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Electrical and Computer Engineering
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Maximized Lateral Inhibition in Paired Magnetic Domain Wall Racetracks for Neuromorphic Computing

Can Cui[1], Otitoaleke G. Akinola[1], Naimul Hassan[2], Christopher H. Bennett[3], Matthew J. Marinella[3], Joseph S. Friedman[2], and Jean Anne C. Incorvia[1]

[1]Electrical and Computer Engineering, University of Texas at Austin, Austin, TX, USA
[2]Electrical and Computer Engineering, University of Texas at Dallas, Richardson, TX, USA
[3]Sandia National Laboratories, Albuquerque, NM, USA

Can Cui | cancui@utexas.edu
Electrical and Computer Engineering, The University of Texas at Austin

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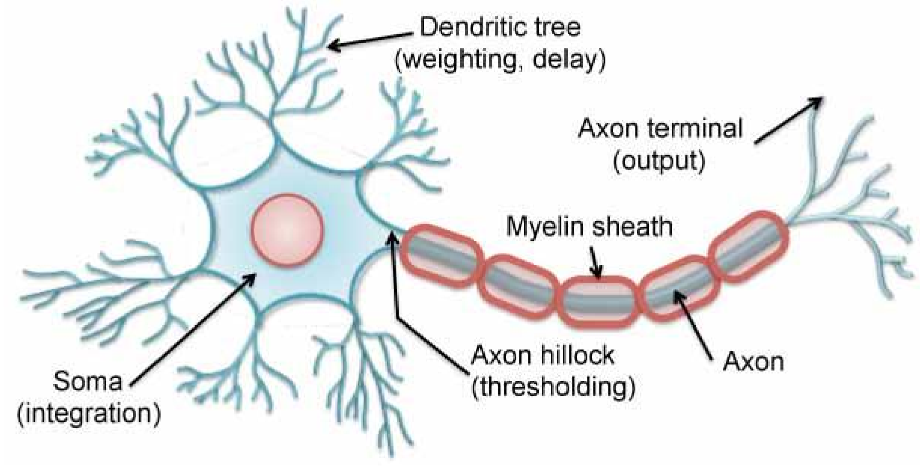
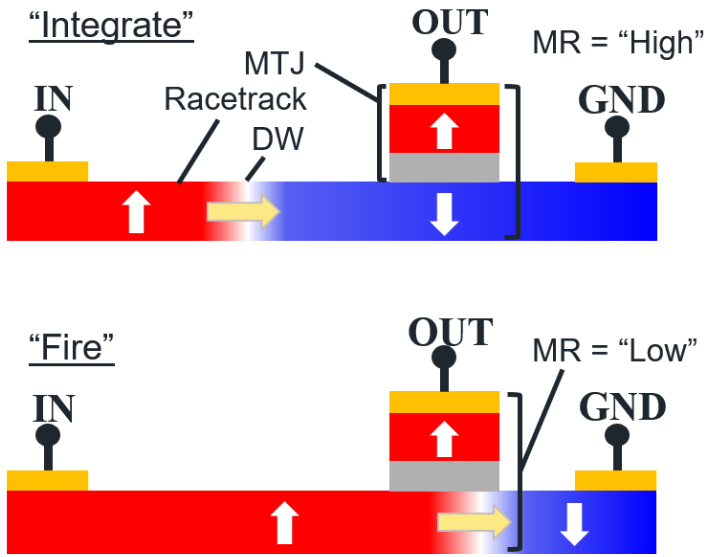
DW-MTJ neurons mimic biological neurons



Biological neuron (integrate-and-fire model)

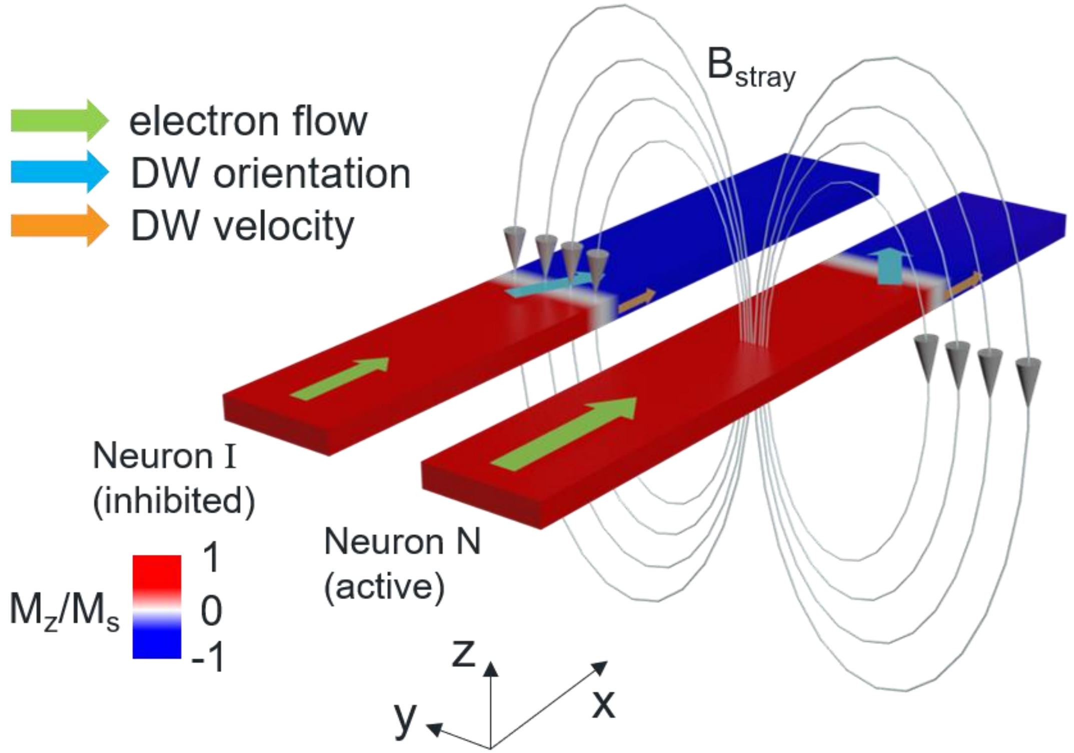
Source: Research group of Dr. Maple P. Fok
http://wave.engr.uga.edu/mfok/research.html



DW-MTJ integrate-and-fire neuron

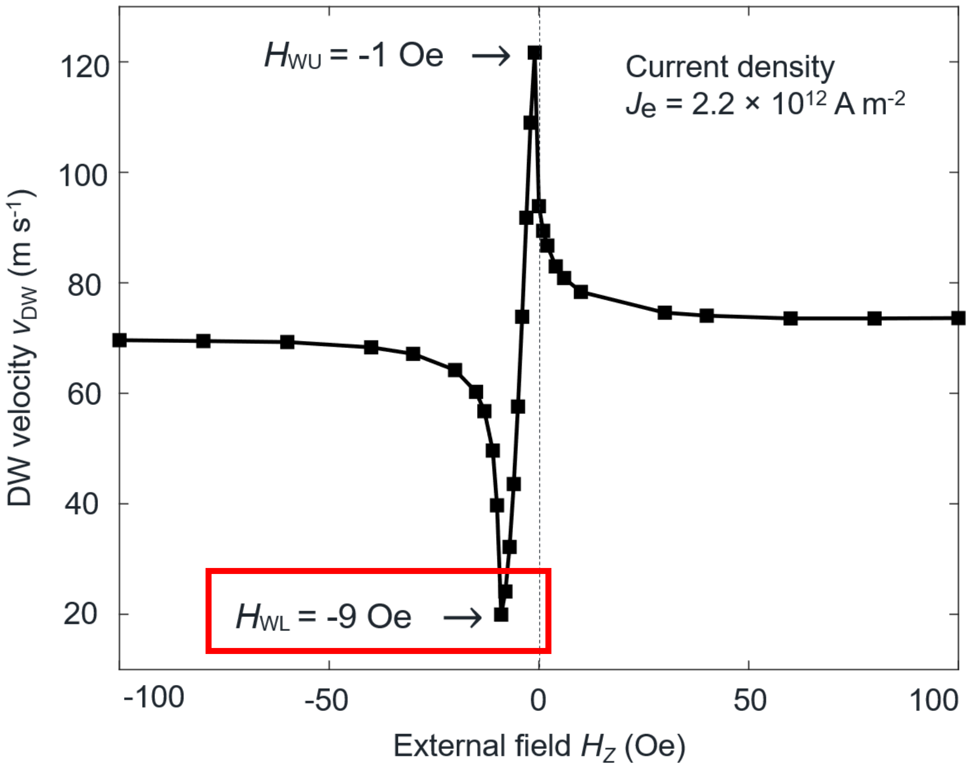
- Racetrack for DW propagation
- MTJ for spike readout
- Neuron activity is encoded in DW velocity

DW-MTJ neurons exhibit intrinsic lateral inhibition



- **Lateral inhibition**: A basic neuronal competition mechanism, that an active neuron prevents its less active neighbor(s) from firing.
- DW_I of Neuron I falls behind DW_N of Neuron N, so it is subjected to a stray field B_{stray} in –z.
- Reciprocally, DW_N is subjected to a stray field in +z (not shown).
- **We shall show that B_{stray} in –z can reduce DW_I velocity, leading to lateral inhibition.**

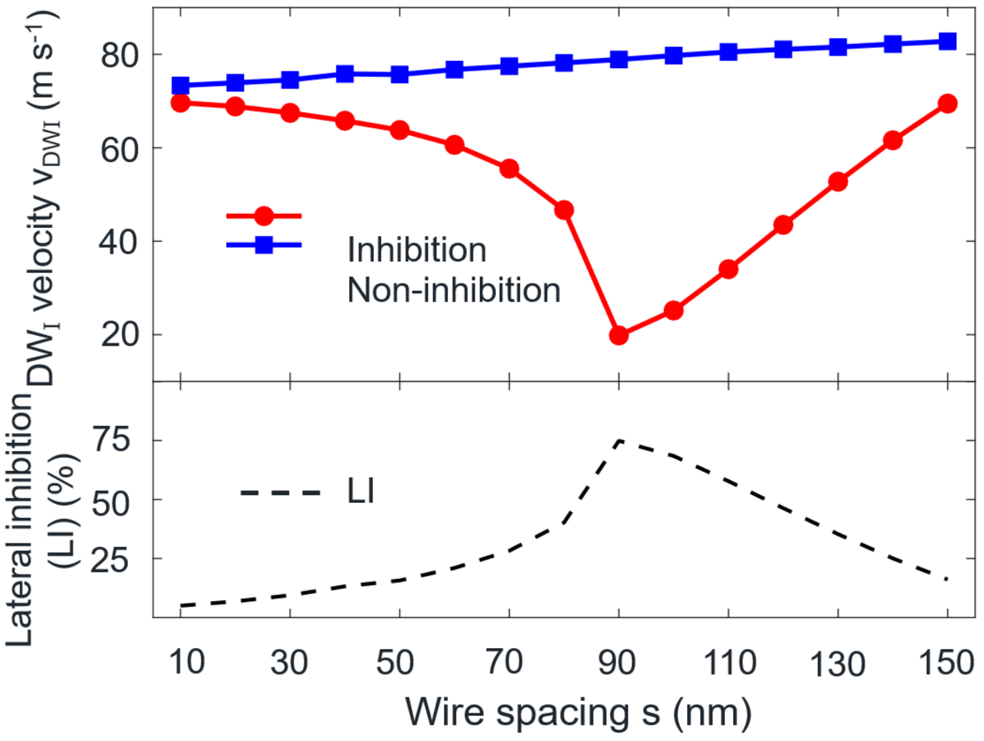
Current-driven DW velocity is tuned by external magnetic field



- Current density set to $J_e = 2.2 \times 10^{12}$ A m^{-2} while varying external field H_z.
- H_z = -9 Oe most effectively reduces DW velocity.
- The desired field magnitude can be achieved by tuning neuron spacing.

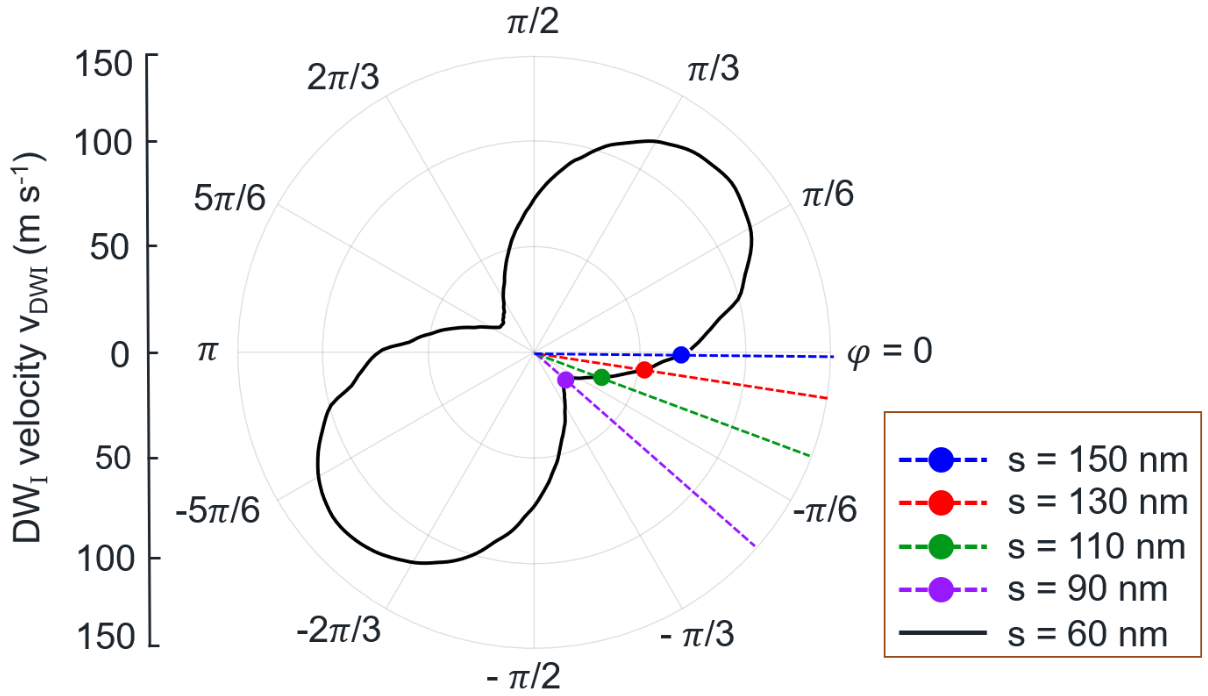
C. Cui, O. G. Akinola, N. Hassan, C. H. Bennett, M. J. Marinella, J. S. Friedman, and J. A. C. Incorvia, Maximized lateral inhibition in paired magnetic domain wall racetracks for neuromorphic computing, Nanotechnology 31, 294001 (2020)

Lateral inhibition is maximized by optimal neuron spacing



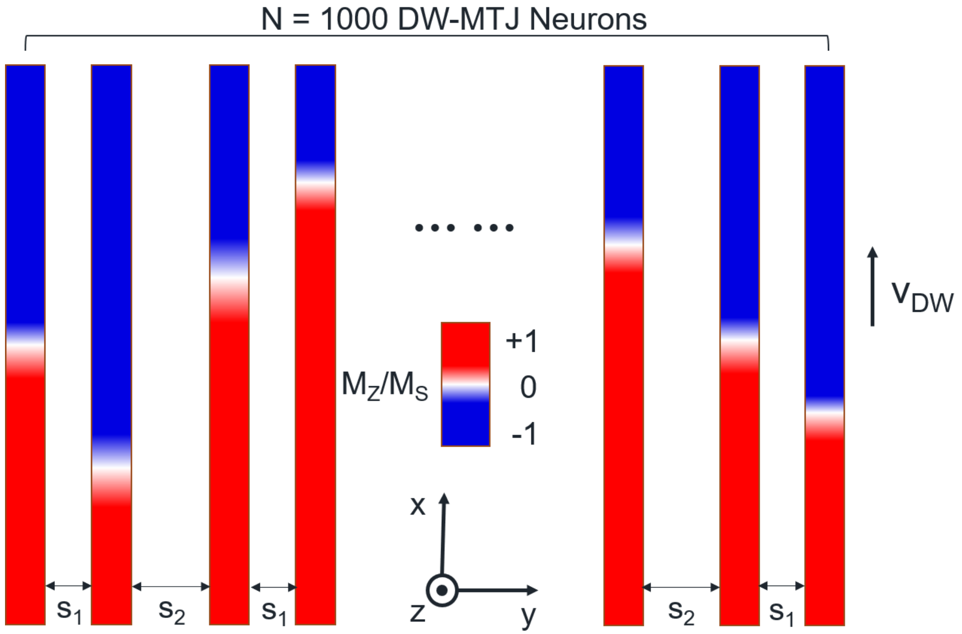
- Magnitude of B_{stray} is tuned by varying wire spacing s.
- DW$_I$ velocity v_{DWI} under inhibition and non-inhibition condition are simulated.
- Lateral inhibition is quantified based on the reduction of v_{DWI} under inhibition.

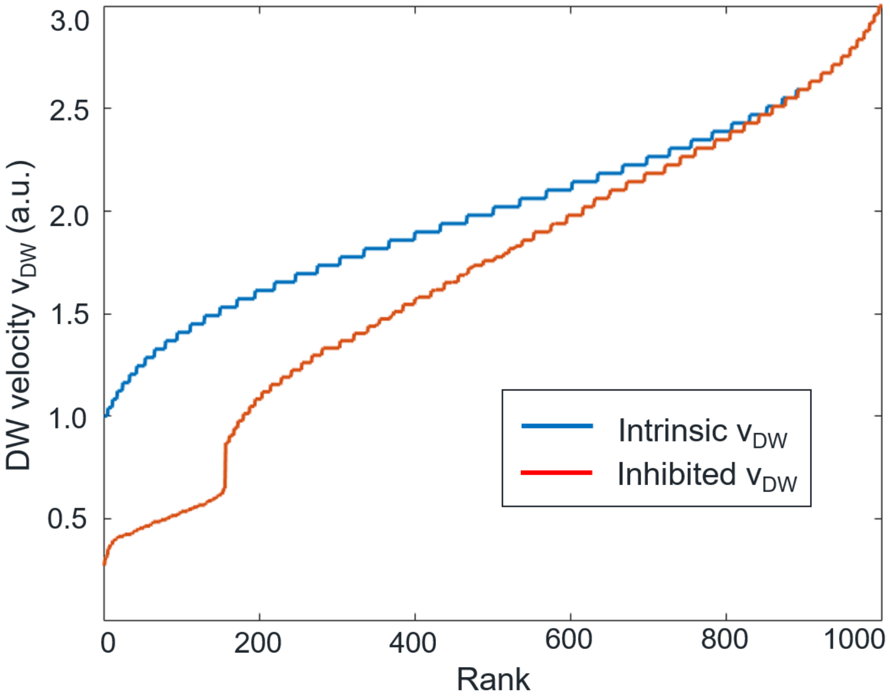
Stray field sets DW angle and velocity



- Neuron spacing s = 60 nm, DW_I angle precesssses (Walker breakdown).
- Neuron spacing s = 90 - 150 nm, DW_I angle is fixed (below-Walker breakdown).
- Inhibited DW_I velocity v_{DWI} is lowest for s = 90 nm, corresponding to maximum lateral inhibition

Lateral inhibition modulates DW velocity distribution in a DW-MTJ array





Conclusion

- DW-MTJ lateral inhibition is maximized by choosing the optimal lateral neuron spacing and therefore the stray field magnitude.

- In a DW-MTJ array, lateral inhibition modulates the DW velocity distribution, and can be potentially used to implement competitive learning algorithms.

Acknowledgments

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