SAND2020-6539PE

Update 1: Shape anisotropy effects on magnetic domain wall dynamics in spintronic devices

Samuel Liu

University of Minnesota-Twin Cities, University of Texas at Austin

Department of Electrical and Computer Engineering

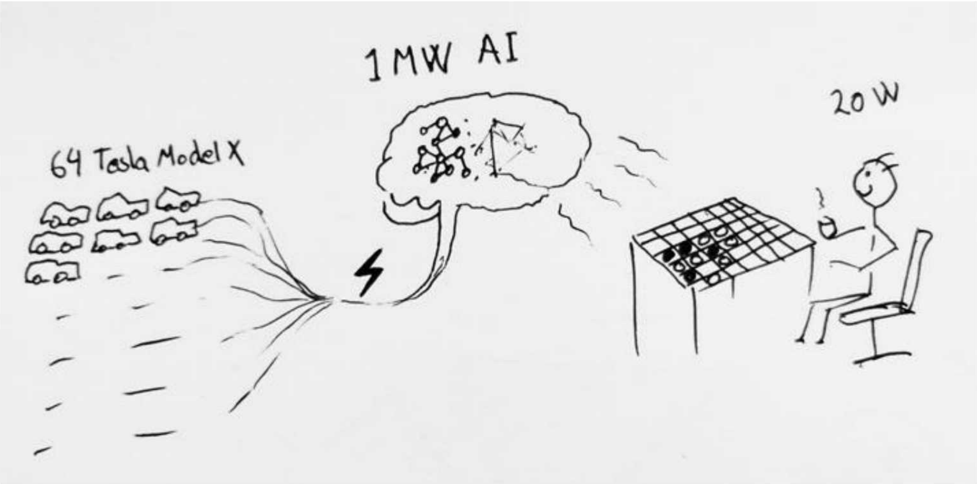
Sponsors:
- Sandia National Laboratories
- O-REU at TAMU

Collaborators:
- Matthew Marinella
- Christopher Bennett
- Tianyao (Patrick) Xiao
- INC Group at UT Austin

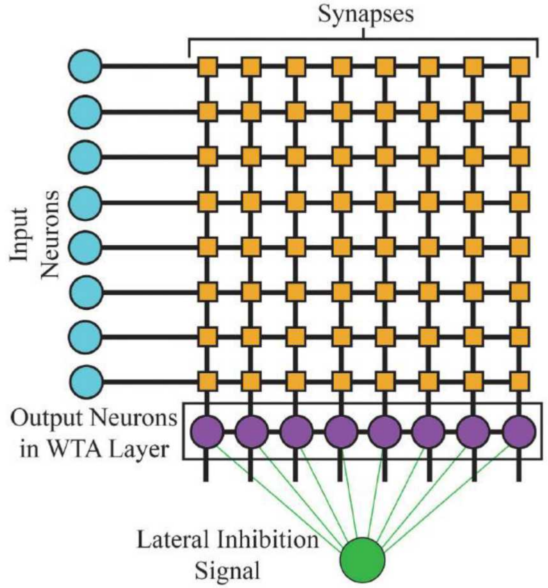
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Beyond-CMOS computing

https://www.imagimob.com/blog/are-there-fashion-trends-in-ai



- For big data applications, neural networks are often used, but traditional CMOS von-Neumann architecture is inefficient
- Magnetic domain wall devices controlled by spin-transfer torque can implement synapses and neurons in a neural network
- Using intrinsic properties of magnetic materials, it is possible to implement controllable non-linear synapses
- Goal: model non-linear synaptic behavior at device and system level



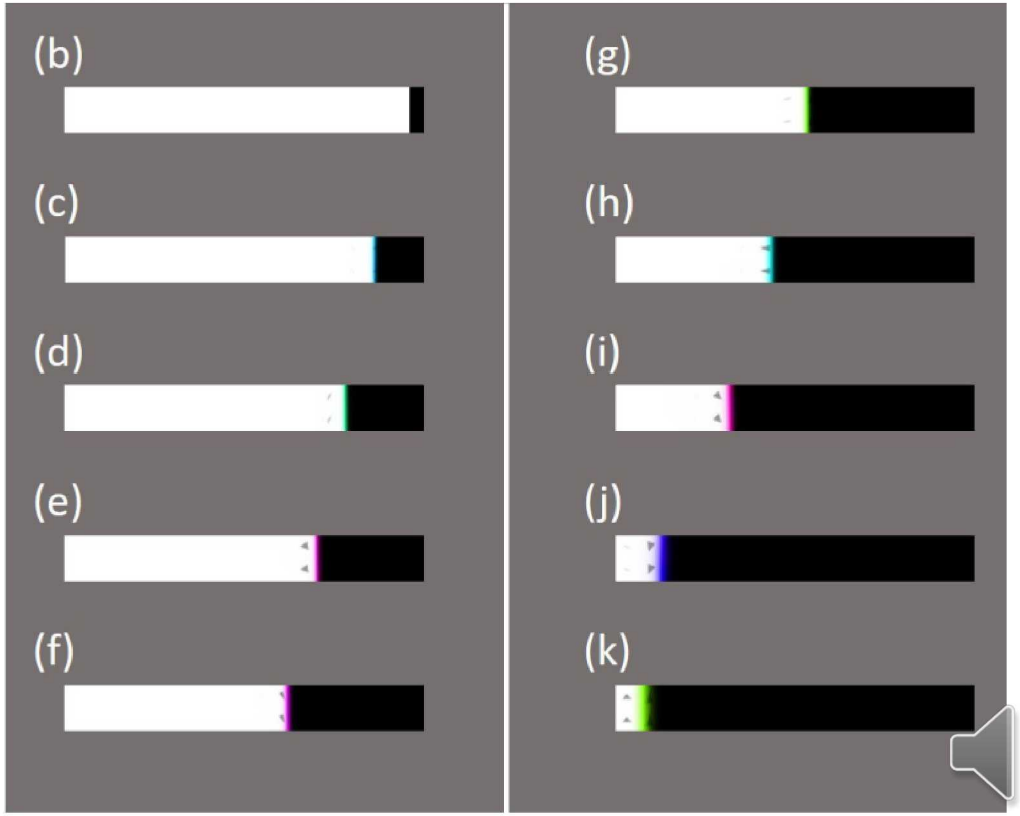
Hassan et al., *Magnetic domain wall neuron with lateral inhibition*

Micromagnetics and SPICE modeling

$$\vec{\tau}_{\mathrm{ZL}} = \frac{1}{1+\alpha^2}((1+\xi\alpha)\,\vec{\mathbf{m}}\times(\vec{\mathbf{m}}\times(\vec{\mathbf{u}}\cdot\nabla)\vec{\mathbf{m}}) + (\xi-\alpha)\,\vec{\mathbf{m}}\times(\vec{\mathbf{u}}\cdot\nabla)\vec{\mathbf{m}})$$

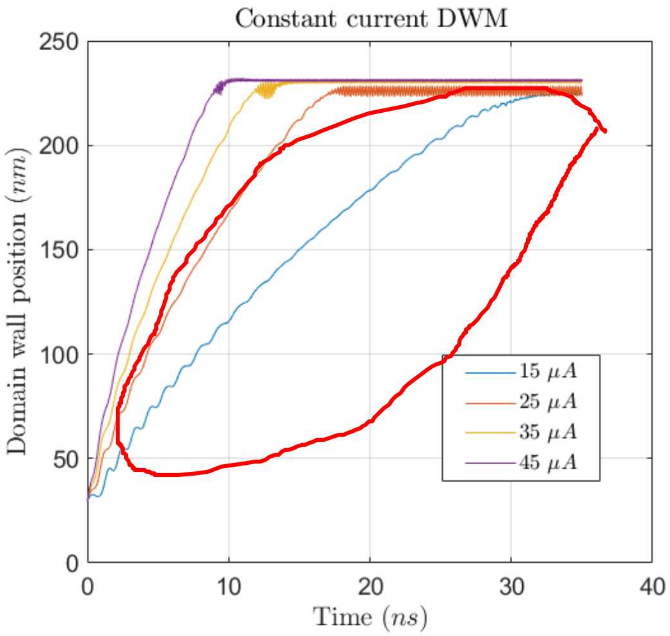
$$\vec{\mathbf{u}} = \frac{\mu_B\mu_0}{2e\gamma_0 B_{\mathrm{sat}}(1+\xi^2)}\vec{\mathbf{j}}$$

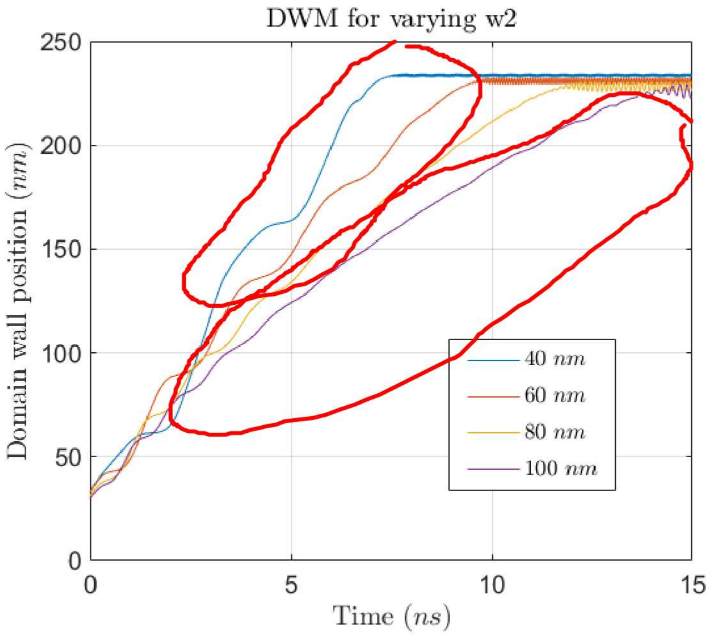
- Develop non-linear spin-transfer torque synapse model using micromagnetics simulation software MuMax3
- Develop model with spin orbit torque enhancement
- Verify behavior on a larger scale by using in conjunction with SPICE software
- Emphasis on ways to minimize leaking behavior in synapses

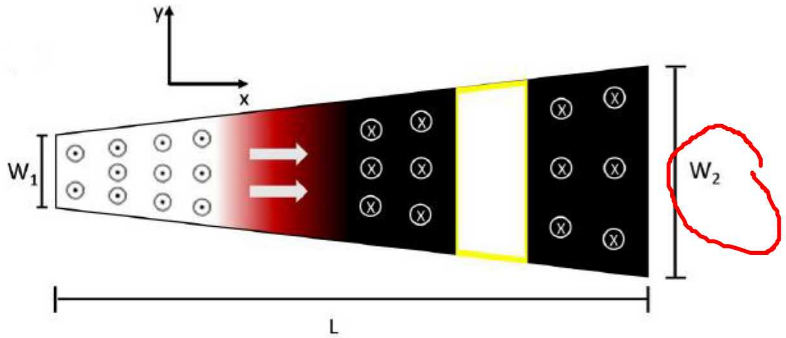


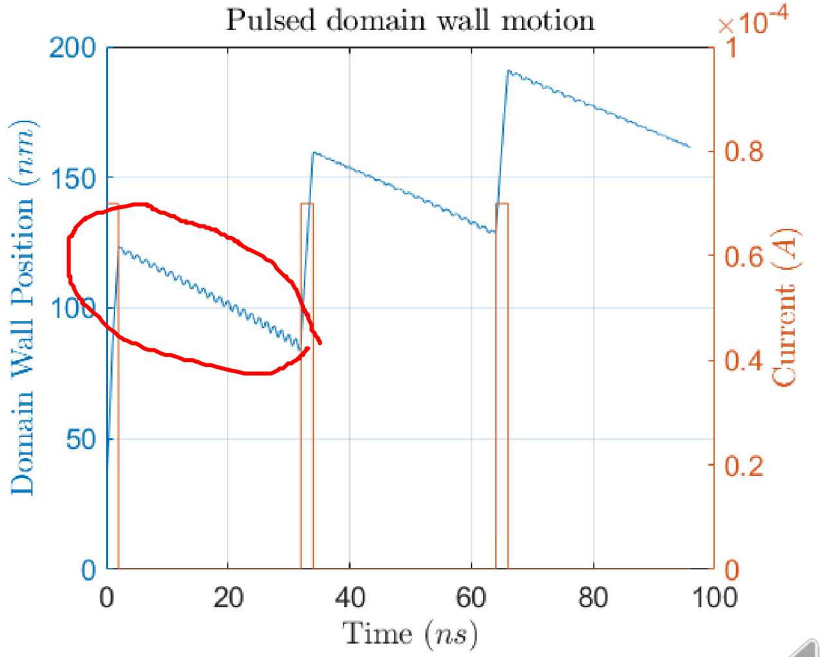
Brigner et al., *Graded-Anisotropy-Induced Magnetic Domain Wall Drift for an Artificial Spintronic Leaky Integrate-and-Fire Neuron*

MuMax results on shaped synapse









Conclusions and research direction

- Set up micromagnetics model of trapezoidal synapse using CoFeB material parameters
- Demonstrated non-linearity behavior of domain wall propagation for constant current pulse
- Next step: different shapes (curved, waves), notches, IMA material, spin orbit torque