THALES Microelectronics S.A.

FAILURE ANALYSIS LABORATORY

THERMAL LASER STIMULATION (TLS / OBIRCH / TIVA)

TLS in the FA flow

I.C. FA flow

Electrical diagnostic

Defect localization

Physical analysis

Current related defects

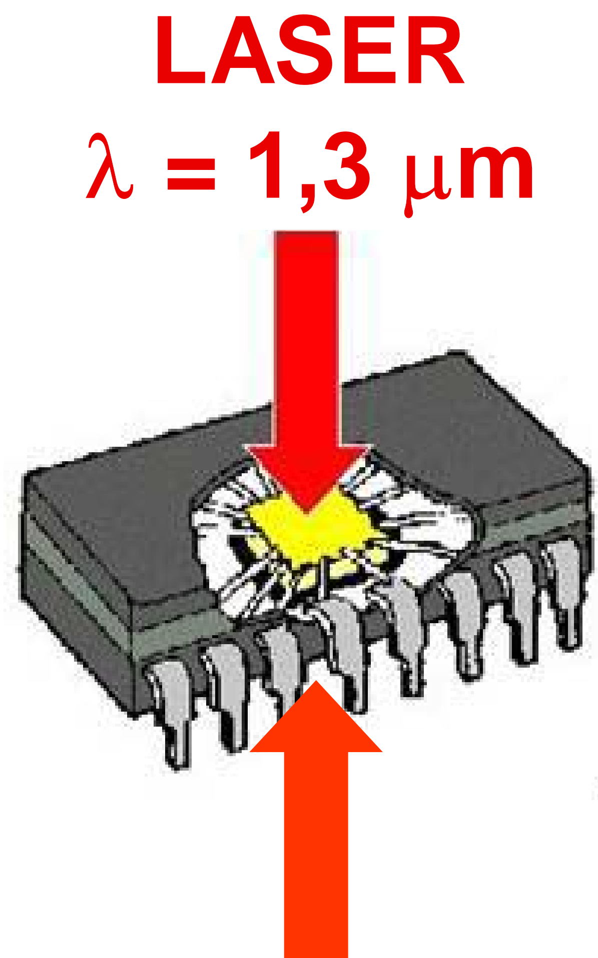
Emission microscopy

Thermal Laser Stimulation

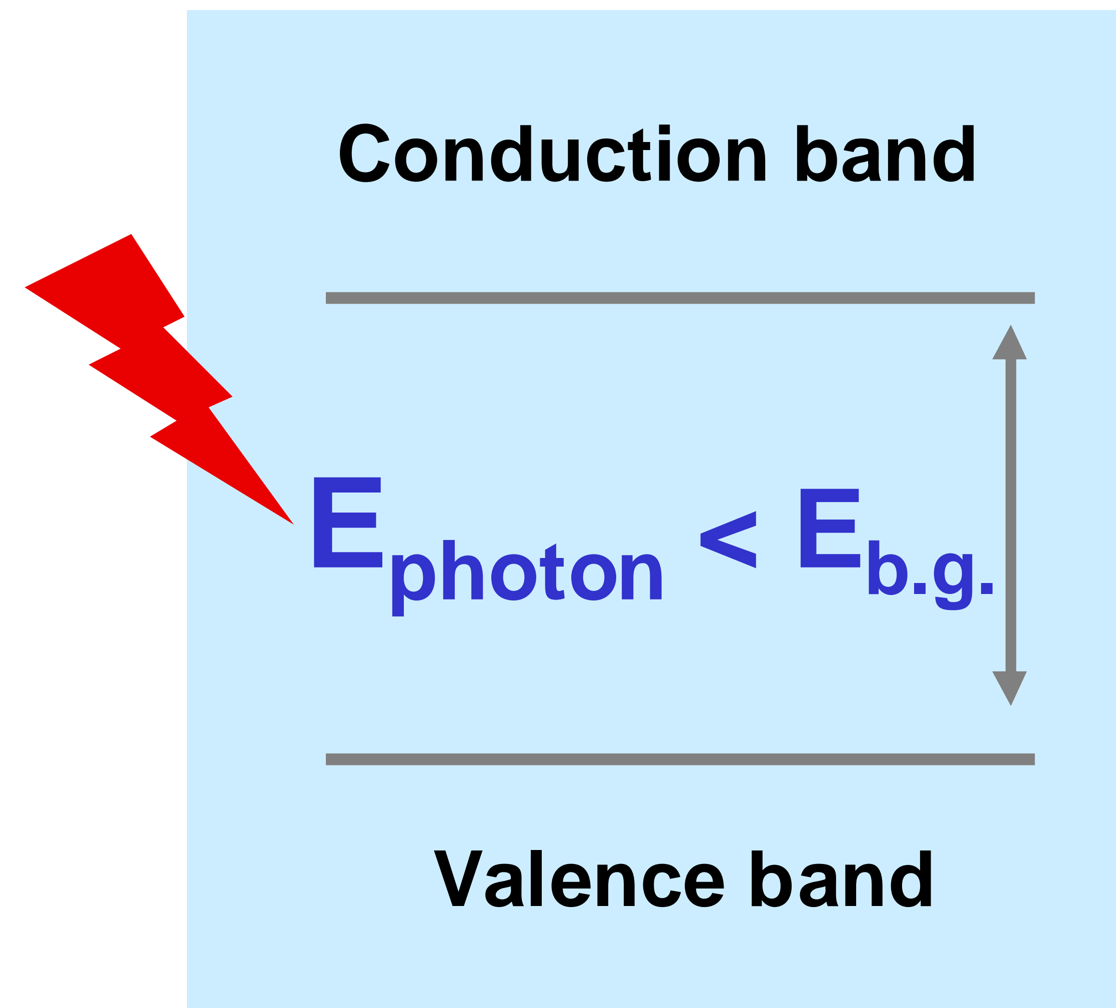
– $I_{leakage}$ junctions
– $I_{leakage}$ oxides

– $I_{leakage}$ metallic shorts

TLS Principles



- **Heating**
- **No e-h pair generation**



High absorption in:

- Metals
- Polysilicon
- Highly doped silicon

$$\alpha_{\text{Aluminium}} = 1{,}1 \text{x} 10^{6}\,\text{cm}^{-1}$$

Laser Heating of Metals

Electric current density :

$$\mathbf{j} \cong \sigma\left[\mathbf{E} + Q\left(-\nabla T\right)\right]$$

$\uparrow$ T° $\rightarrow$ **Current variation**

∇ T° $\rightarrow$ **Additional current**

A. Resistance Variation

$$\Delta R = \frac{\rho_0 L}{S}\left(\alpha_{TCR} - 2\delta_T\right)\Delta T$$

$\alpha_{TCR} \rightarrow$ Temperature Coefficient of Resistivity

$\delta_T \rightarrow$ Coefficient of Thermal linear dilatation

Aluminium

$\alpha_{TCR} = 4{,}29 \times 10^{-3}$

$\delta_T = 2{,}36 \times 10^{-5}$

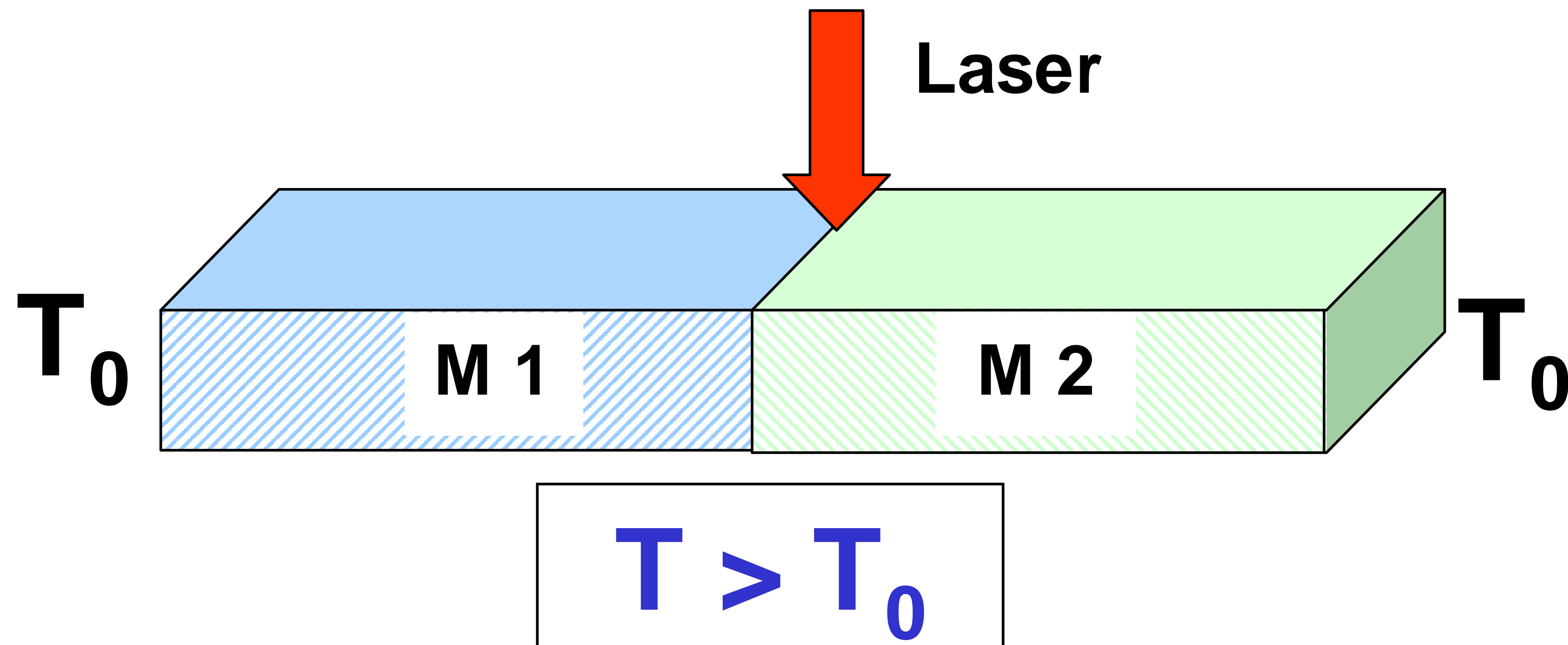
Current Source (TIVA)

$$\Delta V = \Delta R \cdot I$$

Voltage Source (OBIRCH)

$$\Delta I = -\left(\Delta R / R^2\right) V$$

B. Electromotive Force Generation



$$V_{12} = (Q_1 - Q_2)(T - T_0) = Q_{12}(T - T_0)$$

Q $\rightarrow$ Thermoelectric power or Seebeck coefficient

Q_{12} $\rightarrow$ Relative Thermoelectric power

Materials	Q_{12} (μV/°C)
Al / W	7,0
Al / n+ Poly	-121
Al / n+ Si (10^{20}cm^{-3})	-105

TLS Model

Parameters:

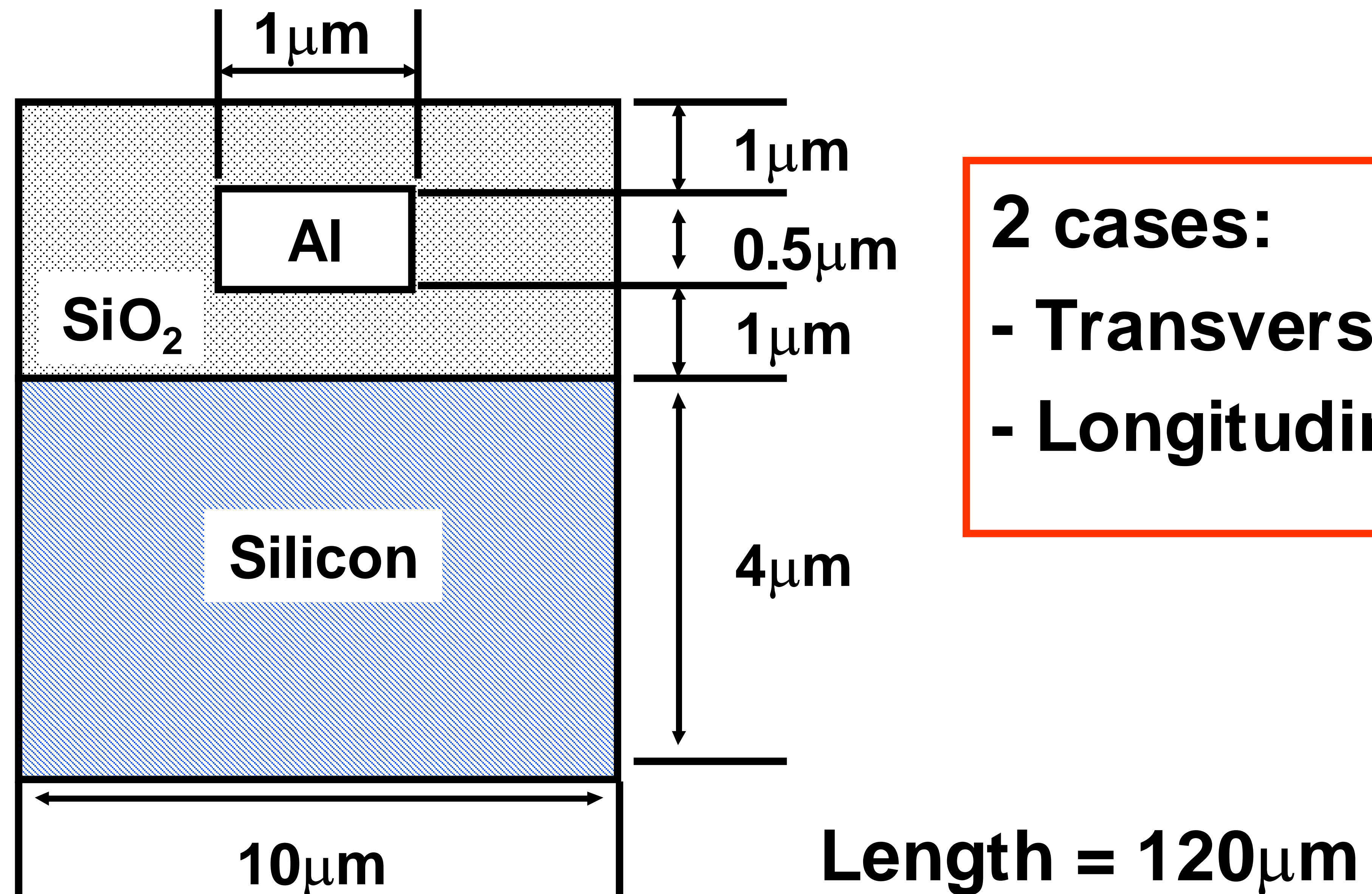
T_{ini}: 25°C

P_{laser}: 100mW

R_{laser}: 0,65µm

V_{fast}: 1,23m/s

V_{slow}: 0,00768m/s



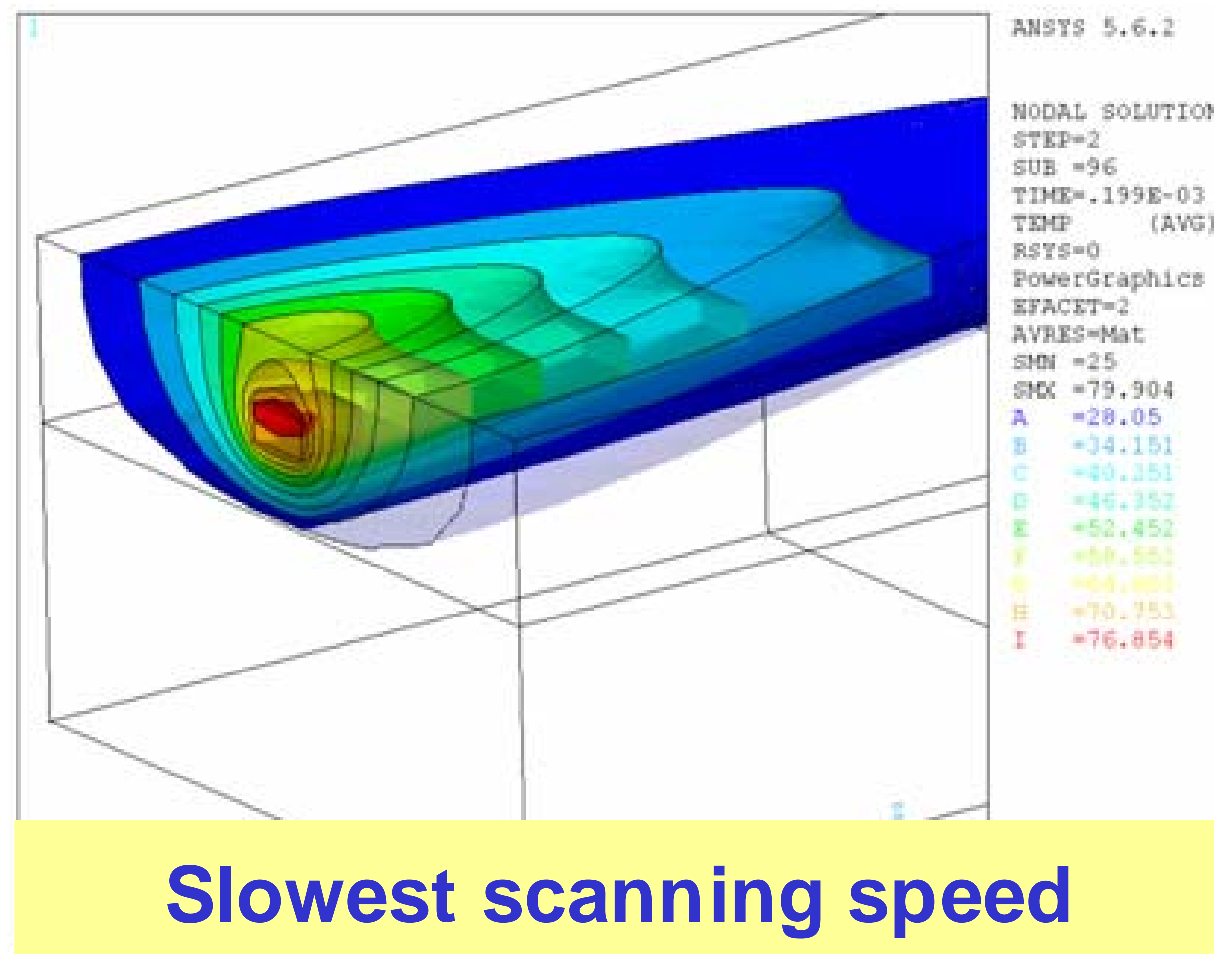
2 cases:
- Transversal
- Longitudinal

Length = 120µm

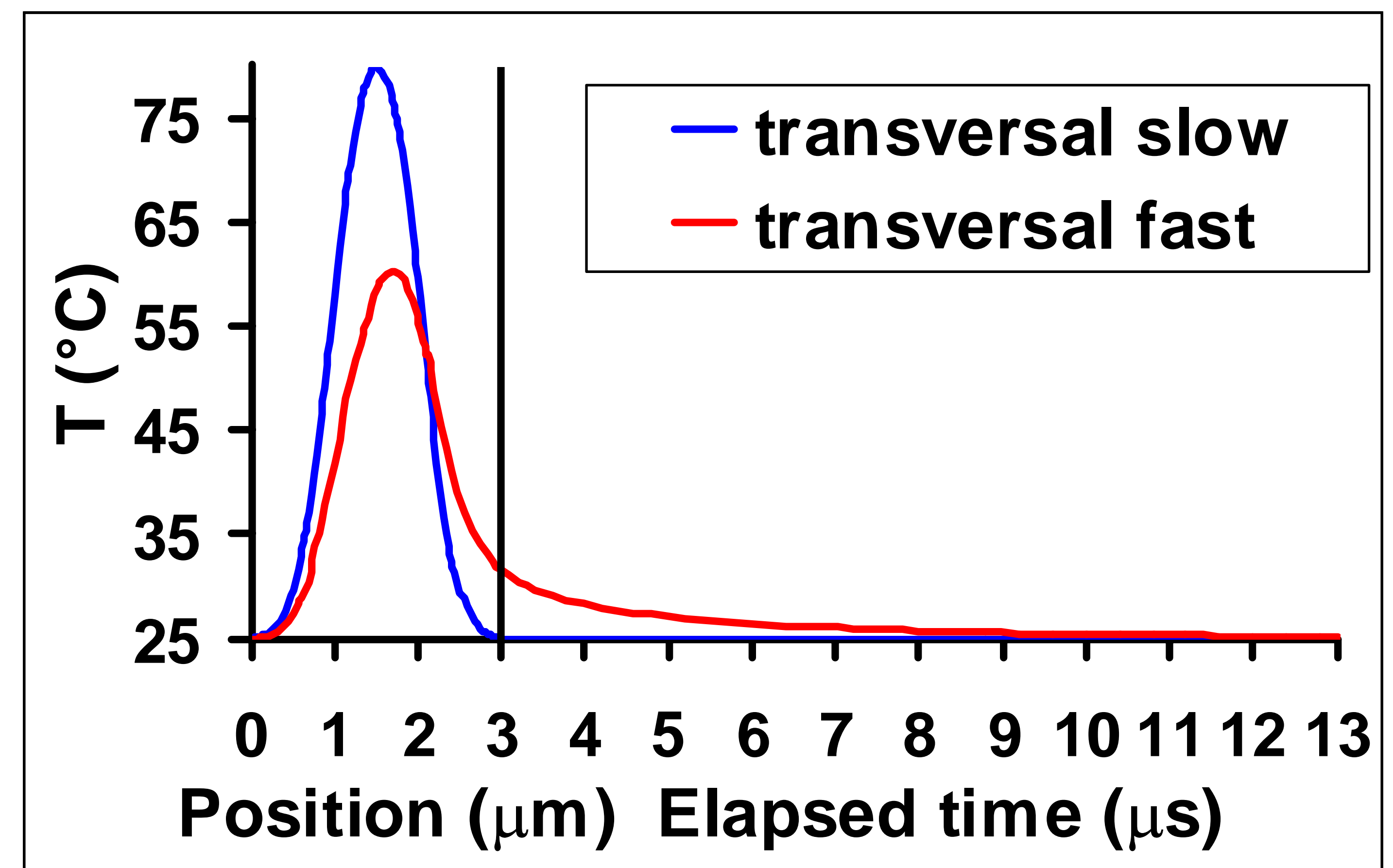
Model: 1µm Al line, Gaussien Laser

A. Transversal Case

- Rapid thermal equilibrium and heat dissipation
- Hottest temperature occurs at laser spot

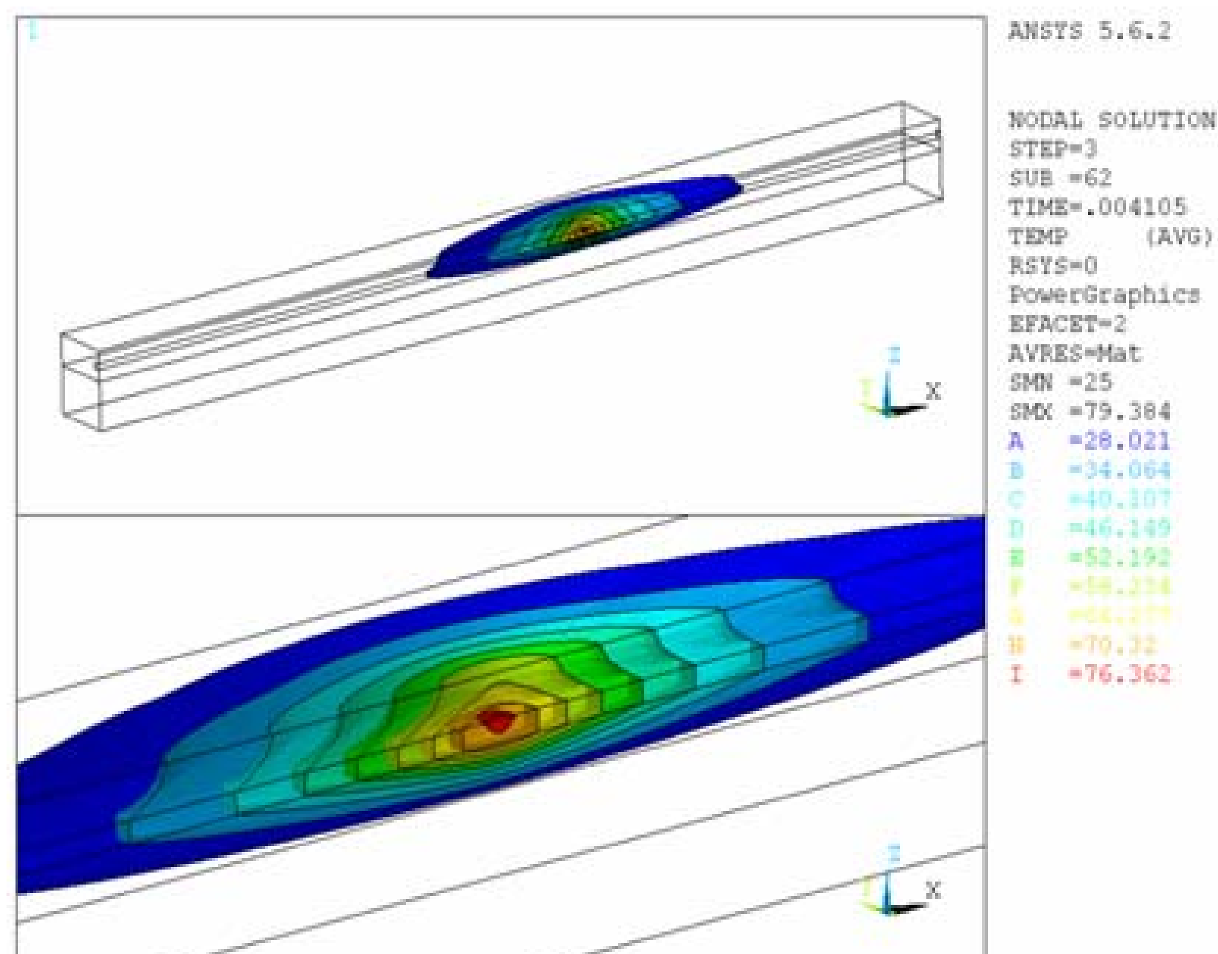


Slowest scanning speed

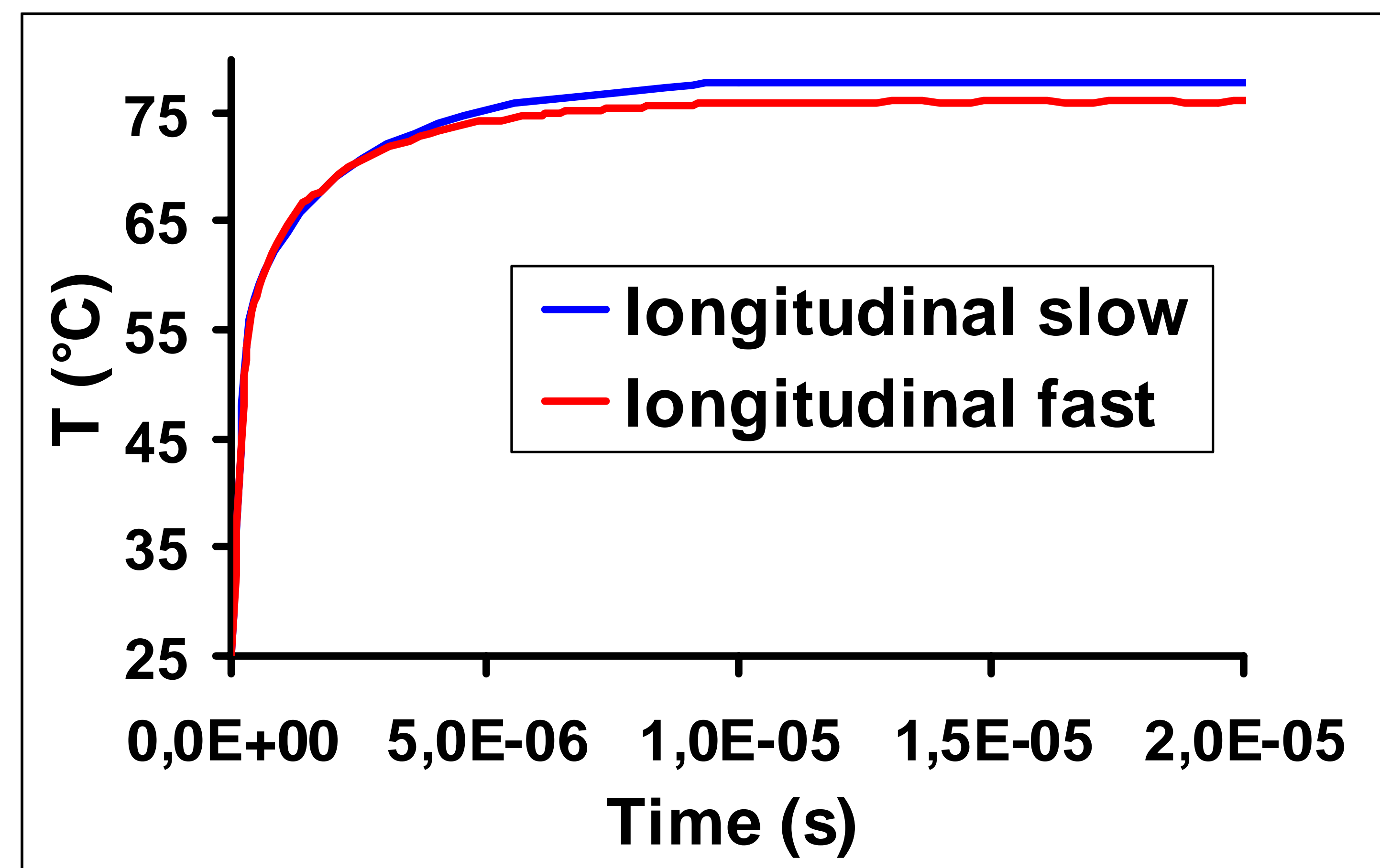


B. Longitudinal Case

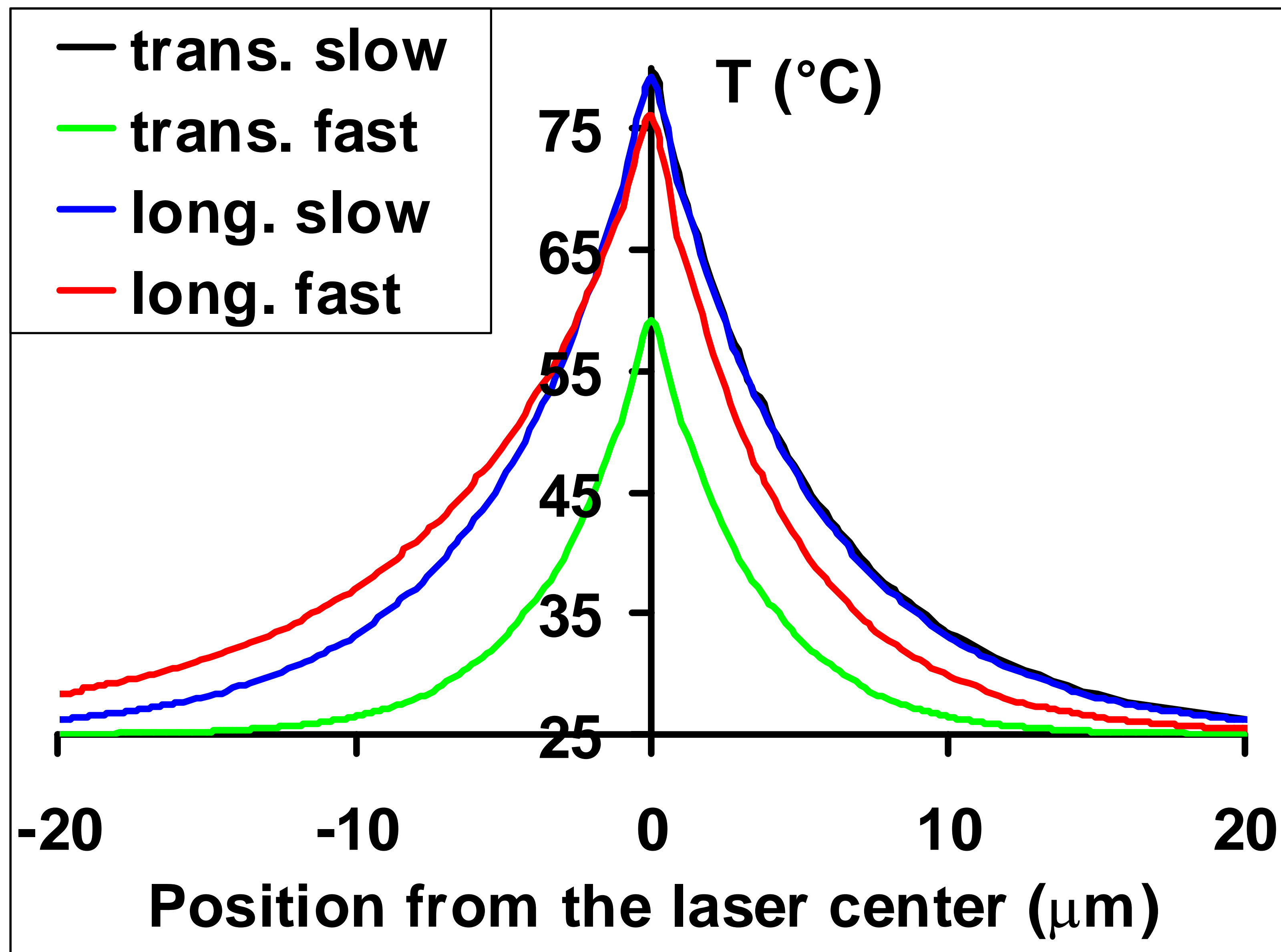
- **Thermal equilibrium reached after 10μs**



Slowest scanning speed



Temperature Calculation



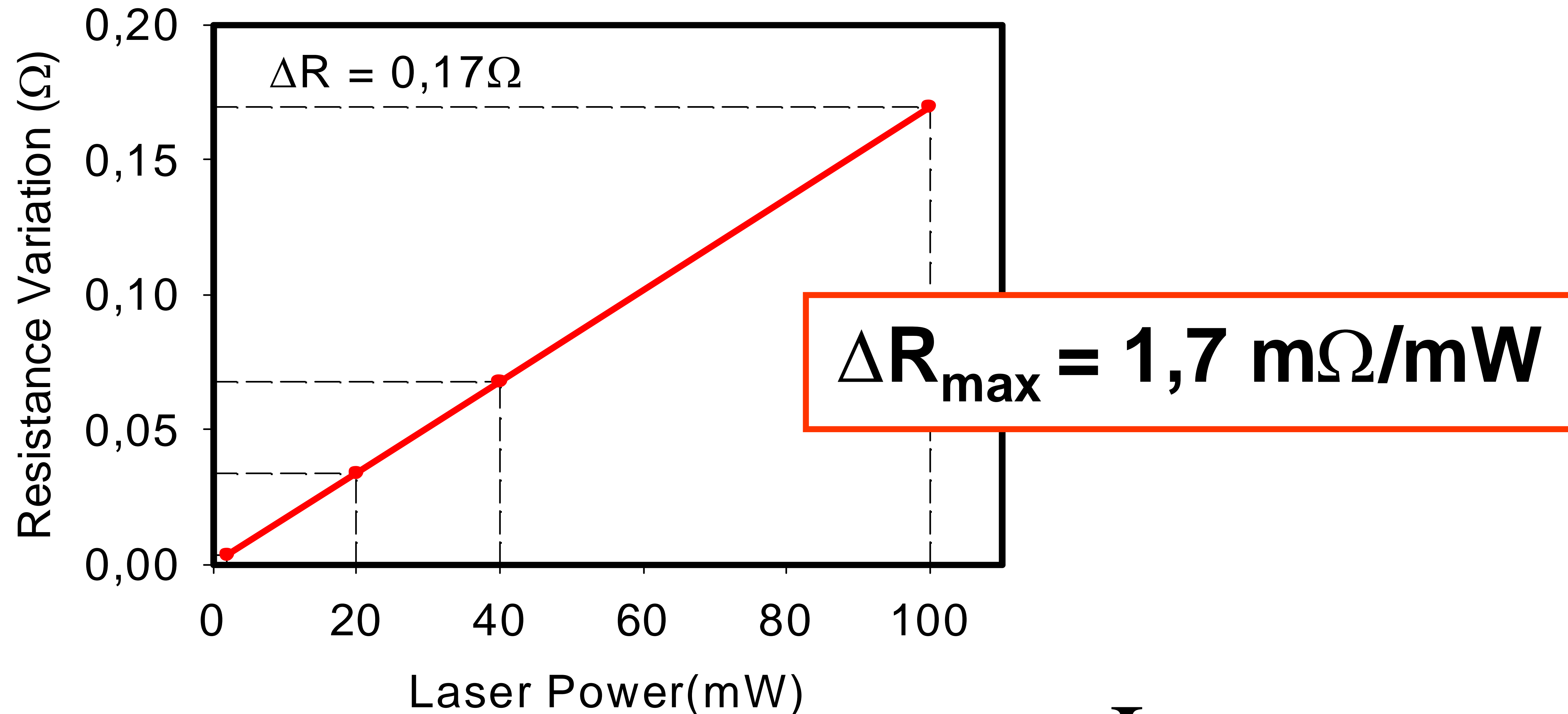
At thermal equilibrium:

Thermal spreading limited to ~ 30µm

Temperature varies linearly with laser power

$\Delta T_{max} = 0.55^oC/mW$

Resistance Calculation



$$\Delta R = \frac{\rho_0 \alpha_{TCR} L}{S}\left(T_{Moy} - T_0\right)$$

Model Conclusion

Localization of defects and lines submitted to $I_{leakage}$

ΔR 1/$\propto$ Section

$\Delta V \propto I_{leakage}$

Localization of junctions and interface defects

Q_{12} or ΔT

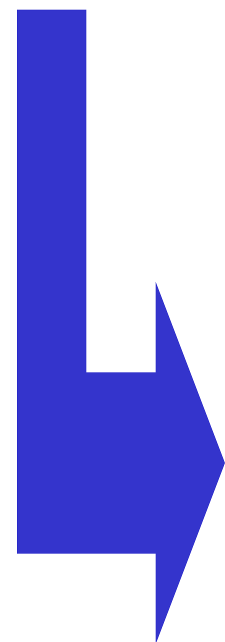
Precise localization

Thermal diffusion < 30µm

T_{max} at center of line and laser beam

TLS System Requirements

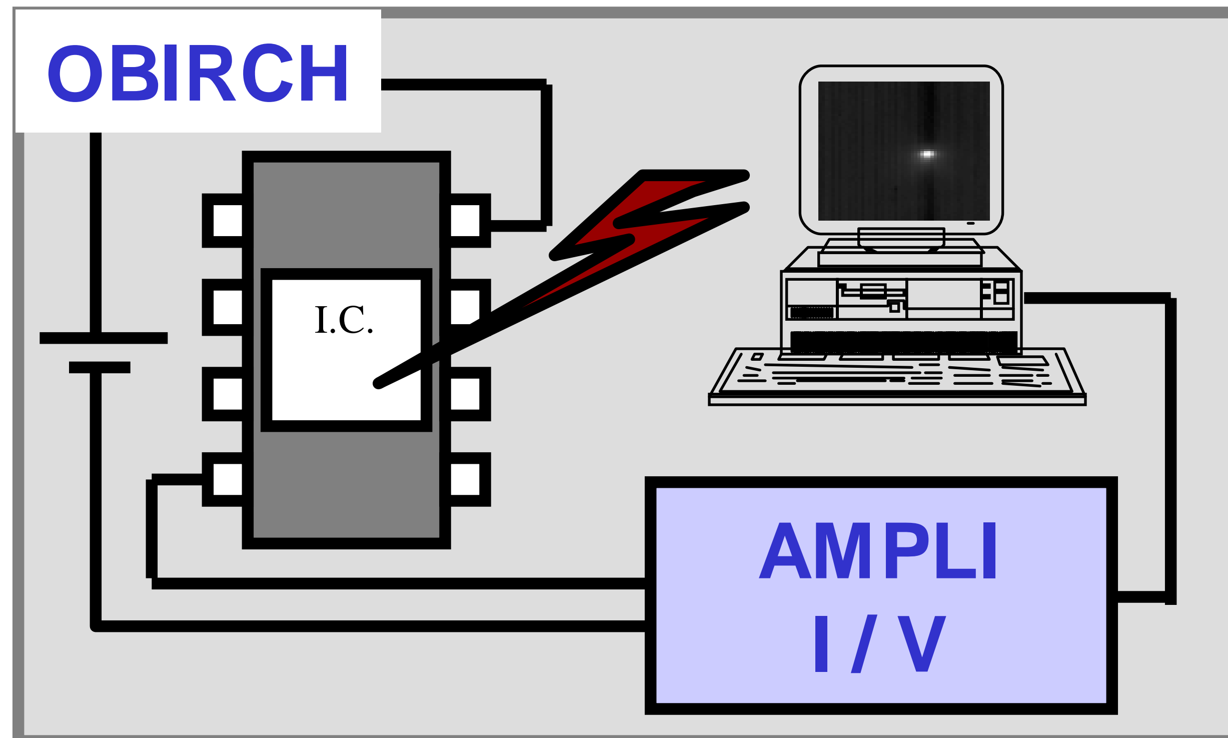
- Laser scanning microscope (LSM)
  - Gaussian laser of λ > 1,1μm
- Acquisition and imaging system
- Biasing and amplification scheme :

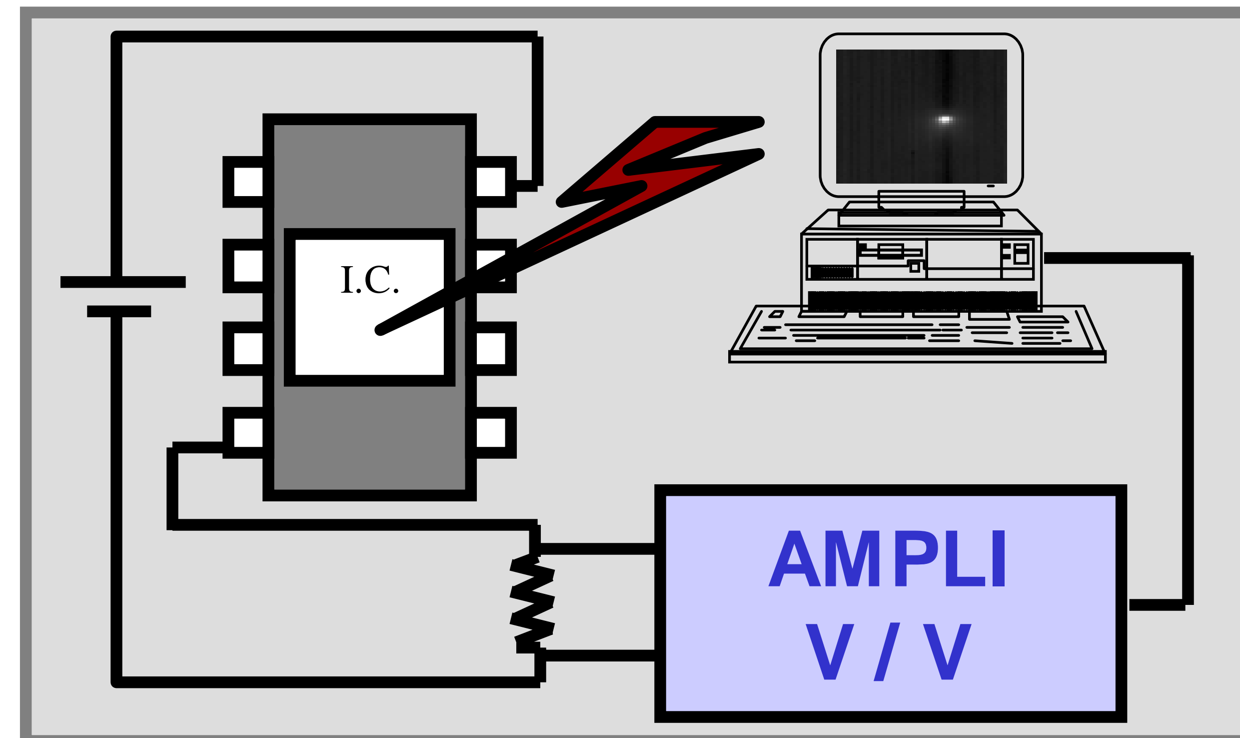


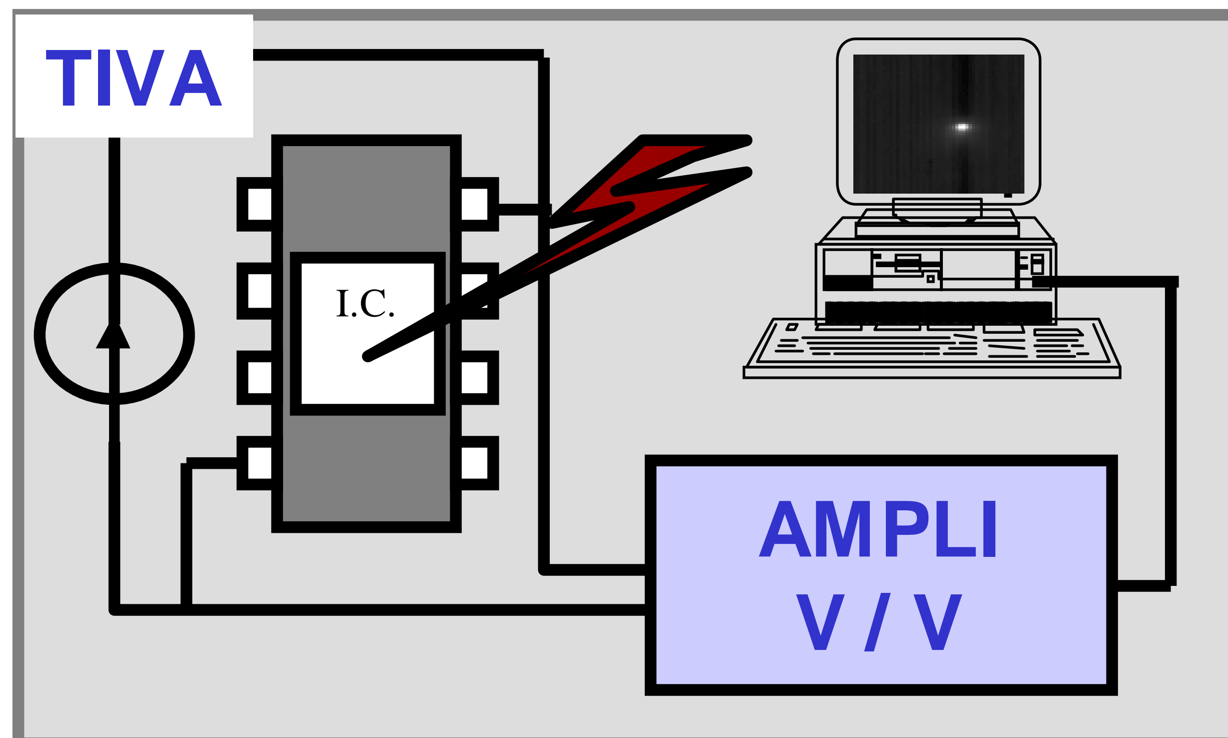
Techniques	Inventor	Bias	Amplifier
OBIRCH	Nikawa	V	I
CC-OBIRCH TIVA	Nikawa Cole	I	V
TBIP XIVA	Palaniappan Falk	V	V
SEI	Cole	I / None	V

TLS

Configurations



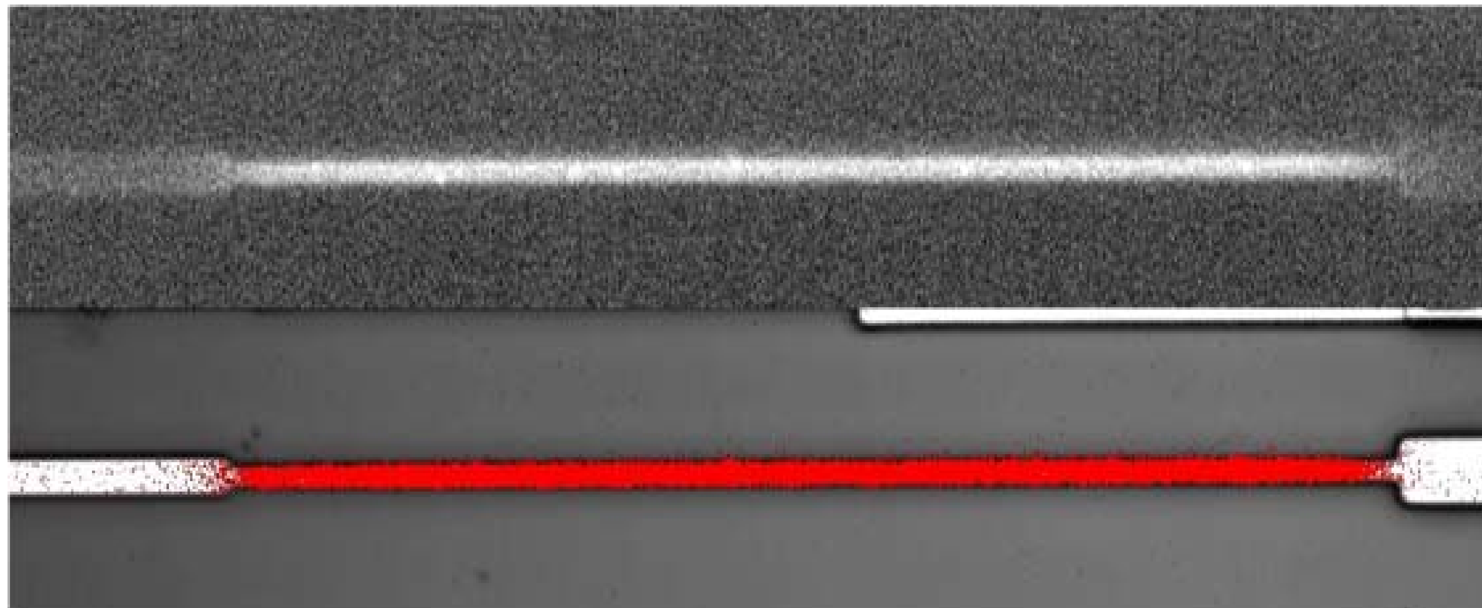




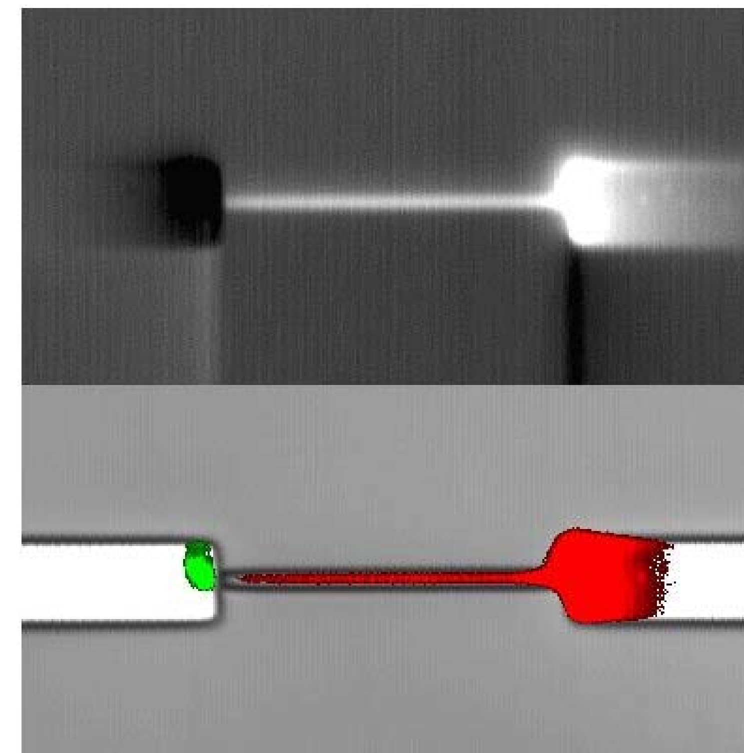
- **Other configurations:**
  - Inductance (TBIP / XIVA)
  - No bias (SEI)

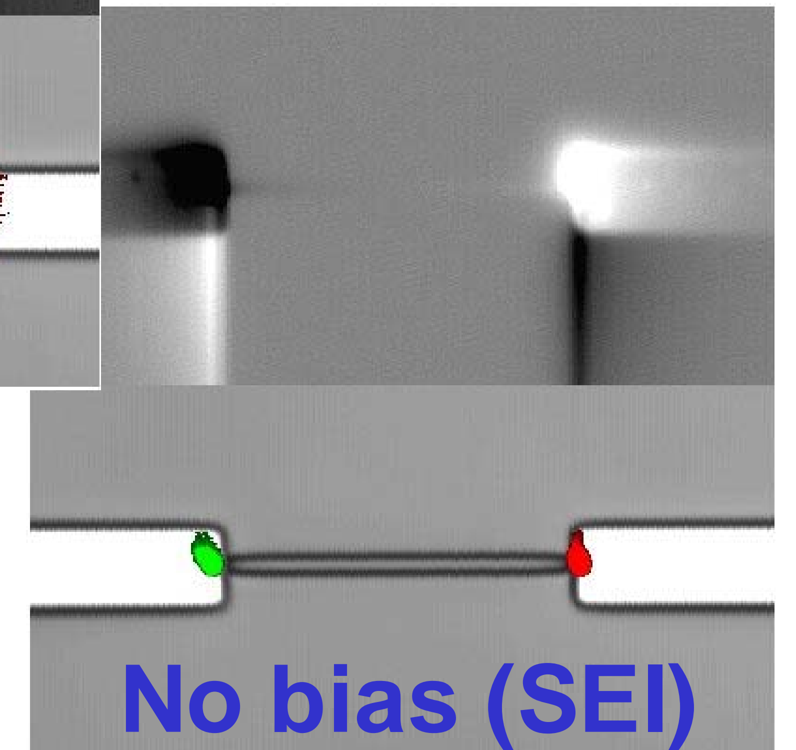
TLS on Test Structures

Al line

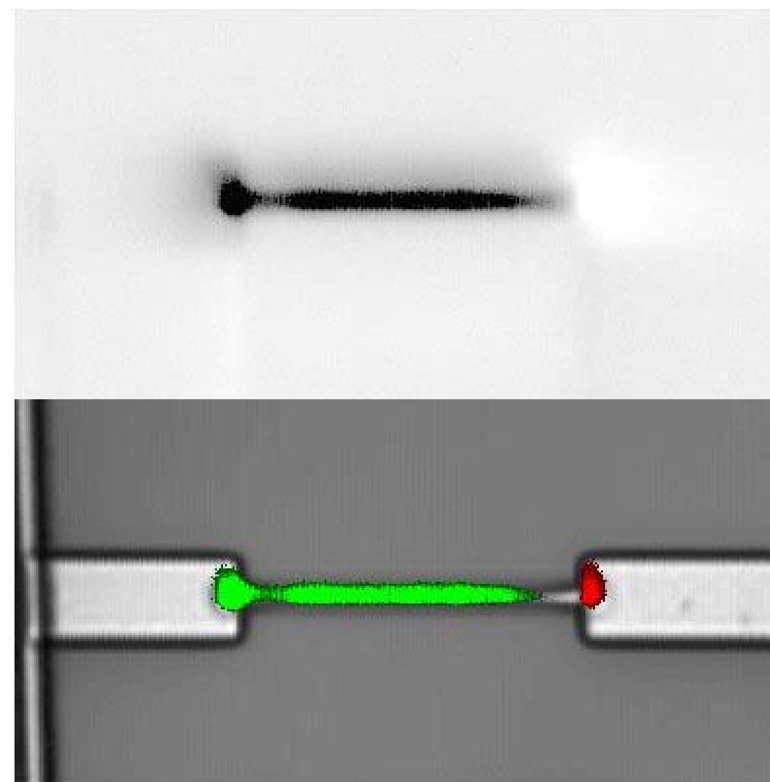


N+ resistance



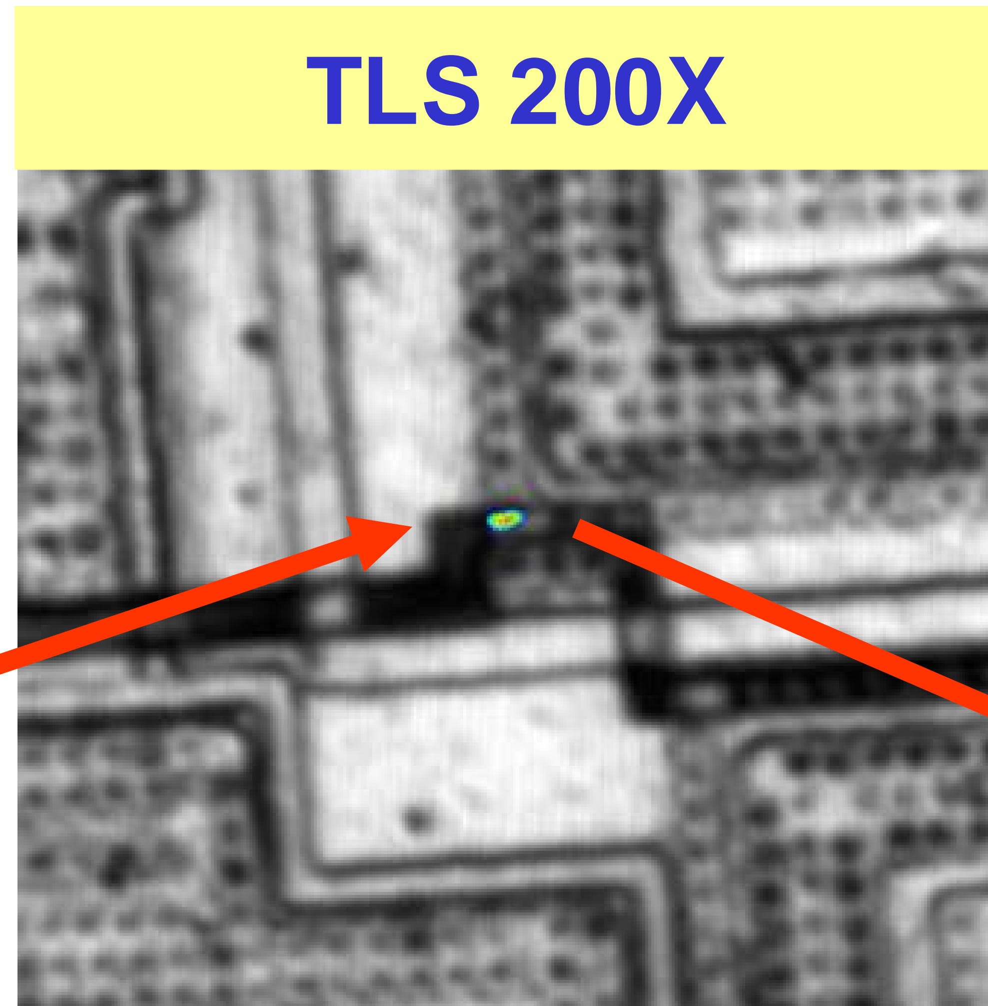


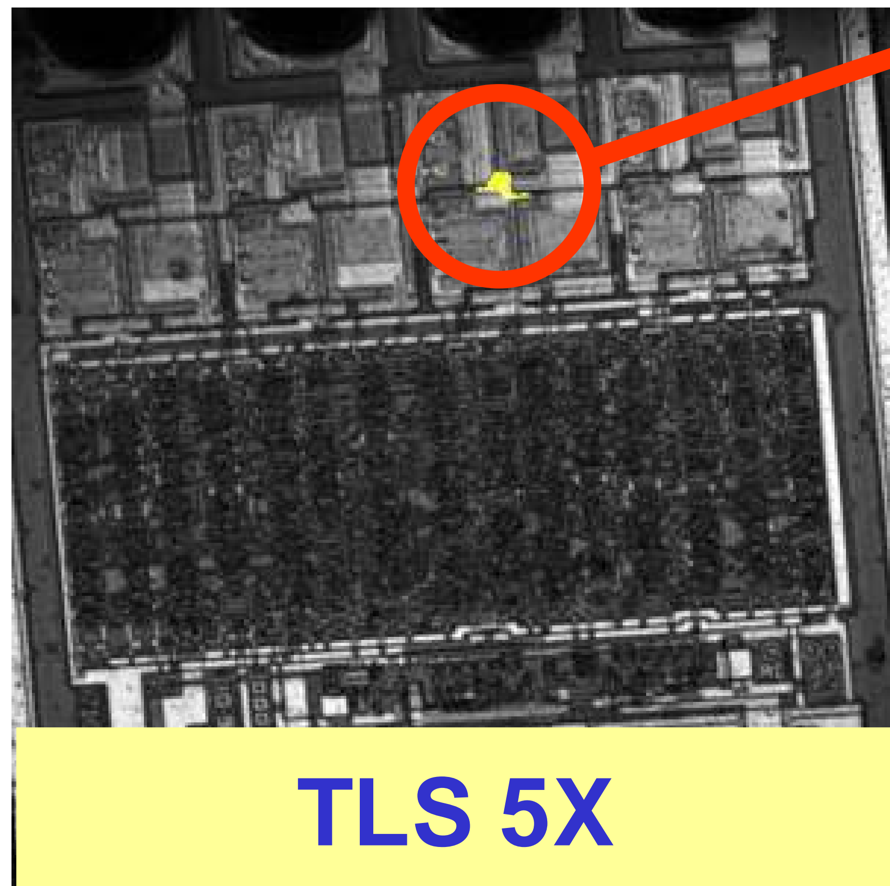
Poly line

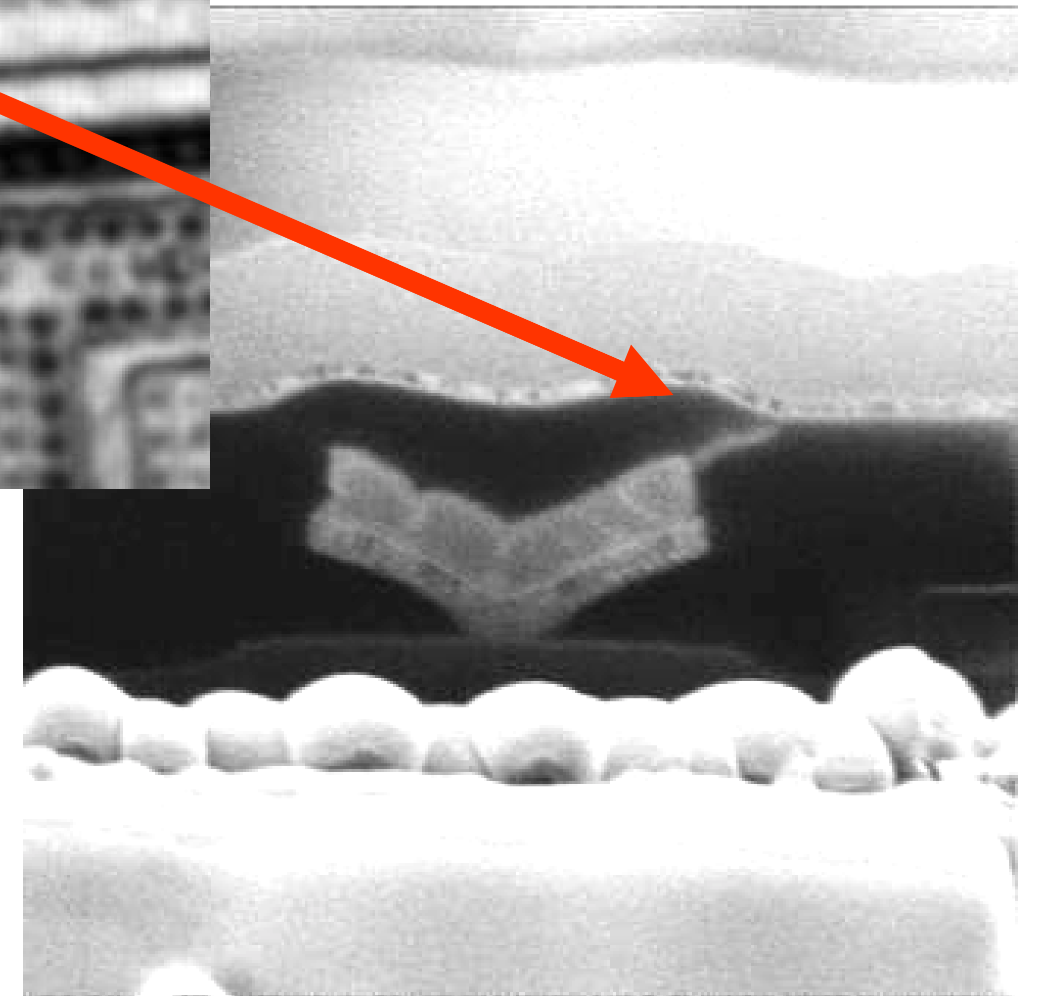


TLS Case Study #1

- **Failed CMOS IC**
  - **I ~ 2mA @ 5V**
- **No emission**
- **Front-side**





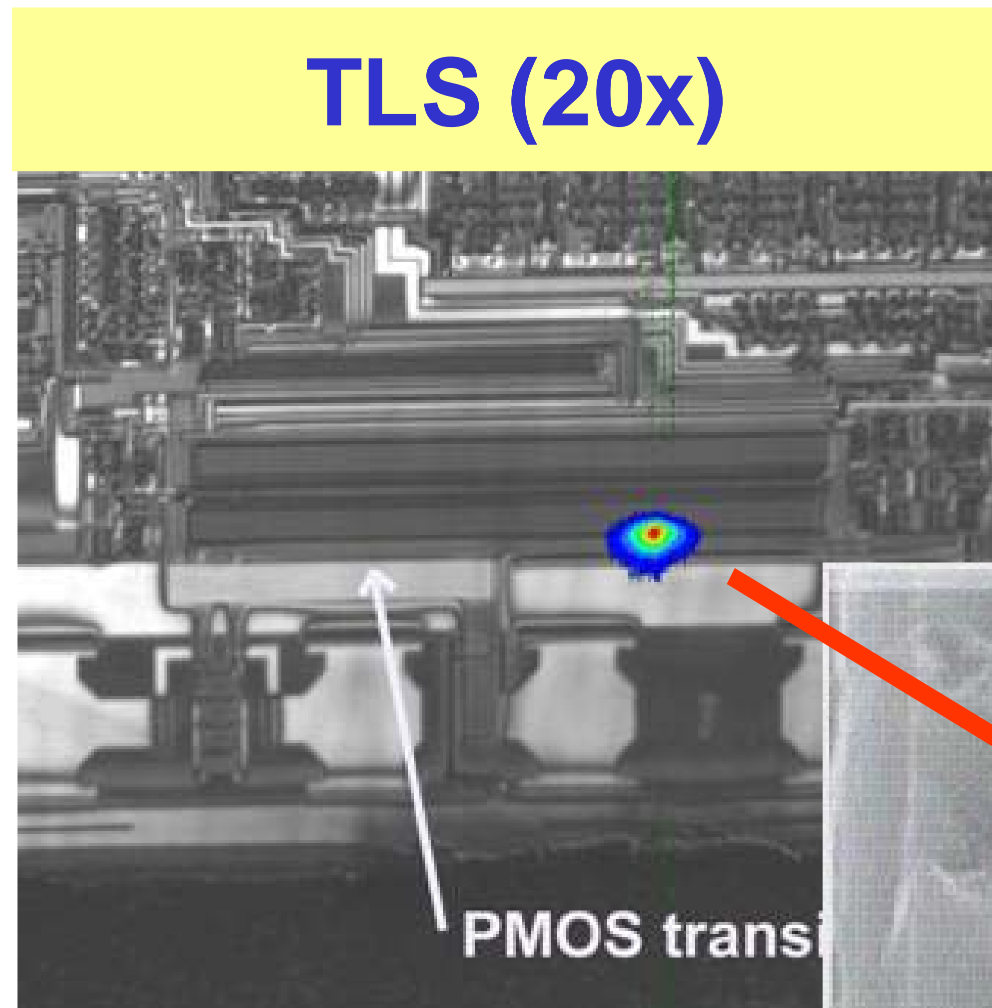


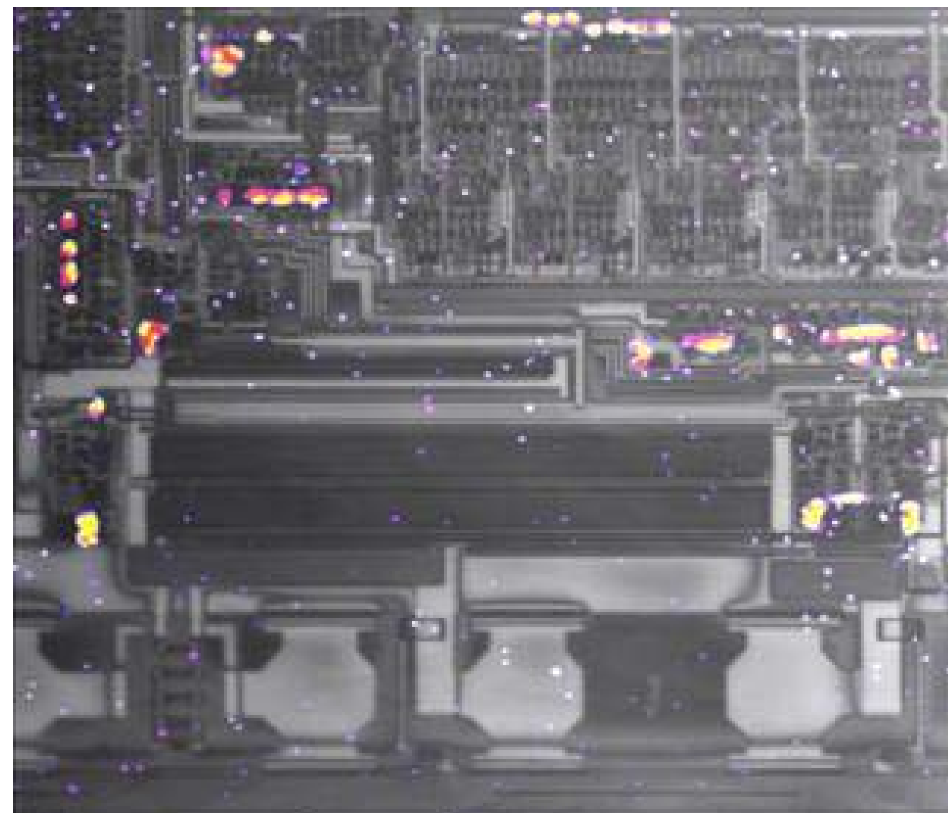
Metal short (M1-M2)

TLS Case Study #2

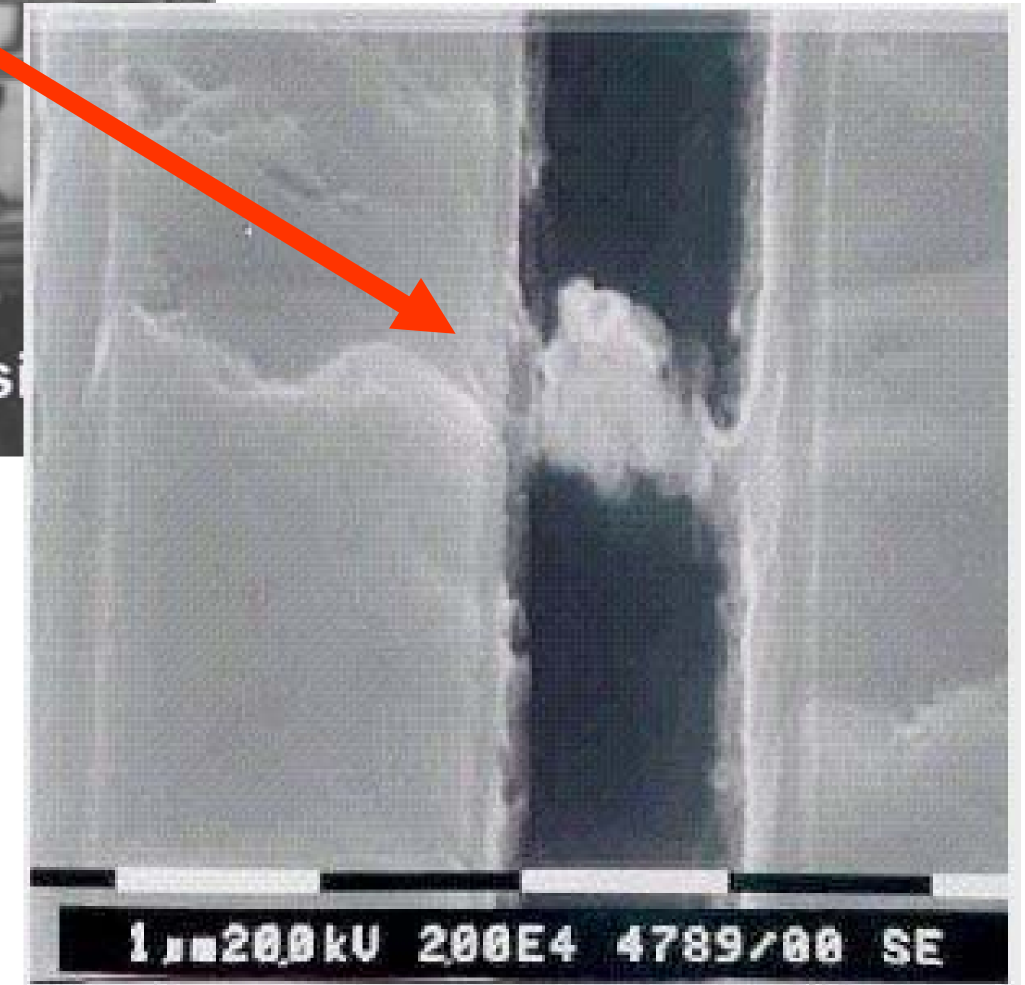
- **Failed BICMOS IC**
  - I > 100 μA (I/O)
- **Backside**
  - 4 metal levels

TLS (20x)





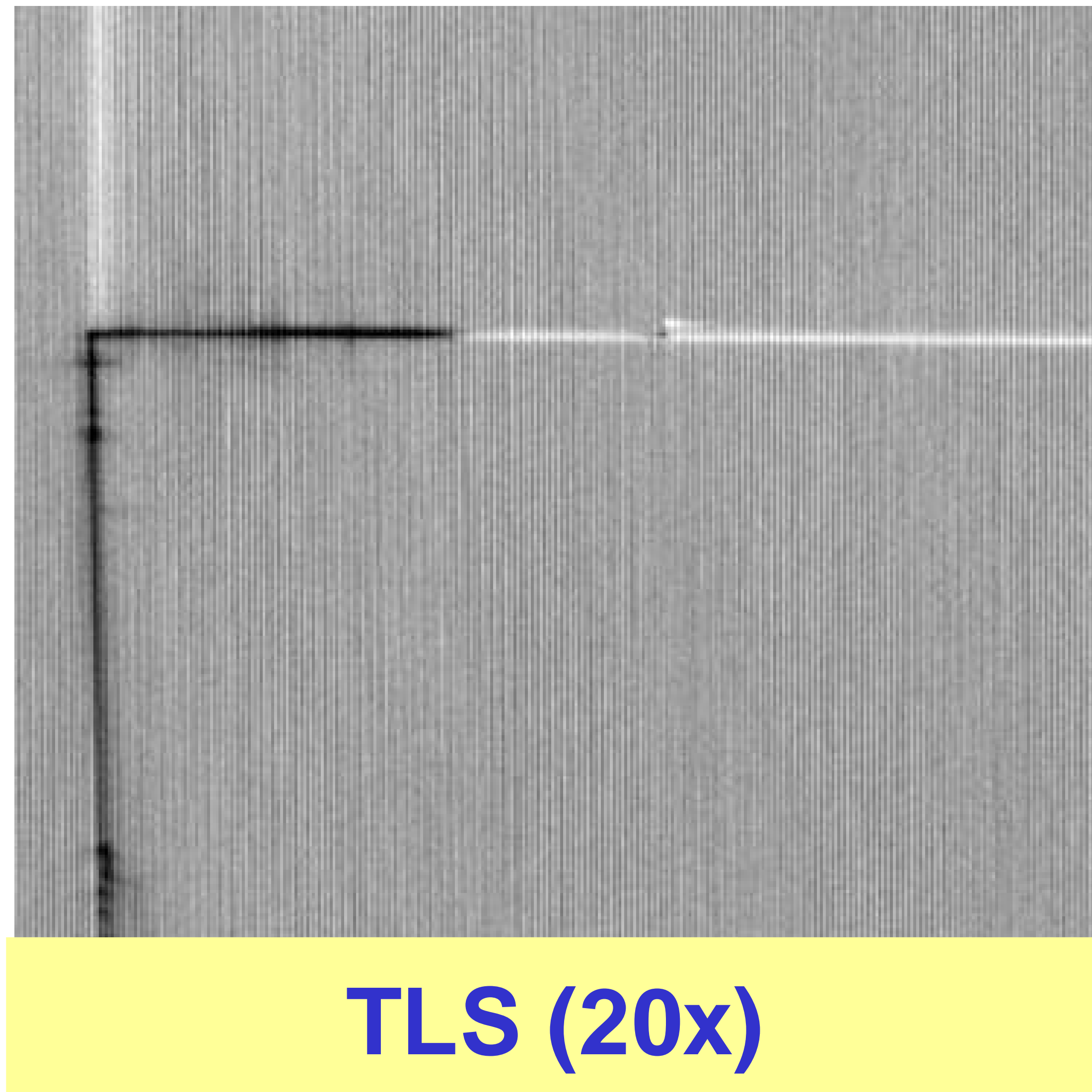
EMMI (20x)



W short
(Drain-Source)

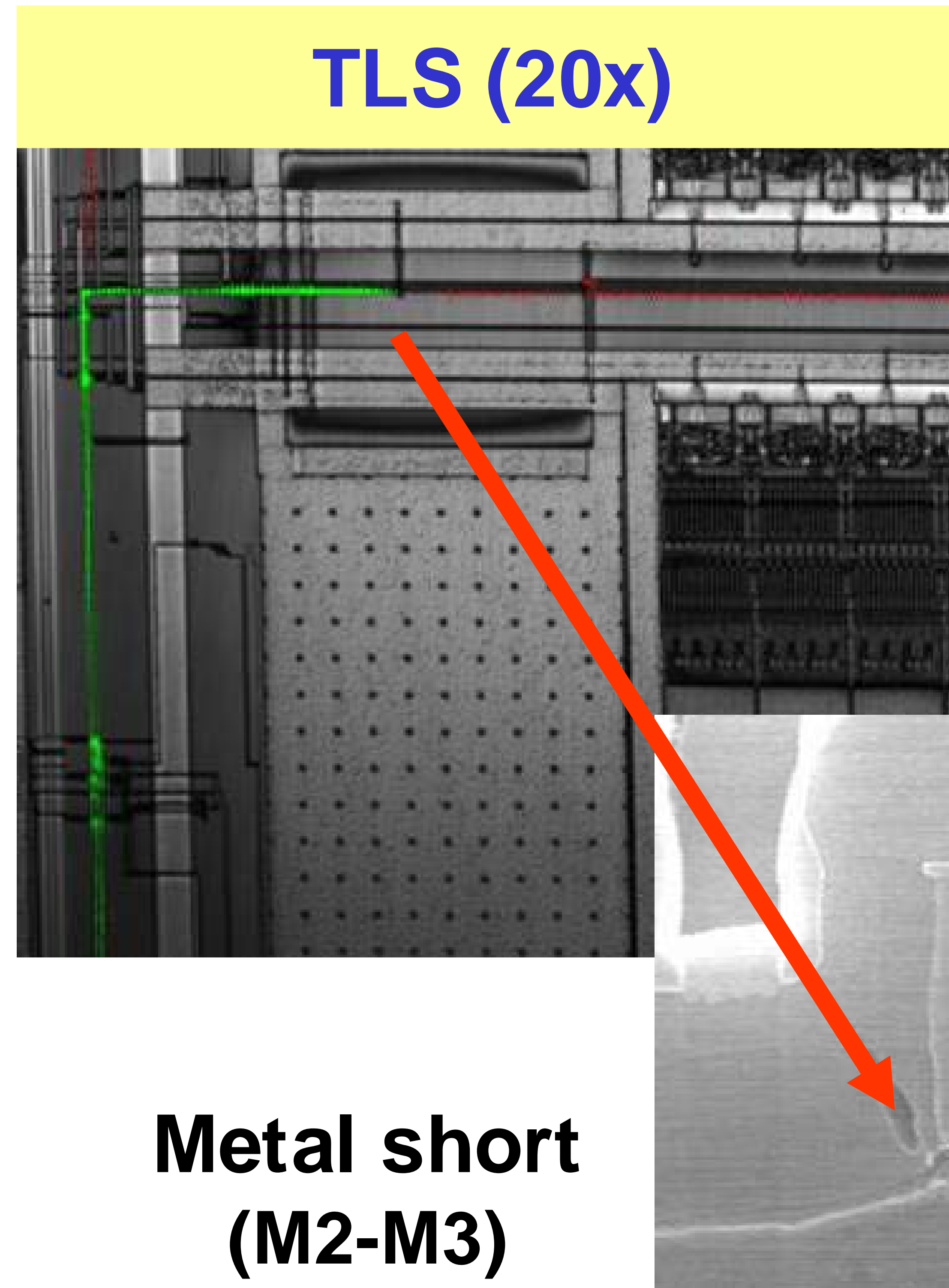
TLS Case Study #3

- **Failed CMOS IC**
  - **I ~ 2 mA @ 3V**
- **Front-side**



TLS (20x)

TLS (20x)

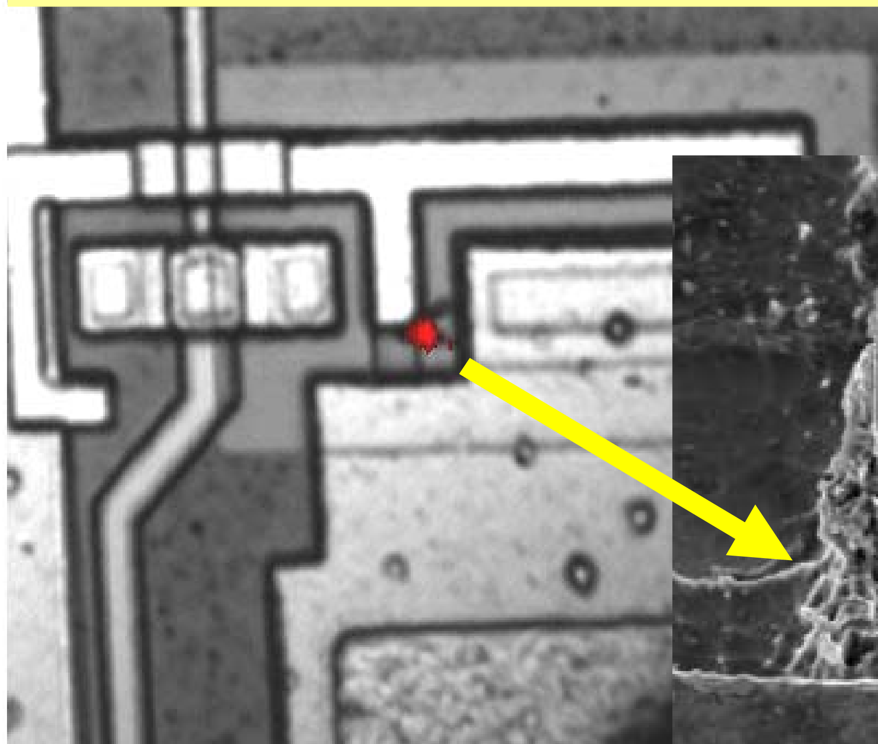


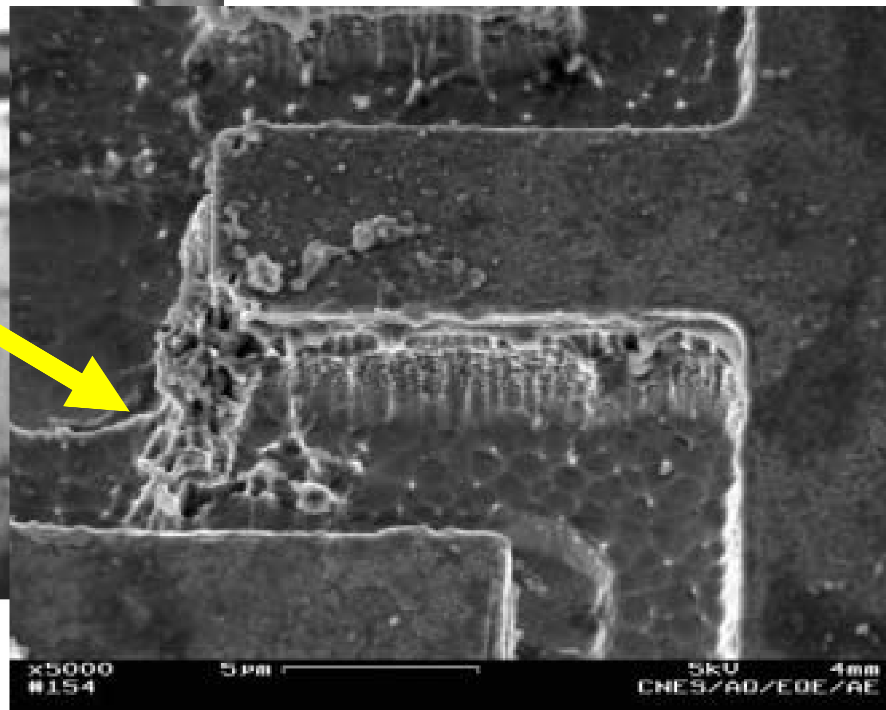
Metal short (M2-M3)

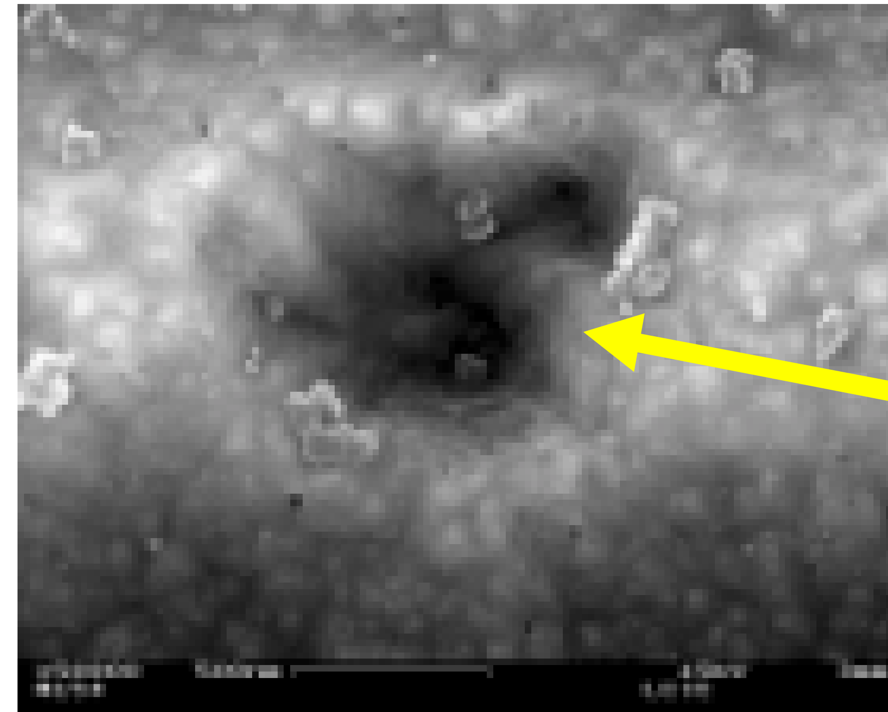
TLS Case Study #4

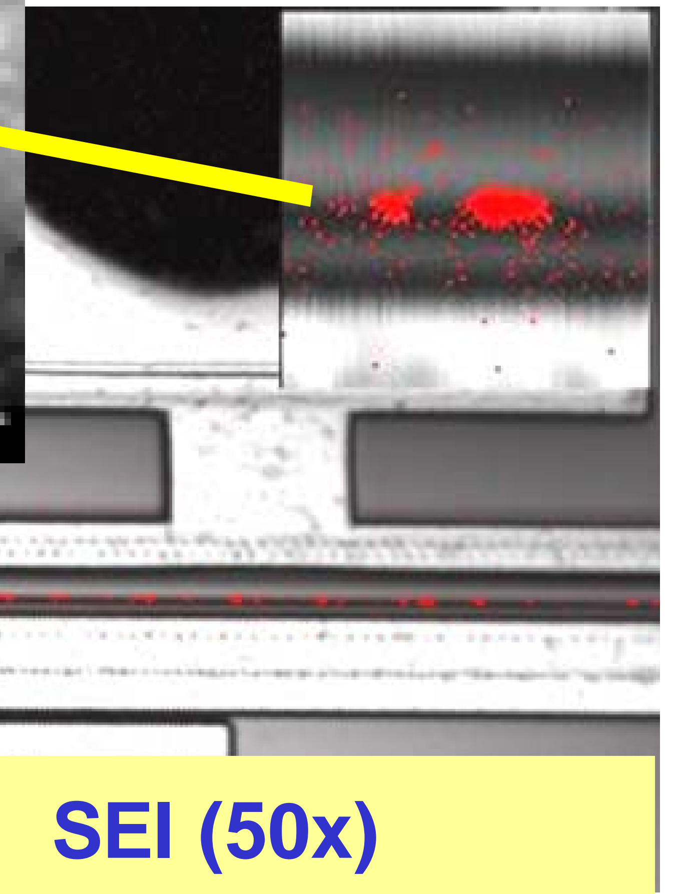
- ESD failed commercial ICs
  - HBM and MM stressed
- Front-side
  - No bias applied (SEI)

SEI (200x)









Molten Si spike

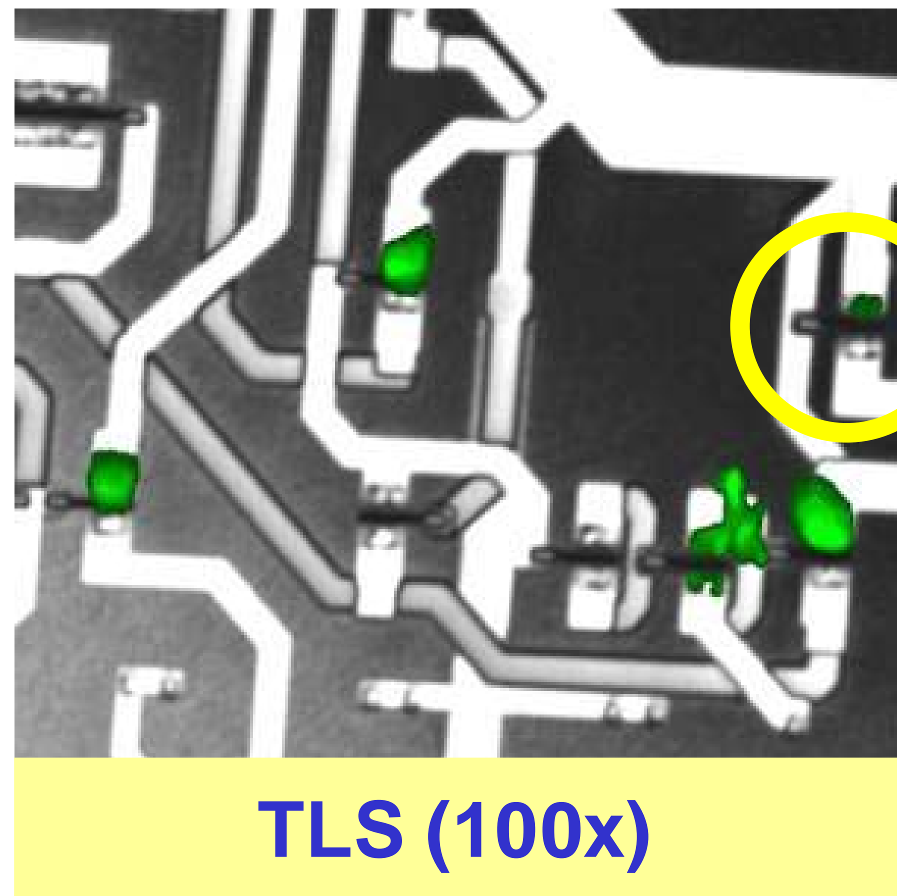
SEI (50x)

Molten Si/Al filament

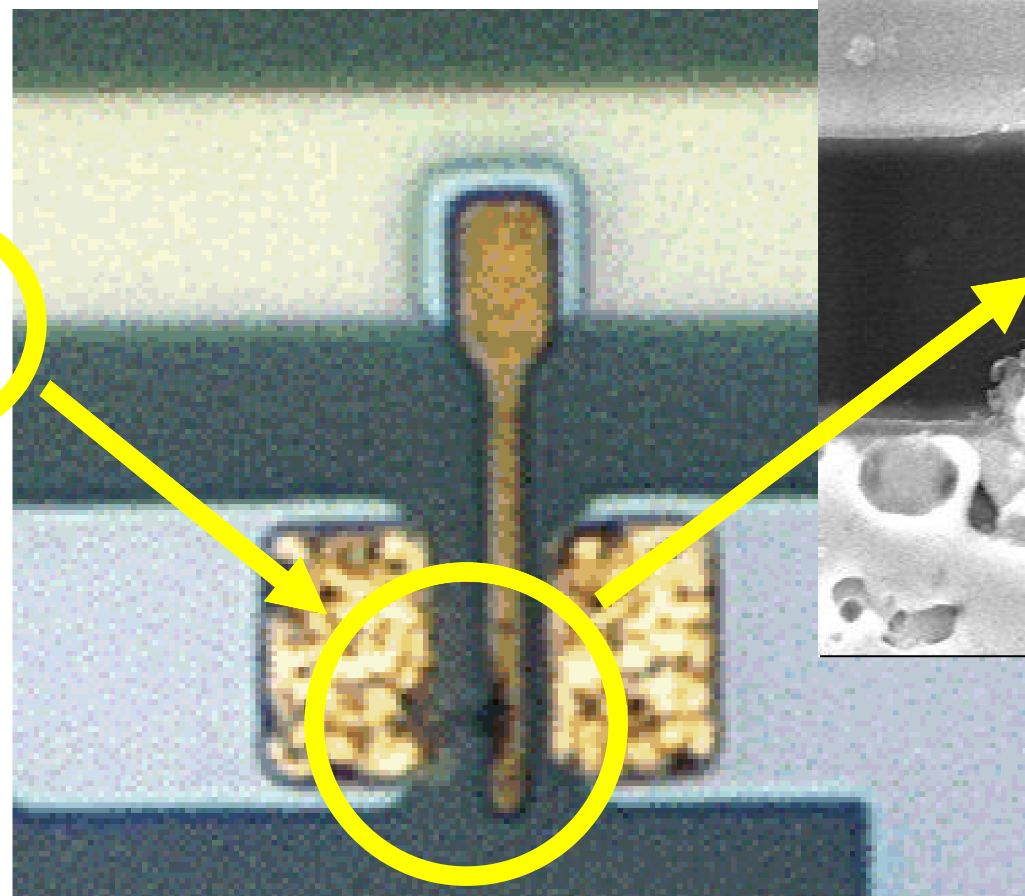
TLS Case Study #5

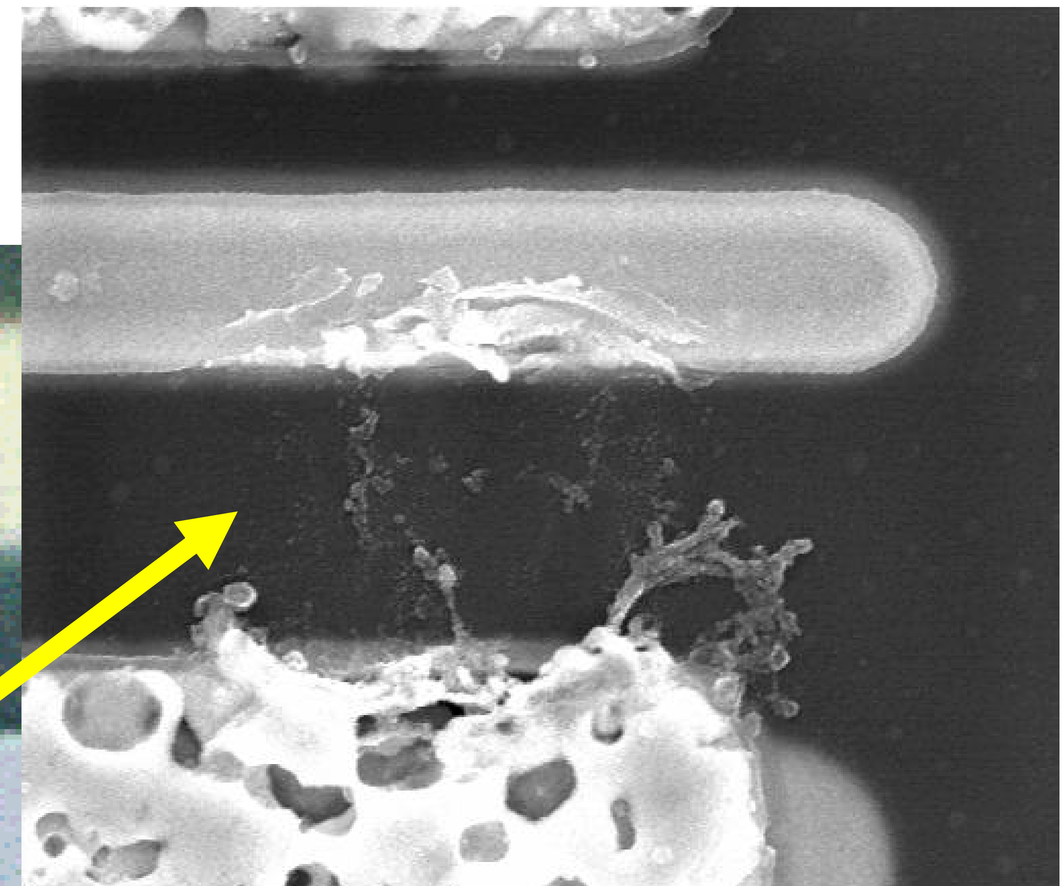
- GaAs failed ASICS
  - I ~ 50 μA @ 3V
- Front-side

Defects induced by CDM type ESD stress



TLS (100x)





Gold filament

Conclusion : TLS Application Field

Thermal Laser Stimulation	Signature	Defect type	Material
Bias	$I_{leakage} > 1\mu A$	Current lines Shorts ESD defects Voids	Al, W, Au, PolySi, Doped Si, Amorph. Si
No Bias	All circuits Comparison	ESD defects Interface defects	Metal / Metal Metal / Si Metal / Poly Si Melted Si / Si