

RADLAS 2024 : 6th Workshop on Laser Testing of Radiation Effects on Components and Systems

📅 11 sept. 2024, 08:45 → 12 sept. 2024, 12:00 Europe/Amsterdam

📍 Newton 2 (ESA-ESTEC)

👤 Christian POIVEY (ESA) , Dale MCMORROW (NRL) , Florent MILLER (Nucléutudes) , Thomas BOREL (ESA) ,
Vincent POUGET (IES - CNRS)

Description



RADLAS 2024 is the 6th edition of a workshop dedicated to laser-based methodologies used to help the radiation sensitivity assessment of electronic components and systems. This edition of RADLAS is organized at the **European Space Research and Technology Centre (ESTEC)** of the **European Space Agency (ESA)**, with the support of the **RADECS association**.

The workshop is based on invited and contributed presentations describing different aspects of the laser testing technique as well as real case studies. Presentations will be given to cover the fundamentals and recent and promising trends of laser and other complementary testing methods as well as how these methods could be used in an industrial frame and acknowledged in standards.

The intended audience includes both beginning and experienced researchers, engineers, and students wishing to share and enhance their knowledge base on this topic.

We encourage students, researchers, engineers, and professionals involved in SEE testing to contribute their expertise and insights to make this workshop a collaborative platform for advancing knowledge and methodologies in the field.

We anticipate that this focused scientific program will stimulate insightful discussions and foster collaboration among participants, ultimately contributing to the advancement of SEE testing methodologies with lasers.

Submit your abstracts and be a part of shaping the future of SEE laser testing. We look forward to your valuable contributions.

Author Instructions:

- Oral
 - Presentations in "PDF" format
 - Time allocated: 15mn + 5mn questions
- Poster
 - Poster in "PDF" format
 - Useable area: A0 in portrait orientation

There is no template, but the RADLAS 2024 logo shall be included: [click here](#)

Important Dates:

- Registration:
 - Starts: 15th of July 2024
 - Ends: 20th of August 2024



RADLAS 2024_Log...

RADLAS Organiser ✉ thomas.borel@ext.esa.int

Inscription



Participants

MER. 11 SEPTEMBRE

09:00 → 09:30 **Coffee** ☕ 30m

09:30 → 09:40 **RADLAS 2024 - Opening**
Président de session: Ali ZADEH (ESA)

09:40 → **11:10** **Invited Talk: Basics and definitions for Laser Testing of Single-Event Effects** ⌚ 30m

The laser method for Single-Event Effects testing is based on the photoelectric interaction of a short and focused laser pulse with the semiconductor material of a device to mimic the transient and localized track of electron-hole pairs that is produced by primary or secondary ionizing particles from radiation environments. We will briefly introduce the fundamentals of the laser testing technique, including an overview of the physical and experimental parameters of the main variants of the technique as well as their main advantages and limitations. Useful concepts like the laser cross section and the equivalent linear energy transfer will be defined and illustrated by recent results. Elements of methodology will be presented together with practical guidelines for an efficient and pertinent use of the laser testing technique for characterizing SEEs in modern devices.

Orateur: Vincent POUGET (IES - CNRS)

10:10 → **11:10** **Session: Recent Laser test results**

10:10 **SEE Laser testing at ESA** ⌚ 20m

Over the past three years, the ESA TEC laboratory has been equipped with a SEE laser facility. During this period, we conducted a variety of tests and assessments on EEE components to evaluate their SEE sensitivity and identify design vulnerabilities. Additionally, we developed several tools to enhance data acquisition and analysis. In this presentation, we will showcase the results of different test cases performed using the SEE laser system.

Orateur: Thomas BOREL (TEC-QEC)

10:30 **Exploration of the Single Event Effect Sensitivity of a 16nm FinFET System-on-Chip using Single-Photon Absorption Laser Testing** ⌚ 20m

We present Single Event Effect (SEE) testing method and results in a complex System-on-Chip (SoC) fabricated with a 16nm FinFET technology using backside Single Photon Absorption (SPA) laser testing, including Single Event Latchup (SEL), Single Event Transient (SET) and Single Event Upset (SEU) results.

Orateur: M. Matthieu FONGRAL (IES)

10:50 **Single-Event Effects Laser Testing of a 7nm FinFET System-on-Chip with AI-Acceleration Capabilities** ⌚ 20m

We present our single-event effects (SEE) laser testing method and results on a commercial programmable 7nm FinFET System-on-Chip (SoC) obtained using backside single-photon absorption (SPA).

Orateur: salma ACHAQ (ONERA/IES)

11:10 → **11:40** **Coffee Break** ⌚ 30m

11:10 → **11:40** **Poster**

11:40 → **12:20** **Session: Recent Laser test results**

11:40 **Pulsed-Laser Single-Event Effects in Wide Bandgap Semiconductor Devices** ⌚ 20m

With their high breakdown voltage and ability to withstand high temperatures, wide bandgap-based devices are ideally suited for high-power and high-frequency applications in satellite communications, RADAR, and defense power switching. However, these devices, based on wide bandgap (WBG) semiconductor materials, are known to be prone to single-event effects (SEE). The susceptibility to single event transients (SETs) in the harsh particle radiation environment of space can disrupt the device's normal operation, potentially leading to failure events and posing a significant reliability issue.

The US Naval Research Laboratory (NRL) developed a laser beam line (Fig. 1) to study SEEs in WBG semiconductors. Single-photon and two-photon absorption processes are used for a pulsed-laser SEE (PL SEE) study on GaN-, Ga2O3-, and SiC-based devices. It is determined that the shape of laser-induced SETs depends strongly on laser pulse energy, deposited charge distribution profile, bias, and the presence of growth-related or radiation-induced defects. SET mapping of WBG GaN (Fig. 2), Ga2O3, and SiC material-based devices reveals regions of enhanced charge collection – “hot spots,” identifying areas most likely susceptible to radiation-induced failure. PL SEE has emerged as a new tool for locating and characterizing defects, with laser wavelength tunability allowing for probing specific electron transitions and tailoring charge deposition profiles to specific experimental needs.

Orateur: Dr Ani KHACHATRIAN (US Naval Research Laboratory)

12:00 **Laser Fault Injection on power off devices** ⌚ 20m

Lasers are employed not only for reliability purposes but also for fault injection attacks in order to assess the security of electronic components.

Nowadays, laser fault injection attacks represent a significant threat to the security of embedded devices. Numerous state-of-the-art studies, mainly based on Single Event Effects, have investigated the use of lasers to inject faults into an electronic device at run-time.

In a recently published paper, we have demonstrated on an experimental basis that it is also possible to perform laser fault injection on an unpowered device.

This attack vector is of particular interest due to the persistent nature of the injected faults. Furthermore, it is possible that certain protection mechanisms may also be compromised.

Finally, laser injection sensors are unable to detect the attack, as they are active components that only function when the circuit is powered on.

In particular, our investigation focused on the Flash non-volatile memory of a widely used off-the-shelf 32-bit microcontroller. We provide an experimental characterization of this phenomenon with a description of the fault model from the physical to the software level for laser-induced faults in NOR Flash memory.

We leverage this new laser fault injection method to perform a complete reverse engineering of the mapping between the logical and physical addresses of the Flash memory. The organization of the Flash memory can be retrieved at both the page and bit level.

Orateur: Paul GRANDAMME (Laboratoire Hubert Curien, Université Jean Monnet, CNRS)

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12:20 → 13:00 **Session: Test Methodology for SEE Laser Testing**

12:20

Pre-screening and classification of sensitivity of COTS parts to Single Event Latchup, based on Pulsed Laser testing ⌚ 20m

The use of pulsed laser for pre-screening COTS parts to SEEs, and more specifically to Single Event Latchup, is beneficial because of the reduced cost and greater availability this method provides, as compared to heavy ions. At TRAD, pulsed Laser is mainly used for this purpose: evaluating part sensitivities to SEEs, prior to heavy ion testing, in order to reject the most sensitive ones, thus reducing the beamtime required for qualification.

In the frame of a study motivated by CNES in 2022-2023, a cross-comparison of laser and heavy ion results on the sensitivity of 12 COTS parts to latchup was performed. A very good correspondence was obtained between both methods and a methodology for quickly classifying part's sensitivities to SEL based on laser test results was developed. Results of this study were presented at RADECS 2023 [1]. The test methodology developed was implemented in 2023-2024 in many cases. Through several laser tests at different pulse energies, sensitivities of parts are classified into different categories, in order to identify the most and less sensitive parts. This methodology will be presented, as well as the lessons learned from the first implementation of this method for industrial purposes. This method will also be illustrated with the work performed through a collaboration with U-SPACE company. More than 35 devices were evaluated under Laser and their sensitivity were classified, for U-SPACE to select the best references for their design. A Laser test on the final design is also planned, to verify the criticality of soft errors on the availability of the equipment.

[1] Review of Alternatives to Heavy Ions Broad Beam for SEL Screening of COTS, S. Dubos et al., presented at RADECS 2023

Orateur: Samuel DUBOS (TRAD Tests & Radiations)

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12:40

Comparison and Applications of Different Scanning Methods using an Industrial Laser System Dedicated to Single Event Effects Testing ⌚ 20m

In the field of single-event effects (SEE) testing, laser testing [1] is commonly used for different purposes. The most well-known application is probably the accurate mapping of SEE sensitive areas in a device, especially in the context of radiation-hardening of an integrated circuit (IC) design. Another application consists in screening different components against critical events like single-event latch-up (SEL). Providing an estimation of the sensitive area (cross section) for specific types of events is also a result that is commonly expected from a laser test campaign. For practical reasons related especially to the duration of the test campaign, it is usually not possible to scan a complete chip at the highest available resolution (i.e. smallest scanning step). Thus, a trade-off needs to be found between the scanning resolution and the scanning time. The result of this trade-off depends on several factors like the priority objectives of the test, the time needed to acquire data from the device-under-test (DUT), and the scanning method, which we define as the way to deliver the laser pulse to the DUT vs space and time.

We present a comparison of the various scanning methods available with our Pulsys-Rad industrial laser system for SEE testing [2]. Beyond the classical method that consists in doing a stop-and-go successively at each point of a regular 2D grid in order to trigger a laser pulse and acquire data at each point [3,4,5], we introduce complementary or alternative scanning methods that provide more options and flexibility when preparing the design of experiment (DoE) of a laser testing campaign. The benefits of each method in terms of scan duration, area coverage and accuracy of SEE localization are presented and discussed as a function of the test constraints, priority objectives, and practical considerations. Understanding the strengths and limitations of each method enables optimizing the efficiency of a DoE. We illustrate the discussion with experimental results obtained on the AMD Xilinx Zynq-7000 system-on-chip (SoC) using the different scanning methods with backside single-photon absorption laser testing.

Orateur: Sebastien JONATHAS (PULSCAN)

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13:00 → 14:20 **Lunch Break** ⌚ 1h 20m

14:20 → 15:00 **Invited Talk: Historical look at the Development of the Focused, Pulsed Laser for SEE Testing of Integrated Circuits** ⌚ 40m

SEE testing using a focused, pulsed laser has reached a level of maturity that the technique is now widely employed in many laboratories around the world to supplement and complement heavy-ion testing. This has led to the publication of a handbook on focused, pulsed SEE laser testing to help those with little experience in optics perform SEE testing successfully and to present a series of steps that could lead to the development of a

Standard. At this point, it is appropriate to look back over the years and recall the many contributions by several research groups to the development of the technique.

Orateur: Steve BUCHNER (NRL)

15:00 → **16:00** **Session: Comparison between Laser and Heavy Ions**

15:00 **A Historical Overview of Ion/Laser Correlation Efforts** ⌚ 20m

After the invention of the laser in 1960, it wasn't long until its potential use to emulate transient radiation-induced effects was recognized. Following the first experimental demonstration of this capability in 1965, a series of studies that aimed to replicate various single-event effects (SEEs) were published in quick succession. However, it wasn't until 1987 when the first attempt to quantitatively reproduce particle-induced SEEs using laser pulses was demonstrated. Since then, attempts to correlate SEEs using a variety of methods have been steadily developed throughout the years.

In this talk, a historical overview of the various efforts to correlate laser data with ion-induced SEEs will be presented. The various studies will be examined through the lens of the main quantities used to establish an empirical correlation between laser pulse energy and the equivalent linear energy transfer (LET). The most common quantities considered for correlation in the literature are 1) SEE cross-sections, 2) collected charge measurements, 3) SEE thresholds, 4) single-event transient shapes. As will be shown, there are different levels of rigor associated with the correlation resulting from the use of these different quantities.

While a universal rule for correlation remains elusive, the long history of these correlation efforts has paved the way for the development of new pulsed laser SEE techniques that aim to be predictive. These predictive techniques aim to reproduce particle-induced results in certain scenarios, without a priori knowledge of specific SEE sensitivity of a device under test. These techniques, heavily informed by past correlation efforts, represent the future of pulsed laser testing.

Orateur: Adrian ILDEFONSO (U.S. Naval Research Laboratory)

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15:20 **Enabling Capabilities for Predictive Testing Using Pulsed Lasers** ⌚ 20m

Surrogate testing approaches that can predict heavy-ion single-event effect (SEE) responses in a device-under-test (DUT) could prove invaluable in easing pressure on oversubscribed heavy-ion facilities. However, predictive testing faces many challenges for successful implementation. The most significant of these challenges is generating a carrier distribution capable of reproducing the desired SEE response and doing this in a reliable and quantitative manner.

Pulsed-laser SEE (PL SEE) approaches have made substantial progress towards predictive testing over recent years and this talk will touch on the various capabilities enabling this effort. Such capabilities include identifying the criteria for predictive testing, tailoring the carrier distribution through beam shaping, accurately estimation of the equivalent LET, and overall improvements in laser systems for stability and wavelength tunability. To underscore the progress made, example case studies of predictive PL SEE testing will be given.

The ultimate goal for predictive surrogate testing is insertion into the radiation effects characterization and qualification pipeline. Towards this integration of surrogate testing, the importance of understanding the role of risk assessment tolerance and testing uncertainty will be addressed.

Orateur: Joel HALES (U.S. Naval Research Laboratory)

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15:40 **A comparison of heavy ion and laser SEE test data for analogue and digital parts** ⌚ 20m

As part of the commissioning activity for the new SEREEL2 pulsed laser single-event effects test system being created at Radtest Ltd's Harwell site, tests have been carried out on two types of component to compare heavy ion test data with the results of laser testing. These results are being used for a comparison exercise to demonstrate the applicability of laser testing for the assessment of components for use in space.

This presentation will elaborate on the scope and motivation of the testing, provide details of the parts tested and show the results obtained. A special focus will be applied to comparing the results from the two sources. One linear, analogue device (the well-known LM124 quad operational amplifier) and one digital device (a SDRAM memory) have been used, allowing several types of single-event effect to be investigated. Latch-up, transients, SEU and MBU have all been observed, using the new SEREEL2 system and heavy ions from HIF at UCL in Belgium. The presentation will show how event rates vary i) with LET from heavy ions and ii) with pulse energy from the laser and will use the results to illustrate the similarity of the two approaches.

Whilst a general, quantitative equivalence between LET and pulse energy remains elusive, the qualitative similarity provides an excellent approach for the screening of components. Other applications of pulsed laser test data include mapping SEE sensitivity across the area of a die, improving the radiation tolerance of parts, investigating deep charge collection phenomena and studying rare events that would require too much heavy ion beam time to be cost-effective. The sensitive regions of the LM124 have been explored in this manner and will be described in the presentation.

Orateur: Richard SHARP (Radtest Ltd)

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16:00 → **16:30** **Coffee Break** ⌚ 30m

16:00 → **16:30** **Poster**

16:30

Laser SEE Testing of Commercial SRAMs and Correlation with Heavy Ion Data

🕒 20m

We present pulsed-laser SEE tests on commercial SRAMs sensitive to SEL and SEU, comparing results to heavy ion data.

Orateur: Mario SACRISTAN BARBERO (Univ. Montpellier - CERN)

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16:50

Comparison between Laser and Heavy Ions test results from NSSC

🕒 20m

The presentation gives a comparative analysis for the results of laser and heavy ion experiments carried out by the National Space Science Center of the Chinese Academy of Sciences for integrated circuits and wide band gap semiconductor devices. By theoretical modeling and determination of the key parameters, the laser heavy ion equivalent relationship models for bulk silicon process and wide bandgap semiconductor process devices were obtained, and the above relationship and uncertainty were verified through a series of experiments with single photon and two-photon absorption mechanism.

Orateur: Yingqi MA

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17:10

Investigating Energetic Heavy Ions in The Solar System with the Juice Mission

🕒 20m

Thorough calibration of silicon detectors and their front-end electronics is a time-consuming and high-cost activity. Not only several particle beams including electron, proton, and heavy ions are needed, but also, depending on the design, other property effects such as temperature, bias voltage, and gain to name a few, might need to be characterized. This is especially true for the JUpiter ICy moons Explorer (JUICE) RADiation hard Electron Monitor (RADEM). RADEM detectors' signal are processed by three, highly customizable IDE3466 VATA IDEAS ASICs. In this work, we used Single Photon Absorption laser with different energies and frequencies to study the energy, gain, and temperature, dependence of the detectors' response. We also performed heavy ion beam testing at RADEF.

These tests showed that the RADEM Low Gain channels respond linearly to energies from at least 5pJ (~21 MeV) to 150 pJ (~536 MeV), at rates up to 500.000 particles per second, indicating a behaviour consistent with the RADEM requirements. While the heavy ion calibration tests showed lower coefficients than the theoretical values, this was attributed to cable loss.

The tests also showed that the ASIC gain can be adjusted from 50% to 150% with a 3rd order polynomial dependence. No changes were found by varying the coincidence window except at its lowest possible value. In that condition, the coincidence time is so large that can hinder particle detection at rates above ~5000 particles per second. The tests also showed that the detector response follows a Boltzmann distribution with temperature.

Overall, laser testing allowed to perform cost-efficient extensive characterization of the RADEM.

Orateur: Marco PINTO (ESA)

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