# Current-Induced Switching in Antiferromagnetic Multilayer System


**Menucha Winchell**[1], Sucheta Mondal[2], Jeffrey Bokor[2]

Los Angeles Valley College[1]

Department of Electrical Engineering and Computer Sciences, University of California, Berkeley[2]


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## Abstract

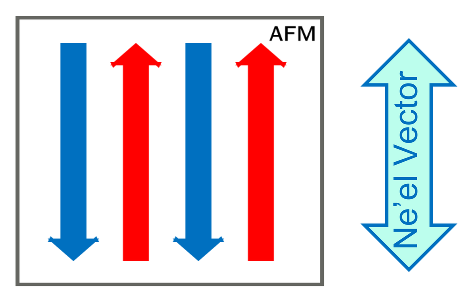
This research study utilized a micromagnetic simulator to observe the ultrafast dynamics and static properties of an antiferromagnetic systems. Static magnetic properties were observed through varying the Zeeman field surrounding the multilayer system, thus numerically describing coupling within the systems. The time evolution of magnetization within the systems was studied by injecting varied amounts of electrical current through a nonmagnetic heavy-metal layer under the antiferromagnet. The flow of charge current resulted in the generation of spin currents, exerting spin torque on the interfaces and thus producing Ne'el vector switching.


## Motivation

- **Ultrafast** switching using a multilayered nanodot and a short current pulse provides **energy efficiency.**
- Antiferromagnets (AFMs) allow for **robust**, **non-volatile** memory storage.

## Background of AFM's [1]

- Exhibit frequencies in the **THz** range during precessional motion.
- Due to compensated spins, antiferromagnets emit **negligible stray fields**.
- Insensitive to applied magnetic fields.
- AFMs usually used as **passive elements** in data storage devices.

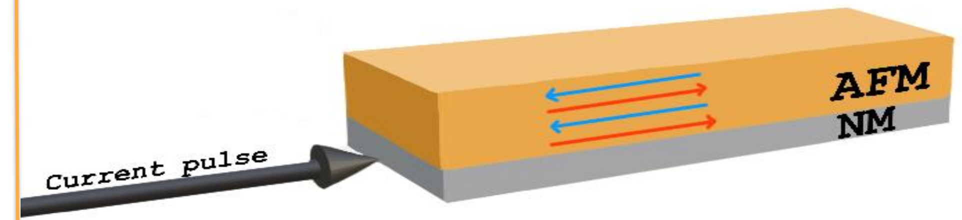



**Antiparallel** magnetic moments in AFMs result in no net magnetization in the system. Ne'el vector points parallel to AFM spins.

## Methods

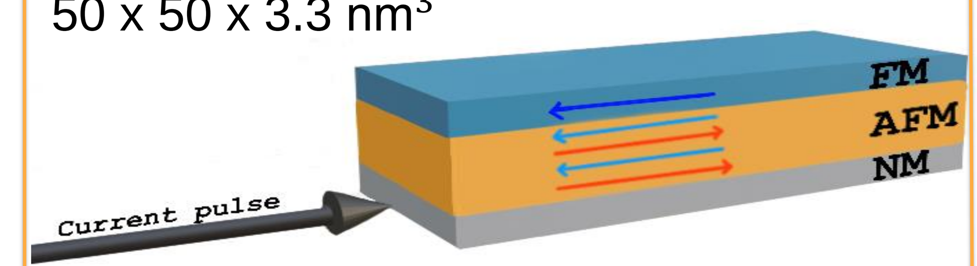
- Constructed two **nanostructures** using OOMMF [2] software:

50 x 50 x 2.5 nm$^3$




Nickel oxide (NiO), an A-type AFM, on top of on top of platinum (Pt), a non-magnetic heavy metal. **(HM/AFM)**

50 x 50 x 3.3 nm$^3$

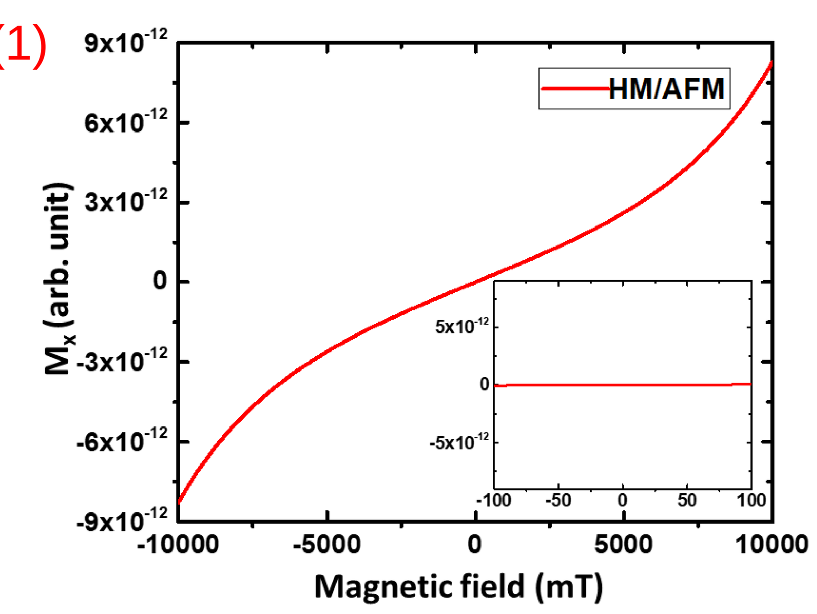



Permalloy (NiFe), a ferromagnet (FM), is layered on top of the previous system. **(HM/AFM/FM)**

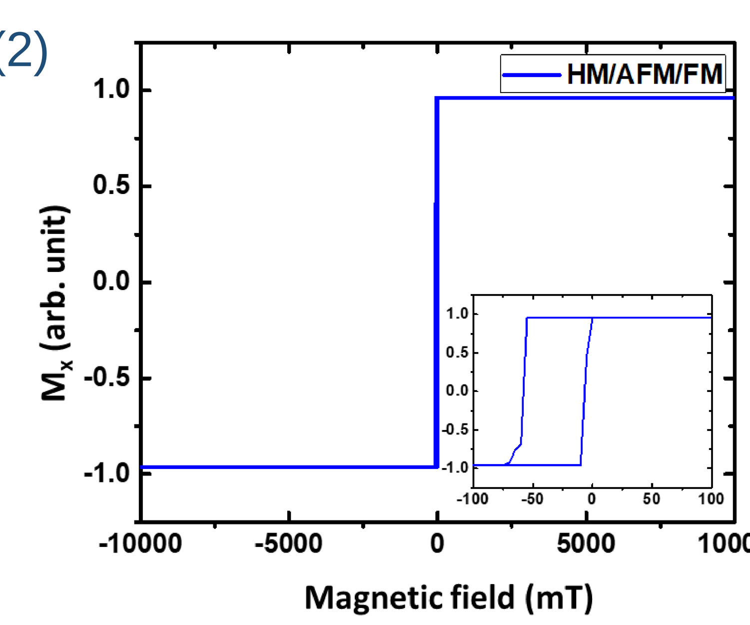
- Varied surrounding Zeeman field and observed hysteresis loops.
- Injected current pulses of varying current density and pulse-width into the non-magnetic layer and observe magnetization / Ne'el vector switching.

## Results

(1)

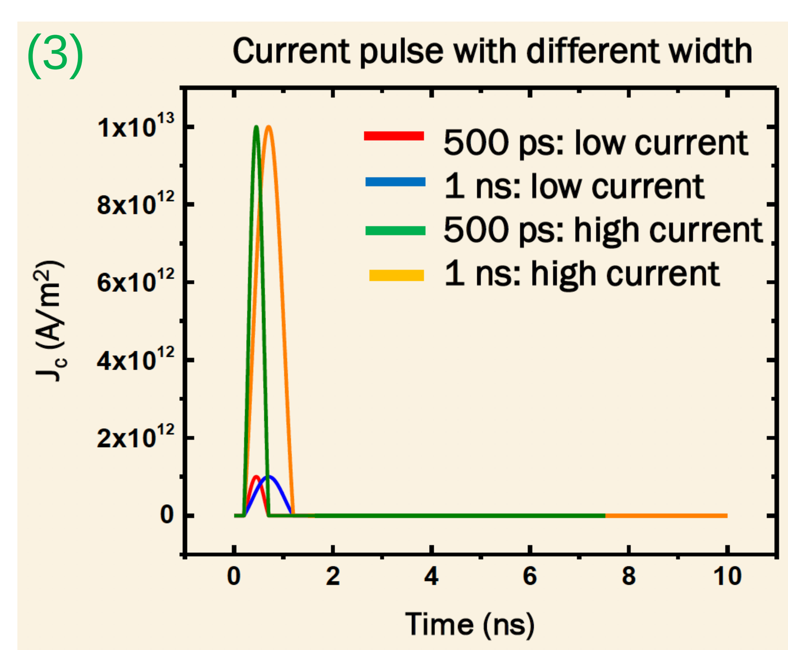



(2)

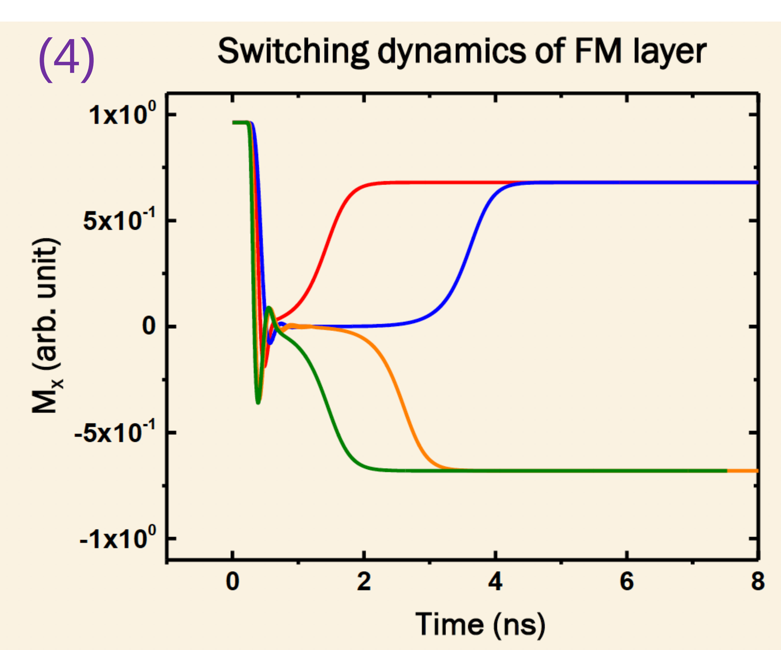


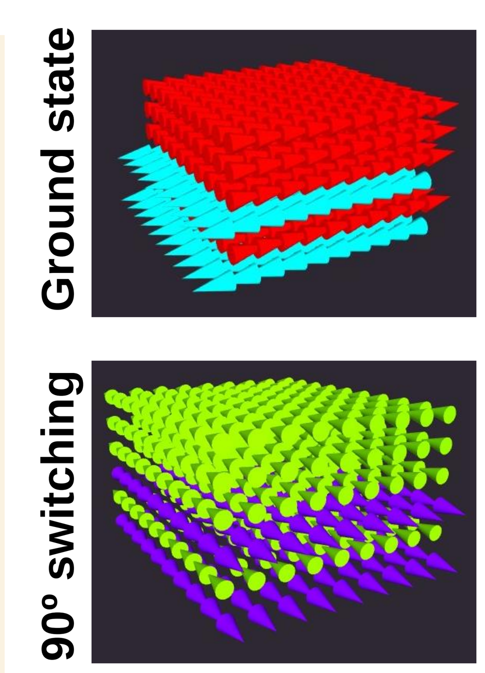

**Statics:** Hysteresis results achieved by applying a Zeeman field ranging from -10T to 10T. (1) HM/AFM displays strong antiparallel coupling. (2) HM/AFM/FM displays a 30 mT exchange bias, showing the coupling between the AFM and FM layers.

(3)



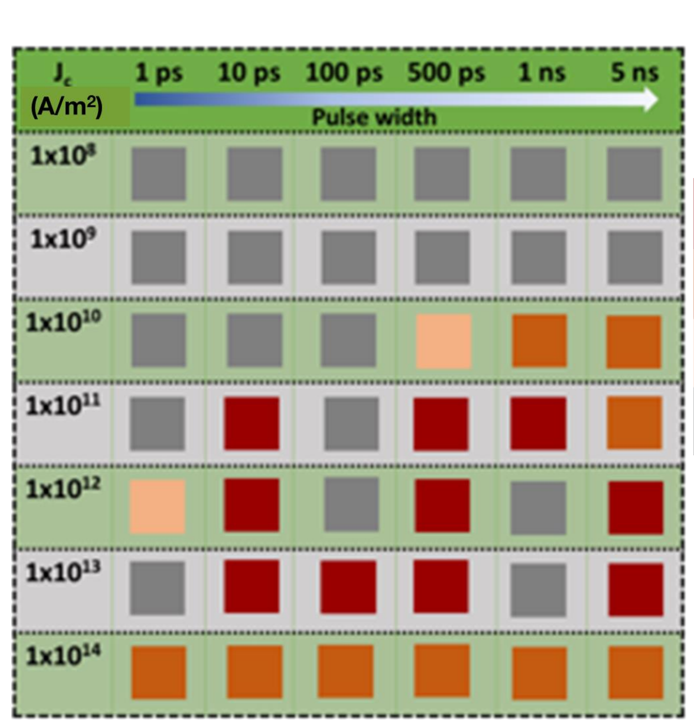

(4)



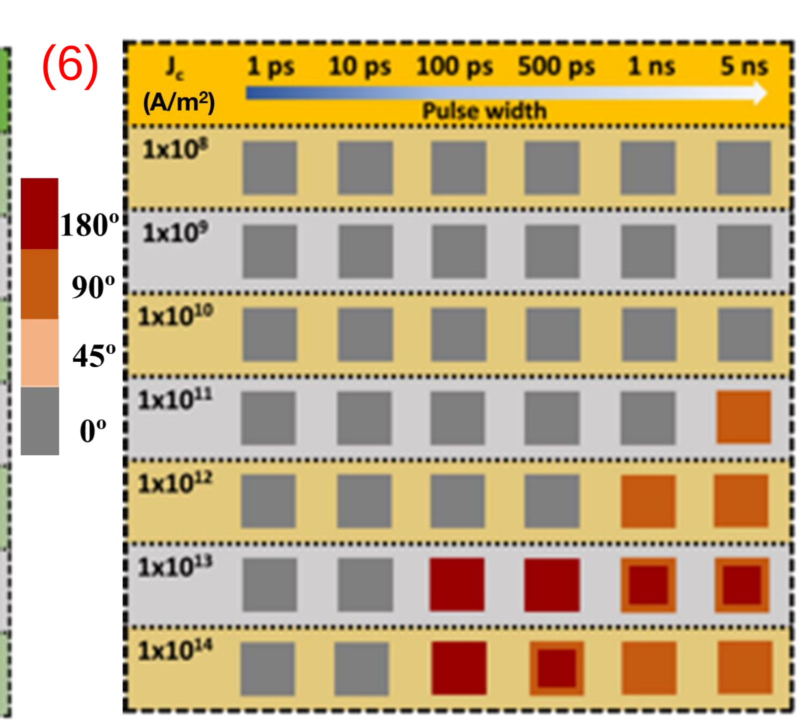




**Dynamics:** (3) Varied pulse widths and current densities, representing low and high current through the HM/AFM/FM system. (4) Switching dynamics for the FM layer in the HM/AFM/FM system. Using low current pulses, no switching occurs in the FM. However, using higher current pulses, the FM layer clearly switches its magnetization direction.

(5)




(6)




**Dynamics:** Switching map depicting the effects of pulse amplitude v. pulse width. (5) Current injected through the HM/AFM system. (6) Current injected through the HM/AFM/FM system.

- A smaller current is required to switch the AFM than the AFM/FM.
- Larger pulse widths cause switching with a smaller amount of current and vice versa.

## Conclusion

- By applying a spin current to the heavy-metal underlayer, we observed both 90 degree and 180 degree switching depending upon the combination of current density and pulse-width.

## References


[1] T. Jungwirth *et al.* "Antiferromagnetic spintronics," Nature Nanotechnology, vol. 11, no. 3, no. 3, March 2016.

[2] M. Donahue and D.G. Porter, "OOMMF User's Guide Version 1.0", Interagency Report NISTIR 6376, MD: National Institute of Standard and Technology, Gaithersburg, 1999.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**Contact Information**

Menucha Winchell

Email: menuchawinchell@gmail.com

Phone: (818)-423-6478



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