1064nm Pulsed Laser Experimental Technique for Quantitative SEE Testing

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Outline

- **General Background –Pulsed Laser SEE**
- **The Preparation for SEE Laser Testing**
- **Pulsed Laser Quantitative SEE Testing Technique**
  - Sensitive Region Location
  - Parametric Pre-characterization
  - Quantitative Calibration
- **Review and Prospect**

General Background

For device manufacture , spacecraft electronic instrument development and the mechanism investigation, the SEE sensitivity of Devices have to be evaluated. Usually by heavy ion accelerator, BUT:

- Time and money consuming (To be booked in advance)
- Need radioprotection-Vacuum
- Not adequate to evaluate sensitivity for sensitive region mapping
- Identical LET not available for some heavy ions penetration depth issue etc.

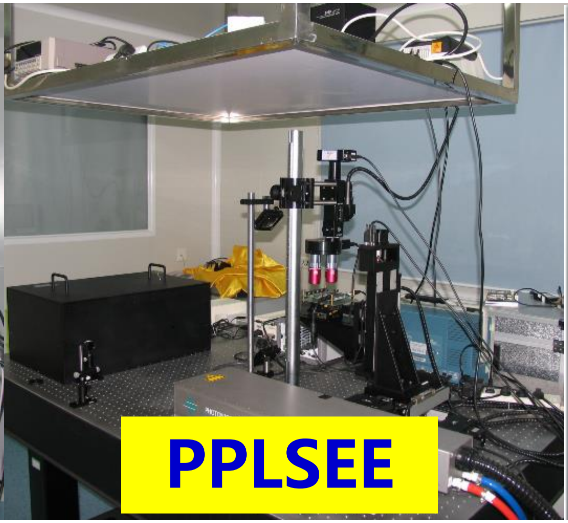
So pulsed laser could be a complementary tool to overcome the above issues. AND:

- SEE sensitive region mapping need visible and accurate location
- SEE fundamental research need the spatial, temporal and original characterization
- SEE pre-evaluation of various configurations/complex components

need a kind of relatively universal calibration between laser and heavy ion

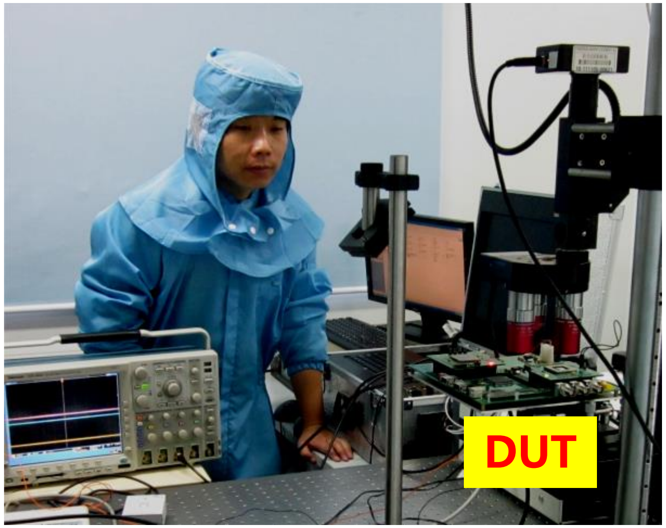
➢Pulsed Laser SEE Facilities of NSSC SEELab

NPLSEE



PPLSEE

FPLSEE

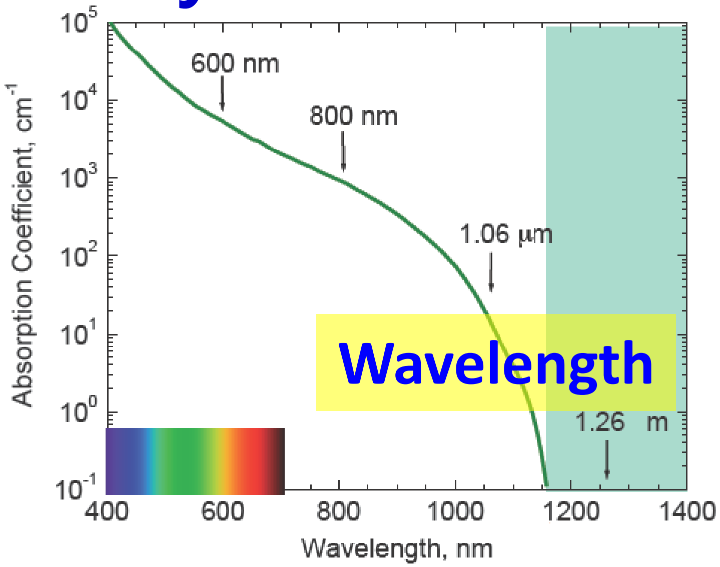


- Fully automated and accurate(laser stability) table tool
- Testing for device manufacture and spacecraft electronic system
- Parametric studies on SEE

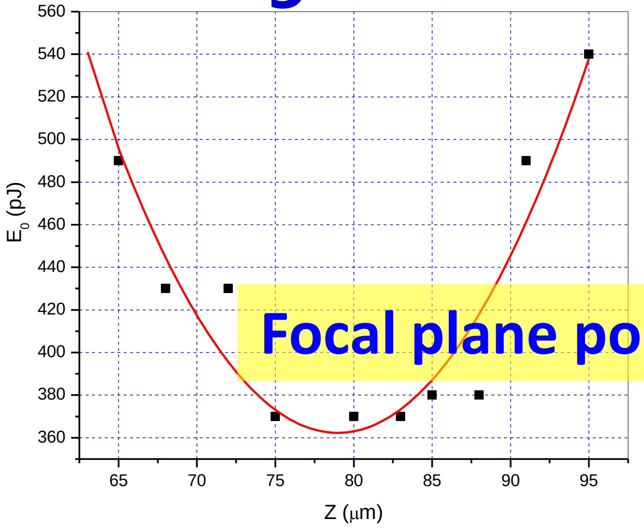
➢1064nm Pulsed Laser Test Conditions

Facility		DUT	
Wavelength	1064nm	**Sample Preparation**	Chip on Board repackaging; SIP SOP plastic packages; Flip chipped device; Ceramic packages possible
Pulse Width	<30ps	**Reflection on the substrate surface**	R=0.38~0.40
Pulsed Laser Energy E_{eff}	Measured value	**silicon substrate thickness h**	Measured value
Penetration Depth	>1000μm	**absorption coefficient α**	Measured value
Spot size Diameter	<3μm	**Reflection on the metal layer interface R'**	Measured value

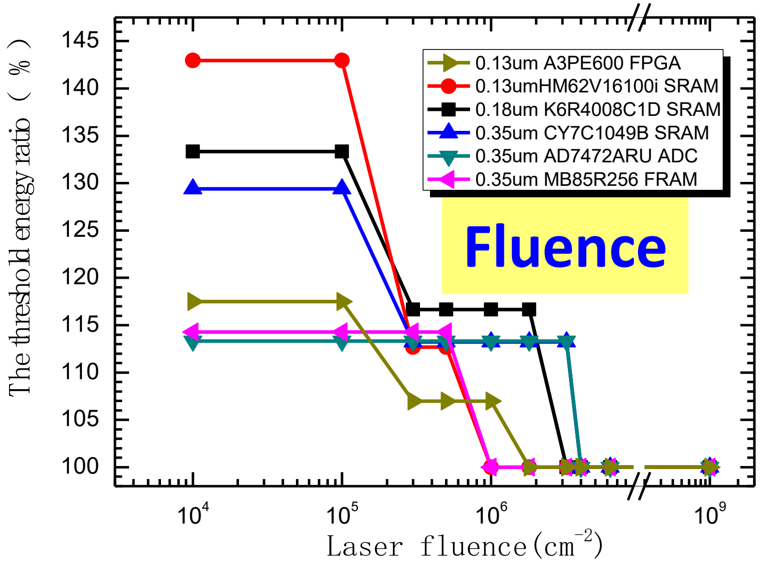
➢The Key Parameters of the Laser Testing



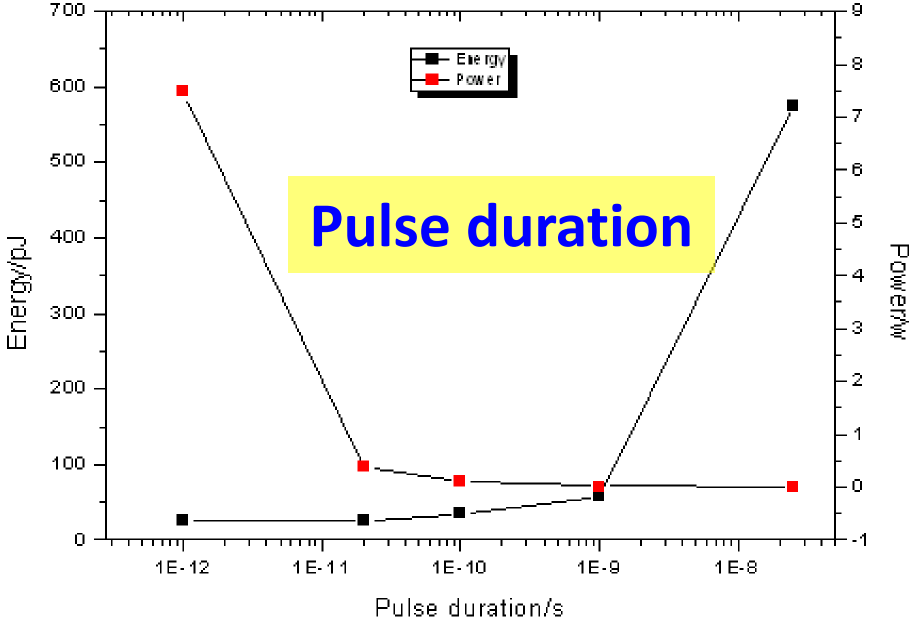
Wavelength



Focal plane position



Fluence

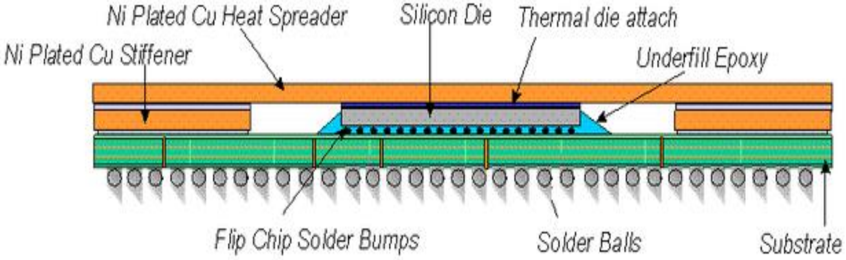


Pulse duration

The Preparation for SEE Laser Testing

Sample Preparation

- Process with feature size ≤ 0.25μm
  Go backside (unless specific laser testing design)
- Appropriate package required ;
  Ceramic packages (laser
  ablation and mechanical polishing) ;
  Chip on board, BGA repackaging…
- Mirror-quality polishing (especially for T

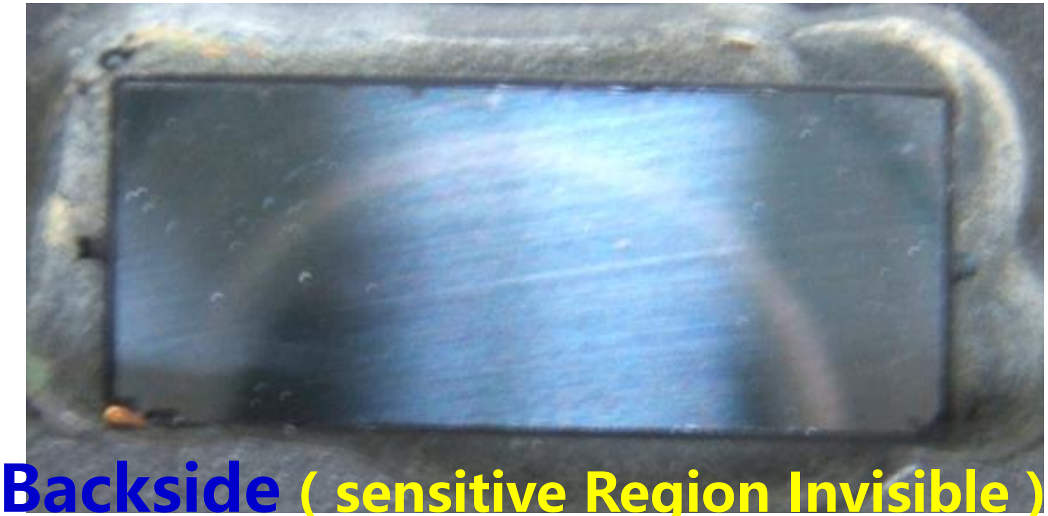


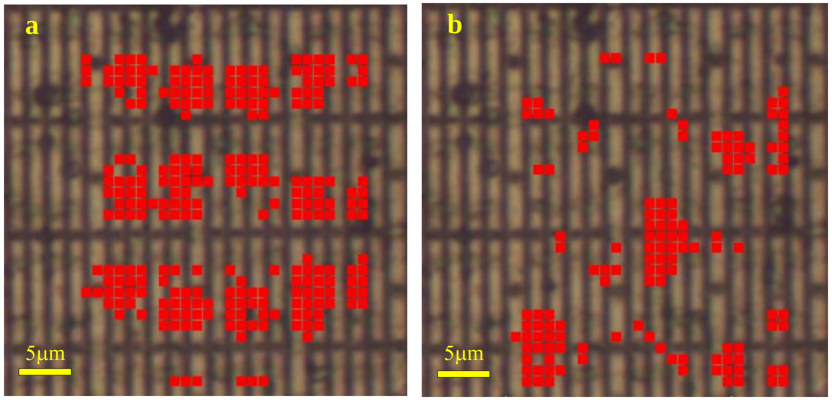
SPA Vs TPA

- SPA Laser source cost is much chipper,
  Energy stability is much better, and the
  risk of sample destruction is low.
- TPA Axial resolution is better, Lateral is improved.

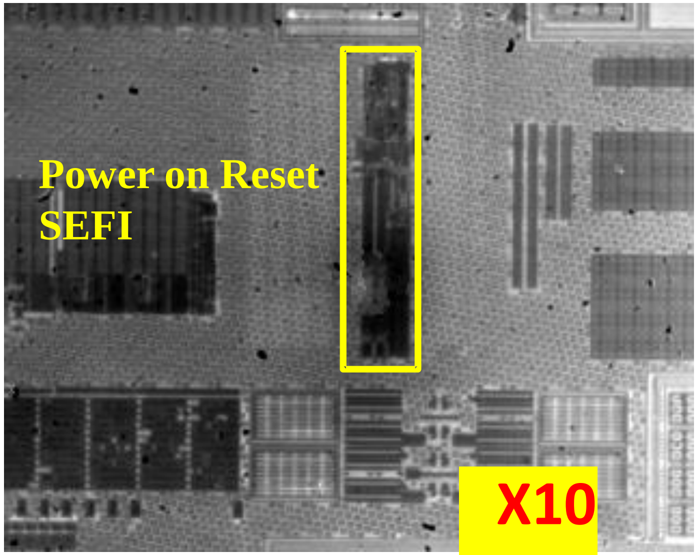
→ **1064nm SPA**

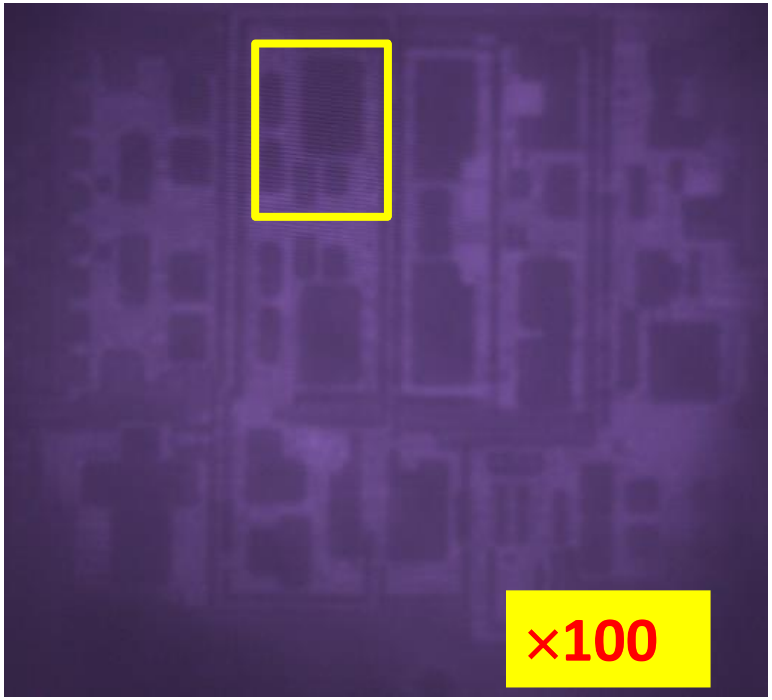
➢SEE Sensitive Region Location





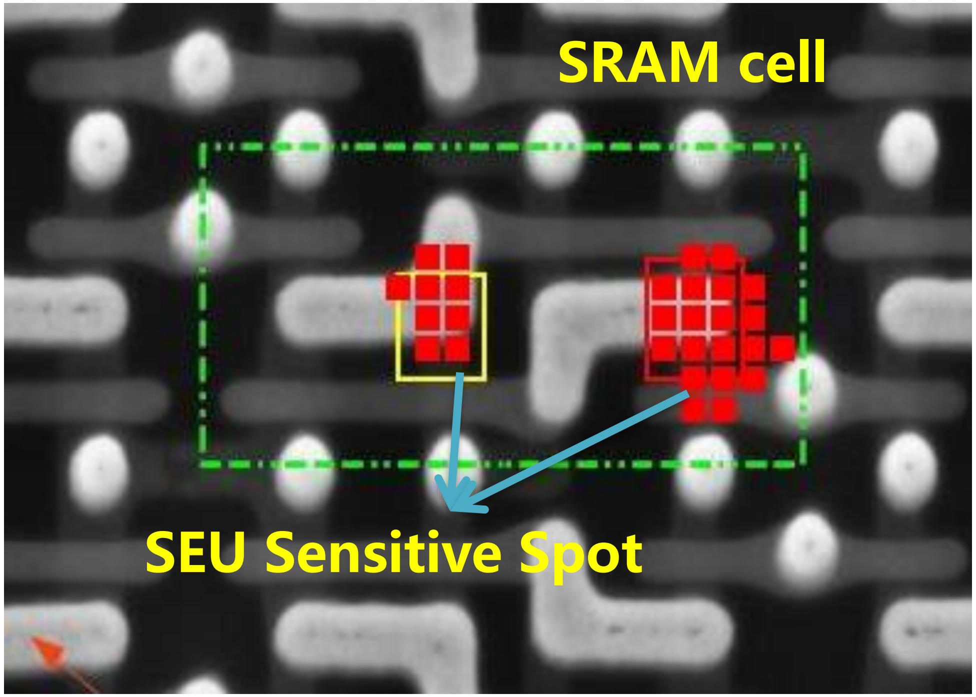
Frontside location





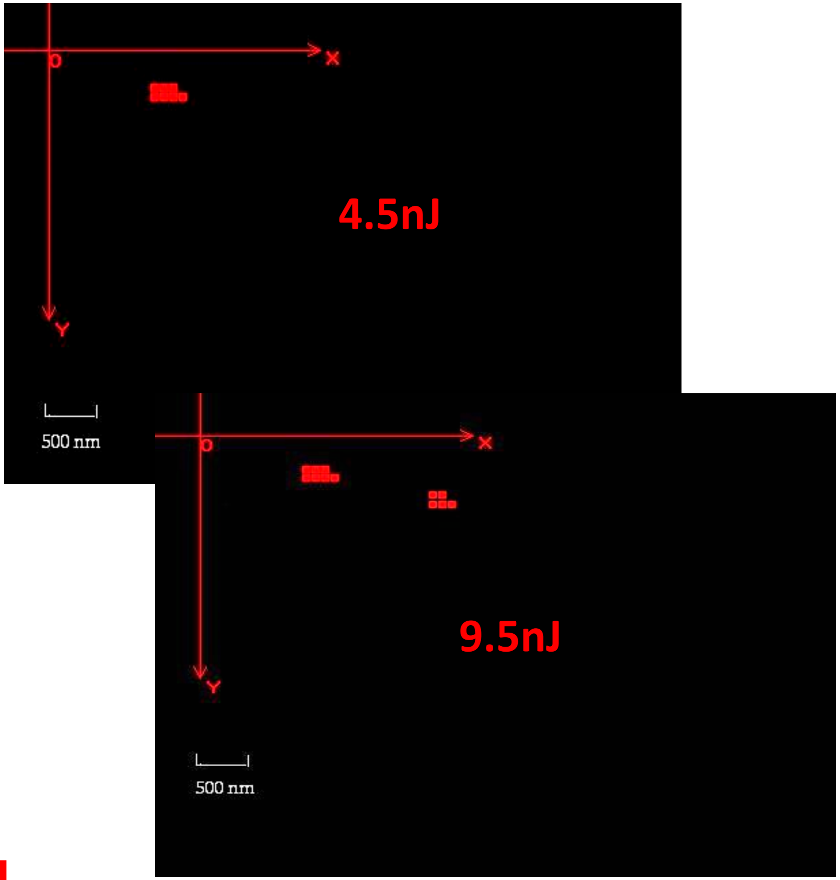
Backside infrared location

✓ SEU Sensitive Region Mapping



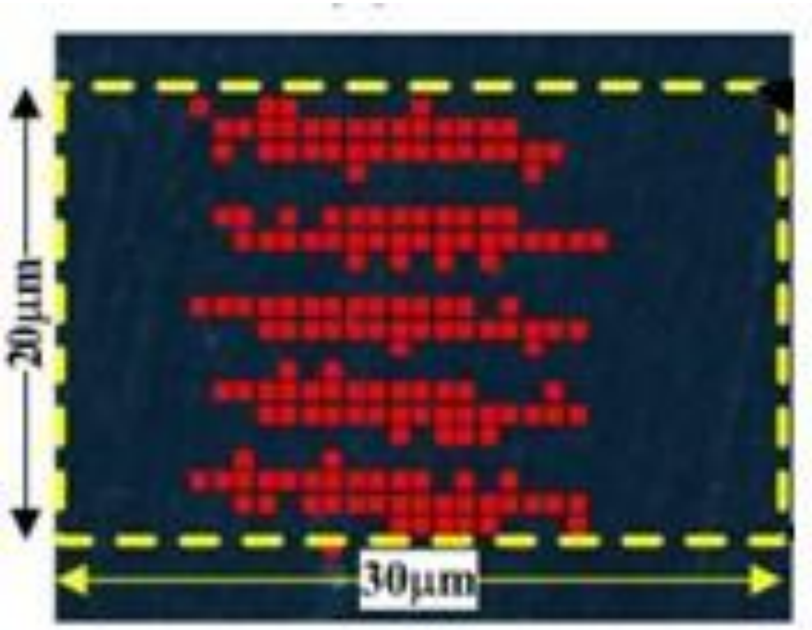
0.18μm SRAM

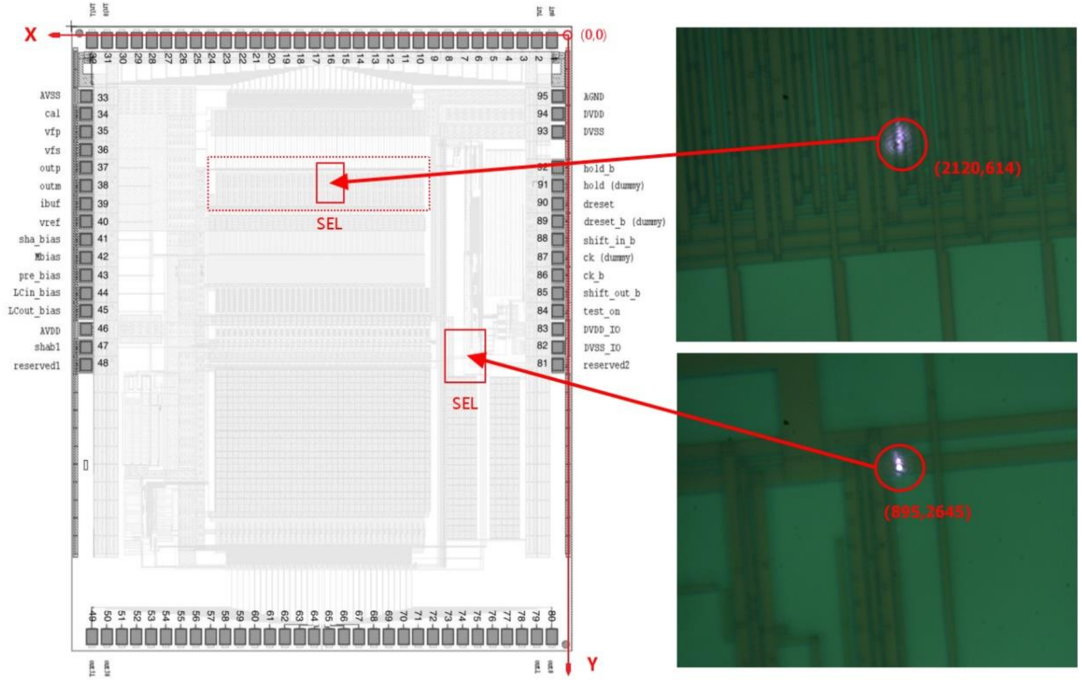
SEU Sensitive Region Mapping（0.1μm）



0.13μm FPGA

✓ SEL Sensitive Region Mapping

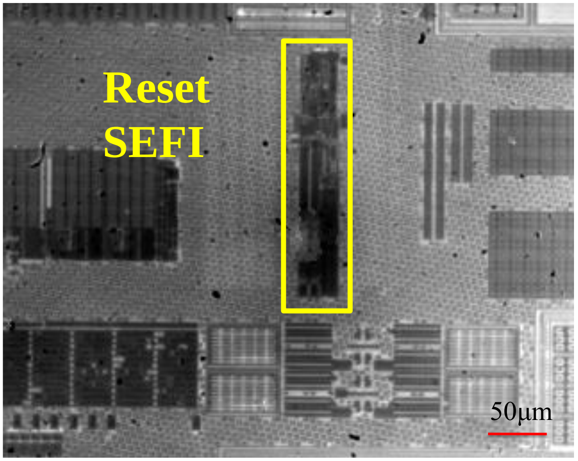


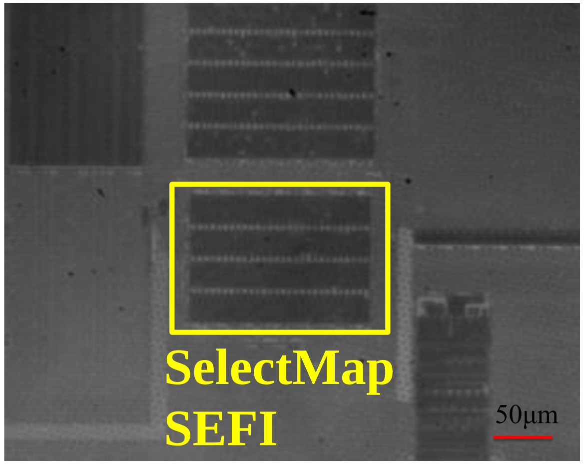


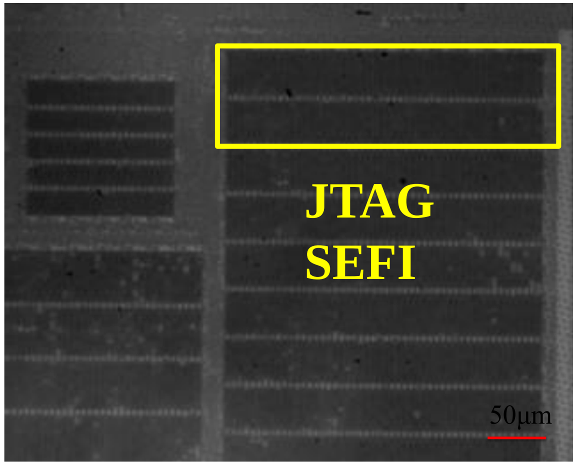
SEL Sensitive Region Mapping(SRAM)

SEL Sensitive Region Mapping(ASIC)

✓ SEFI Sensitive Region Mapping

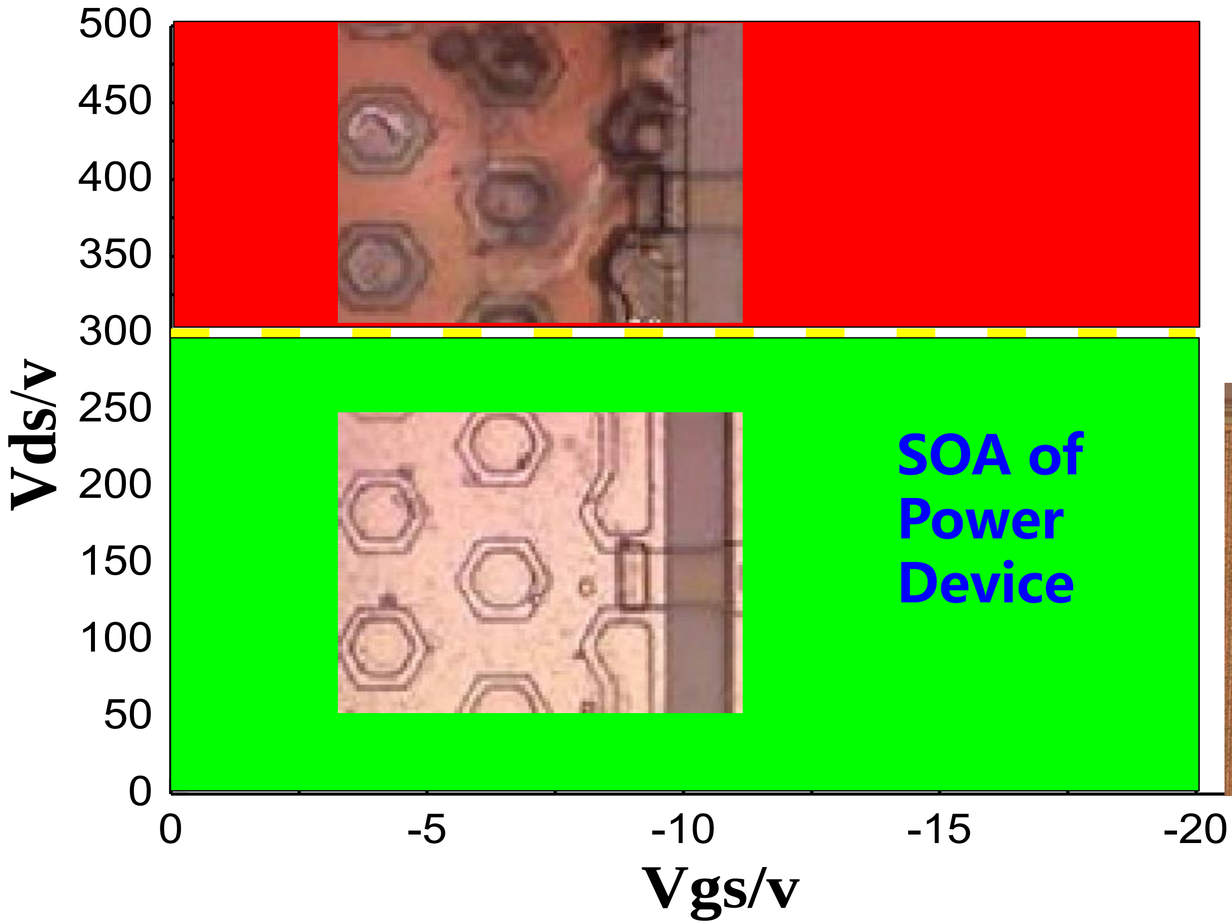


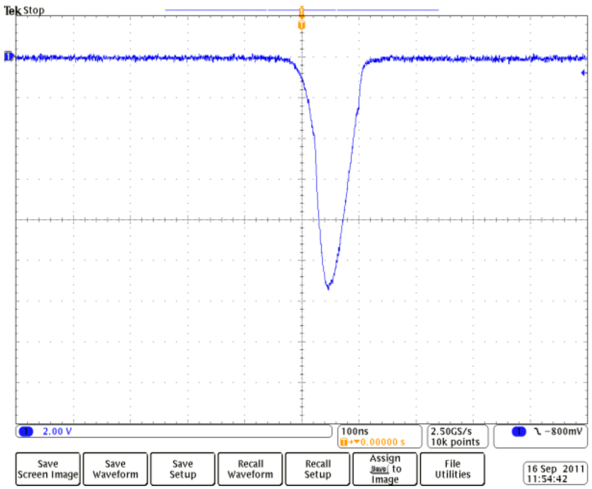


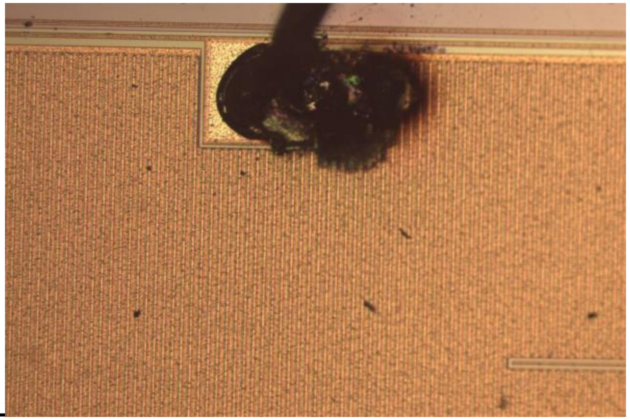


✓ SEB Sensitive Region Mapping

SEB of Power MOSFET and DCDC

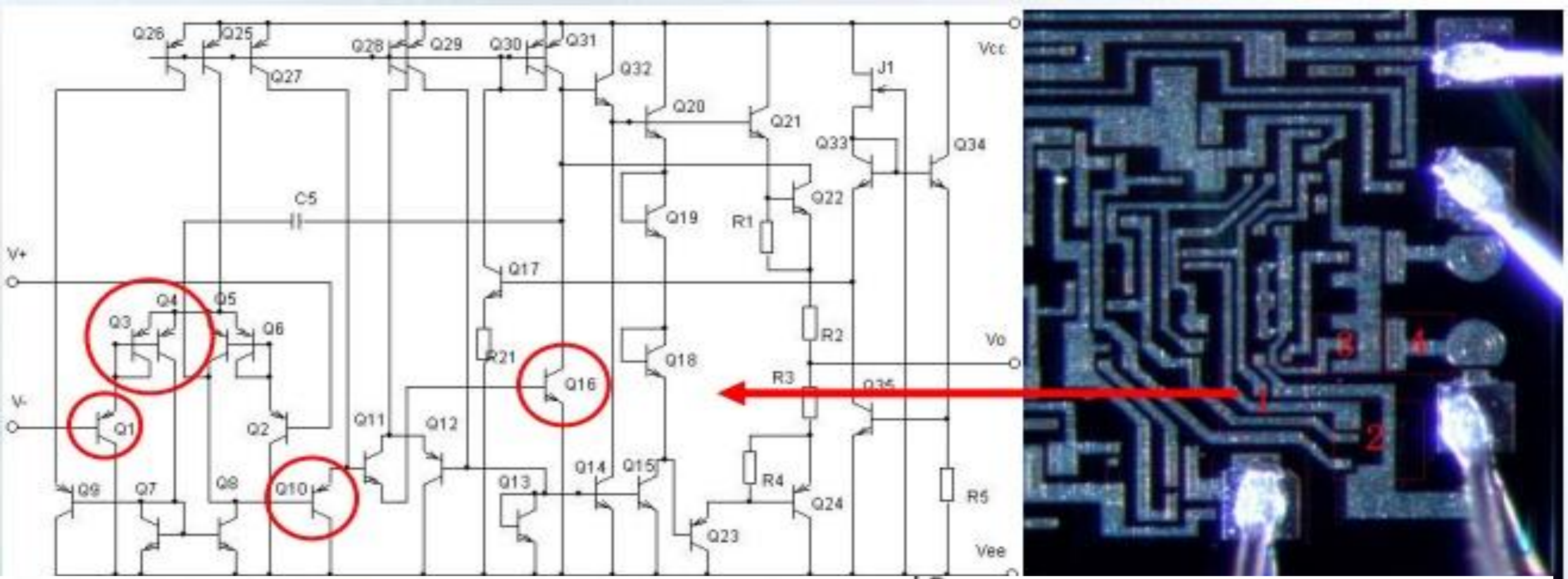


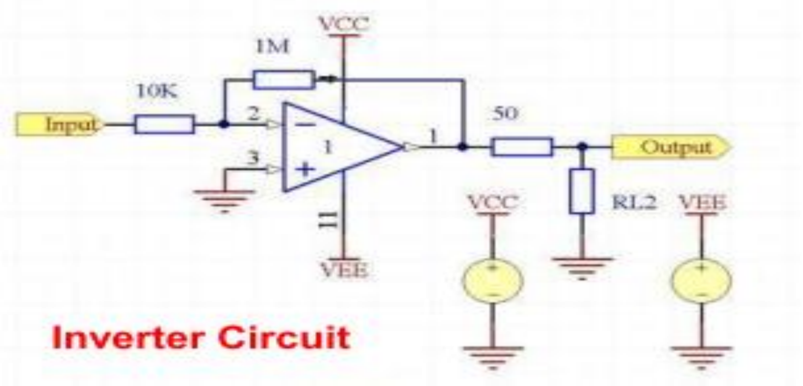




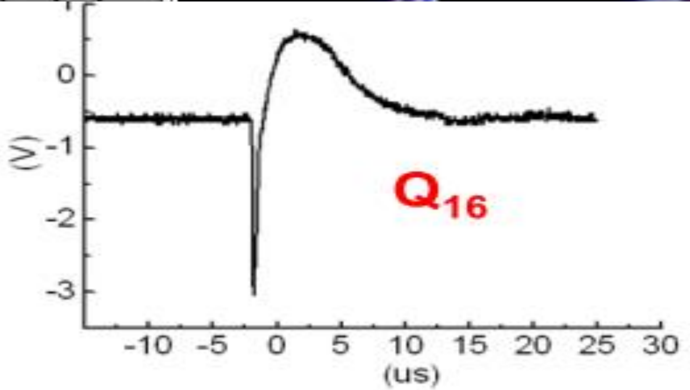
✓ SET Sensitive Region Mapping

SET of Linear Device

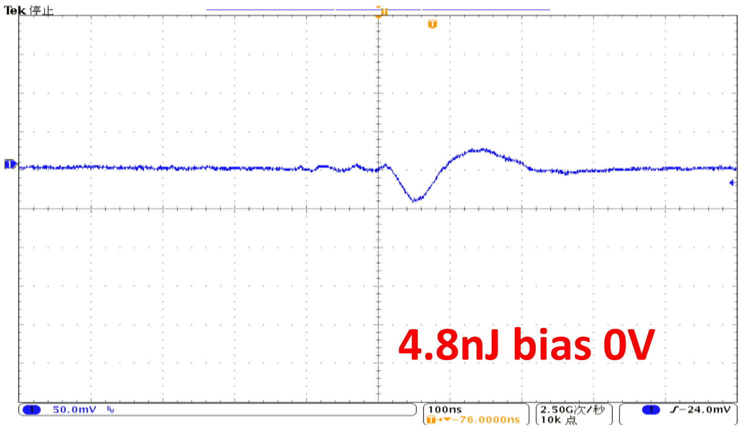




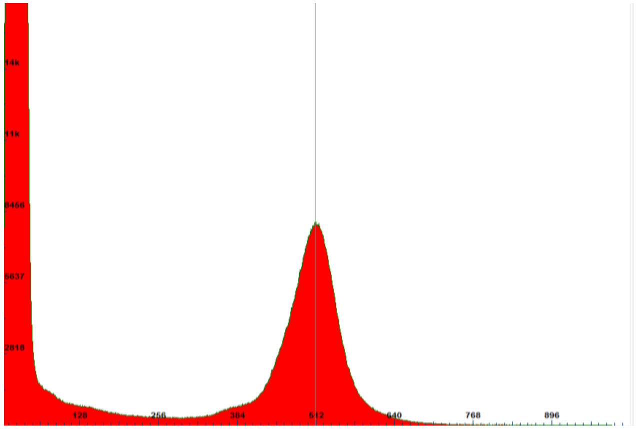
Inverter Circuit



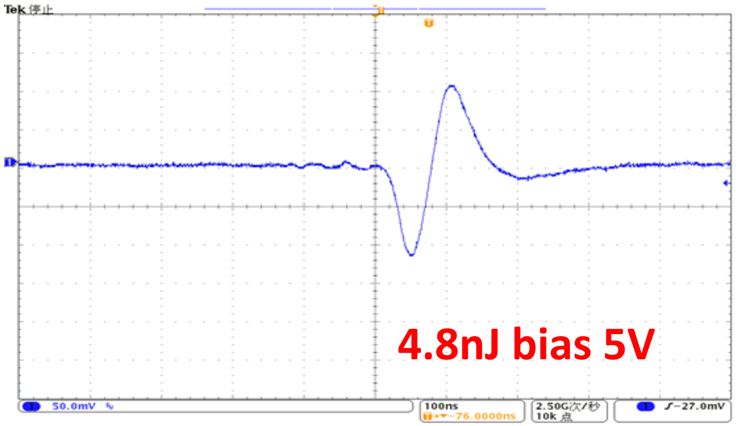
➢Parametric Pre-characterization



4.8nJ bias 0V

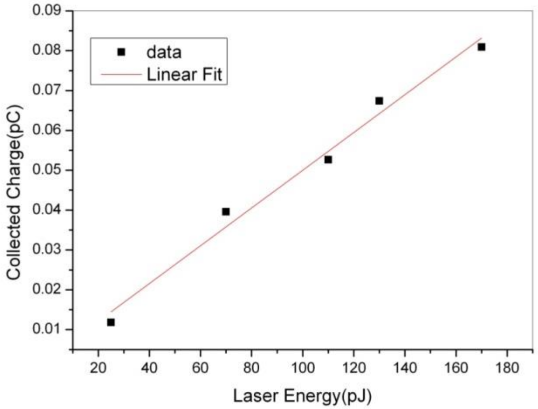


Spectral response of SRAM Device



4.8nJ bias 5V

Transient Current induced by laser

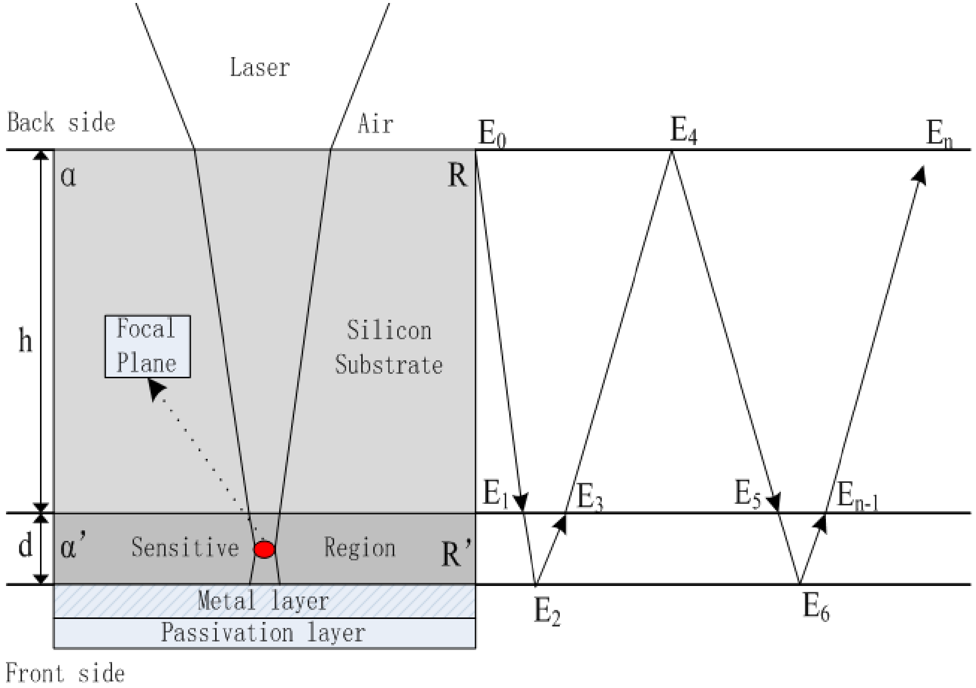


SEU Charge Collection Test of SRAM

✓Laser Energy Propagation Process in Backside Testing

Considering Multiple Reflections

Where λ=1064nm, E_{ion}=3.6eV, $h=4.14\times10^{-15}$eV·s, $c=3\times10^{8}$m/s, ρ=2.33g/cm^3, α'=10cm^{-1}.

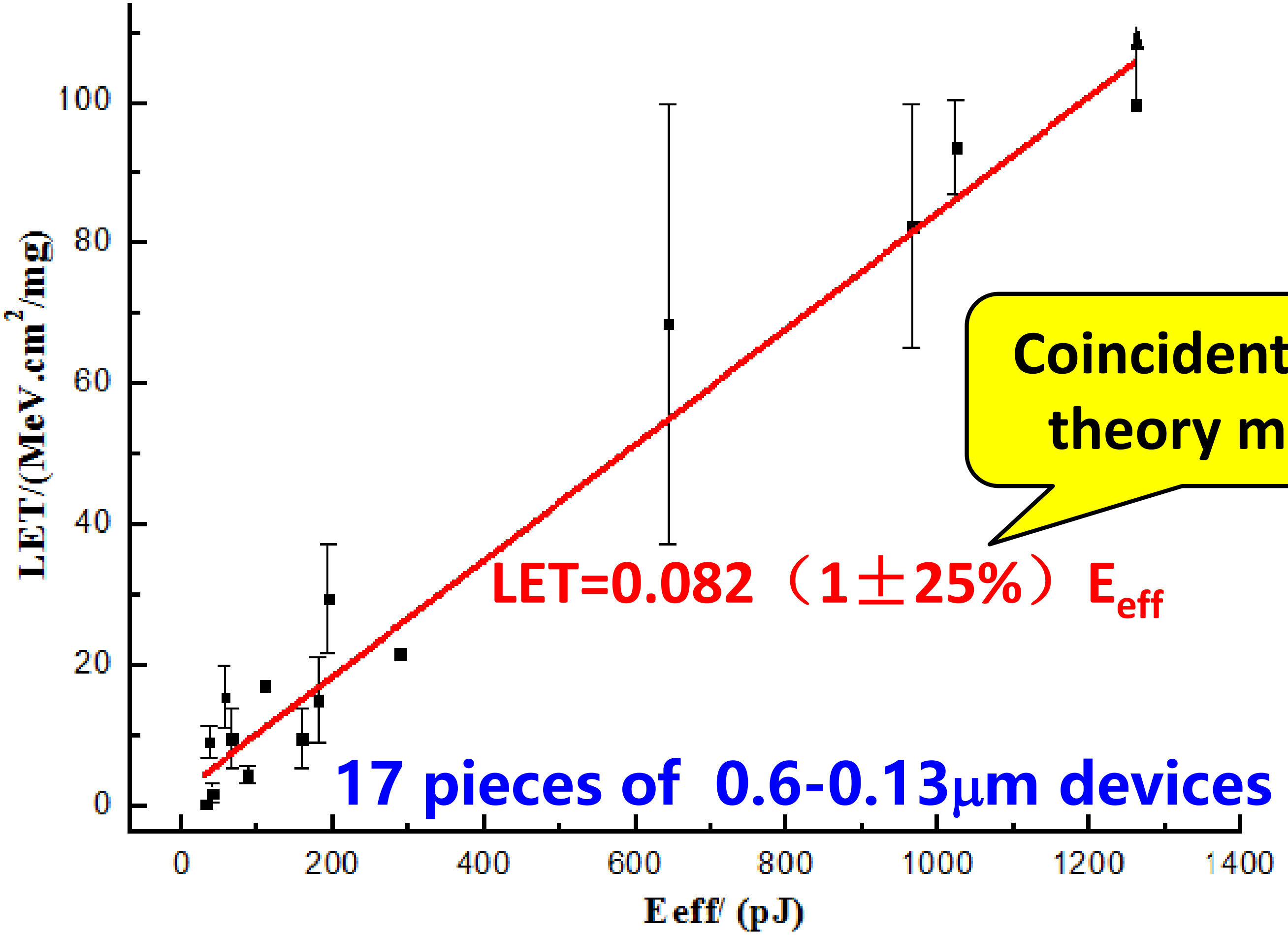


$$ELET = \frac{e_f}{\rho}\cdot\frac{\Delta E}{\Delta x} = \frac{e_f}{\rho d}\,\frac{(1-e^{-\alpha' d})(1+R'e^{-\alpha' d})(1-R)e^{-\alpha h}}{1-RR'e^{-2(\alpha' d+\alpha h)}}E_0$$

First Approximate calculation

$$LET = \frac{e_f}{\rho}\alpha' E_{eff}$$

✓SEL Laser Quantitative Calibration



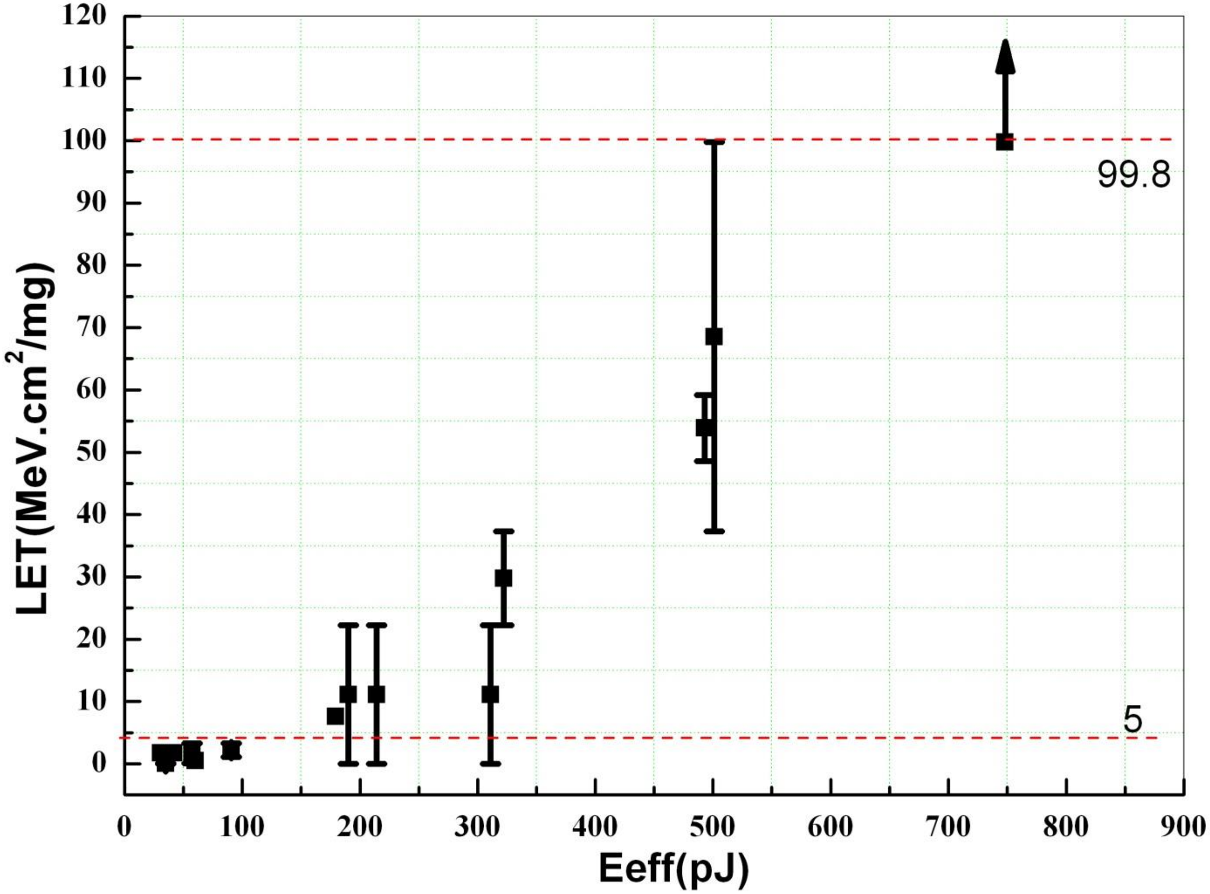
Coincident with theory model

$LET=0.082（1\pm25\%）E_{eff}$

17 pieces of 0.6-0.13μm devices

SEL threshold of laser energy-HI LET

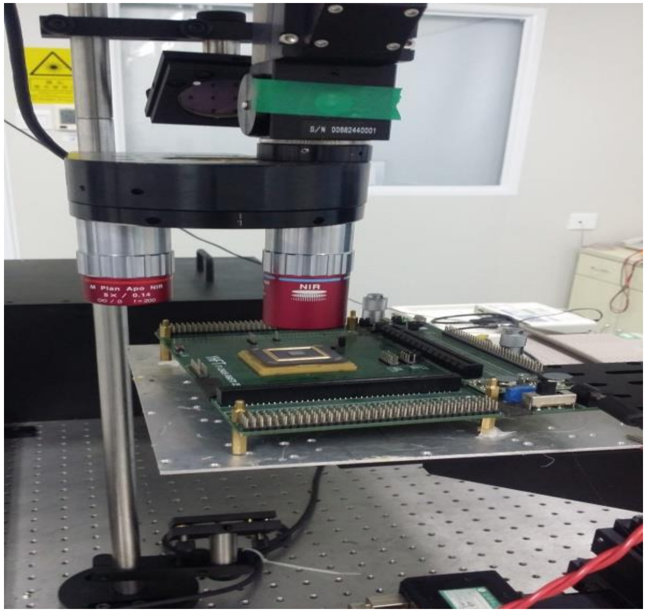
✓SEU Laser Quantitative Calibration

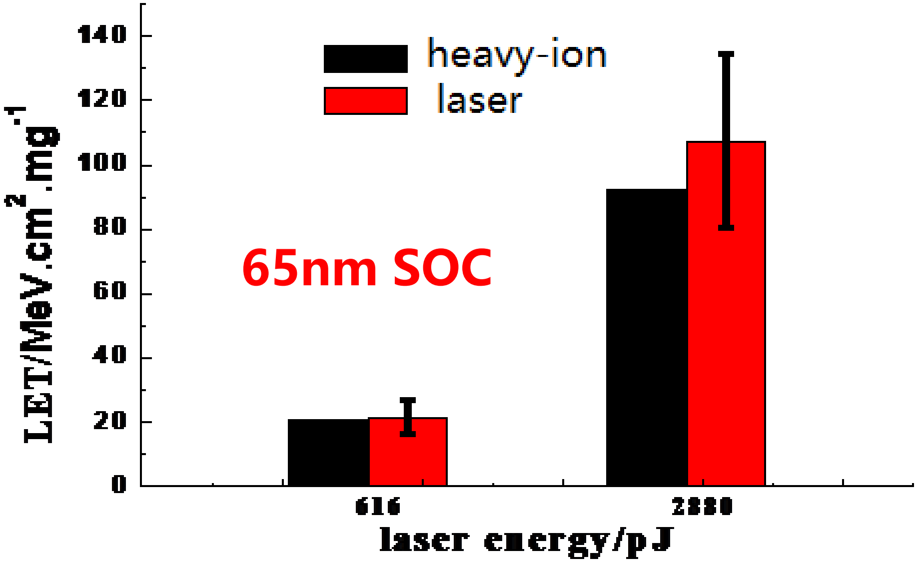


16 pieces of 40nm-0.35μm bulk-Si devices

SEU threshold of laser energy-HI LET

✓Verifacation of Laser Quantitative Calibration





Device	Part Type	Equivalent LET thresholds/ MeV·cm^2/mg	Heavy ion LET thresholds/ MeV·cm^2/mg
CAN BUS	SJA1000T	12.5±2.7	5.7-17.3
DDS	AD9852	13.7±2.9	5.7-17.3

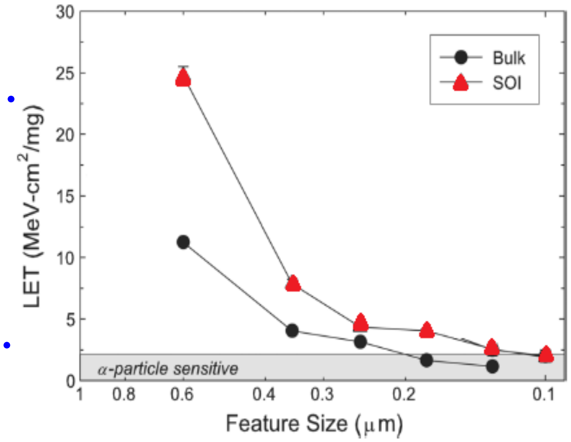
Review and Prospect

Pulsed Laser SEE Testing Technique including **quantitative calibration, sensitive region location, parametric pre-characterization** bring the new capabilities for the SEE testing.

- 1064nm laser could be an suitable choice with applicable depth of penetration and easier sample preparation.
- Quantitative laser testing is what engineers need.

Technology scaling = increase of charge sharing

- Not a major issue yet for SEU at 90nm or 65nm
- calibration and location more difficult for 28nm…



Prospect

- Standardization: reliable calibration, repeatability, reference dataset

How to be equivalent with ground-based accelerator ions and outer-space particles is still an challenging job, especially for the new structure nano devices. Collaboration with each other for the calibration is needed.

Thank you for your attention！