Altermagnetism

In an effort to reshape the foundations of military computing and electronics, the Defense Advanced Research Projects Agency (DARPA) is exploring one of the newest and strangest frontiers in physics: altermagnetism.

Recently, the agency's Defense Sciences Office (DSO) issued a Request for Information (RFI) titled "Altermagnetism for Devices," inviting researchers to help chart a course toward practical electronic and spintronic technologies that could harness this exotic magnetic behavior.

Altermagnetism sounds like something pulled from science fiction. It combines properties of two long-known types of magnetism—ferromagnetism (the kind that drives refrigerator magnets) and antiferromagnetism (found in many metals but invisible to the naked eye).

However, its true intrigue lies in what DARPA calls its "non-relativistic spin splitting," a phenomenon that allows materials to act magnetically without producing any net magnetic field.

In practical terms, altermagnetic materials could enable circuits that manipulate the quantum spin of electrons without the interference, power drain, or sluggishness that plague conventional electronics.

The RFI notes altermagnetism "exhibits features of both ferromagnetism and antiferromagnetism." Like the latter, the magnetic spins inside these materials point in opposite directions, canceling each other out. However, unlike antiferromagnets, the spins are related by a rotational symmetry that still allows for energy band splitting, a property more like ferromagnets.

That seemingly small structural quirk could be transformative. The agency notes that altermagnets "might sidestep the major roadblocks ferromagnets and antiferromagnets face when designing spintronic devices." This makes it possible to design "ultralow energy computation" technologies that vastly outperform the energy efficiency of traditional semiconductor architectures.

If successful, DARPA's program could lay the groundwork for an entirely new category of computing systems that are smaller, faster, and orders of magnitude more energy-efficient than anything in existence today.

Spintronics, short for "spin electronics," has already found its way into the real world. Modern hard drives, magnetic sensors, and emerging MRAM chips all rely on the quantum spin of electrons rather than their charge to read, store, or sense information. These technologies are fast, durable, and energy-efficient. However, they still use spin only in a limited way.

DARPA is looking to do something more ambitious by using spin to not only store data but also compute with it. That would require materials capable of switching and controlling spin states as quickly and precisely as transistors manipulate charge.

Current existing options fall short. Ferromagnets, though easy to magnetize, create interfering magnetic fields and switch too slowly for logic operations. Antiferromagnets avoid interference but lack the internal spin-splitting needed to manipulate spin-polarized currents.

However, altermagnets could change that balance. With zero net magnetization yet naturally spin-split electronic bands, they offer the tantalizing possibility of fast, interference-free spin-based computation. This breakthrough could finally make true spintronic processors possible.

The big problem? No one yet knows how to build a working device out of altermagnets. "While several device-switching proposals have been put forward, the ideas remain experimentally untested," DARPA writes.

Additionally, as DARPA notes, "characterization of altermagnetism is also a challenge." The current "gold standards" for verifying altermagnetism rely on techniques usually reserved for large-scale physics facilities, and methods like spin-resolved photoelectron spectroscopy, muon spin rotation, and neutron scattering.

That means many potential research groups lack the infrastructure to explore these materials at all, let alone integrate them into working prototypes.

To change that, DARPA is soliciting "realistic, data- or theory-supported information on the types of improvements expected when using altermagnetism versus state-of-the-art computing architectures." The agency also wants feedback on the fundamental limitations of such devices, and on the technical hurdles that must be overcome to make them practical.

This suggests DARPA isn't merely chasing a curiosity—it's laying the groundwork for a new national research initiative that could parallel other efforts like "*INSPIRE*" (Investigating how Neurological Systems Process Information in Reality), which seeks to understand how the human brain constructs reality.

While DARPA's notice doesn't explicitly mention defense applications, the potential implications are clear. Altermagnetic devices could become the foundation for ultralow-power AI processors, cryptographic accelerators, or radiation-resistant electronics suitable for space and battlefield conditions.

The Department of Defense has long sought to reduce power requirements for deployed systems, whether in satellites, autonomous drones, or field-deployable sensors. Altermagnetism could offer a way to shrink computational energy costs by orders of magnitude, enabling persistent surveillance and decision-making at the edge without the need for constant resupply or cooling.

It could also revolutionize secure communications. Spintronic devices based on altermagnets might allow quantum-level control of electron spins, paving the way for tamper-resistant data encoding and secure hardware architectures that are inherently immune to many forms of cyberattack.

All of these potential defense applications could also ripple far beyond the battlefield, shaping the commercial technology sector in profound ways. For example, a study published earlier this year showed that the Pentagon's drive to cut fuel costs during the height of the Global War on Terror inadvertently helped ignite America's modern clean ene

The science of altermagnetism is still in its infancy. First described in 2019, the phenomenon was only experimentally confirmed last year by researchers at the University of Nottingham.

More recently, *The Debrief* reported that scientists had discovered the first organic altermagnet—a material capable of bending light in unusual ways. The finding suggests that altermagnetic effects may extend well beyond traditional metallic crystals, potentially emerging even in complex molecular systems.

For the DAPRPA, which has a history of spotting revolutionary physics before they enter the mainstream, altermagnetism appears to be the next big bet.

If altermagnetism delivers even a fraction of its promise, it could mark a turning point in the evolution of computing—an escape route from the energy and heat limits of silicon transistors.

As DARPA's notice makes clear, the agency wants to move beyond theory toward tangible devices that "exploit altermagnetism" to enable next-generation electronics.

Whether those devices end up in quantum communication networks, AI-enabled defense systems, or spaceborne computers remains to be seen. However, it's clear that the strange physics of altermagnetism has caught the Pentagon's attention. This alone could propel the field from obscure physics labs to the front lines of technological innovation.

According to the RFI, DARPA is inviting responses from across the research landscape, including universities, national labs, FFRDCs, and private industry. Submissions should focus on device design, not just materials discovery, and must outline measurable improvements over current computing technologies. Responses are due by November 12, 2025.

The RFI emphasizes that this is not a funding solicitation but a data-gathering effort to inform possible future programs. Still, as history has shown, DARPA's RFIs often foreshadow significant investments.

"DARPA seeks ideas and information on the state of the art and possible future directions for designing and constructing practical electronic and spintronic devices that exploit altermagnetism," the agency writes. "DARPA encourages realistic, data- or theory-supported information on the types of improvements expected when using altermagnetism vs. state-of-the-art computing architectures (both commercial and research stage)."