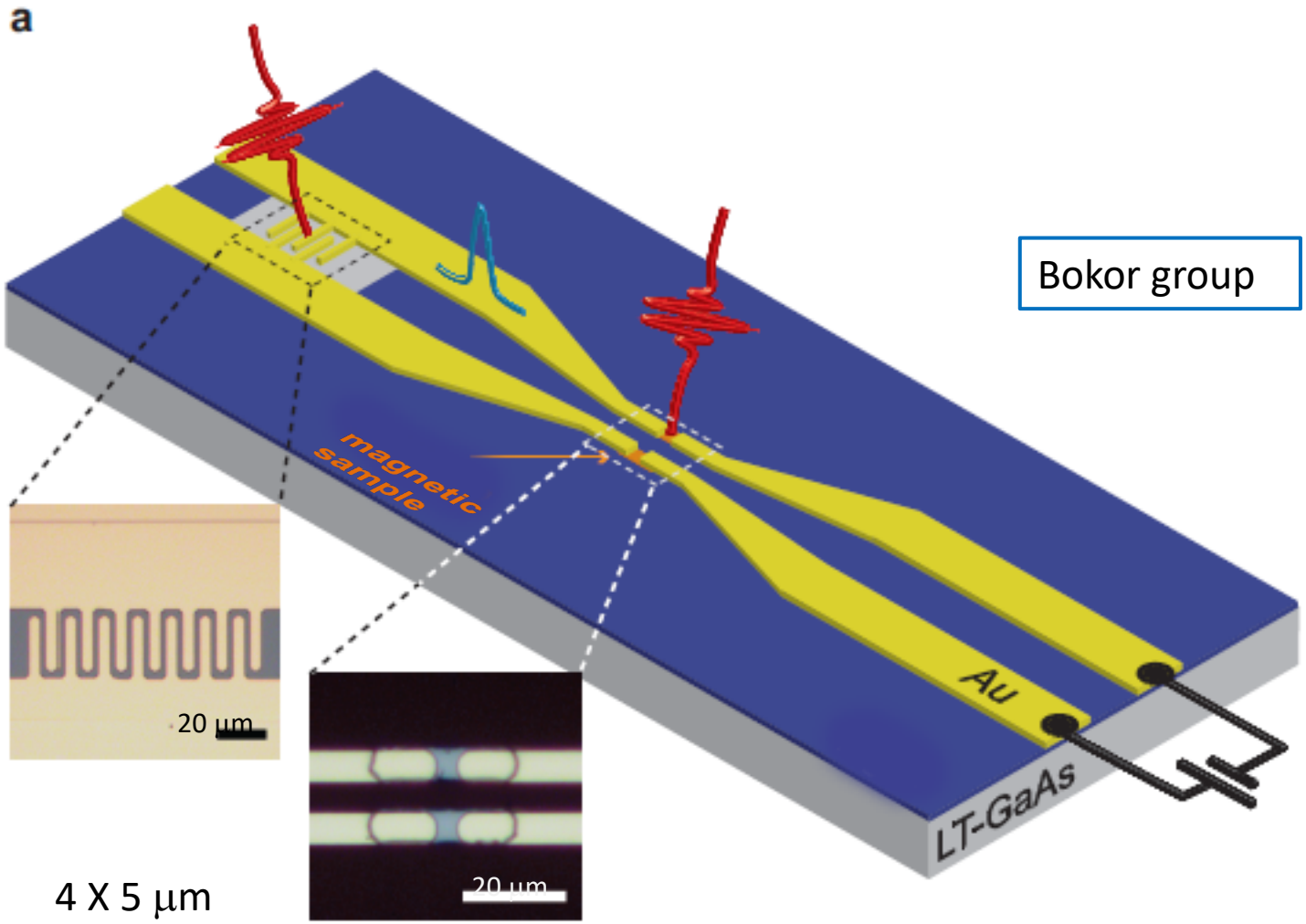
Ultrafast Magnetic Switching

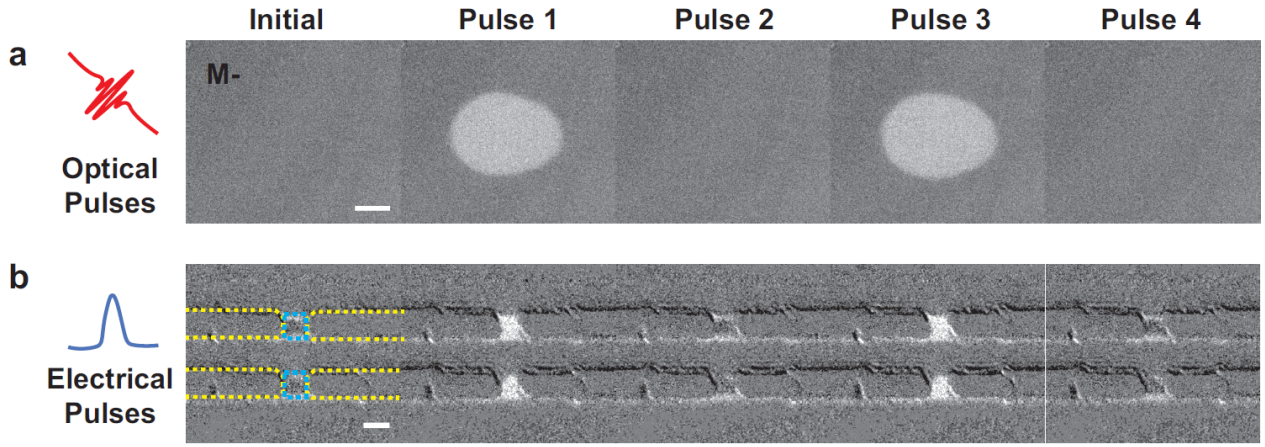


Bokor group

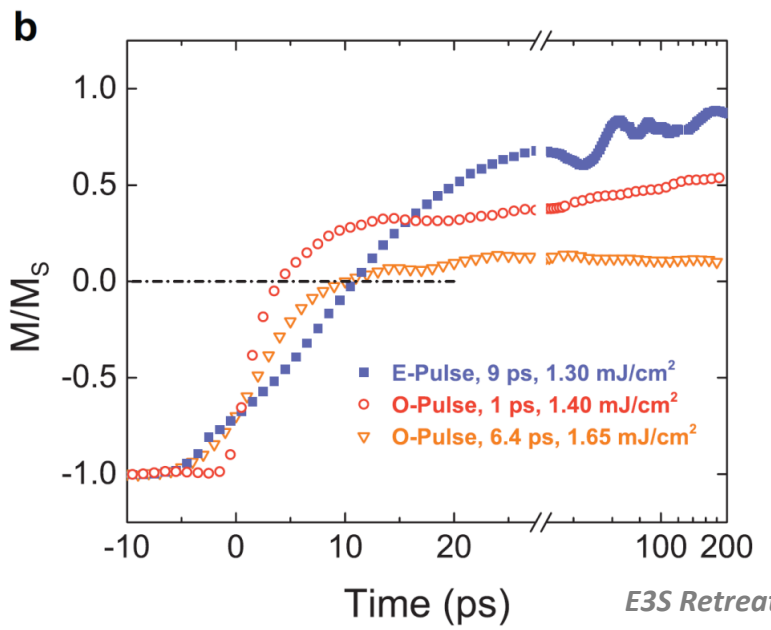
4 X 5 μm

Ta(5)/$Gd_{30}Fe_{63}Co_7$(20)/Pt(5)

Ultrafast Electrical Switching



Bokor group

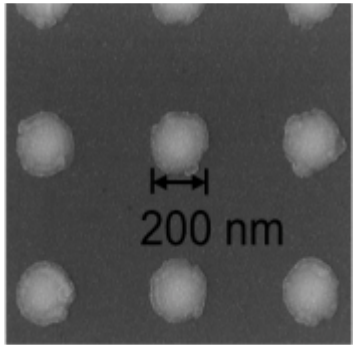


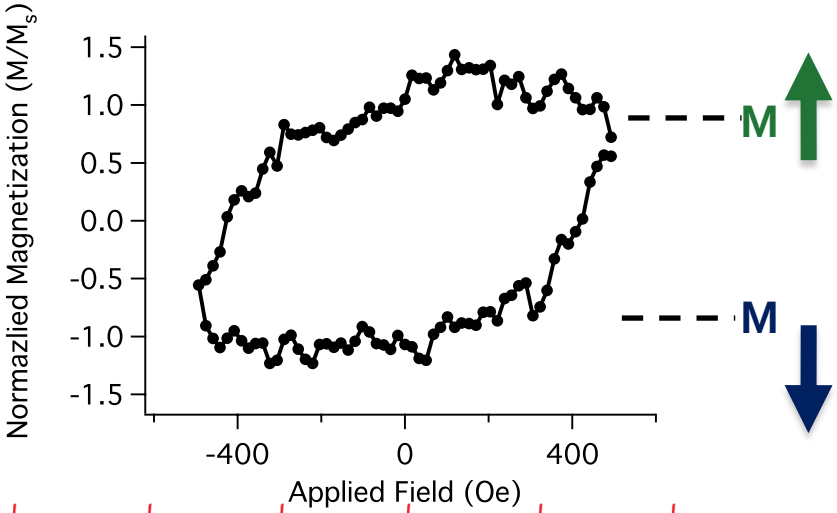
- Current density ~ 7 X 10^8 A/cm^2 (peak)
- Over 10^{10} switching cycles!
- For (20nm)^3 cell estimate: Scaled switching energy ~3.5fJ, switching current ~10s of μA

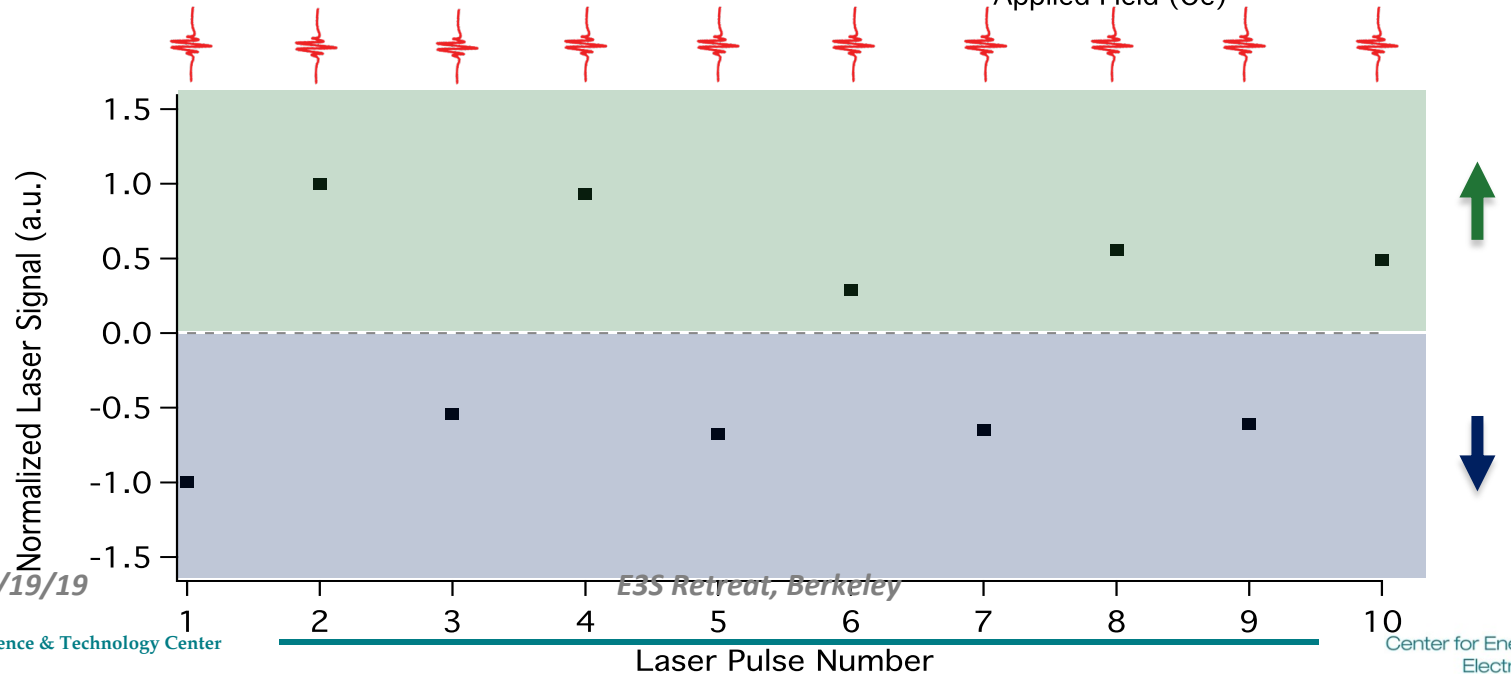
Does switching scale to nano dimensions?

AOS of Nanoscale GdCo Dots

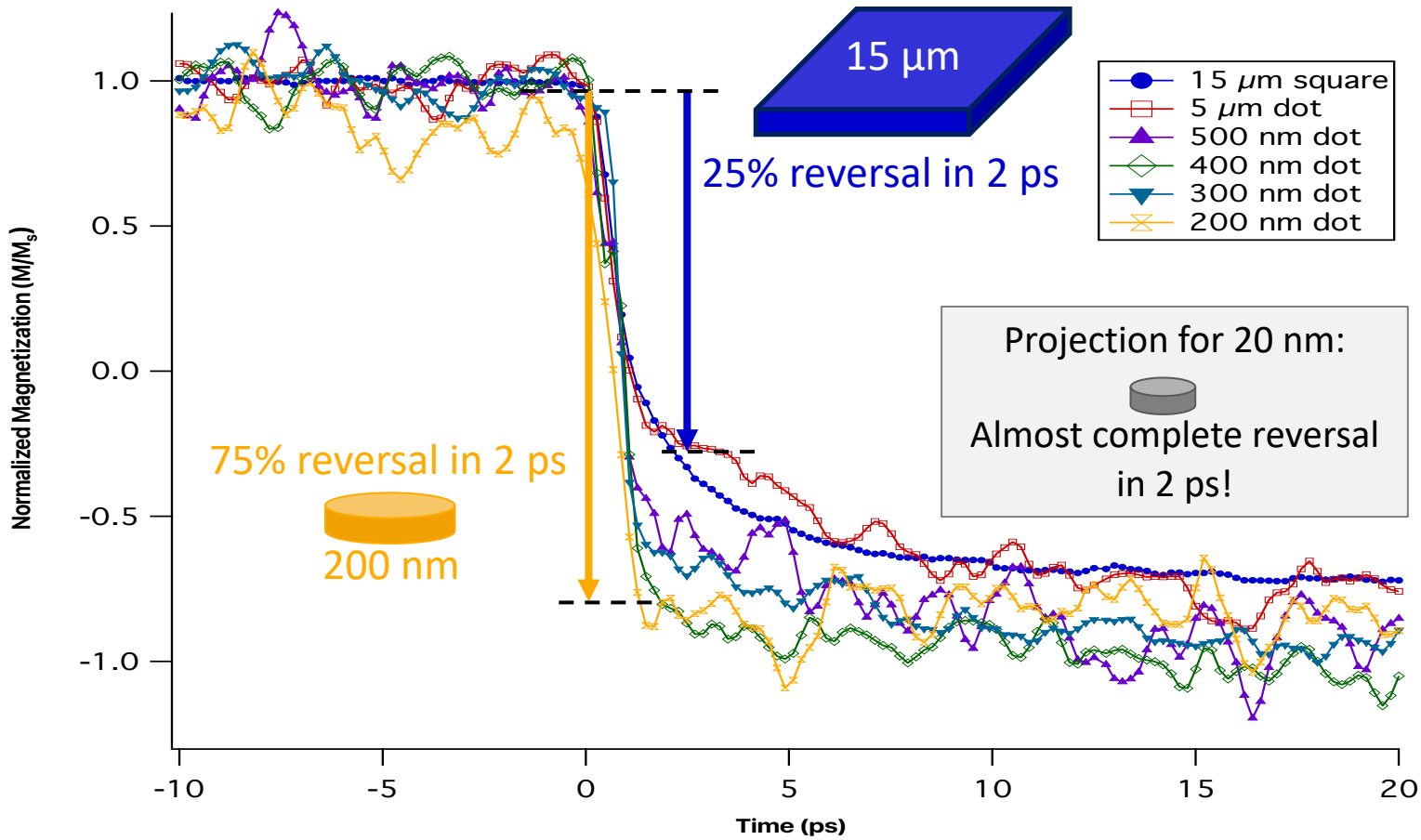
Laser MOKE experiment (200 nm)





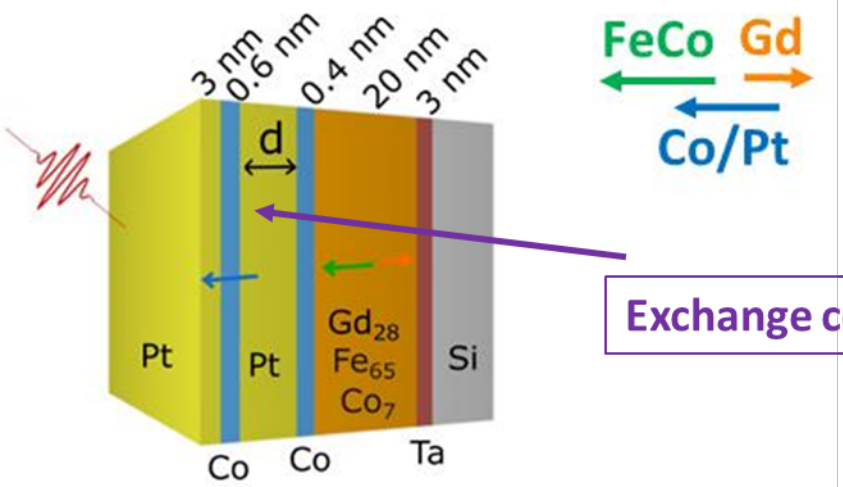


Smaller GdCo Dots Switch Faster!

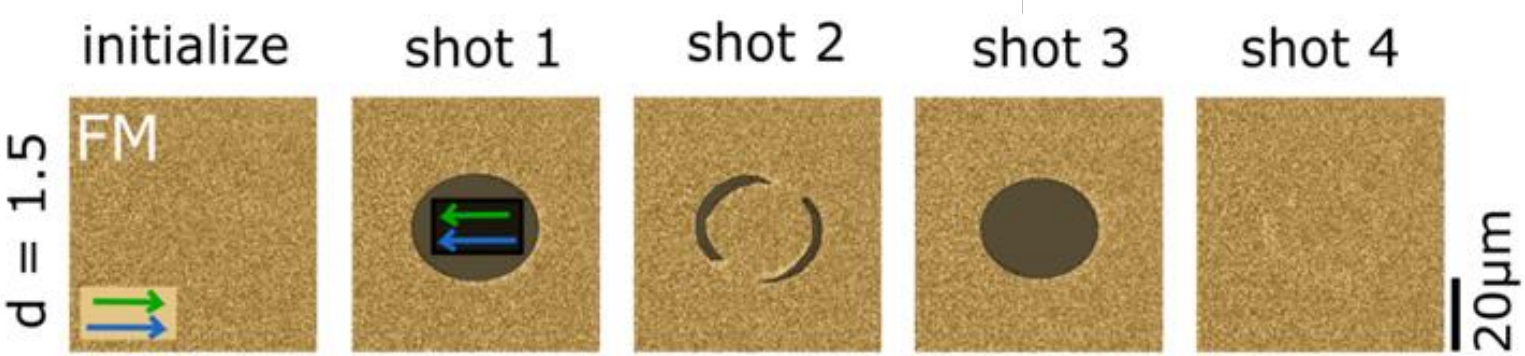


A. El-Ghazaly, et al., APL *vol. 114, p. 232407, 2019.*

Single-shot all-optical switching of a ferromagnet

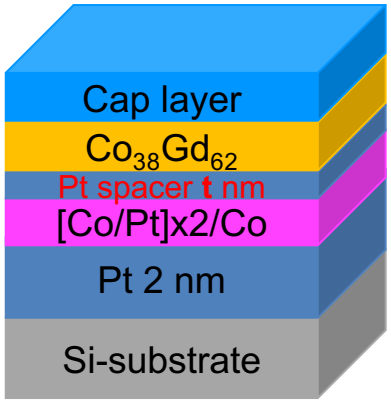


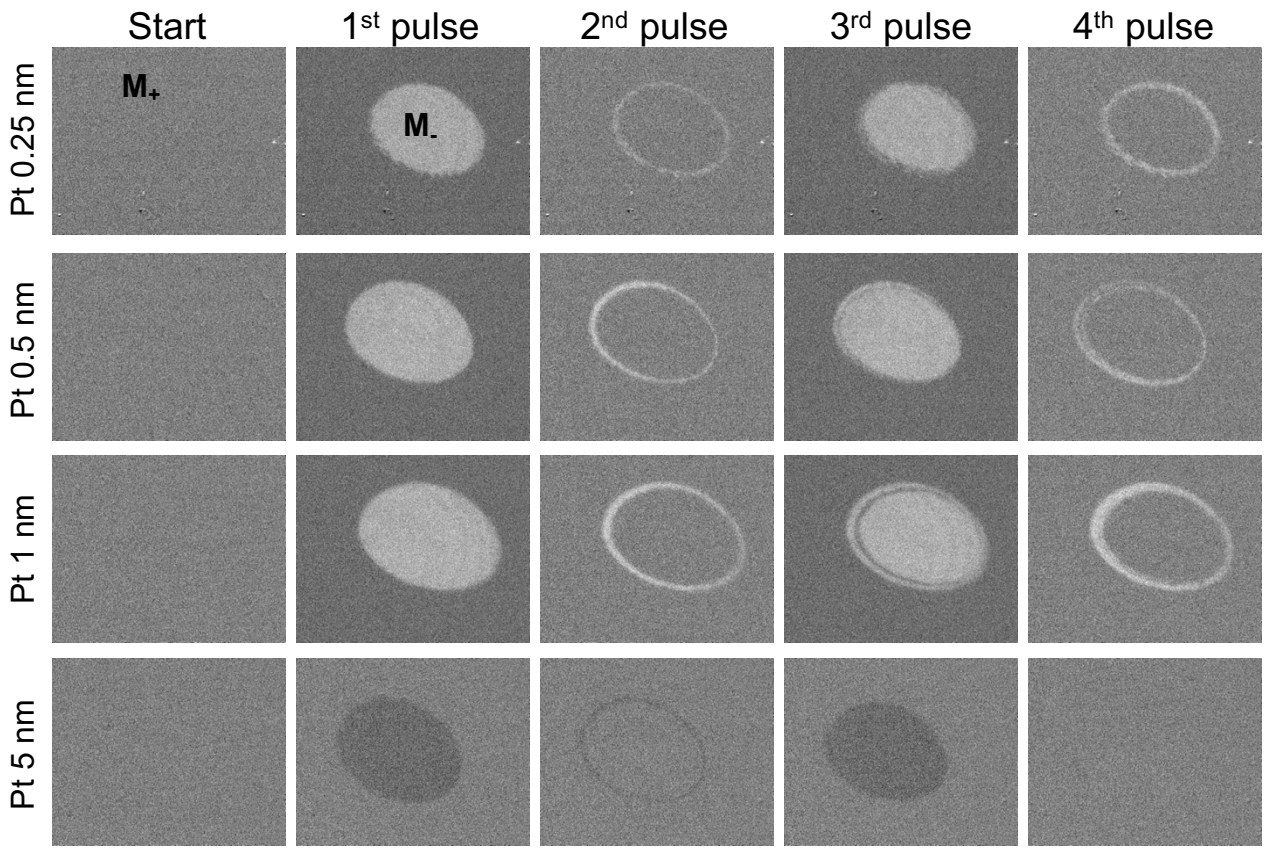
Exchange coupling to GdFeCo



Single-Shot switching of Co/Pt!

Co/Pt FM Switching by CoGd

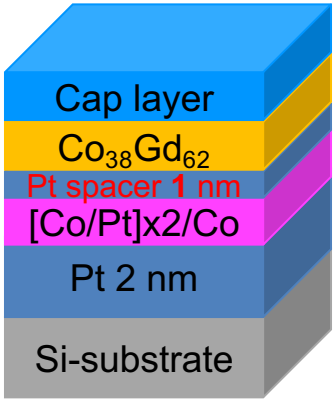




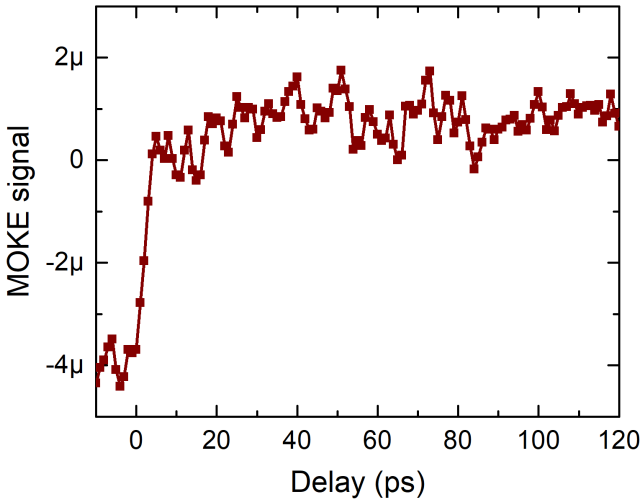
- Co/Pt MLs are ferromagnetically coupled for 0.25, 0.5 and 1 nm Pt spacer thickness
- Exhibits single shot helicity independent all-optical switching (HI-AOS).

Depth resolved time resolved magnetization dynamics

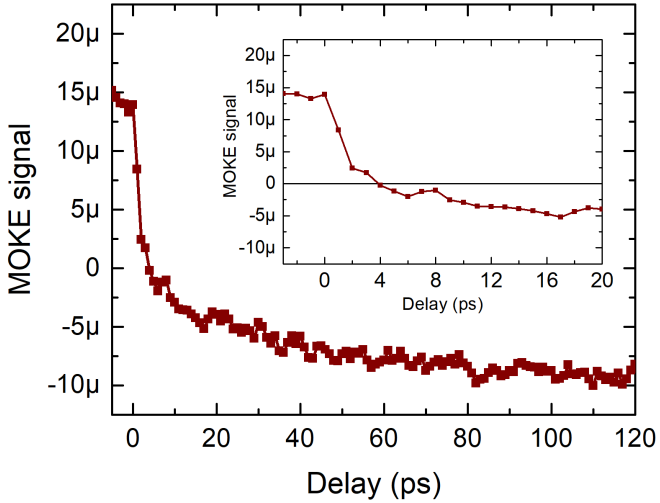
Coupled ferro-ferri sample
Pt spacer 1 nm



CoGd

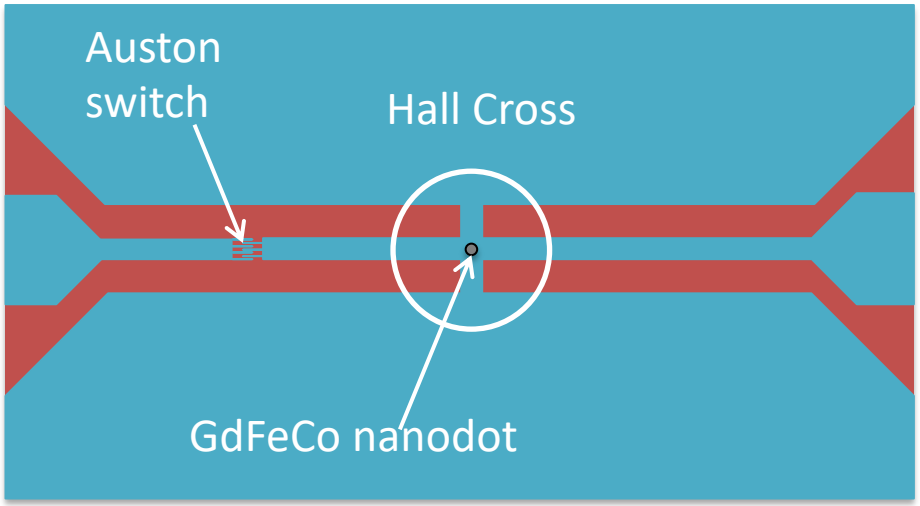


Co/Pt MLs



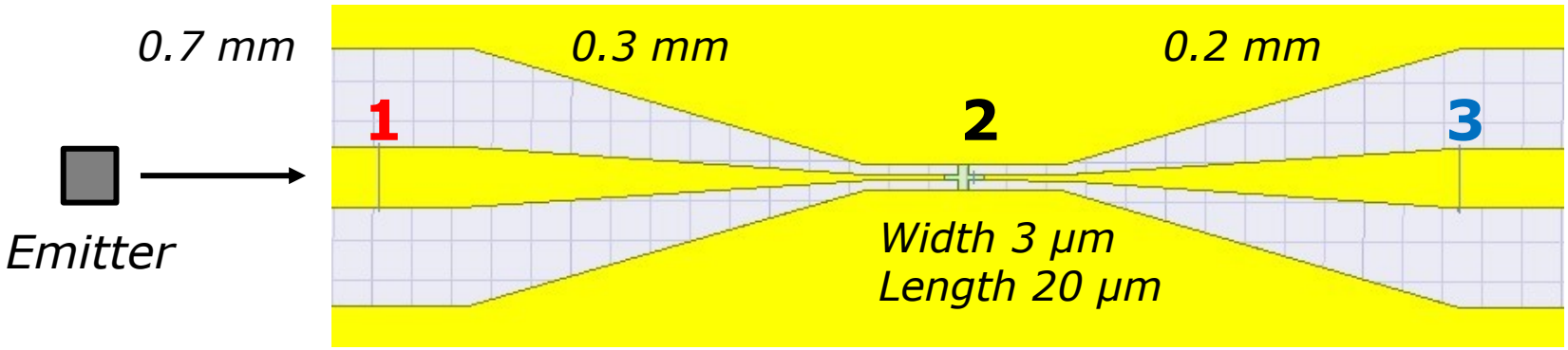
Magnetization of CoGd and Co/Pt reverses within ~3-4 ps time scale.

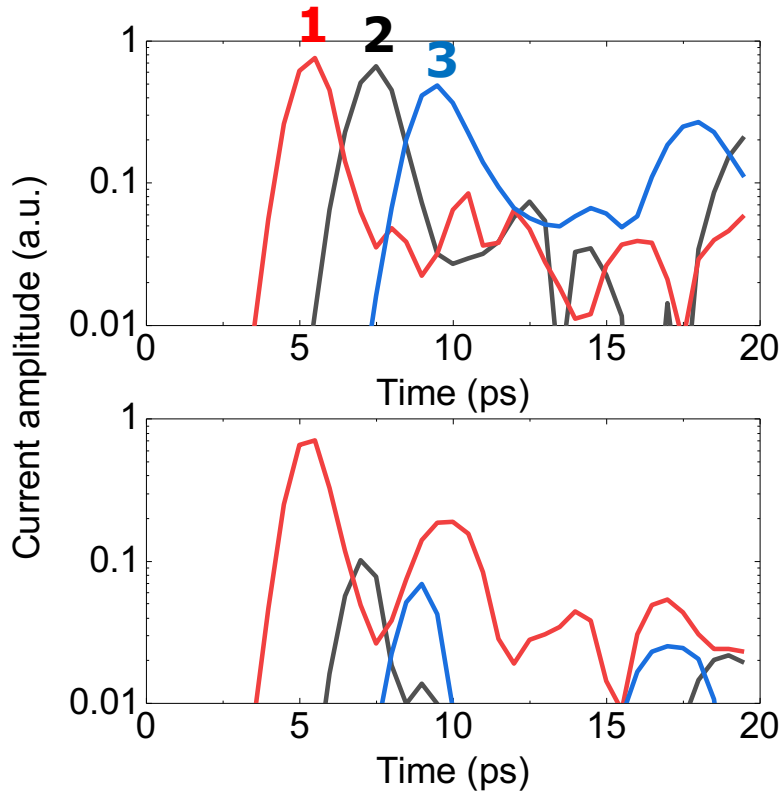
All-Electrical Switching and Readout of GdFeCo Nanodots



- Fabricate AHE/Transmission Line with Auston switch on LT-GaAs substrate for single GFC dot
- Test magnetization switching using a sub-picosecond electrical current pulse
- Measure electrical resistance after switching using the AHE cross bars

Current propagation in CPW with a Hall bar

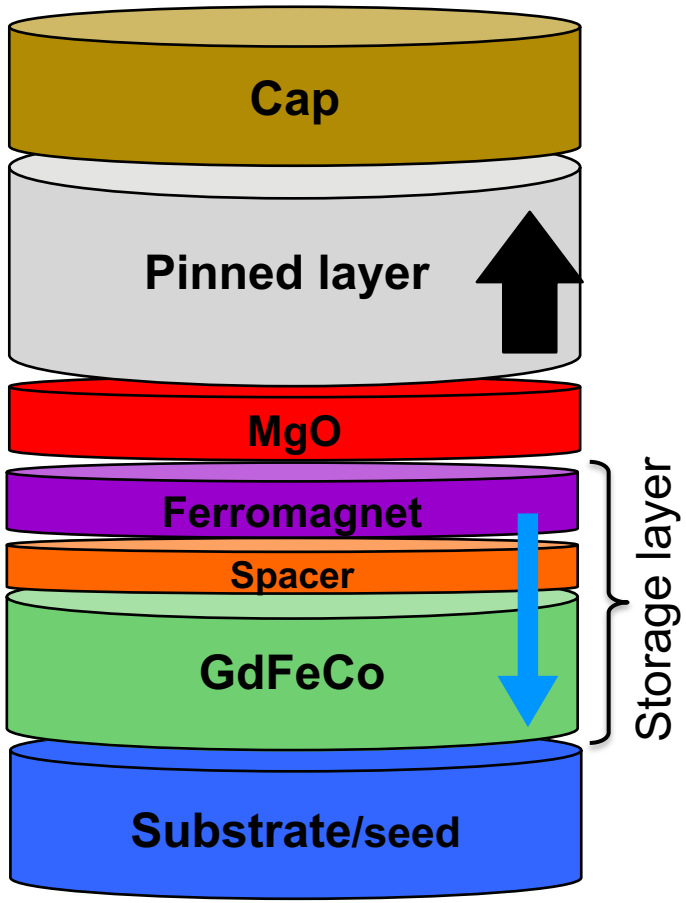




Without a Hall bar
$I_2/I_1 = 0.88$

With a Hall bar
$I_2/I_1 = 0.14$

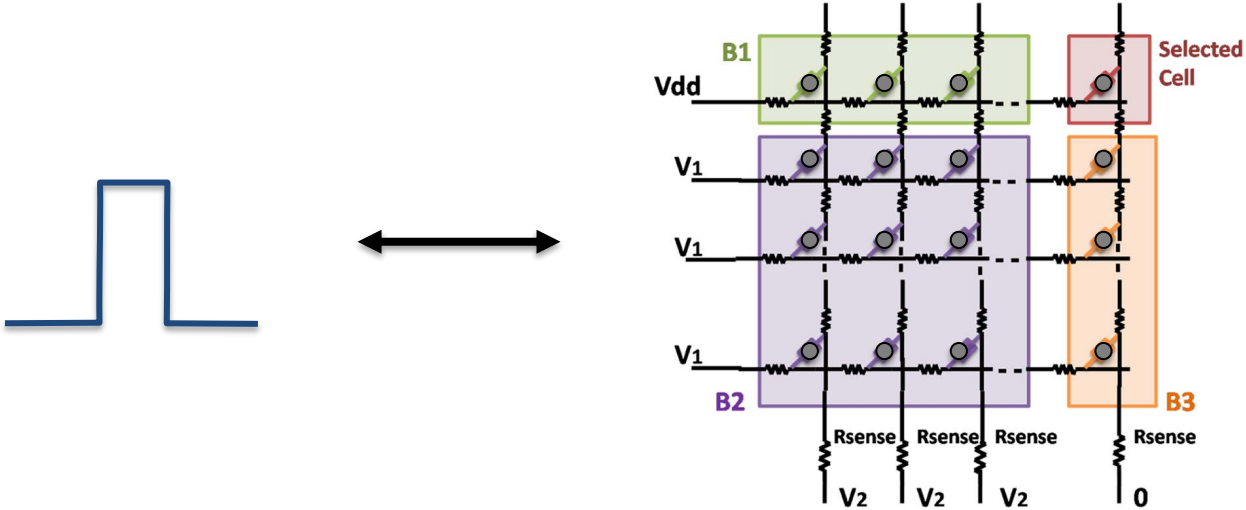
Integrate MTJ Readout



- Ferromagnetic layer coupled with GdFeCo and interfaced with MgO tunnel barrier
- Stack with reasonably high TMR for electrical reading
- Applications: High level cache and non-volatile logic

Full Integration of Ultrafast Memory System

Can it be integrated for minimal current consumption?



Complete integration of GdFeCo nanodot MTJ into CMOS with picosecond pulse generator.