



A compact model of precessional spin-transfer switching for MTJ with a perpendicular polarizer

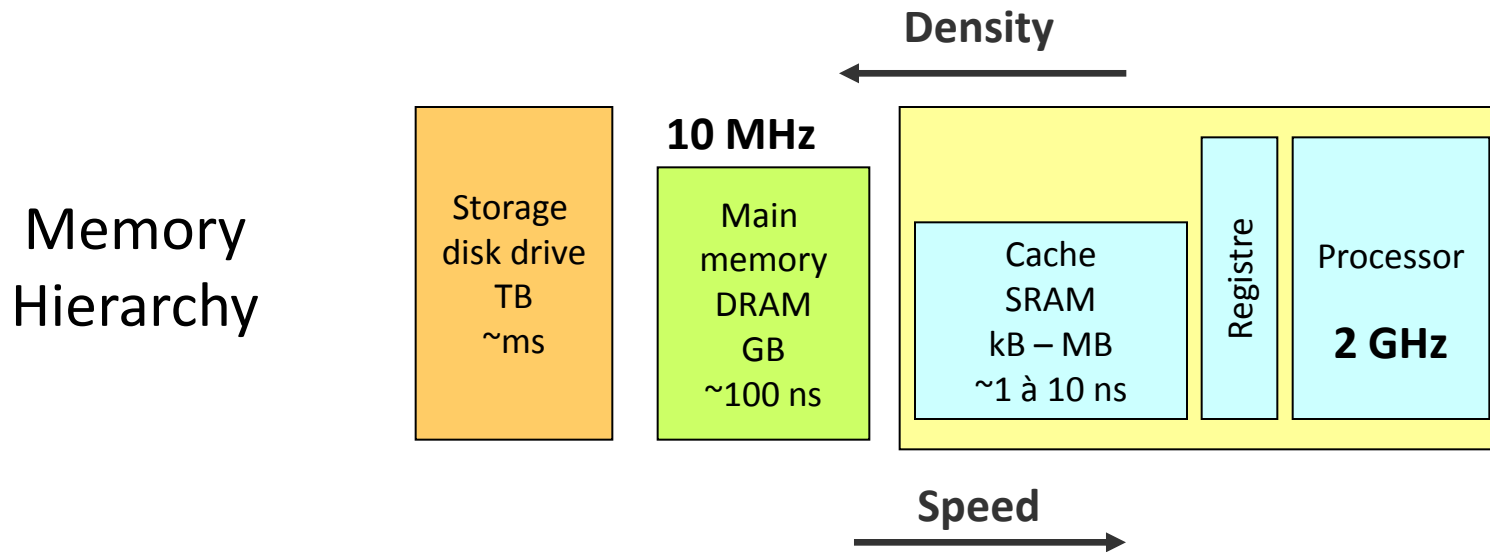
Abdelilah Mejdoubi, Guillaume Prenat, Bernard Dieny

SPINTEC Laboratory – CEA Grenoble, France





Idea: elaborate a **Spin Transfer Torque - MRAM** with an ultrafast switching to achieve the sub nano second-scale writing time



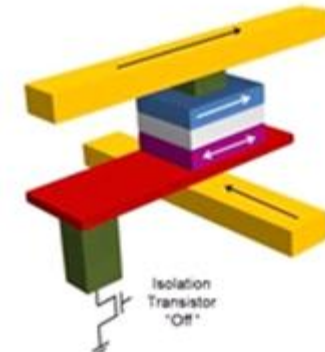
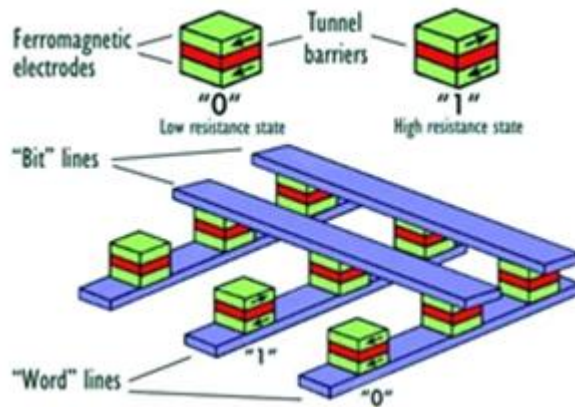
Ultrafast MRAM :

- Replacing SRAM memory
- Building non volatile logic circuits with low-energy consumption

Spin Transfert Torque

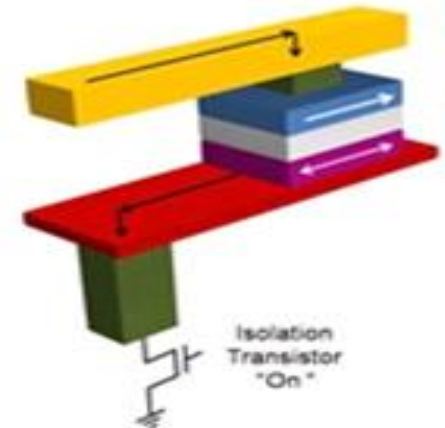
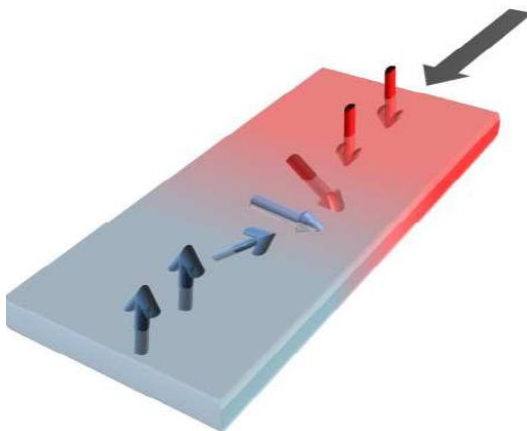
Magnetic Field

Freescale 2008, Crocus 2011

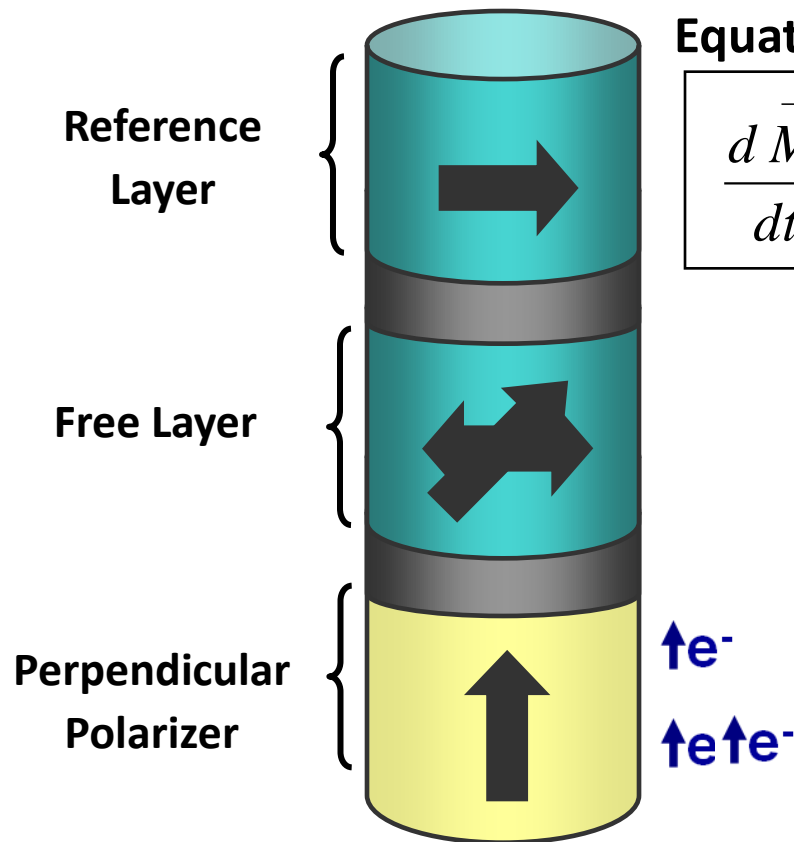


Spin Transfert

IBM, Samsung, Hitachi



MRAM with perpendicular polarizer



Equation of motion

$$\frac{d\vec{M}}{dt} = -\gamma_0 \vec{M} \times \vec{H}_{eff} + \frac{\alpha}{M_s} \vec{M} \times \frac{d\vec{M}}{dt} + a_j \vec{M} \times (\vec{P} \times \vec{M})$$

→ Out-of-plane oscillations of free layer magnetization



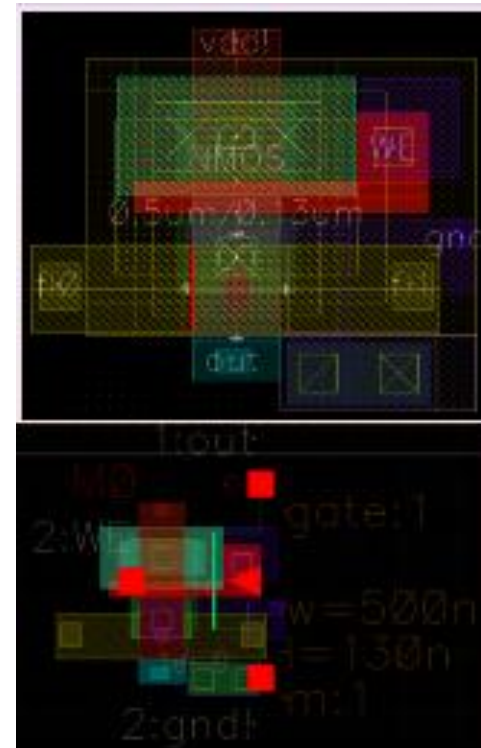
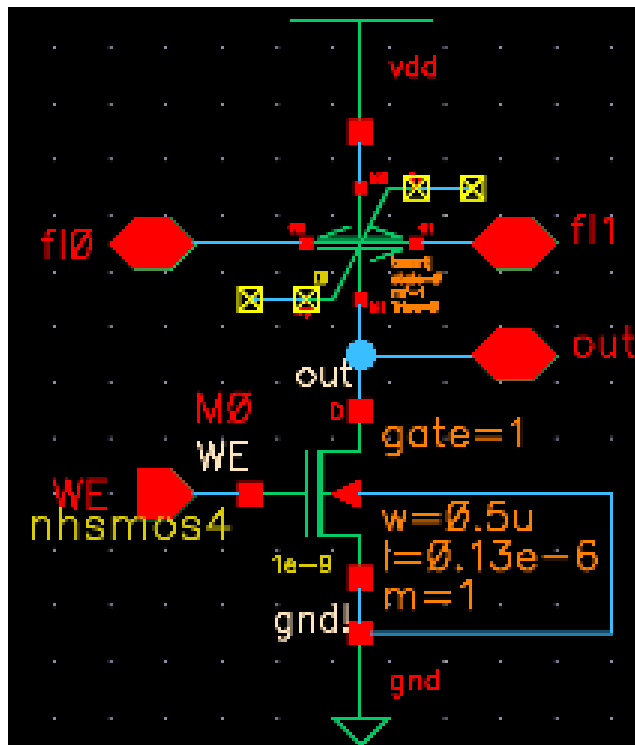
- ✓ Ultrafast oscillations ~ GHz
- ✓ Switching in less than 1ns
- ✓ No incubation delay (P⊥M)

O. Redon, B. Dieny and
B. Rodmacq, US Patent (2003)

Application in MRAM cells with an
ultrafast switching
→ precessional writing

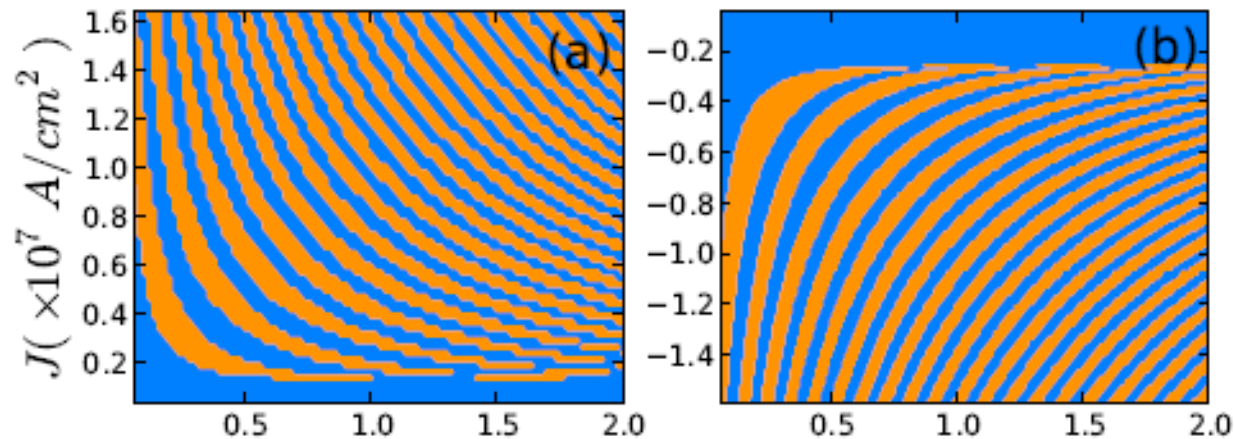
Magnetic technology parameters added to the CMOS technology files:

- Design Rules Checking (DRC)
- Extraction
- Layout Versus Schematic (LVS)

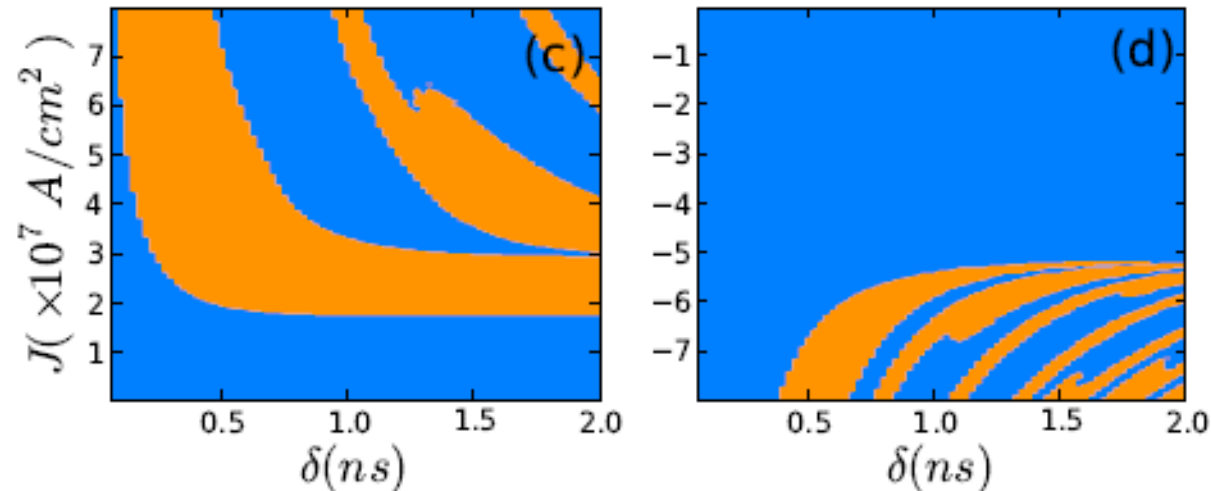


- Probability of switching

(a) and (b): without analyzer



(c) and (d): with analyzer

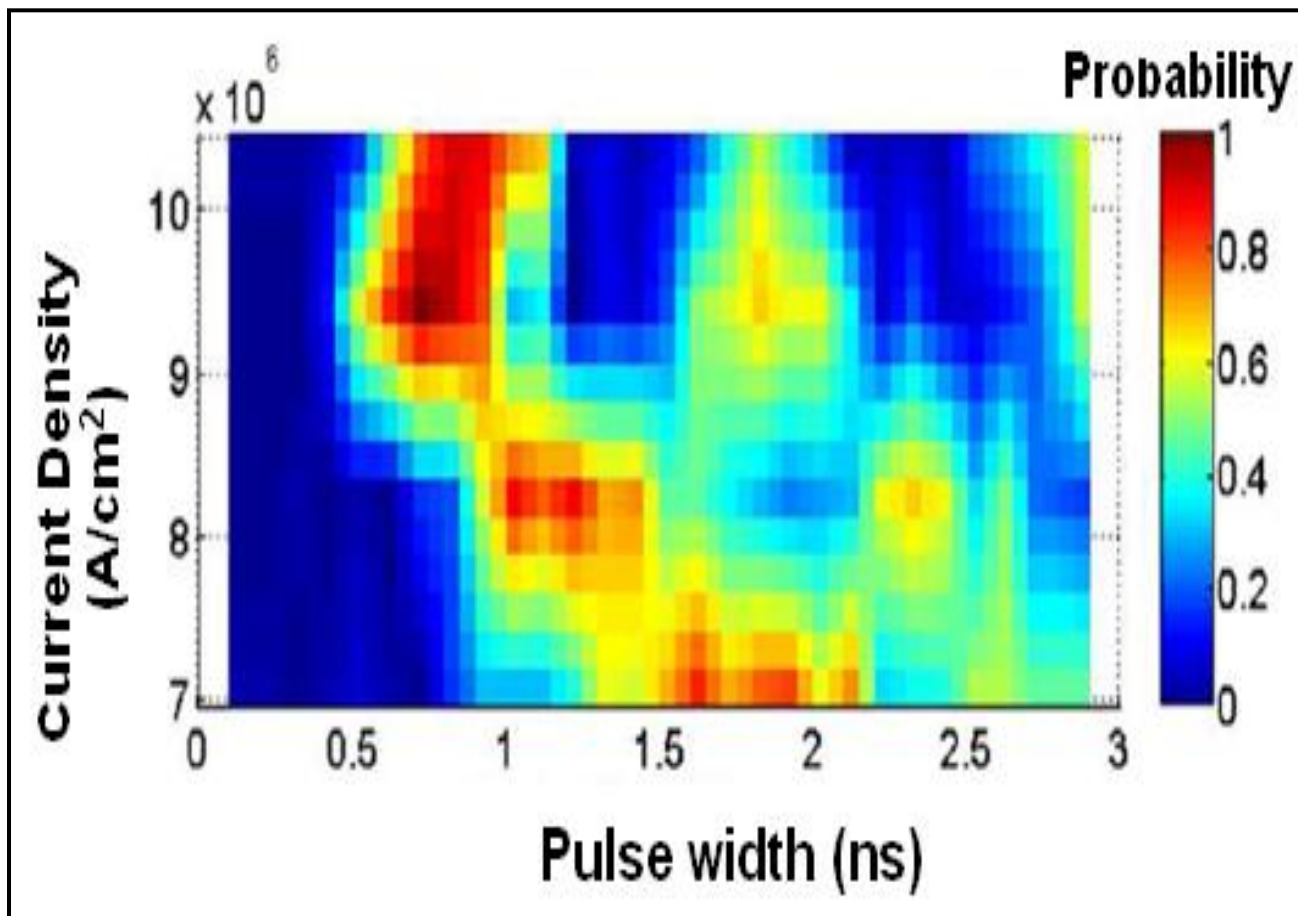


$$r = \frac{a_{jLONG}}{a_{jPERP}} = 10$$

Phase Diagram

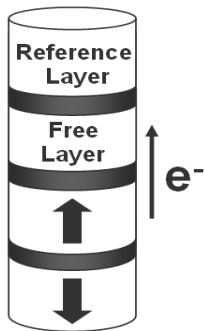
Experimental data

(Maria Marins de Castro Souza)

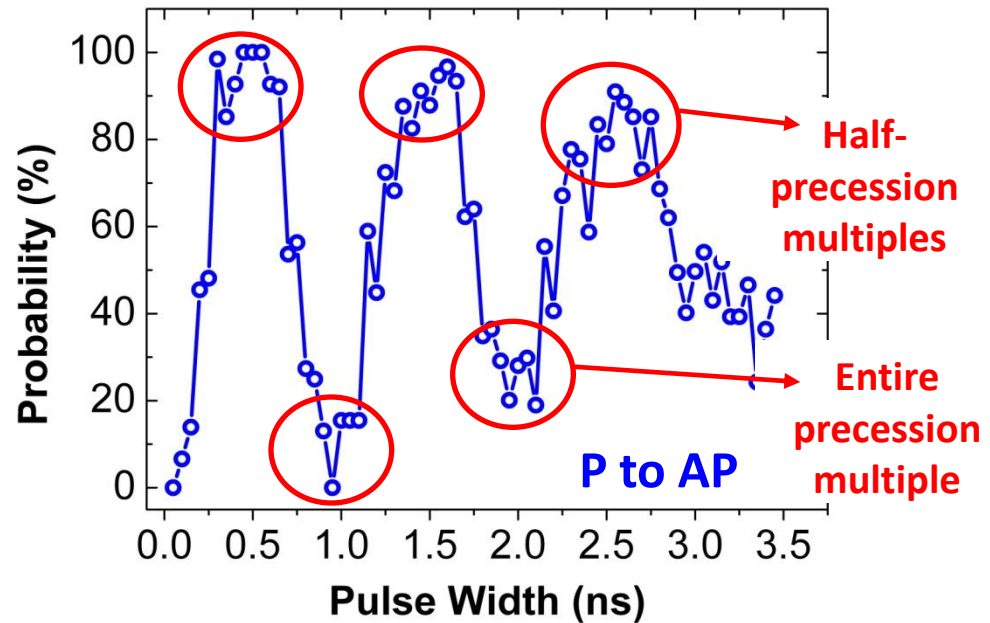


Experimental data

(Maria Marins de Castro Souza)

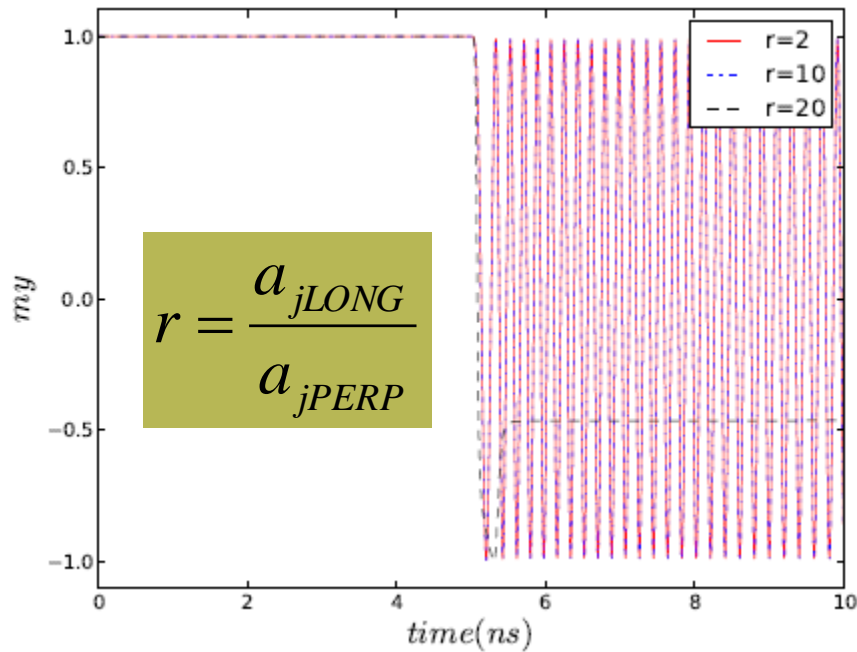


1.48 V \rightarrow 9.25 MA/cm²

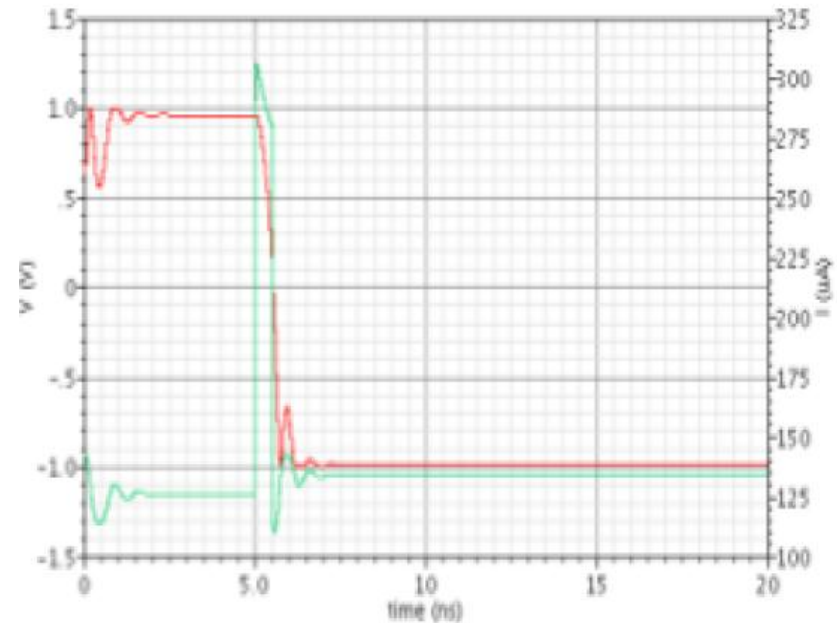


- Oscillations of the switching probability due to the perpendicular polarizer
- Ultrafast switching of less than 500ps
- As the pulse current density is increased, the precessional motion shows a higher degree of coherence

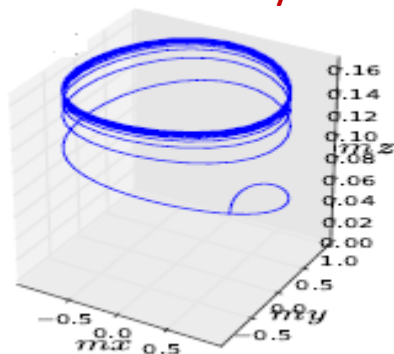
Magnetization



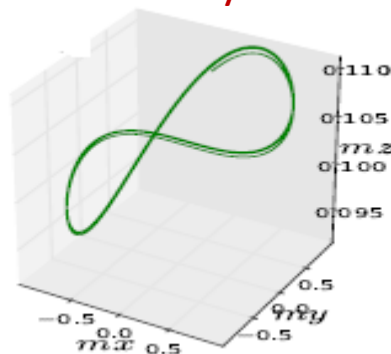
Switching & current



Without analyzer



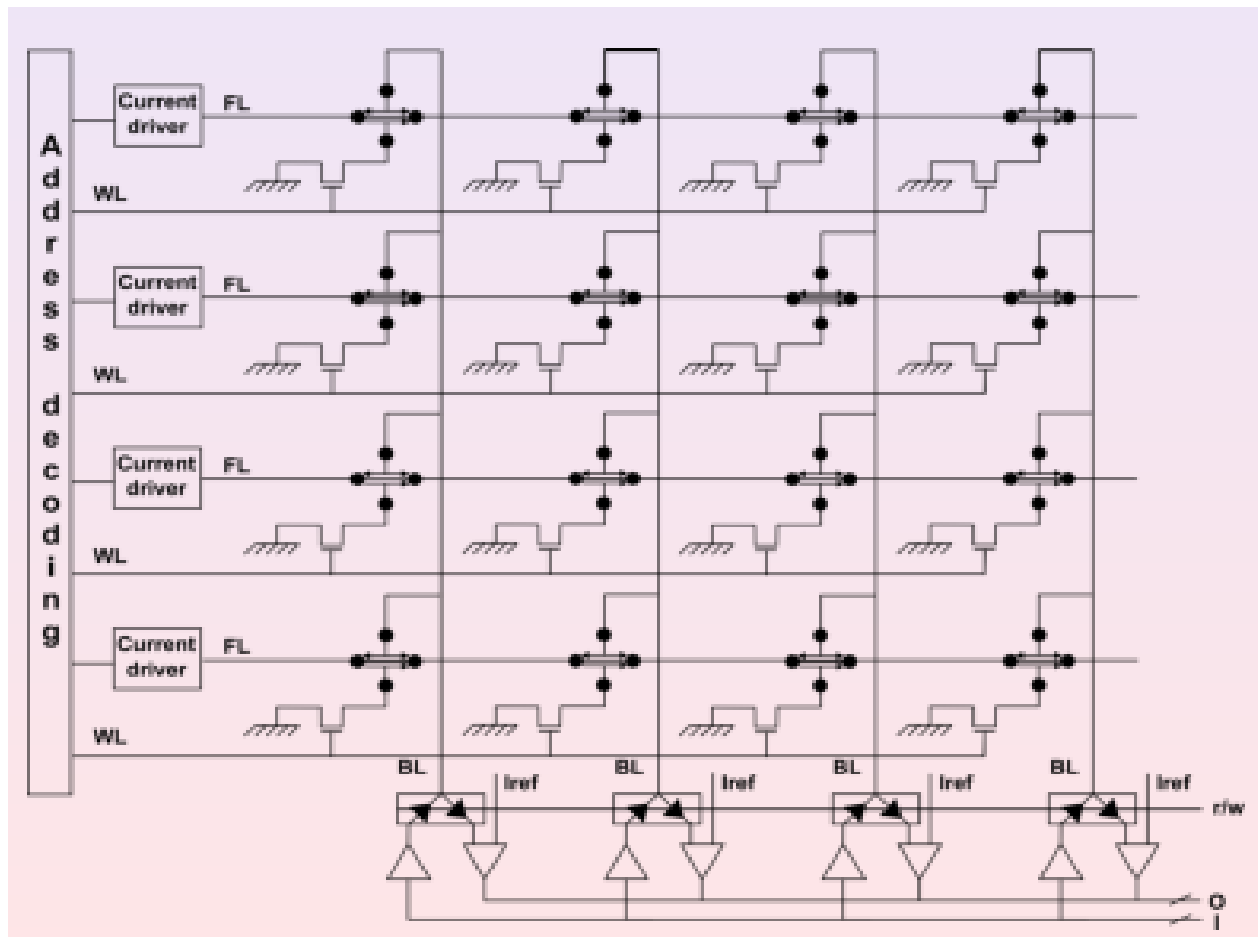
With analyzer



$$\theta_0 = 50^\circ$$

1T-1MTJ memory array

- As dense as DRAM



- Integration of a perpendicular polarizer in a magnetic tunnel junction with good TMR signal
- Ultra fast switching of less than 500 ps
- Oscillation of the switching probability as a function of the pulse width
- Validation of precessional switching

Thank you