

Graham E. Rowlands

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RAYTHEON BBN TECHNOLOGIES: QUANTUM ENG. & COMP., 77 FAWCETT ST., CAMBRIDGE, MA 02138, USA
Research Scientist graham.rowlands@raytheon.com ↗ +1 (617) 873-3036

In addition to extensive fabrication and characterization experience, I am well versed in computational methods that enable more sophisticated data acquisition, data analysis, and numerical simulation techniques than are possible with conventional software products used in laboratory environments. My research efforts have focused on magnetic dynamics in nanostructures, both from an applications standpoint and in the interest of better understanding the physical phenomena that we will rely on in next generation devices. I have leveraged these skills to win new programs and in my experience as a principal investigator.

Current Research Interests

- Cryogenic magnetic memories for superconducting computing applications utilizing novel magnetic RAM technologies such as multi-polarizer spin valves and three-terminal devices driven by the spin-Hall effect.
- Disruptively fast simulation methods for modelling nonlinear magnetic microwave devices.
- Magnetic/superconductor heterostructures and their potential applications.
- Superconducting hardware implementations of neuromorphic computing architectures.

Education

- 2008–2012 Ph.D. in Physics, *University of California, Irvine*
2007–2008 M.S. in Physics, *University of California, Irvine*
2003–2007 B.A. in Physics, Cum Laude, With Distinction, *Boston University*

Employment

- 2015–present Research Scientist, *Raytheon BBN Technologies*
2012–2015 Postdoctoral Research Associate with Robert Buhrman, *Cornell University*
2008–2012 Research Assistant for Ilya Krivorotov, *University of California, Irvine*
2007–2008 Teaching Assistant, *University of California, Irvine*

Experience and Skills

Projects and Management

- Principal Investigator of the M3IC (Magnetic Miniaturized and Monolithically Integrated Components) modelling program.
- Take lead research role on C3 (Cryogenic Computing Complexity) helping to manage measurements and fabrication efforts across several academic and industrial institutions.

Nanofabrication

- Fabrication of nanoscale magnetic devices such as spin valves, magnetic tunnel junctions (MTJs), and three-terminal spin Hall effect devices.
- DC and RF magnetron sputter deposition, electron-beam and thermal evaporation.
- Photo- and electron-beam lithography, and narrow tolerance alignment between these processes.
- Ion milling, reactive ion etching (RIE) (including methanol RIE of magnetic materials).
- Atomic force microscopy (AFM) and scanning electron microscopy (SEM).

High Throughput Measurements and Characterization

- High-throughput switching experiments for magnetic RAM devices using pulse generators, arbitrary waveform generators, high-speed data acquisition, and custom high-performance software.
- Familiar with microwave signal delivery and a wide variety of microwave test equipment and components.
- Developed a new technique for mapping time-domain electrical response in magnetic systems to real-space magnetization dynamics.

Other Lab Skills

- Vacuum systems, cryogenic systems, and electronics.
- Vibrating sample and SQUID magnetometry.
- Machining with vertical mill, lathe, etc..
- Maintenance of sputter deposition and ion milling systems.

Programming, Numerical Simulations, and Computing

- Well versed in and Python, Julia, and C/C++. Familiar with a number of other languages. Extensive CUDA, OpenGL, and Qt experience.
- Developed open source *Auspex* instrument control software for magnetic and qubit measurements.
- Micromagnetic simulations with OOMMF, Mumax, nmag, etc. Developed custom micromagnetic eigensolver. Wrote code to automatically deploy large scale simulations on cloud computing platforms.
- Developed and maintain *Muvview2*, a free open source OpenGL based 3D viewer for micromagnetic simulation data.
- Familiar with a variety of scientific software packages including MATLAB and Mathematica.
- Experienced with graphic design, 3D modeling and rendering.

Publications

1. **G. E. Rowlands**, C. A. Ryan, L. Ye, L. Rehm, D. Pinna, A. D. Kent, T. A. Ohki, Coherent spin-transfer precession switching in orthogonal spin-torque devices, *arXiv preprint arXiv:1711.10575* (submitted to APL) (2017)
2. T.A. Gosavi, S. Manipatruni, S.V. Aradhya, **G. E. Rowlands**, D. Nikonov, Experimental Demonstration of Efficient Spin-Orbit Torque Switching of an MTJ With Sub-100 ns Pulses, *IEEE Trans. Mag.* **53**, 1-7 (2017).
3. **G. E. Rowlands**, S. V. Aradhya, S. Shi, E. H. Yandel, J. Oh, D. C. Ralph, Nanosecond magnetization dynamics during spin Hall switching of in-plane magnetic tunnel junctions, *Appl. Phys. Lett.* **110**, 122402 (2017).
4. M. Kazemi, **G. E. Rowlands**, S. Shi, R. A. Buhrman, E. G. Friedman, All-spin-orbit switching of perpendicular magnetization, *IEEE Trans. Elec. Dev.* **63**, 4499-4505 (2016).
5. S. V. Aradhya, **G. E. Rowlands**, J. Oh, D. C. Ralph, R. A. Buhrman Nanosecond-timescale low energy switching of in-plane magnetic tunnel junctions through dynamic oersted-field-assisted spin Hall effect, *Nano Lett.* **16**, 5987-5992 (2016).
6. C. L. Jermain, **G. E. Rowlands**, R. A. Buhrman, D. C. Ralph, GPU-accelerated micromagnetic simulations using cloud computing, *J. Mag. Mag. Mat.* **401**, 320-322 (2016).
7. P. G. Gowtham, **G. E. Rowlands**, R. A. Buhrman, A critical analysis of the feasibility of pure strain-actuated giant magnetostrictive nanoscale memories, *J. Appl. Phys* **118**, 183903 (2015).
8. J. Park, **G.E. Rowlands**, O.J. Lee, D.C. Ralph, R.A. Buhrman, Macrospin modeling of sub-ns pulse switching of perpendicularly magnetized free layer via spin-orbit torques for cryogenic memory applications, *Appl. Phys. Lett.* **105**, 102404 (2014).
9. **G. E. Rowlands**, J. A. Katine, J. Langer, J. Zhu, I. N. Krivorotov, Time Domain Mapping of Spin Torque Oscillator Effective Energy, *Phys. Rev. Lett.* **111**, 087206 (2013).
10. M. T. Rahman, a. Lyle, P. Khalili Amiri, J. Harms, B. Glass, H. Zhao, **G. E. Rowlands**, J. A. Katine, J. Langer, I. N. Krivorotov, et al., Reduction of switching current density in perpendicular magnetic tunnel junctions by tuning the anisotropy of the CoFeB free layer, *J. Appl. Phys.* **111**, 07C907 (2012).
11. **G. E. Rowlands**, I. N. Krivorotov, Magnetization dynamics in a dual free-layer spin-torque nano-oscillator, *Phys. Rev. B* **86**, 1–8 (2012).
12. J. Zhu, J. A. Katine, **G. E. Rowlands**, Y.-J. Chen, Z. Duan, J. Alzate, P. Upadhyaya, J. Langer, P. Amiri, K. Wang, I. N. Krivorotov, Voltage-Induced Ferromagnetic Resonance in Magnetic Tunnel Junctions, *Phys. Rev. Lett.* **108**, 197203 (2012).
13. P. Amiri, Z. Zeng, P. Upadhyaya, **G. E. Rowlands**, H. Zhao, Low Write-Energy Magnetic Tunnel Junctions for High-Speed Spin-Transfer-Torque MRAM, *Device Lett. IEEE* **32**, 2010–2012 (2011).
14. Z. M. Zeng, P. Khalili Amiri, **G. E. Rowlands**, H. Zhao, I. N. Krivorotov, J.-P. Wang, J. A. Katine, J. Langer, K. Galatsis, K. L. Wang, H. W. Jiang, Effect of resistance-area product on spin-transfer switching in MgO-based magnetic tunnel junction memory cells, *Appl. Phys. Lett.* **98**, 072512 (2011).
15. H. Zhao, a. Lyle, Y. Zhang, P. K. Amiri, **G. E. Rowlands**, Z. Zeng, J. Katine, H. Jiang, K. Galatsis, K. L. Wang, et al., Low writing energy and sub nanosecond spin torque transfer switching of in-plane magnetic tunnel junction for spin torque transfer random access memory, *J. Appl. Phys.* **109**, 07C720 (2011).
16. P. Upadhyaya, P. K. Amiri, A. a. Kovalev, Y. Tserkovnyak, **G. E. Rowlands**, Z. Zeng, I. N. Krivorotov, H. Jiang, K. L. Wang, Thermal stability characterization of magnetic tunnel junctions using hard-axis magnetoresistance measurements, *J. Appl. Phys.* **109**, 07C708 (2011).
17. P. K. Amiri, Z. M. Zeng, J. Langer, H. Zhao, **G. E. Rowlands**, Y. Chen, I. N. Krivorotov, J. Wang, H. W. Jiang, J. A. Katine, et al., Switching current reduction using perpendicular anisotropy in CoFeB–MgO magnetic tunnel junctions, *Appl. Phys. Lett.* **98**, 112507–112507 (2011).
18. **G. E. Rowlands**, T. Rahman, J. A. Katine, J. Langer, A. Lyle, H. Zhao, J. G. Alzate, A. a. Kovalev, Y. Tserkovnyak, Z. M. Zeng, et al., Deep subnanosecond spin torque switching in magnetic tunnel junctions with combined in-plane and perpendicular polarizers, *Appl. Phys. Lett.* **98**, 4–6 (2011).
19. D. E. Nikonov, G. I. Bourianoff, **G. E. Rowlands**, I. N. Krivorotov, Strategies and tolerances of spin transfer torque switching, *J. Appl. Phys.* **107**, 113910 (2010).

Invited Talks

1. **G.E. Rowlands**, E. Toomey, A. Wagner, G. Ribeill, L. Ranzani, M. H. Nguyen, S. Shi, S. V. Aradhya, A. Dane, K. Berggren, R. A. Buhrman, T. A. Ohki, “How nanosecond magnetization dynamics during spin-Hall switching of in-plane MTJs enables a cryogenic memory cell with superconducting line drivers.” *APS March Meeting 2018, Los Angeles, California*.
2. **G. E. Rowlands**, M.H. Nguyen, S. V. Aradhya, C. A. Ryan, D. C. Ralph, R. A. Buhrman, T. A. Ohki, “Towards a Cryogenic operation of three-terminal spin-Hall effect memory elements”, *Conference on Magnetism and Magnetic Materials 2016, New Orleans, Louisiana*.
3. **G.E. Rowlands**, J. Zhu, J.A. Katine, J. Langer, and I.N. Krivorotov, “A time-domain method for mapping stochastic dynamics in spin torque oscillators” *SPIE Optics & Photonics, San Diego, California, August 2013*.

4. **G.E. Rowlands**, J. Zhu, J.A. Katine, J. Langer, and I.N. Krivorotov, "Time Domain Measurements of Stochastic Dynamics in Spin-Torque Oscillators" *New York University, New York, New York, June 2012*.
5. **G.E. Rowlands**, J. Zhu, J.A. Katine, J. Langer, and I.N. Krivorotov, "Time Domain Measurements of Stochastic Dynamics in Spin-Torque Oscillators" *Cornell University, Ithaca, New York, April 2012*.

Contributed Talks

1. **G. E. Rowlands**, S. V. Aradhya, S. Shi, M.H. Nguyen, D. C. Ralph, R. A. Buhrman "Fast Switching of In-Plane Magnetized Three-Terminal Devices with the Spin-Hall Effect" *Conference on Magnetism and Magnetic Materials 2016, San Diego, California*.
2. **G.E. Rowlands**, P. G. Gowtham, J. Park, D. C. Ralph, R. A. Buhrman, "Influence of Structural and Compositional Non-Uniformities on the Reversal Properties of Perpendicular Magnetic Films." *Conference on Magnetism and Magnetic Materials 2014, Honolulu, Hawaii*.
3. **G.E. Rowlands**, J. Zhu, J.A. Katine, J. Langer, P. Khalili Amiri, K.L. Wang, and I.N. Krivorotov, "Time-Domain Measurements of Real-Space Magnetization Trajectories in Spin Torque Oscillators." *American Physical Society March Meeting 2012, Boston, Massachusetts*.
4. **G.E. Rowlands**, P. Khalili Amiri, J.A. Katine, J. Langer, K.L. Wang, and I.N. Krivorotov, "Time Domain Measurements of Stochastic Spin-Torque Oscillator Dynamics." *Conference on Magnetism and Magnetic Materials 2011, Scottsdale, Arizona*.
5. **Graham Rowlands**, Tofizur Rahman, Jordan Katine, Juan Alzate, Alexey Kovalev, Yaroslav Tserkovnyak , Kosmas Galatsis, Pedram Khalili Amiri, Kang Wang, Jian-Ping Wang, and Ilya Krivorotov, "High Speed Spin Torque Memory with Combined Perpendicular and In-Plane Polarizers," *American Physical Society March Meeting 2011, Dallas, Texas*.
6. **G. Rowlands**, T. Rahman, J. Katine, A. Lyle, H. Zhao, J. G. Alzate, A. Kovalev, Y. Tserkovnyak, Z. Zeng, H. Jiang, K. Galatsis, P. Khalili Amiri, K. L. Wang, J. Wang, and I. Krivorotov, "High Speed Spin Torque Memory with Combined Perpendicular and In-Plane Polarizers," *Conference on Magnetism and Magnetic Materials 2010, Atlanta, Georgia*.
7. **G. Rowlands**, I. N. Krivorotov, "Phase Diagram of Spin-Torque Oscillators with Dual Free Layer," *American Physical Society March Meeting 2010, Portland, Oregon*.
8. **G. Rowlands**, I. N. Krivorotov, "Frequency-doubling spin-torque microwave oscillator," *American Physical Society March Meeting 2009, Pittsburg, Pennsylvania*.

Awards and Honors

1. Best Poster Award: "Time Domain Analysis of Stochastic Spin-Torque Oscillators," *Western Institute of Nanoelectronics (WIN) Annual Review Session 2011*.
2. Best Poster Award: "Multi-Polarizer Structures as Spin-Torque Magnetic RAM Elements," *UCI Institute for Surface and Interface Science (ISIS) Poster Session 2010*.

Personal Notes

Interests: Cooking, rock-climbing, cycling, guitar, violin.