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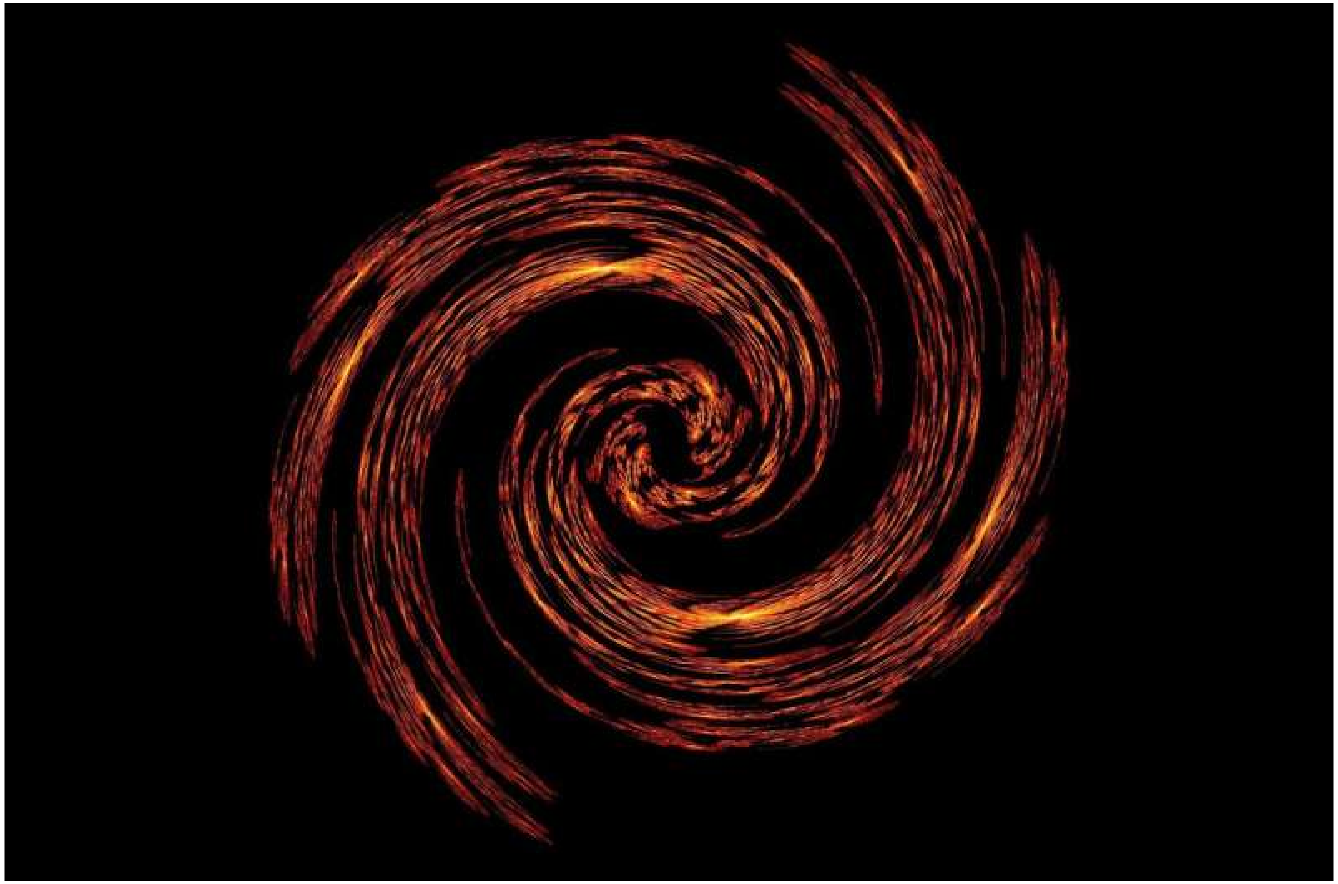
Electrical spin filtering the key to ultra-fast, energy-efficient spintronics

by ARC Centre of Excellence in Future Low-Energy Electronics Technologies (FLEET)



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Spin-filtering could be the key to faster, more energy-efficient switching in future spintronic technology, allowing the detection of spin by electrical rather than magnetic means.

A UNSW paper published last month demonstrates spin detection using a spin filter to separate spin orientation according to their energies.

Ultra-fast, ultra-low energy 'spintronic' devices are an exciting, beyond-CMOS technology.

Detecting spin via electrical means in future spintronics

The emerging field of spintronic devices use the extra degree of freedom offered by particles' quantum spin, in addition to its charge, allowing for ultra-fast, ultra-low energy computation.

The key is the ability to generate and detect spin as it accumulates on a material's surface.

The aim of researchers is to generate and detect spin via electrical means, rather than magnetic means, because electric fields are a lot less energetically costly to generate than magnetic fields.

Energy-efficient spintronics is dependent on both generation and detection of spin via electrical means.

In strongly spin-orbit coupled semiconductor systems, all-electrical generation of spin has already been successfully demonstrated.

However, detection of spin-to-charge conversion has always required a large range of magnetic fields, thus limiting the speed and practicality.

In this new study, UNSW researchers have exploited the non-linear interactions between spin accumulation and charge currents in gallium-arsenide holes, demonstrating all-electrical spin-to-charge conversion without the need for a magnetic field.

"Our technique promises new possibilities for rapid spin detection in a wide variety of materials, without using a magnetic field," explains lead author Dr. Elizabeth Marcellina.

Previously, generation and detection of spin accumulation in semiconductors has been achieved through optical methods, or via the spin Hall effect-inverse spin Hall effect pair.

However, these methods require a large spin diffusion length, meaning that they are not applicable to strongly spin-orbit coupled materials with short spin diffusion length.

All-electrical spin filtering

The UNSW study introduces a new method for detecting spin accumulation—using a spin filter, which separates different spin orientations based on their energies.

Typically, spin filters have relied on the application of large magnetic fields, which is impractical and can interfere with the spin accumulation.

Instead, the UNSW team exploited non-linear interactions between spin accumulation and charge, which facilitate the conversion of spin accumulation into charge currents even at zero magnetic field.

"Using ballistic, mesoscopic gallium-arsenide holes as a model system for strongly spin-orbit coupled materials, we demonstrated non-linear spin-to-charge conversion that is all-electrical and requires no magnetic field," says corresponding author A/Prof Dimi Culcer (UNSW).

"We showed that non-linear spin-to-charge conversion is fully consistent with the data obtained from linear response measurements and is orders of magnitude faster," says corresponding-author Prof Alex Hamilton, also at UNSW.

Because the non-linear method does not need a magnetic field nor a long spin diffusion length, it promises new possibilities for fast detection of spin accumulation in strongly spin-orbit coupled materials with short spin diffusion lengths, such as TMDCs and topological materials.

Finally, the rapidness of non-linear spin-to-charge conversion can enable time-resolved read-out of spin accumulation down to 1 nanosecond resolution.

More information: E. Marcellina et al. Nonlinear spin filter for nonmagnetic materials at zero magnetic field, *Physical Review B* (2020). DOI: 10.1103/physrevb.102.140406

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