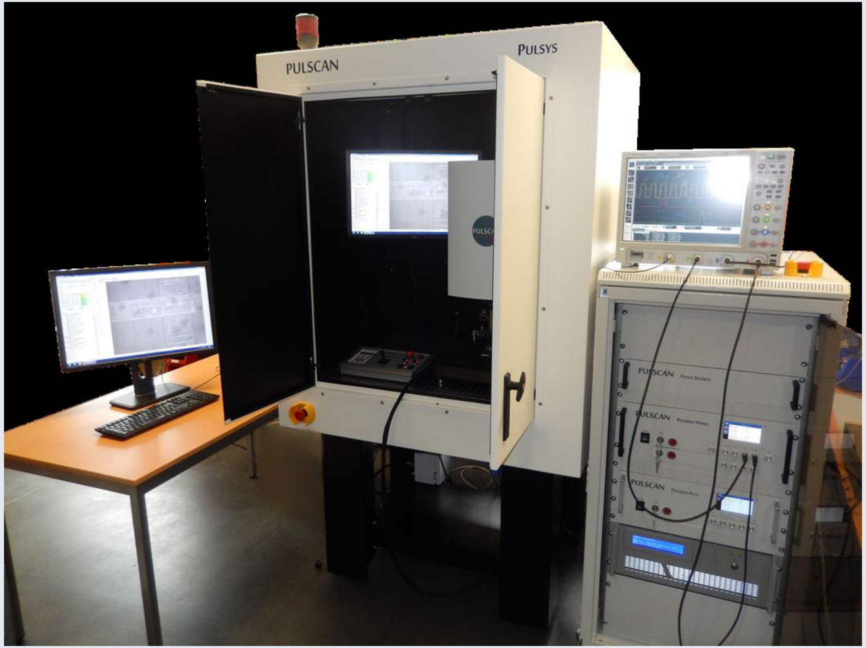
3. Experimental Design
   - Differences between Heavy-Ion and PL SEE Testing
     - Facility
     - Irradiation
     - Devices
     - Testing
   - Considerations for PL SEE Testing
     - Mechanical Stability and Mounting
     - Cabling
     - Thermal Considerations
   - Experimental Design Checklist



Chapter 4: PL SEE Systems and Parameters



Photograph of a typical PL SEE microscope setup (left) and schematic detailing the laser beam delivery, parameter controllers and monitors, and microscope (right). BS – beamsplitter.



Off-the-shelf PULSCAN-PULSYS product

Chapter 4: PL SEE System and Parameters

System Parameters

- Pulse energy
- Wavelength
  - Single-photon absorption (SPA)
  - Two-photon absorption (TPA)
  - Wavelength/penetration depth
- Focusing optics, spot size, beam propagation
- Pulse width
- Stage parameters: range, resolution and mechanical stability

Desk reference will answer:

- How to select the appropriate approach for various mechanisms, technologies, and part type
- Practical impact of objective and spot size on SEE mechanism
- Test planning considerations – mechanical, board size, board layout, DUT orientation, exclusion zones, adapting evaluation cards, etc.

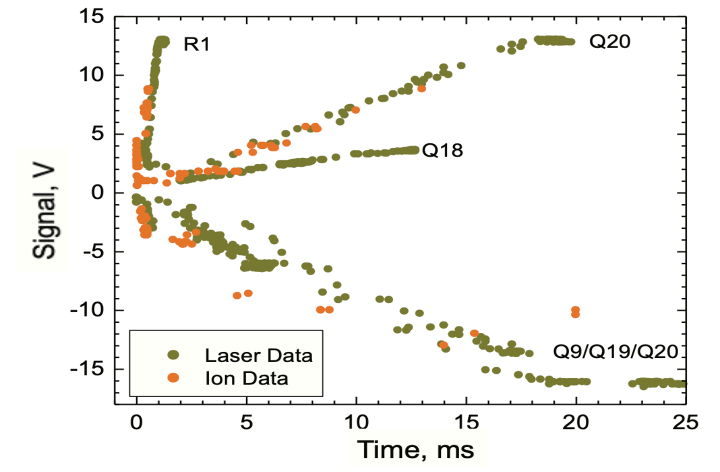
Chapter 5: DUT Considerations

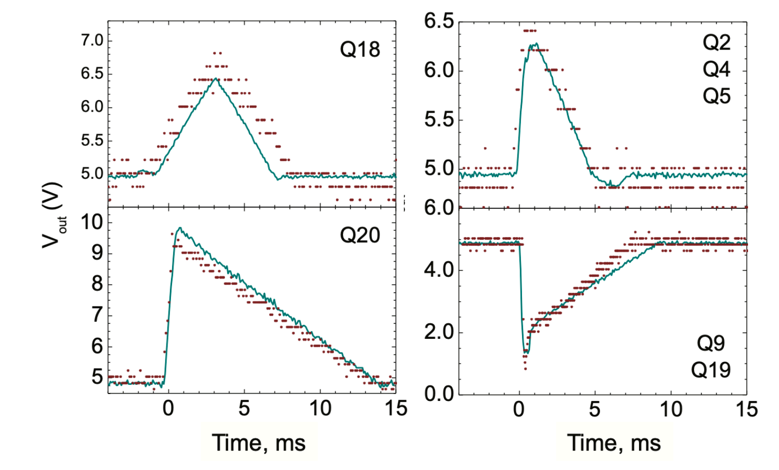
- Semiconductor Materials Considerations
  - Semiconductor Materials
  - Doping Consequences and Processing Modifications
- Optical Access
  - Considerations for Top-side or Back-side Testing
- Packaging Scenarios and De-Processing Techniques
  - Wire-Bonded Parts
- Flip-Chip Components
  - Bare Die
  - General Comments
- Relevant Considerations for DUT Preparation

Chapter 6: Practical Guidance - Example Case Studies

<u>*Specific Examples:*</u>

6.1 Single-Event Latchup (SEL)
6.2 Single-Event Upset (SEU)
6.3 Single Event Functional Interrupt (SEFI)
6.4 Analog Single Event Transient (ASET)
6.5 Digital Single Event Transient (DSET)
6.6 Basic mechanisms studies





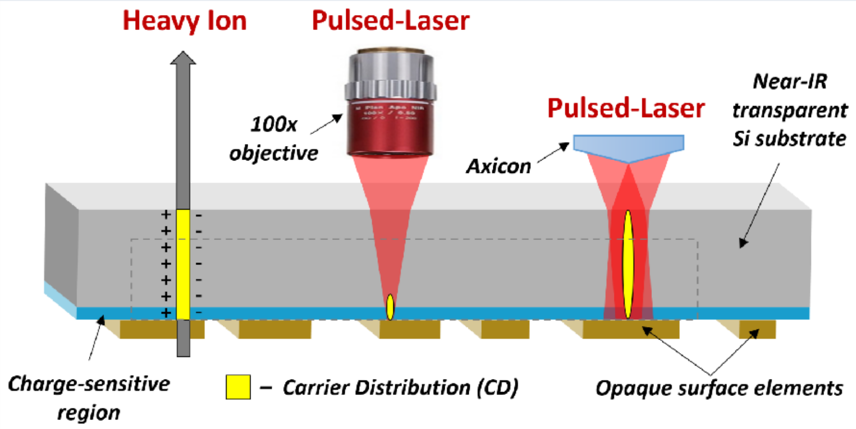
<u>*Representative Subsections:*</u>

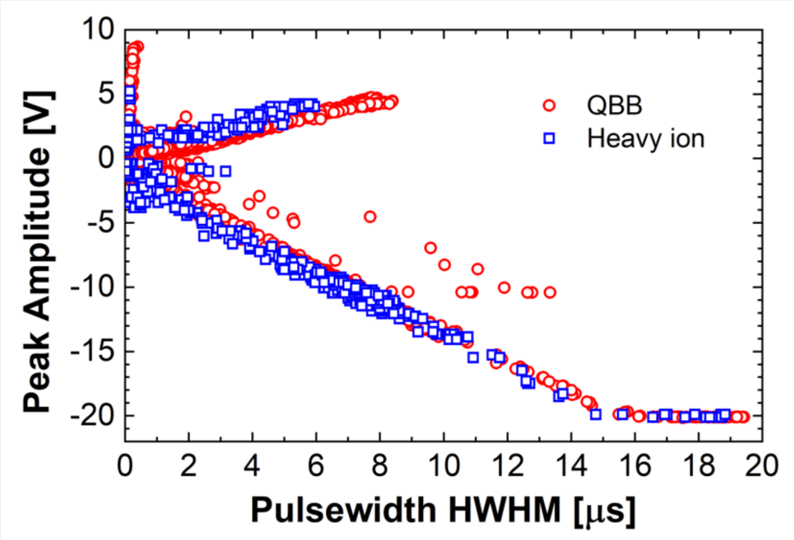
General Definition
Specific Goals
General Experimental Procedure
Data Acquisition and Equipment Considerations
Measurement Challenges
Example Case Studies

This document has been reviewed and determined not to contain export controlled technical data.

Laser-Ion Correlation – LM124 Op Amp (NRL)

Hales, et al, accepted to NSREC 2022, Paper B-2





- Quasi-Bessel Beam (QBB) produces a carrier distribution and LET that more closely resembles that of a heavy ion
- LM124 is a good candidate for laser-ion correlation due to complicated SET features with strong spatial dependencies
- Heavy-ion testing performed at LBNL (NEPP, G. Allen, April 2022) on LM124 device (Texas Instruments) at multiple LETs
- Entire chip tested using QBB as well and V-Δt curves (at similar LET) show very good correlation

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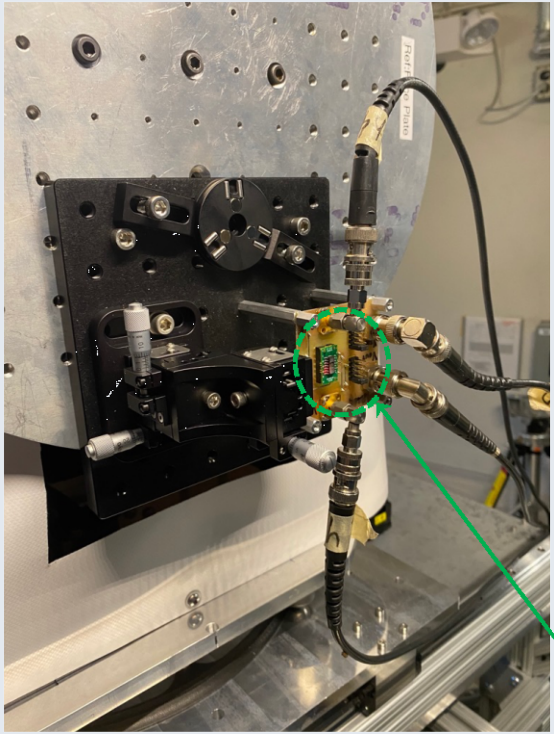

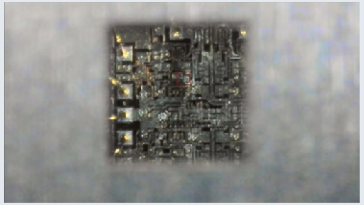

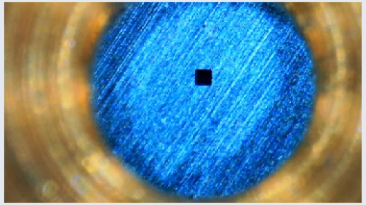

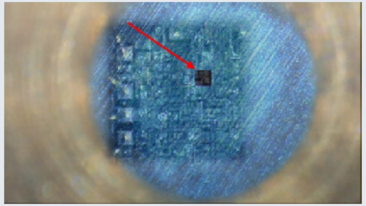

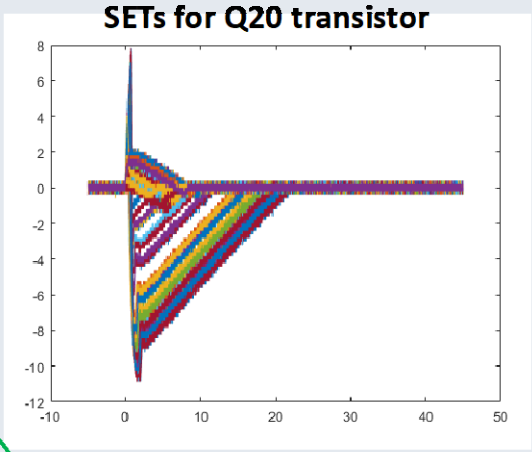

Location for pinhole during testing

- Used a movable 100 αm pinhole in order to better localize heavy-ion testing over a specific transistor
- Goal is to better evaluate SET correlation by limiting broadbeam testing to specific location (like for QBB testing)
- Heavy-ion SETs for Q20 (left) look like QBB SETs and analysis is underway to compare V-Δt curves, cross-sections and SETs for evaluating laser-ion correlation

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