PULSCAN

OPTICAL AND ELECTRONIC SOLUTIONS FOR TESTING AND FAILURE ANALYSIS

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

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esa

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Introduction

- Laser testing has become a common way to test IC for Single-Event Effects
- Main advantages:
  - In-lab tool
  - Ease of use
  - Spatial and temporal information about SEE sensitivity
  - No dose effect
  - Reduction of the parts selection and qualification total cost
- Even if laser testing is easy to use, especially thanks to industrial laser systems, many parameters have to be considered to optimize the efficiency of the test
- This presentation will focus on the different scanning methods used depending on the objective of the laser test campaign:
  - Events Screening
  - Events Counting
  - Events Mapping

Outline

- PULSCAN laser system: PULSYS-RAD
- Focus on specific scanning modes
- Examples of Applications
- Conclusions

The PULSYS-RAD System

PULSYS Main Frame

- Microscope
- Antivibration Table
- General Interlock
- Protective enclosure

PULSBOX Laser source(s)

- Laser source
- Energy control
- Trigger control
- Pulse monitoring

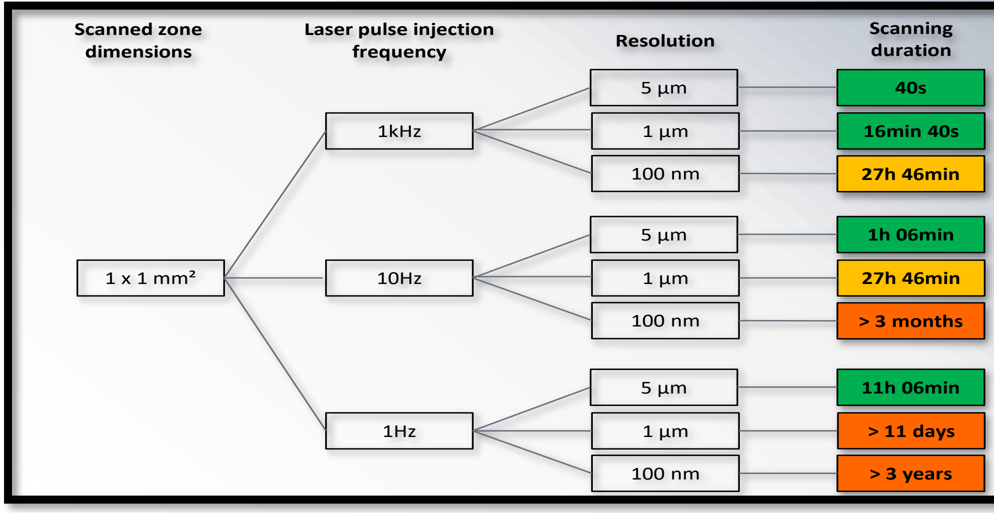
Control

- PULSWORKS Software
  - Laser control
  - Scanning control
  - Data acquisition and analysis
- Control Pad

Motivation

- Scanning a complete chip at high resolution is usually not recommended / possible
  - Complete scan is often not relevant
    - Symmetries, repetitions
    - Well known non-sensitive area (pad…)

=> Split the DUT area into Regions Of Interest (ROI) < 1mm²

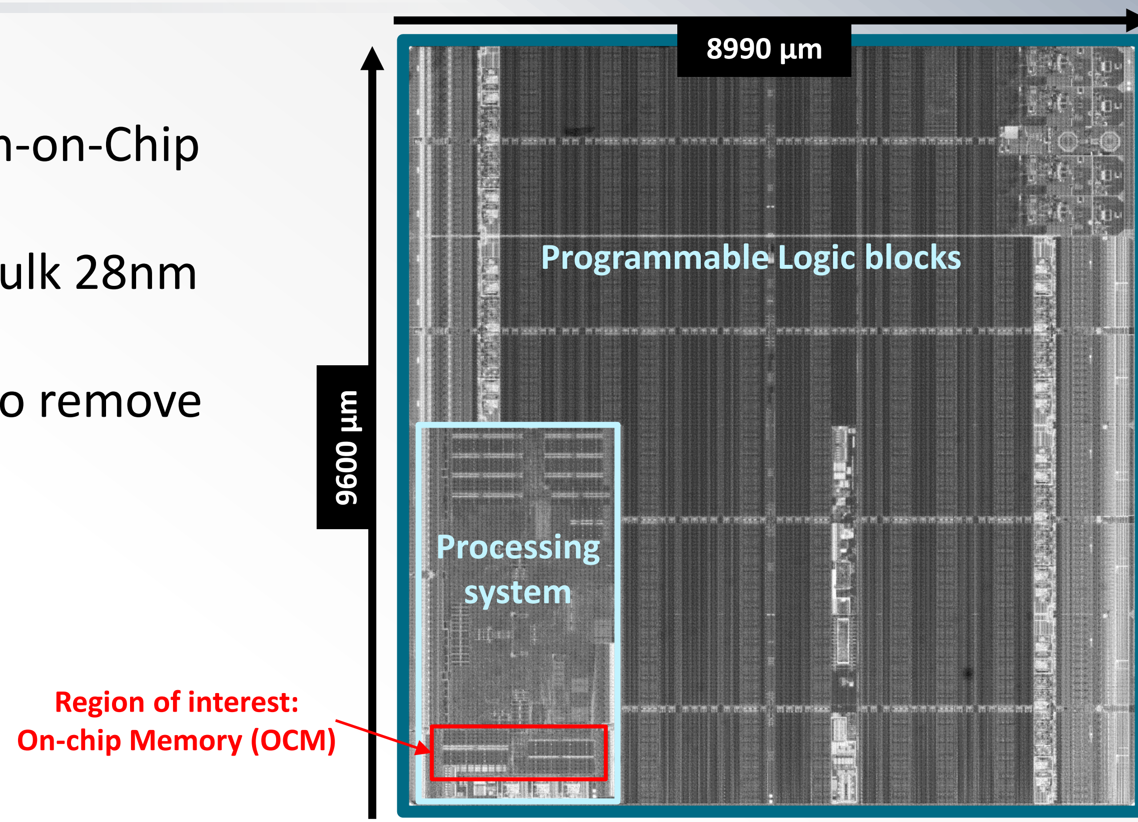


- Scanning time is set by adjusting:
  - The laser pulse injection **frequency** mainly limited by:
    - The test loop period (monitoring, data acquisition, data transfer…)
    - The pulse to pulse accumulation of the generated charges
  - The scanning step (**resolution**)
- When preparing the design of experiment (DoE), a trade-off need to be found between:
  - Objective of the campaign
  - Time period of the test loop

Various scanning methods provide more options and flexibility when preparing the DoE

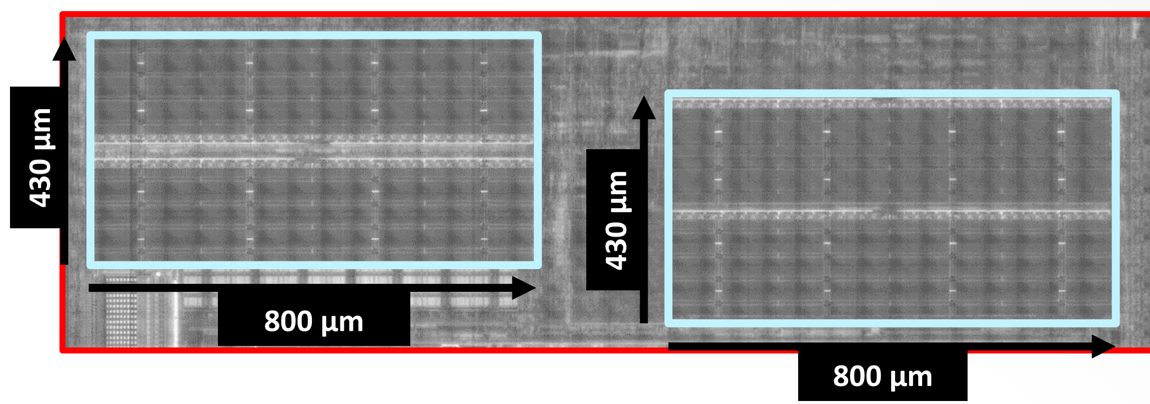
Device Under Test

- AMD Xilinx Zynq-7000 System-on-Chip (SoC) FPGA
- Technology process: planar bulk 28nm
- Flip-chip package
- Backside is mirror polished (to remove the engraved inscriptions)
- Substrate thickness : 656µm



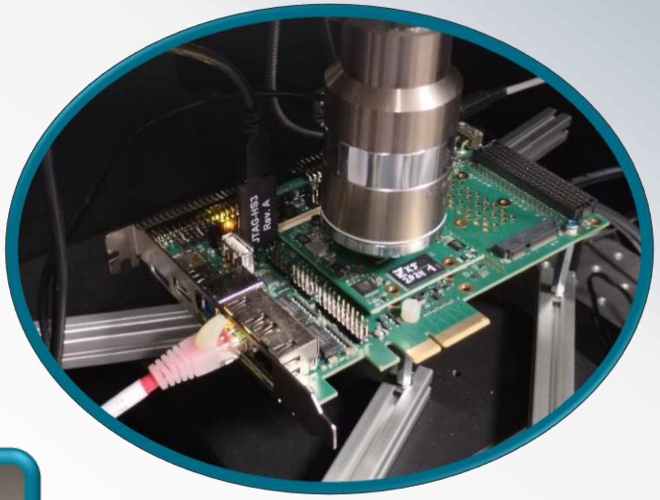
OCM: 256 KB

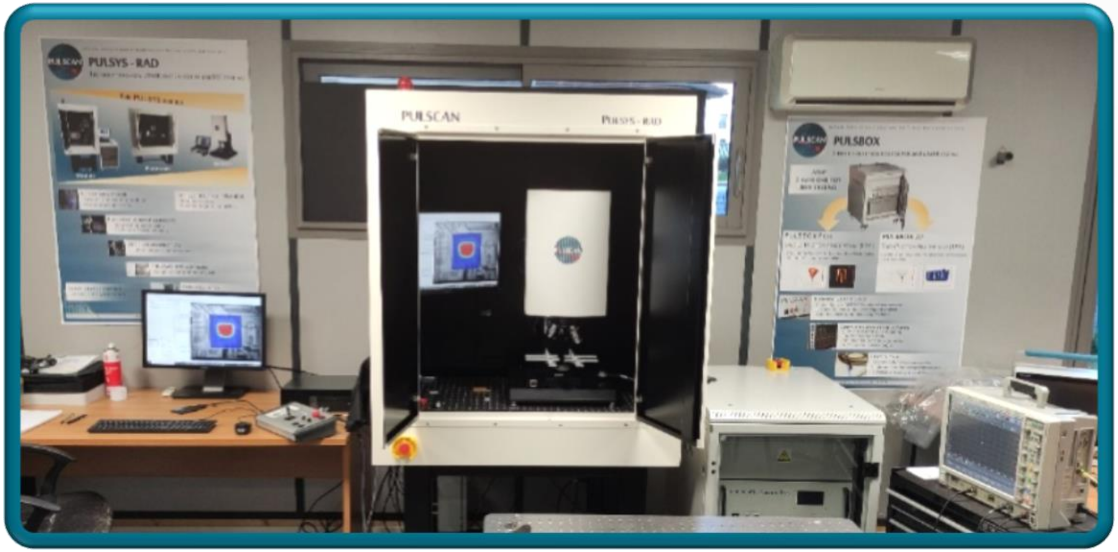
2 physical blocks, 4 logical Banks (64 KB each) named OCM0-1-2-3



Test set-up: laser facility

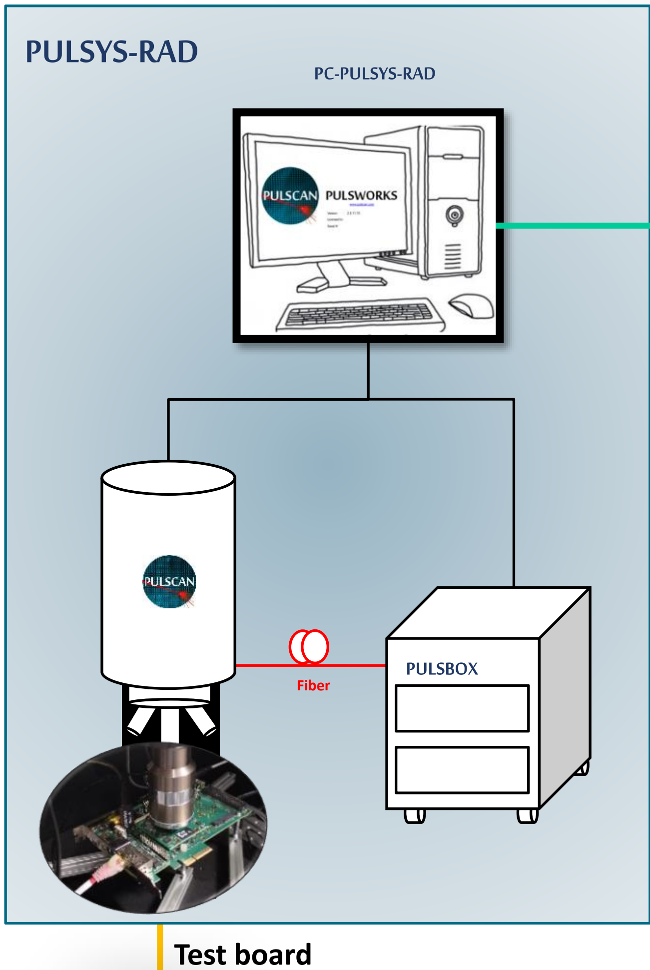
- PULSYS-RAD STD in its Single Photon configuration
  - Wavelength: 1064nm
  - Pulse duration: 30ps
  - Repetition Rate: Single pulse to 1MHz
  - Energy range: pJ to nJ
  - Scanning resolution: 10nm



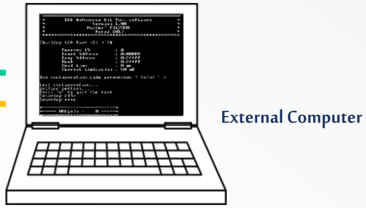


Test set-up: data acquisition

- OCM self-test by DUT Arm core



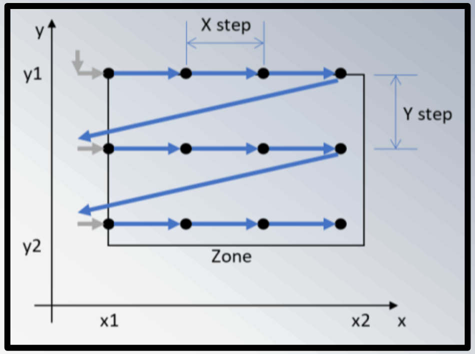
- Interfacing with PULSWORKS
  - Send data for mapping
  - Pause the scan during reset



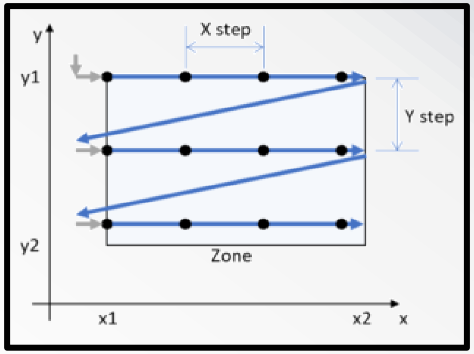
- Generating boot file
- Programming by JTAG
- Connecting to the DUT for command and report
- Logging outputs
- Running watchdogs
  - Monitoring supply current (SEL)
  - Monitoring output flow (SEFI)

Different kinds of scan modes

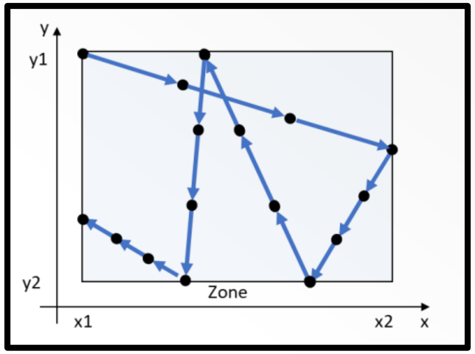
- Standard scan
  - Stop-and-go at each point of a regular 2D grid
  - ⇒ Events Mapping
  - ⇒ Events Screening
  - ⇒ Events Counting



- Fast scan
  - Move continuously along each line (no stop at each point)
  - Laser pulses are automatically triggered at evenly spaced points
  - ⇒ Events Screening
  - ⇒ Events Counting



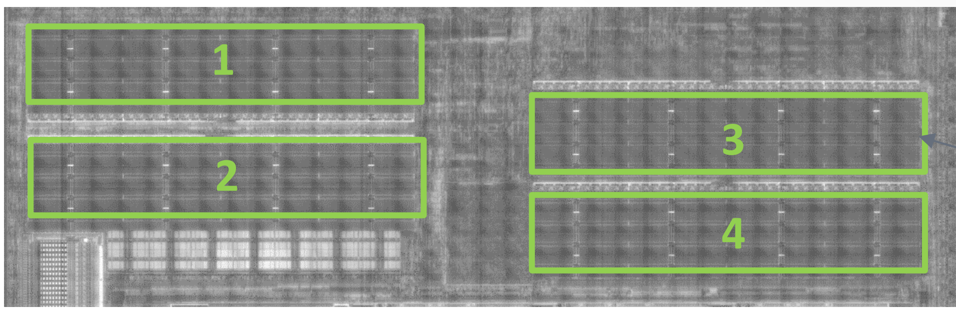
- Random scan
  - Move along randomly generated segment
    - Fast area coverage
    - Various resolutions during the same scan
    - Non-deterministic succession of events triggering
  - ⇒ Events Screening
  - ⇒ Events Counting



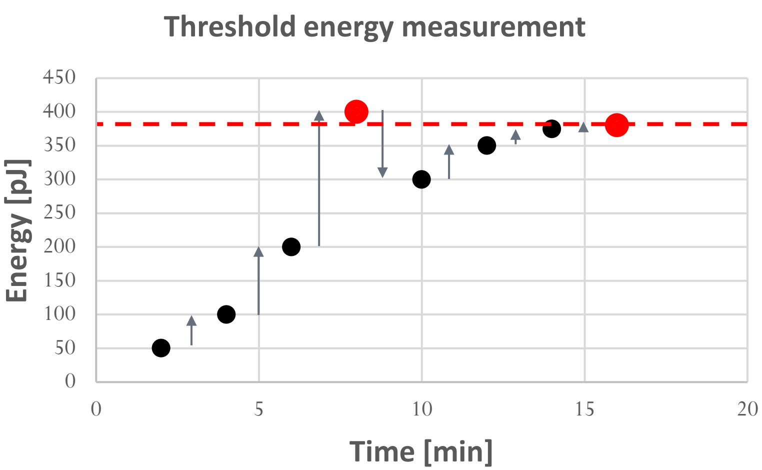
SEU Threshold Energy

Scan	Fast
Fast axis	X
Direction	Alternate
Step X	0,2µm
Step Y	10µm

- Using the **Fast Scan** mode (for screening or counting events only)
  - Scanning speed and resolution adjusted to have 1 laser pulse / 1ms / 0.2µm
  - Asynchronous test at lower frequency: test loop = 9ms
- Let's consider each half block separately (symmetry)



Scanning time: 2min
(per half block and per energy)



Threshold energy: 380pJ

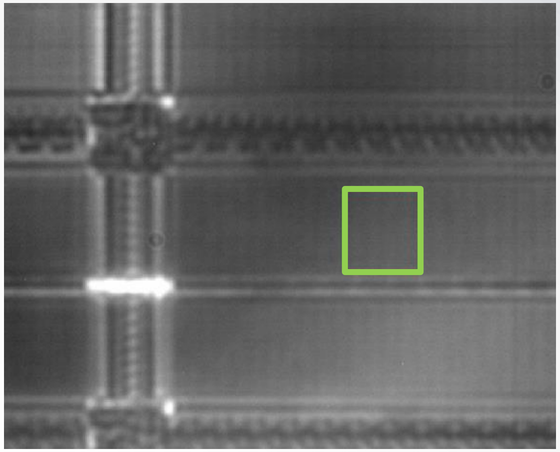
Fast and accurate solution to measure the SEU threshold energy of the OCM

Note:

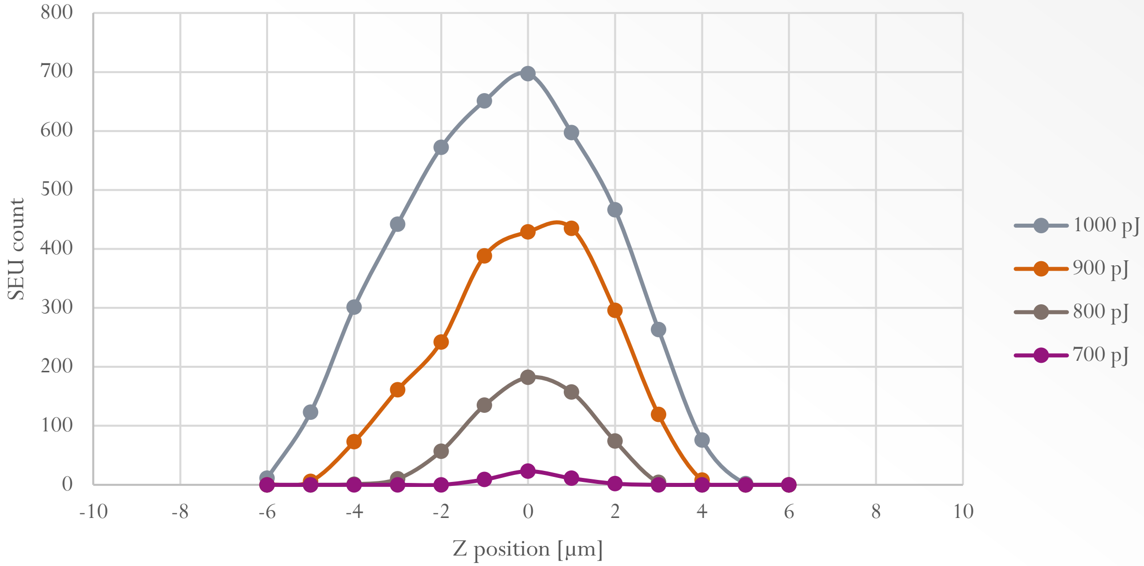
- estimated equivalent LET
  - with infinite radius: 22.83 MeV.cm2/mg
  - by considering the spot size effect (0,2µm): 6.20 MeV.cm2/mg
- HI test results: < 7 MeV.cm2/mg

Z position

- Scanned zone dimensions:
  - 12 x 13 µm²
  - Z exploration: 14 µm
- Scanning resolution:
  - 1µm x 1µm x 1µm
- Scanning time: 22min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms



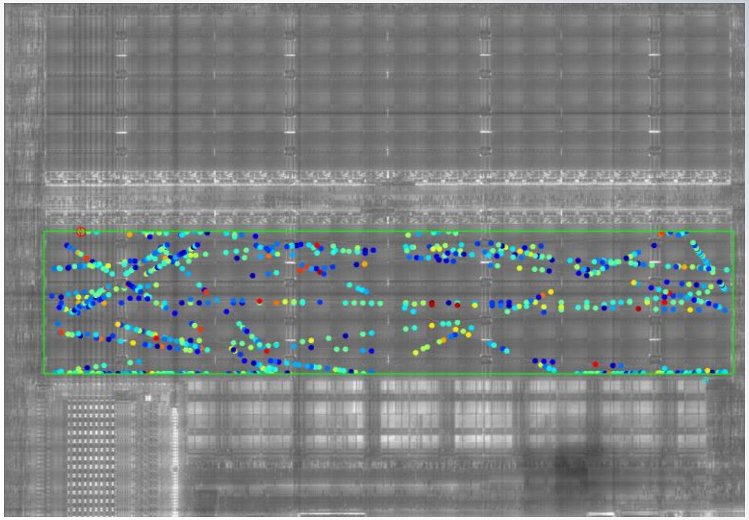
Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Step Z	1µm



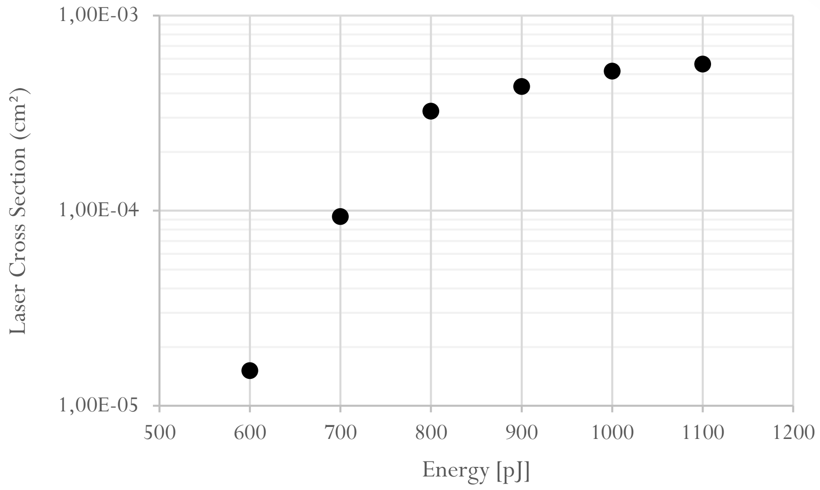
For long scans, we will set the energy @1000pJ (more tolerant to focus variation)

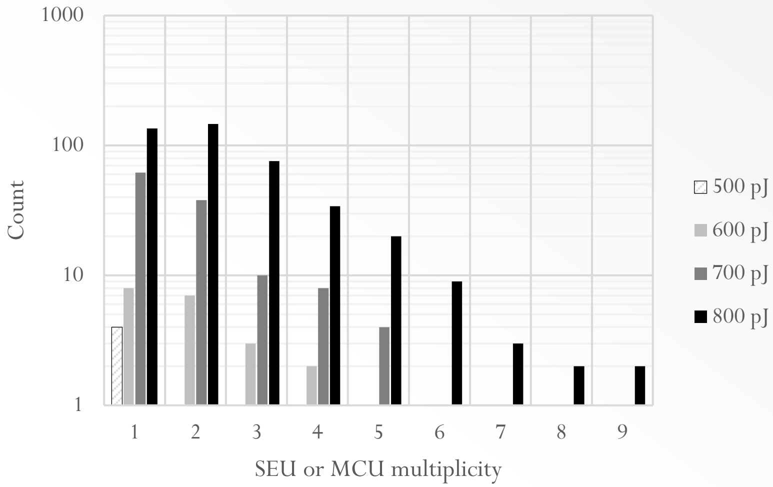
Laser cross section

- Using the **Random Scan** mode
- Scanned zones dimensions:
  - Block 2: 810 x 167 µm²
- Scanning resolution:
  - Number of points per segment: 81
  - Number of segments: 22
- Scanning time: 3min per energy
- Asynchronous test:
  - Laser injection period 100ms ; test loop = 60ms



Scan	Random
Fast axis	-
Direction	-
Step X	10
Step Y	7,8



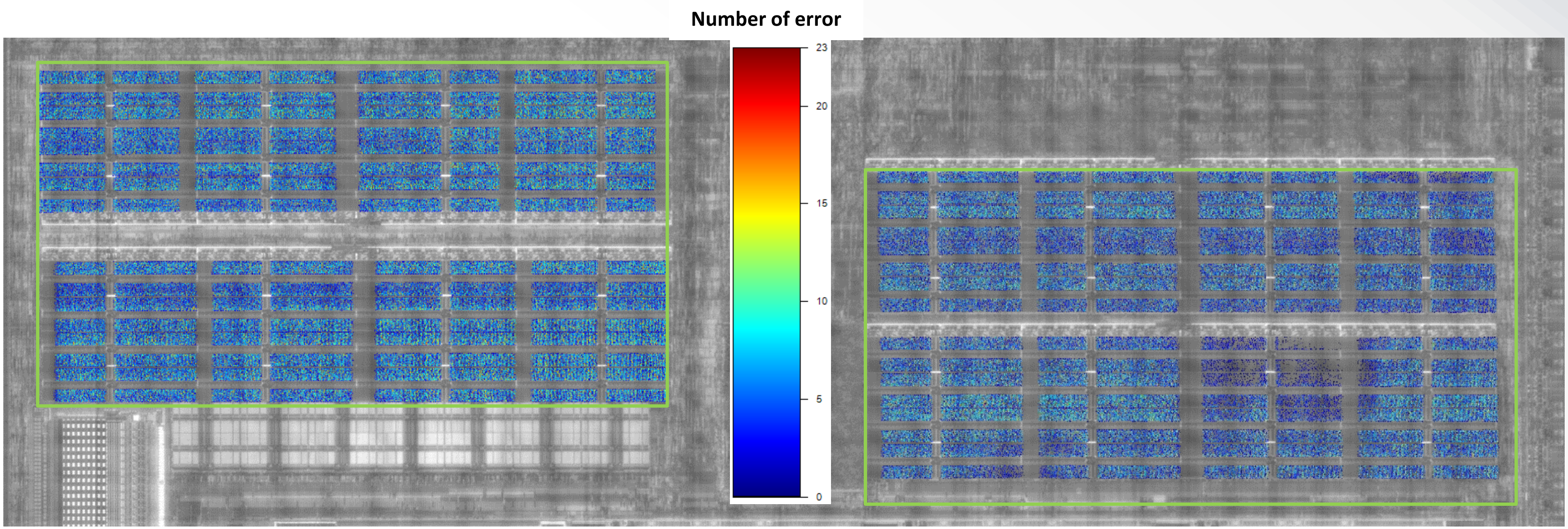


Do not need a systematic scan

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 µm²
  - 799 x 438 µm²
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

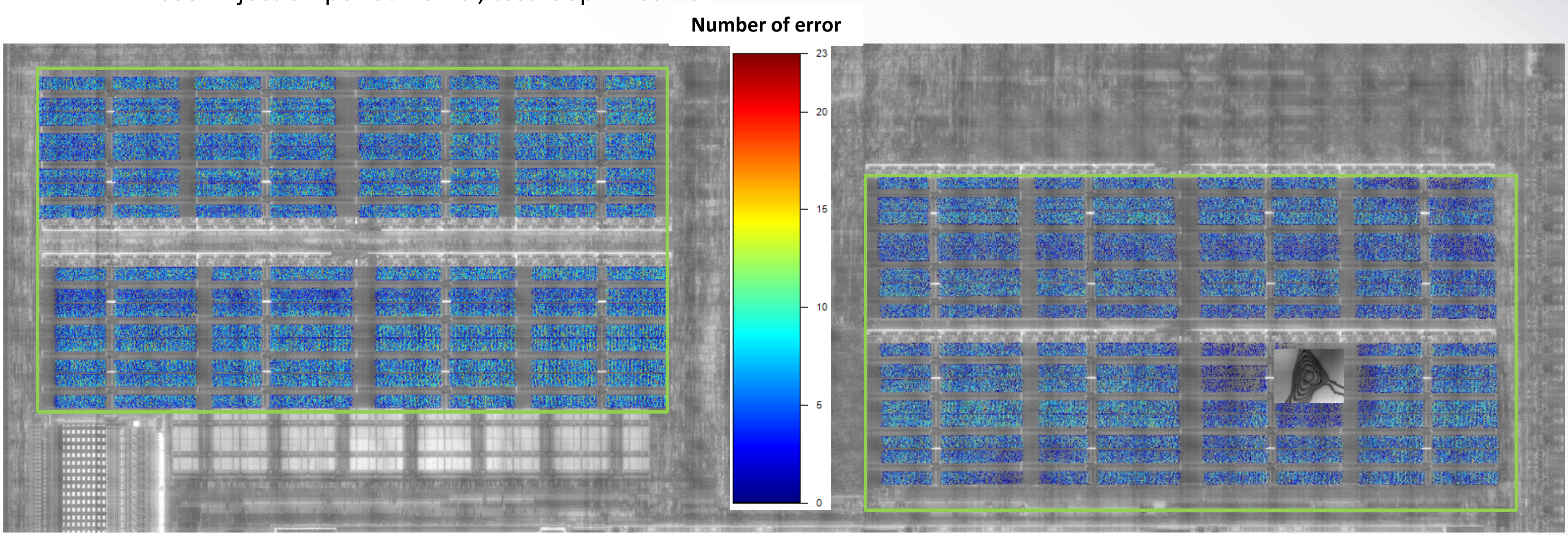


Full report

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 μm^2
  - 799 x 438 μm^2
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

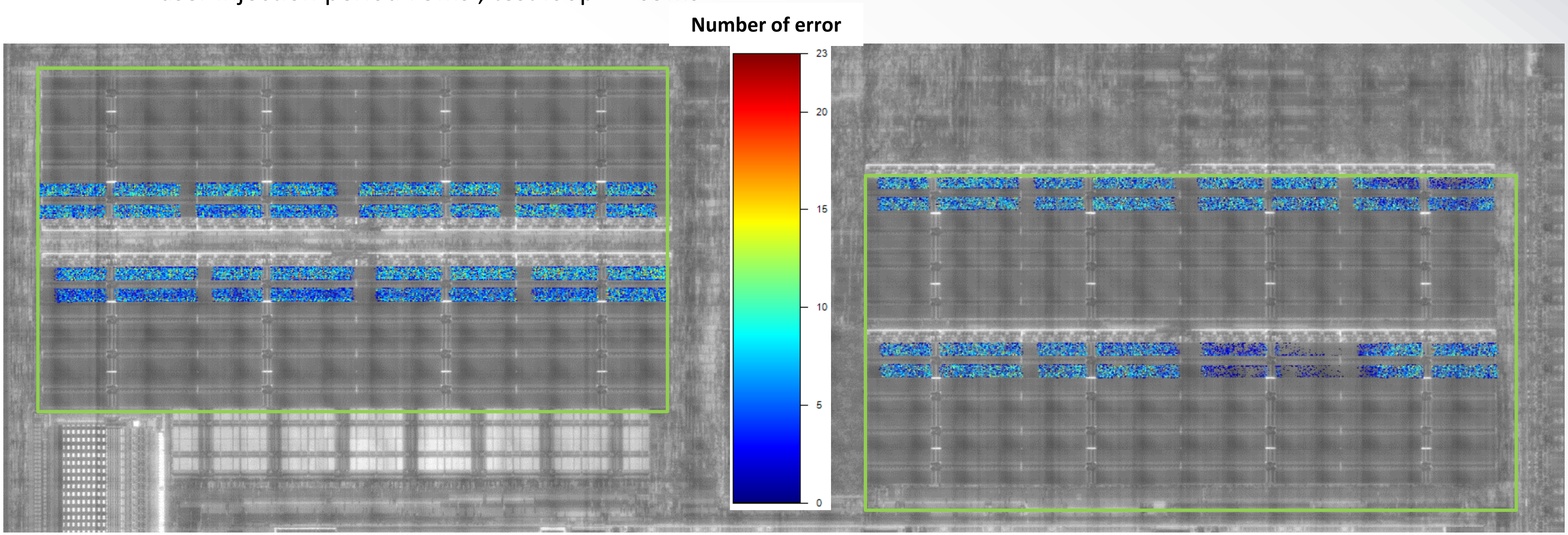


Full report

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 µm^2
  - 799 x 438 µm^2
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

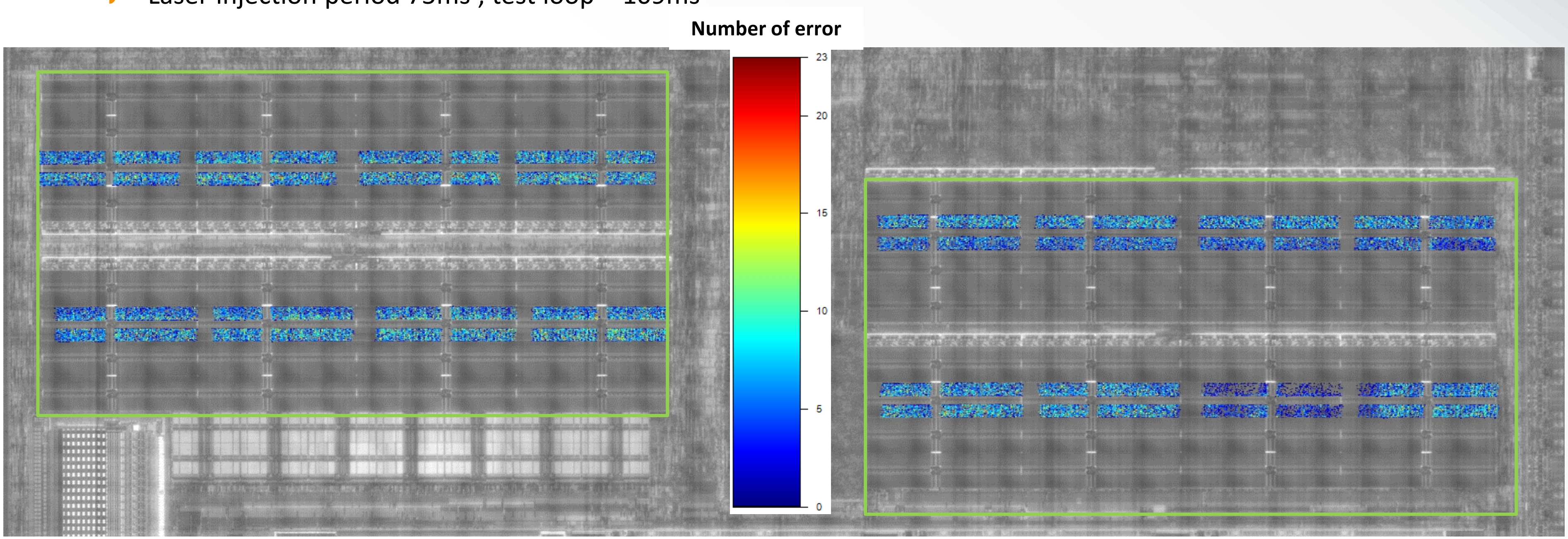


OCM_0

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 µm²
  - 799 x 438 µm²
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

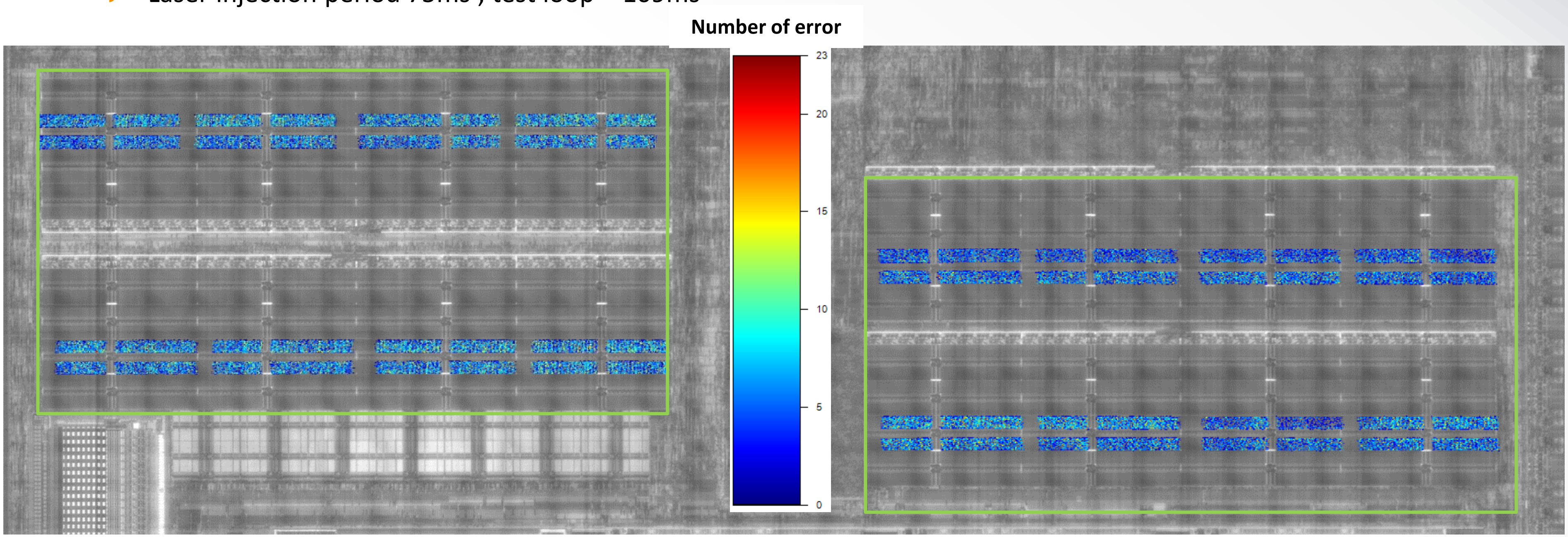


OCM_1

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 µm²
  - 799 x 438 µm²
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

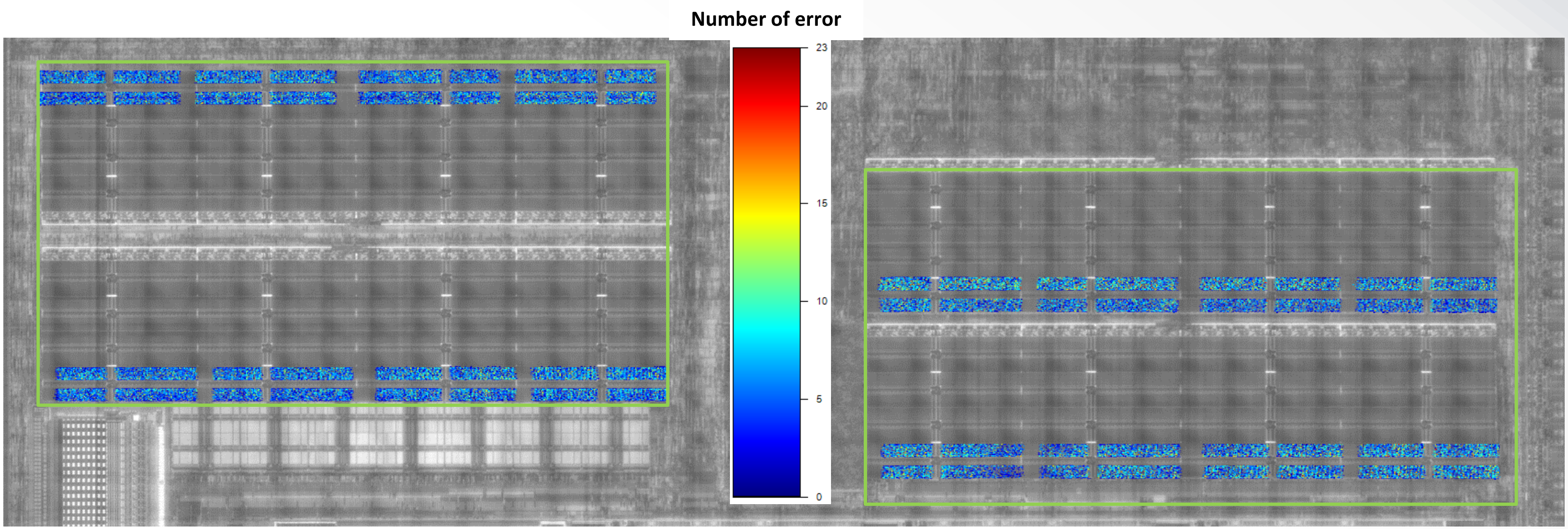


OCM_2

Standard scanning of the full OCM @1nJ

- Scanned zones dimensions:
  - 822 x 431 µm^2
  - 799 x 438 µm^2
- Scanning resolution: 1µm x 1µm
- Scanning time: 17h30min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

Scan	Standard
Fast axis	X
Direction	Alternate
Step X	1µm
Step Y	1µm
Energy	1nJ

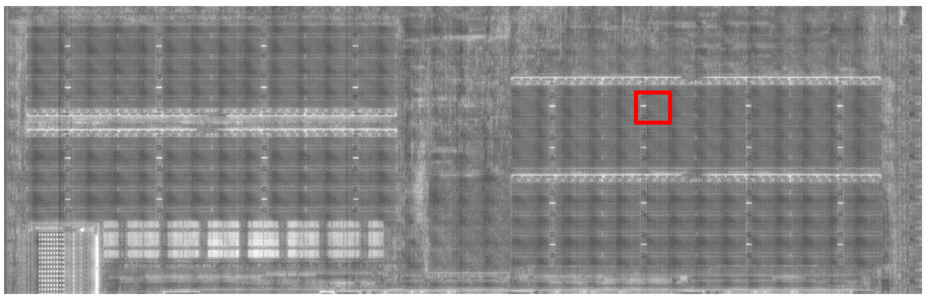


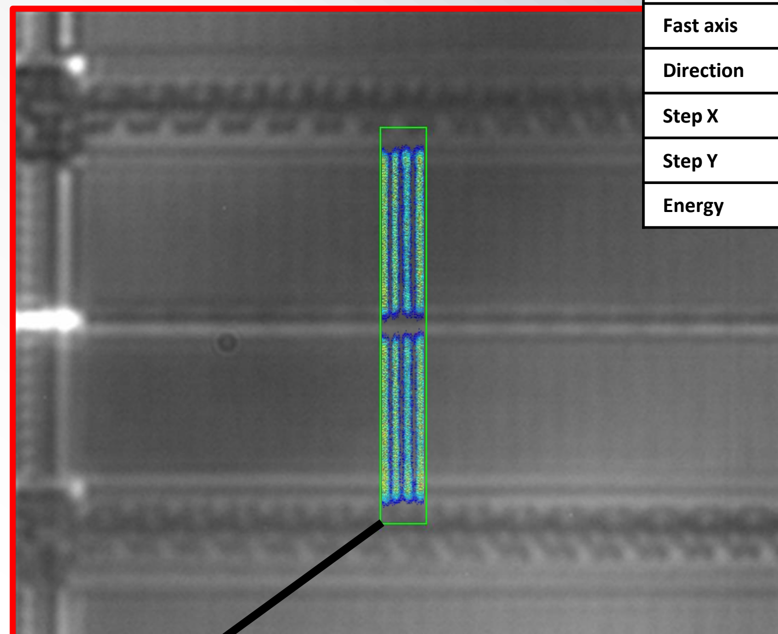
OCM_3

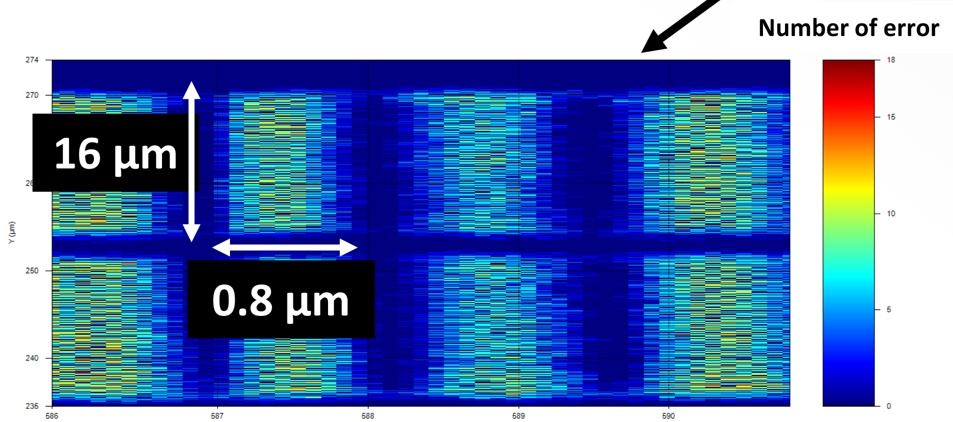
Standard scanning with high resolution @1nJ

- Scanned zones dimensions:
  - 4.9 x 39.5 μm^2
- Scanning resolution: 0.1µm x 0.1µm
- Scanning time: 27min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms

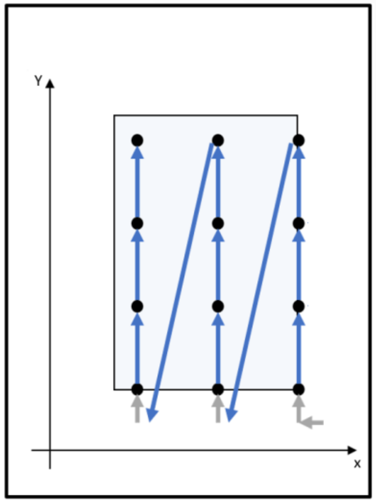
Scan	Standard
Fast axis	Y
Direction	Constant
Step X	0,1µm
Step Y	0,1µm
Energy	1nJ





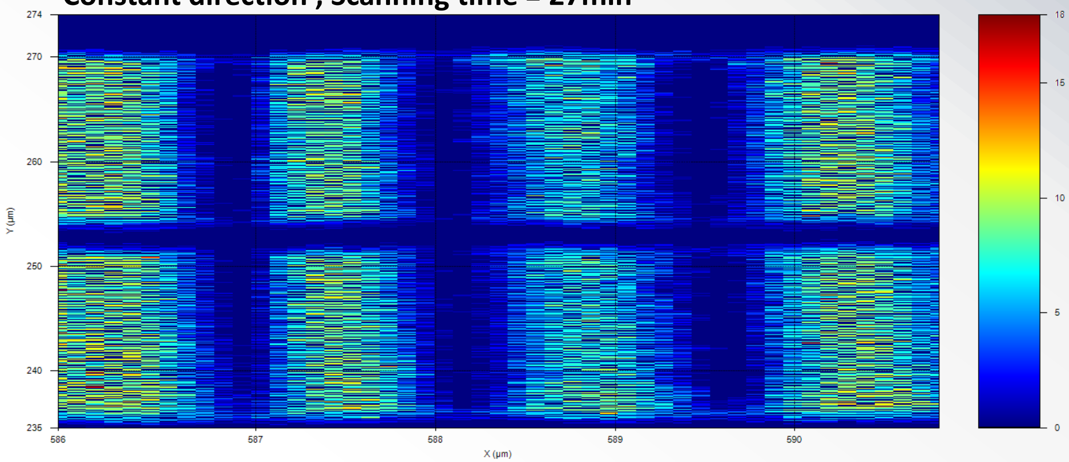


Alternate direction vs Constant direction

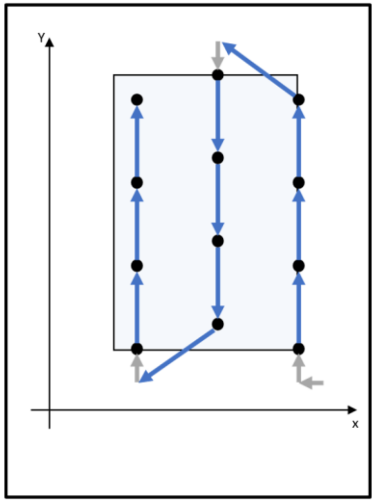


Constant direction ; Scanning time = 27min

Number of error

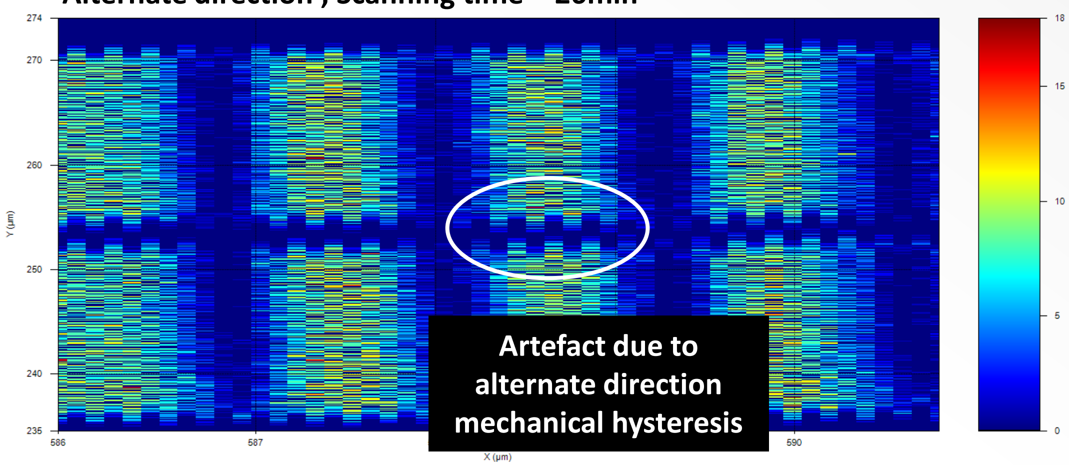


Scan	Standard
Fast axis	Y
Direction	Constant
Step X	0,1µm
Step Y	0,1µm
Energy	1nJ



Alternate direction ; Scanning time = 26min

Number of error



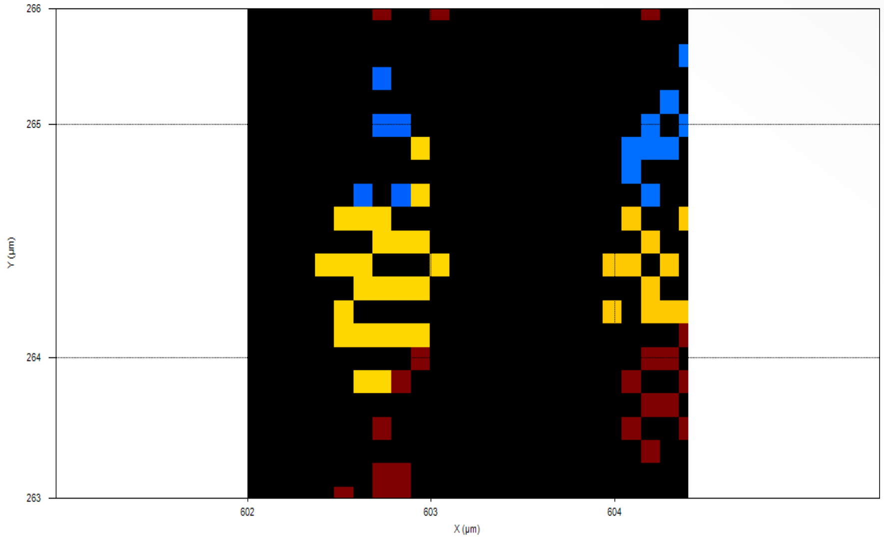
Scan	Standard
Fast axis	Y
Direction	Alternate
Step X	0,1µm
Step Y	0,1µm
Energy	1nJ

Alternate direction slightly faster but introduces an artefact due to the mechanical hysteresis
=> Alternate direction more dedicated to large zones and Fast scan mode

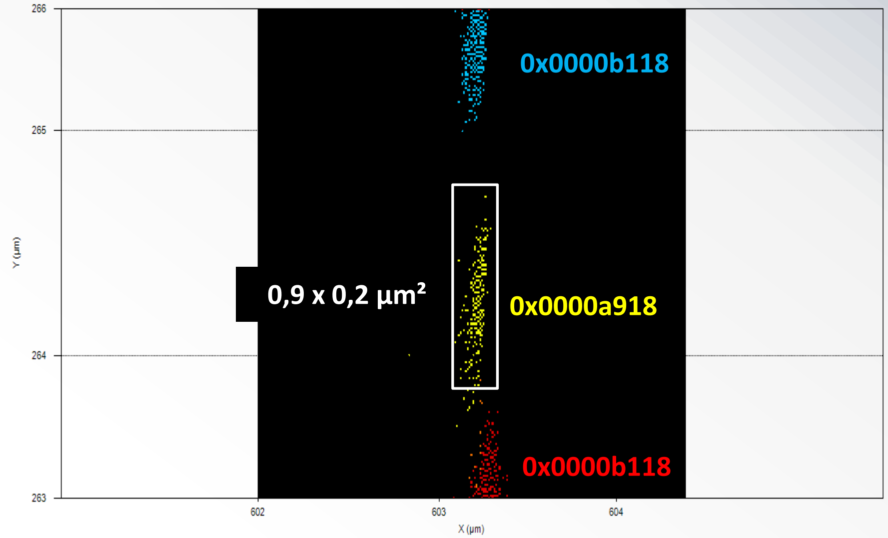
Interest of the sub-spot size resolution

- Energy: 700pJ
- Scanned zone 2.4 x 2.1µm²

Scanning resolution 100 nm
(scanning time: 41s)



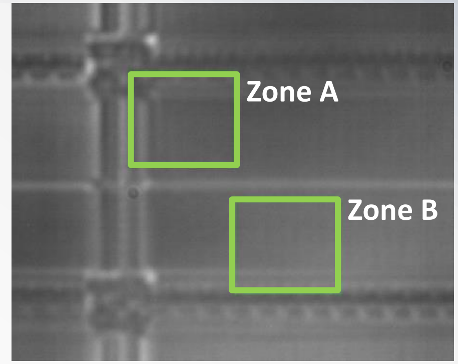
Scanning resolution 10 nm
(scanning time: 3min 52s)



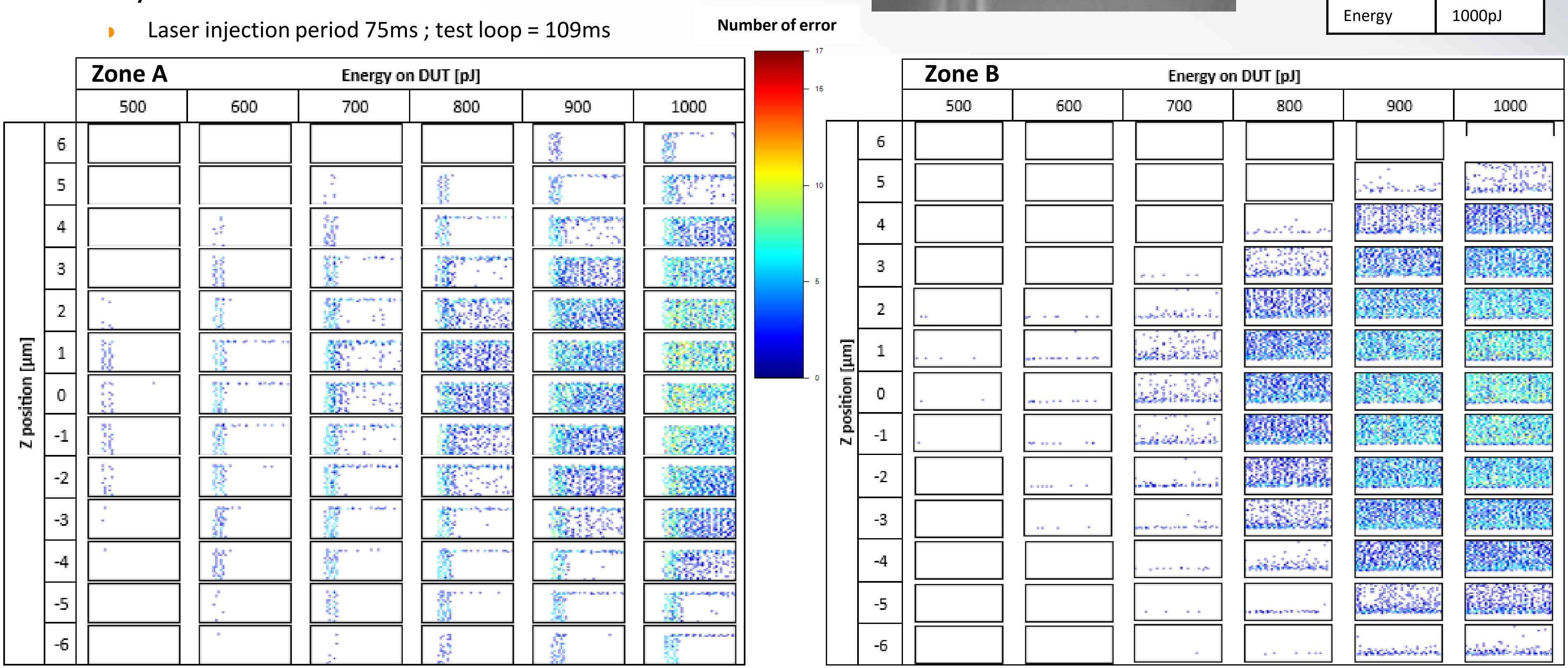
Scanning resolution below the spot size enables resolution of submicron structures

Multi-Zones / Multi-Energy / Multi-Z standard scanning

- Scanned zones dimensions:
  - 40 x 36 µm²
- Scanning resolution:
  - 0.5µm x 0.5µm
- Scanning time: 5h20min
- Asynchronous test:
  - Laser injection period 75ms ; test loop = 109ms



Scan	Standard
Fast axis	X
Direction	Alternate
Starting point	NW
Step X	0,5µm
Step Y	0,5µm
Step Z	1µm
Energy	1000pJ



Border of the matrix most sensitive

Conclusions

- Laser testing is not a replacement for particle beam testing, but a powerful complementary tool
- Complete scan of a large complex die is often not relevant or not possible
  - Recommendation to split the DUT area into Regions Of Interest (ROI)
- Then a trade-off need to be found between
  - Scanning area coverage
  - Scanning resolution
  - Scanning time
- Different scanning modes can be used to scan the ROI efficiently:
  - **Fast scan** provides fast results for events screening and events counting
  - **Random scan** can also be used for events screening and events counting in a non-deterministic sequence of pulse injection locations
  - **Standard scan** is suitable for accurate mapping of the SEE sensitive areas
    - Also suitable for events screening and events counting depending on the zone size and desired scanning resolution

Thank you

Need more information?
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