Physicists demonstrate using non-polarized light to produce spin voltage in metal for first time

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With apologies to Isaac Asimov, the most exciting phase to hear in science isn't "Eureka," but "That's funny..." A "that's funny" moment in a Colorado State University physics lab has led to a fundamental discovery that could play a key role in next-generation microelectronics.

Publishing in *Nature Physics* April 25, the scientists, led by Professor of Physics Mingzhong Wu in CSU's College of Natural Sciences, are the first to demonstrate using non-polarized light to produce in a metal what's called a spin voltage - a unit of power produced from the quantum spinning of an individual electron. Controlling electron spins for use in memory and logic applications is a relatively new field called spin electronics, or spintronics, and the subject of the 2007 Nobel Prize in Physics.

Wu and his group's passion is to find new, better ways to control electron spins, the physics of which isn't completely understood. Spintronics exploits the notion that electron spins can be manipulated and used to process and store information, with a fraction of the power needed in ubiquitous, conventional electronics.

Consider that the iPhone and every electronic device out there is built upon centuries of science around charge current - the physics of positive or negative charges flowing through a device. The perennial problem is the enormous power consumption of charge-current devices, and the electrical resistance that causes power loss in the form of heat - which is why your laptop keeps overheating.

It's these power and heat barriers that are holding smaller, more powerful electronics back. And it's why science is turning to spintronics, because it offers a completely new way of making a device work. To utilize power from an electron spin, there's no charge current necessary. All that's needed is a magnetic field or a magnetic material, which can orient the spins "up" or "down." The up and down spins are the analogue to positive and negative charges.

What the CSU scientists have found is a brand-new method for creating spin currents. Existing methods include using a charge current, microwaves or a heat source. But for the first time, the CSU team demonstrates using light - or in the quantum world, photons - to generate their spin currents.

Other scientists have done similar things, but they used a special kind of polarized light. Here, the CSU scientists used unpolarized, plain light - "a halogen bulb purchased at Ace Hardware," said graduate student David Ellsworth who is the first author on the paper. They demonstrated a "pure" spin current - involving no charge movement whatsoever. It was an unprecedented feat.

The breakthrough came about while the scientists were studying a different way to make spin currents, using heat from their halogen bulb, called the Spin Seebeck effect. They noticed some background data they couldn't explain.

Ever curious, they checked all possibilities and determined this seemingly light-induced spin current could be a new quantum phenomenon. They tested it by designing unique control measurements involving different magnetic insulators and metallic thin films, such as platinum. After replicating their results in the lab, they turned to theoreticians at UC Irvine and Fudan University to help them interpret the physics of what they'd discovered, and who are co-authors on the *Nature Physics* paper.

Wu said the discovery is too new to think about real applications; where they're at now is continuing to make breakthroughs in the understanding of spin currents. "Just like with the photovoltaic effect when it was first discovered, no one thought at first of a solar cell," Wu said. "Technologies take time before they are used in real devices. This is a fundamental, new discovery."

Said Jake Roberts, chair of the Department of Physics: "There have been tremendous technical advances in controlling light. What I see in this discovery is that now, they've linked light to spin control. Using a simple light source to produce a spin current offers new opportunities for power control and generation."

The researchers will continue exploring making spin currents with light by swapping out materials and trying different light sources. They demonstrated light control in the infrared range, Ellsworth said. Moving into the visible or UV range would likely offer more robust applications for devices.

"The framework for generating and detecting spin currents is non-trivial," Ellsworth explained. "Meanwhile, there are hundreds of years of generating charge currents and knowing how to measure them and manipulate them and characterize them. Spintronics is a new field, and devices are just now coming onto the market that utilize some small part of this."

More information: Photo-Spin-Voltaic Effect, *Nature Physics*, DOI: 10.1038/nphys3738

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