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A new laser facility at CNES for the study of SEE behavior of electronic devices

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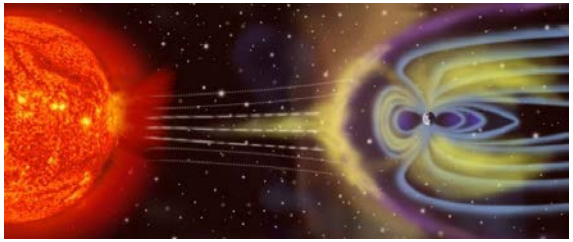
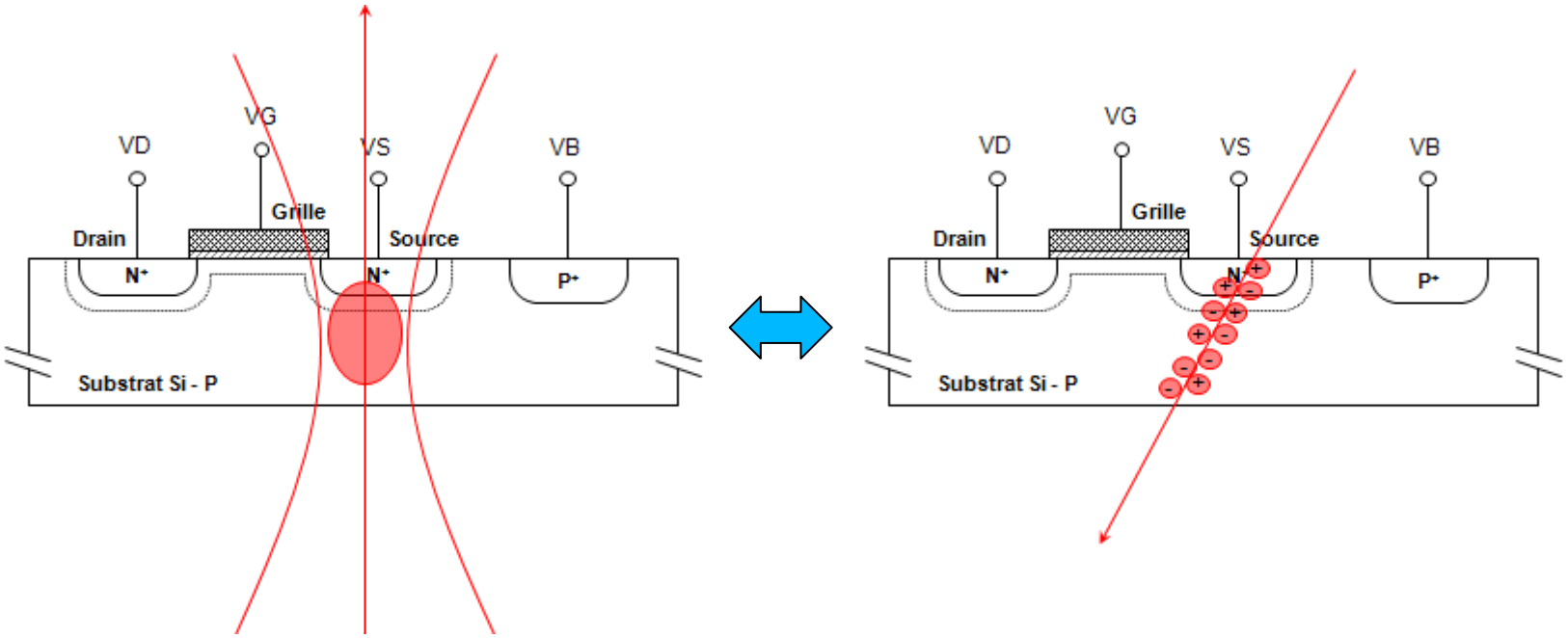
- **SEE sensitivity is one of the major concern for the use of microelectronic in space environment.**



- **Heavy ion test stay the best way to evaluate this sensitivity but other approaches based on pulsed laser stimulation can be used as a complement or preparation.**

- **CNES take the choice to invest on such laser to provide support, evaluation, study or expertise on SEE sensitivity.**

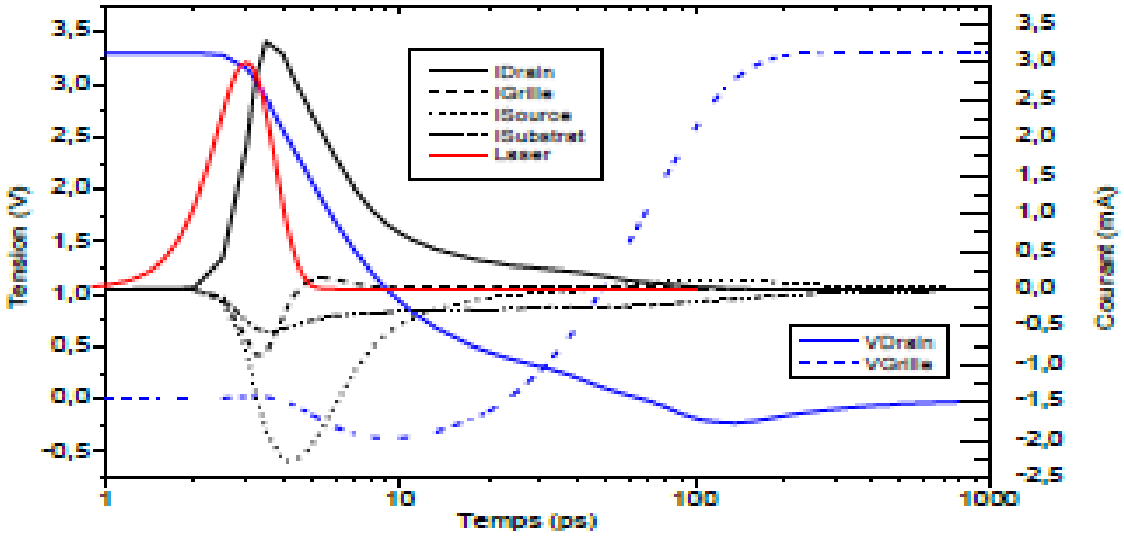
- **Correlation between effect induced by high energy particle and focused laser pulse have been demonstrated**

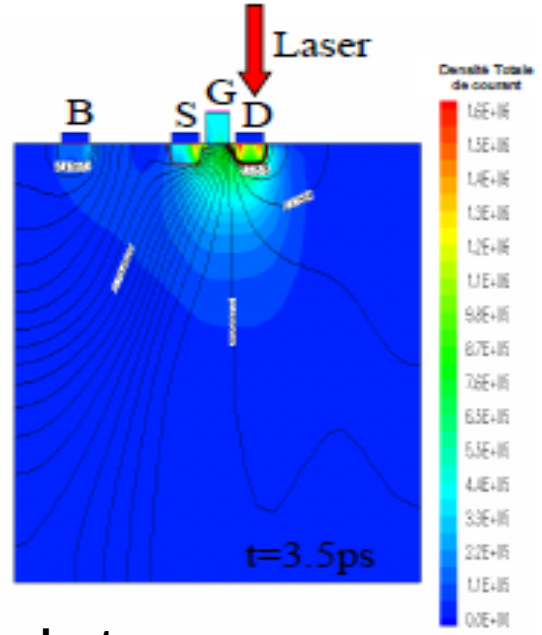


- **In consequence: several kind of SEE can be induced under laser**
  - **Single Event Transient, Single Event Upset and Single Event Latchup**

- **Correlation between effect induced by high energy particle and focused laser pulse have been demonstrated**

Simulation data for 1ps pulse at 2.2pJ (IMS Bordeaux)



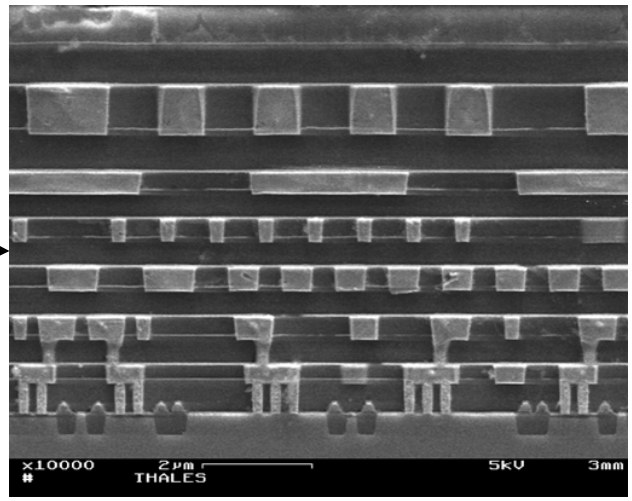


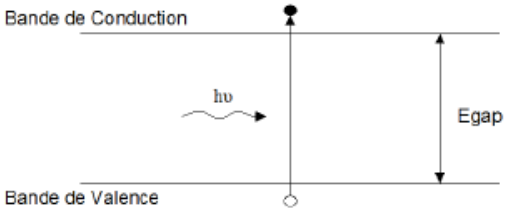
Laser is inducing high carrier density that will be collected thanks to parasitic bipolar transistor activation, junction and funneling effect

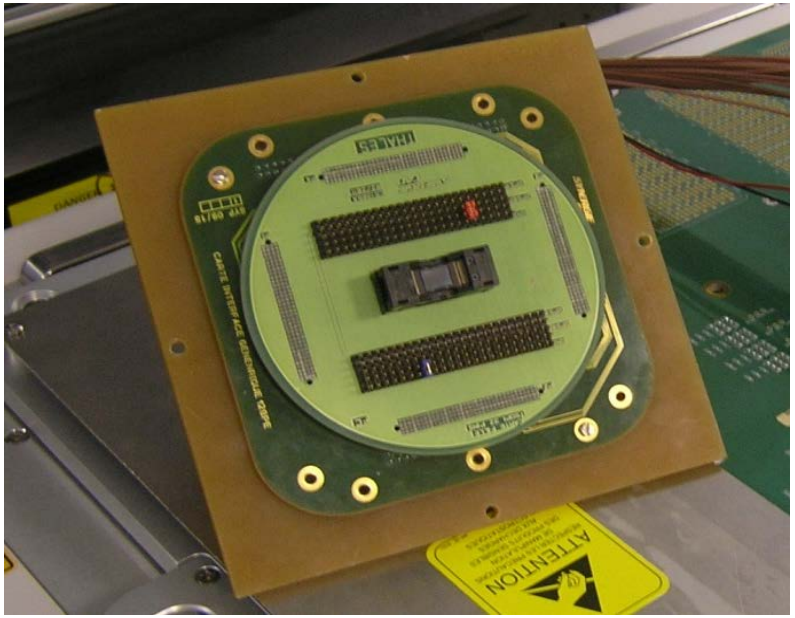
Laser source characteristics – Wavelength selection

- **Photoelectric effect and silicon transparency for possibility of front side and back side analysis was requested**

90nm technologies
7 metal layers







- **1064nm is selected:**
  - **Photogeneration in Si ($E > E_{GAP}$ (1,1eV))**
  - **Silicon transparency on several hundred of micrometer**

Laser source characteristics – Laser energy selection

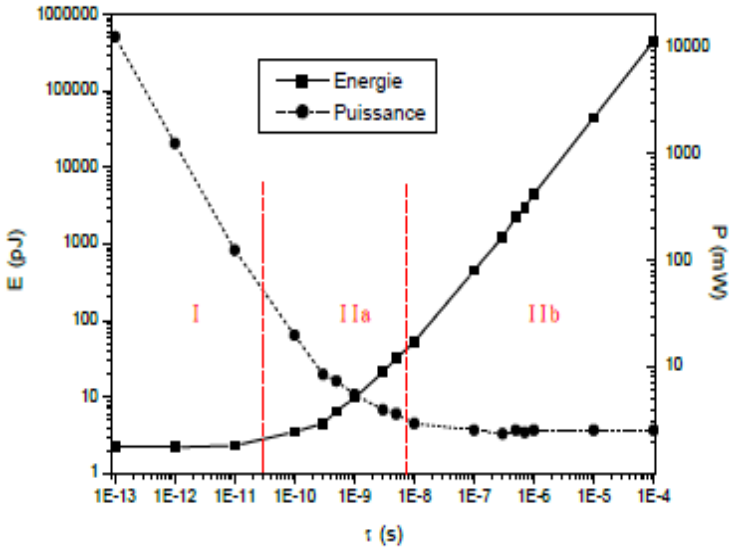
- **An energy threshold exist and below this threshold SEE is not generated.**
- **Optical loss induced by the integration in the platform and insertion of beam shaping tools is taking into account.**

=> Nano Joule range (Max) at sample level is targeted

Laser source characteristics – Pulse length selection

- **Two main domain of laser effect is identified as function of the pulse length**
- **Section I was targeted with a pulse length lower than 10ps as input for the laser selection**

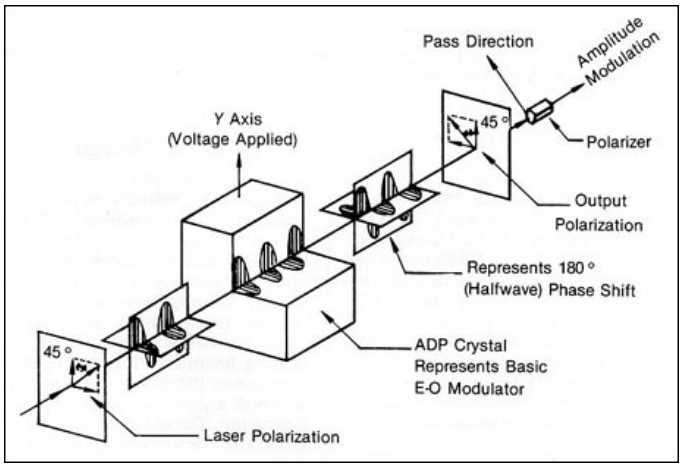
Threshold Energy and max. power threshold for different pulse length



- **Section I: pulse < 30ps**
  - **Drift phenomena is predominant**
- **Section II: Pulse > 30ps**
  - **Diffusion phenomena is predominant**

Repetition rate & Pulse Picking

- **Repetition rate need to be adjustable as function of the device under test.**
  - **High speed device can accept high laser pulse frequency**
  - **But, cumulative effect need to be avoided…**
- **Solution based on pockel cell that change the polarization of the input laser light depending on the voltage applied is selected**

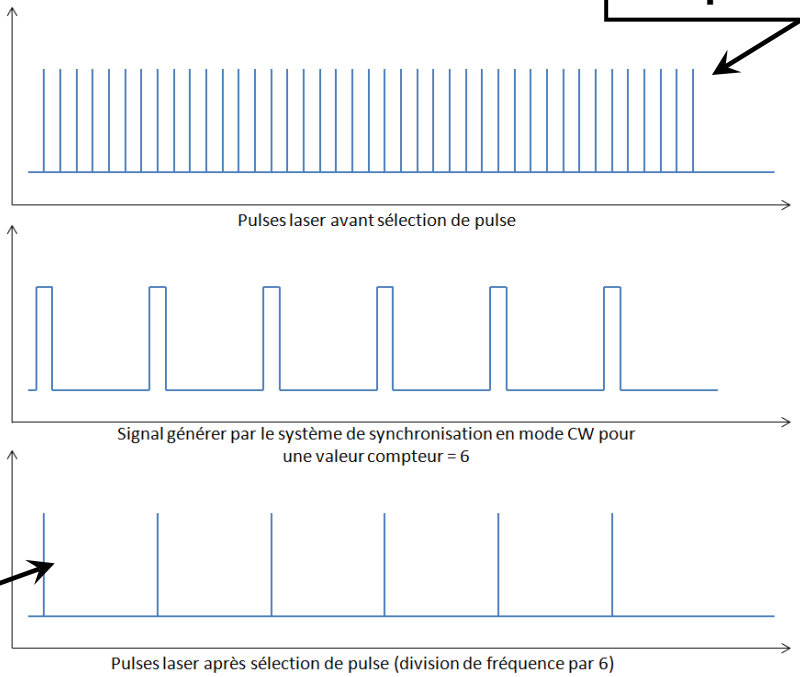


- **Electronic control of the “Pulse Picker” was implemented to give the possibility between 3 configurations:**
  - **Frequency divider**

Frequency division is based on a count down module

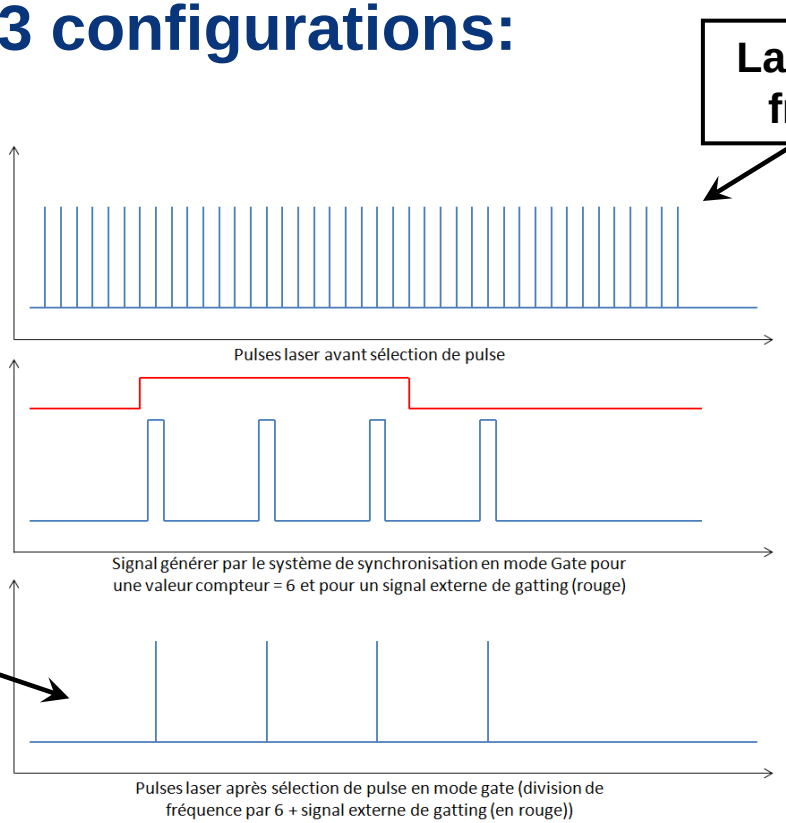
Output pulses deposited on the DUT is adjustable from Hz to 40MHz

Laser source frequency (80MHz)

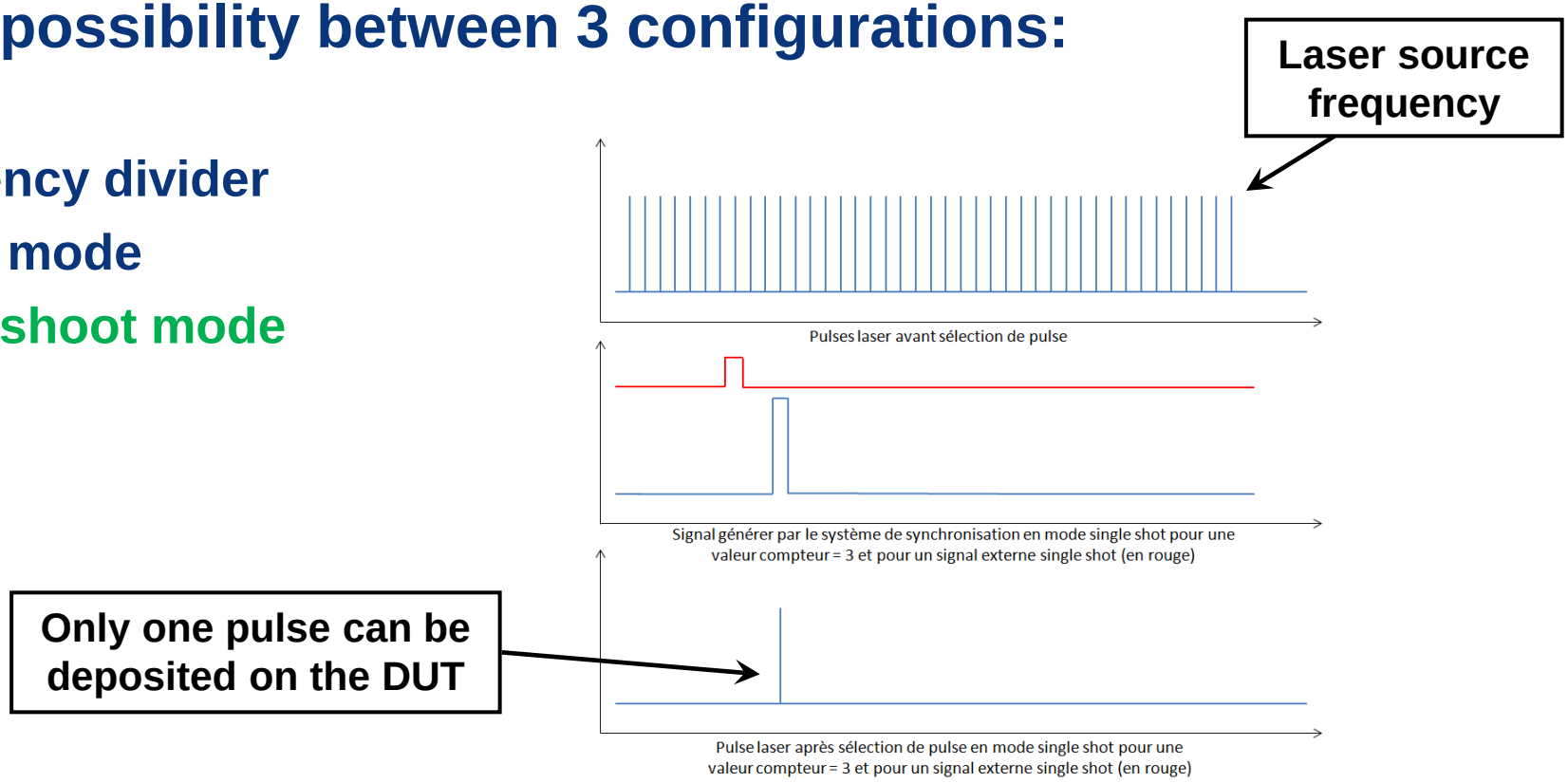


- **Electronic control of the “Pulse Picker” was implemented to give the possibility between 3 configurations:**
  - **Frequency divider**
  - **Gating mode**

Output pulses deposited on the DUT is controlled by the frequency decreasing and the gating



- **Electronic control of the “Pulse Picker” was implemented to give the possibility between 3 configurations:**
  - **Frequency divider**
  - **Gating mode**
  - **Single shoot mode**



- **Electronic control of the “Pulse Picker” was implemented to give the possibility between 3 configurations:**

  - **Frequency divider**
  - **Gating mode**
  - **Single shoot mode**

Test sequence of the device under test functionality and laser stimulation pulses are not synchronized.

Test sequence of the device under test can be synchronized with the laser stimulation pulses.

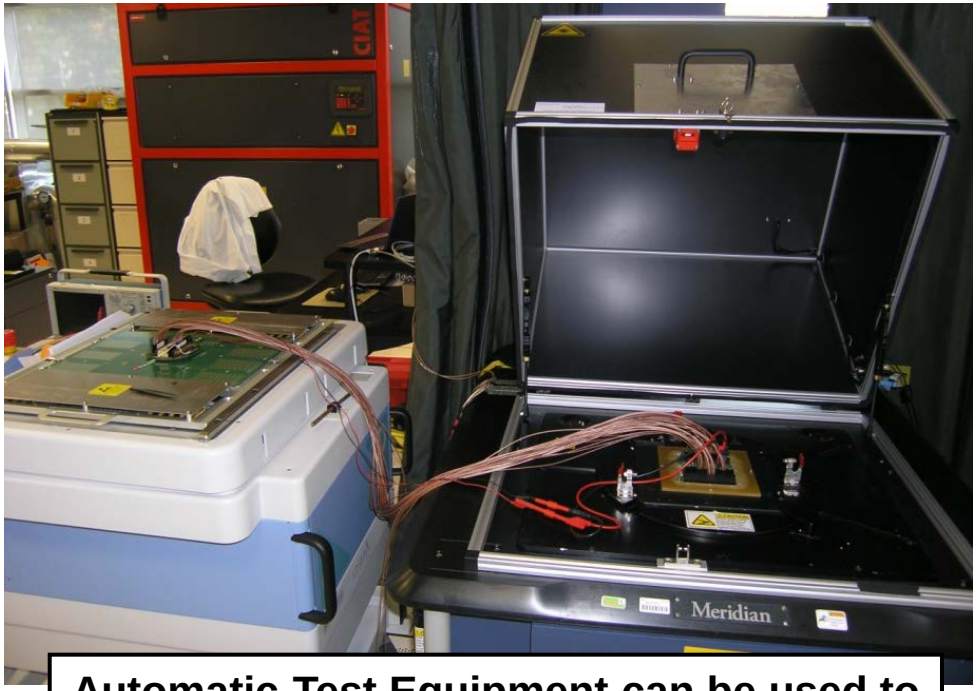
Sensitivity to SEE can be characterized in position and time (X, Y, t)

Pulsed laser platform

- **Final solution is implemented on a Meridian II from DCG Systems**
  - **This tools is a Laser Scanning Microscope (LSM) dedicated for defect localization. It was modified to integrate the pulse laser and the pockel**

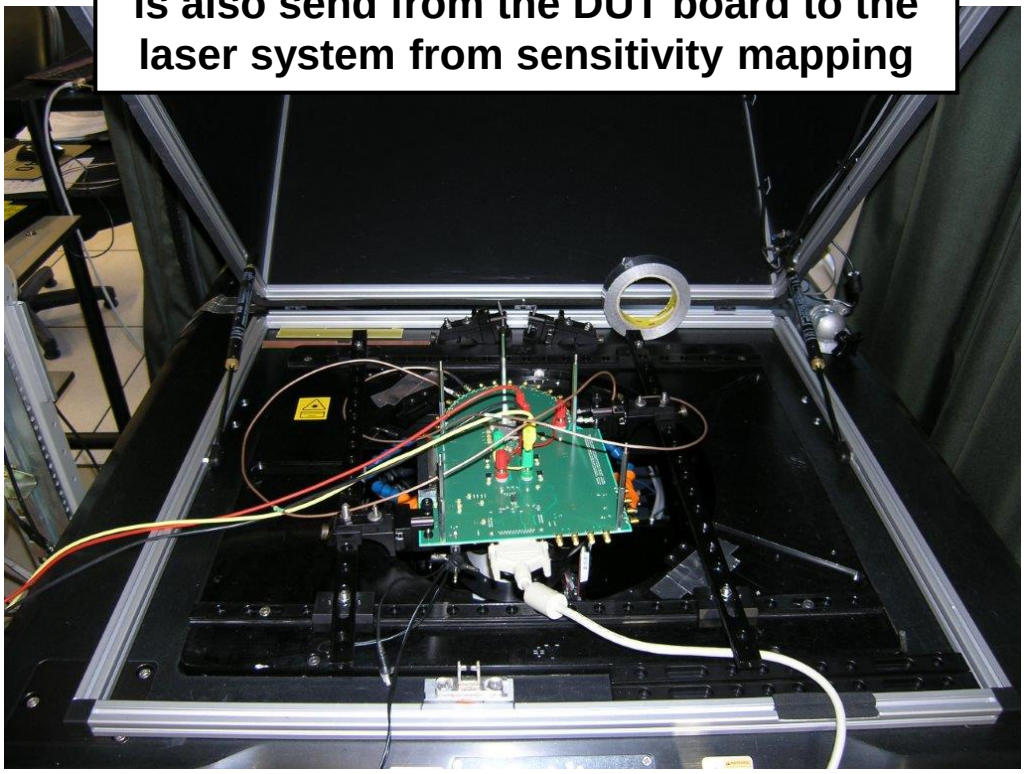
Wavelength	*1064nm*
Pulse width	*7,19ps*
Energy per pulse	*From pJ to 3nJ*
Laser spot size	*6µm, 2.5µm and 1µm*
Pulse laser frequency	*Single shoot to 40MHz*

Pulsed laser platform



Automatic Test Equipment can be used to stimulate and control the dive under test. Electric signal is send from the ATE to the laser systems

Dedicated board can be used. A signal is also send from the DUT board to the laser system from sensitivity mapping



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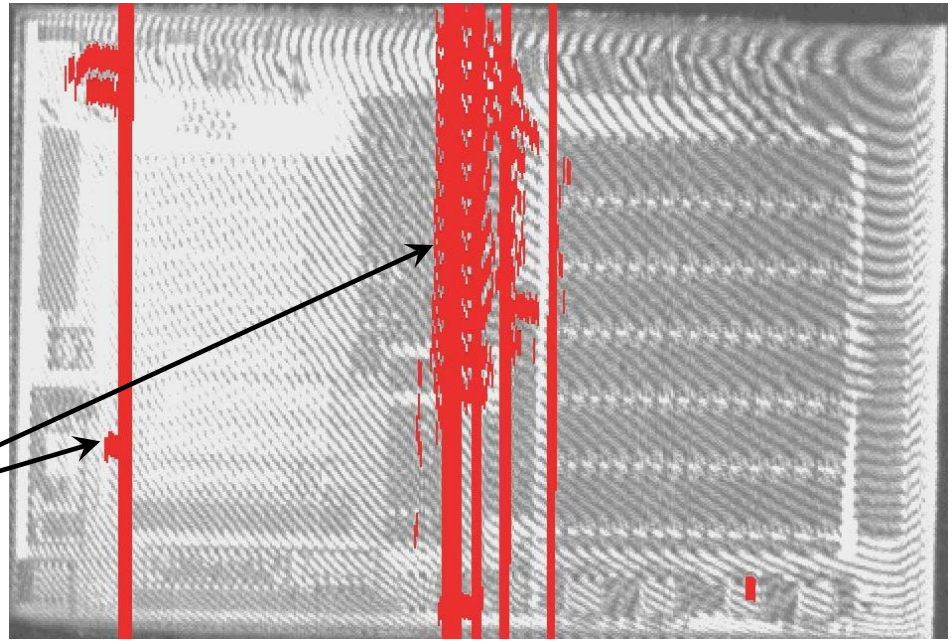
Applications examples

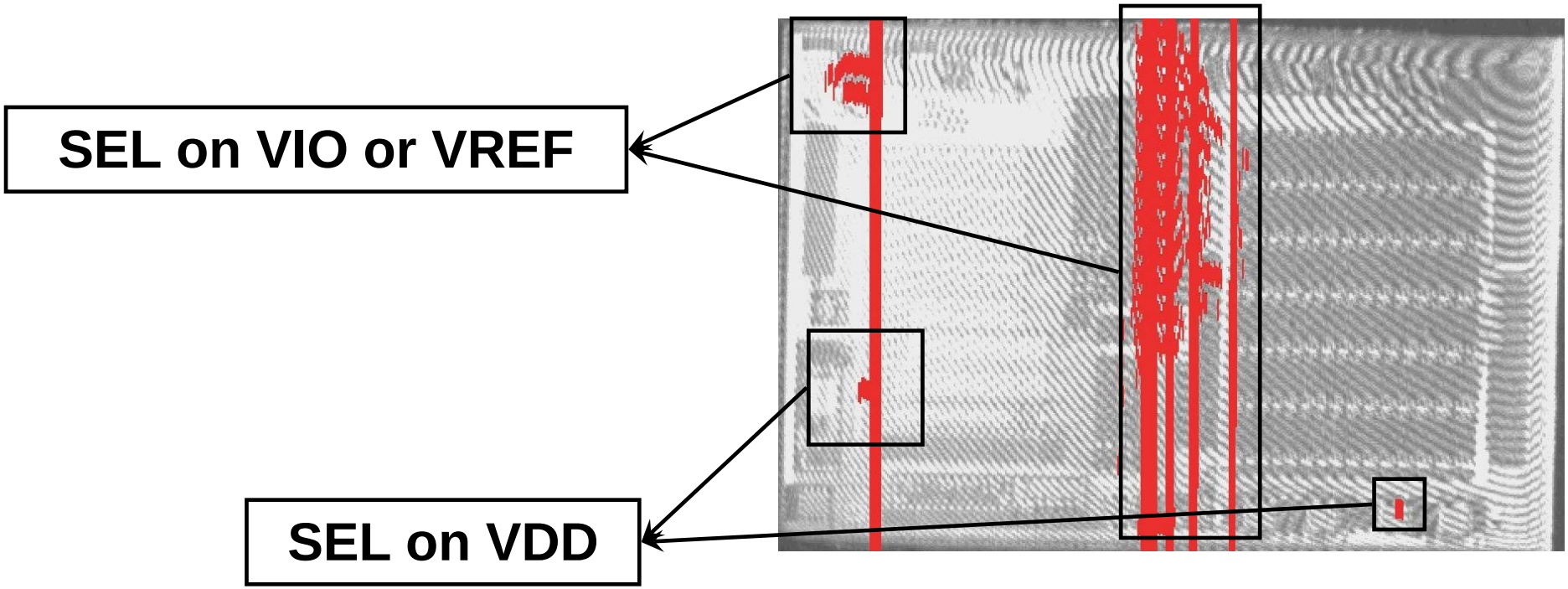
- **AD7982 powered by TILU for latch up monitoring and protection**
  - **TILU Outputs is used as input for the LSM to built a sensitive map**

	VIO	VDD	VREF
Seuil (mA)	**6**	**3**	**4**
Seuil (V)	**2,3**	**2,3**	**2,3**
Consigne (V)	**2,5**	**2,5**	**2,5**

SEL detection in RED



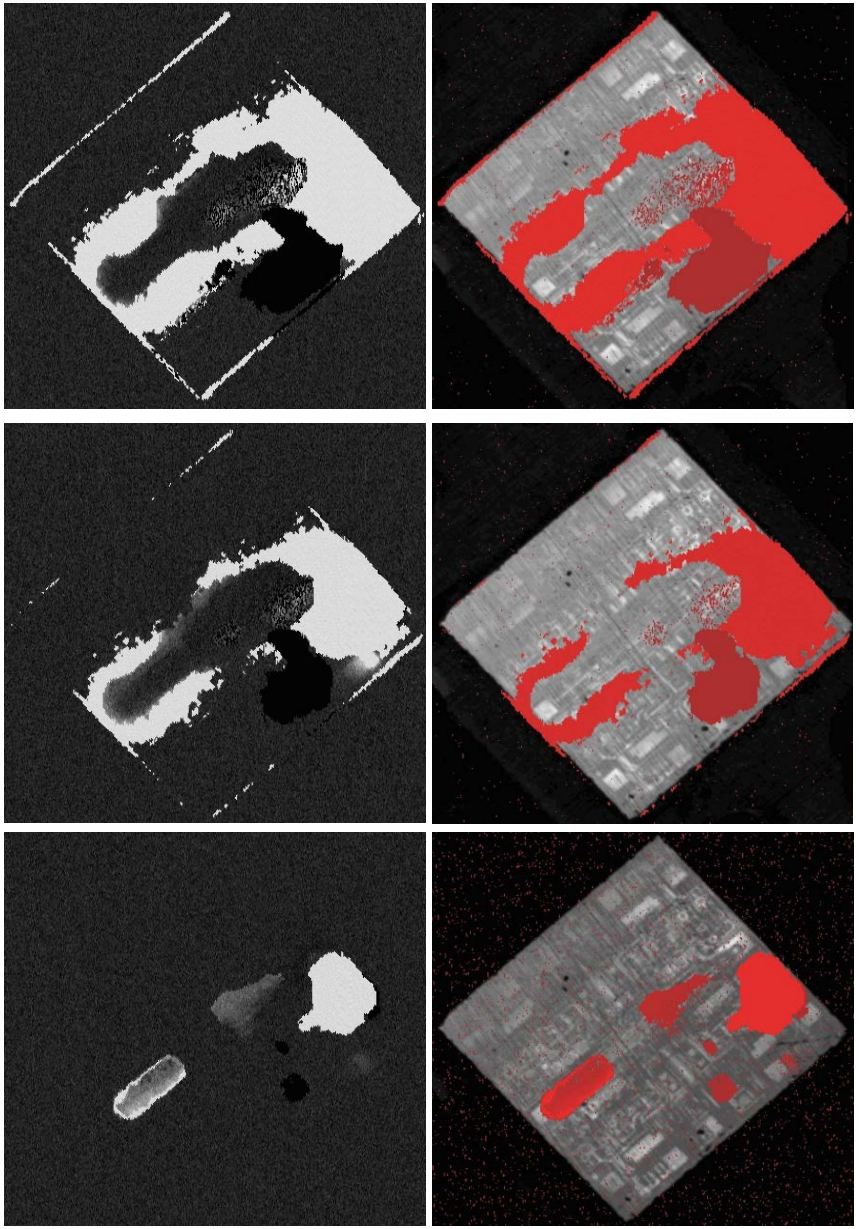
- **AD7982 powered by TILU for latch up monitoring and protection**
  - **SEL TILU Output is used as input for the LSM to built a sensitive map**



Single Event Transient in AOP

- **LM124 in inverter mode**
- **VDD (-5V to 5V)**
- **Objective lens at 2.5X**
- **AOP output is used for the mapping**

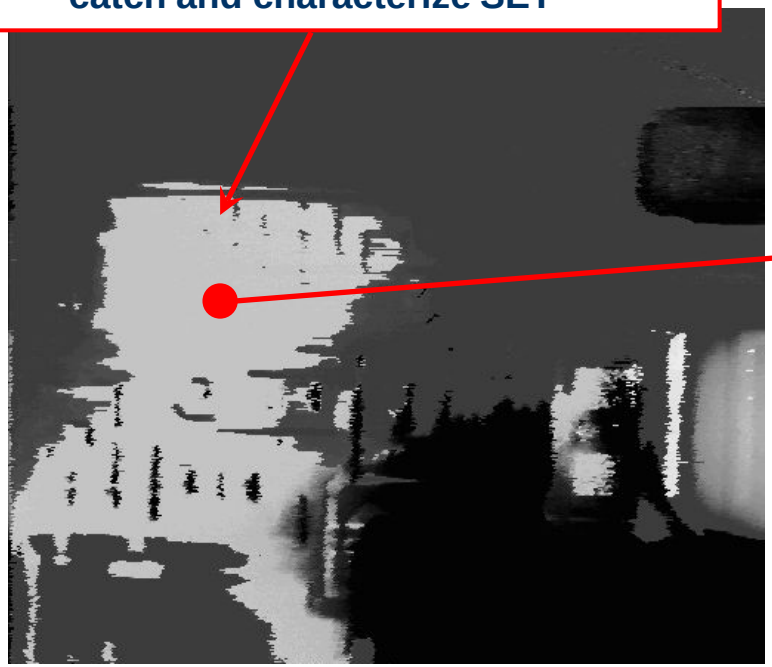
Laser scanning mode:
White area: Positive SET **Black area: Negative SET**

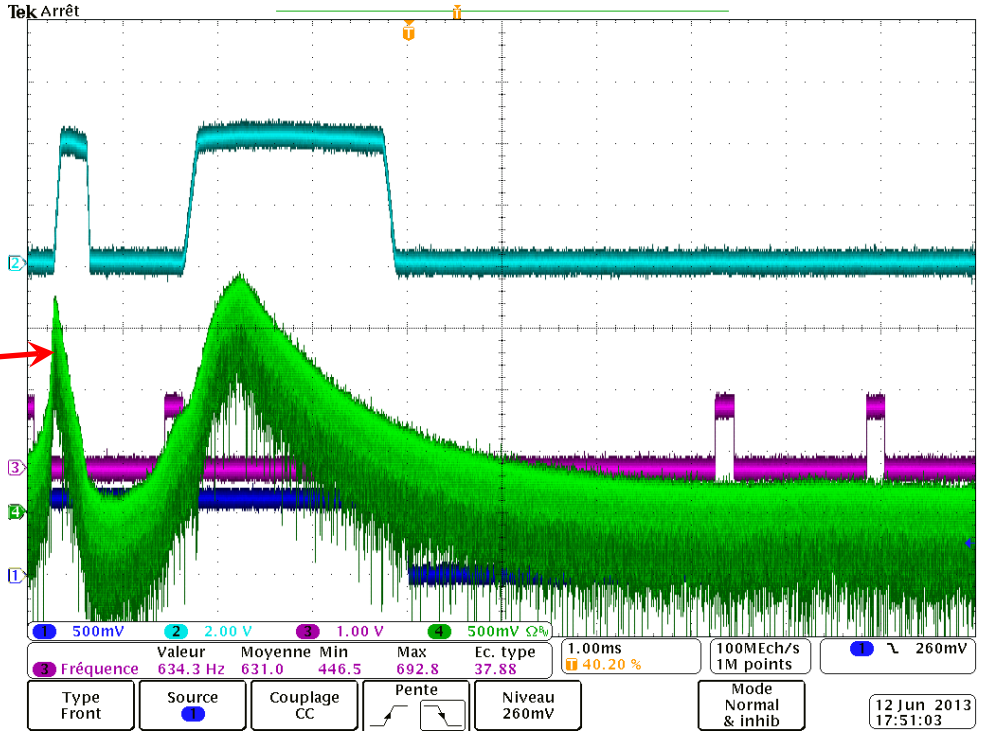


Laser power

- **LM124 in inverter mode under smaller spot size and higher magnification (20X lens)**

Fixed point laser beam can be used to catch and characterize SET

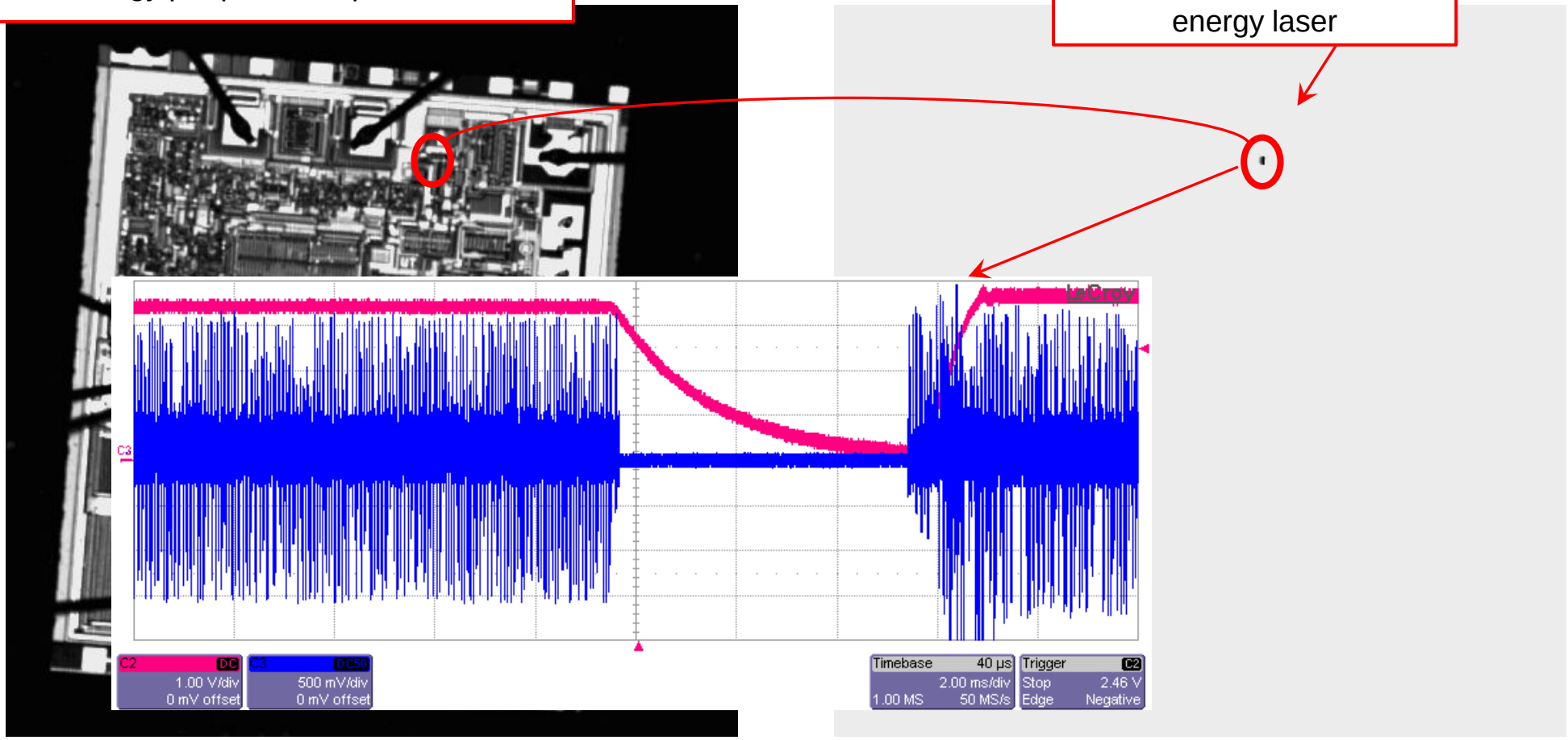




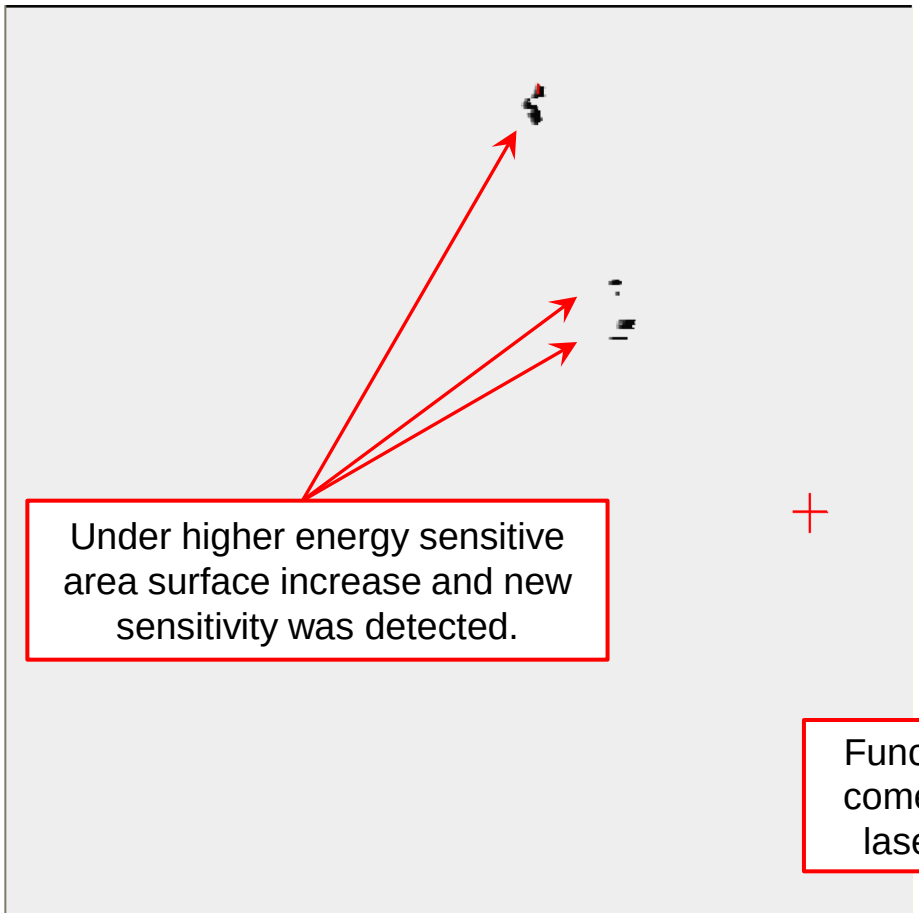
Single Event Transient in BiCMOS devices

2,5X lens
Laser pulse frequency at 10kHz
Energy per pulse <50pJ

Identification of the most sensitive area under low energy laser

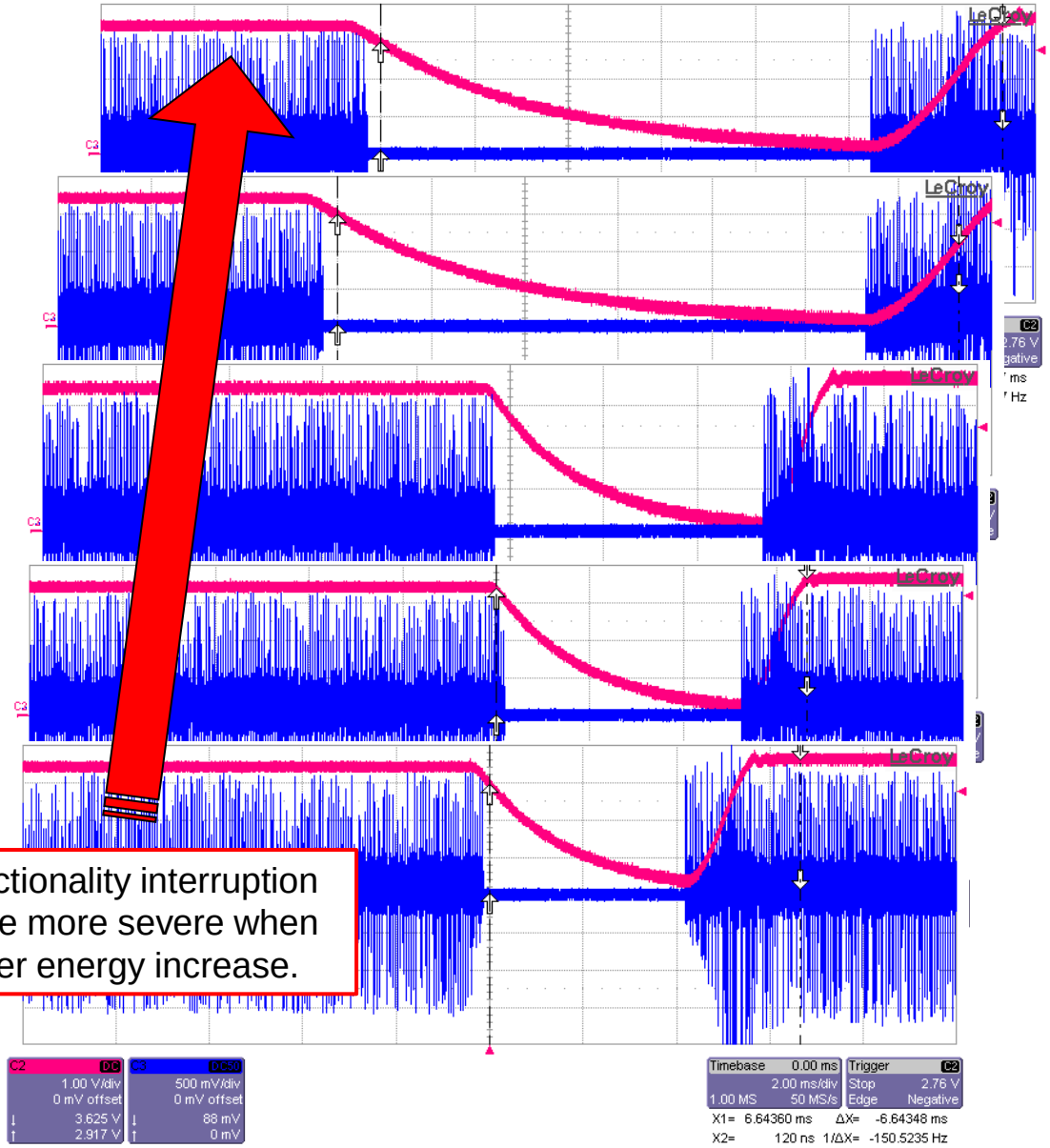


SET perturbations under increasing pulse energy

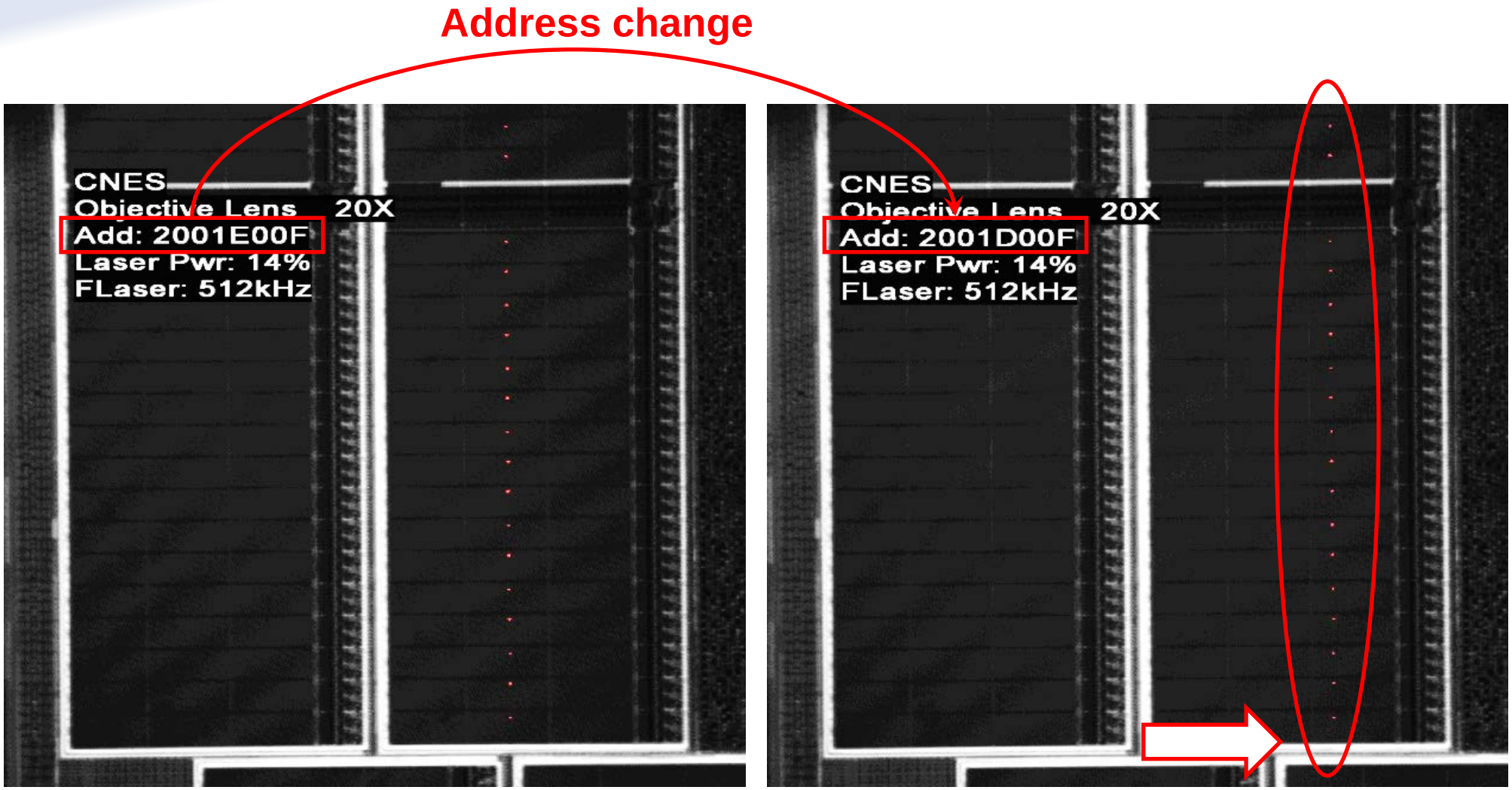


Under higher energy sensitive area surface increase and new sensitivity was detected.

Functionality interruption come more severe when laser energy increase.

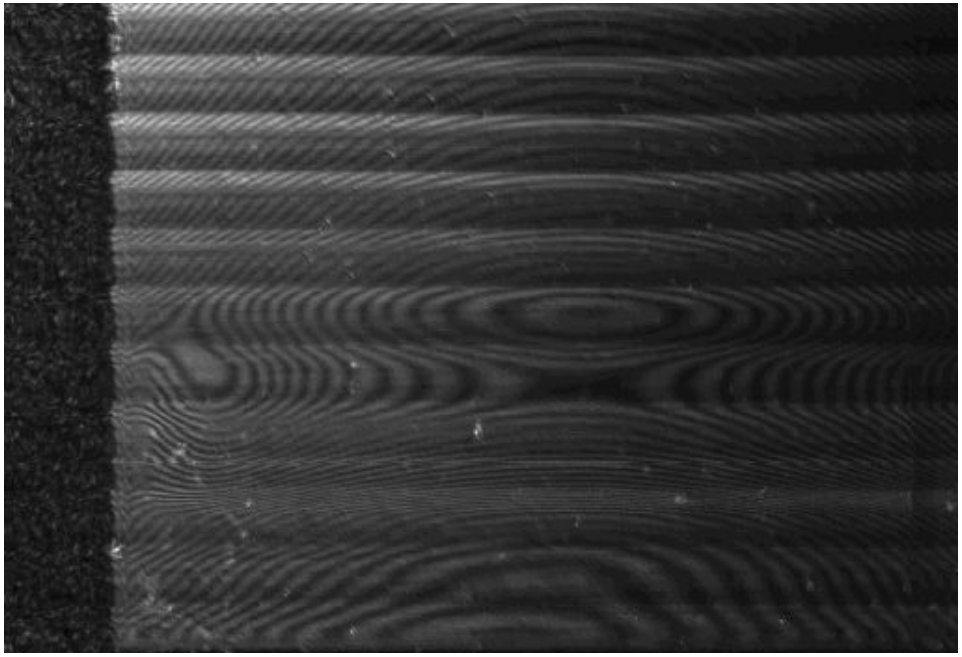


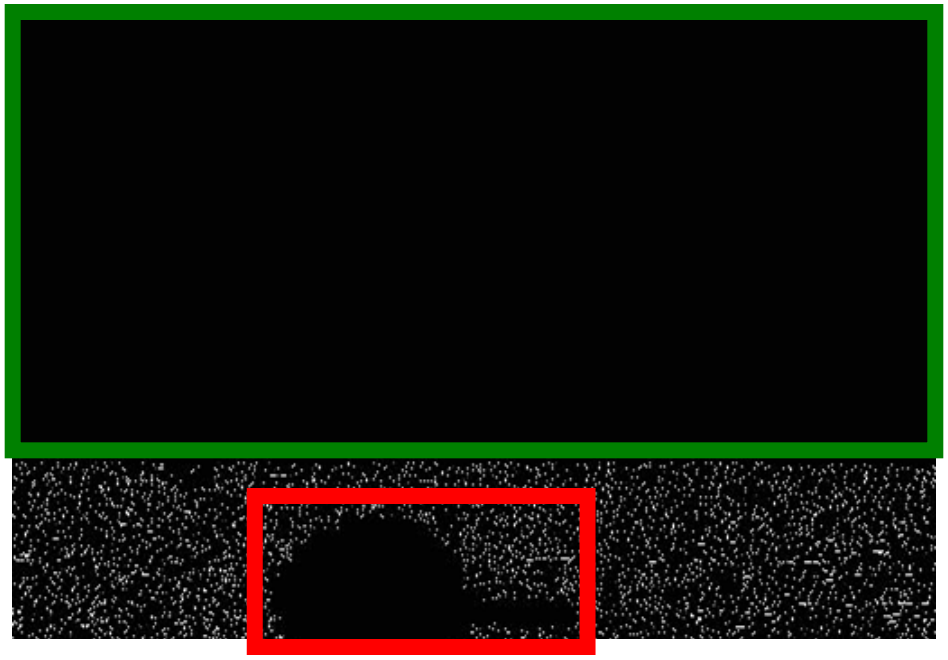
Single Event Upset in embedded SRAM



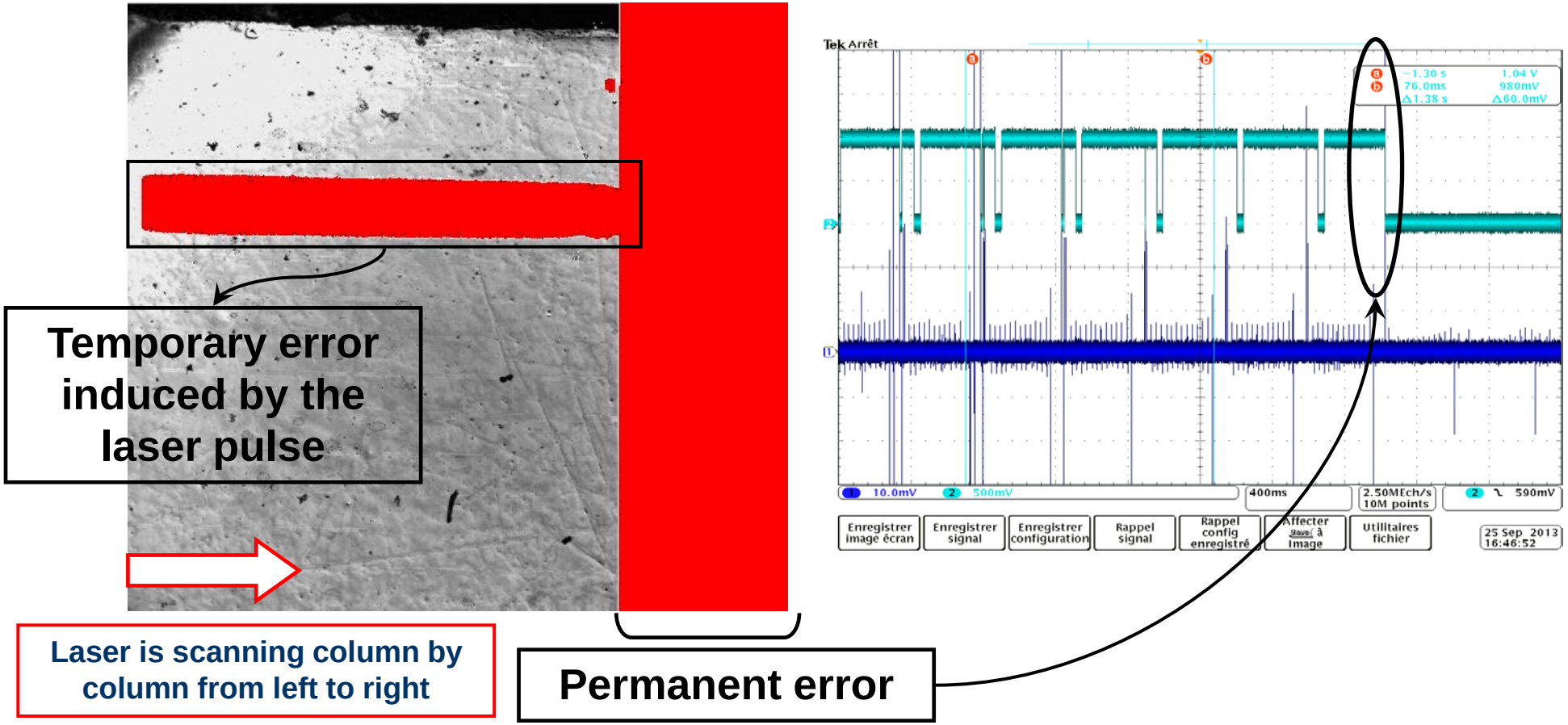
SEFI detection inside 90nm Microprocessor

- **STM32 microcontroller under arithmetic operation in loop mode.**
- **“End of operation” output pin is followed under laser stimulation.**





- **EEPROM device in continuous read mode under low magnification (2.5X) on one address through ATE**



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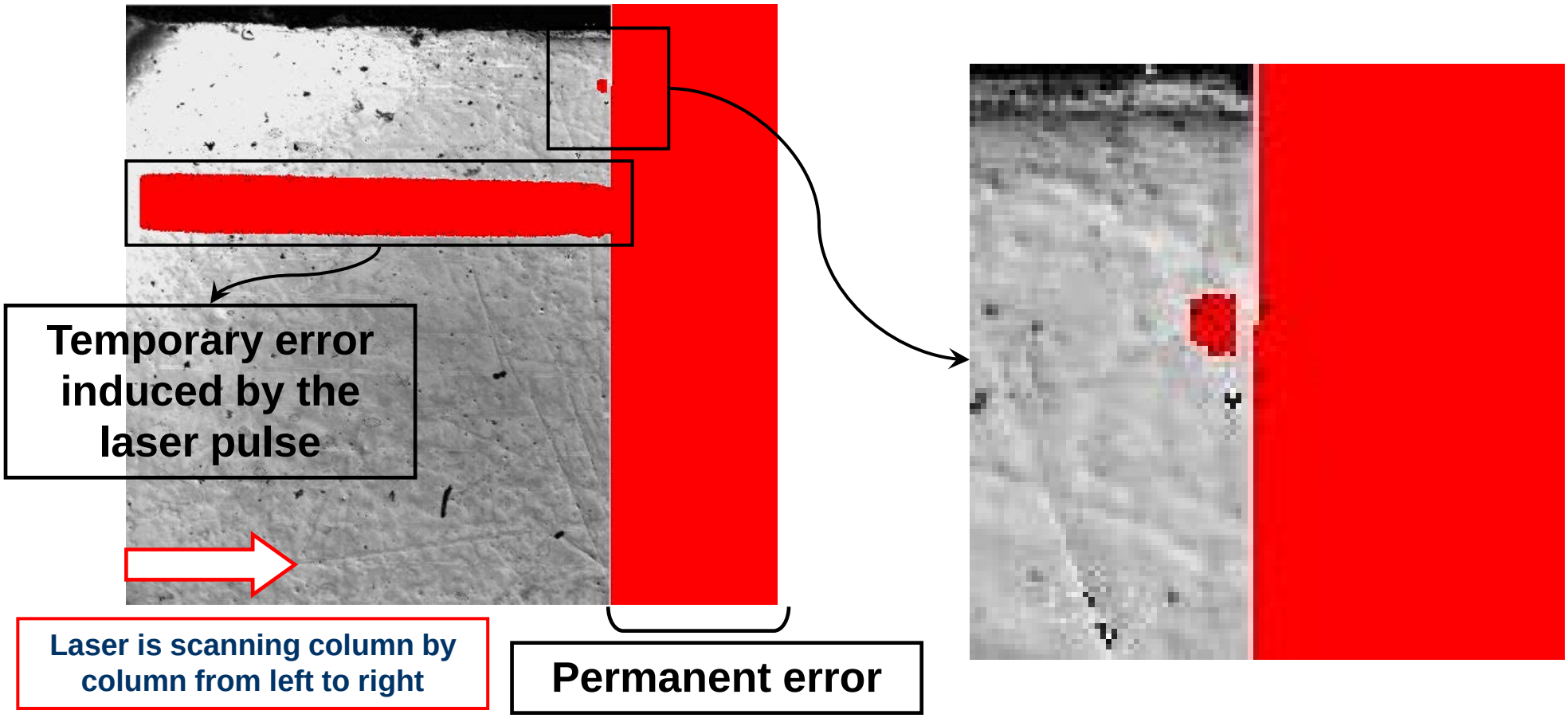

Conclusion

- **SEE simulation by pulsed laser was implemented on a traditional defect localization tool (Laser Scanning Microscope)**
  - **SEL, SET, SEU and SEFI capabilities was demonstrated on several technology node.**
  - **High laser scanning flexibility is offered by the LSM**
    - Scan direction, Region Of Interest, fixed position, scan speed from µs per pixel to several ms per pixel, …
  - **High level of integration with dedicated board or Automatic Test Equipment is possible**

- **Main drawback of laser solution stay the optical resolution (~1µm) and difficulties to correlate nJ laser with eV.**

Memory descrambling under pulsed laser