Pulsed-Laser Single Event Effects (PL SEE) Testing – A Practical Desk Reference

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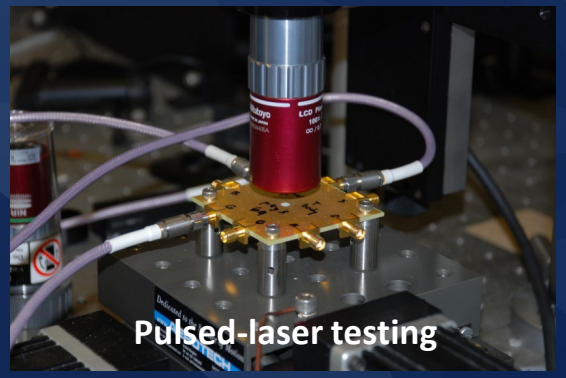
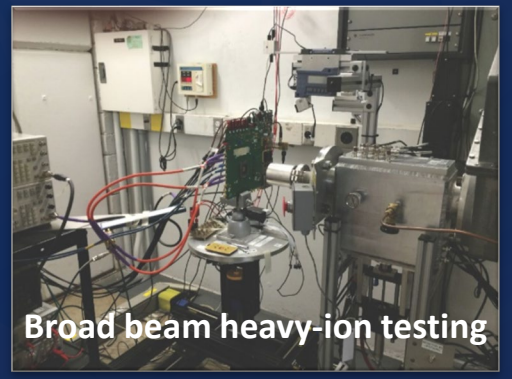

Pulsed-laser testing


Broad beam heavy-ion testing

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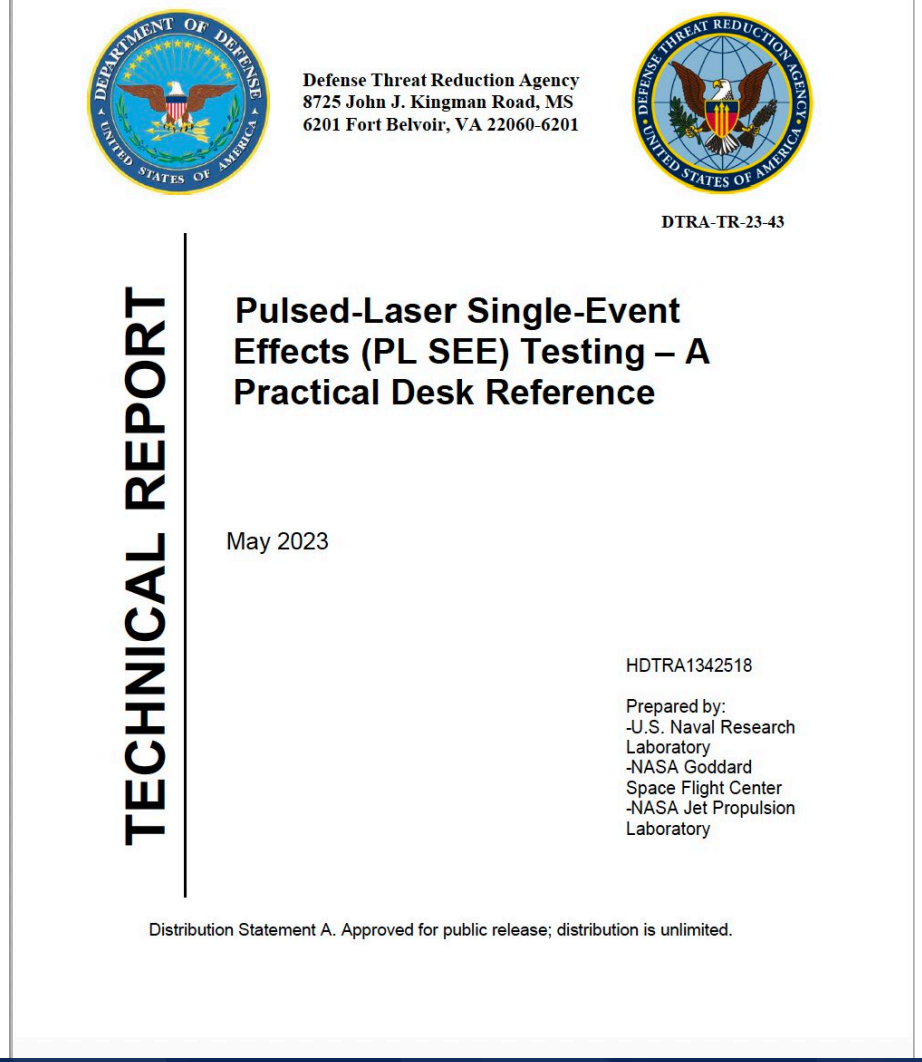

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TECHNICAL REPORT

Pulsed-Laser Single-Event Effects (PL SEE) Testing – A Practical Desk Reference

May 2023

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Prepared by:
-U.S. Naval Research Laboratory
-NASA Goddard Space Flight Center
-NASA Jet Propulsion Laboratory

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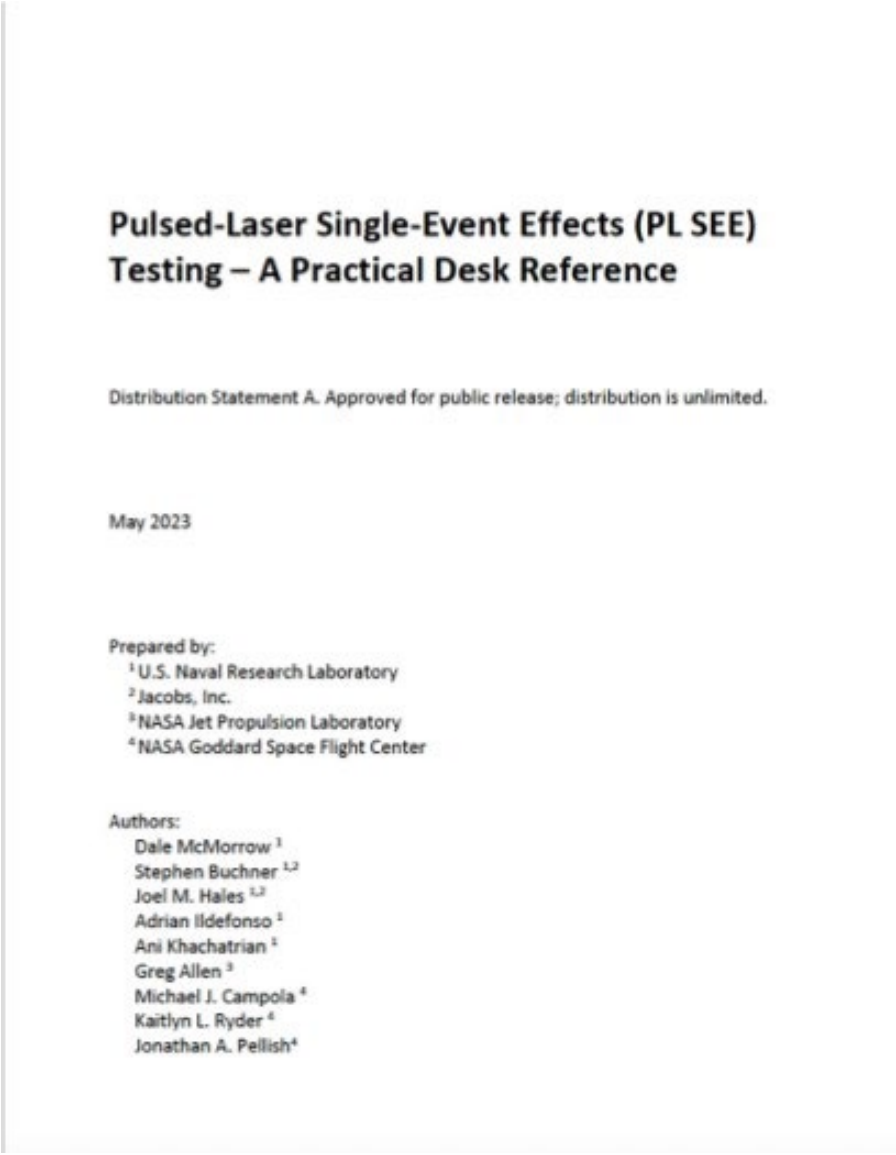

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Why a PL SEE Test Guideline Document?

- Existing literature on PL SEE is extensive, but is not focused on practical concerns

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Why a PL SEE Guideline Document?

Existing Resources

- 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

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Why a PL SEE Test Guideline Document?

- Existing literature on PL SEE is extensive, but is not 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. It's about "how" to think about and execute a PL SEE test.
- This is not a formal test method
- Target audience is PL SEE users, not facilities

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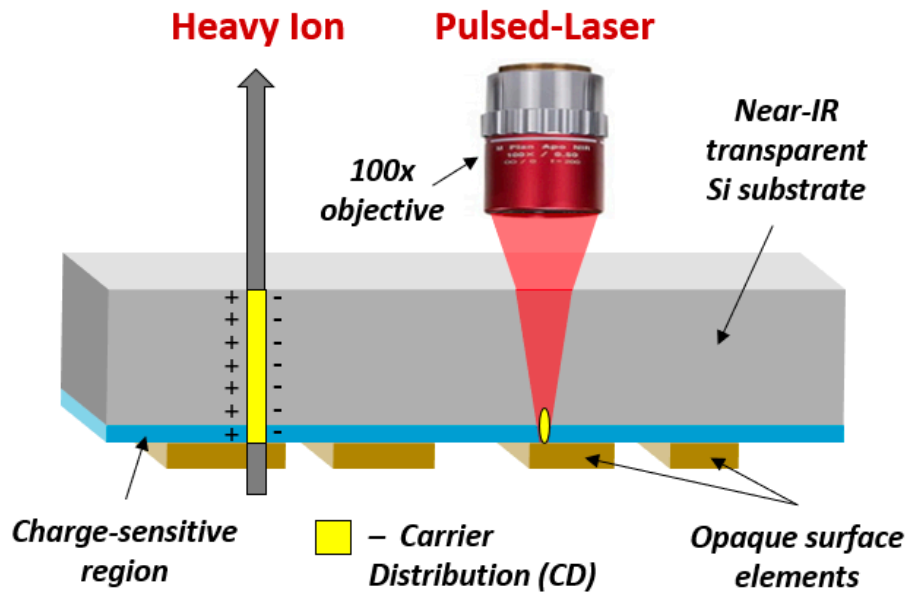

The PL SEE Desk Reference

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The PL SEE Desk Reference

Chapter 1 Purpose and Scope

This Pulsed-Laser Single-Event Effects (PL SEE) Desk Reference is intended to provide practical guidance to assist in planning for PL SEE test campaigns. This guidelines document will provide the reader with guidance in both test development and execution, resulting in enhanced efficiency and use of facility time, while providing insights into avoiding common mistakes and pitfalls.

This document is intended for scientists and engineers planning for, or considering, future PL SEE test campaigns. The target audience includes both novice and experienced radiation scientists, radiation engineers, test engineers, program managers, and students. It is particularly well suited for those with some particle beam SEE testing experience because the differences between heavy-ion and PL test approaches are noted frequently.

This desk reference is focused on test methodologies, that is, how to test, rather than SEE mechanisms. The document discusses both the capabilities and limitations of the PL SEE approach, including suggestions as to when, or if, PL SEE testing is appropriate. The important components of a PL SEE test setup are described, with guidelines on the appropriate choice of laser parameters for testing specific types of devices. Detailed discussions on device preparation and board design are provided.

These guidelines are intended for PL SEE users, rather than operators, or those wishing to design or build a PL SEE system; such details are beyond the scope of this document. A similar comment applies to such topics as PL SEE modeling, dosimetry, data analysis, and laser-ion correlation. However, this document will provide the reader with an extensive list of references for these more in-depth subjects, as well as the specific topics covered herein.

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2.4 Target Applications for PL SEE

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

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2.5 SHOULD YOU USE PL SEE?

The question often arises as to when the use of PL SEE should be considered. While there clearly are pros and cons associated with laser testing, PL SEE testing can provide value in many circumstances, and this guideline document will help understand what PL SEE testing can and cannot accomplish. Most generally, PL SEE is a tool for understanding the error modes of the device under test, whether those error modes arise from SEU, ASET, DSET, SEL, SEFI, or SEB. However, it is not (yet) an acceptable method for measuring quantitative SEE cross-section curves, which are used for predicting error rates in space. An important function of PL SEE is to reveal spatial and temporal information about SEE sensitivity.

Below are a guiding set of questions that should be addressed prior to considering the use of PL SEE testing. Answering these questions with a 'yes' suggests that PL SEE testing could prove valuable.

- Does your experiment require spatial sensitivity? Do you have a need for generating a spatial map showing the locations of SEU or SET?
- Does the laser beam have access to the active regions of the device, either from the top side, or through the wafer from the back side? If not, can the board/DUT be modified such that optical access is possible?

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3.3 Experimental Design Checklist

The checklist below is provided as a convenient guide on what to do prior to undertaking PL SEE testing at a remote facility.

- Prior to testing, have you communicated the goals of the test with the facility operators?
- Prior to testing, have you shared a test plan with the facility operators and verified that the experiments are realistic and executable within the allotted time?
- Prior to testing, have you verified that the test equipment is operating properly, the software is free of bugs, and can capture the signatures desired?
- If shipping equipment, have you arranged so that it arrives in advance of the test date and can you arrive a day early to familiarize yourself with the test setup and operational procedures?
- If the facility is going to provide equipment, such as a power supply, make sure that it is in proper working order and can perform the necessary function before visiting the facility for the first time.
- Have you communicated with the facility operators in advance to develop handshaking for any communication between the facility equipment (stage, oscilloscope, etc.) and the test setup required to automate the test?

Chapter 4: PL SEE System and Parameters

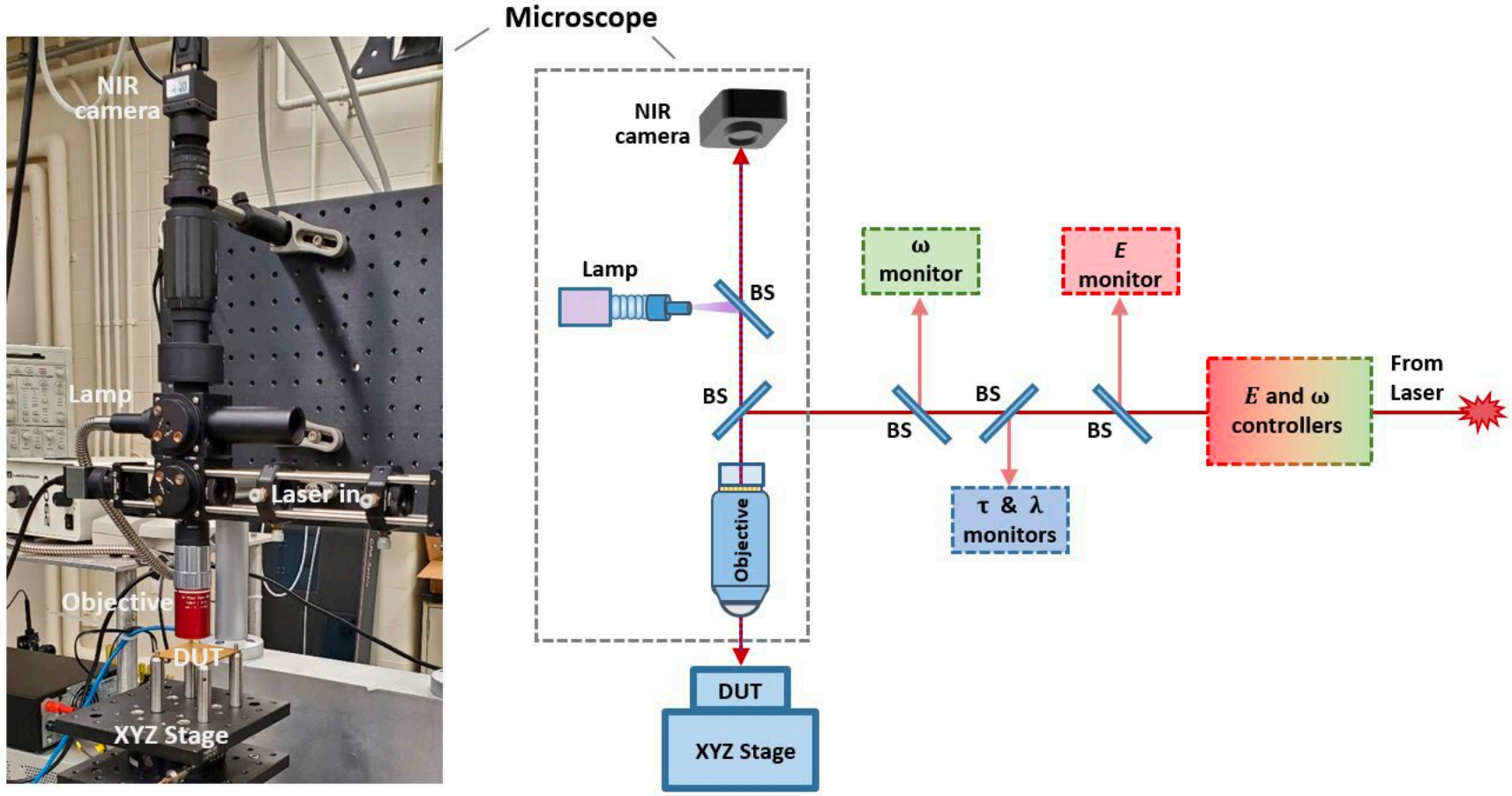

Figure 4.1. *Photograph of a typical PL SEE microscope setup (left) and schematic detailing the laser beam delivery, parameter controllers and monitors, and microscope (right). BS – beamsplitter.*

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Chapter 4: PL SEE System and 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.

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4.7 Preparation for Facility Testing

Much like in preparation for heavy-ion testing, it is important to be aware of the laser parameters and general capabilities of a laser test facility before committing to a visit to ensure that the desired experiments are feasible. Unlike most heavy-ion test facilities, the pertinent information is not typically publicly available and so it is necessary to reach out to the facility manager/director for details. To this end, some guiding questions are listed below that should facilitate these communications. Certain facilities may provide a document detailing the key capabilities and parameters of the testing system and so it is worth inquiring about this prior to a visit.

- Is the PL SEE system designed for SPA or TPA testing?
- What are the operational laser wavelengths and are these appropriate for the candidate DUT?
- Can testing be conducted via top-side or back-side excitation?
- Which objectives are typically used and what focused spot sizes do they provide?
- What is the pulse width and repetition rate of the laser? Are these parameters adjustable?
- What are the typical pulse energies or LET_L values used for testing?
- What are the stage specifications in terms of travel range and step size?
- How are the laser parameters characterized and monitored?

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Chapter 5: DUT Considerations

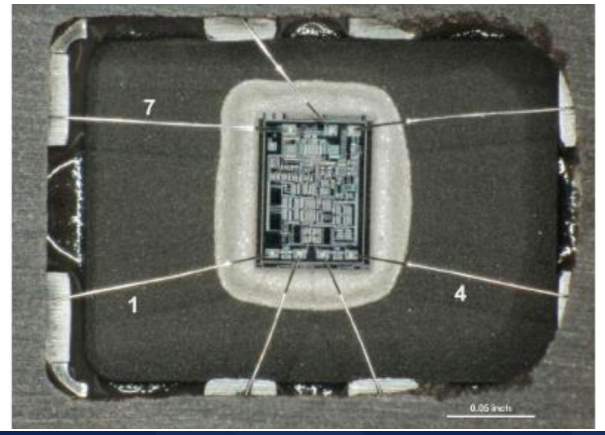

Figure 5.5. *Fully de-lidded ceramic cavity showing the exposed die and wirebonds.*

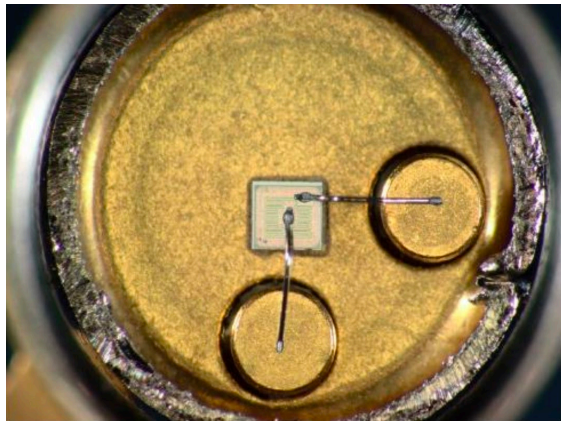

Figure 5.6. *De-lidded TO-style metal can package.*

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5.4 Relevant Considerations for DUT Preparation

The following list of questions summarizes the many considerations discussed in this chapter regarding DUT preparation. These questions should be evaluated when deciding to test a given component at a pulsed laser facility.

- What is the material system (*e.g.*, Si, GaAs, GaN, SiC) and/or fabrication process used for the DUT?
- What wavelength do you intend to use? Can the laser facility provide it?
- Or, similarly, can you use one of the wavelengths provided by the facility?
- What type of metal coverage is expected for this device type (*e.g.*, most likely dense for highly scaled digital chips, less dense for legacy analog chips) and how does this affect the feasibility of pursuing PL SEE testing?
- After considering the metal coverage, DUT type, package, and material system, should you aim for top-side or back-side excitation?
- Is it possible to perform the required de-processing in-house, or should a vendor be contacted?
- Are there bare die available, and would packaging be simpler than de-processing?

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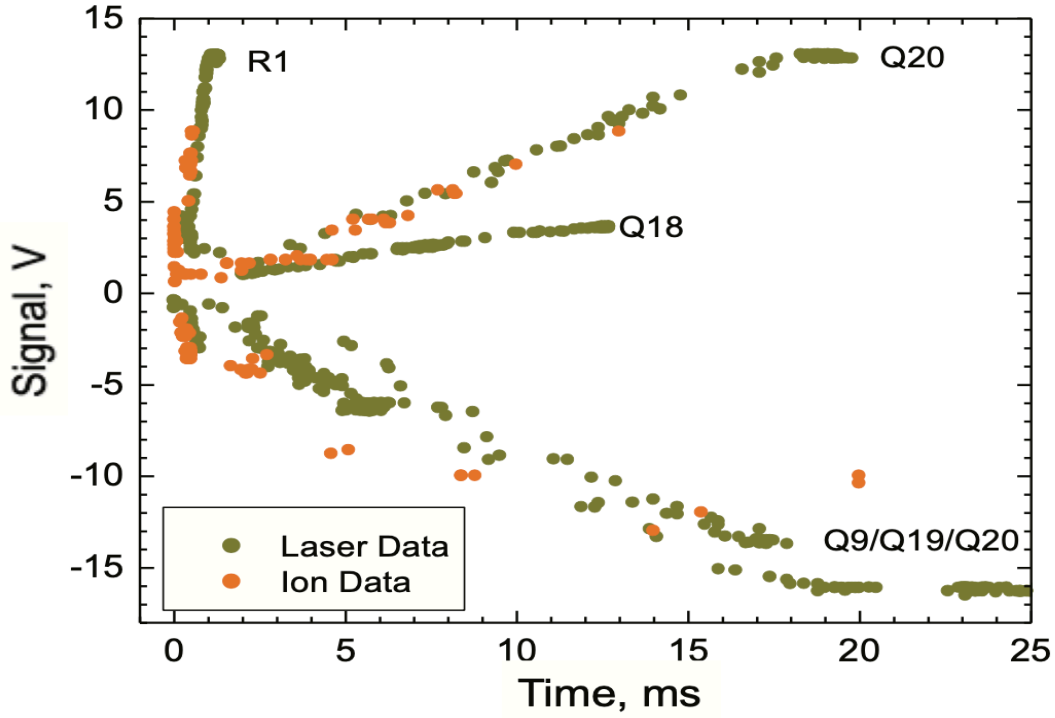
Chapter 6 Practical Guidance – Example Case Studies

1. Single-Event Latchup (SEL)
2. Single-Event Upset (SEU)
3. Single-Event Functional Interrupt (SEFI)
4. Analog Single-Event Transient (ASET)
5. Digital Single-Event Transient (DSET)
6. Transient Charge Collection for Basic Mechanisms Studies
7. Single-Even Burnout (SEB)



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Chapter 6

For Each Phenomenon:

Subsections:

General Definition

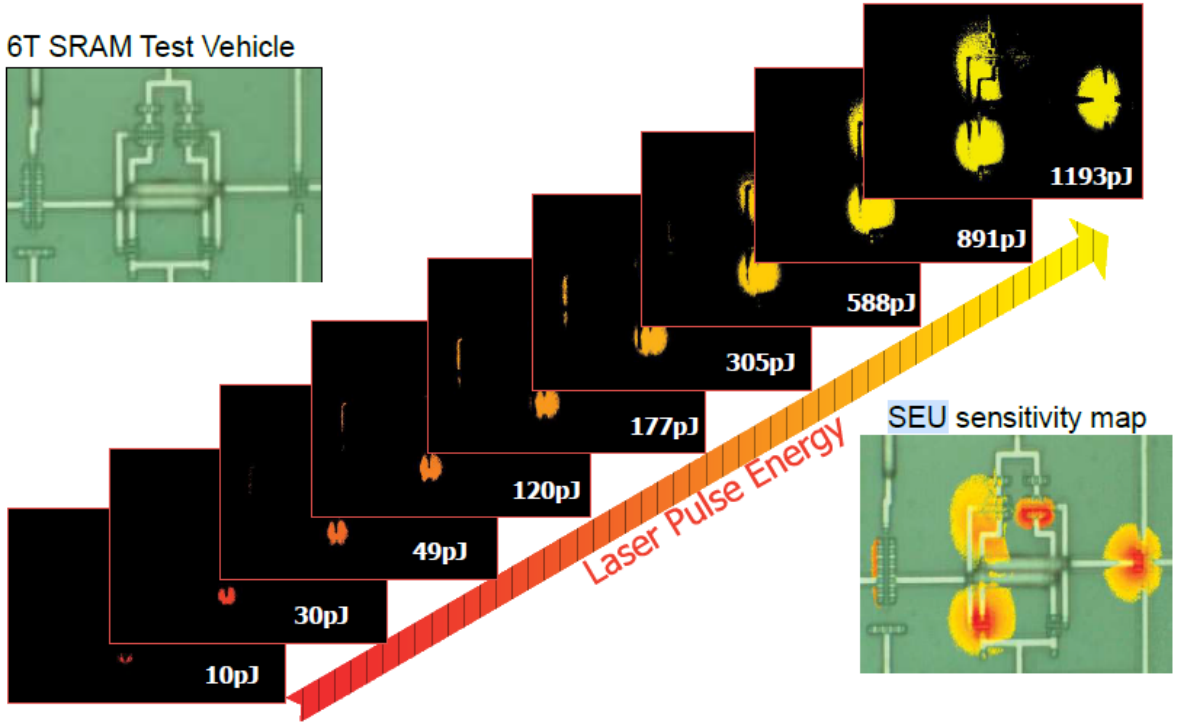
Specific Goals

General Experimental Procedure

Data Acquisition and Equipment Considerations

Measurement Challenges

Example Case Studies



Conclusion

Now Available!