

2023 PhD Projects

Project title	Theory of Spintronics
Principal supervisor	Andrey Umerski
Second supervisor	Marc Pradas
Discipline	Applied mathematics
Research area/keywords	Applied Mathematics, Theoretical Physics, Quantum Mechanics, Spin Transport
Suitable for	Full-time or part-time applicants

Project background and description

Spintronics is a hugely important scientific field which attempts to exploit the spin of the electron in addition to its electric charge [1]. As such it can be thought of as a generalisation of traditional electronics which only ever utilises the charge of the electron. The field spans a large area of scientific endeavour from theoretical physics to engineering and is a sub-discipline of nanotechnology. It has applications to magnetic field sensors, data storage, as well as quantum and neuromorphic computing.

The modern day hard-disk read-head was the first commercial spintronic device to utilise the spin of an electron rather than its electric charge [2]. Other spintronic devices currently being developed include, novel types of ultra-fast non-volatile memory and spin-based transistors and logic gates that use electron spin for information processing. Such devices may work with virtually no applied current, superseding present-day traditional electronic technology.

This project will focus on various fundamental aspects of a phenomenon called "interlayer exchange coupling" in "out-of-equilibrium" systems. This has application to a new form of non-volatile memory called MRAM (magnetic random access memory) [3], which promises to eventually surpass all other computer memory including RAM becoming a "universal memory". The project will use a mixture of traditional pencil and paper applied mathematics, computer algebra and high performance numerical computing. The project applicant should have a sound knowledge of undergraduate quantum mechanics and applied mathematics. The ability to program in a numerical computer language such as C or FORTRAN would be of benefit, but could be learned during the studentship.

Background reading/references

- 1 D.D. Awschalom, M.E. Flatte and N. Samarth, *Scientific American*, pp66-73, June 2002.
- 2 J. Mathon and A. Umerski, 'Theory of Tunneling Magnetoresistance and its Application to Hard Disk Technology', in 'UK Success Stories in Industrial Mathematics', (2016), Springer, pp. 179-204, ISBN-10: 3319254529
- 3 Akerman, J. (2005). "APPLIED PHYSICS: Toward a Universal Memory". *Science*. 308 (5721): 508–510. doi:10.1126/science.1110549.