Semiconductor Device & Analysis Center
Berlin University of Technology

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Semiconductor Device & Analysis Center Berlin

Scope:

- Research: FA Techniques for Faster Turnaround
  - Edit techniques on devices
  - Physical interactions of devices for localization
  - Standard solutions (cook book etc.)
  - Device Design & Characterization

- Education: Full Device Development Process
  - Semiconductor Devices in Basic Curriculum
  - Full Microelectronic Business Process (FET)
  - Failure Analysis, Power & Special Devices

- Service: Commerical-like Application Lab
  - Lab unique for service of design verification and failure analysis processes from chip backside

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Resources:

- 1 Lead Engineer (permanent)
- 3 PhD Students based on educational track
- 4 Technical Staff (permanent contracts)
- More PhD Students per cooperation contracts
- State of the Art tools Hamamatsu Phemos 1000, NPTest OPTIFIB, Agilent 83000 Tester
- Device Simulation & Know How (FET, Power, PV)
- Sample Preparation Mech, Chem Wet &Dry
- 1000 sqft Small Clean Room Technology
- More than 5000 sqft lab and office space

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Who we are

Device Dynamics Make the Difference in Functional Analysis

Challenges of Backside Approach

Device Localization with Laser Stimulation

Device Repair (Circuit Edit) with FIB

Where we want to go

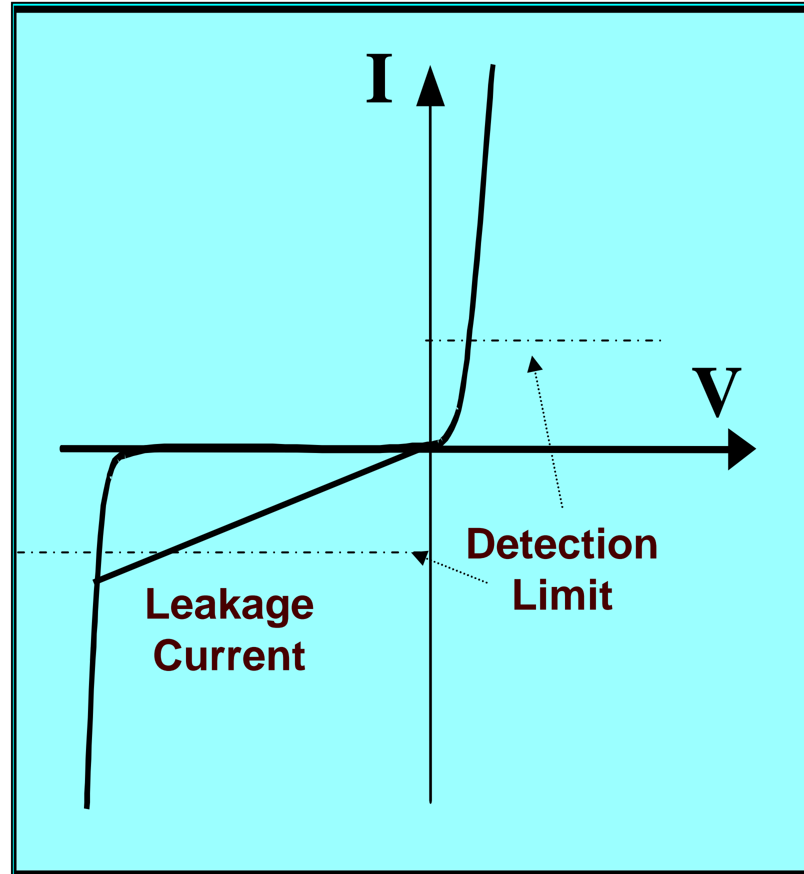
Photon Emission Basics: Electroluminescence

The Two Basic Mechanisms of Photon Emission in IC

P/N Junction:

Reverse Bias

1) Deceleration:
Radiant loss of energy gained in electrical field

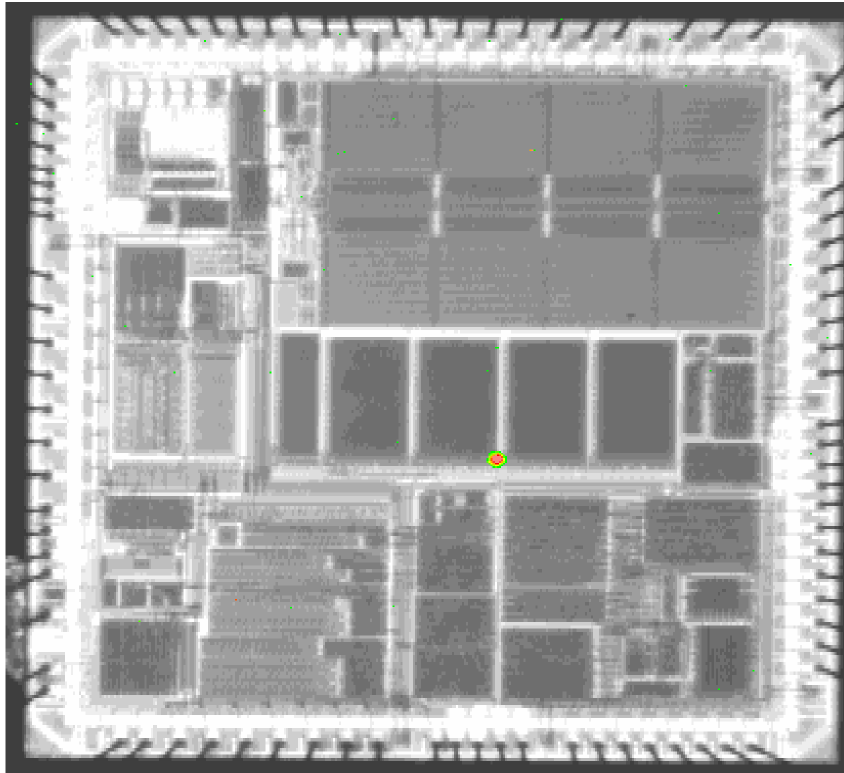


Forward Bias

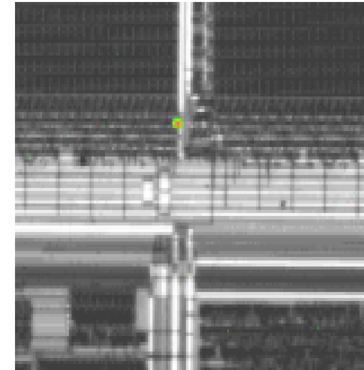
2) Injection:
Radiant Interband Recombination

Photon Emission Microscopy

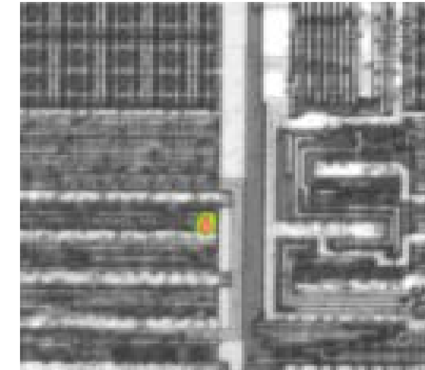
Direct defect identification: Gate oxide defect



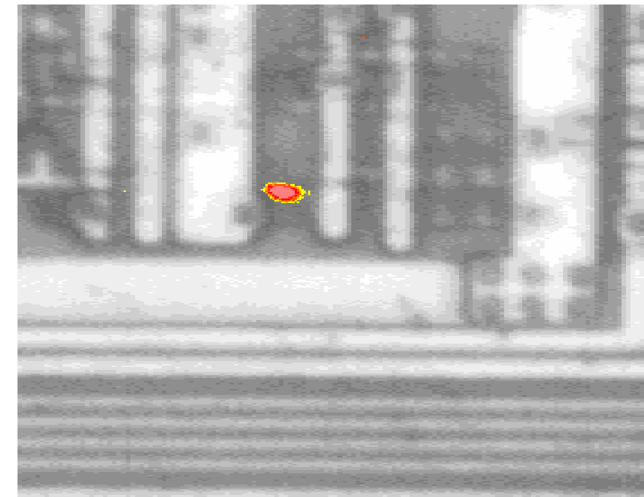
X 0.8



X 5



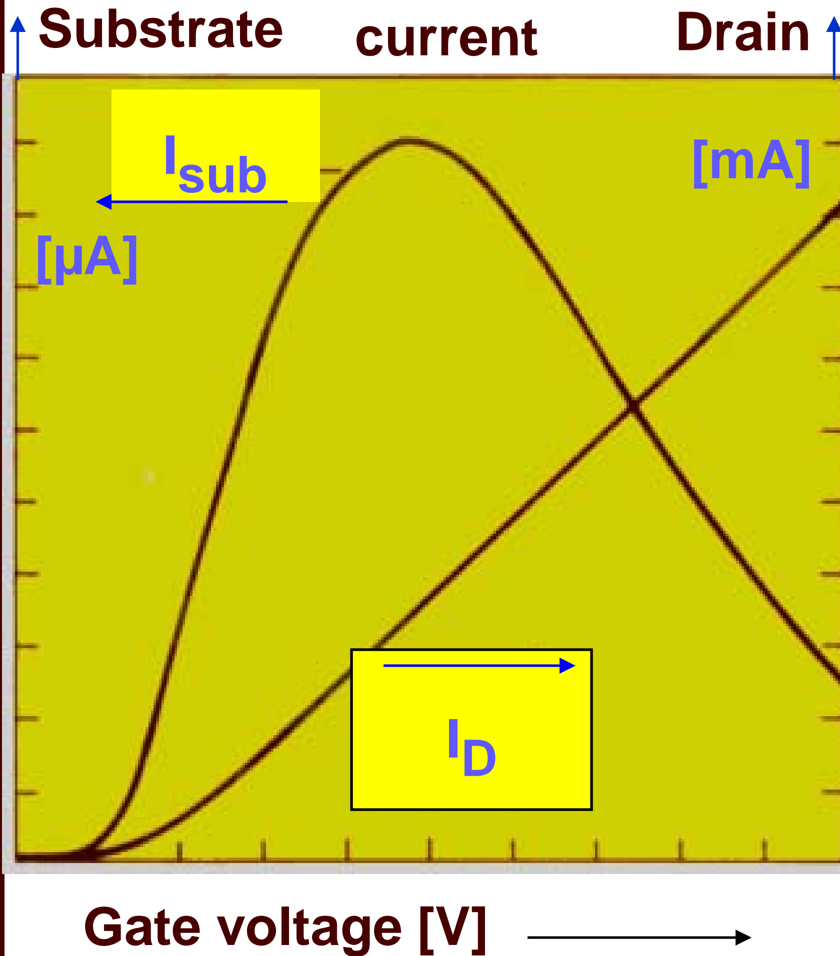
X 25



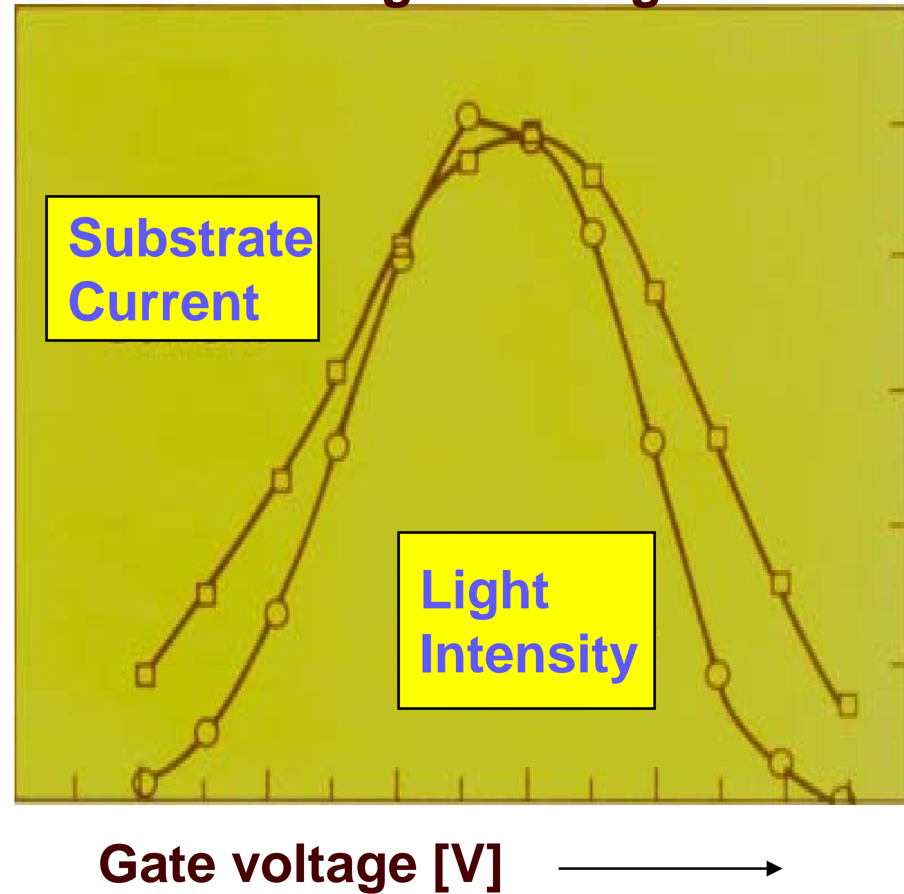
X 100

Emission images at magnification:

Correlation of MOSFET Light Emission to Electrical Operation Mode

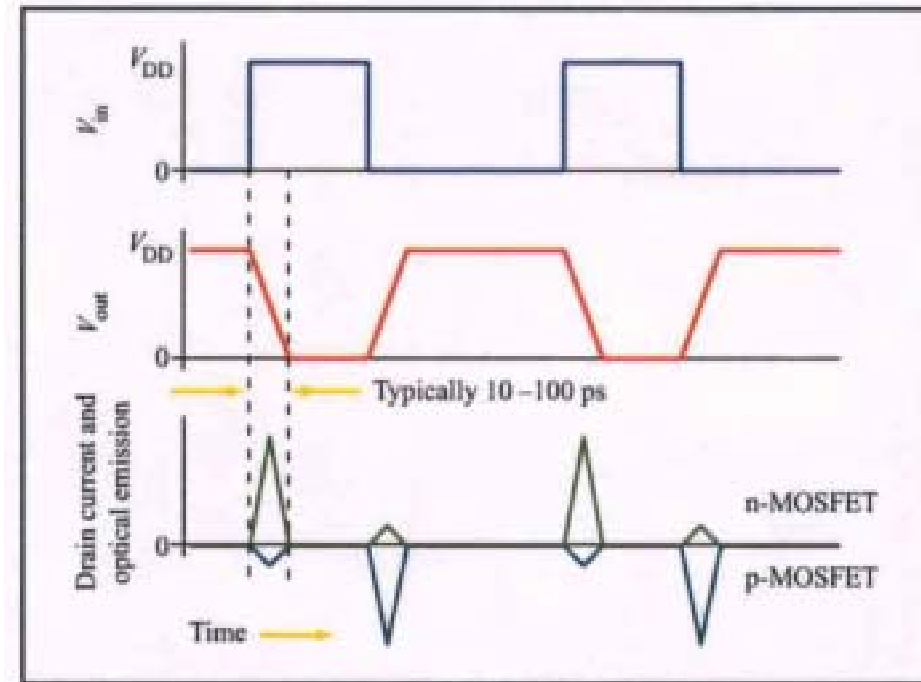


Light emission and substrate current vs. gate voltage



Dynamic Photon Emission in CMOS

- Photon Emission in Switching Phase of FET
- Required Time Resolution: 30 - 40 ps
- Measurement Challenge: ~ 1 photon / 10^5 events
- Stroboscopic Imaging: IC Signal Tracing



All figures from J.C. Tsng, Picosecond imaging circuit analysis

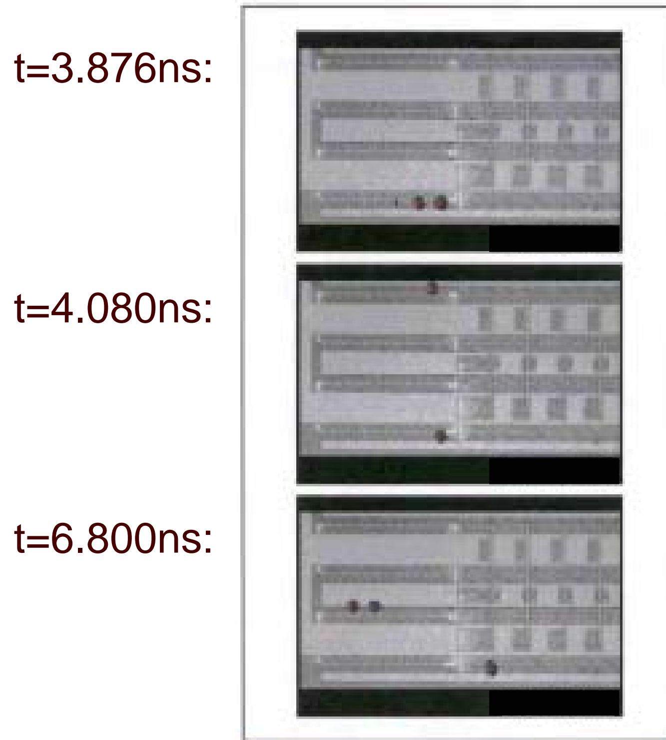
Design Verification: Signal Propagation in IC visualized with Dynamic Photon Emission

Example: ring oscillator:

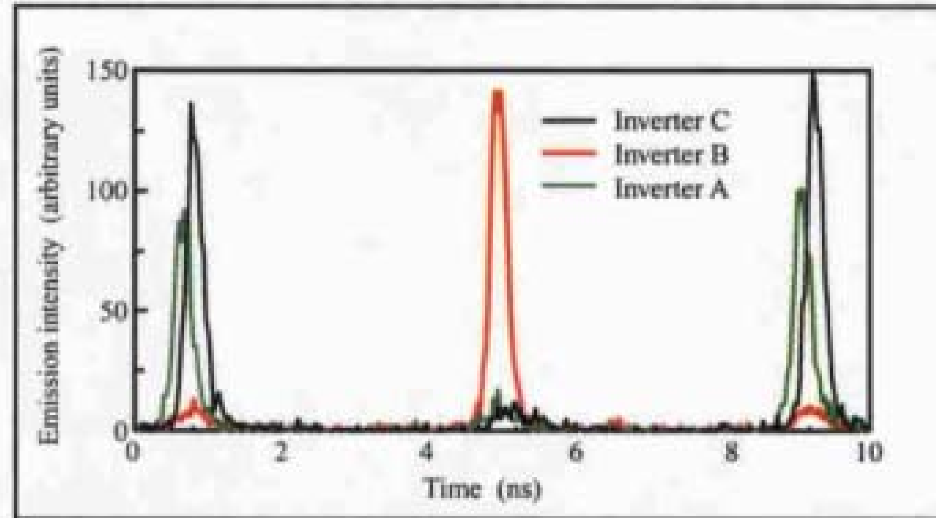
t=3.876ns:

t=4.080ns:

t=6.800ns:



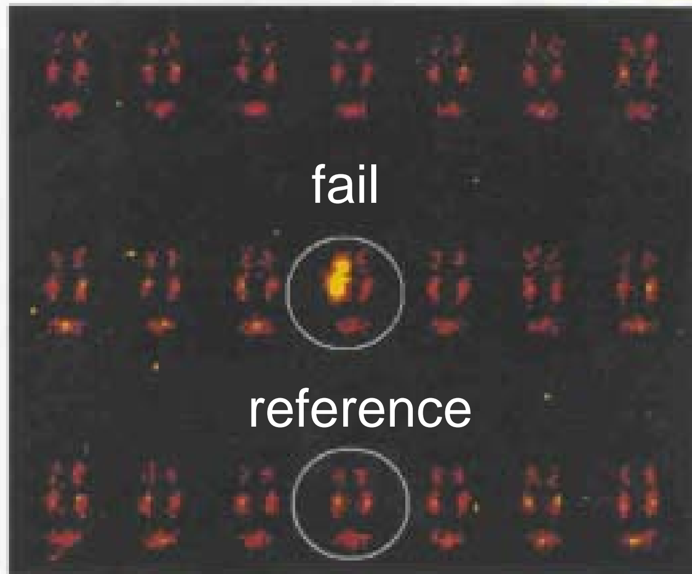
Emission from a ring oscillator at various times.



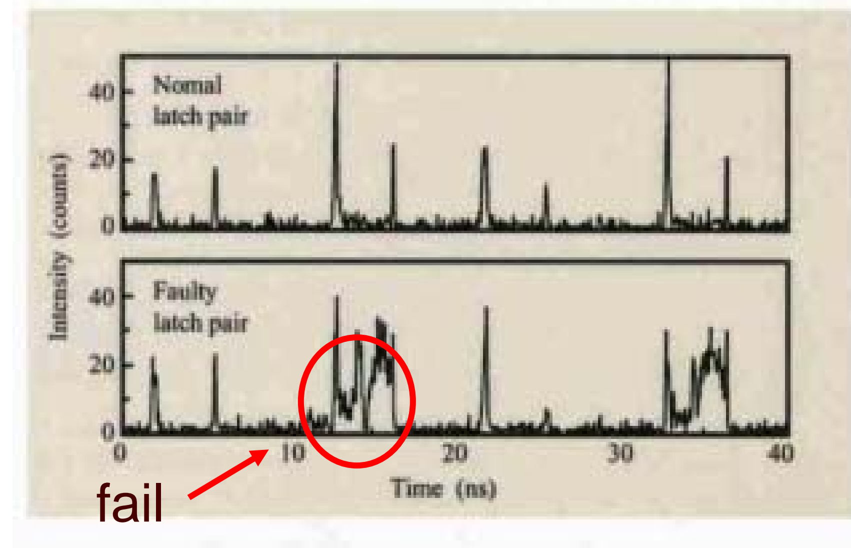
Three ‚optical waveforms‘ of switching induced light emission from neighbouring inverters of the ring oscillator;
Vdd -> 0V: high intensity
0V -> Vdd: low intensity

All figures from J.C. Tsng, Picosecond imaging circuit analysis

Design Verification & Failure Analysis: Identification and Localization of Erratic Device



Time integrated image of light from a register file while running a test pattern producing a fail

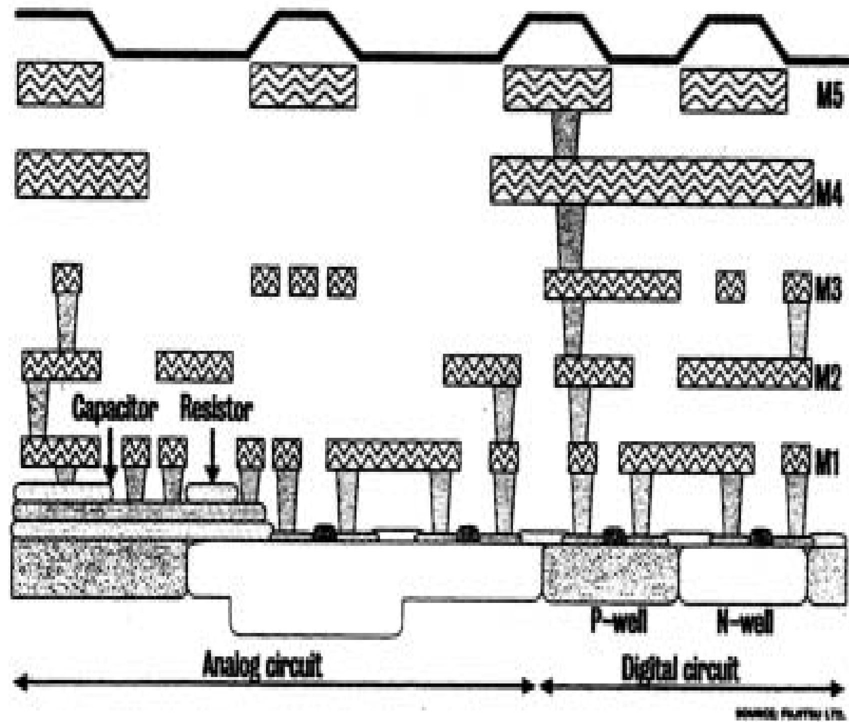


‚optical waveform' from normal and faulty latch pair

All figures from J.C. Tsng, Picosecond imaging circuit analysis

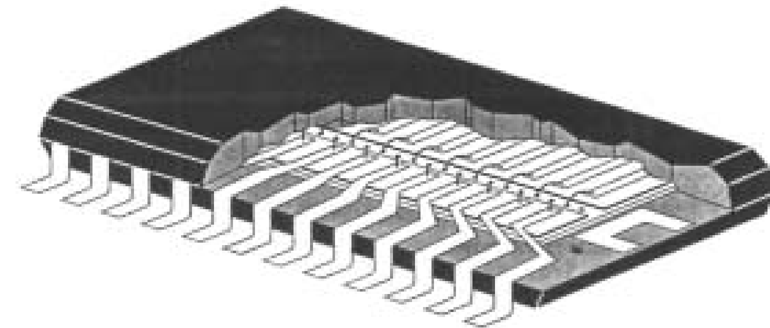
Why FA through Backside of the Die?

Multi-Level Metallization

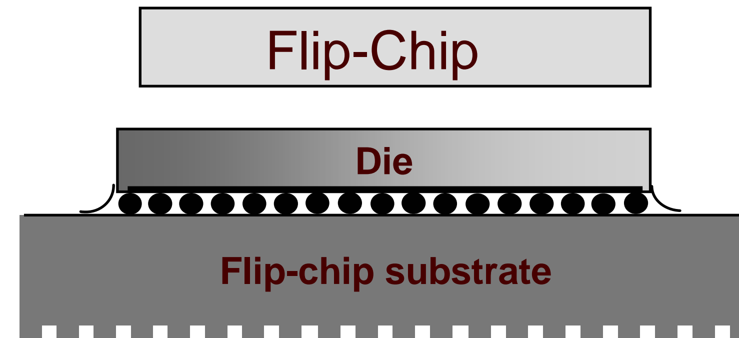


New Packages

LOC (Lead On Chip)

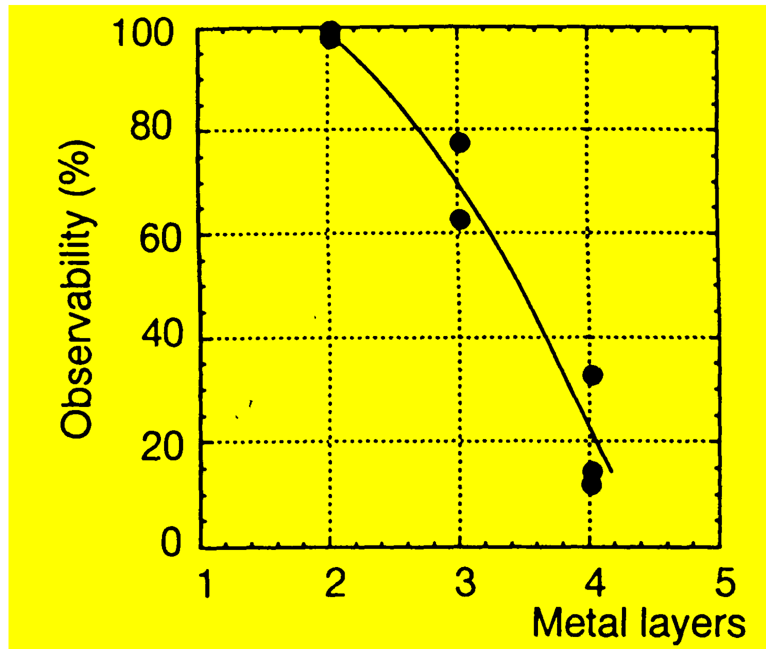


Flip-Chip



Data taken from Fujitsu

Observability of Signals with Beam Techniques Drastically Reduced by Multi Layer Wiring



Data taken from N. Kuji et al., NTT, ESREF97

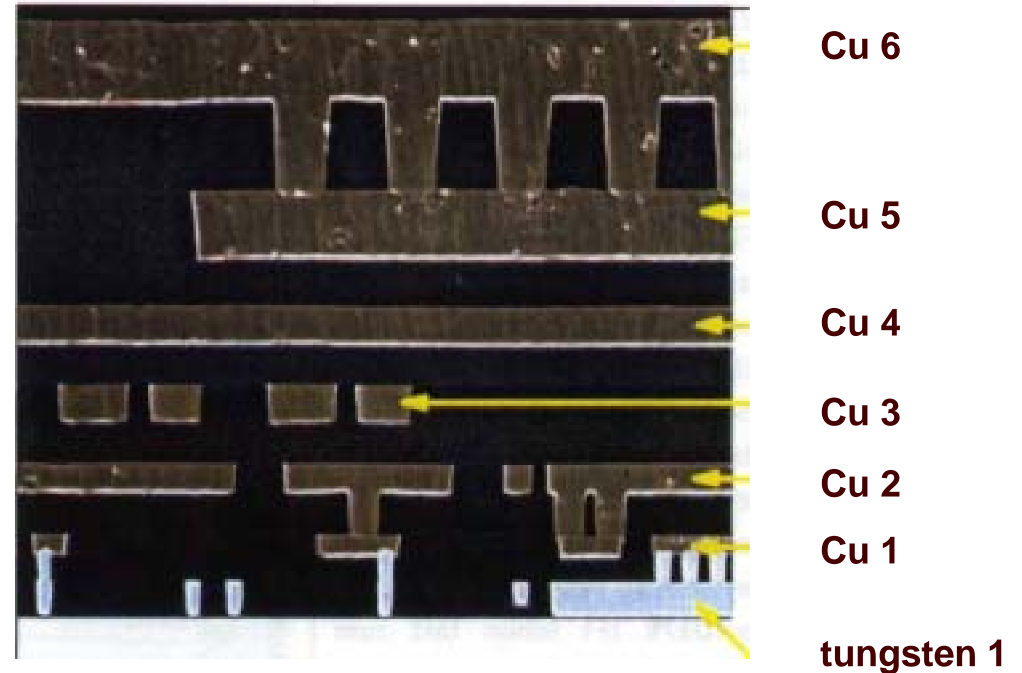
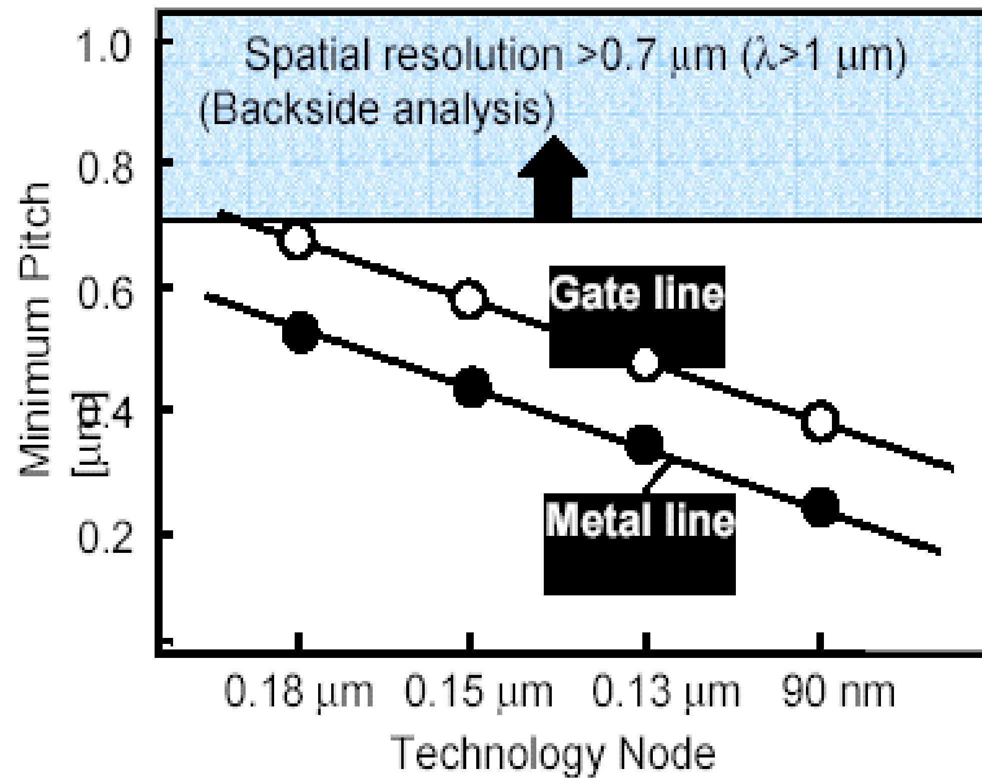


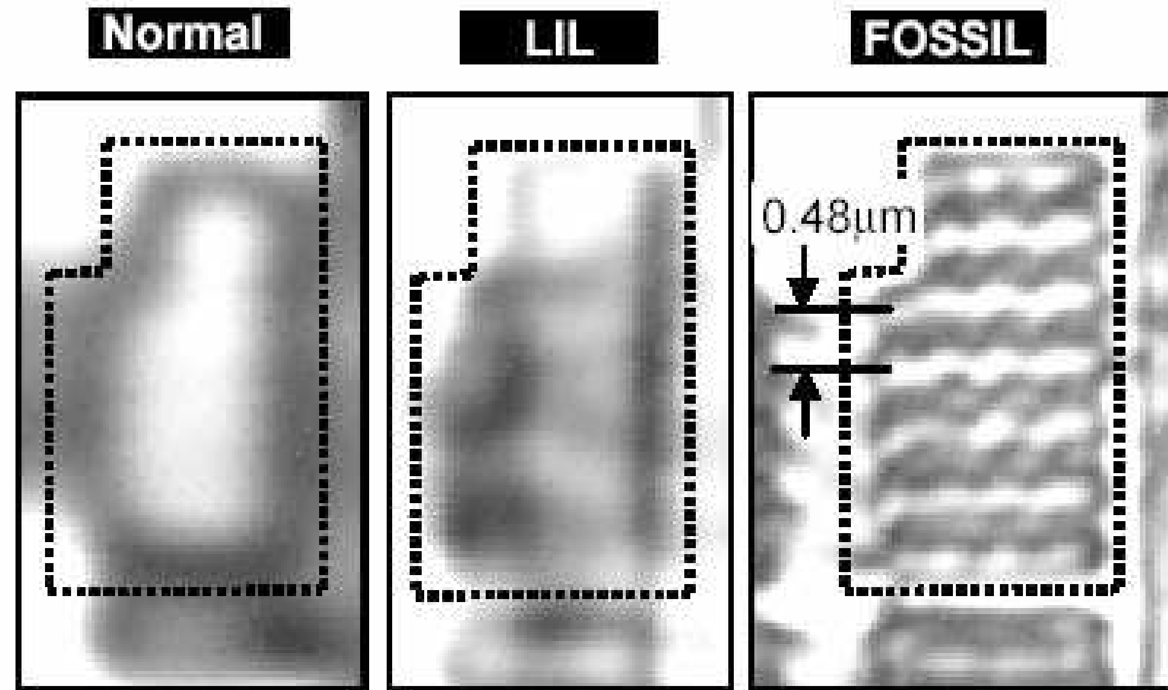
Image taken from IBM Research Labs

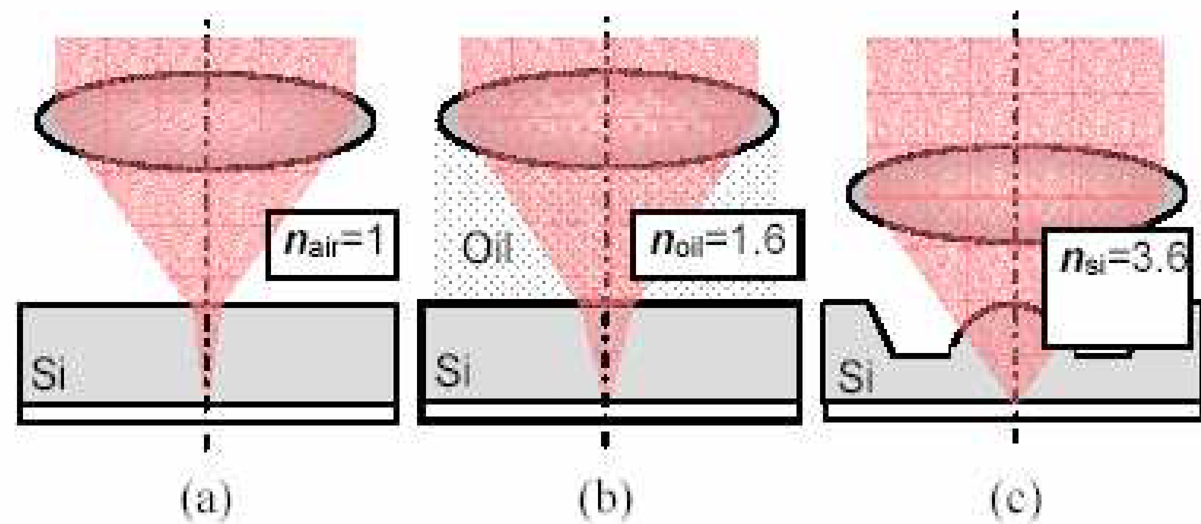
Challenge of Analysis Techniques Through Chip Backside: IR Optics Resolution vs. Feature Size



berlin

Resolution of different immersion media
gas, air (a), liquid, oil(b), solid, Si (c)





Paradigm Shift in Functional Analysis of Semiconductor Devices

Functional Analysis through Chip Backside

- Gain of material pervasive techniques
- Re invent full analysis process
- Systematic understanding of effects lacking = techniques not yet employed to their potential

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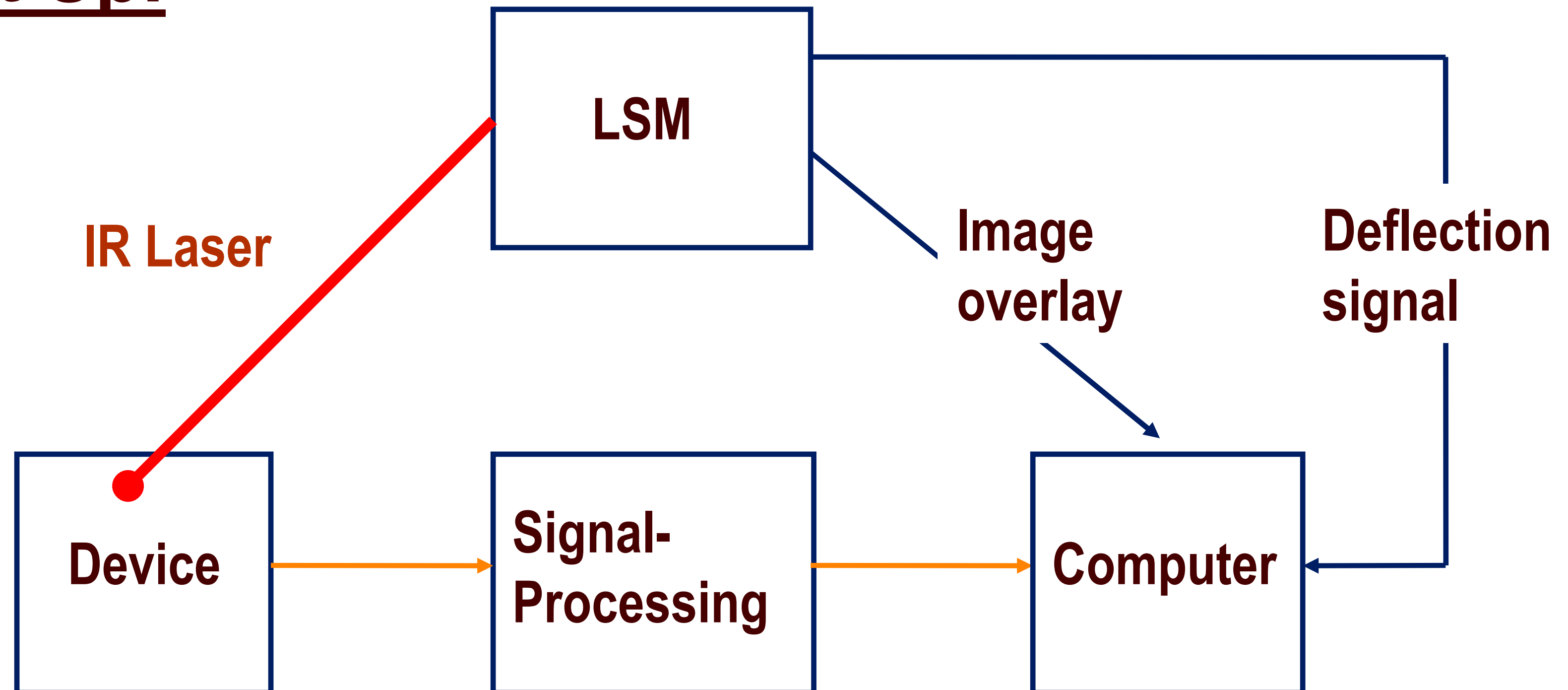
Device Localization with Laser Stimulation

Device Repair (Circuit Edit) with FIB

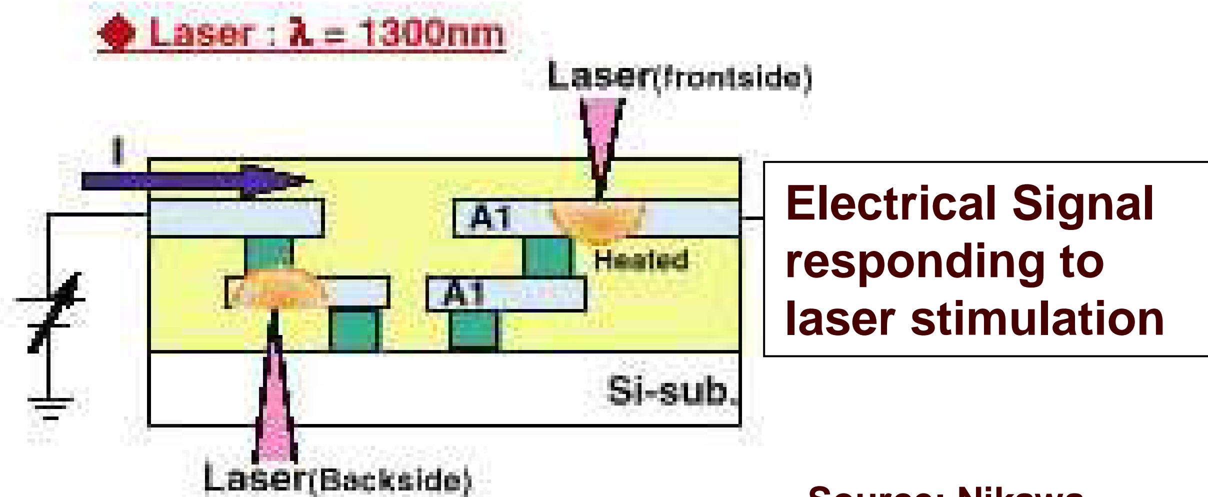
Where we want to go

Beam Induced Device Stimulation

Set Up:



Principle of Laser Induced Thermal Stimulation

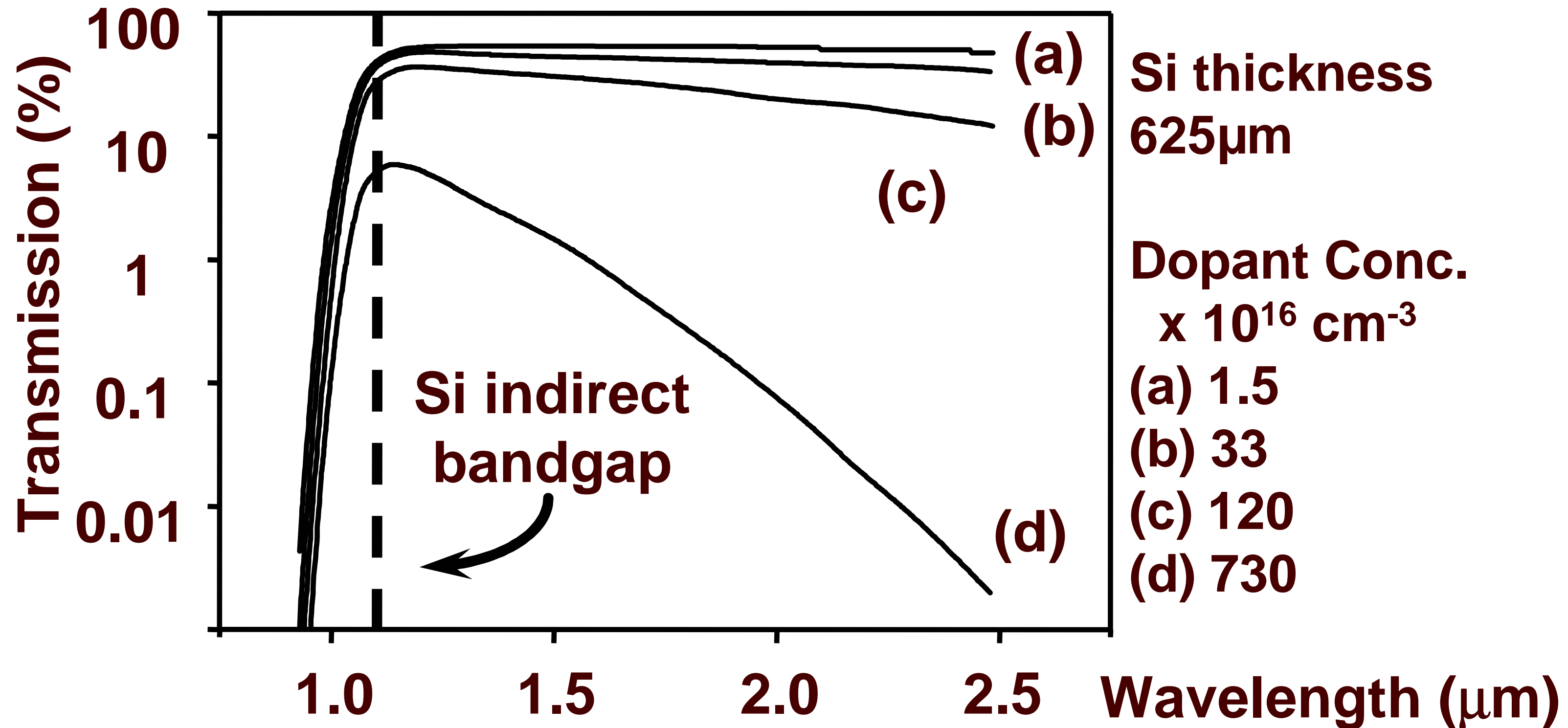


Electrical Signal responding to laser stimulation

Source: Nikawa

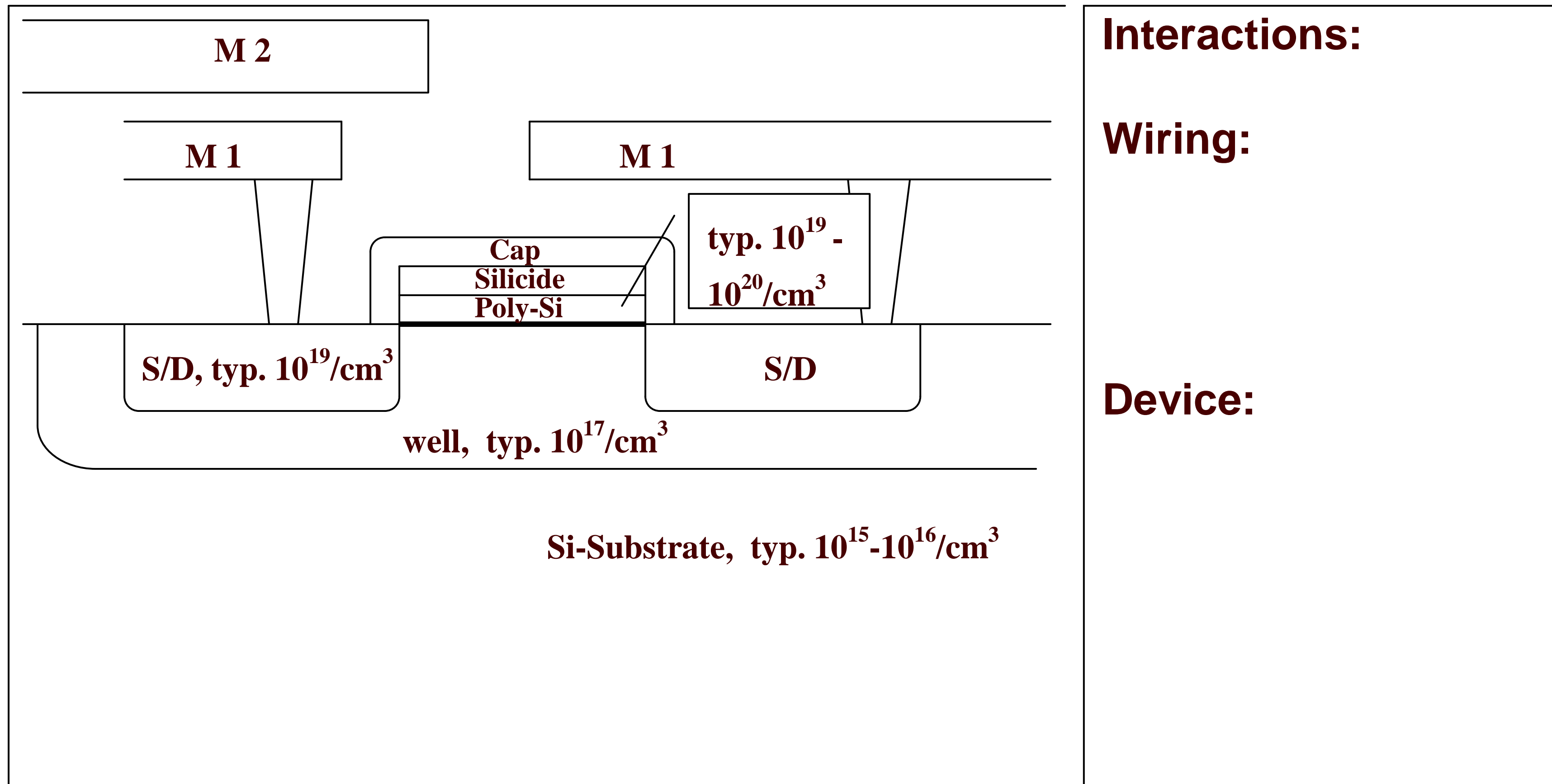
High ΔR if R high: sensitive to high R interconnects
Local thermovoltage at high currents: sensitive to low R sections
Problem: Signal Path from excitation to terminal not well defined

Thermal Stimulation of Silicon Device by IR Laser
Intraband Free Carrier Absorption :



IR Absorption in Highly Doped Layers: 0.1 to 0.05% of 1.3µm Laser power → Local Heating of Active Device

Thermal Laser Stimulation in Metal Wire & in Semiconductor Device

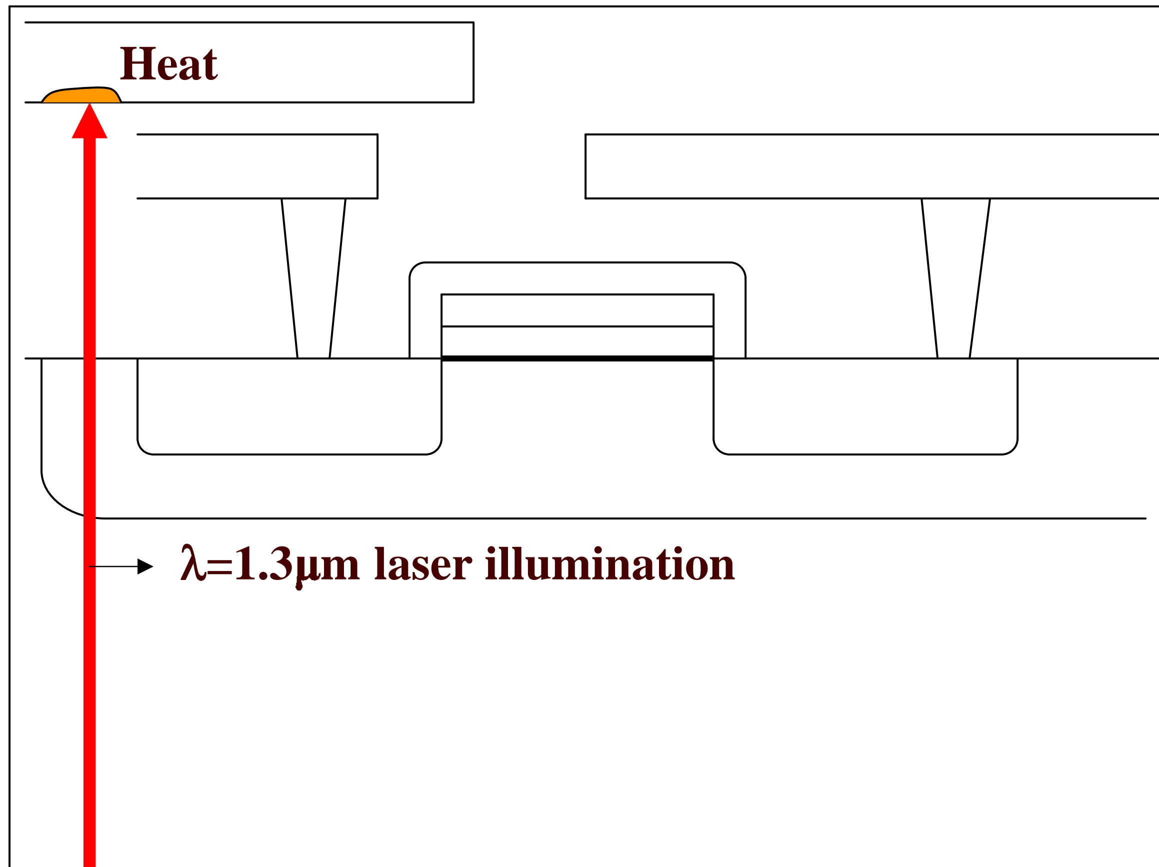


Interactions:

Wiring:

Device:

Thermal Laser Stimulation in Metal Wire & in Semiconductor Device



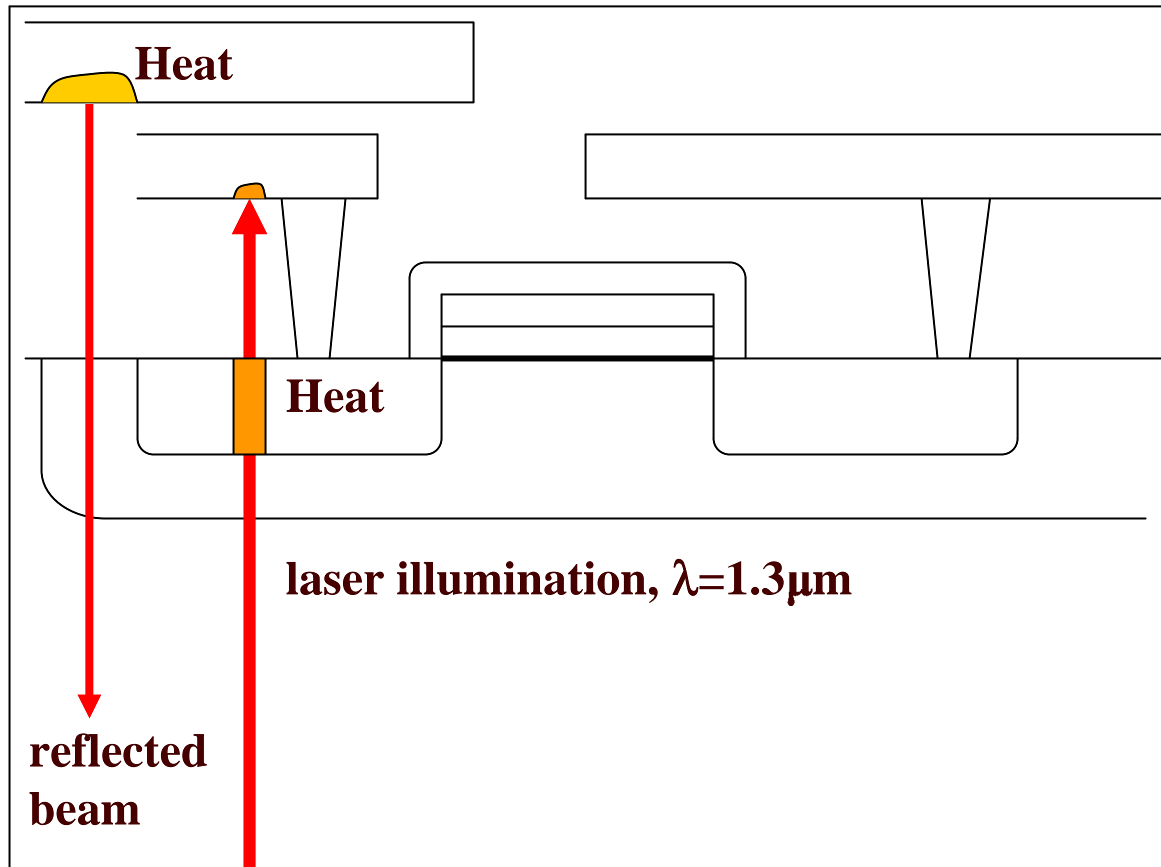
Interactions:

Wiring:
- Voltage Alteration
- Resistive Change

Device:

Thermal Laser Stimulation

in Metal Wire & in Semiconductor Device



Interactions:

Wiring:

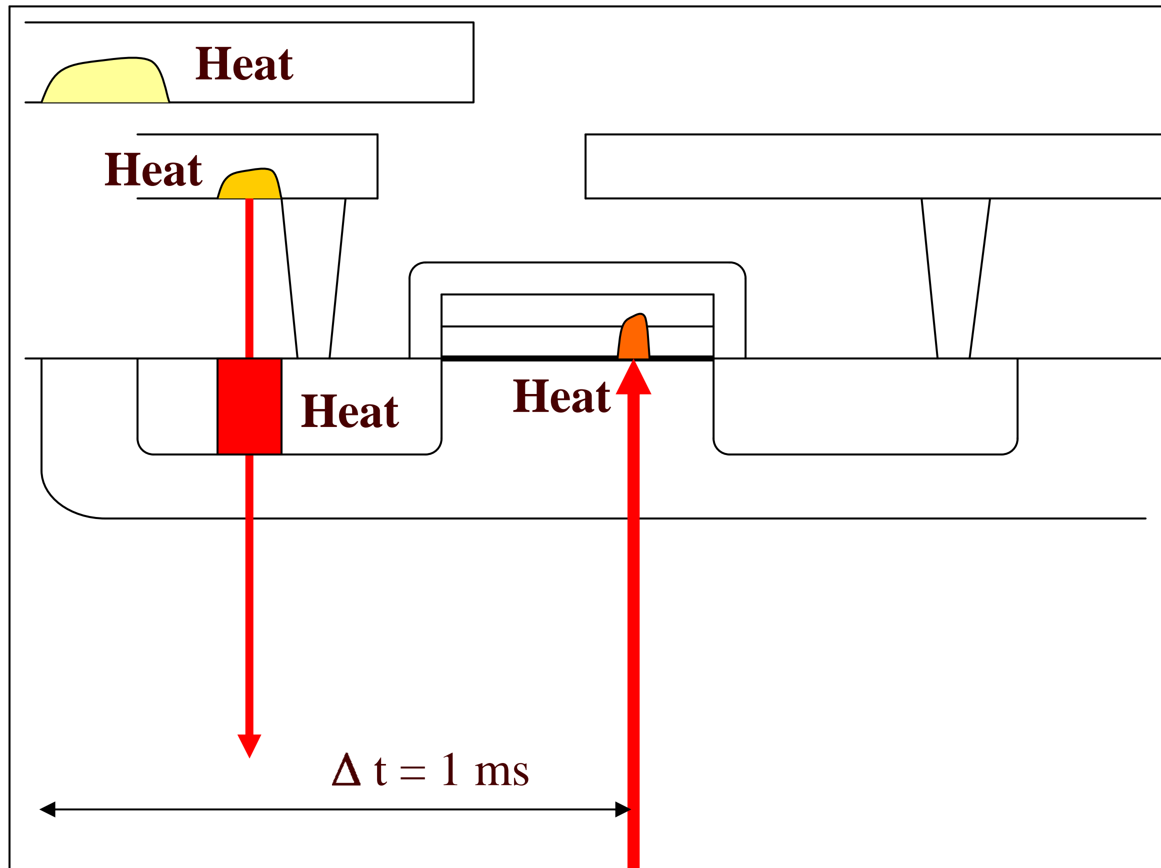
- Voltage Alteration
- Resistive Change

Device:

- Performance Reduction
  - Mobility
  - Vτ
  - Speed

Thermal Laser Stimulation

in Metal Wire & in Semiconductor Device



Interactions:

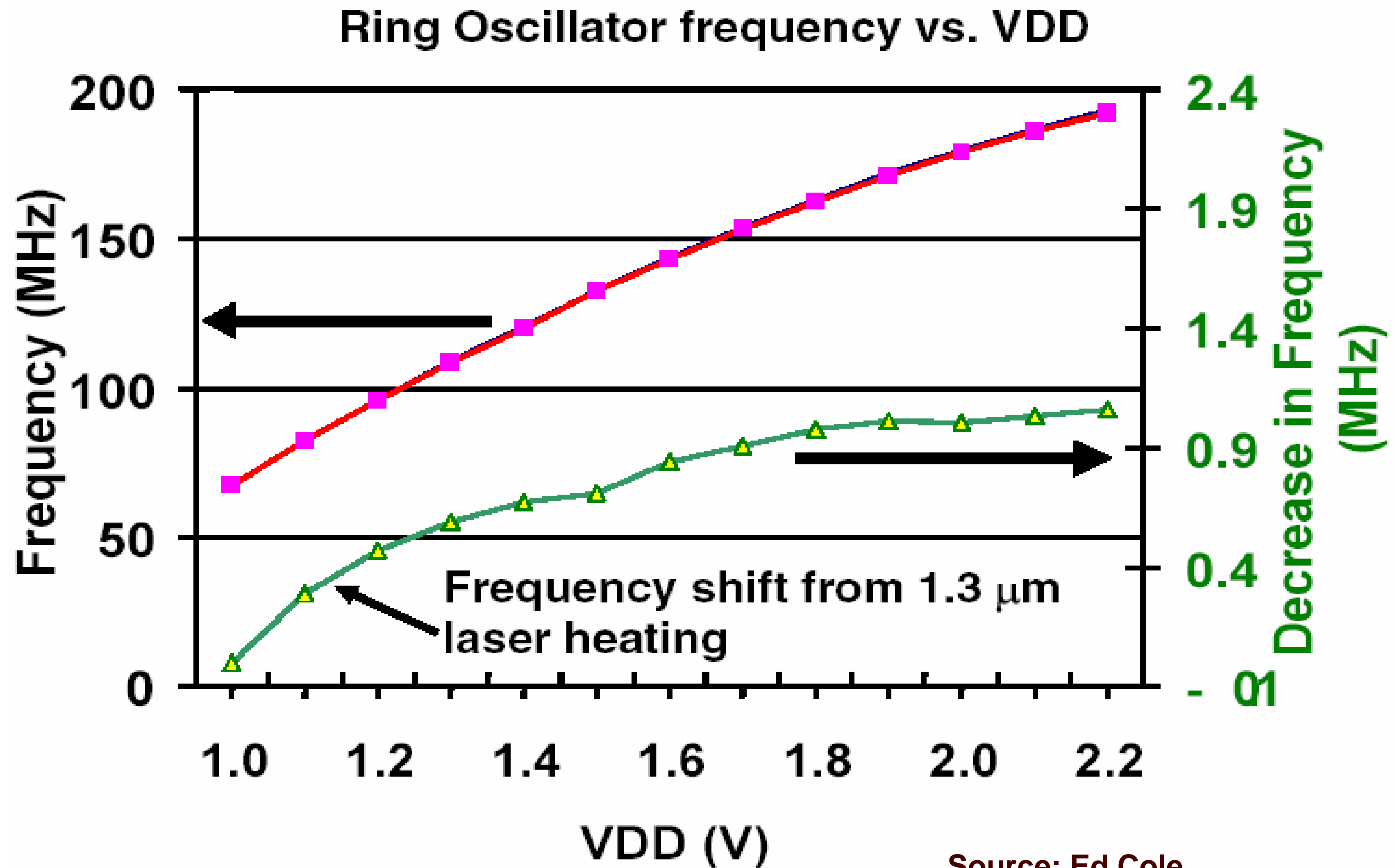
Wiring:

- **Voltage Alteration**
- **Resistive Change**

Device:

- **Performance Reduction**
  - **- Mobility**
  - **- Vτ**
  - **- Speed**

Soft Defect Localization - FET



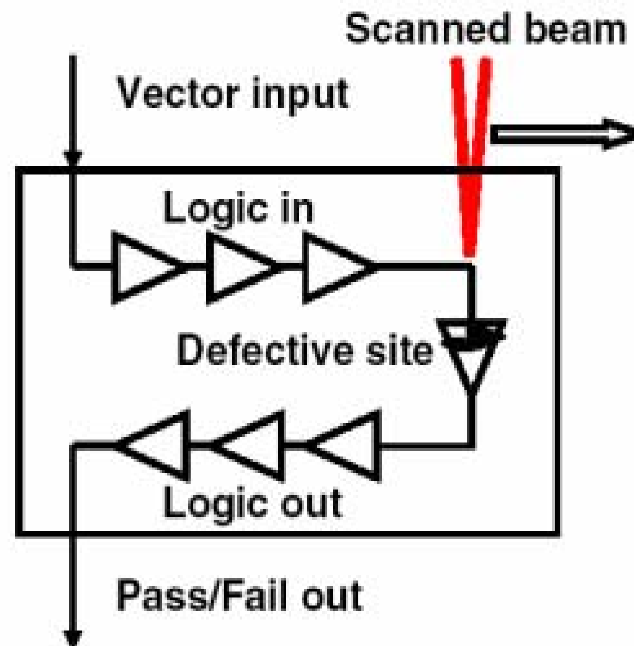
Source: Ed Cole

Soft Defect Localization

Soft Defect: Test Fail occurring only in special Environment

Source: Ed Cole

- Vector input to IC
- Laser heating changes pass/fail condition
- Pass/Fail condition used to produce image contrast
- 1.3 µm laser wavelength avoids photocurrents



TUB Research Result:
Quantitative Investigation of FET Device Parametrics with Thermal Laser Stimulation to be submitted 10/03

TLS Thermal Laser Stimulation of Soft Defects:

Will be important Innovation in Localization of IC Device Functionality and Failures

- Probe = parametric modification of device
- Signal path for detection defined by tester
- Can determine gradual device performance
- Understanding of effects scattered

=> research necessary for proper use in industry

Next Generation Localization Techniques

- Key: further improvement of turnaround

- **Detection of further signals emitted by device, i.e. magnetic field (SQUID)**

- **Interaction of circuitry time delay and propagation of induced signal**

- Signal tracing with all available dynamic techniques (Laser induced, photon emission, other?)

Outline:

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Device Dynamics Make the Difference in Functional Analysis

Challenges of Backside Approach

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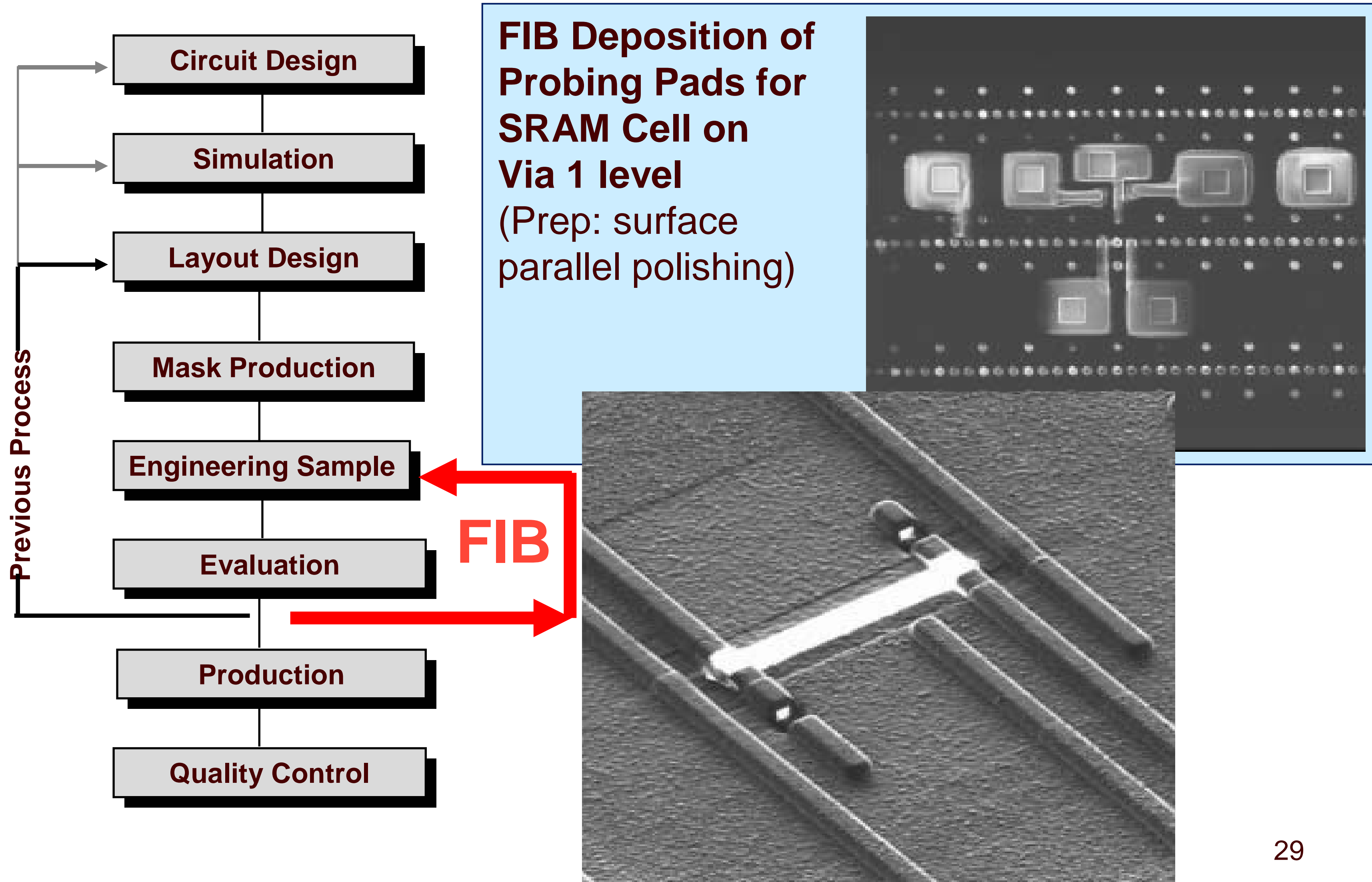
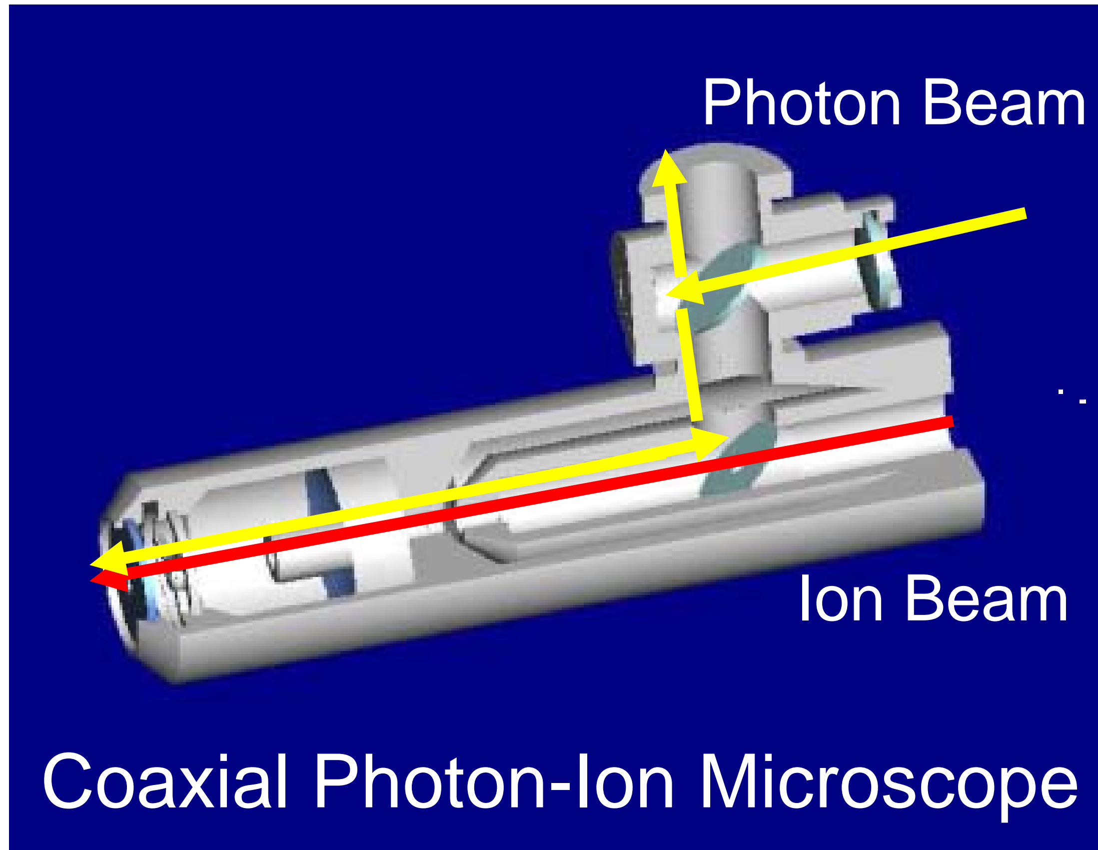
Device Repair (Circuit Edit) with FIB

Where we want to go

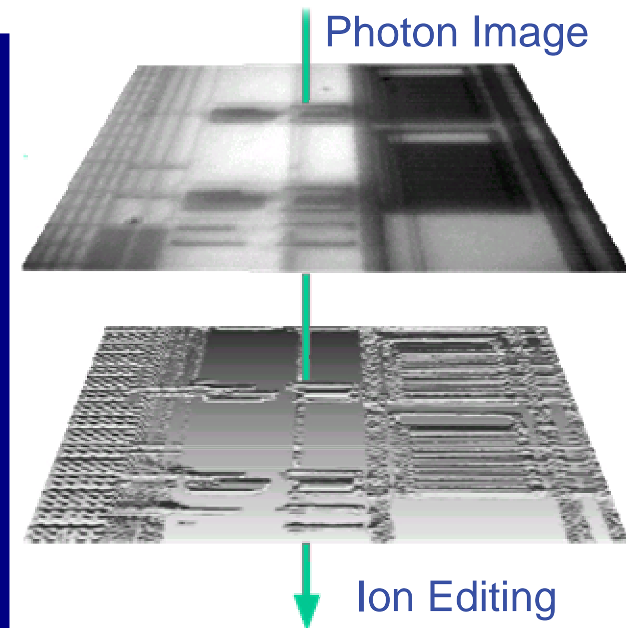
Device Repair (Circuit Edit) with FIB: Short Redesign Loop and Access to Cells



The OptiFIB Column

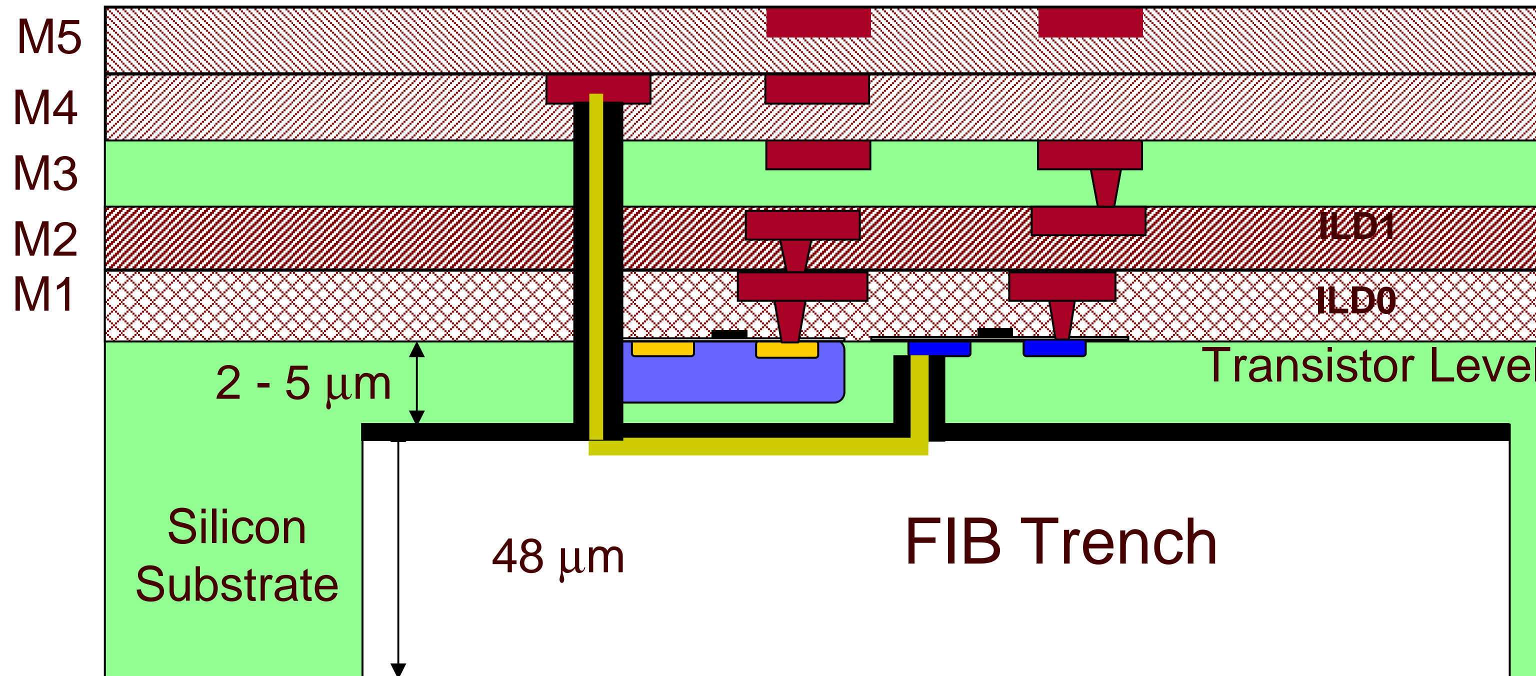


Simultaneous Imaging & Editing



100nm FIB Placement Accuracy

FIB Editing of ICs through Si Backside



Very thin remaining bulk Si

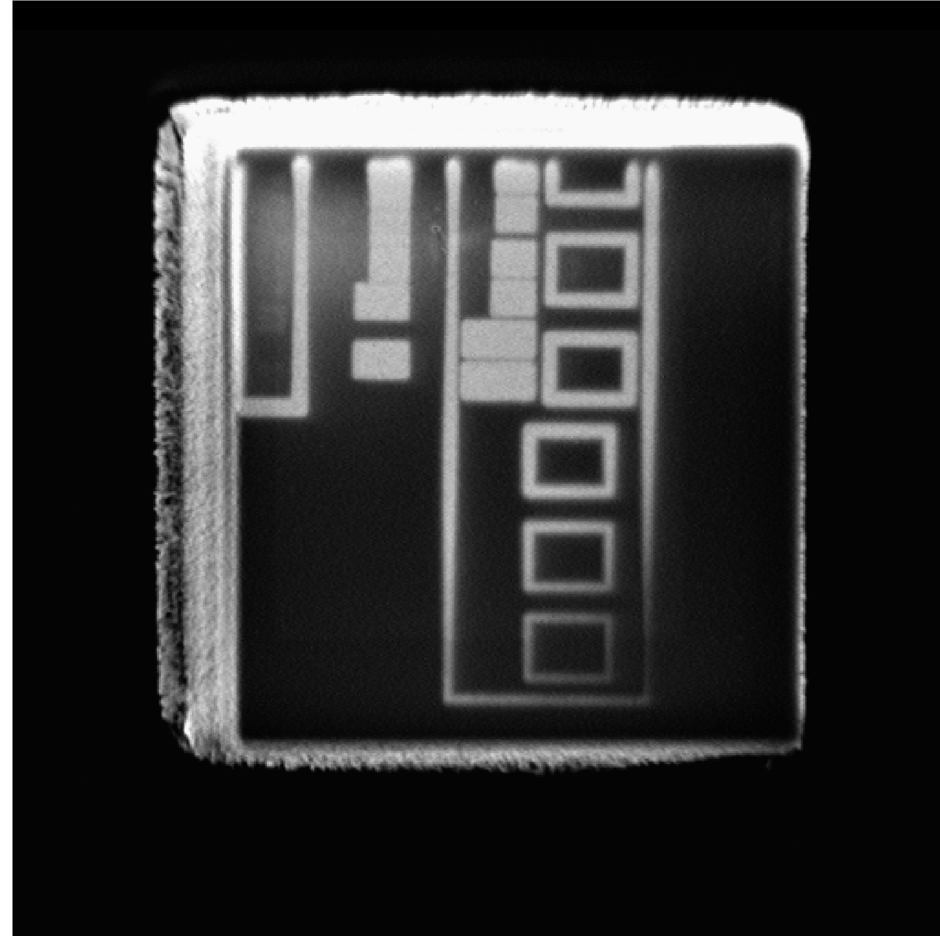
- Risks: Flatness, Endpoint, Navigation

Voltage Contrast by Silicon Active Volume

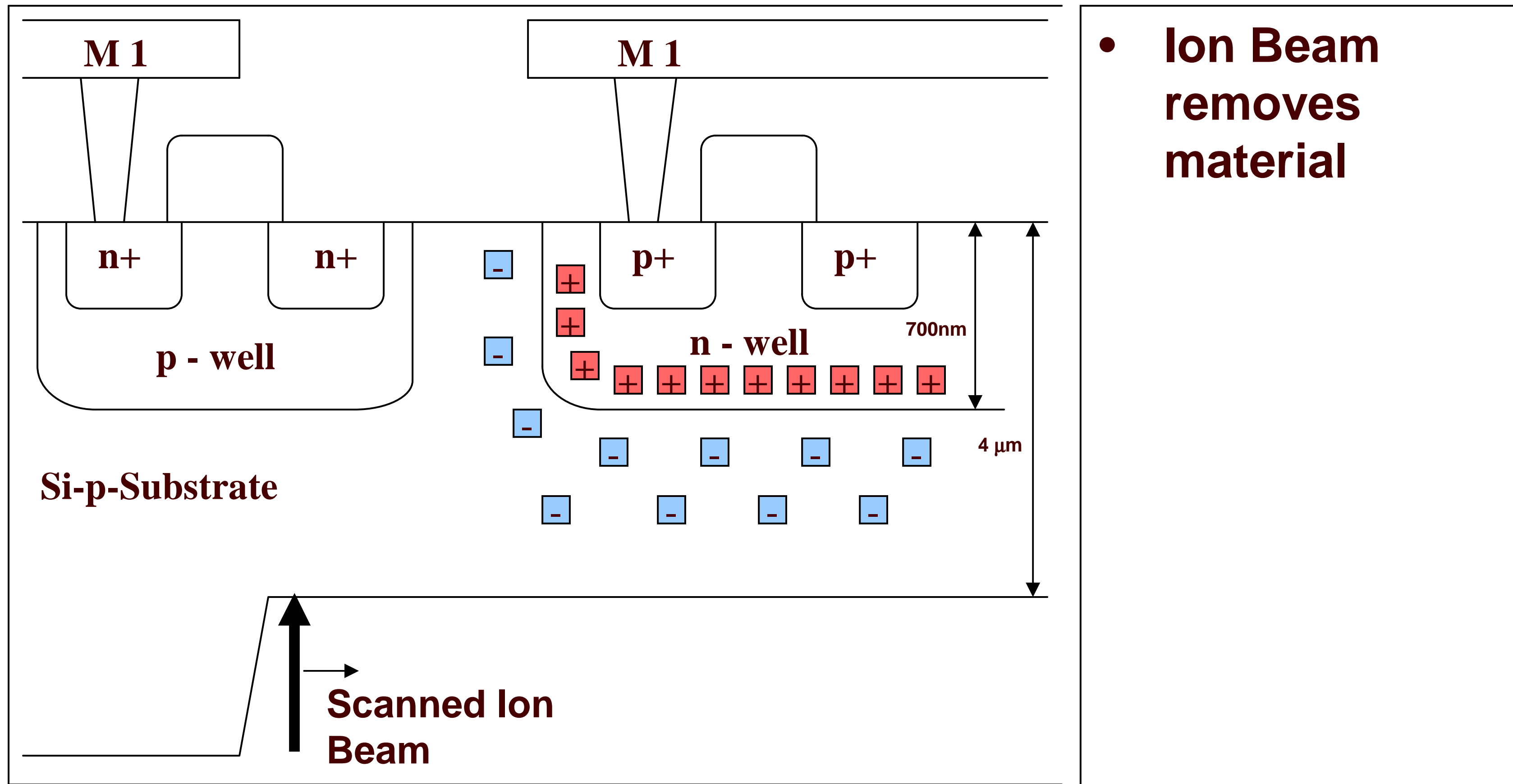
TUB Research Result:

FIB Image Contrast of n-Wells for
- Endpoint Control and
- Navigation

to be presented at ESREF & ISTFA 03

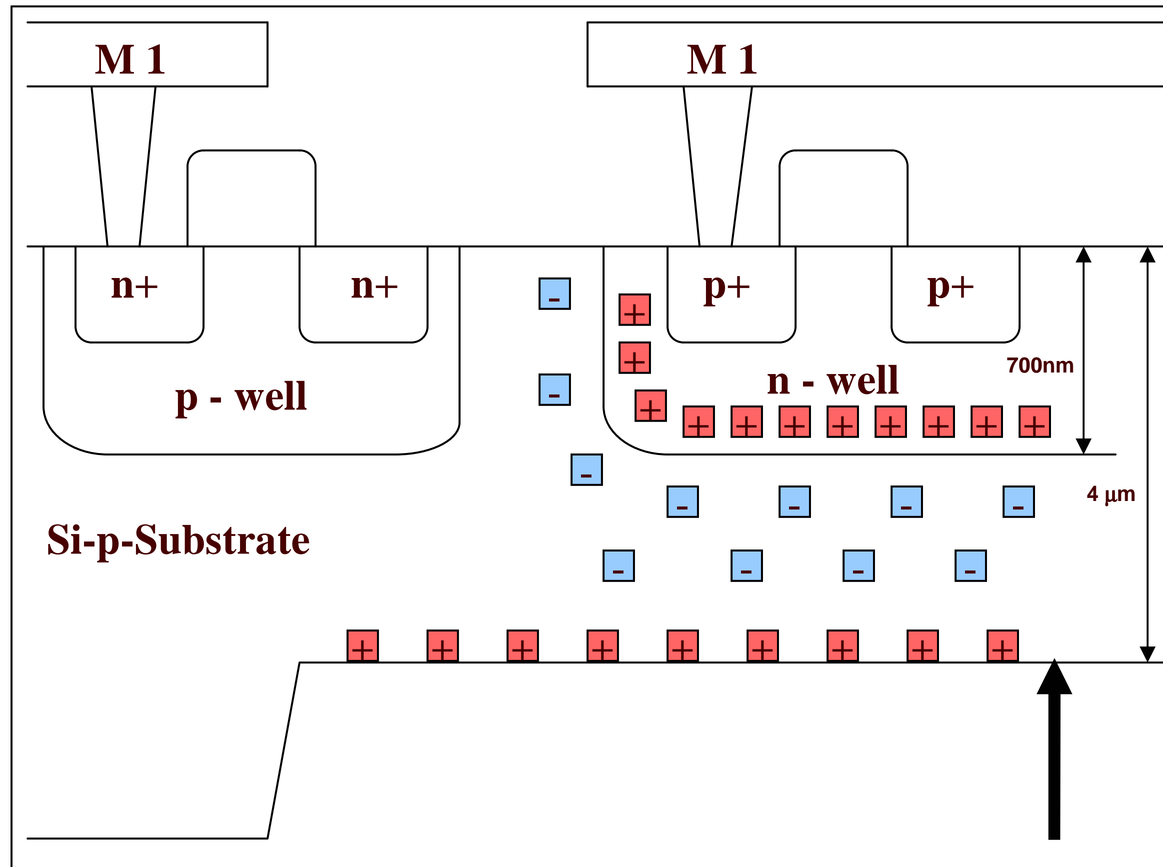


Endpoint Detection for Active Si Volume



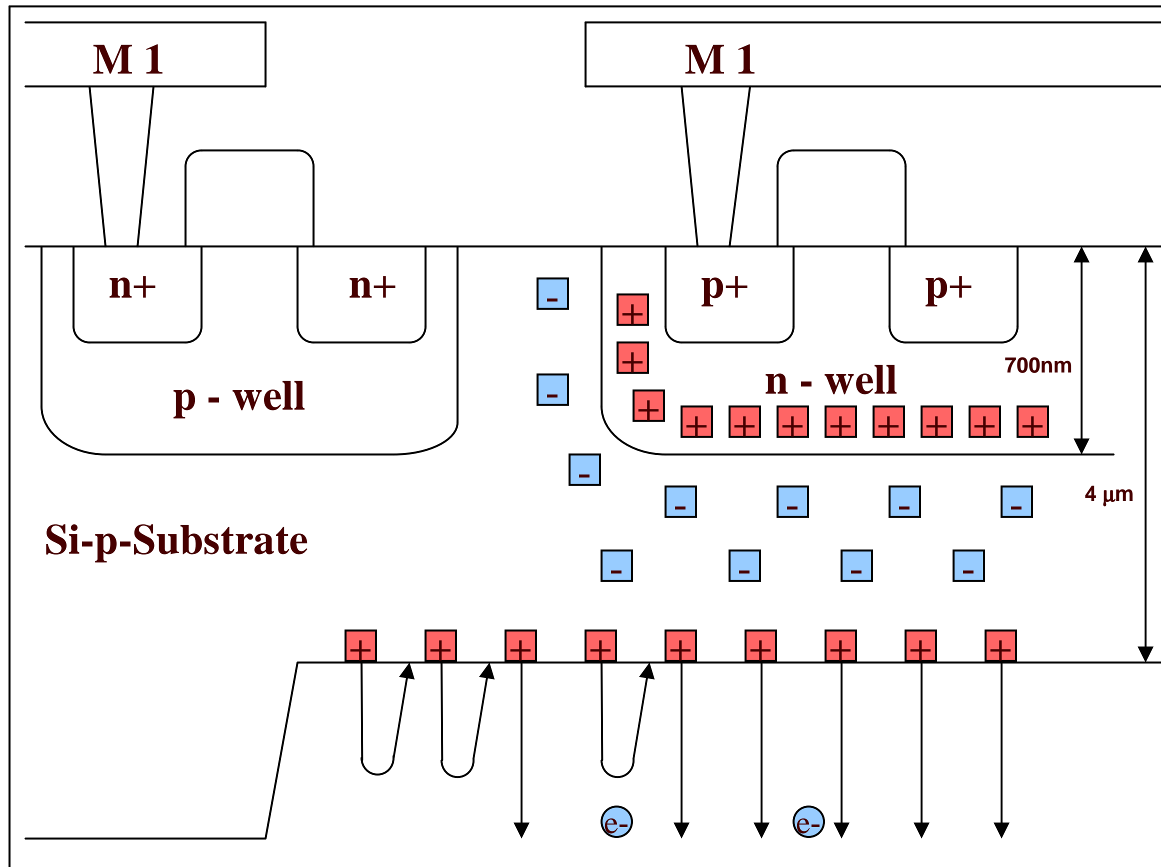
- Ion Beam removes material

Endpoint Detection for Active Si Volume



- Ion Beam removes material
- and implants Ga ions into the back surface.

Endpoint Detection for Active Si Volume



- Ion Beam removes material
- and implants Ga ions into the back surface.
- Influence of SCR causes contrast of secondary particle emission rate

Semiconductor Device & Analysis Center Berlin: **Where we want to go**

- **Establish TUB as Solution Center for Advanced Analysis Problems in Electronic Devices**

Microelectronics:

- **Dynamics of Device and Analysis**
- **Pervasive Techniques (i.e. SQUID)**
- **Focused Ion Beam Processes for Edit in Si**

Power Devices & Compound Semiconductors:

- **Adaption of Localization Techniques to Discrete Devices, Band Gap and Mechanisms of Direct SC**
- **Adaption of FIB processes to Material Components**