Stochastic Magnetic Tunnel Junctions for Probabilistic Computing and Solving Combinatorial Optimization Problems

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Abstract

Magnetic tunnel junctions (MTJs) are widely used as nonvolatile memory elements, but they can also serve as controllable, high-rate sources of random bits [1]. In this talk, I will describe experimental studies of perpendicularly magnetized MTJs that are magnetically stable at room temperature [2,3]. Instead of relying on spontaneous thermal magnetization fluctuations (superparamagnetism), stochastic behavior is generated on demand by actuating the device with nanosecond electrical pulses in the ballistic spin-transfer regime. This approach enables precise control of the switching probability. I will present measurements showing high-rate (up to 100 MHz/MTJ), reproducible generation of random bit streams [4] and random telegraph noise [5]. By interfacing individual pMTJs with custom electronics and a field-programmable gate array (FPGA), we generate truly random numbers that pass the full NIST statistical test suite with no post-processing [6]. I will also show how such actuated stochastic MTJs (A-sMTJs) can be electrically connected in simple circuits to generate tunable, circuit-mediated interactions that map onto effective Ising couplings. Finally, I will discuss the potential of stochastic MTJs for physics-inspired computing systems, including their use for solving combinatorial optimization problems [7].

References

[1] For a recent review, see: J. Z. Sun et al., "Superparamagnetic and stochastic-write magnetic tunnel junctions for high-speed true random number generation in advanced computing," J. Phys. D: Appl. Phys. 59, 013002 (2026). **[2]** L. Rehm et al., "Stochastic magnetic actuated random transducer devices based on perpendicular magnetic tunnel junctions," Phys. Rev. Appl. 19, 024035 (2023). **[3]** L. Rehm et al., "Temperature-resilient true random number generation with stochastic actuated magnetic tunnel junction devices," Appl. Phys. Lett. 124, 052401 (2024). **[4]** A. Sidi El Valli et al., "High-Speed Tunable Generation of Random Number Distributions Using Actuated Perpendicular Magnetic Tunnel Junctions," Appl. Phys. Lett. 126, 212403 (2025). **[5]** A. Sidi El Valli et al., "Tunable Random Telegraph Noise in Stable Perpendicular Magnetic Tunnel Junctions for Unconventional Computing," arXiv: 2509.13458 (to appear in PR Applied). **[6]** T. Criss et al., "Magnetic tunnel junction as a real-time entropy source: Field-Programmable Gate Array-based random bit generation without post-processing," J. Appl. Phys. 139, 013903 (2026). **[7]** Dairong Chen, Andrew D. Kent, Dries Sels, and Flaviano Morone, "Solving combinatorial optimization problems through stochastic Landau-Lifshitz-Gilbert dynamical systems," Phys. Rev. Research 7, 013129 (2025).

Bio

Andrew Kent is a Professor of Physics and the Founding Director of the Center for Quantum Phenomena at New York University. He earned his B.Sc. with Distinction in Applied and Engineering Physics from Cornell University and his Ph.D. in Applied Physics from Stanford University. His research focuses on the physics of magnetic nanostructures, nanomagnetic devices, and magnetic information processing. He is a Fellow of the American Physical Society (APS) and the Institute of Electrical and Electronics Engineers (IEEE). Dr. Kent has received numerous awards and honors, including an Honorary Doctorate from the University of Lorraine, France (2013), the French Jean d'Alembert Research Fellowship (2017), and appointments as Professor at the University of Lorraine in 2018 and 2023.

Host

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