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How superconducting memory could help data centers reduce their carbon footprints

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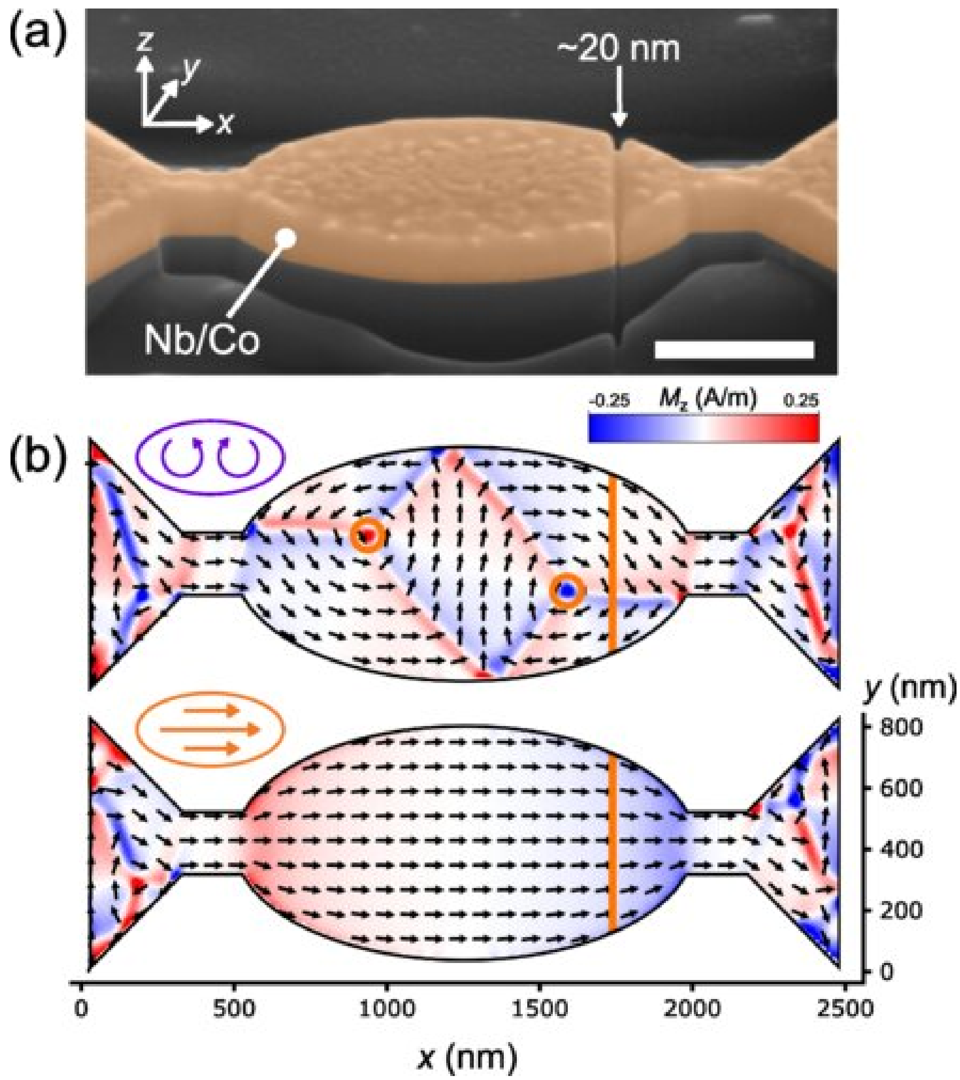

(a) False-color scanning electron micrograph of the ellipse-shaped S/F/S junction device A. The Co weak link is formed by the indicated trench ~20 nm in size) that separates the two Nb electrodes. The scale bar corresponds to 500 nm.
(b) The simulated bistable spin textures at zero field. The cobalt either is

magnetized along the long axis of the device (M state) or hosts two stable vortices (V state). Orange circles highlight the vortex cores, and the orange line indicates the trench location. The color scale indicates the out-of-plane magnetization of the top of the cobalt layer. Credit: *Physical Review Research* (2022). DOI: 10.1103/PhysRevResearch.4.033136

Few of us realize that listening to music on Spotify or watching Netflix or YouTube releases CO_2 in the process. Online services use data stored on servers in data centers, and they guzzle energy. Physicist Remko Fermin researched methods to make the memory in data centers more energy efficient.

At the moment data centers use 1 percent of the total energy consumed in the world, making them responsible for around 0.3 percent of total CO_2 emissions. Information and Communications Technology (ICT) as a whole (this includes personal digital devices, televisions and mobile networks) generates more than 2 percent of global emissions.

This puts the carbon footprint of ICT at the same level as that of the aviation industry. The worst-case scenario predictions are that data centers will account for 10 percent of global energy consumption by 2030.

Fermin was shocked to discover these figures and wanted to help save energy. He looked to physics to develop methods that could help make the computers in data centers more energy efficient. "Imagine we can avoid that 10 percent; that's an incredibly important goal."

One of the solutions he looked at is memory that would be suitable for superconducting computers. Superconductors are materials with no electrical resistance. This means it takes no energy to send electricity through them. The drawback is that superconductors only work at really cold temperatures: just above the absolute zero of -273 degrees Celsius.

Fermin says, "Cooling our PCs to that level isn't an option but it would be for data centers. Despite having to be cooled, the big computers there would be more energy efficient if this made them superconductors."

Research has already been done into how superconductors can be used for calculations. But much less research has been done into how a computer can store data with the aid of superconductivity. Fermin and his colleagues succeeded in making a superconducting memory element. "As proof of concept we made a memory element consisting of a single bit. This shows that it is possible to make a superconducting memory element by combining a superconductor and a magnet."

A successful superconducting memory element must meet four criteria.

First it must be able to switch between two states, just like how a bit in a computer can have the value 0 or 1. Lots of bits together form a code that can be translated into a text, photo or video, for example. Second it should take very little energy to read and switch between the two states. Third the memory element must retain its memory as the computer heats up and is no longer superconducting. Fourth it must be scalable because we need lots of bits if we are to store all those films and music.

Superconducting memory elements had already been developed before Fermin's research but none met all four criteria. Fermin can tick off at least three. By playing with the shape of the memory element, he has managed to create two states in the magnet . To ensure that it takes little energy to read the state of the element, he stacked a superconductor on a magnet.

A groove in the superconducting part of the ellipse ensures the current is conducted through the magnet. As a result, a superconducting current can determine the magnet's state. In other words, a current that consumes no energy reads the memory element.

The only criterion that remains is scalability. Fermin says, "The ellipse we made is 1,500 nonometers long. That is less than a tenth of the thickness of a human hair. Yet that is relatively big if you compare it with the transistor (electronic switch that can allow or prevent electricity from passing, ed.) in a phone, for example. That's around a thousand times smaller. We can make our element smaller but more research is needed to see if it actually works in practice, so we can carry on watching YouTube in the future without feeling guilty."

The study is published in the journal *Physical Review Research*.

More information: R. Fermin et al, Mesoscopic superconducting memory based on bistable magnetic textures, *Physical Review Research* (2022). [DOI: 10.1103/PhysRevResearch.4.033136](https://dx.doi.org/10.1103/PhysRevResearch.4.033136)

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