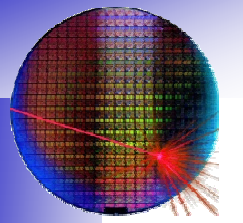

TPA determination of SET sensitive volumes

CNES contract n°71337/00

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IMS, University of Bordeaux, Talence, France
CNES, Toulouse, France

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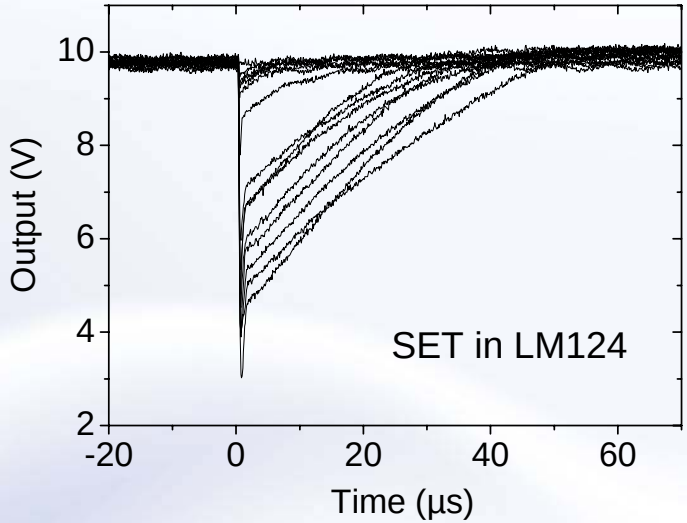
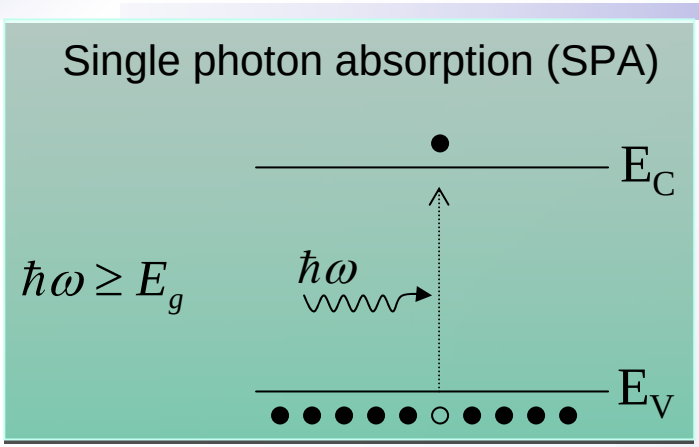
Motivation

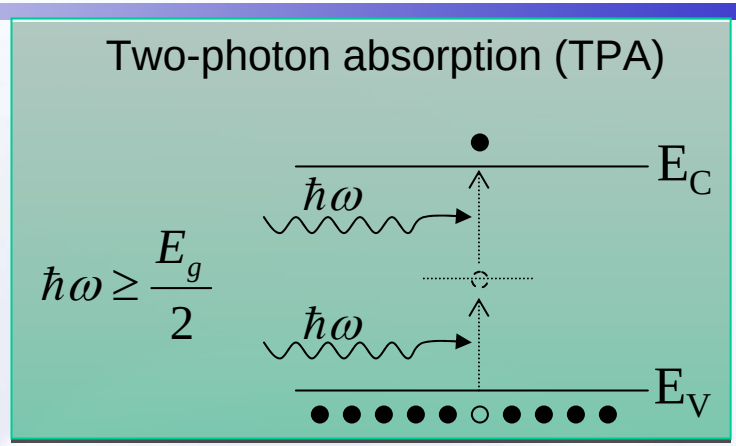
- SET in linear devices
  - ns to ms perturbation of analog parameters
  - Strong implications for system design
- SET rate prediction
  - Heavy ion cross section
  - Sensitive volume depth ?
- SET laser testing
  - Easy in-lab investigation of electrical set-up effects, rare events, lot-to-lot variations…
  - Screening
- Two-photon absorption (TPA)
  - In-depth resolution of charge deposition



Can TPA laser testing help in measuring SET sensitive volumes in linear devices ?

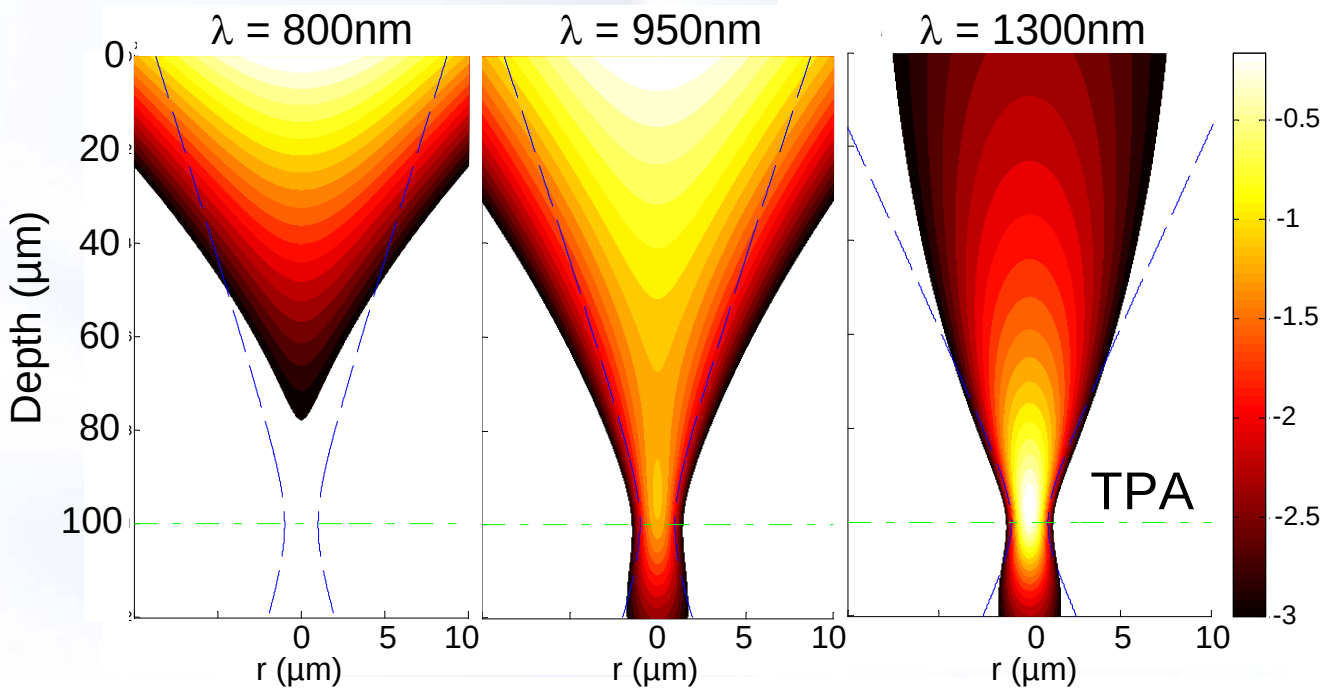
Single vs Two-Photon Absorption





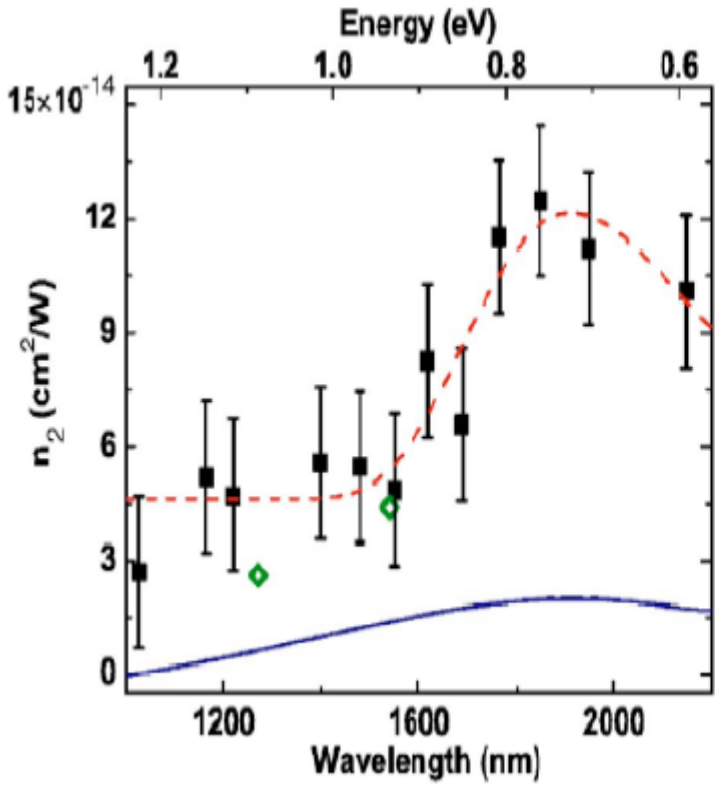
Backside approach

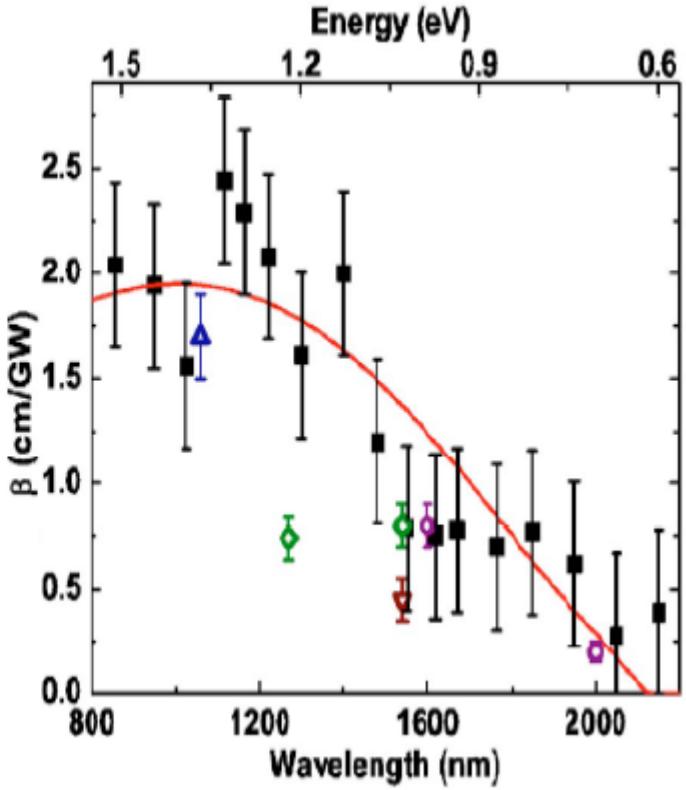
100µm substrate



Generated carriers density (log)

Two-photon absorption coefficient





A. D. Bristow, N. Rotenberg, H. M. van Driel, “Two-photon absorption and Kerr coefficients of silicon for 850–2200 nm”, Appl. Phys. Let. 90, 191104, 2007

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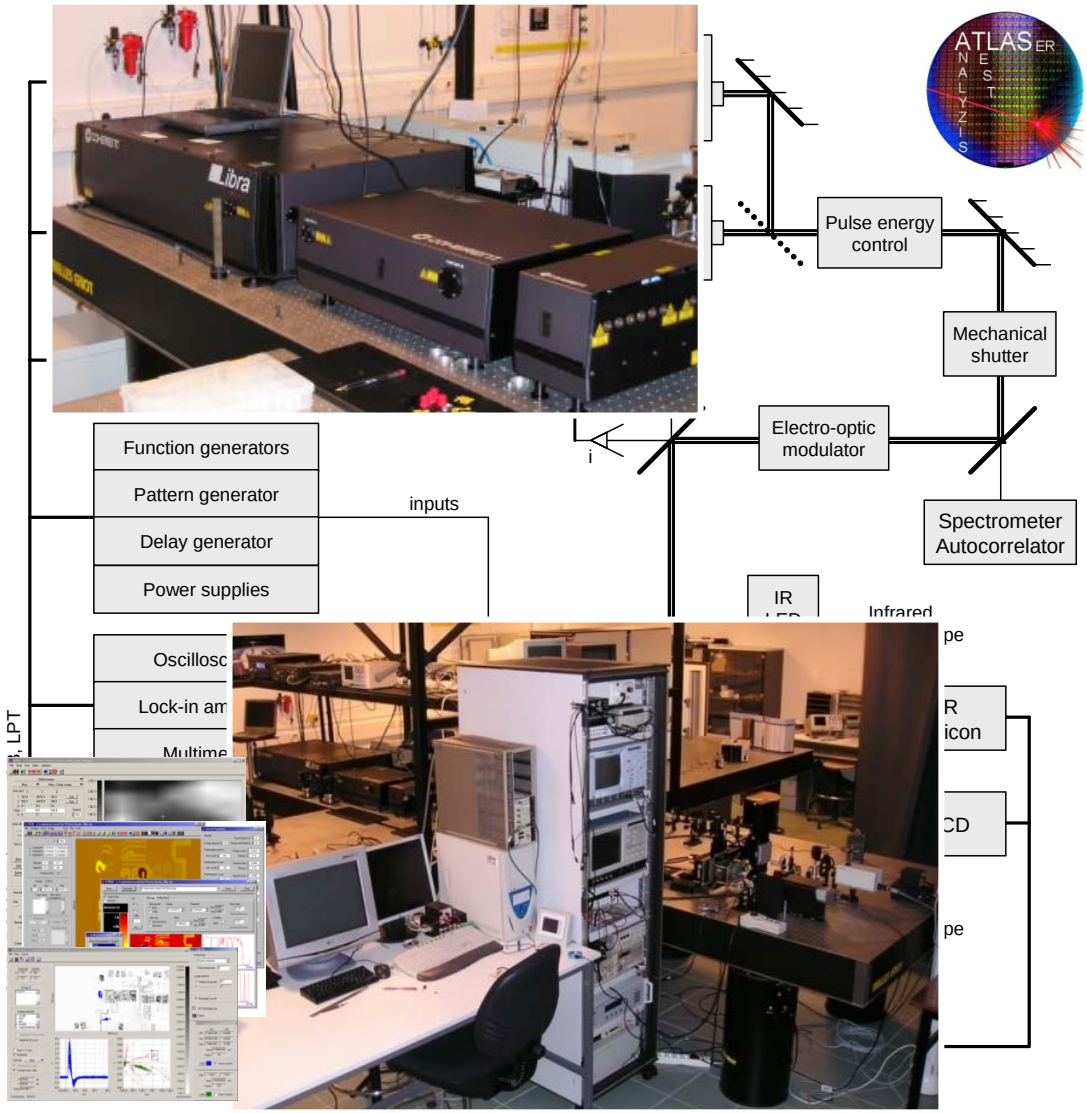
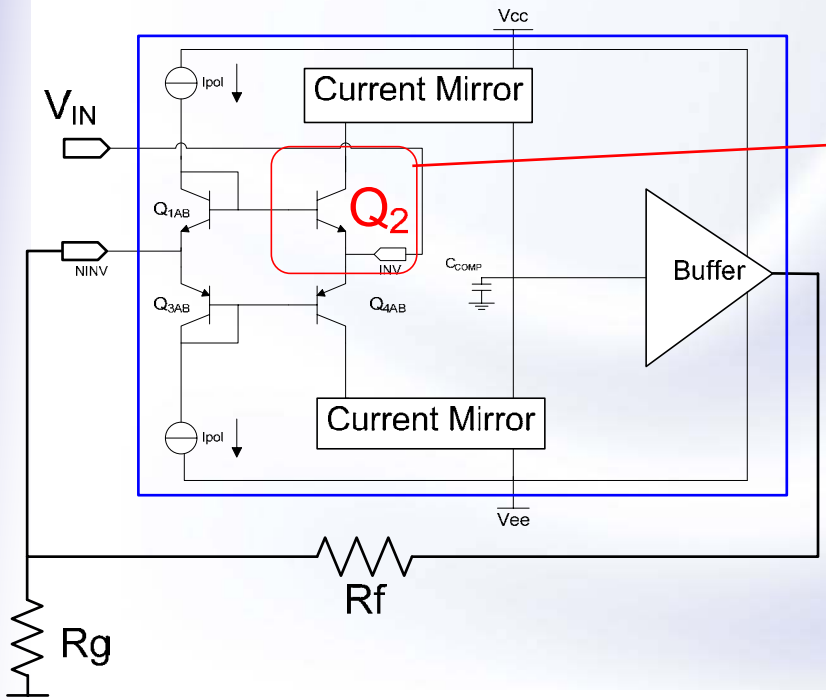
ATLAS Laser Facility at IMS

- Single-Photon Absorption
  - Source: NIR-tunable picosecond oscillator
  - Wavelength: 980nm
  - Pulse duration: 1ps
  - Pulse energy: ~100pJ
- Two-Photon Absorption
  - Source: NIR femtosecond parametric amplifier
  - Wavelength: 1300nm
  - Pulse duration: 150fs
  - Pulse energy: ~100nJ
- Automation
  - 3D scanning
  - Transient acquisition

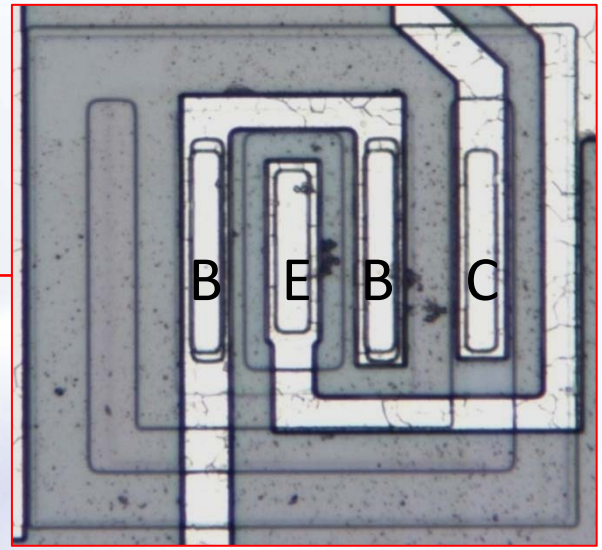


Devices under test

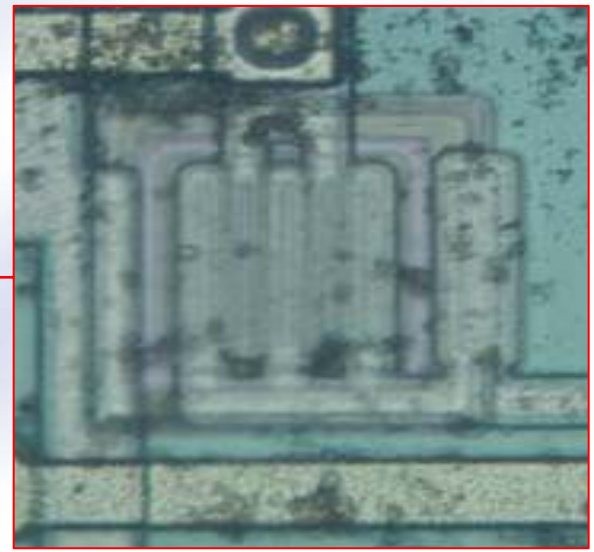
- LM6181, AD9617
- Current feedback operational amplifiers
- Non-inverting set-up, Gain=2
- Input=0.5V, Vcc=±5V
- NPN transistor in the input stage



LM6181

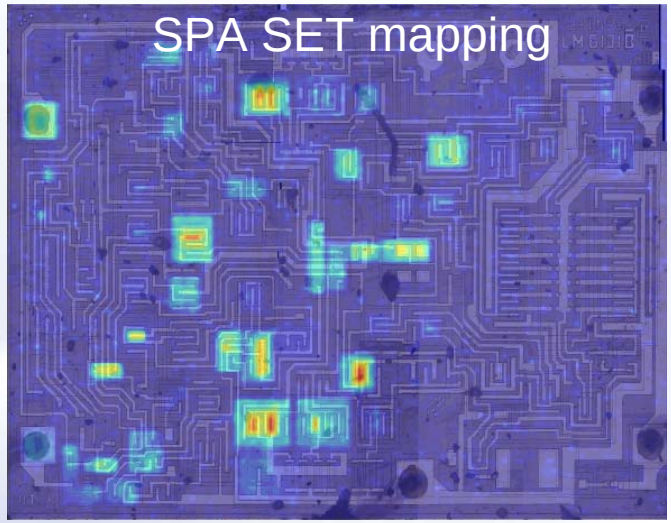


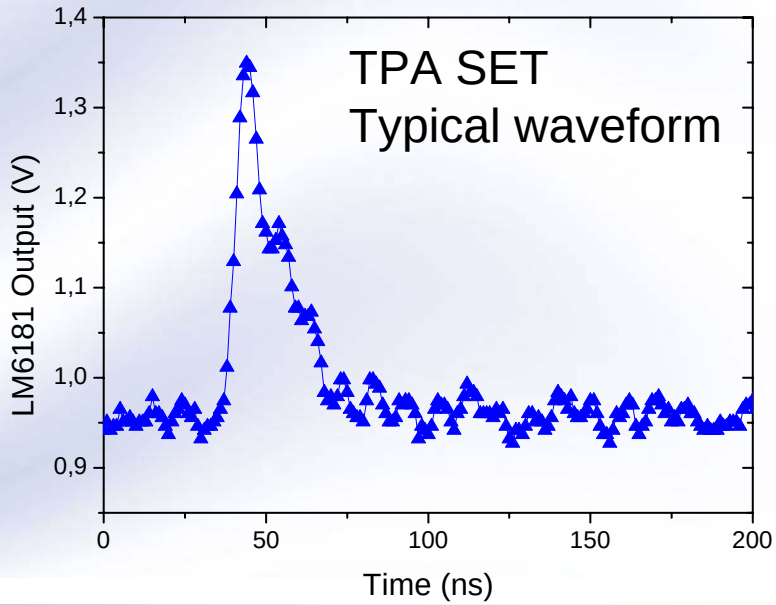
AD9617



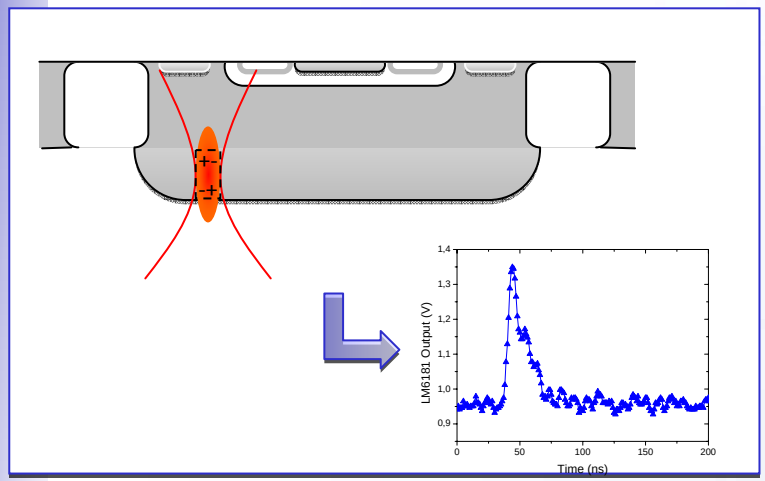
Preliminary steps

- Single photon scan reveals sensitive areas
  - Allows backside navigation without real-time IR imaging
- Definition of the region of interest (ROI)
- Switch to TPA beam
- Observation of first SET waveforms to adjust pulse energy and set-up the acquisition chain



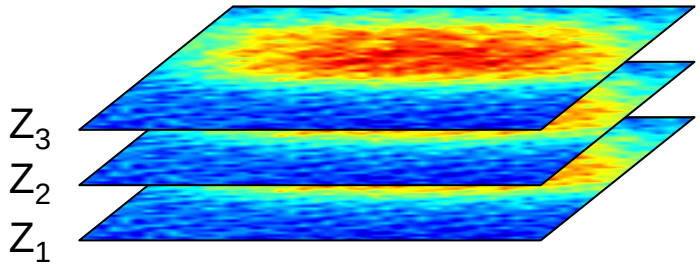


Tomographic reconstruction methodology



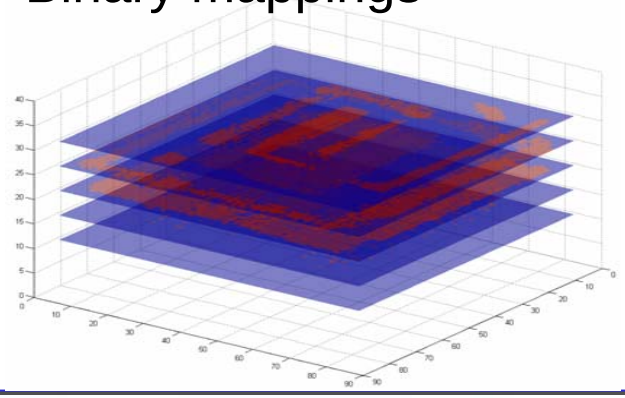
3D scan

SET amplitude mappings



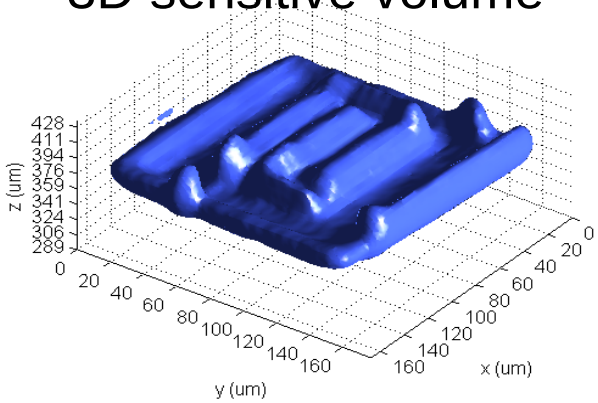
Threshold

Binary mappings



3D render

3D sensitive volume



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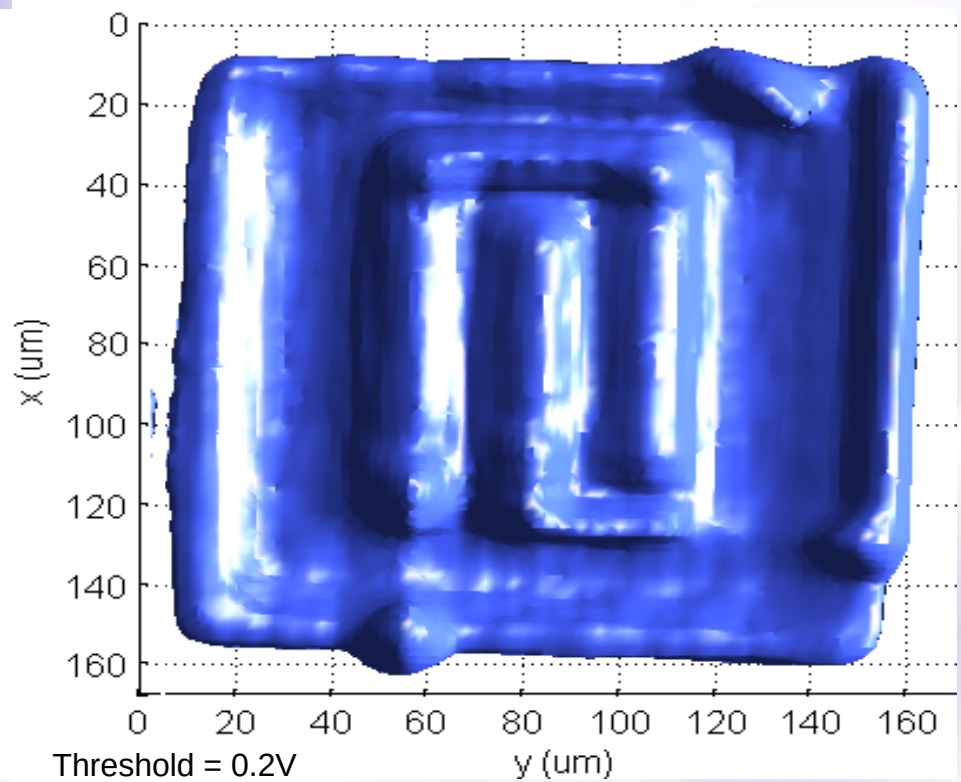
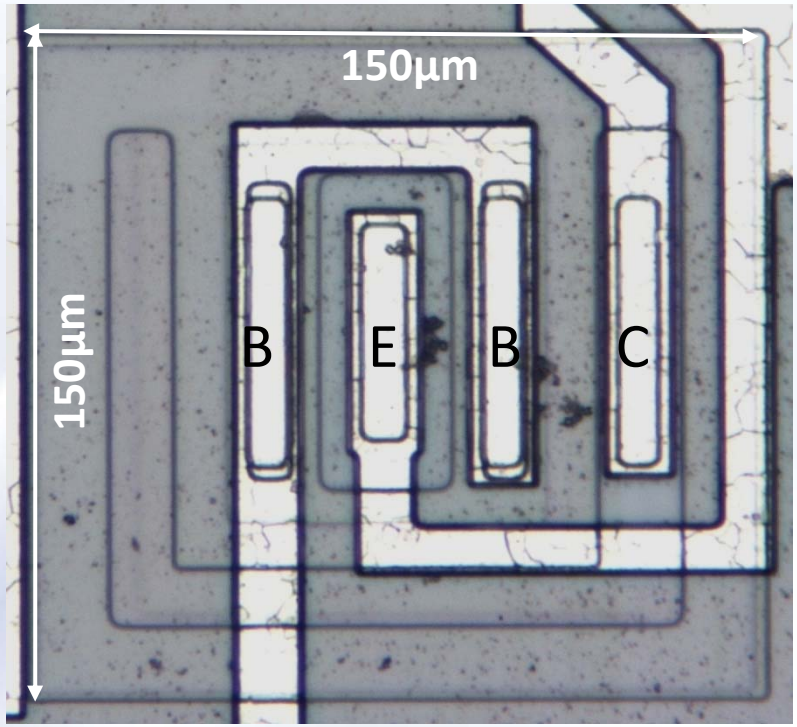
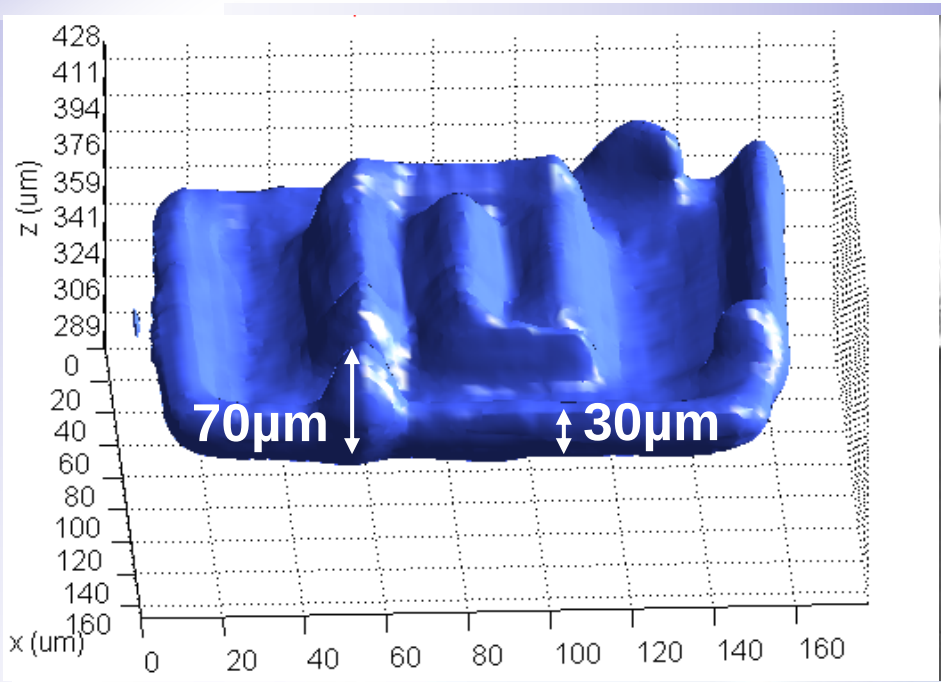
LM6181 results: top-side view

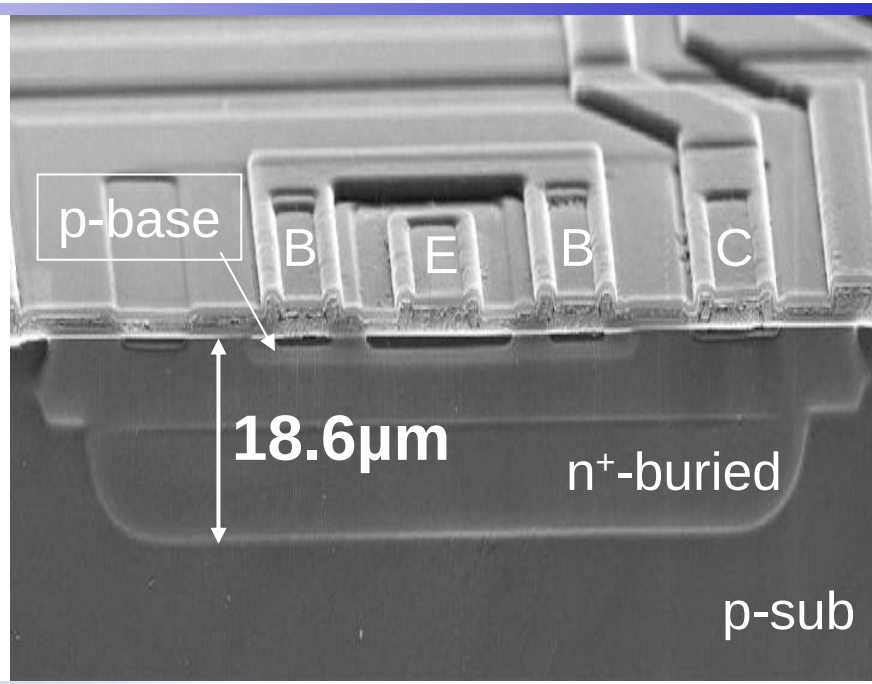




- Not a simple rectangular or ovoid shape
- Transistor topology clearly visible: junctions, contacts, metallization
- Lateral dimensions as expected: diffusion limited to P-well

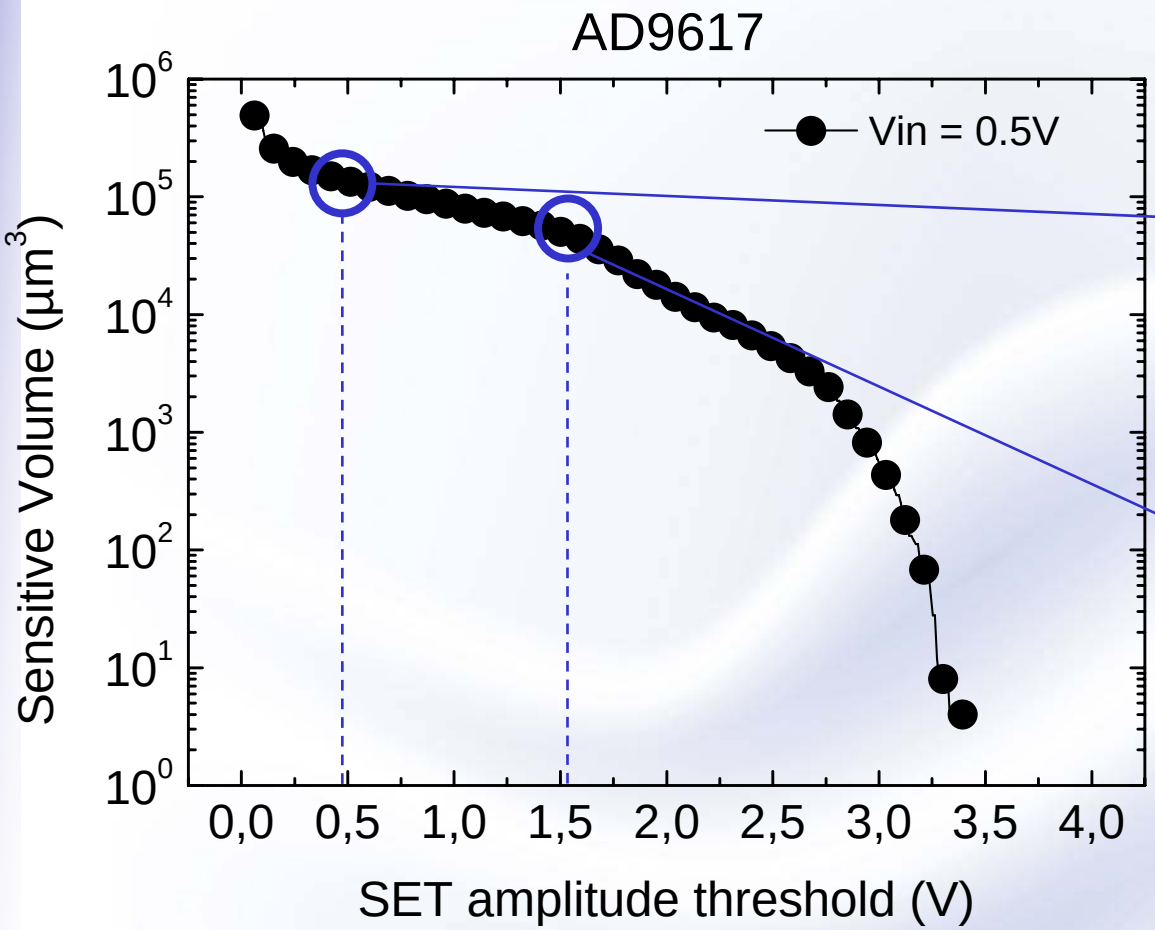
LM6181 results: profile view

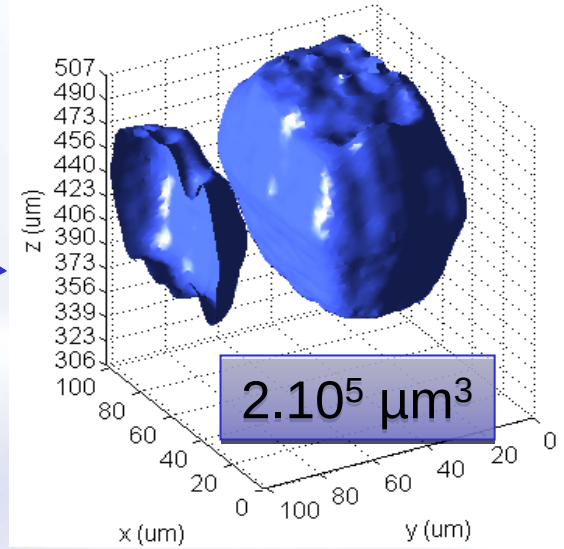


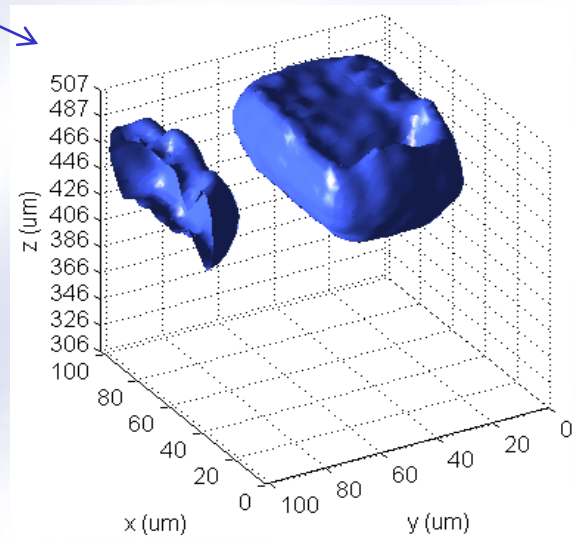


- SV extends much deeper than technology dimensions
- Bumps correlated to technology relief: optical artifacts ?
- Reflection on metal lines and contacts could explain upper relief

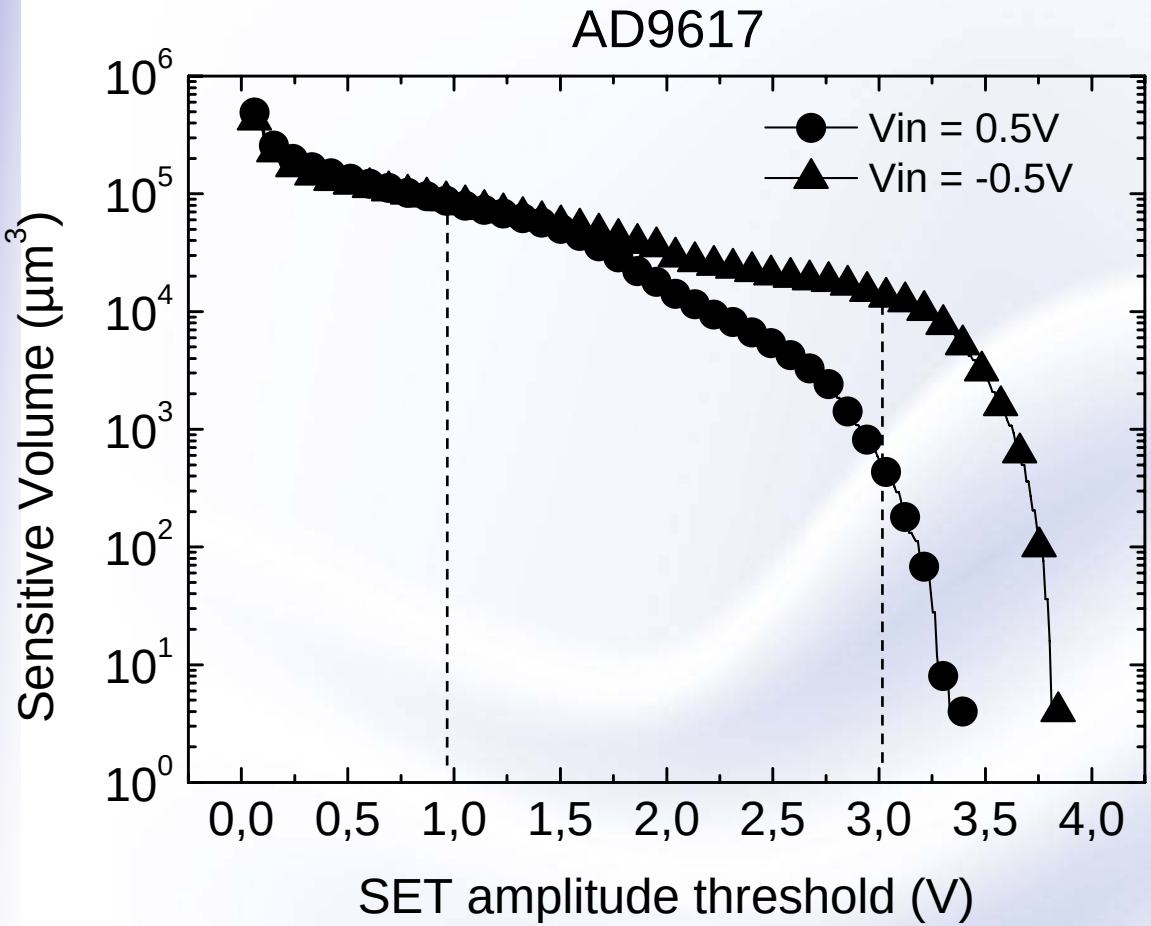
Sensitive Volume vs SET Threshold (1/2)



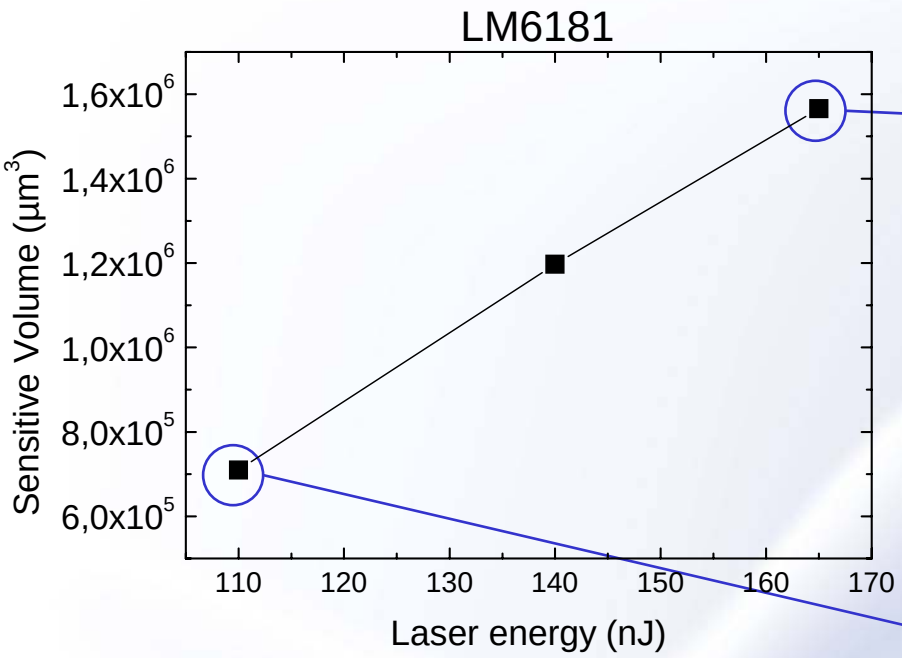


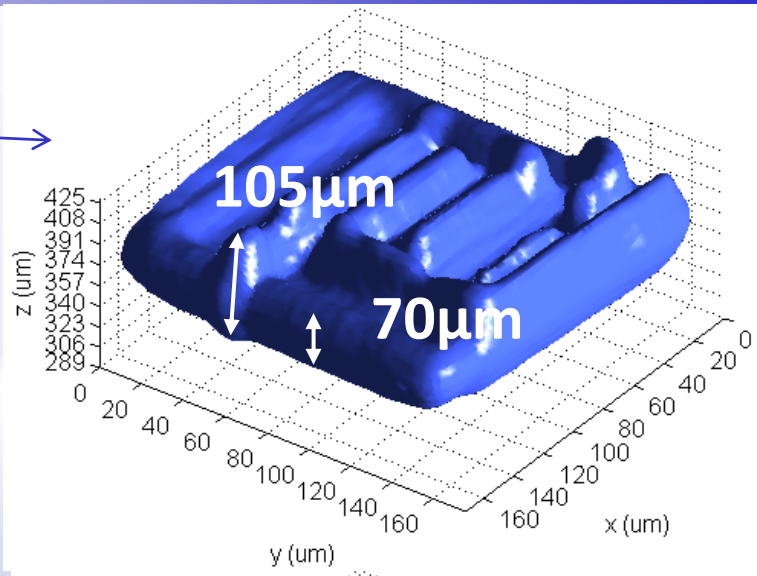


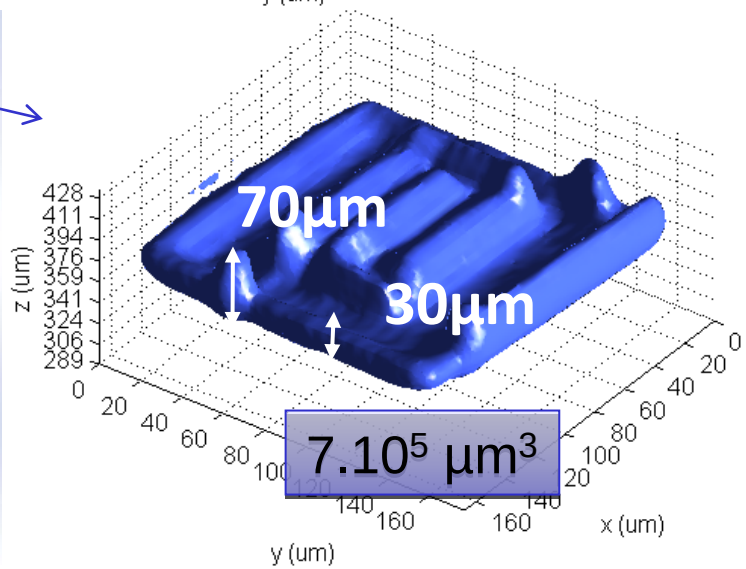
Sensitive Volume vs SET Threshold (2/2)



Influence of Laser Pulse Energy (1/2)







- Sensitive volume increases with energy
- Two possible contributions
  - Charge collection processes (diffusion, potential redistribution)
  - Experimental artifact related to TPA generation

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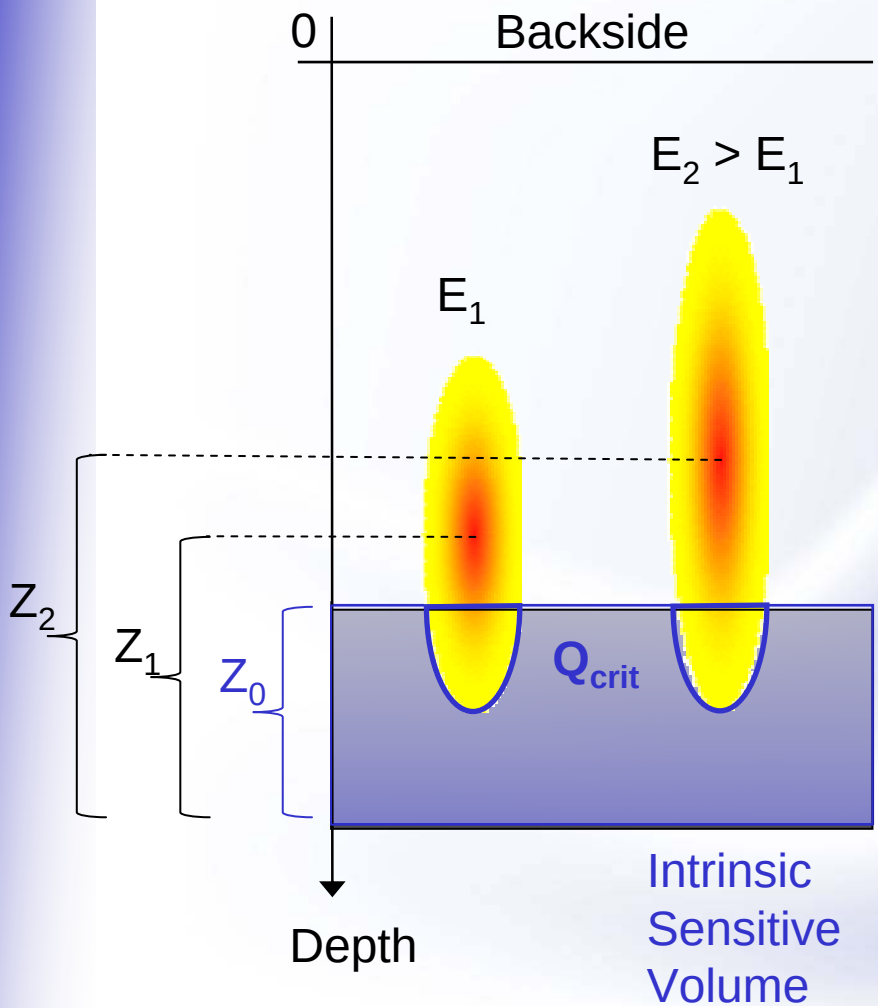
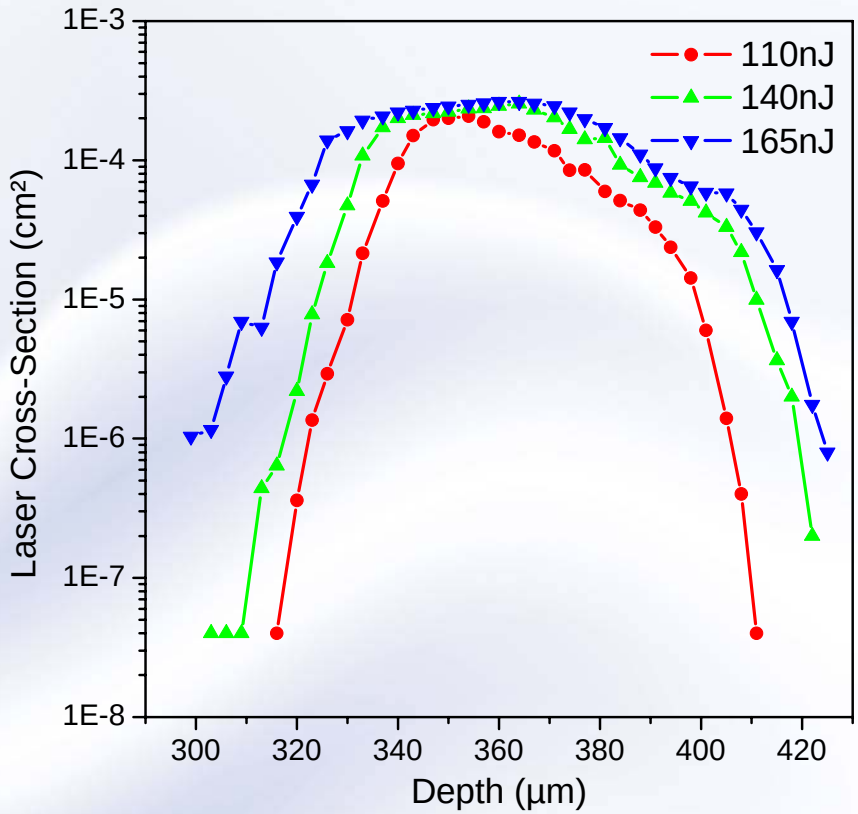
Influence of Laser Pulse Energy (2/2)

- TPA iso-generation surface extends in Z direction as energy increases



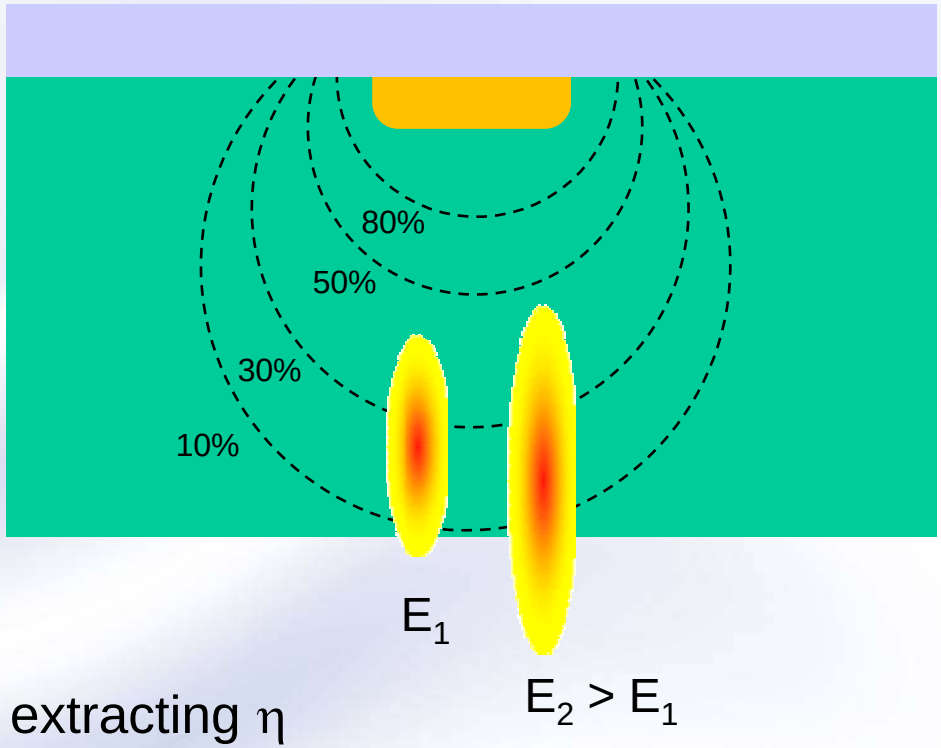


- SV measurement at threshold energy should be close to intrinsic SV

Charge collection efficiency volumes

- RPP model too simple
- Model based on charge collection efficiency distribution

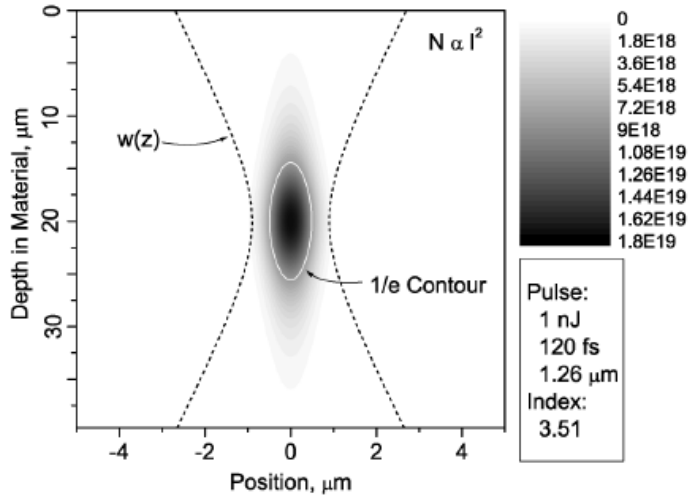
$$\eta_{RPP} = \iiint \rho(r) \cdot \int \eta(r,\theta) \, d\theta \, dr$$



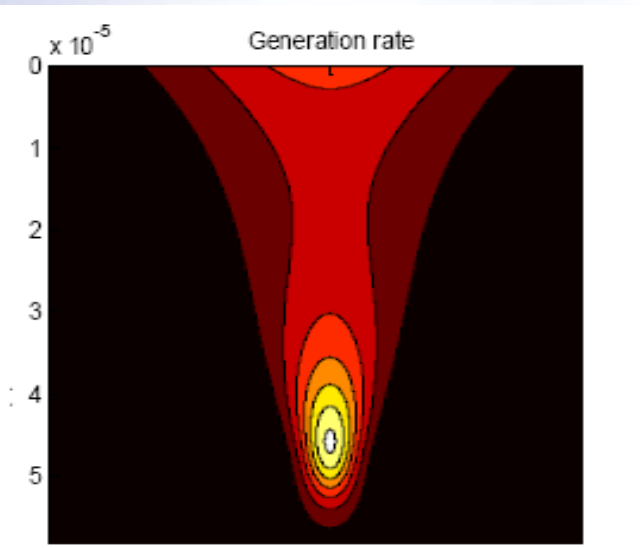
- Good model of G required for extracting η by deconvolution

TPA generation rate modeling

- No rigorous analytical
- Simplified analytic model not realistic enough
  - Beam depletion, nonlinear refraction not included
- Iterative numerical model
  - More realistic shape
  - Nonlinear refraction still not included
- FDTD modeling in progress with RSOFT tools
  - Calculation of laser intensity distribution in the presence of nonlinear effects
  - Generation rate extraction



MCMORROW *et al.: SUBBANDGAP LASER INDUCED SEEs, IEEE TNS 2002*



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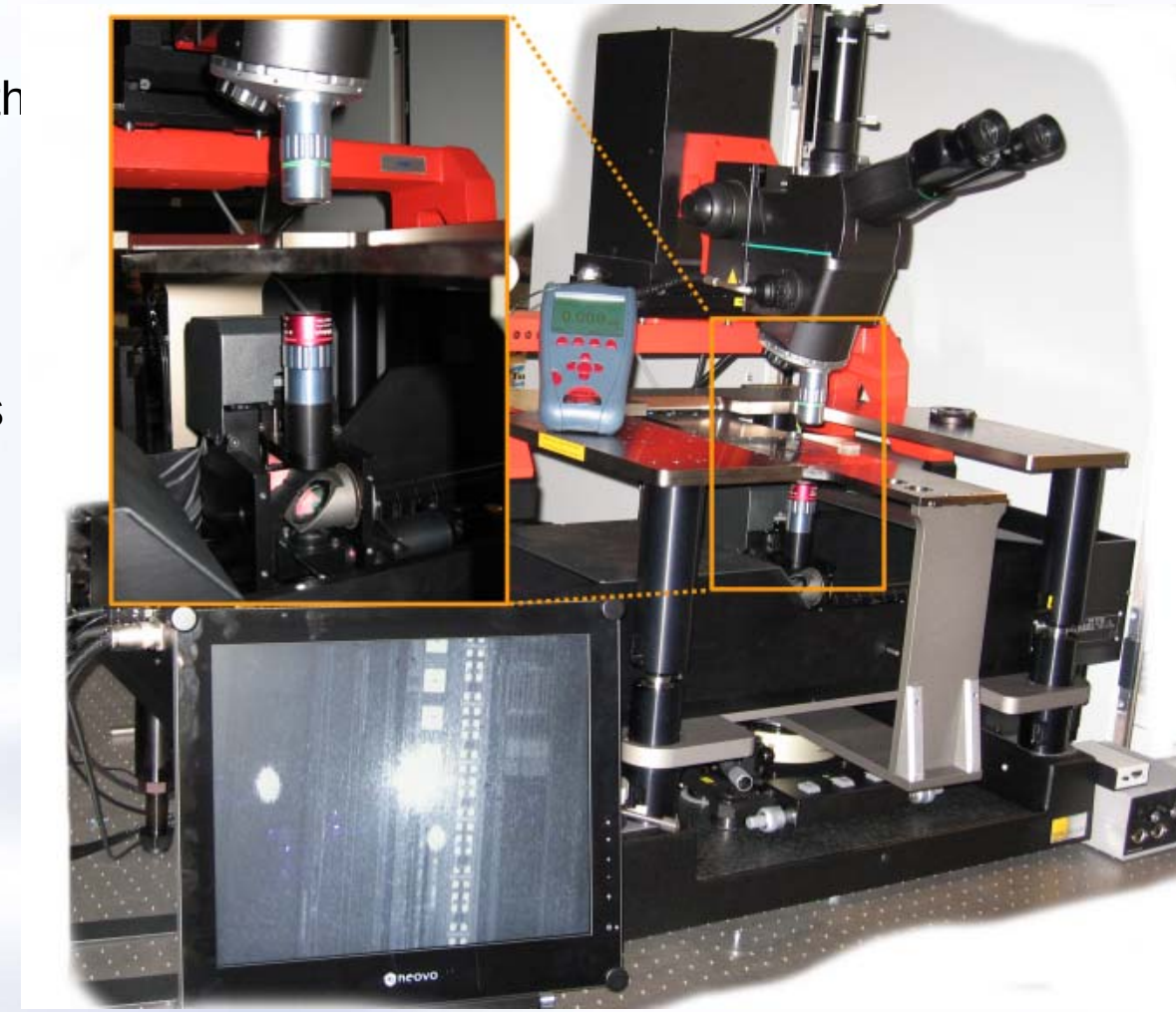
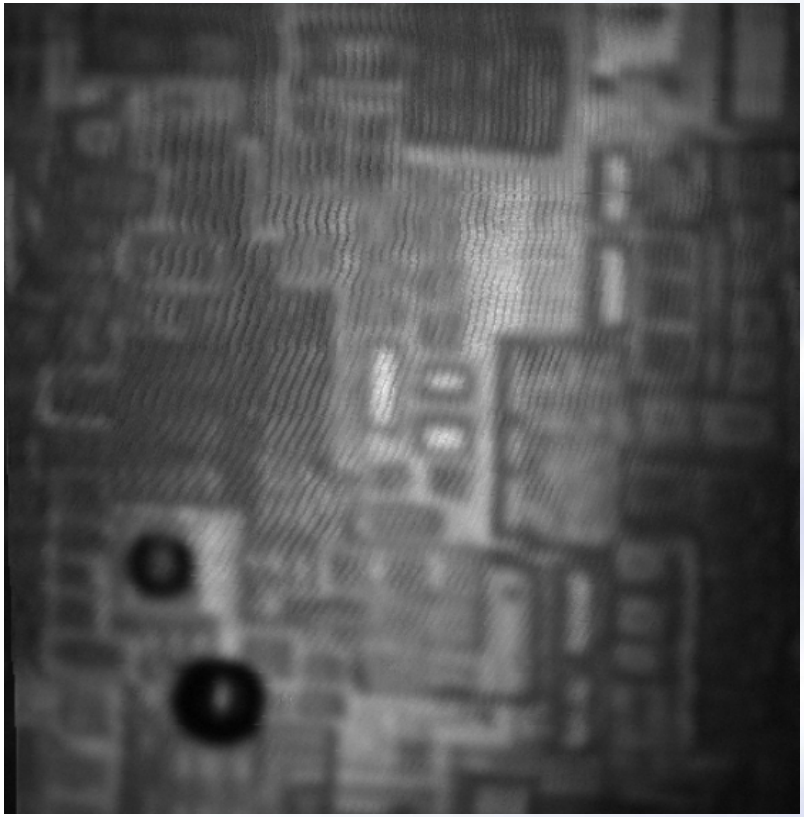
New TPA setup at ATLAS

- TPA implemented on microprobing station with scanning mirrors
- Laser scanning microscope (LSM) with CW 1.3µm beam allows backside imaging

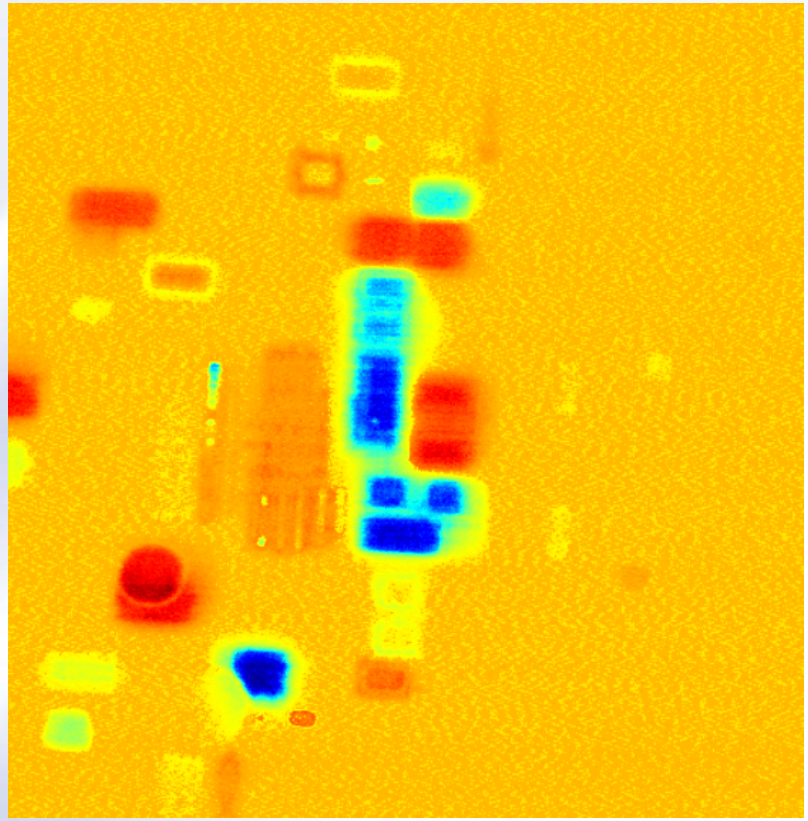


AD9617 - 5X microscope objective

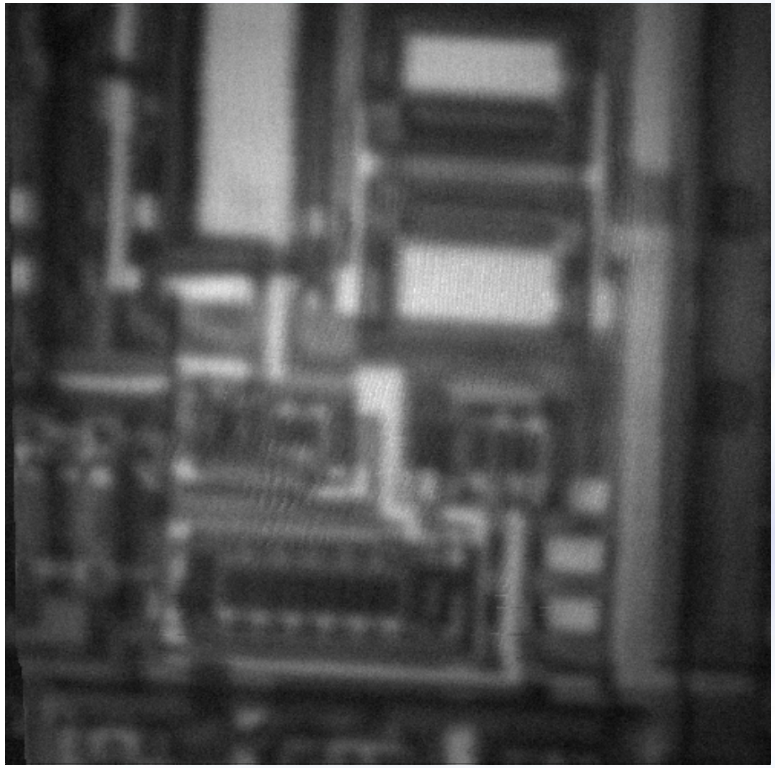
- Backside imaging with laser scanning microscope
- 600x600 pixels: ~ 1min

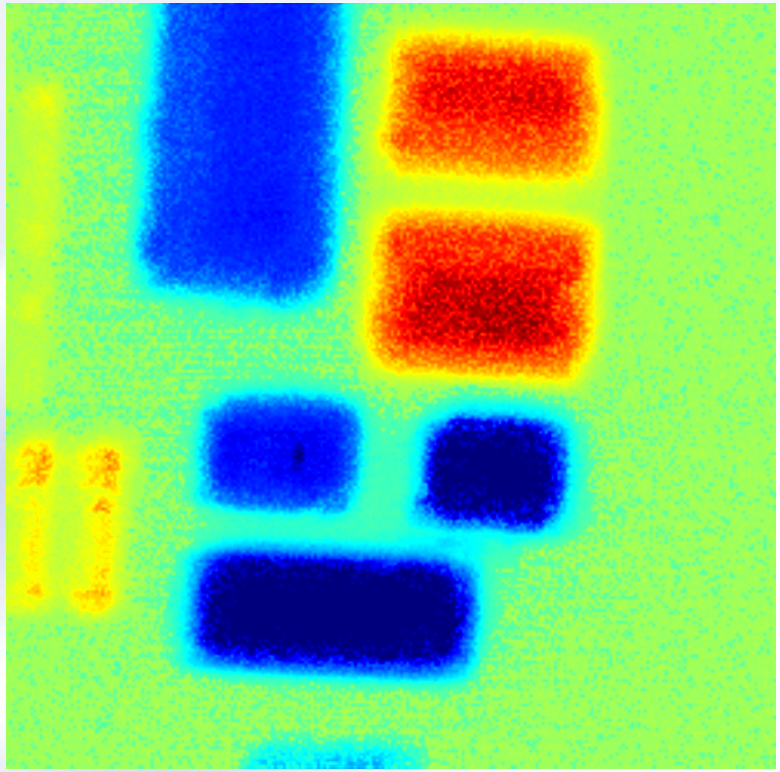


- TPA SET amplitude image
- 300x300 pixels: ~ 2min

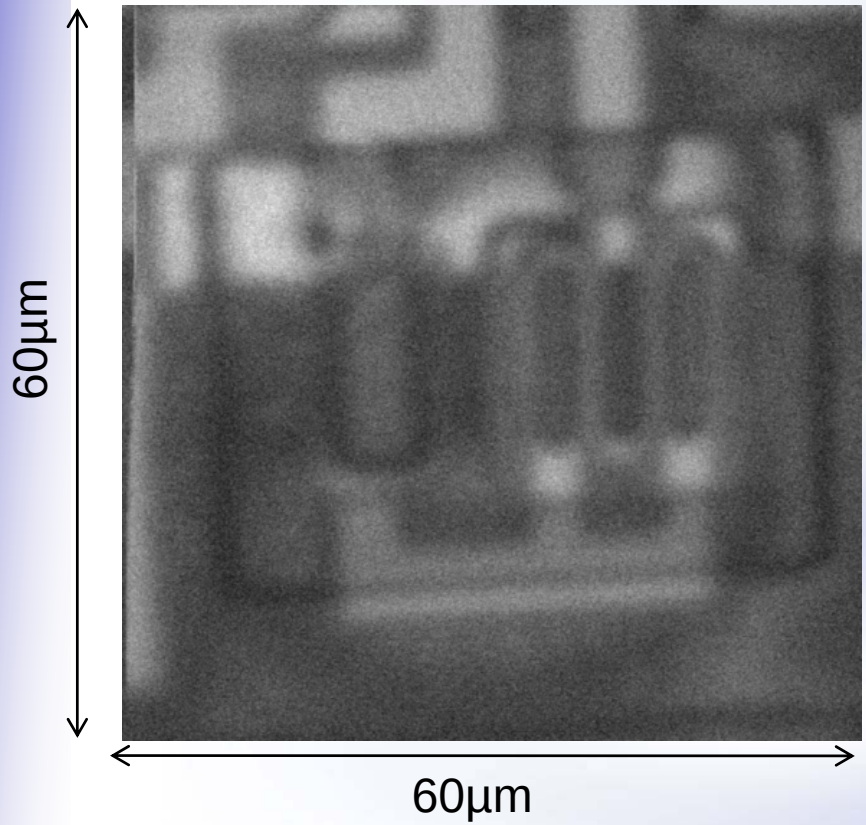


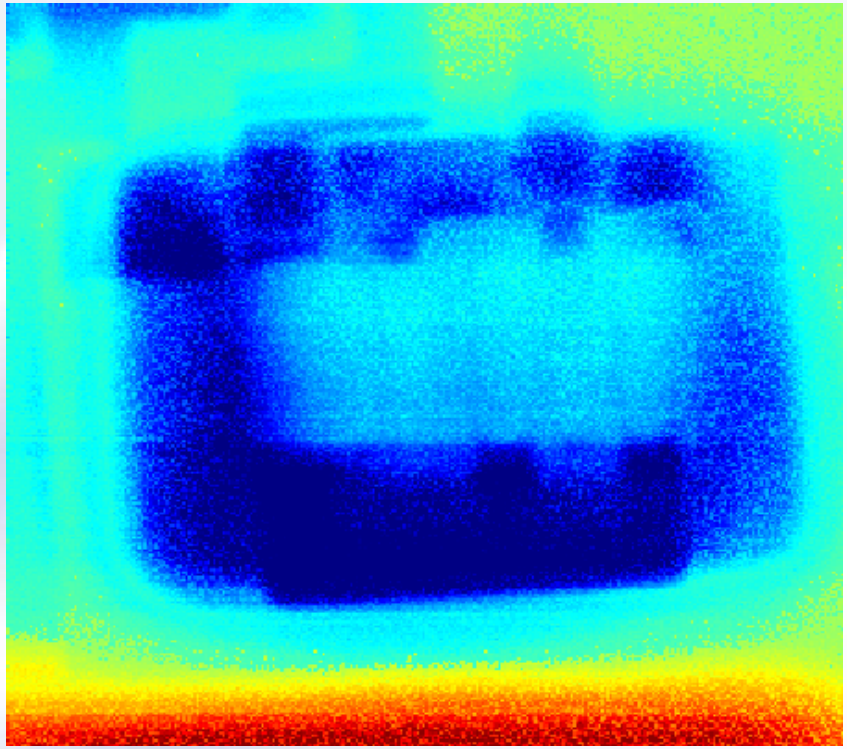
AD9617 - 20X microscope objective





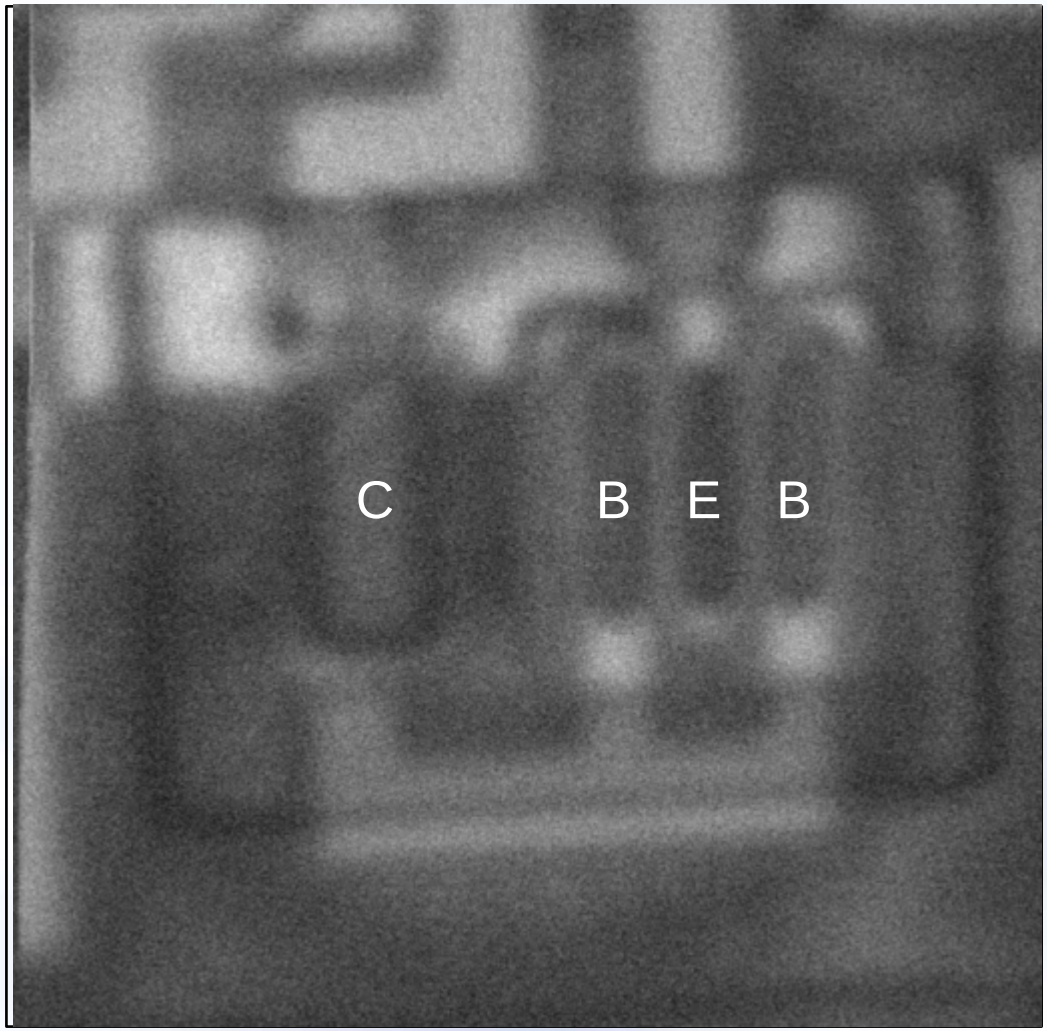
AD9617 - 50X microscope objective



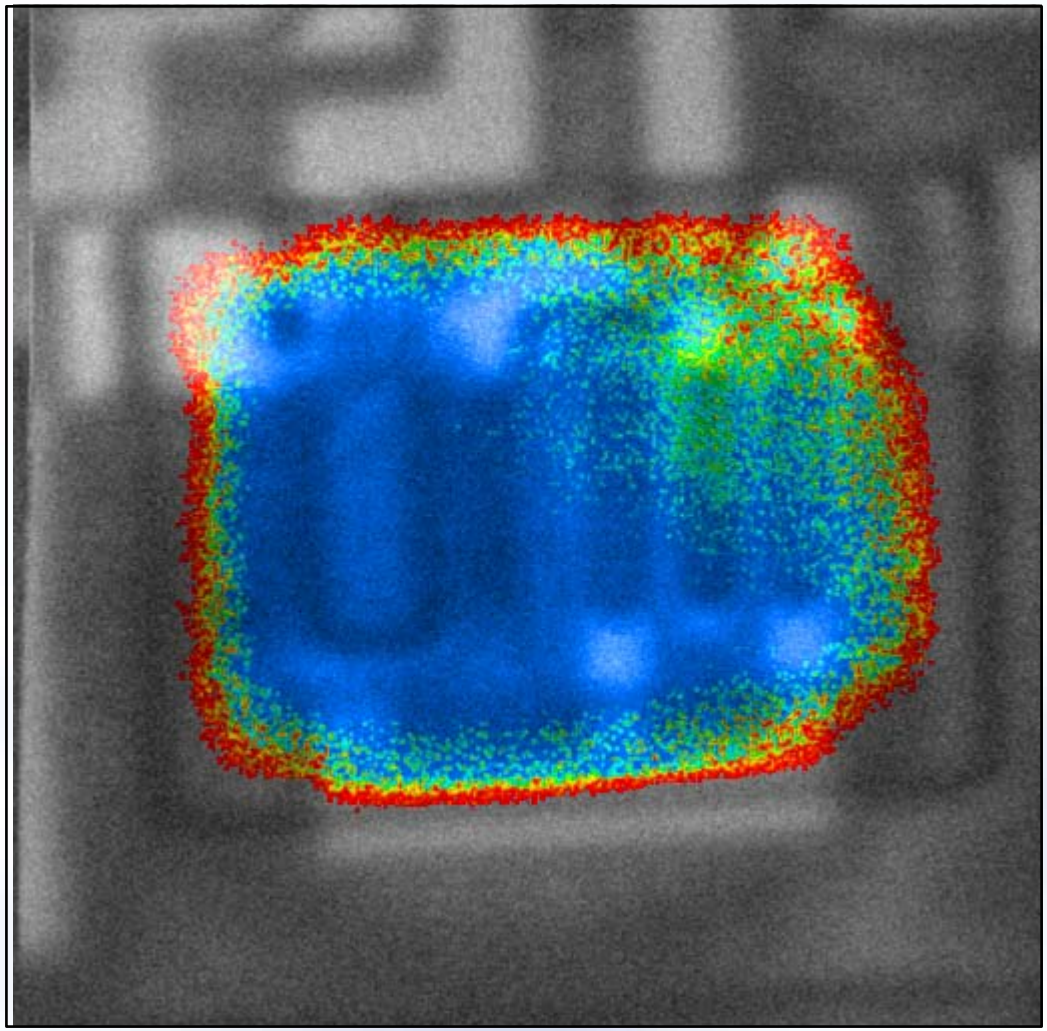


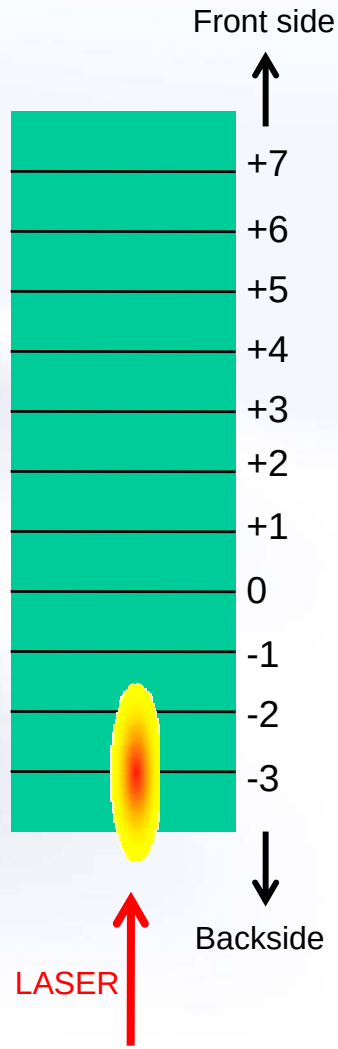
AD9617 - 50X

- Optimum focus of the LSM defined as origin of the Z axis



AD9617 - 50X





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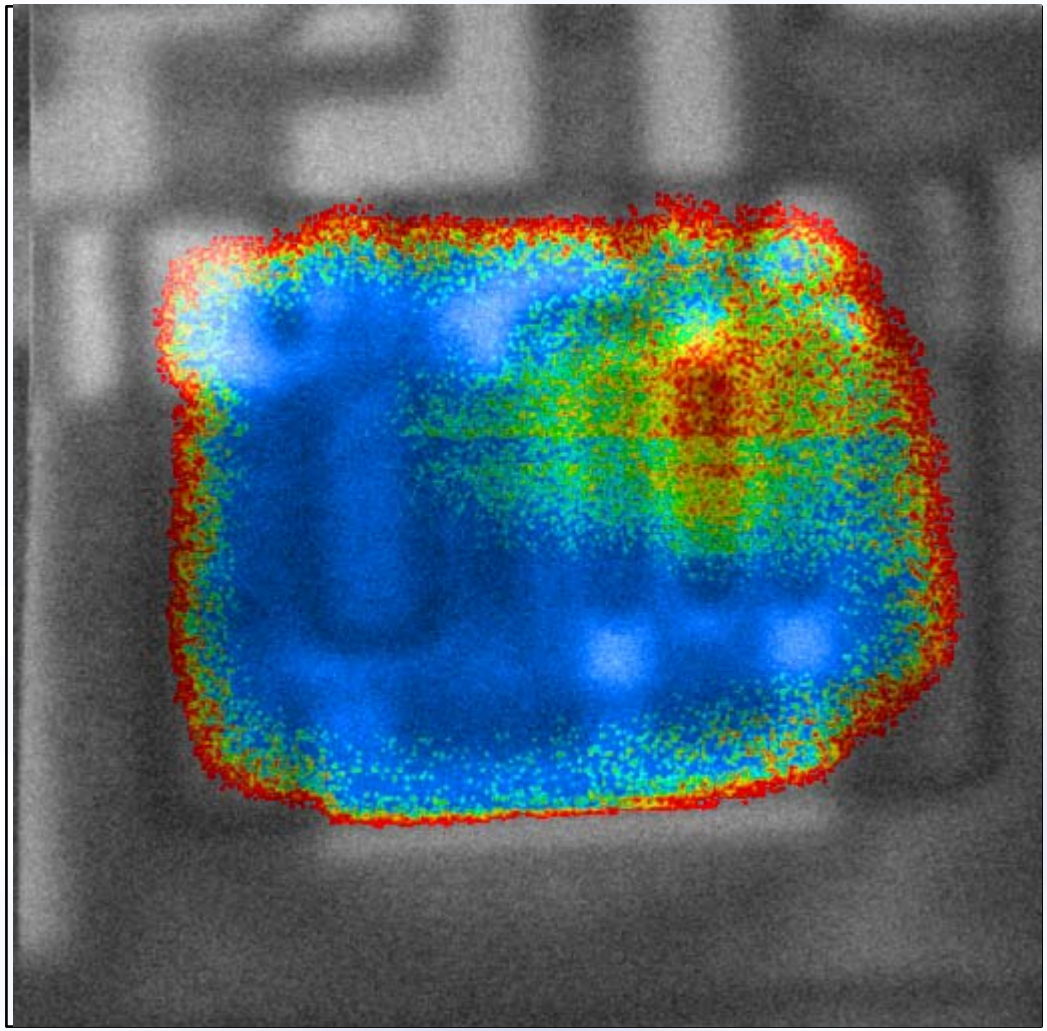

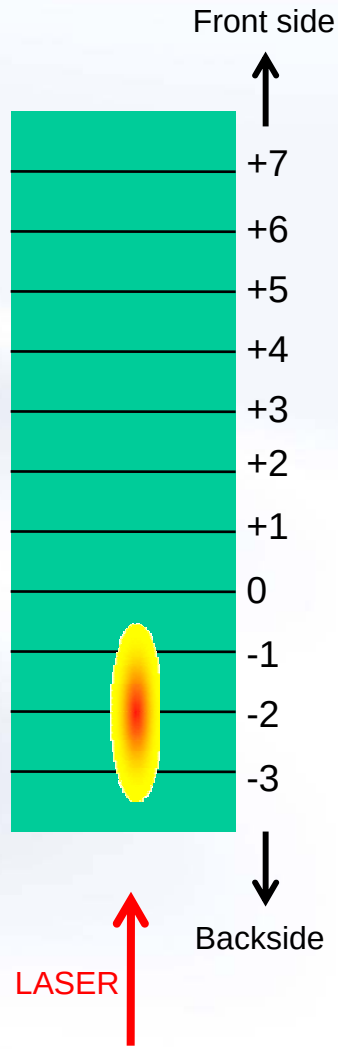

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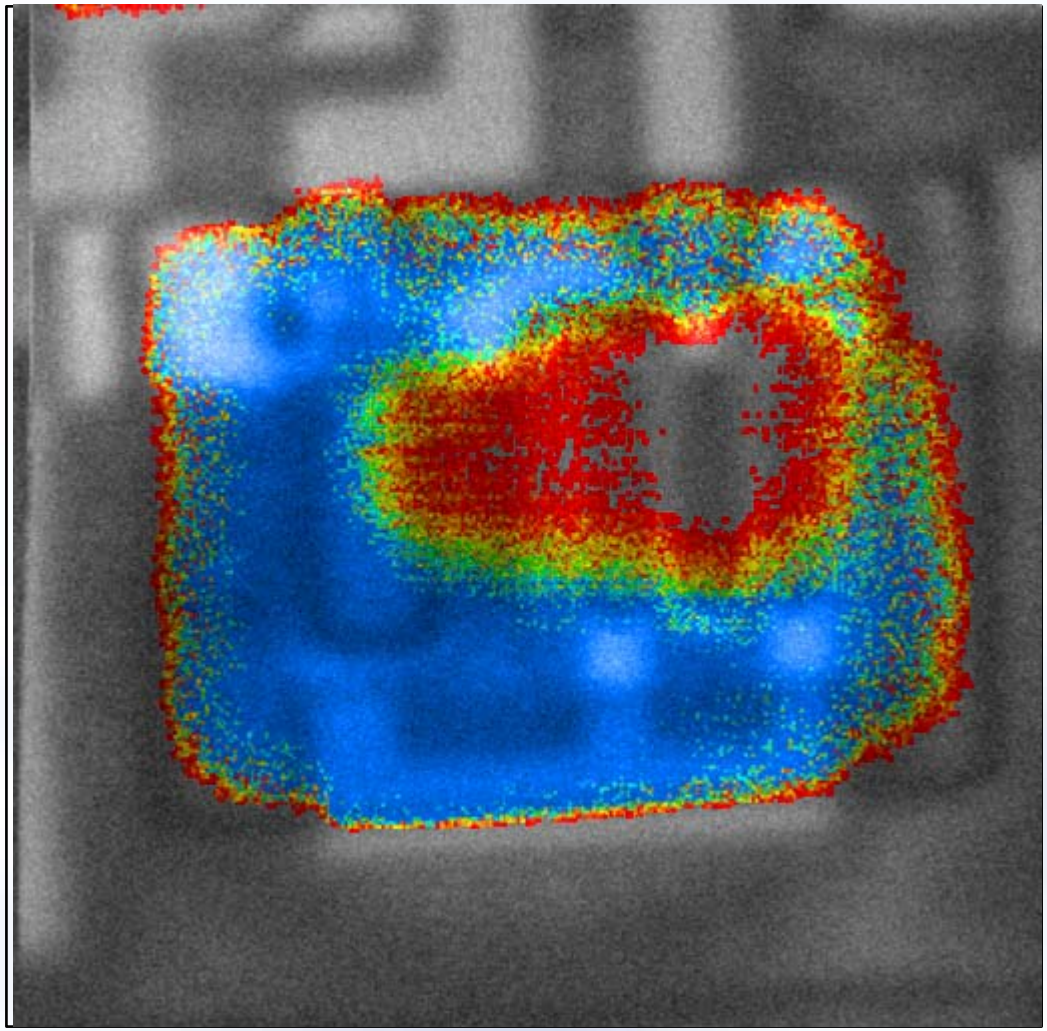
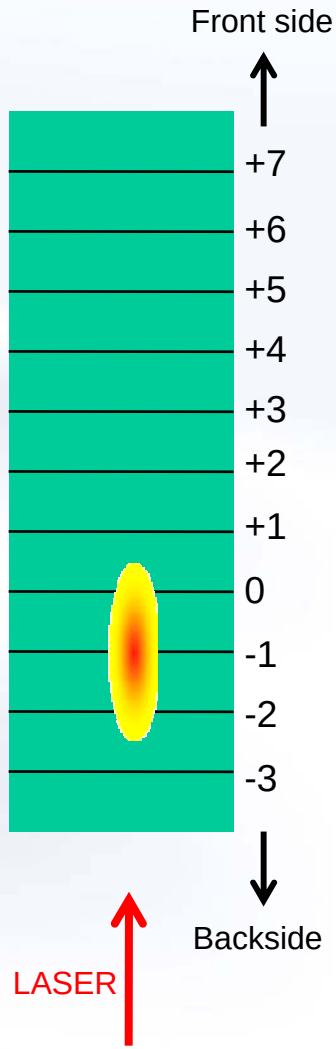
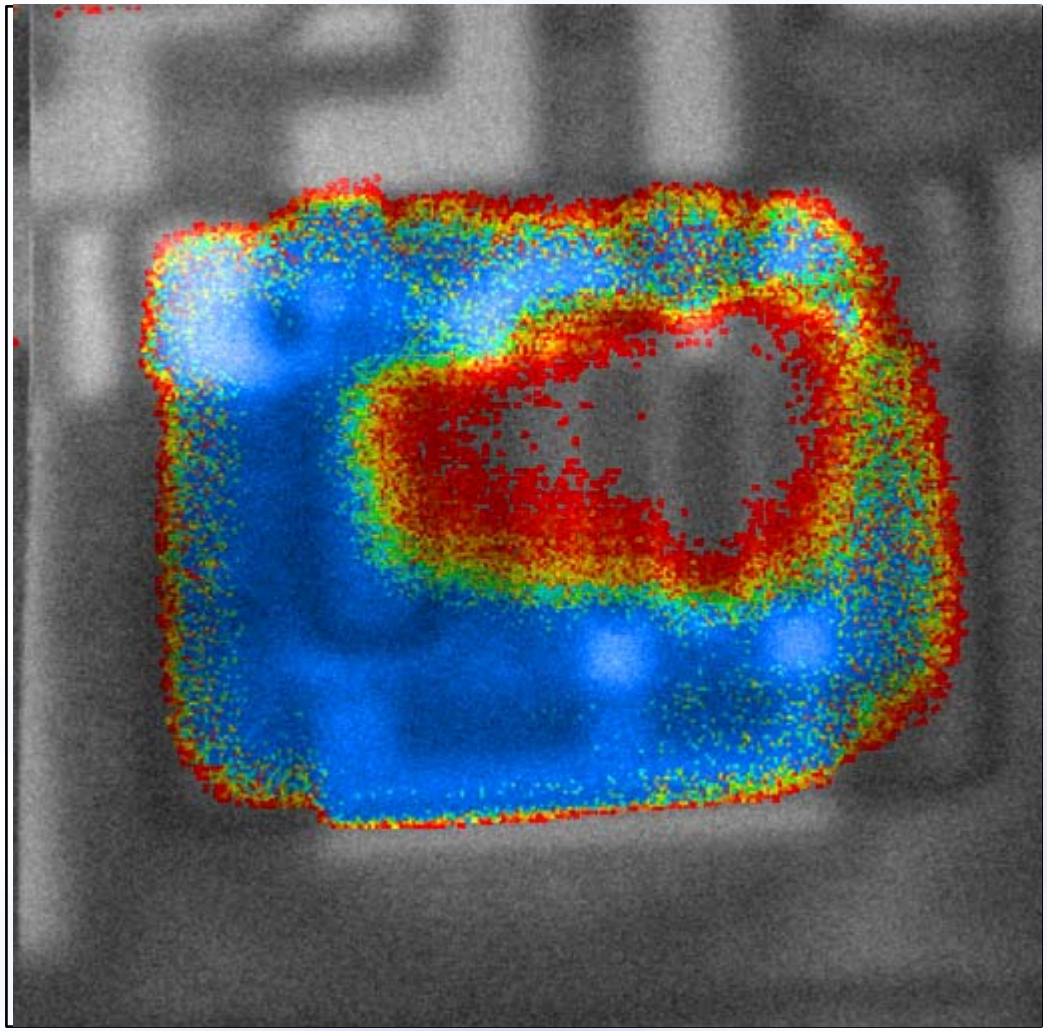
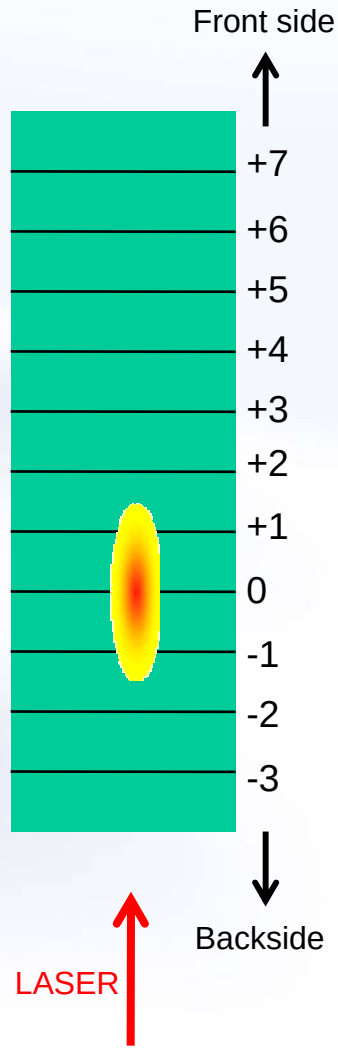


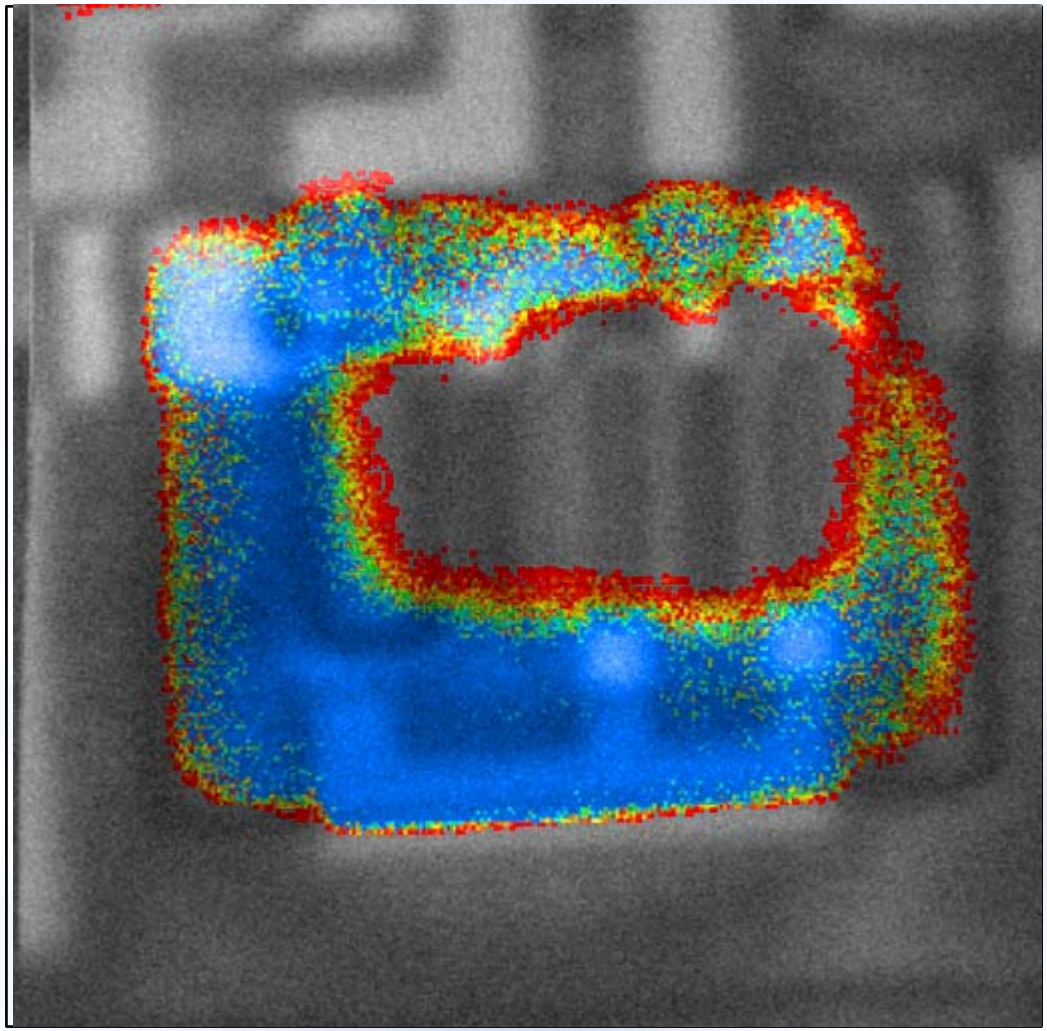


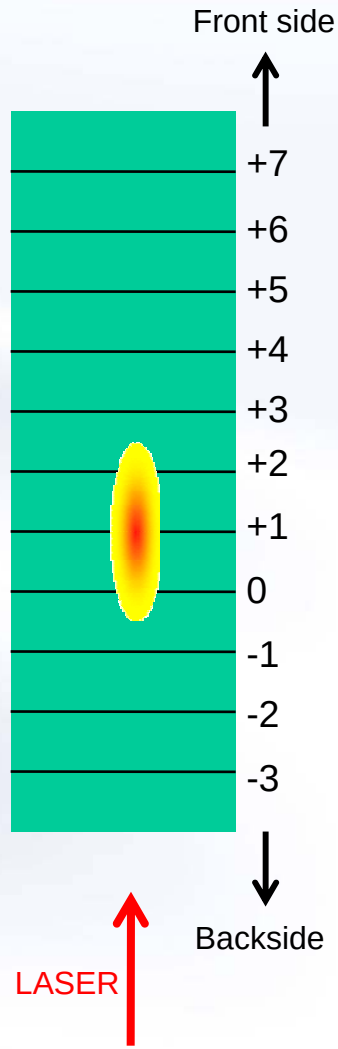
AD9617 - 50X





AD9617 - 50X





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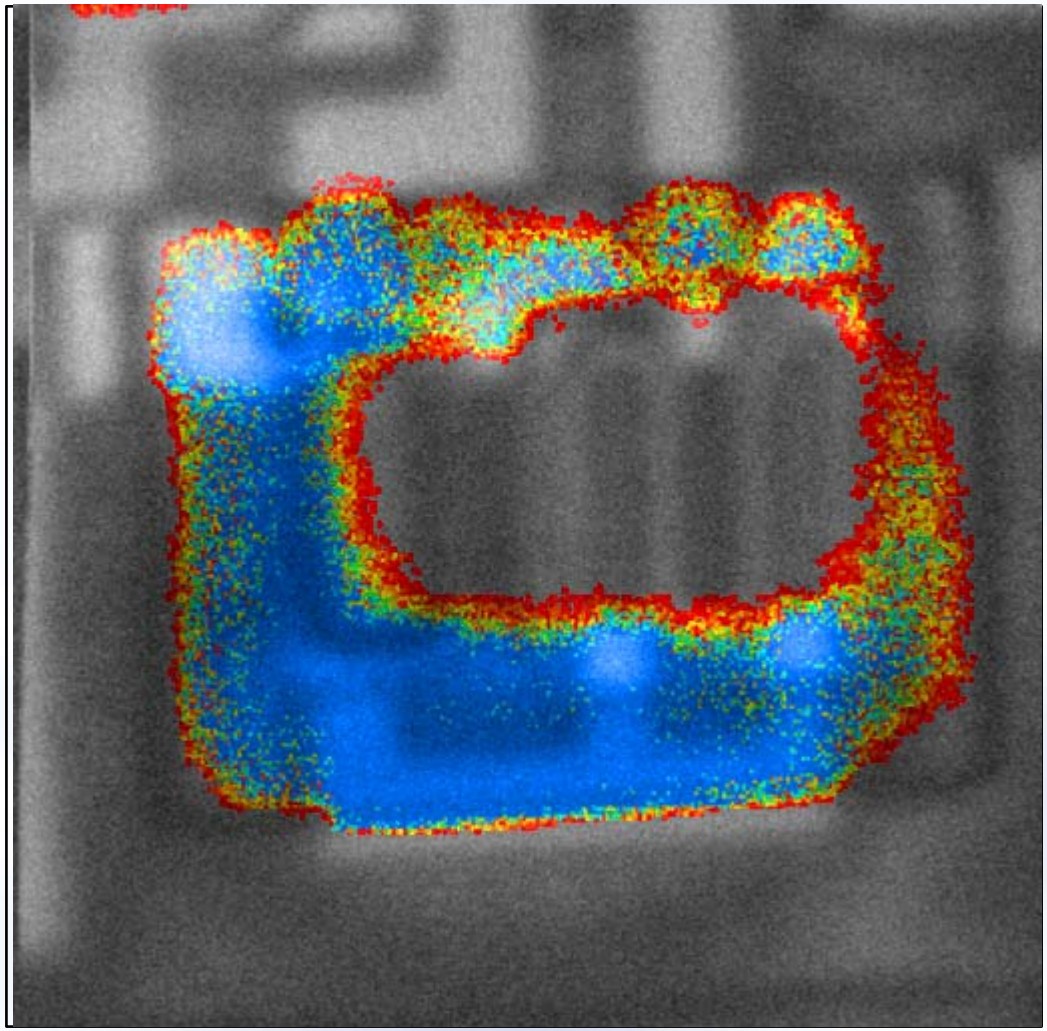

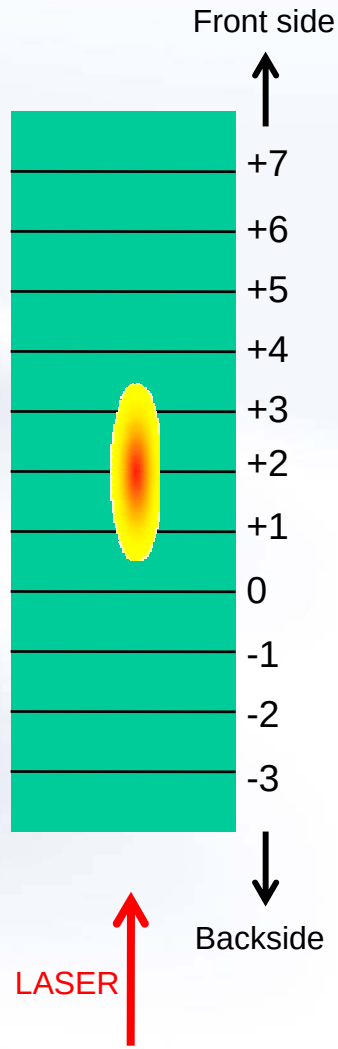

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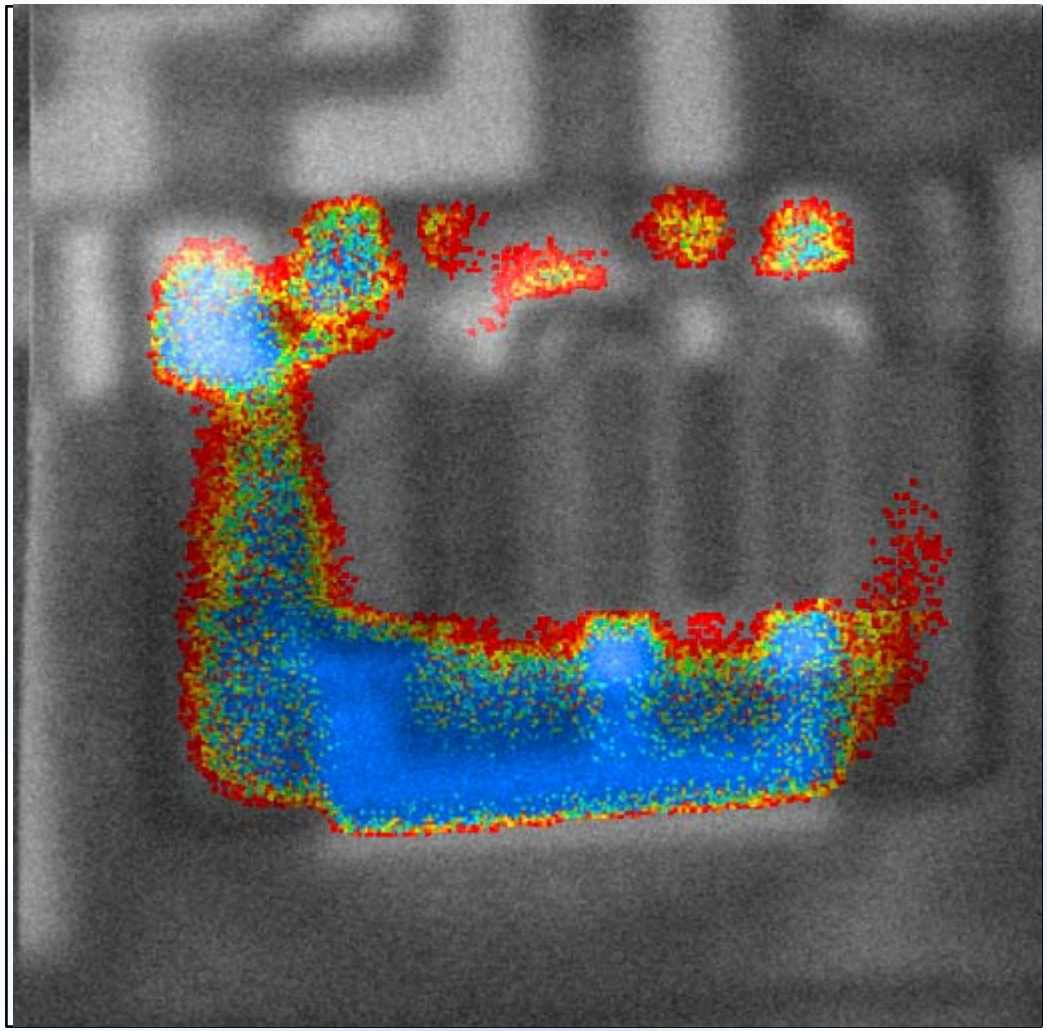

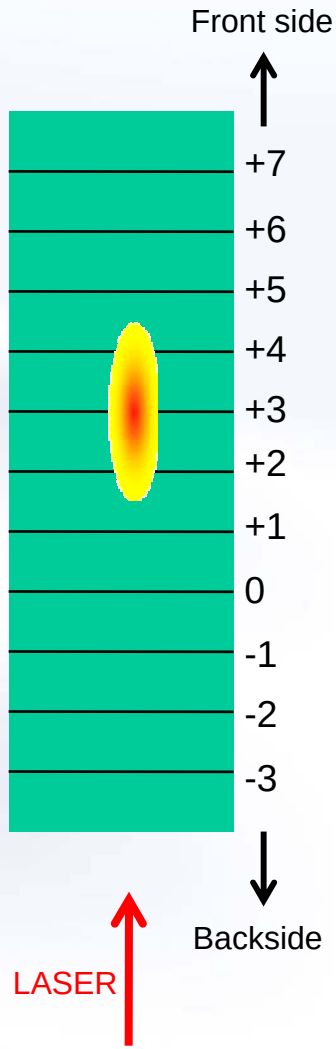

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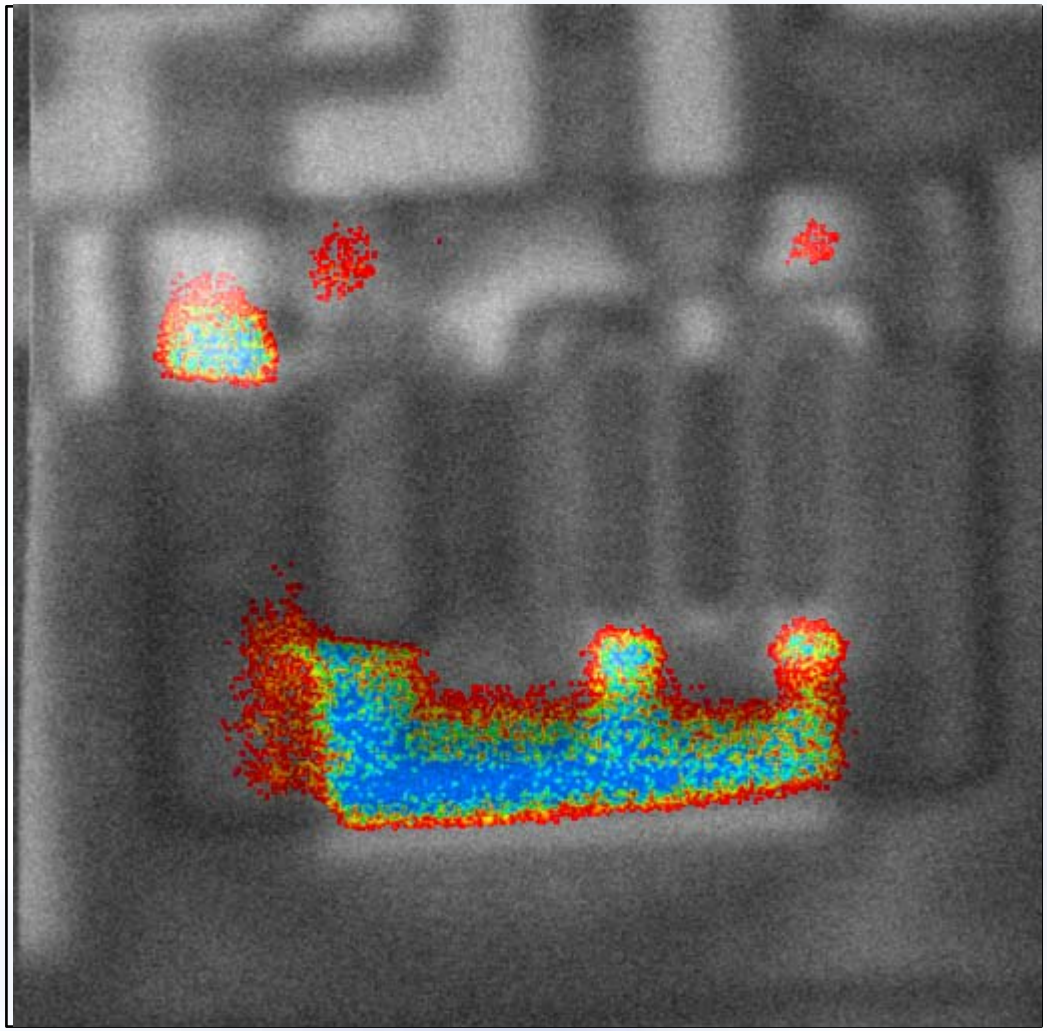

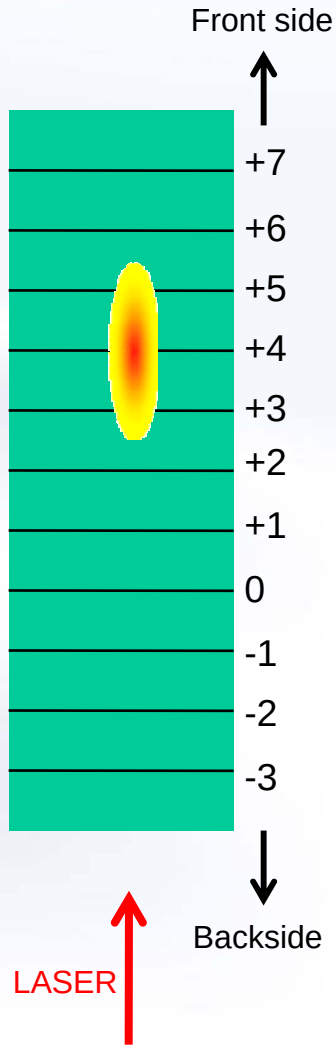

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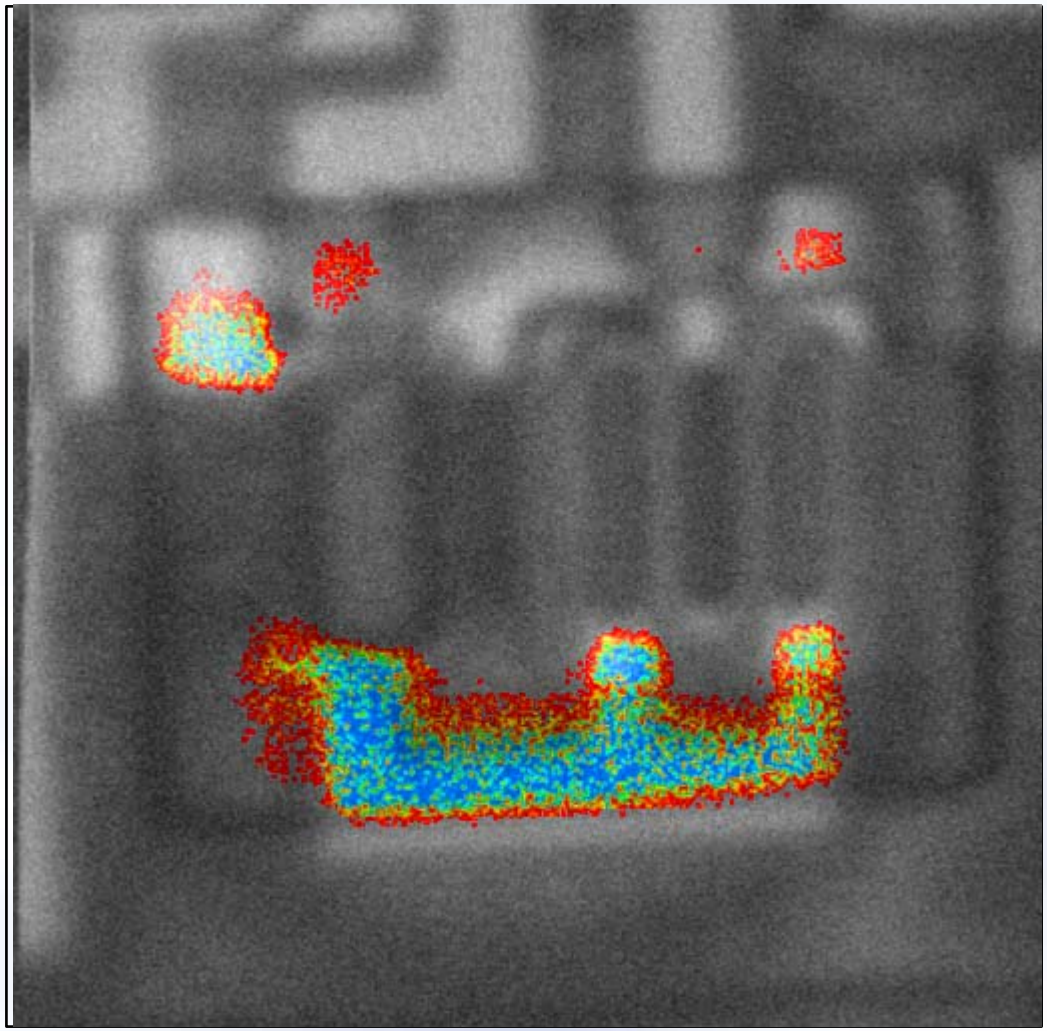

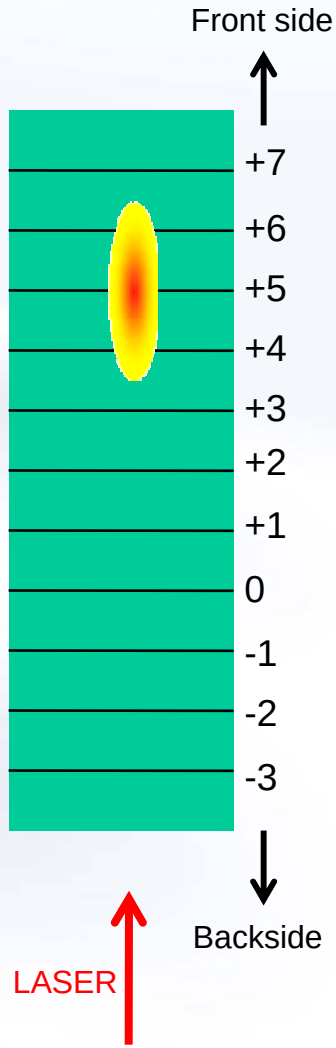

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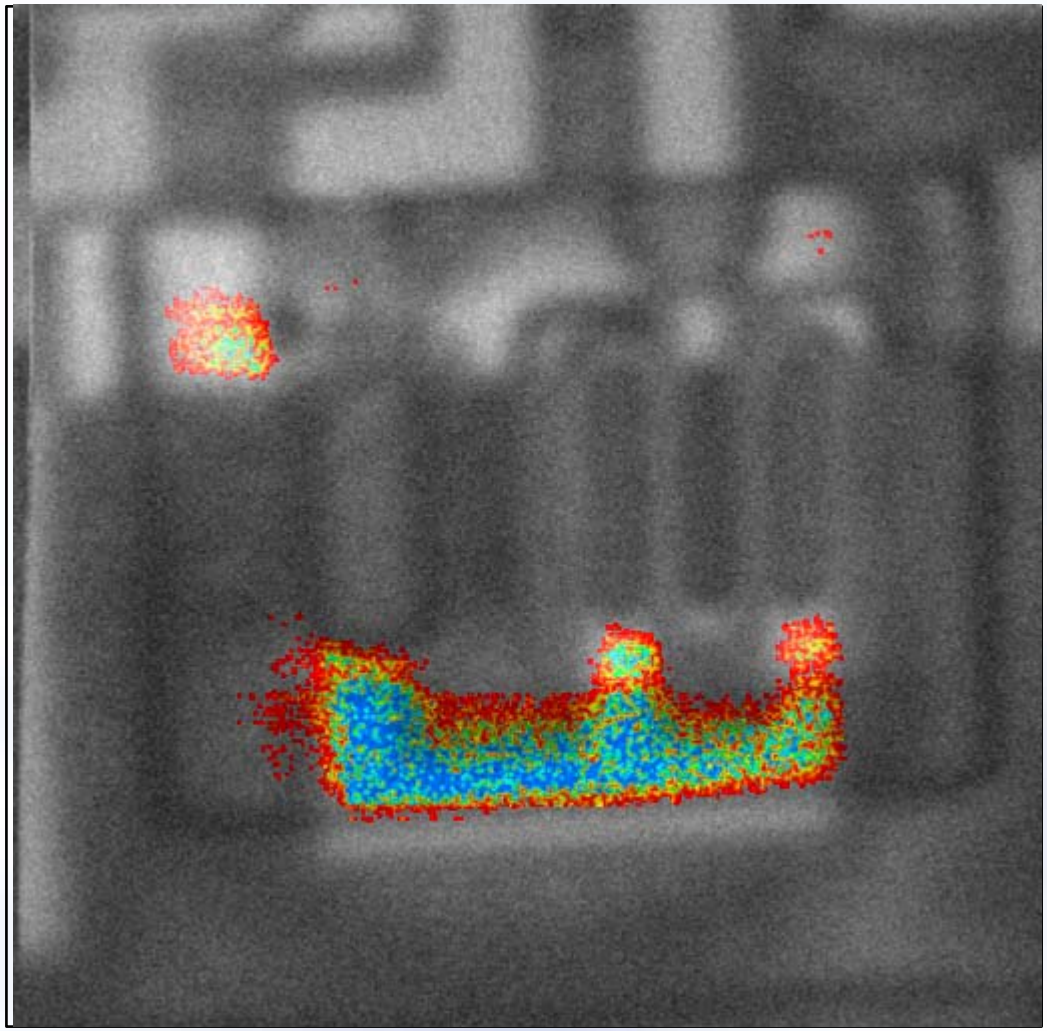

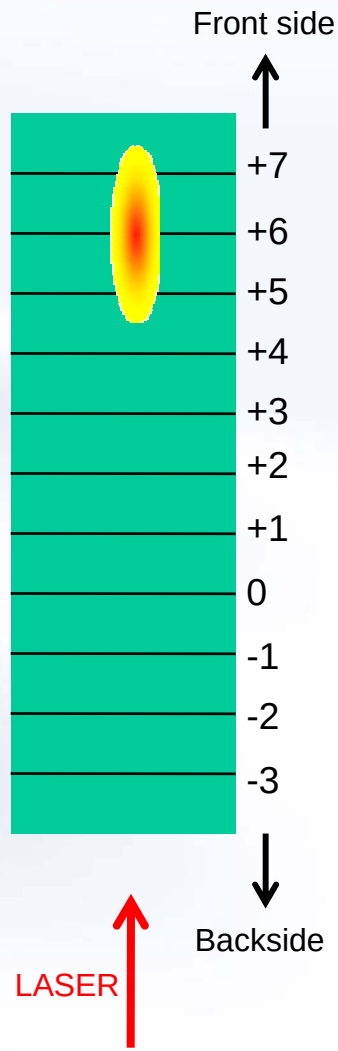

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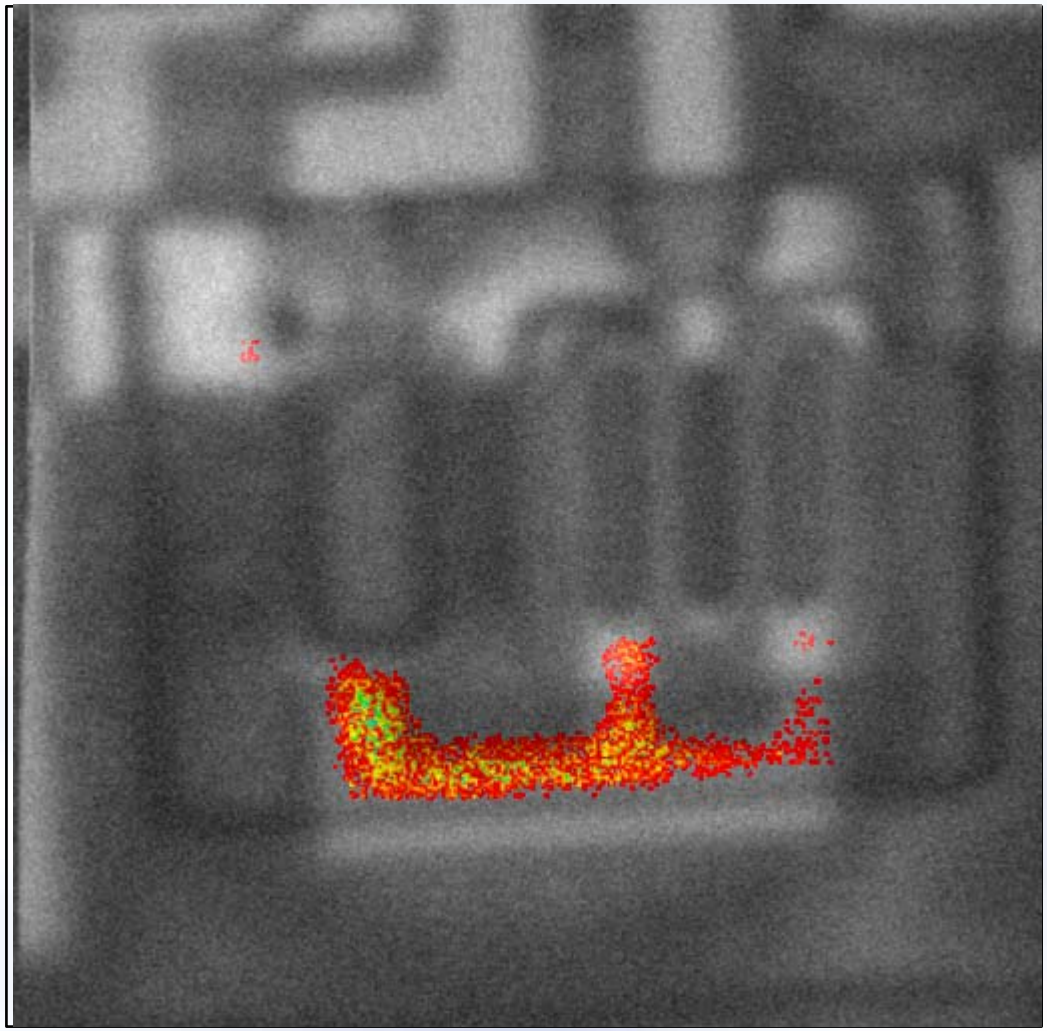

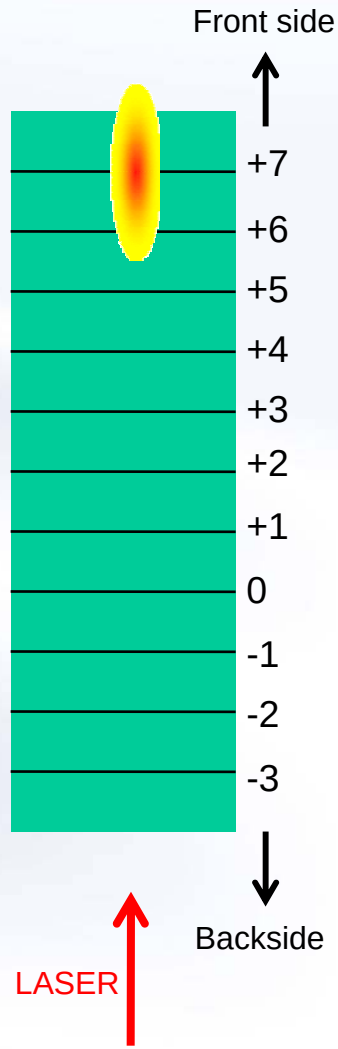

Conclusions

- First experimental results of 3D imaging of SET sensitive volume with two-photon absorption laser testing
- New possibility for non-destructive analysis of large « sensitive volumes »
- Some optical artifacts under investigation for correction
- Recent experimental development open new capabilities for TPA as a routine tool for full die SET scanning
- Next steps within the CNES contract
  - SET: waiting for prepared silicon: LM324, OP470, OP400
  - Application to other SEE with large sensitive volumes:
    - SEL: CYPRESS SRAM
    - SEB: IRFF110, IRF360
  - Correlation with TCAD and heavy ion experiments
- IMS R&D in progress: can we improve the resolution in order to probe smaller sensitive volumes ?