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Discussion on the Model of Laser Induced Faults in SRAM Memory cells

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Context

- Faults are often modeled according two fault models:
  - Bit Set (resp. Reset)
  - Bit Flip

- Not much analysis on the fault model in SRAM:
  - Faults type
  - Effects of the fault injection on the SRAM

➡ Analyze the fault model on SRAM memory cell

Contents

- Introduction
  - Fault model
  - Fault injection mechanism
  - Sensitivity zones
- Experiments on the SRAM cell
  - Description of the SRAM memory cell
  - Sensitivity map
- Spice Simulation
  - Sensitivity map
  - Simulation on the edge zone
- Conclusion & Perspectives

Introduction

Bit set(resp. reset)

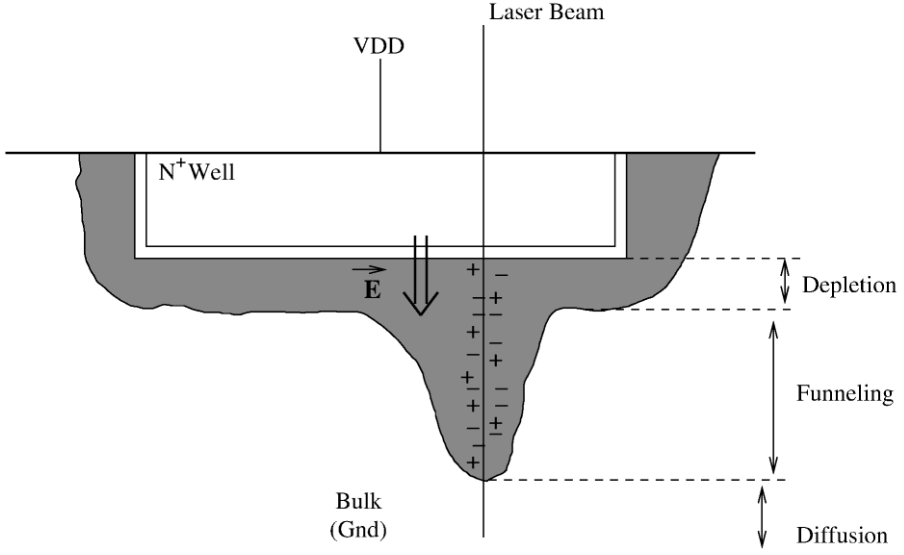
- Its value is changed: ‘0’ => ‘1’(resp. ‘1’=>’0’)
- Result in a calculation error
- Unfaulted if its value was already ‘1’(resp. ‘0’)
- **Allow to mount safe error attacks**

Bit flip

- Independent of the data value (‘0’ => ’1 or ‘1’ => ‘0’)
- Induces a calculation error
- Better fault injection rate
- Quicker analysis of the faulted results

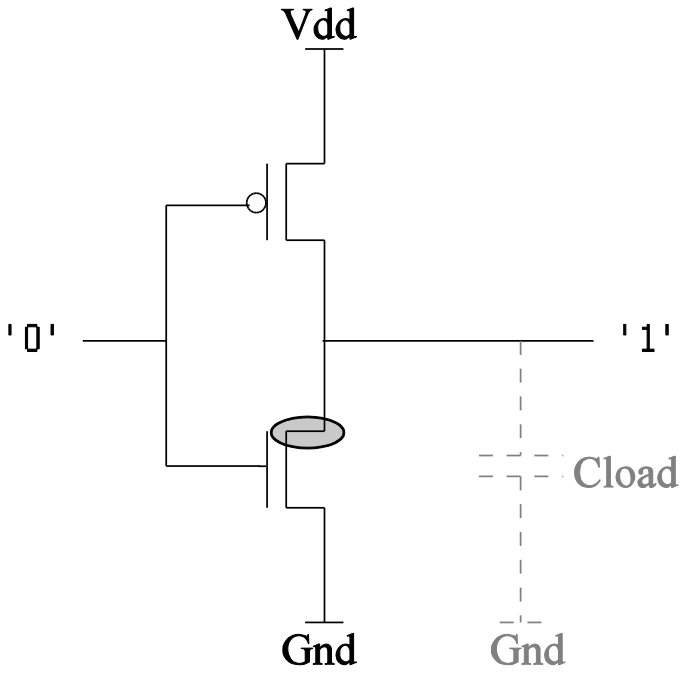
Fault injection mechanism

- Creation of electron-hole pair along the laser beam due to the photoelectric effect
- Stretch the electric field
- Creation of a transient current
- Possible SEE on PN junction
  - Source and drain of transistors



Sensitivity zones

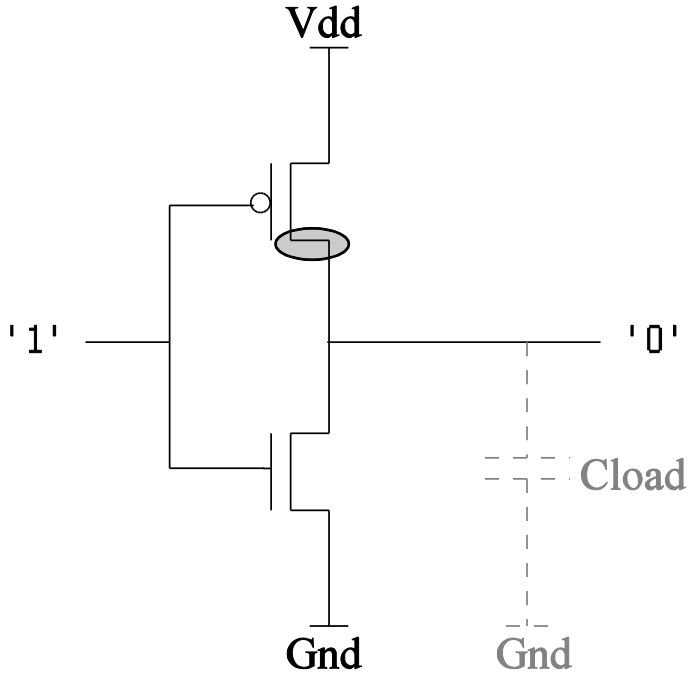
- Inverter's case:
  - 1st Case (output = '1')
    - PMOS ON
    - NMOS OFF
    - Only a strike on drain of NMOS will discharge the load and change the output state



The sensitivity zone is the drain of the OFF NMOS transistors

Sensitivity zones

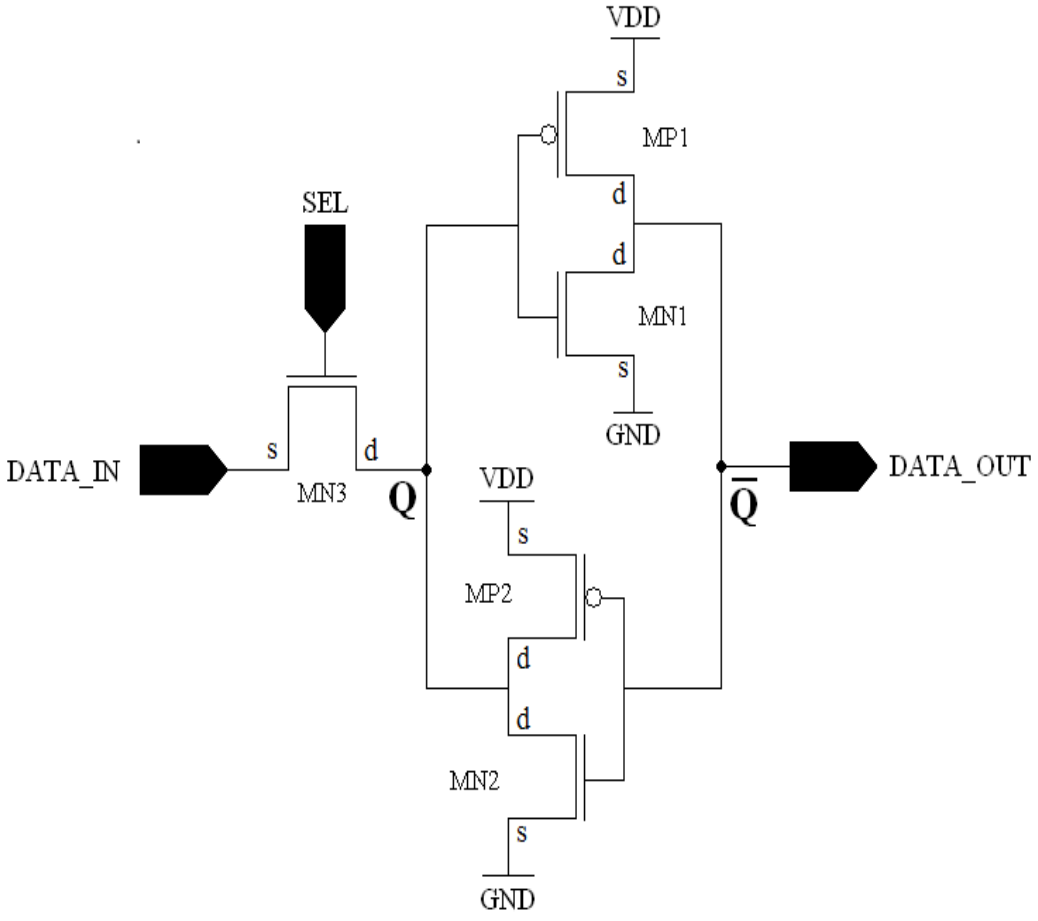
- Inverter's case:
  - 2st Case (output = '0')
    - PMOS OFF
    - NMOS ON
    - Only a strike on drain of PMOS will charge the load and change the output state



The sensitivity zone is the drain of the OFF PMOS transistors

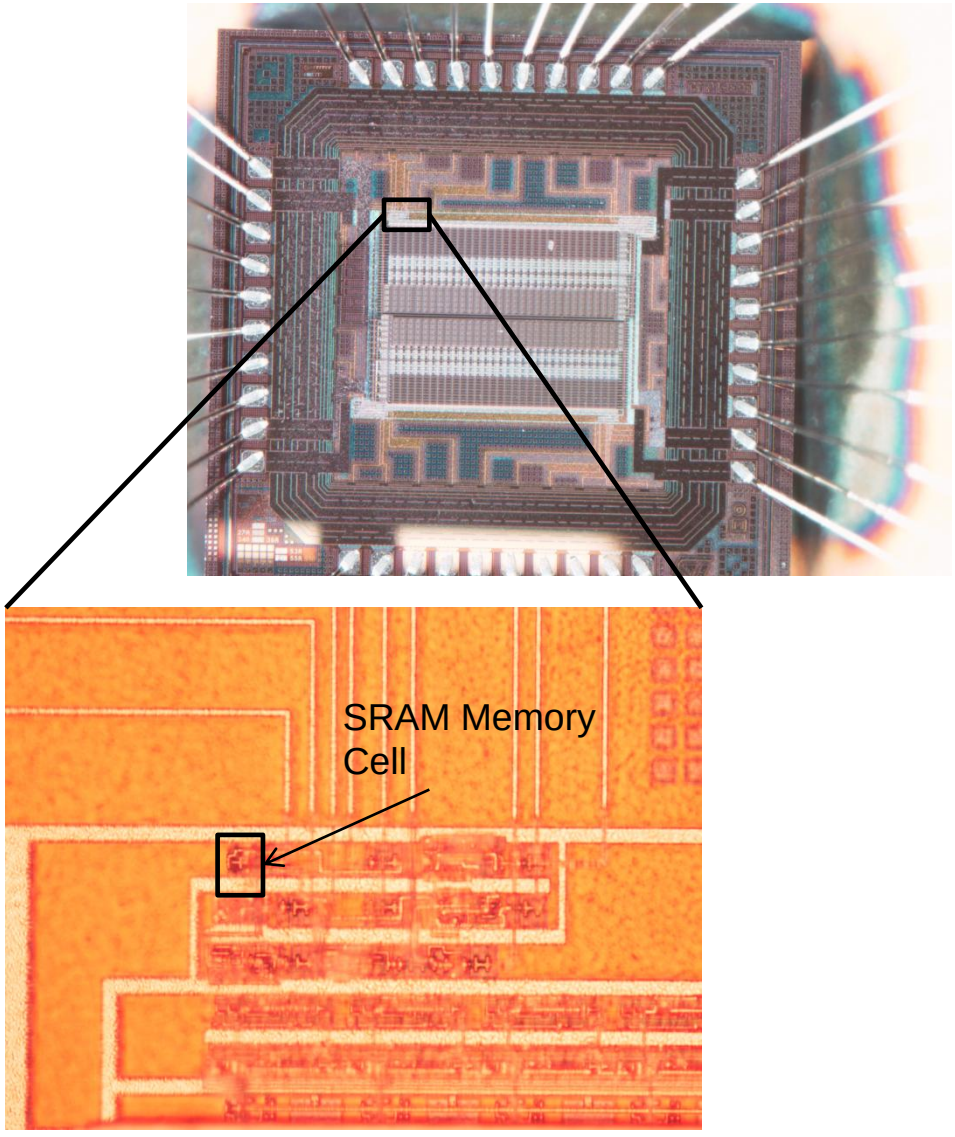
SRAM Memory Cell

- Configuration SRAM (programmable logic)
  - 5 transistors
- 0.25µm CMOS Technology
- Size: 9µm x 4µm



Experimental setup

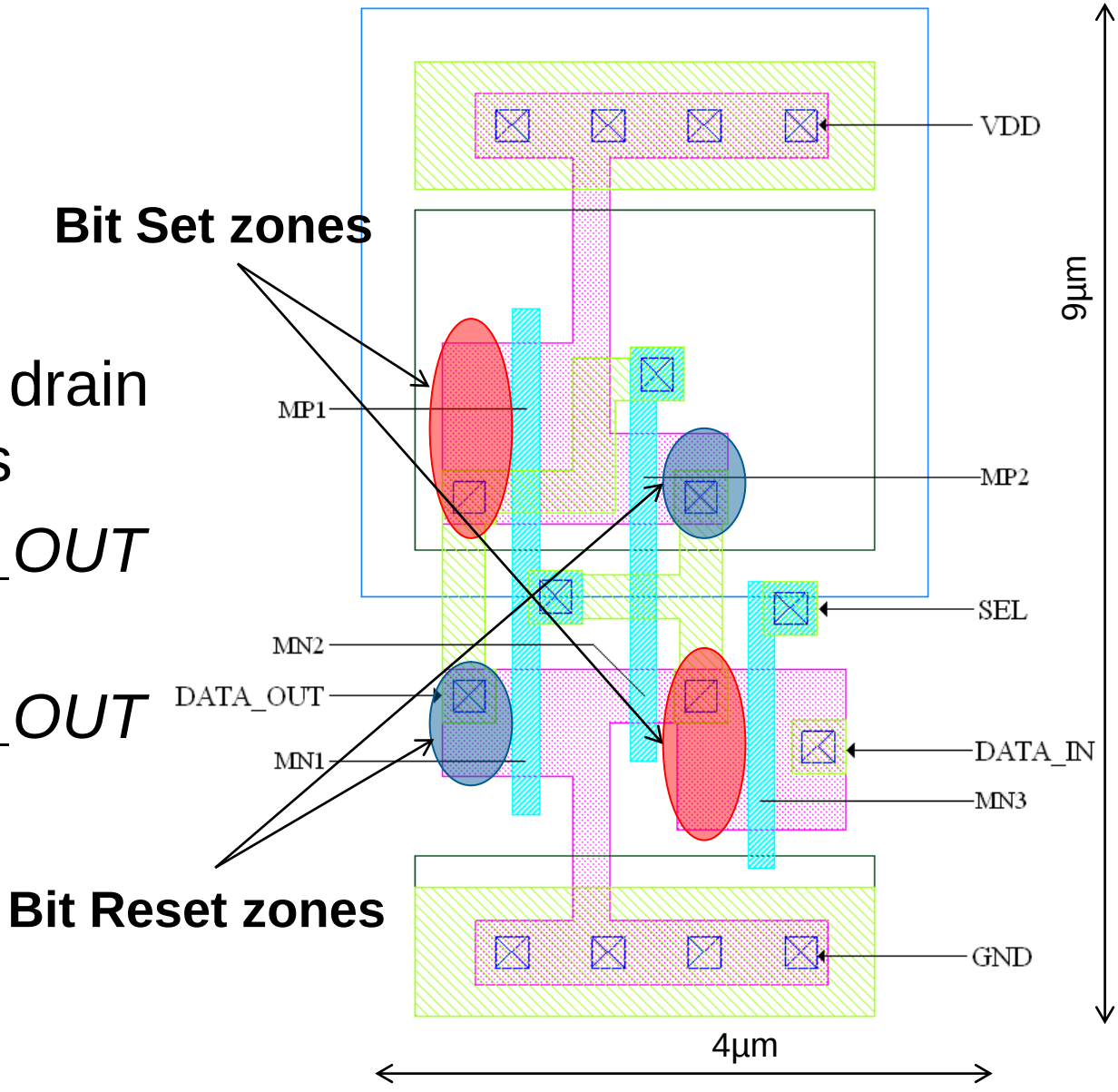
- Front side fault injection
- 1064nm wavelength
- Spot size: 1µm
- Pulse duration: 50 ns
- Energy from 1W to 1.6W
- SRAM grid pattern: 0.2µm



SRAM Memory Cell

Sensitivity zones

- 4 theoretical zones
  - Corresponding to the drain of the OFF transistors
  - 2 zones when *DATA_OUT* is in high state ■
  - 2 zones when *DATA_OUT* is in low state ■

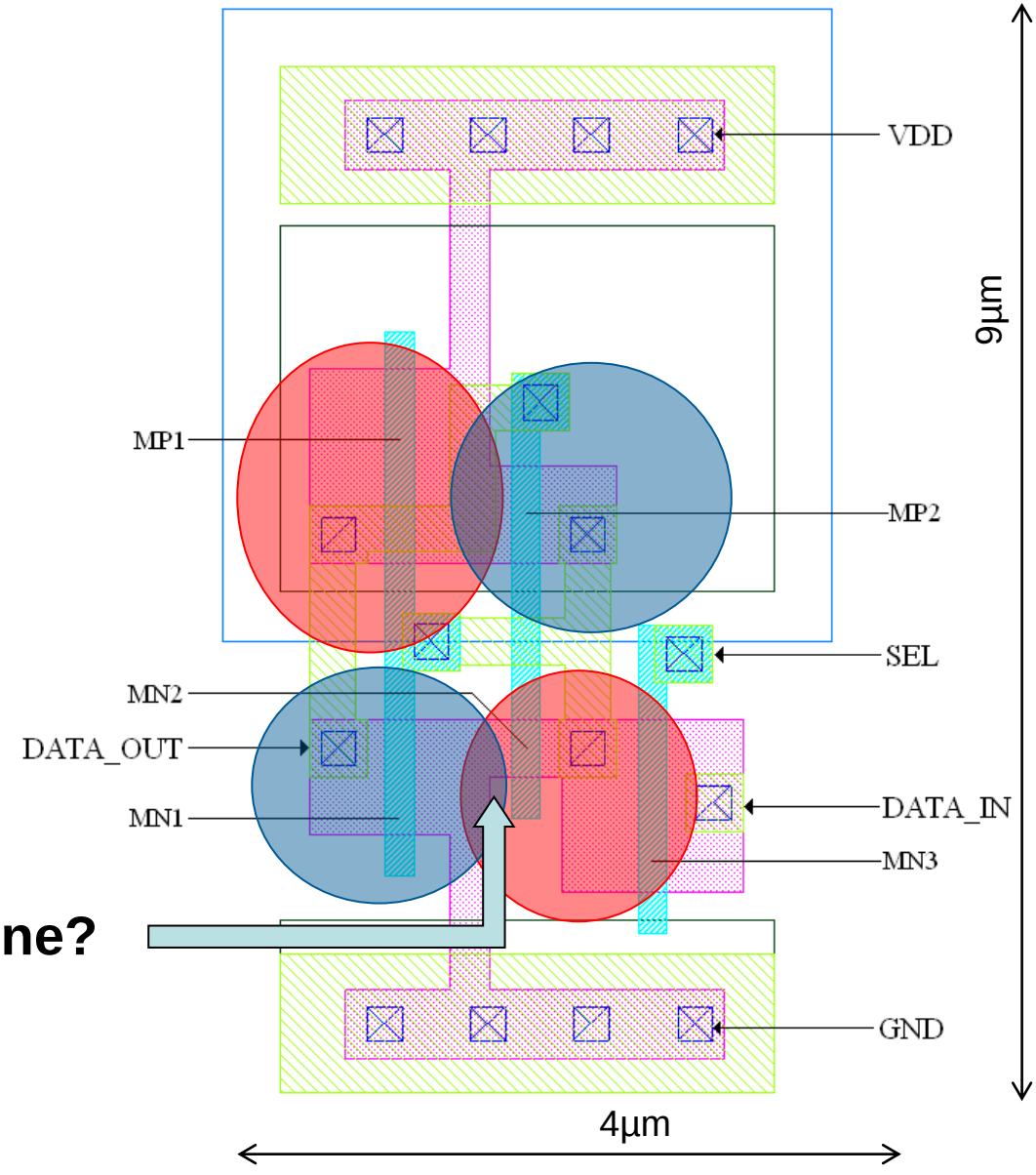


SRAM Memory Cell

Sensitivity zones

- Laser spot size of 1µm
  - Sensitivity zones extended
  - Bit set and reset zones overlap
  - For some positions: faults injected should be bit flip

Bit flip zone?

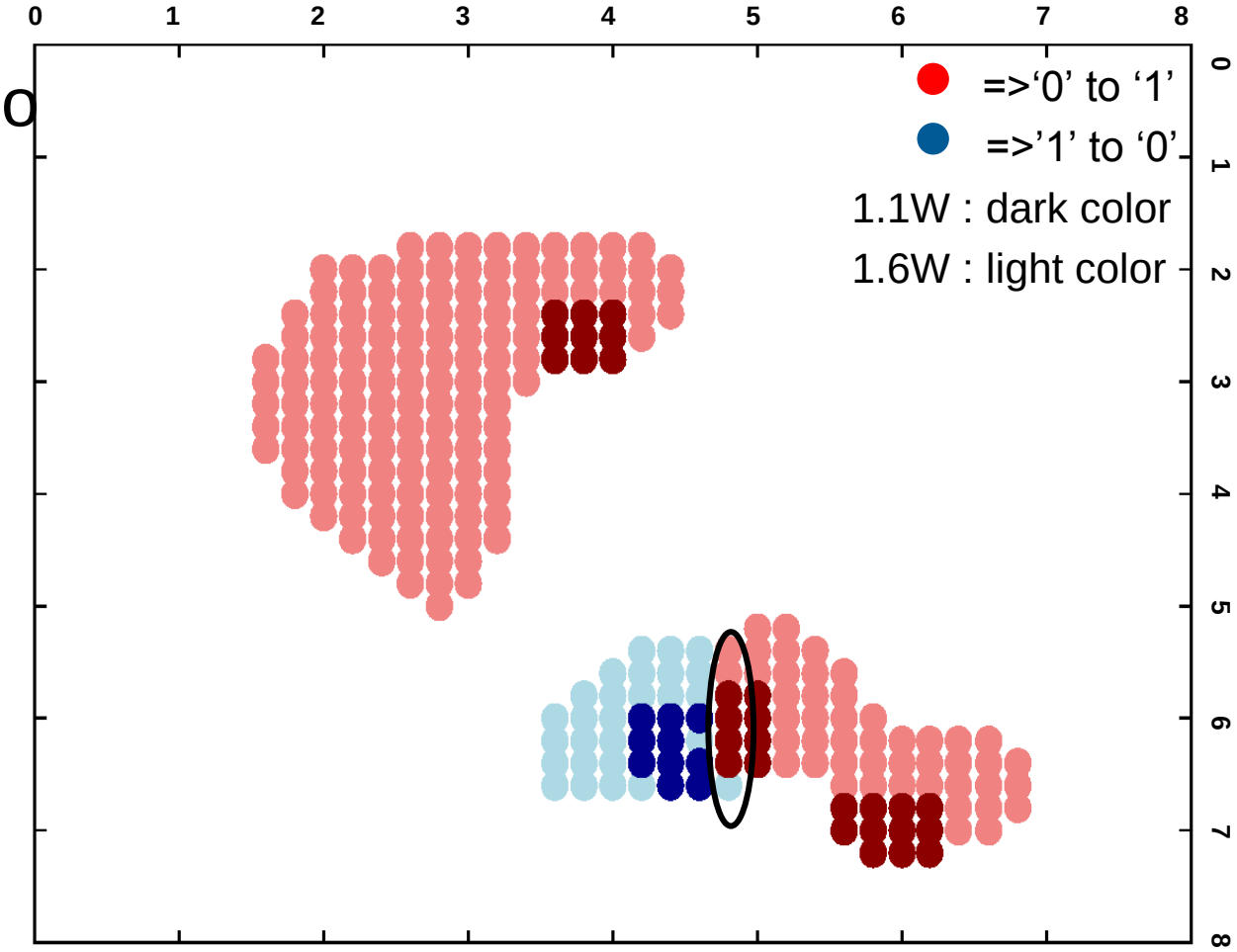


Faults Injection

Sensitivity map of the memory cell

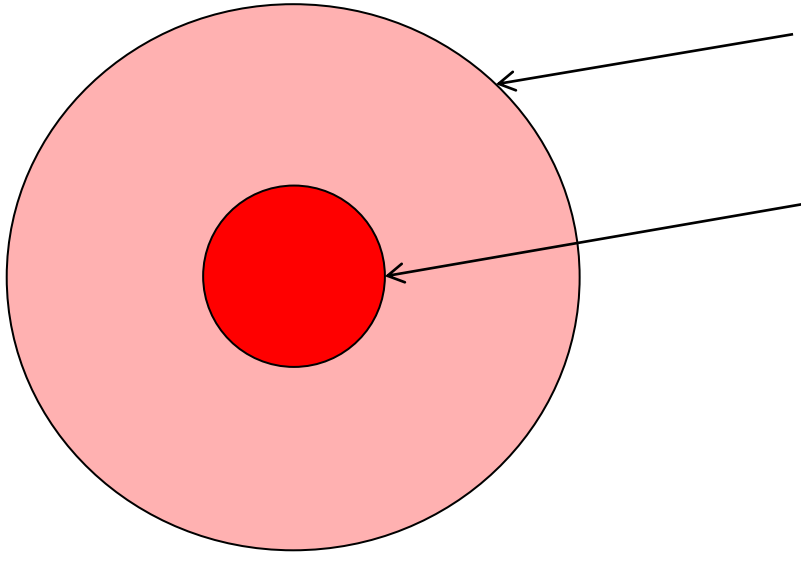
- Red zone and blue zone do not overlap.
- **No bit flip**
- Only 3 zones are really sensitive.

- **SPICE simulation on the edge zone**



SPICE Simulation

- Based on the model of *Sarafianos et al.[1]*
  - Model developed with 90nm CMOS technology
  - Using Voltage controlled current source
  - Multiple current sources (several sensitive zones)



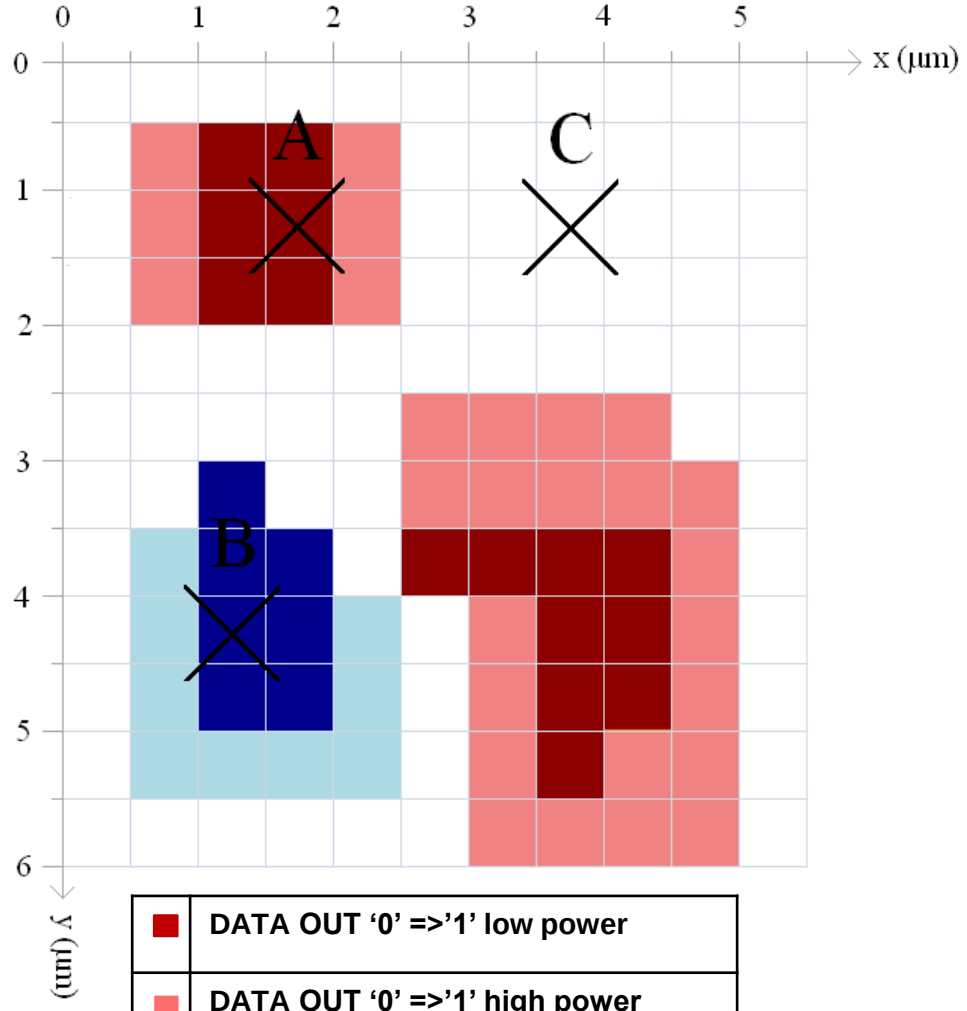
- The laser beam can reach several sensitivity zones of the cell

[1]Electrical modeling of the photoelectric effect induced by a pulsed laser applied to an NMOS transistor, A. Sarafianos, O. Gagliano, M. Lisart, V. Serradeil, J.M. Dutertre, A. Tria, IRPS 2013

SPICE Simulation

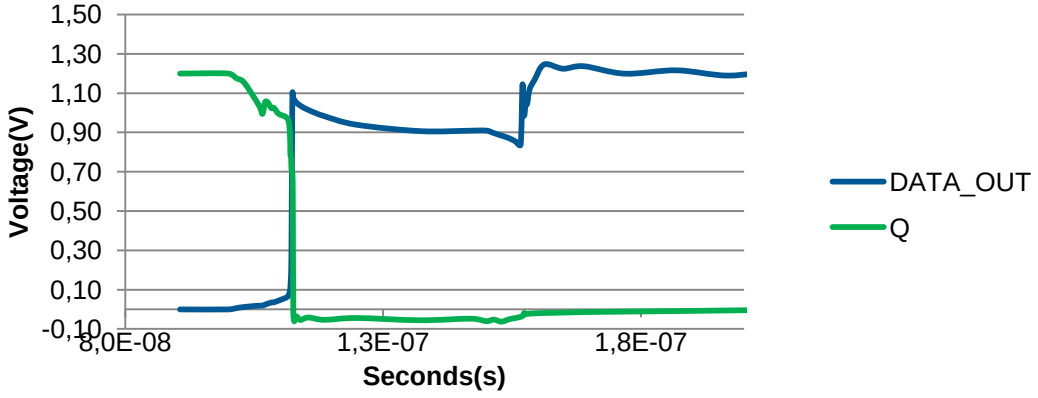
First simulation

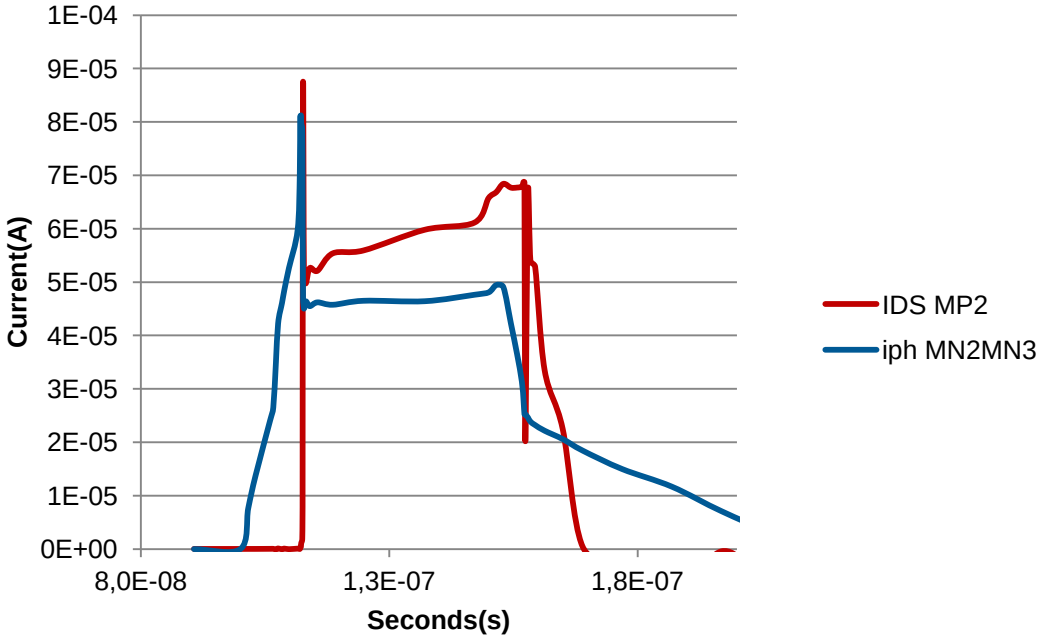
- Similar to the experiments
- Same hidden zone
- No bit flip

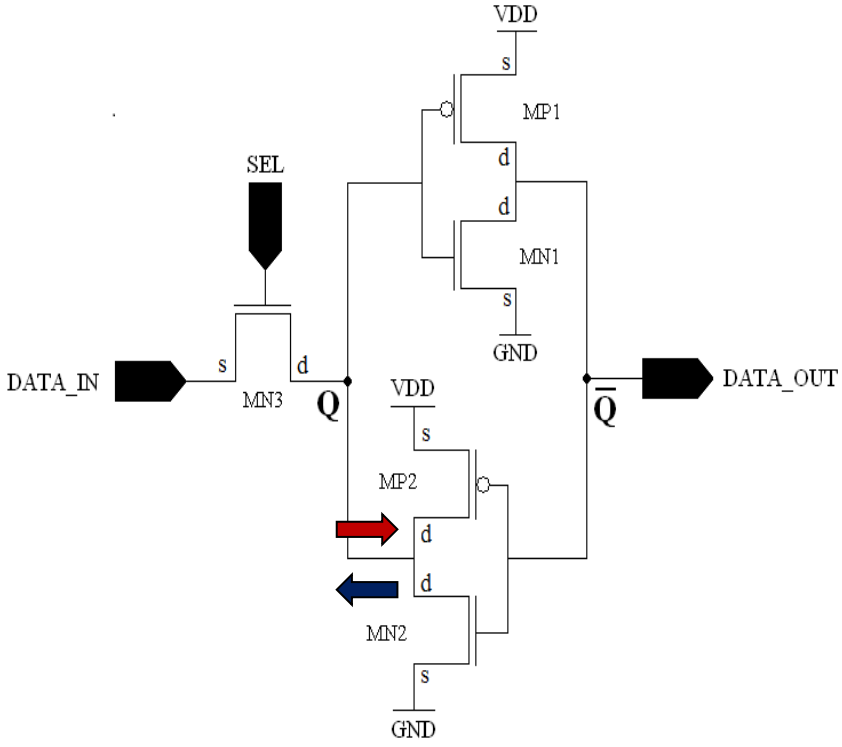


SPICE Simulation

Simulation of the edge zone



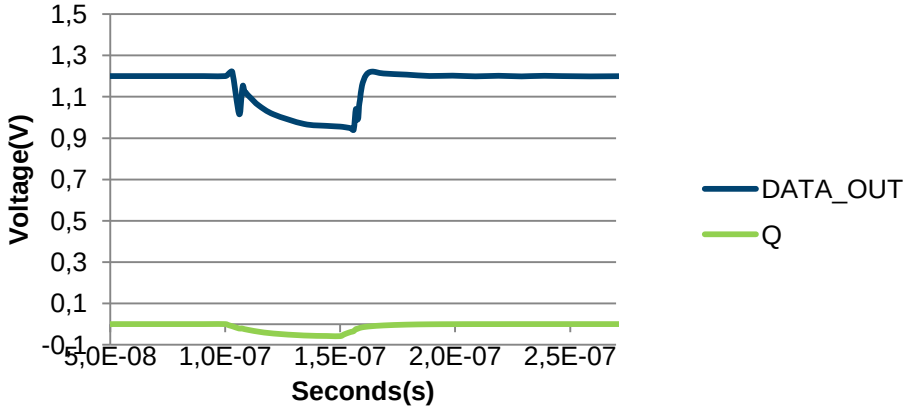


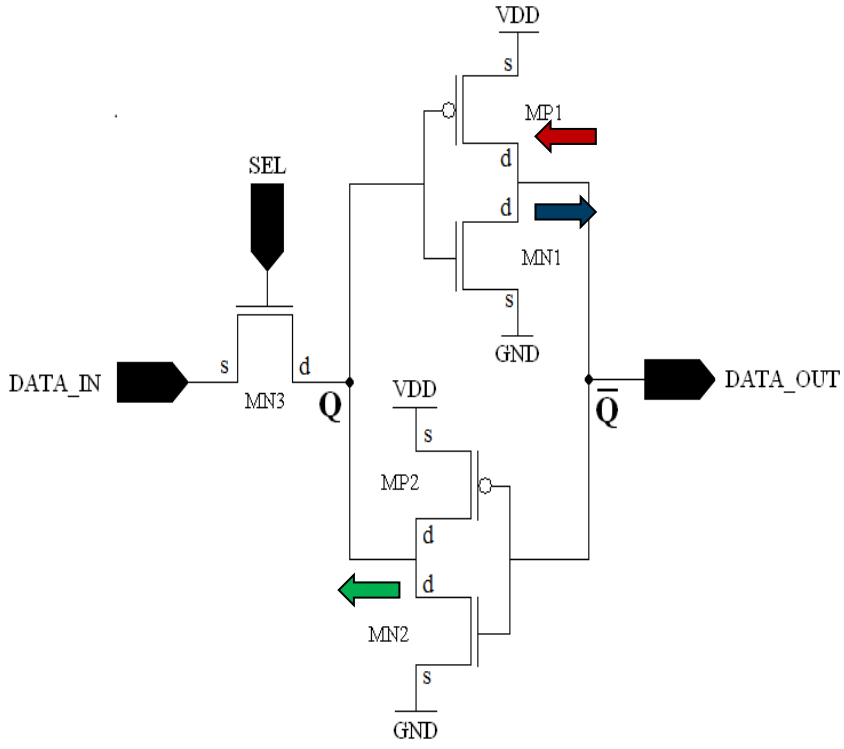


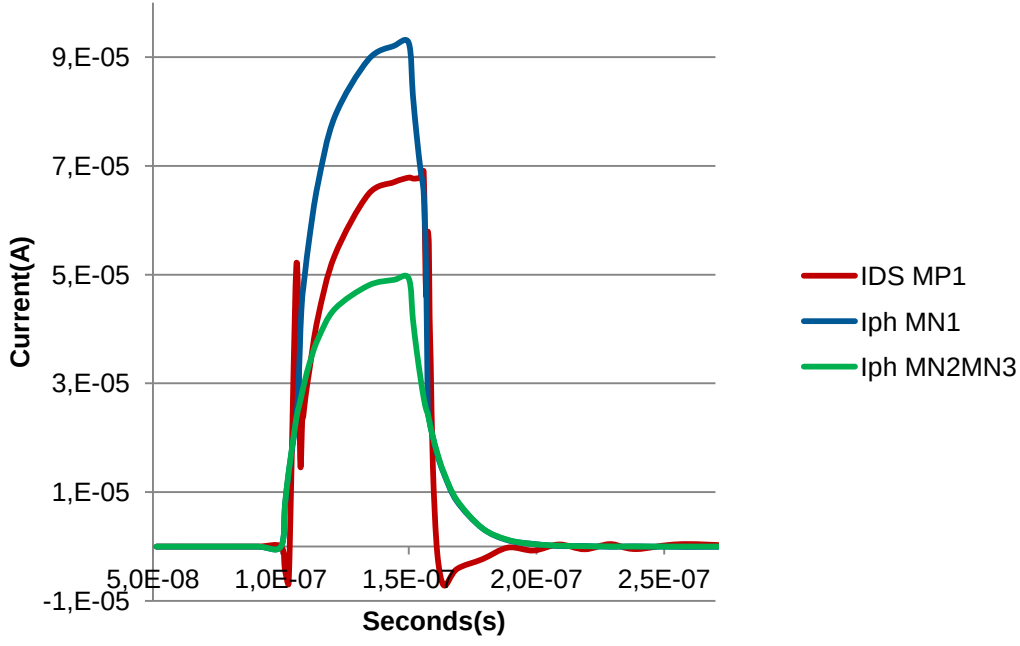
- Current injected on the drain of MN2
- Current of MP2 in opposition
- State has already changed
- **Fault is injected** (bit set)

SPICE Simulation

Simulation of the edge zone







- Current injected in drain of MN1
- Two other current are in opposition
- **No fault injected**

Conclusion & Perspectives

- **No bit flip**
  - Despite the laser beam effect zone (Ø 1µm & 5µm)
  - Energy between 1W and 1.6W
  - Balanced current that avoid fault

- **Good correlation between simulation and experimentation**
  - Same edge zone
  - Analyze the hidden zone
  - Countermeasures will be investigated in future works

Thank you for your attention.

Questions?

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