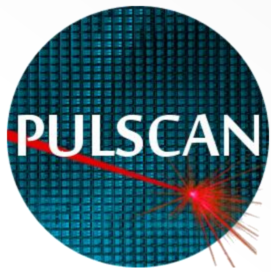


OPTICAL AND ELECTRONIC SOLUTIONS FOR TESTING AND FAILURE ANALYSIS

# Single-Photon and Two-Photon correlation case study on digital devices

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# Outline

- Motivation
- Devices under test (DUT)
- Test setup
- PULSCAN laser system
- Experimental results
  - SRAM
  - MRAM
- Conclusions



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# Motivation

- Demand on laser testing is raising up
- Recurent question: reference data and/or calibration
- Provide additional laser testing results to the community
- Measure SEU and SEL laser energy threshold on COTS memories with SPA and TPA laser system
- Compare SPA and TPA laser energy for different Single Event


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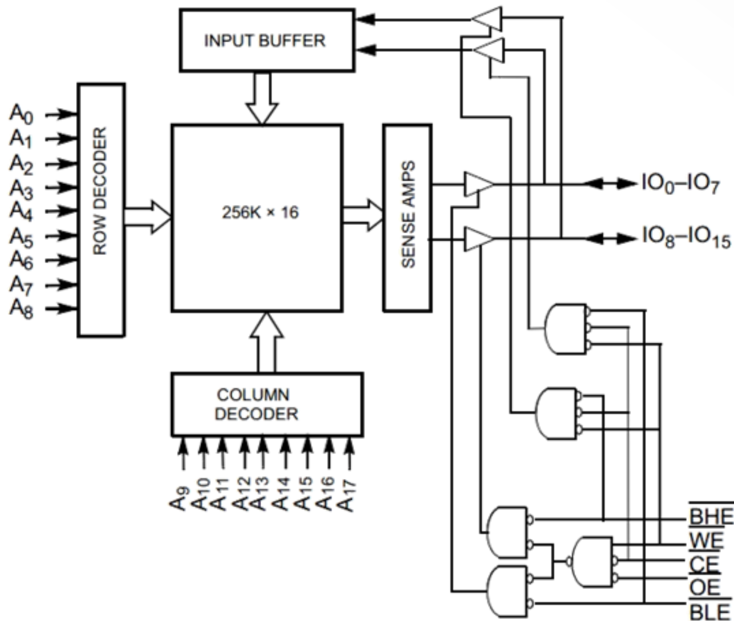
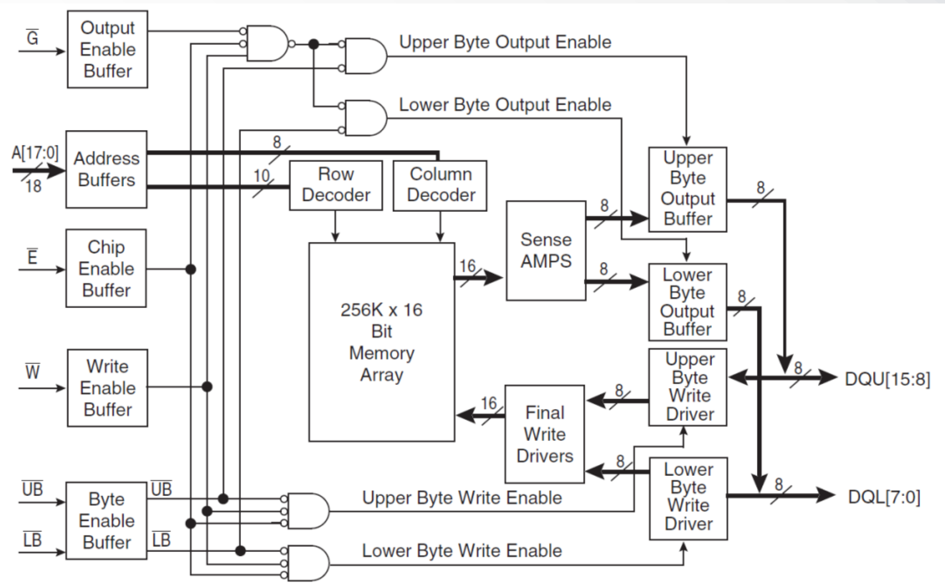
# Devices Under Test (DUT)

| DUT | Manufacturer | Part Number | Package | Power supply voltage (Typ.) | Capacity | Technology | Substrate thickness |
|---|---|---|---|---|---|---|---|
| **SRAM** | Cypress | CY7C1041DV33 | TSOPII-44 | 3.3V | 4-Mbit | 90nm | 246µm |
| **MRAM** | E2V | EV2A16A | TSOPII-44 | 3.3V | 4-Mbit | 180nm | 40µm |




**SRAM CY7C1041DV33 – Block diagram**




**MRAM EV2A16A – Block diagram**



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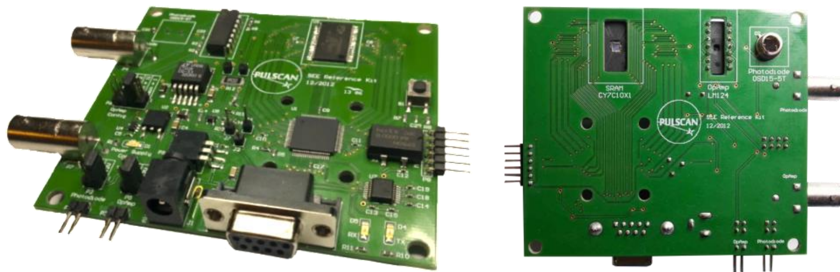
# Test setup

- Two test boards:
  - SRAM : PULSCAN SEE Reference Kit;
  - MRAM : Xilinx dev board + PULSCAN daughter board.
- Both boards include a current limiter to protect the DUT from destructive SEL (power supply recycling):
- Each board has its dedicated software to initialize the DUT, detect and report different types of events.



**PULSCAN SEE Reference Kit**

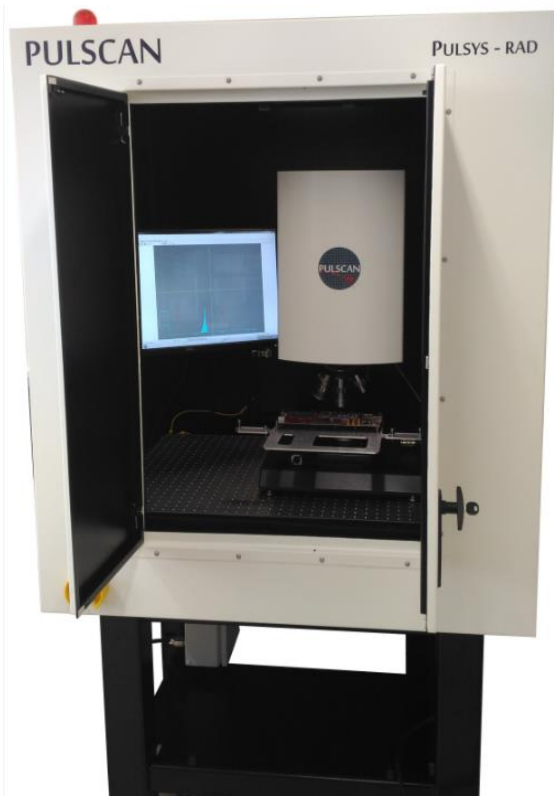
**Xilinx AC701 + Daughter board**

# PULSCAN laser system (PULSYS-RAD)

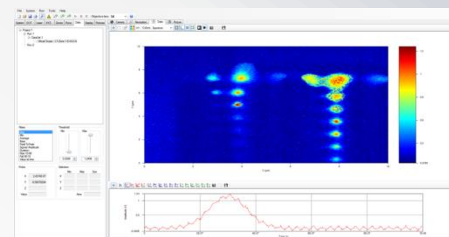
**PULSYS main frame**
Laser injected Infrared microscope

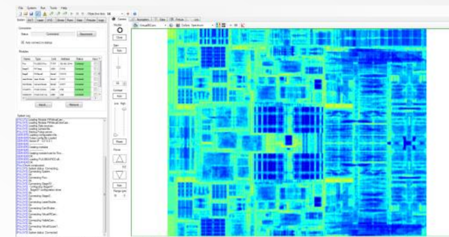
**PULSBOX Pico/2P**
Smart laser source

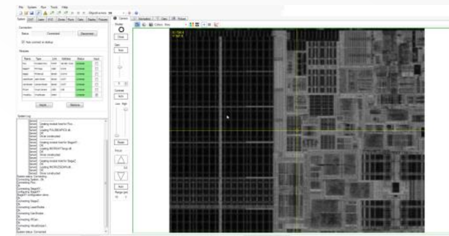
**PULSWORKS**
Laser testing dedicated software




| PULSBOX | Pico | 2P |
|---|---|---|
| Absorption mechanism | SPA | TPA |
| Wavelength | 1064nm | 1550nm |
| Pulse duration | 30ps | 450fs |
| Maximum Energy at the fiber output | 50nJ | 50nJ |









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# PULSYS-RAD and test board communication

## Typical test procedure

PULSYS Computer

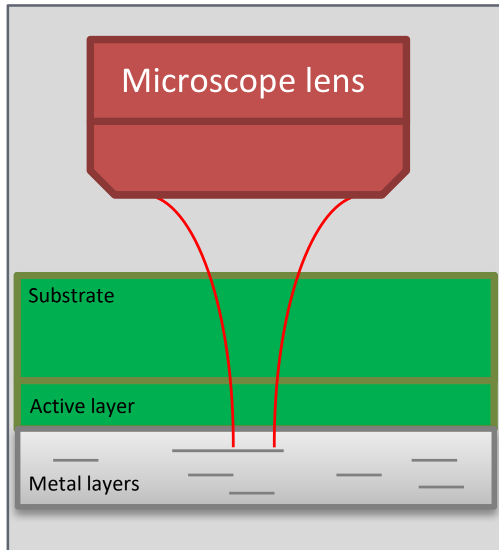
User Tester

| PULSWORKS | Data Transmission | User Code |
| --- | --- | --- |
| System Connect | INIT; → | Initialization |
| Run Begin | STARTTEST; → | Run specific initialization |
| Run Loop | GETALLEVENTS; → <br> ← Events\n | Test routine and event returned |
| Run End | STOPTEST; → | Test finished instructions |

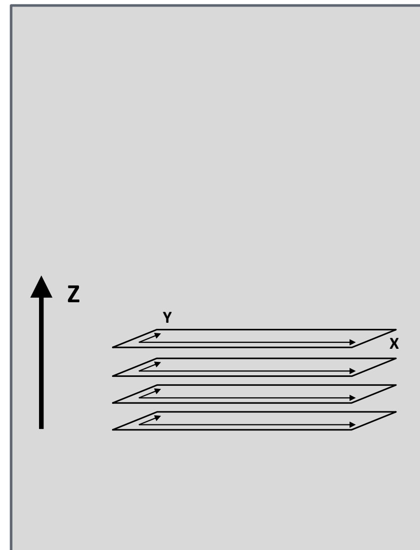
# Data analysis with PULSWORKS

# SRAM: SEU threshold energy

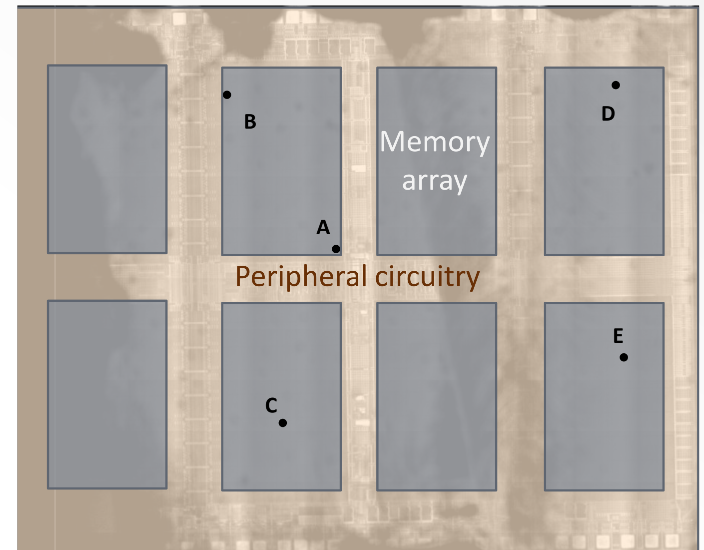
- Test procedure
  - 5µmx5µm scan in the memory array
    - XY step: 0.5µm
    - Z step: 1µm from the focus position up to 10µm above the focus
  - Increase laser energy (step 10pJ) until a SEU was detected
  - Measure the laser energy threshold for SEU on different location on the SRAM



Backside laser injection



Scanning routine



SRAM structure overview with sensitive points



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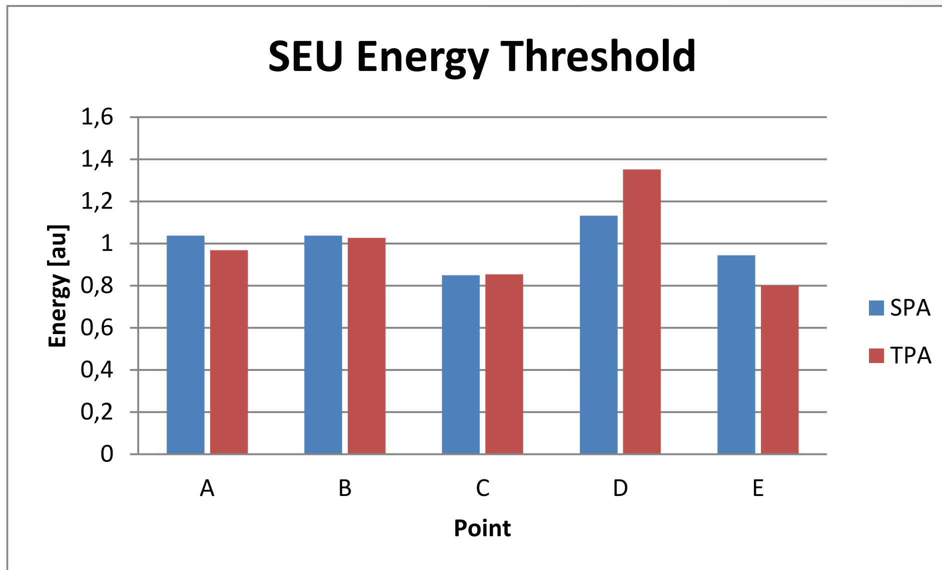
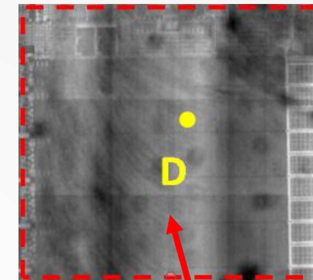
# SRAM: SEU threshold energy results

| SEU Threshold energy | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Point** | **A** | **B** | **C** | **D** | **E** | **Mean** | **STD** |
| **SPA (nJ)** | 0,110 | 0,110 | 0,090 | 0,120 | 0,100 | 0,106 | 11% |
| **TPA ($nJ^2$)** | 0,109 | 0,116 | 0,061 | 0,152 | 0,113 | 0,113 | 22% |




*Drilling marks on the backside surface induce laser scattering*

- SEU threshold energy variation relative to the location
  - Mainly depend on the backside surface quality
- TPA technic more sensitive to bad backside preparation



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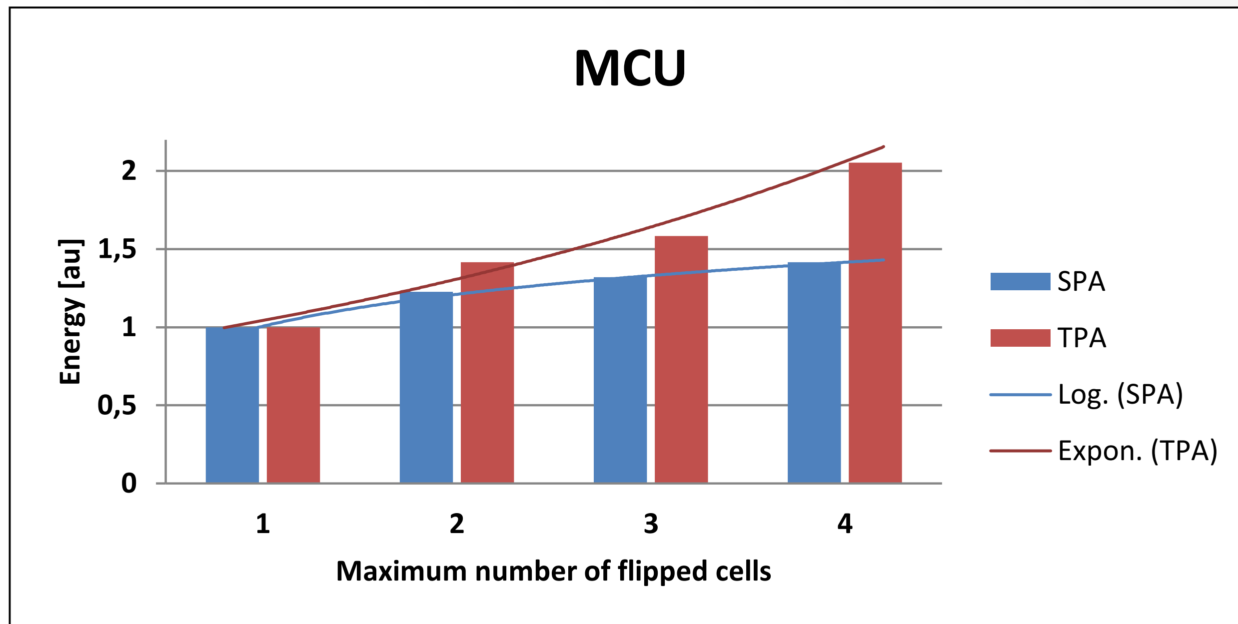
# SRAM: MCU threshold energy results (1/2)

- By increasing laser energy, several cells flipped

| MCU Threshold energy | | | | |
|---|---|---|---|---|
| **Number of flipped cells** | **1 (SEU)** | **2** | **3** | **4** |
| **SPA (nJ)** | 0,106 | 0,130 | 0,140 | 0,150 |
| **TPA ($nJ^2$)** | 0,113 | 0,160 | 0,179 | 0,232 |




- MCU generation need more energy in TPA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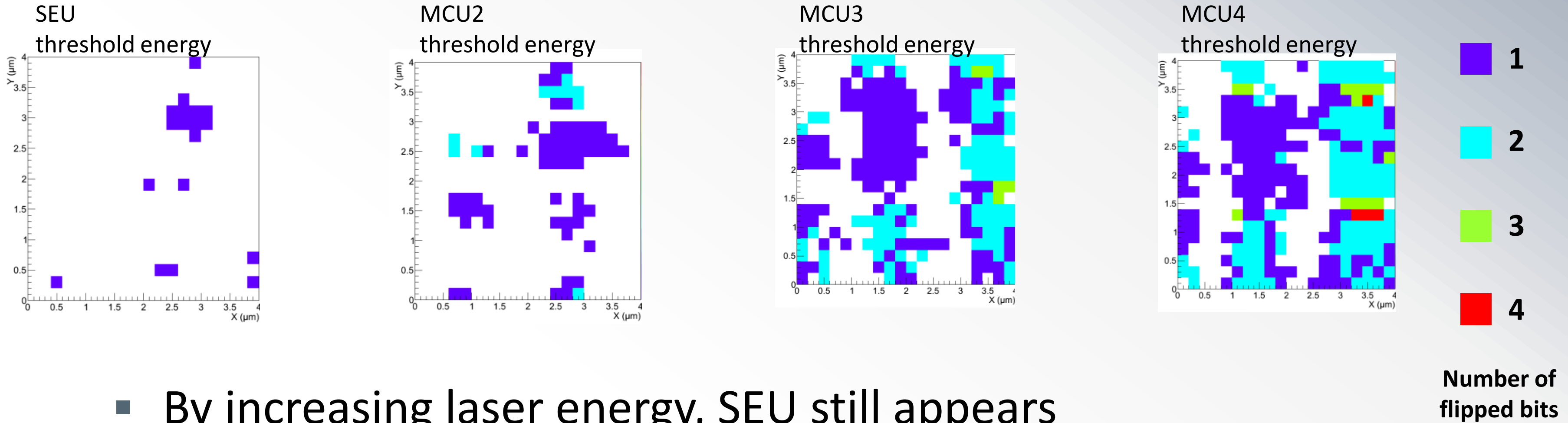
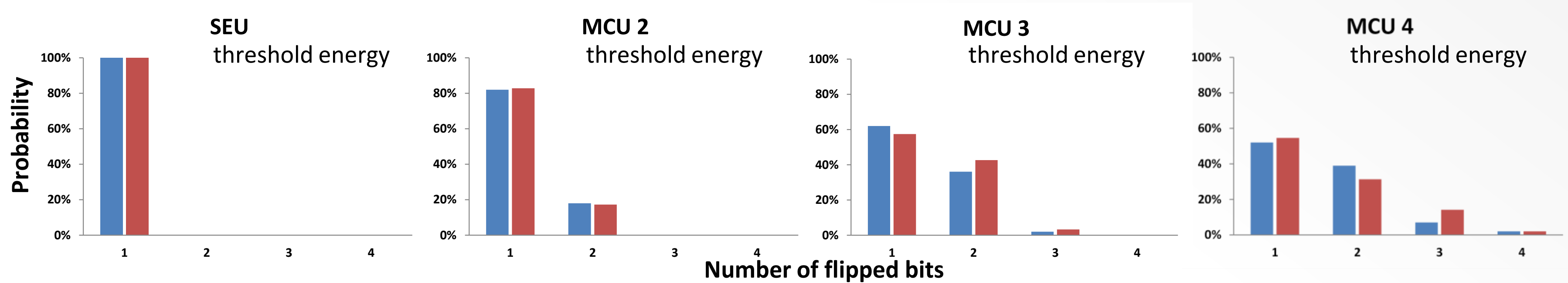
# SRAM: MCU threshold energy results (2/2)




- By increasing laser energy, SEU still appears




- Probability of MCU apparition with SPA and TPA is very close



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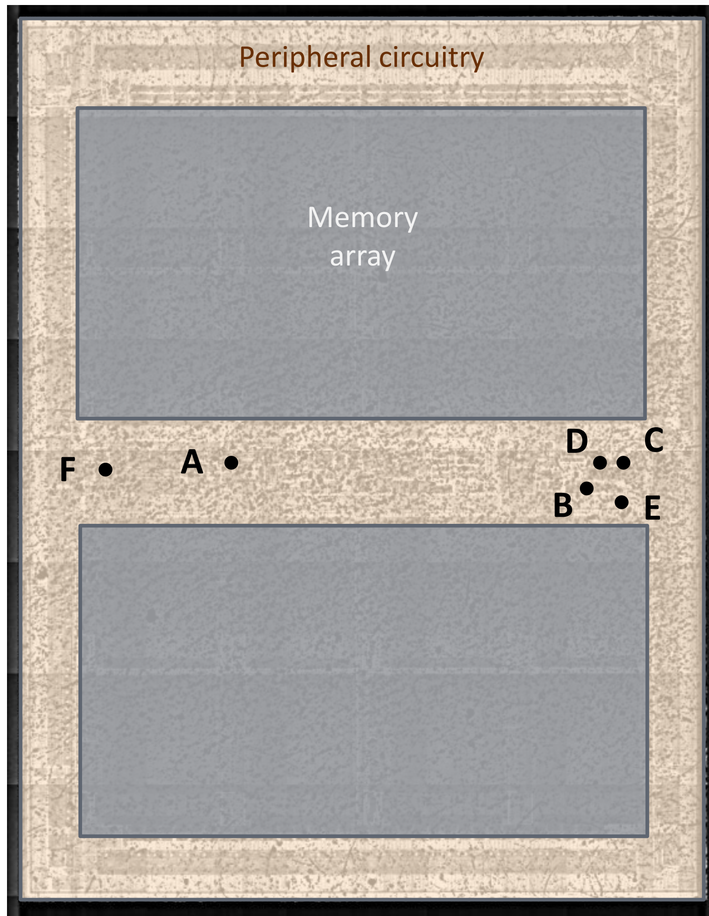
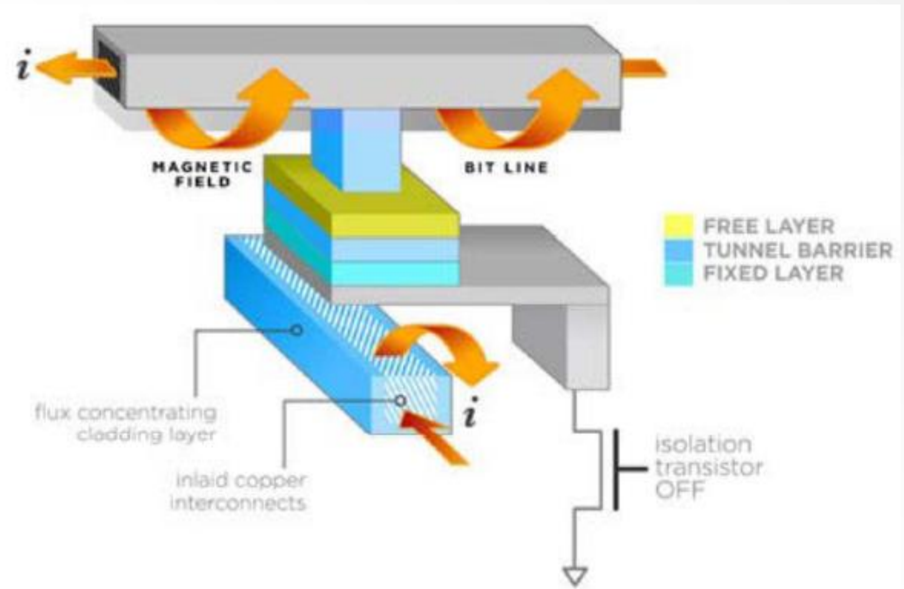
# MRAM: SEL and SEU threshold energy

- Scan of the peripheral circuitry
- Increase the laser energy until event appears (SEL or SEU)




- Magneto-resistive bit cells:
  - Immune to SEE





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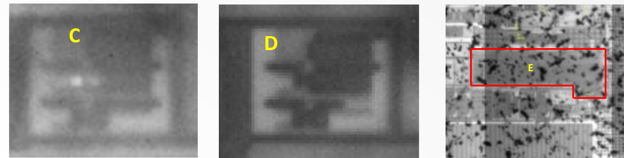
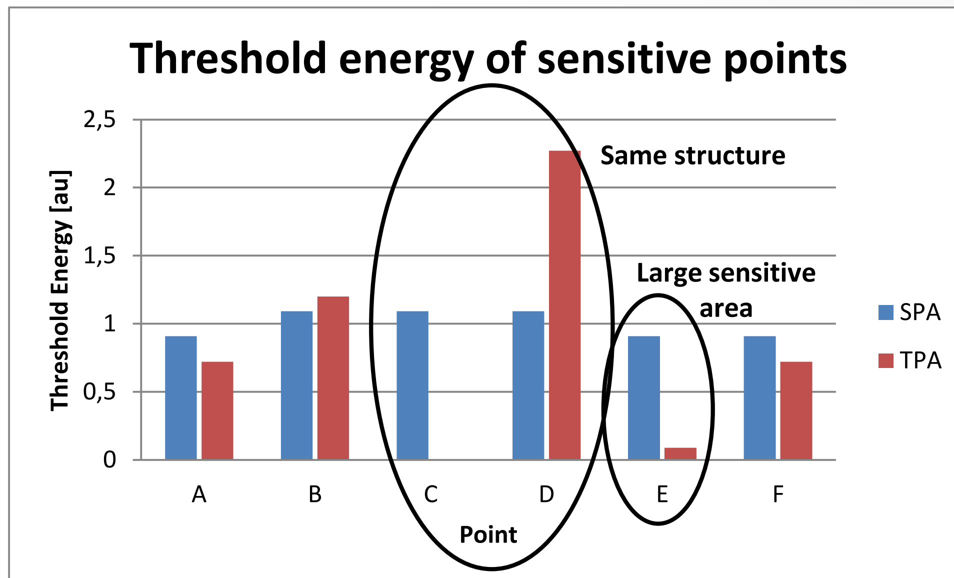
# MRAM: SEL and SEU threshold energy results

| Threshold energy | | | | | | |
|---|---|---|---|---|---|---|
| **Point** | **A** | **B** | **C** | **D** | **E (zone)** | **F** |
| **Event** | SEL | MCU | SEL | SEL | MCU | SEL |
| **SPA (nJ)** | 0,690 | 0,828 | 0,828 | 0,828 | 0,690 | 0,690 |
| **TPA ($nJ^2$)** | 2,40 | 4,00 | No event | 7,57 | 0,29 | 2,40 |





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# Conclusion

- SEU, MCU and SEL threshold energy was measured on different point on COTS SRAM and MRAM
- Good agreement between SPA and TPA measurements for SEU thresholds on the SRAM
- Some differences observed on specific points of the MRAM probably explained by layout and circuit details
- Threshold energy measurement is more sensitive to backside surface quality with TPA
  - SPA recommended for scanning large areas
- Future works:
  - Similar measurements on smaller nodes and correlation with heavy ion data



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