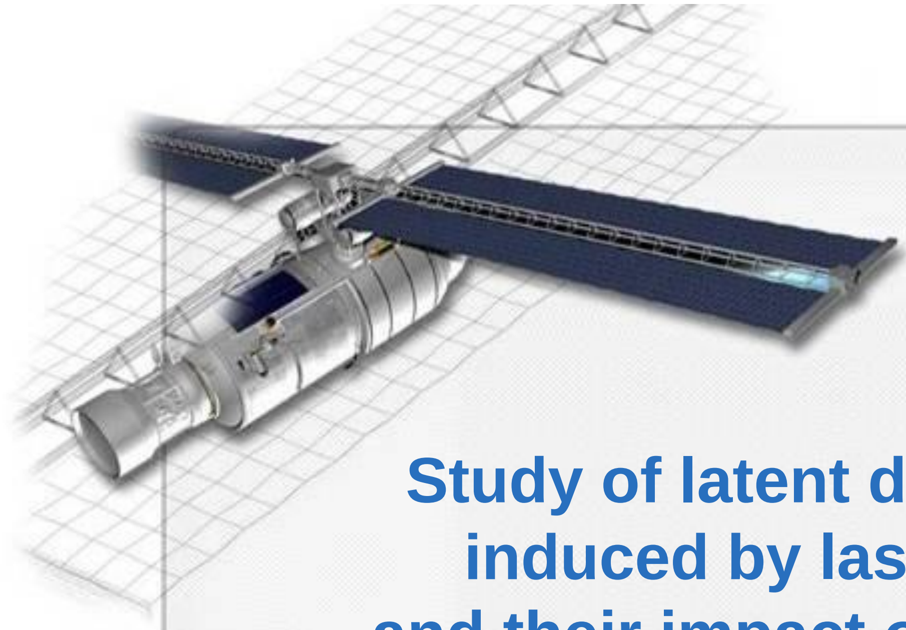

Study of latent defects related to SEL induced by laser pulses on COTS and their impact on long-term reliability

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TRAD

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Context and objectives

Context

- **Study funded by CNES – device reliability team (contact : Gianandrea QUADRI)**
- **"New Space" trend → increasing use of COTS**
- **Many CMOS-based COTS are sensitive to SEL**
  - New-Space → more flexible requirements in terms of reliability
  - Implementing a delatching system
- **Still possible to add a SEL-protection system, but …**
  - Latent damages induced by SEL electrical stress ?
  - Impact on "reliability" ?

Objectives of this preliminary study

- **Build and validate a method to evaluate the impact of SEL on reliability based on literature**
- **Tests using pulsed Laser**
  - Cost-efficient
  - Spatial and temporal resolution (focused area, control of SEL triggering, reproducibility)
  - Complementary to heavy ion testing
  - But need to validate the method by comparison with heavy ion testing

Bibliography

[Davydov,2017] G. G. Davydov *et al.*, « Approach to estimation of modern IC's sustainability after series of single events », RADECS 2017 IEEE Proceedings
[Tsirkov,2018] A. N. Tsirkov *et al.*, « Latent SEL-induced damage in CMOS ICs », RADECS 2018 IEEE Proceedings
[Skorobogatov,2017] P. K. Skorobogatov « Behavior of modern integrated circuit after latch-up parrying », RAD Conference, 2017

Content of the study

Content of this preliminary study

- **Selection of COTS sensitive to SEL with available heavy ion data**

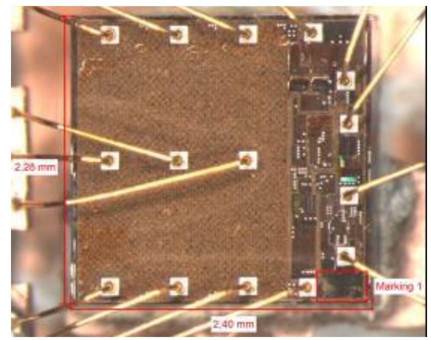
- **SEL triggering using pulsed Laser**
  - Device delidding and test bench development
  - Validation of Laser test representativity by comparison with heavy ion tests
  - Identification of sensitive area locations
  - Triggering of a defined number of SEL in these sensitive areas

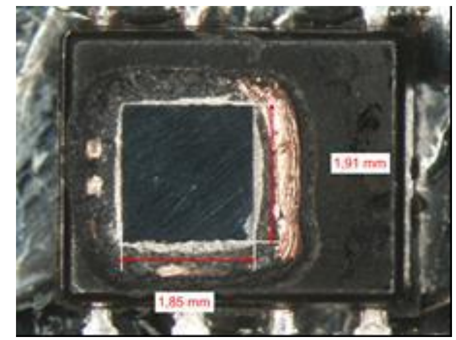
- **Impact of SEL on reliability**
  - Life Test on one COTS reference over
    - 5 backside delidded devices
    - 1 backside delidded device (non irradiated)
    - 1 non-delidded devices used as reference
  - Life Test 1000h at 125°C
  - Electrical parameters verified after the test
    - Consumption current I_{CC}
    - Other interesting parameters

Devices under study

- **Selection of 2 COTS references**
  - **TF6002 : DC-DC converter**

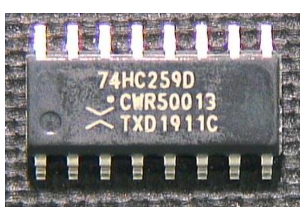
Device	Manufacturer	Function	Input Voltage	Output current
TF6002	Telefunken	2A, 26V, Synchronous Rectified Step-Down Converter	-0.5 to 7 V	± 25 mA

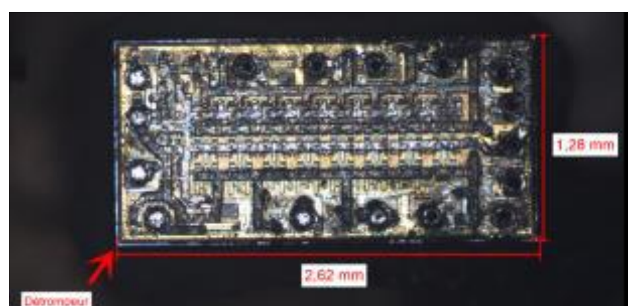


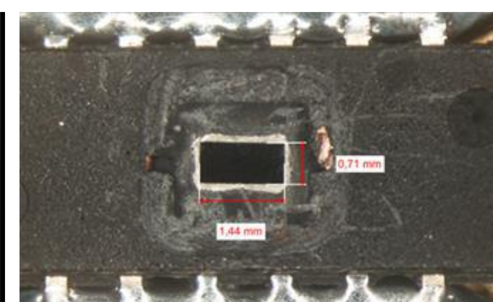


  - **74HC259D : 8 bits adressable latch (buffer)**

Device	Manufacturer	Function	Input Voltage	Output Voltage
74HC259D	Nexperia	8-bit addressable latch	4.5V to 26V	0.923V to 23V

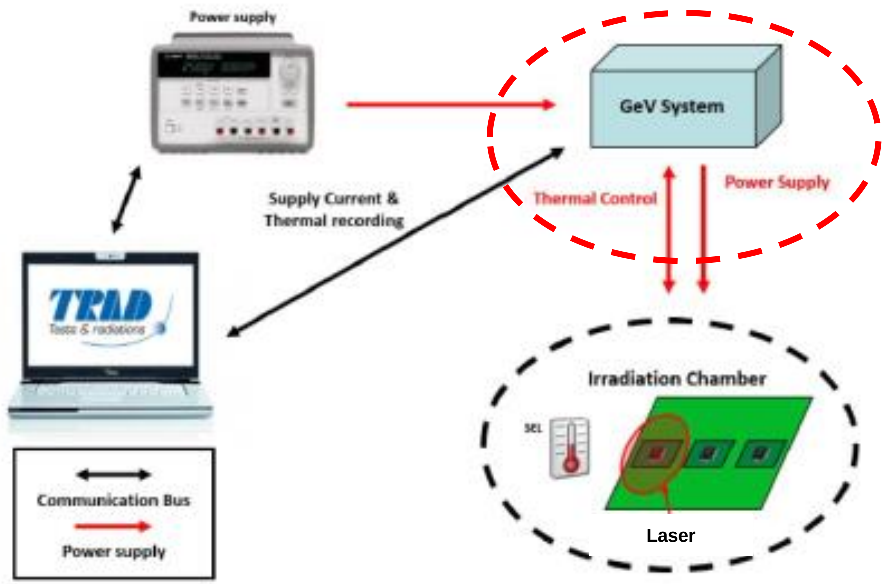




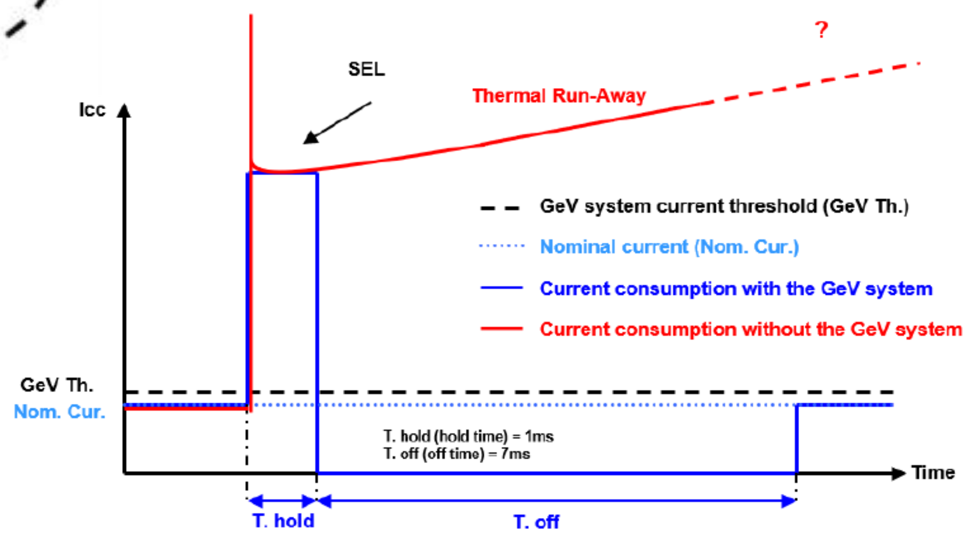


Description of the test bench

Test Bench – General Overview



GeV delatching system parametrization
- SEL detection threshold
- Hold time
- Off time



Description of the test bench

TF6002 DC-DC converter

- Laser test only

Supply voltage	Nominal supply current	Temperature
V_{IN} = 4.5V to 26V	22 mA to 53 mA	25°C and 85°C

74HC259D 8 bits adressable latch (buffer)

- Laser test
- Life Test

Supply voltage	Nominal supply current	Temperature
V_{IN} = 4.5V to 26V	22 mA à 53 mA	25°C and 85°C

Test board

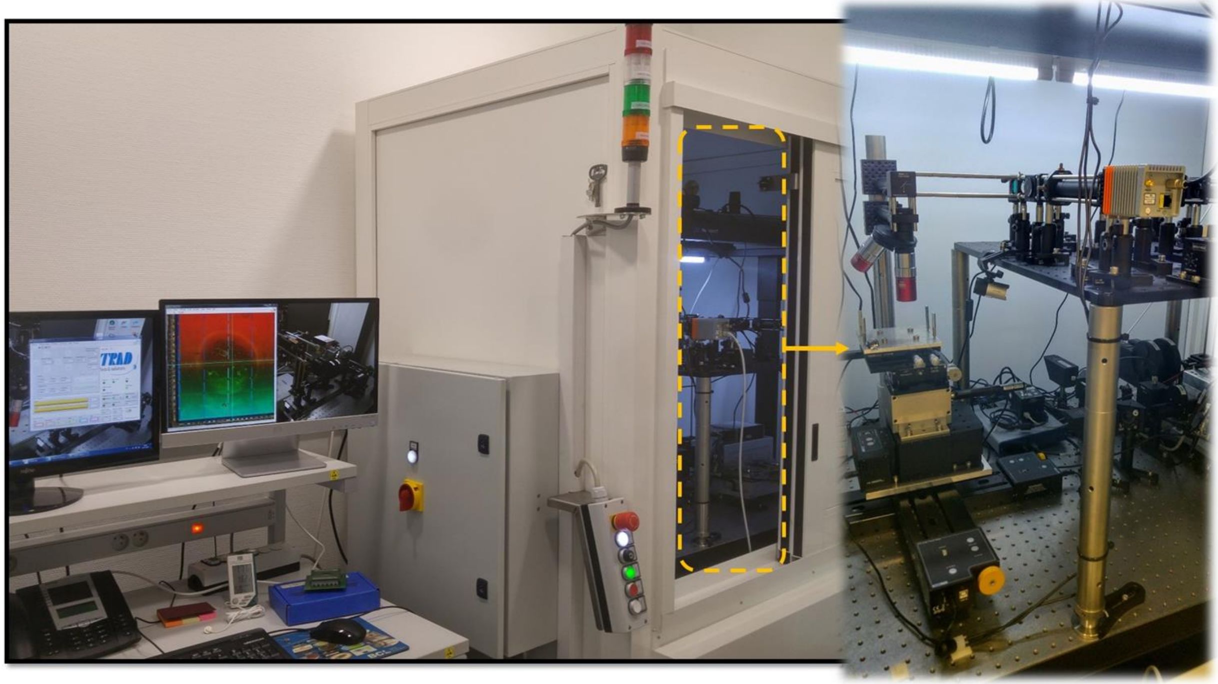
- Clock CLK generated by a LTC6900
- 74HC259D test conditions:
  - CLK in D input
  - Q_0 output = D
  - Q_7 output = low level

Life Test conditions

- I_{CC}
- V_{OL} et V_{OH} : low and high clock level in Q_0 output
- Q_7 : validation of low level

TRAD Laser test facility

- **Pulsed laser tests at LISA NG facility**
  - **Facility available at TRAD in Labège –** *L*aser *I*rradiation system for ***S****EE* ***A****nalysis*
  - **Pulsed Laser parameters**
    - Wavelength λ = 1064nm
    - Pulse duration τ = 400 ps
    - Pulse energy : ajustable from 0,1 nJ à > 100nJ
    - Focusing : plan apochromat Objectives, spot diameter 2.6µm @ $1/e^2$
    - Motorized linear stages XYZ, 0.1µm accuracy

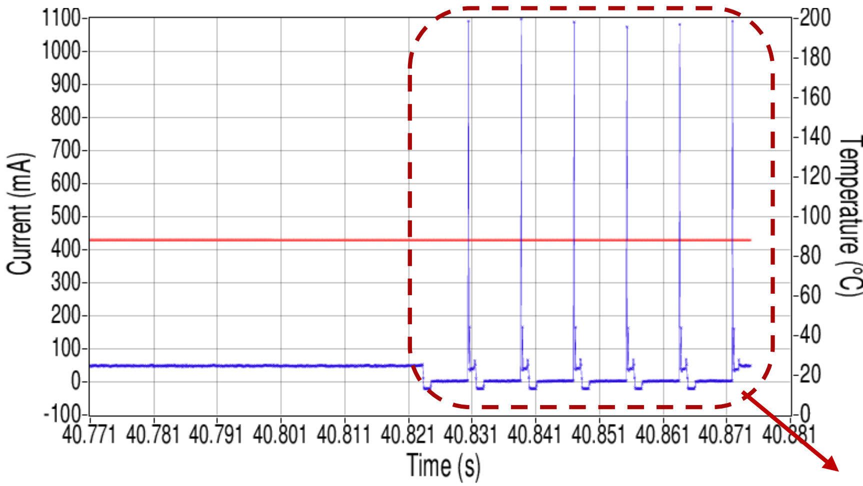


  - **Tests performed on backside-delidded components**

Preliminary Laser tests

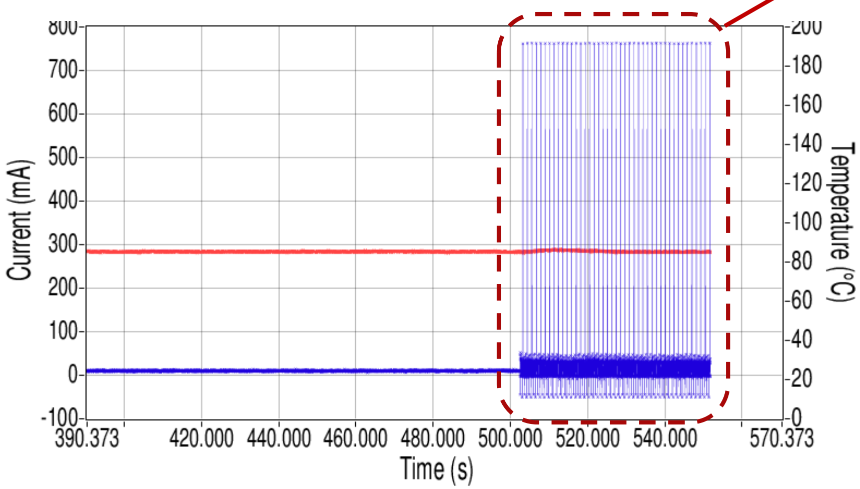
▪ Preliminary pulsed laser test → Laser vs Heavy Ion validation

- TF6002



Laser test
Pulse energy = 14nJ
V_{CC} = 18V
T = 85°C

SEL Loop (device out of order)



Heavy ions
LET = 45.8 MeV.cm².mg^{-1}
V_{CC} = 18V
T = 85°C

Observations

- Destructive SEL triggered either by laser pulses and heavy ions
- Same SEL current signature
- Many attemps to generate non-destructive SEL with laser (reduction of V_{CC} and of pulse energy)

→ systematic destruction, as it was during heavy ion tests

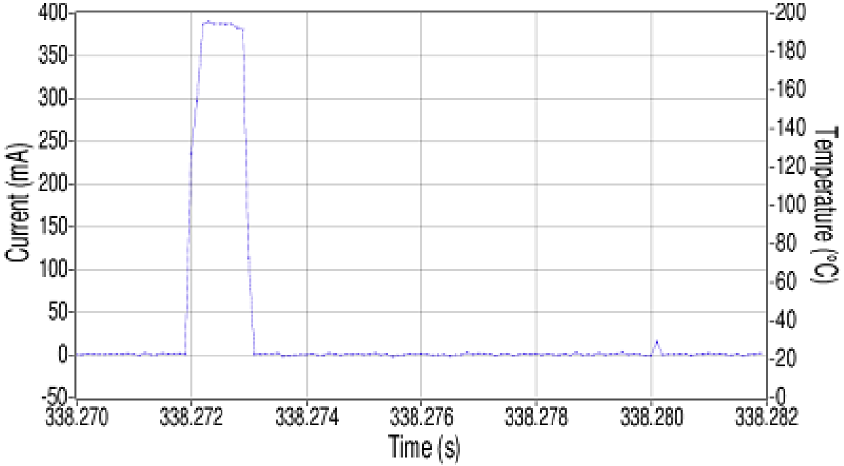
Conclusion → Good representativity of Laser

GeV delatching system parametrization

SEL detection threshold current	Hold time	Off time
35 mA to 75 mA	200 ms to 500 ms	7 ms

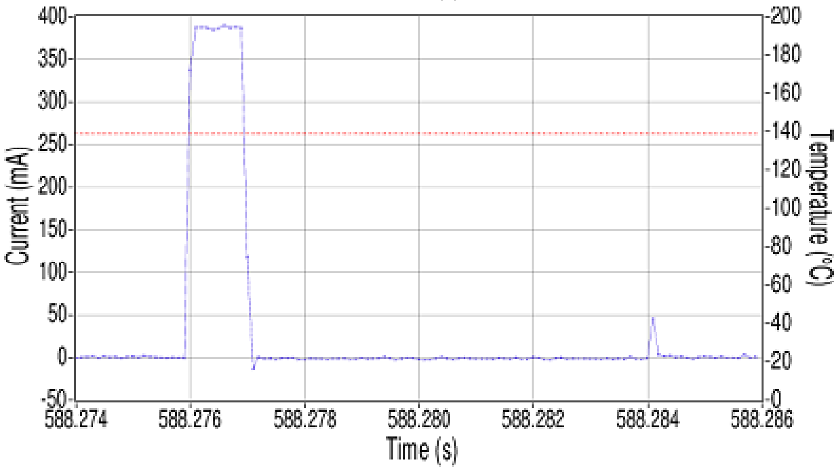
Preliminary Laser tests

- **Preliminary pulsed laser test → Laser vs Heavy Ion validation**
  - **74HC259D**
    - Events triggered in sensitive regions



Laser test
Pulse energy = 2.1nJ
V_{CC} = 5V
T = 125°C

SEL detection parameters
Threshold current = 30mA
Hold time = 1ms



Heavy ions
LET = 46.1 $MeV.cm^2.mg^{-1}$
V_{CC} = 5V
T = 125°C

SEL detection
Threshold current = 10mA
Hold time = 1ms

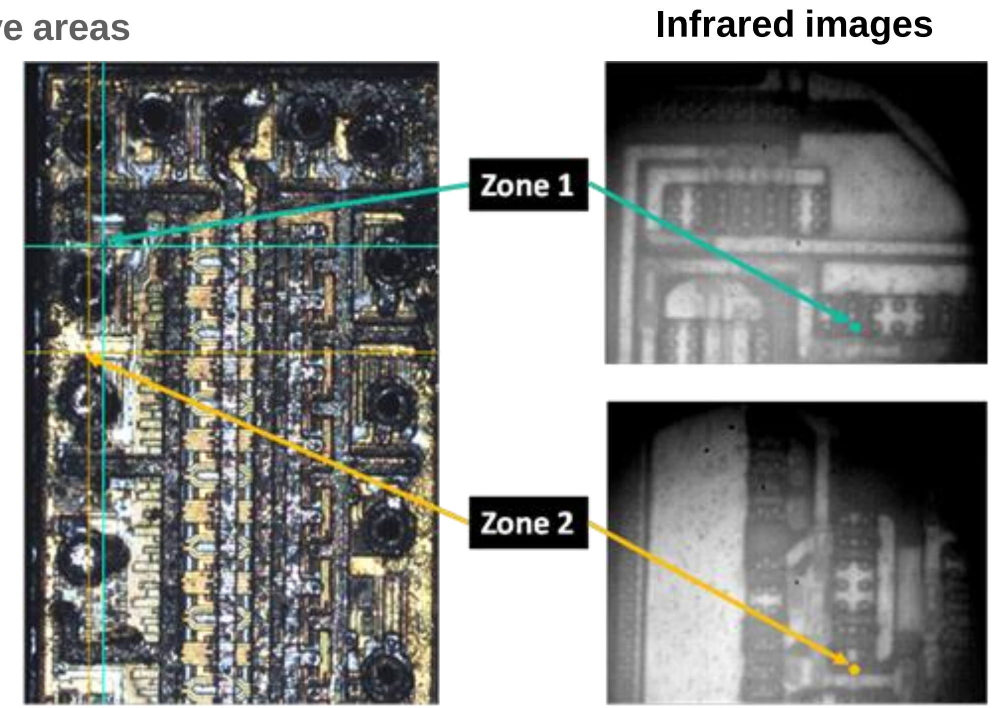
Observations

- Same current signature

Conclusion → Good representativity of Laser

- **Laser tests → location of SEL sensitive areas on 74HC259D**
  - **Location of sensitive areas**
    - Pulse energy = a few nJ
    - Accurate mapping with Laser to localize sensitive areas
    - Focus on these areas for the purpose of the study

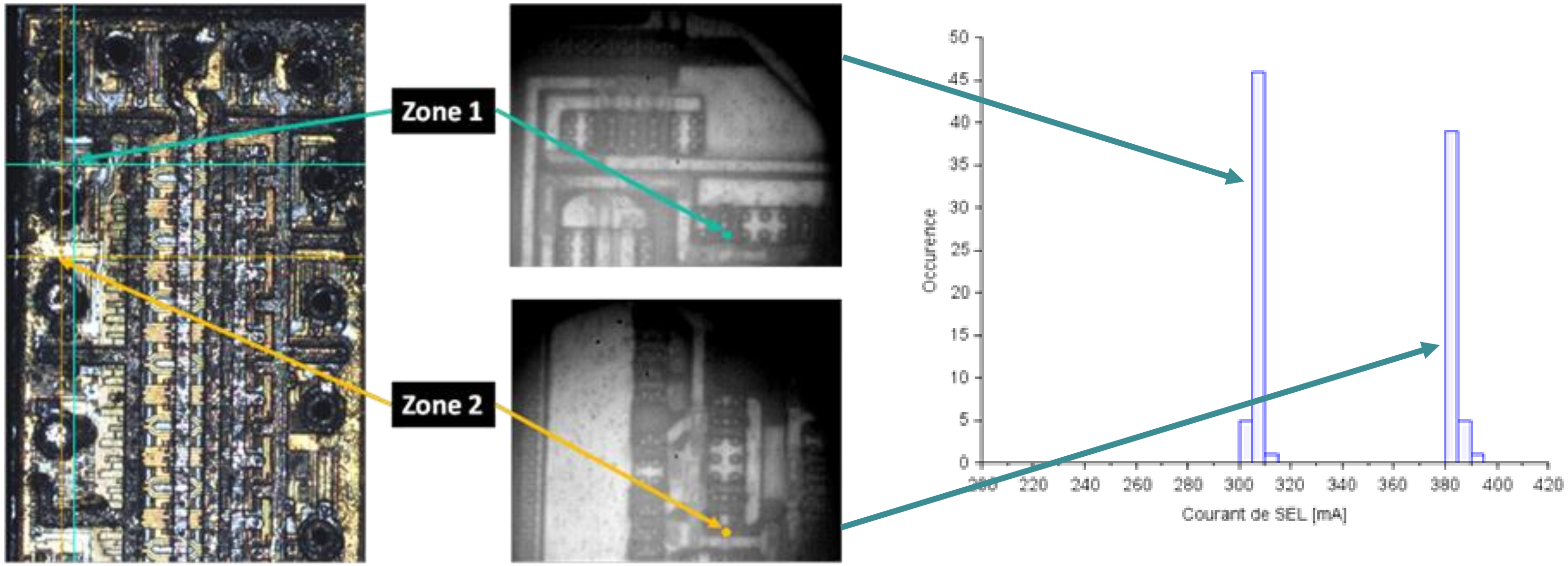
  → **Identification of two sensitive areas**
    → Very localized



- **Test procedure : 100 SEL (50 per sensitive zone) over 5 devices**

Laser tests

- **74HC259D : SEL current histograms**
- **100 SEL**
  - 50 in Zone 1
  - 50 in Zone 2



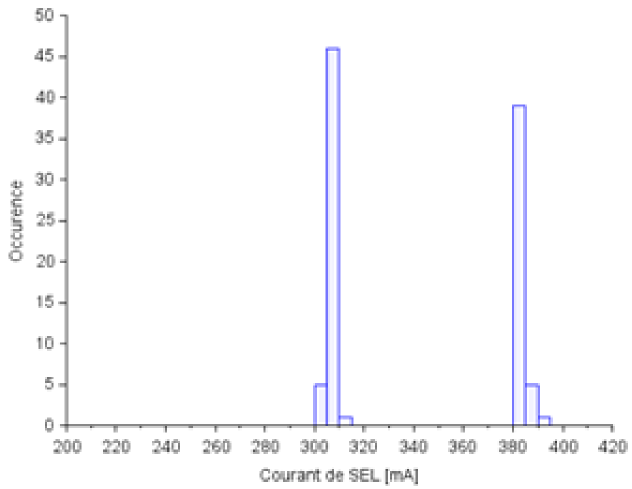
Laser test
Pulse energy = 2.1nJ
VCC = 5V
T = 125°C

SEL detection parameters
Threshold current = 30mA
Hold time = 1ms

Consistency with HI tests

Comparison with Heavy Ions test results

74HC259D : SEL current histograms



Laser test
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SEL detection parameters
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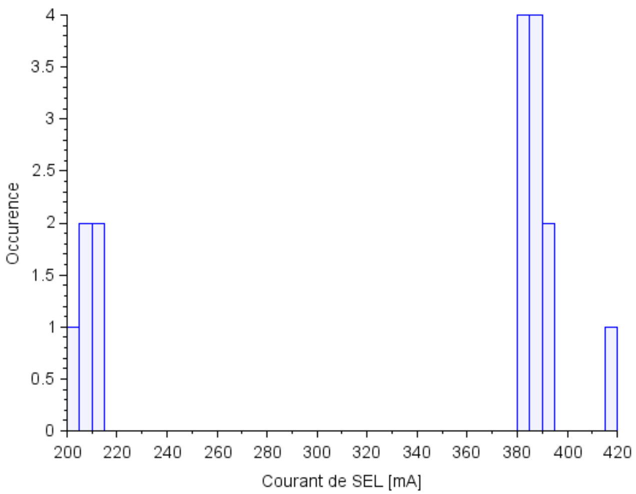


Heavy ions
LET = 46.1 MeV.cm².mg^{-1}
V_{CC} = 5V
T = 125°C

SEL detection
Threshold current = 10mA
Hold time = 1ms

Observations

- Same distribution with two distinct groups of SEL currents
- SEL current values slightly different
  → attributed to HI / laser test conditions

Life Test

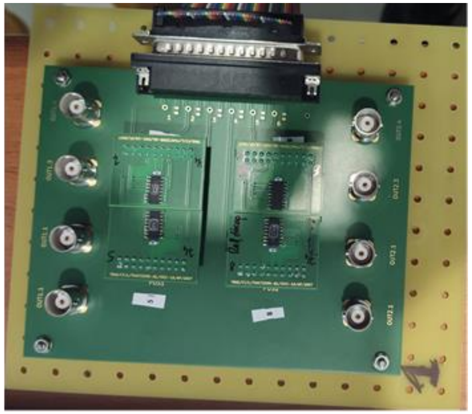
Life test on 74HC259D

- Performed at TRAD Montpellier
- Devices 3 to 9
  - 2 reference device

Devices used for Life Test

Device number	Comments
1	Use for validation
2	Delidded + 100 SEL + LifeTest
3	Delidded + 100 SEL + LifeTest
4	Delidded + 100 SEL + LifeTest
5	Delidded + 100 SEL + LifeTest
7	Delidded + 100 SEL + LifeTest
8	Delidded + LifeTest
9	LifeTest (reference)

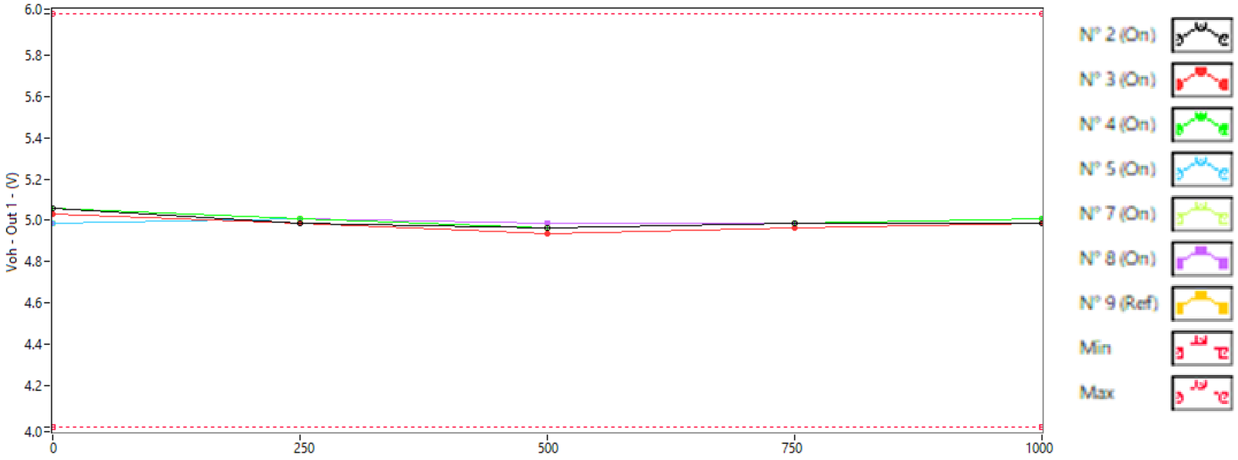
- Life test parameters

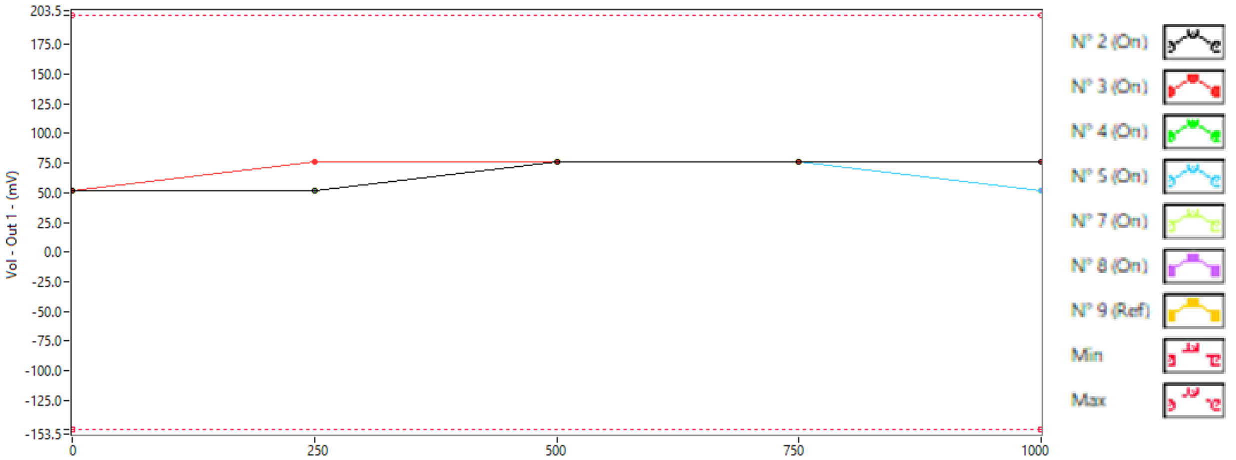


- Life test test board and conditions
  - Placed in the oven
  - Opening each 250h

Duration	Temperature	Continuously measured parameter	Parameters measured every 250h
1000h	125°C	Consumption current I_{CC}	Q_0 : V_{OH}, V_{OL}, clock frequency Q_7 : (low level signal)

- **Evolution of studied electrical parameters**
  - **Low level V_{OL} and high level V_{OH} of Q_1 (CLK)**

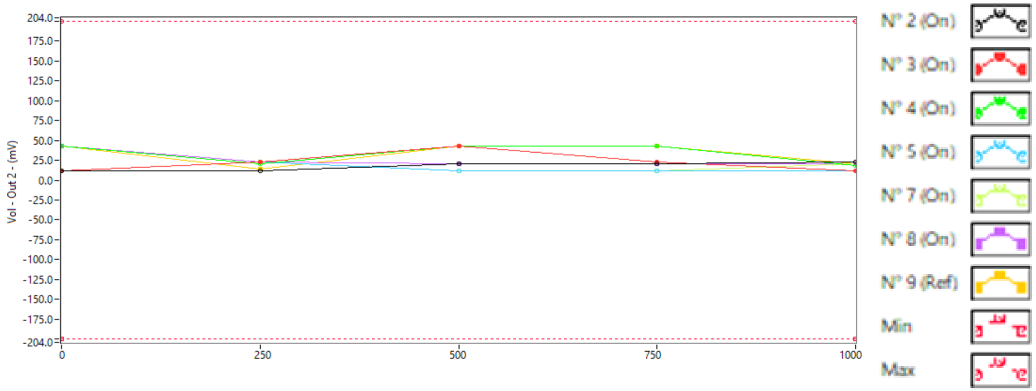




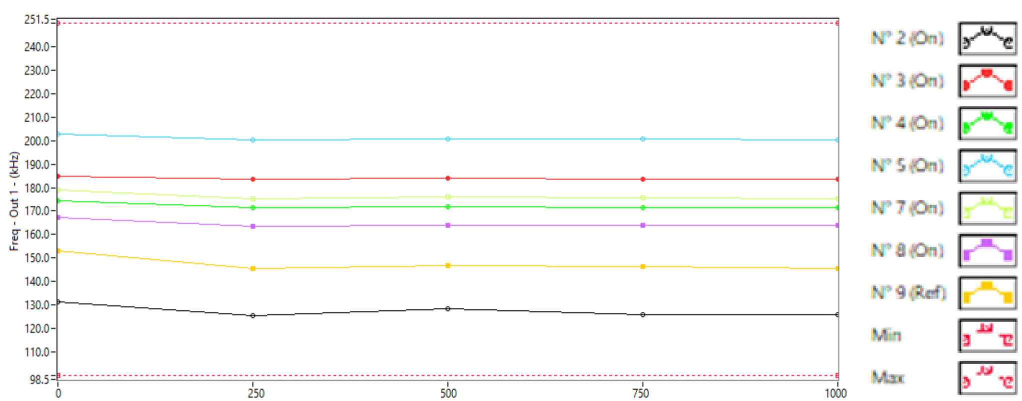
small variations due to measurement-induced noise

Life Test results

- **Evolution of studied electrical parameters**
  - **Q_7 output (low level)**



  - **Output frequency**



- Current consumption I_{CC} : no impact

Observations

- Small variations due to measurement-induced noise
- No measurable impact of SEL
  - on studied parameters
  - in these conditions
  - Stressed 50 times the same area

→ Can help validating the implementability in a design with a lacthup protection system

Conclusion

- **Conclusion of this preliminary study**
  - **Laser = reliable facility to reproduce the effects of heavy ions to trigger SEL**
  - **Strategy → validated the feasibility of a test approach**
    - Use laser to localize sensitive area(s)
    - Trigger a controlled number of SEL in each sensitive area (50 times)
    - The Life Test is performed on :
      - Many irradiated devices to get a strong enough reliability
      - One delidded un-irradiated device to measure the impact of delidding
      - One undelidded unirradiated device used as a reference)

  → **cost-efficient strategy to observe if a SEL induces a degradation on the studied component**
    → Before implementing a delatching system in the design
    → But need to validate the method by comparison with heavy ion testing

- **Upcoming study in 2021**
  - **Tests on many devices from**
    - Different technologies / complexities / functionalities
    - Various technological nodes

  → **Have a broader sampling to validate the approach / more complete study on reliability**

  - **Refine the laser test parameters**
    - Bibliography to get physical device parameters (structure, doping levels…)
      → Analytical estimation of laser energy to reproduce the LET used during heavy ion tests