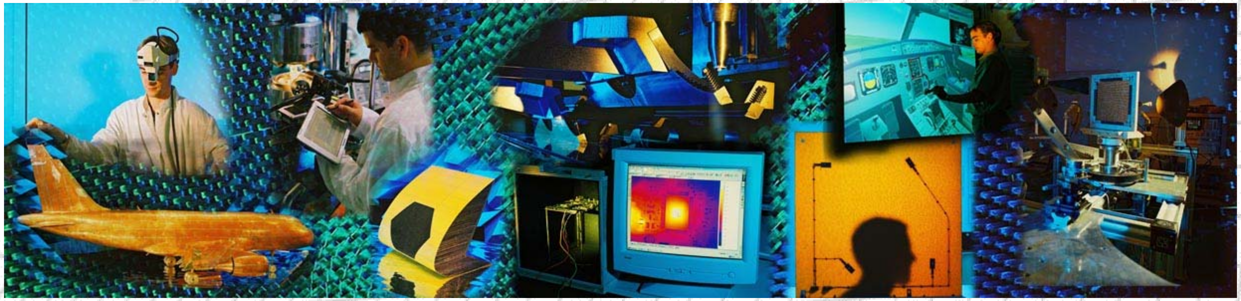
Probing SET Sensitive Volumes Using a Focused Laser Beam



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Objectives

Study the influence of the laser wavelength on the sensitivity of electronic components

► **SET tests on LM124 (OPA)**

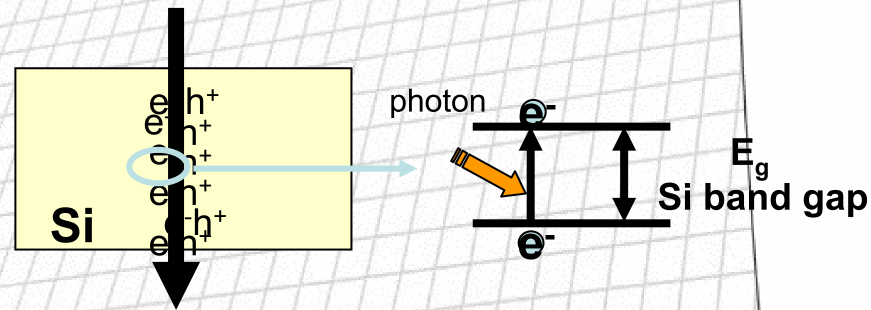
- A variation of the wavelength allows
  - to change the penetration depth,
  - to determine the sensitivity profile.
- Comparison with experimental heavy ion data
- Based on threshold mapping

Basic laser interaction mechanisms

Laser is a pre characterization tool for the evaluation of radiation effects on components. It has proved its ability to simulate SEU, SET and SEL

- **Charge creation : photoelectric process :**
  - Ionization condition :

    $E_{photon} > E_g = 1.12eV$ ie **λ<1.1µm**



- **Laser loss of energy:**

  Beer-Lambert law

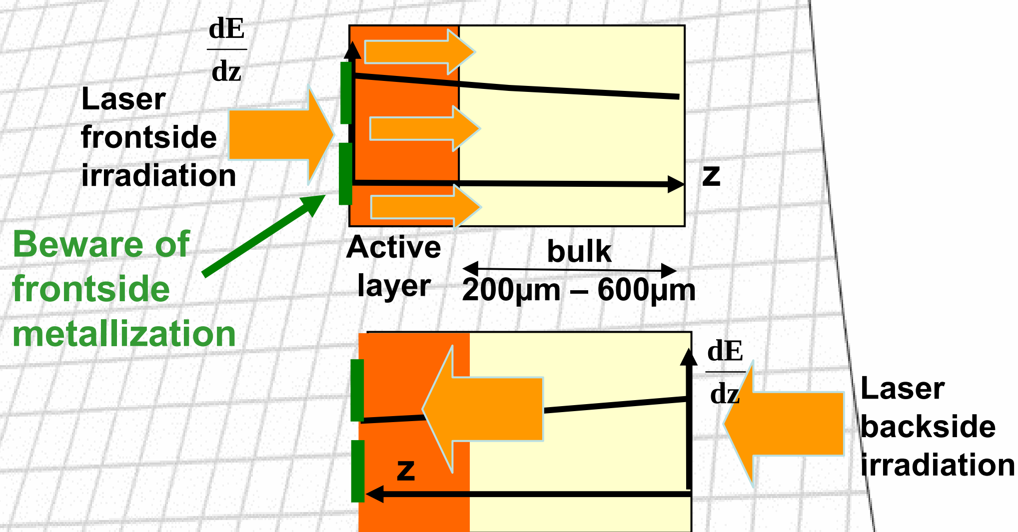
$$E(z) = E(0).\exp(-\alpha.z) \qquad \frac{dE}{dz} = -\alpha.E(z)$$

α varies with wavelength and doping level

For **λ=1.06 µm**

α is weak enough (1/α: 300 to 1000 µm)

➔ backside irradiation



1.06µm laser is able to cross the whole device

Presentation of the EADS laser bench

RALF (Radiation Analysis Laser Facility)

Fully automated bench

Eye secure (optical fibers)

Motorized stages

Industrial design :

Stability, Repeatability, Reliability

Laser threshold mapping

It consists in :

MAPPING : laser scanning of a component, identification of the sensitive areas

THRESHOLD : For each position, the laser energy is adjusted to detect the threshold of the event.

- **SRAM : SEU or SEL threshold**
- **linear component : SET whose amplitude is greater than a reference value**

Low threshold energy
= high sensitivity

High threshold energy
= low sensitivity

Study description

3 wavelengths : 1064, 905 et 850nm, frontside and backside irradiations

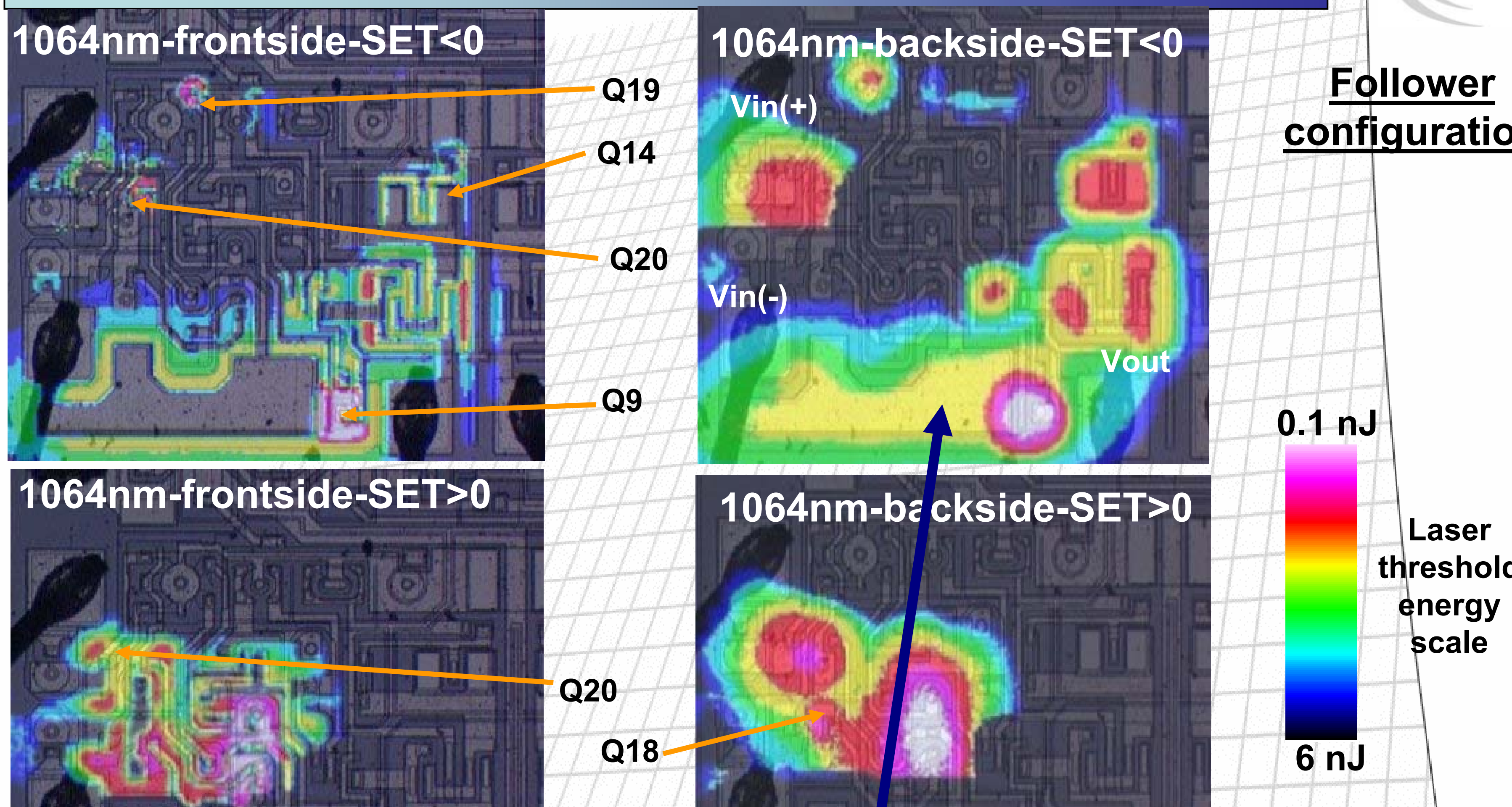
Vdd = +/- 15V   Vin = 10V

2 configurations : follower and gain

- Threshold mappings at 1064nm
- Comparison with SET heavy ion populations
- Threshold mappings at 850nm and 905nm
- Sensitive depth estimation
- Cross section

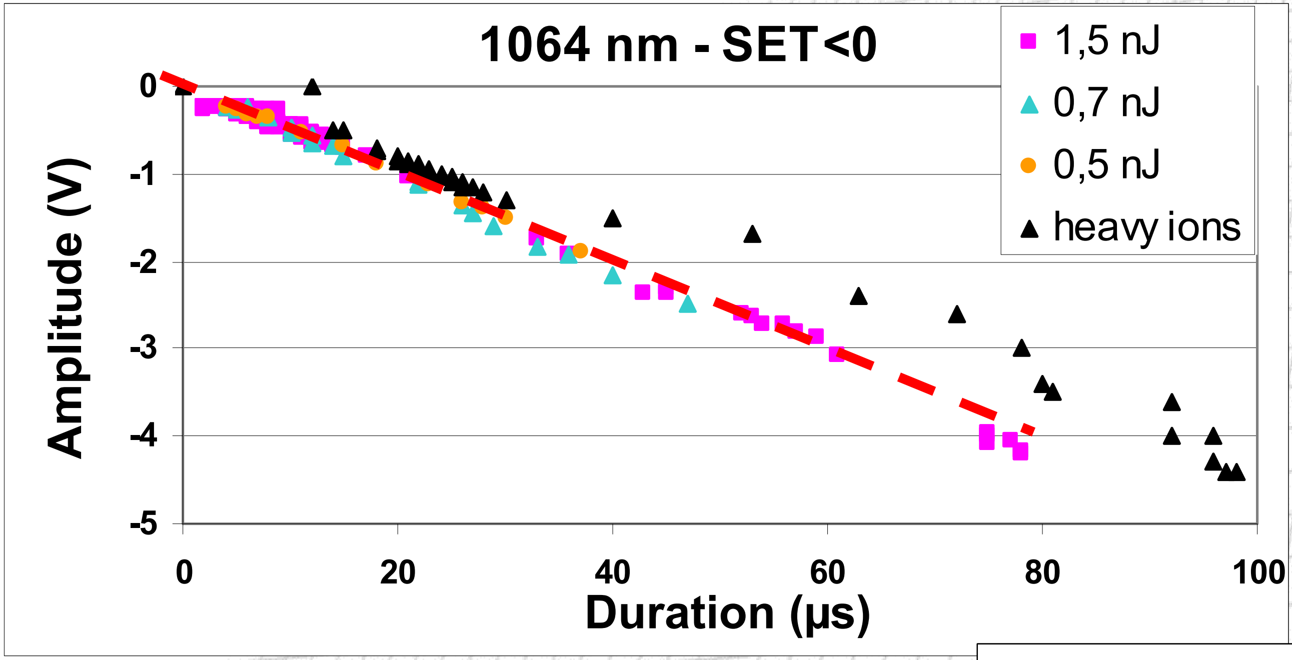
Threshold mapping

Follower configuration



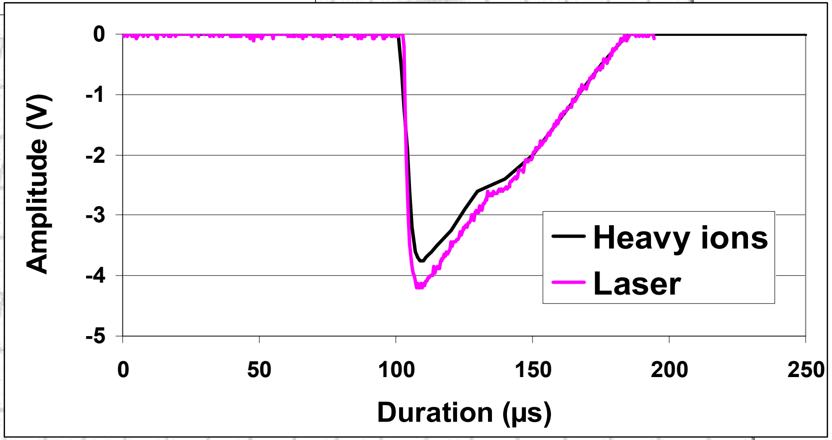
The sensitive areas recovered by metallization are revealed during backside irradiation.

Comparison with heavy ions – SET<0



▲Heavy ion results for a LET eff=85.15 MeV.cm²/mg (LET=20.6MeV.cm²/mg, tilt=76°, Range eff=23.7µm)

Duration



Same shape and same population between laser and heavy ions

Slight shift due to a different data processing

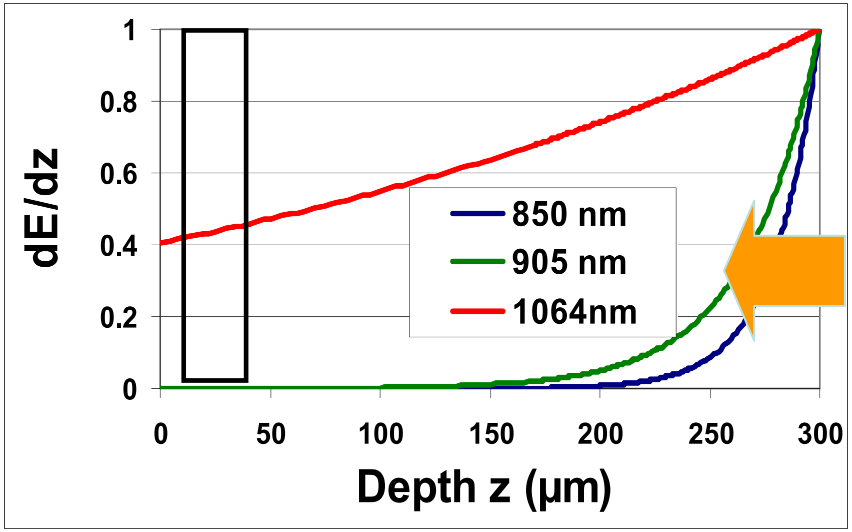
Wavelength exploration

Penetration depth for a doping of 2.10[18] cm[-3]

λ (nm)	Absorption coefficient α (cm^{-1})	Penetration depth 1/ α (µm)
850	490	20
905	300	33
1064	30	333

➡ **1/α high for 1064nm**

$$E(z) = E(0).\exp(-\alpha.z) \qquad \frac{dE}{dz} = -\alpha.E(z)$$



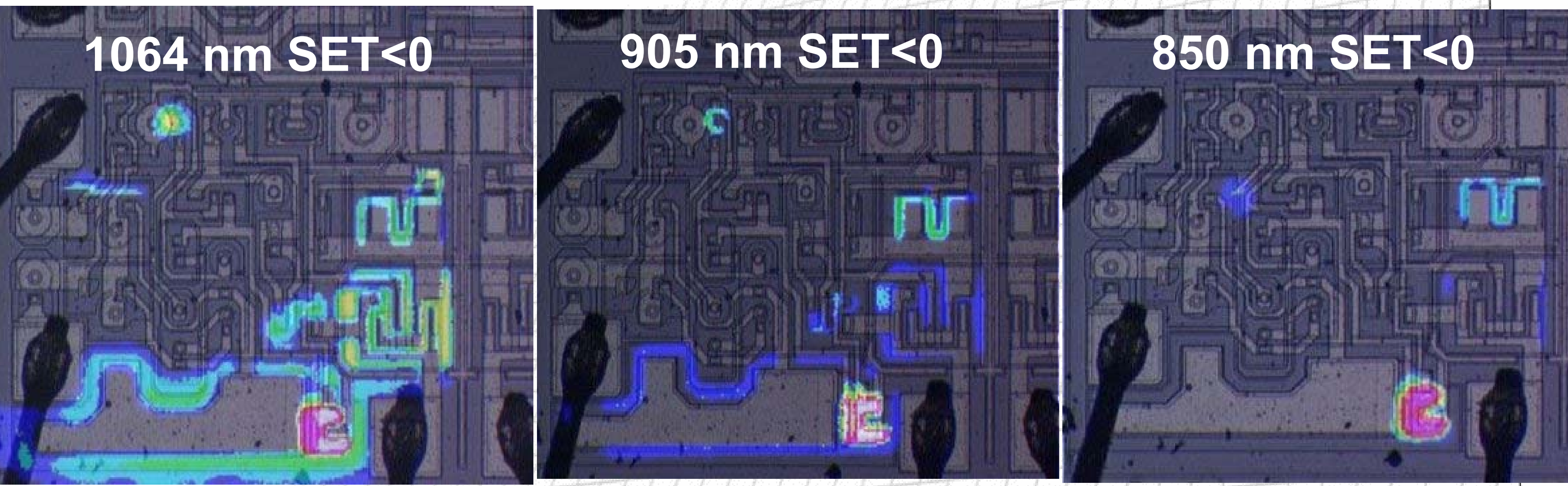
Laser backside irradiation

At 850nm, the sensitive areas are revealed only on few microns.

At 905nm, the sensitive areas are revealed on about 20 microns.

At 1064nm, all sensitive areas are revealed .

Threshold mapping – SET<0



0.1 nJ

3 nJ

Laser threshold energy scale

same LET but different ranges

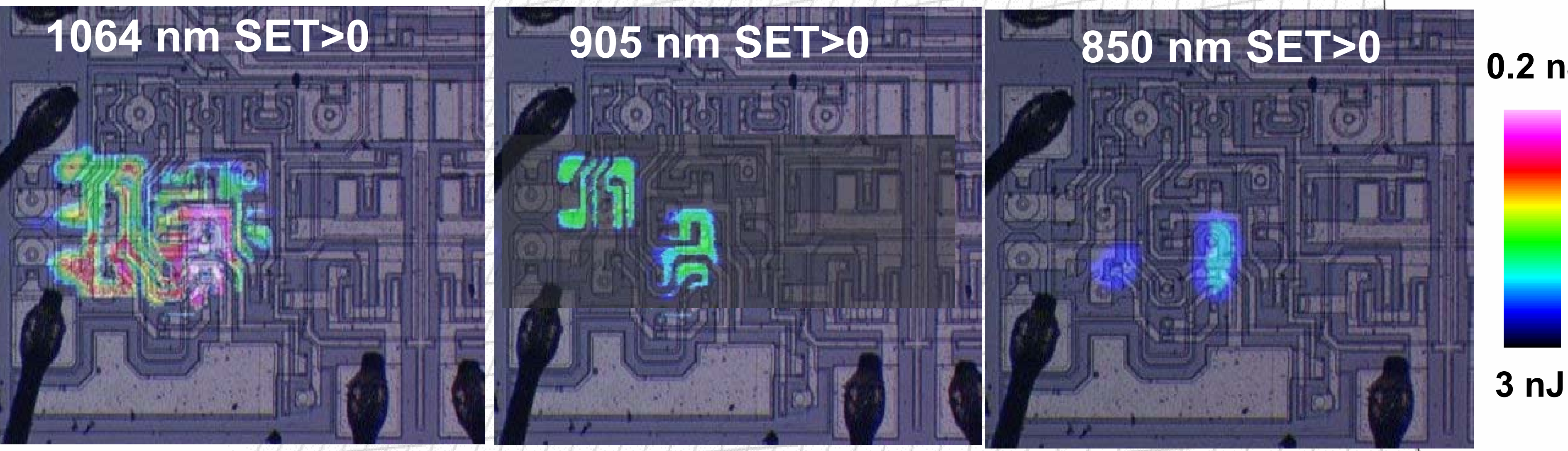
More sensitive areas are revealed at 1064nm.

By decreasing λ, the surface of sensitive areas is decreasing.

A direct interpretation is difficult, because of several factors for each area

- **Depth (Z)**
- **Thickness (h)**
- **Triggering threshold (Qc)**

Threshold mapping – SET>0

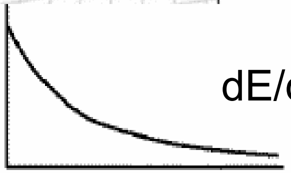


Laser threshold energy scale

➡ **An analytical method is required.**

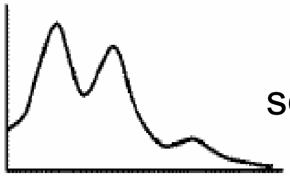
Sensitive depth estimation

Laser energy deposited at the depth Z : $$\frac{dE}{dz} = (1-R)\,\alpha\, E_{laser,\lambda}\, \exp(-\alpha z)$$



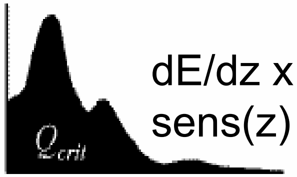
dE/dz

$$Q_{crit} = \int_0^{\infty} \frac{dE}{dz}\, sens(z)\, dz$$



sens(z)

$$Q_{crit} = (1-R)\, E_{laser,\lambda}\, \exp(-\alpha Z)\,[\exp(\alpha h) - \exp(-\alpha h)]$$



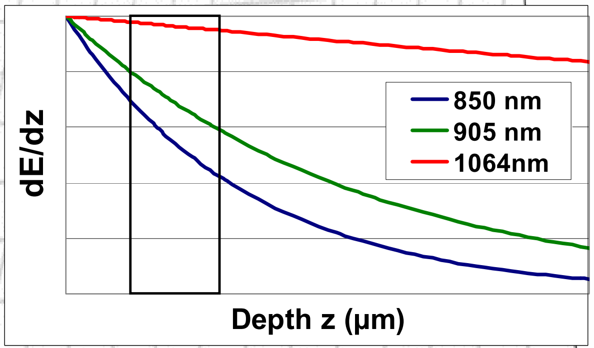
dE/dz x sens(z)

For a fixed location, with only one sensitive volume (with depth Z and thickness 2h)

If sensitive thickness <<penetration depth

2h <<1/α

$$Z = \frac{\ln\left(\frac{\alpha_2\, E_{laser,\lambda 2}}{\alpha_1\, E_{laser,\lambda 1}}\right)}{\alpha_2 - \alpha_1}$$

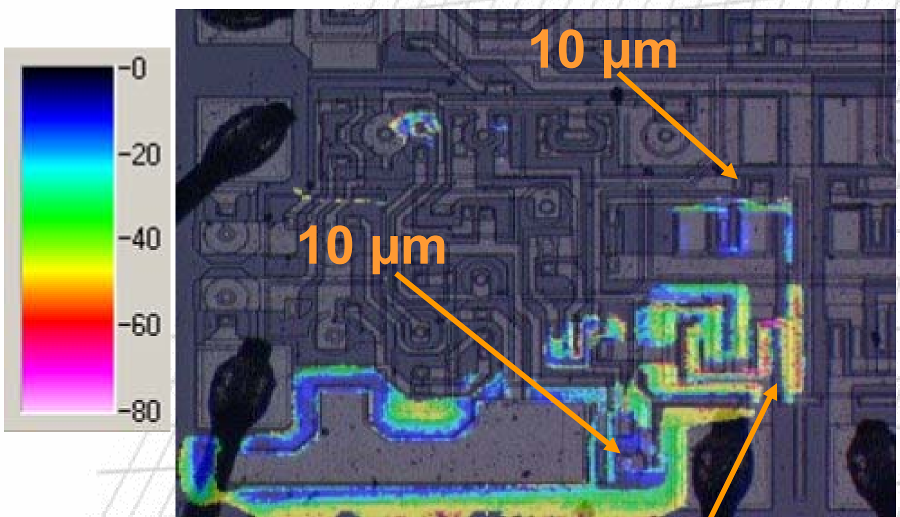


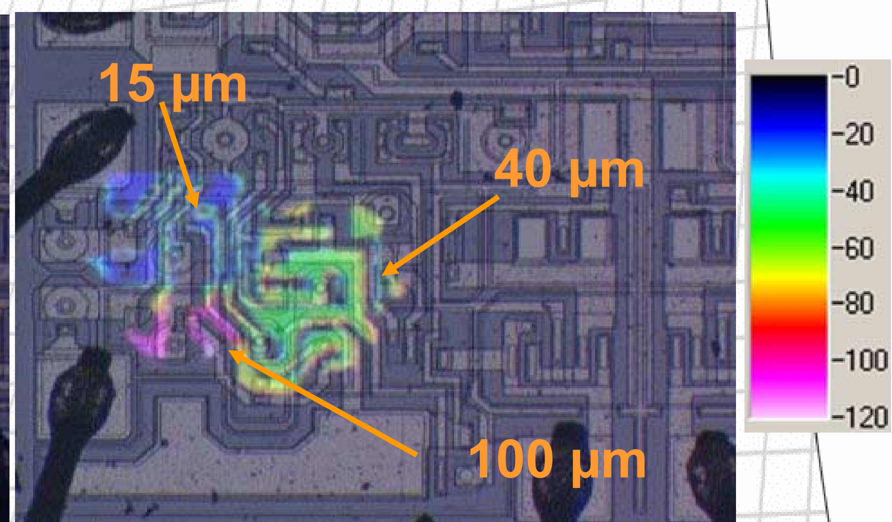
Sensitive depth estimation

Equation is applied for each position

$$Z = \frac{\ln\left(\frac{\alpha_2 \; E_{laser,\lambda 2}}{\alpha_1 \; E_{laser,\lambda 1}}\right)}{\alpha_2 - \alpha_1}$$

Scale (µm) SET<0 SET>0 Scale (µm)





Cross section curve
Comparison with heavy ions

Equivalence between LET and laser energy deposited at the surface

The laser energy deposited per volume unit at the depth Z :

$$\frac{dE}{dz}(J/cm^3) = (1-R)\,\alpha\,E_{laser}\,\exp(-\alpha z)$$

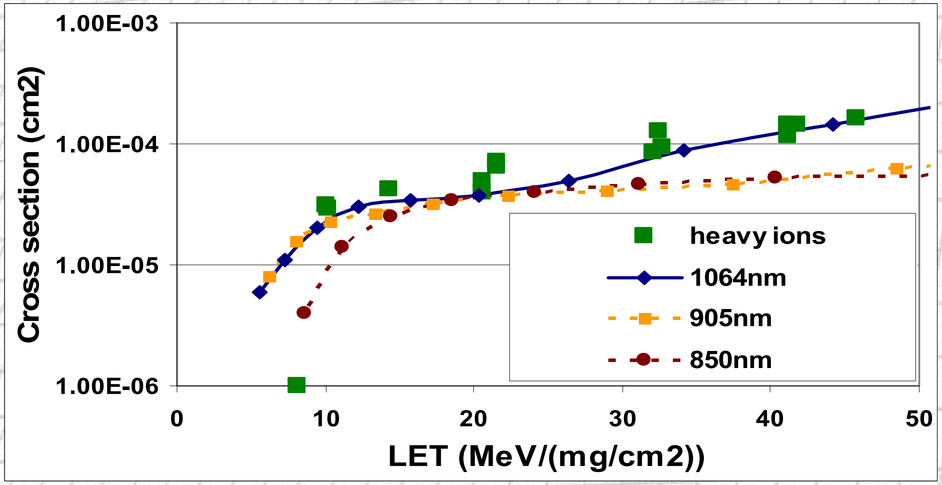
If z<<1/α

$$LET_{équivalent} = \frac{1}{\rho}\left(\frac{dE}{dz}\right) = \frac{1}{\rho}\,(1-R)\,\alpha\,E_{laser}\,/\,q$$

at 850nm 1 nJ ↔ 950 MeV.cm²/mg

at 905nm 1 nJ ↔ 580 MeV.cm²/mg at 1064nm 1 nJ ↔ 60 MeV.cm²/mg

SET<0



The 1064nm cross section is similar to the heavy ion cross section.

Conclusion

- Good correlation between laser and heavy ion, especially at λ=1064nm

- Laser testing at different wavelengths allows determining the sensitive depths inside a linear component.

But limitations:

-Front side test: due to metal opacity, areas under metallization are not revealed. Optimization of wavelengths for backside irradiation.

- Multi depths sensitive zones

- Other ways to investigate the sensitive depth:
  - TPA (Two photon absorption)
  - Variation of the focused depth of a laser at fixed wavelength (1.06µm)