# Lasers make magnets behave like fluids

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For years, researchers have pursued a strange phenomenon: When you hit an ultra-thin magnet with a laser, it suddenly de-magnetizes. Imagine the magnet on your refrigerator falling off.

Now, scientists at CU Boulder are digging into how magnets recover from that change, regaining their properties in a fraction of a second.

According to a study published this week in *Nature Communications*, zapped magnets actually behave like fluids. Their magnetic properties begin to form "droplets," similar to what happens when you shake up a jar of oil and water.

To find that out, CU Boulder's Ezio Iacocca, Mark Hoefer and their colleagues drew on mathematical modeling, numerical simulations and experiments conducted at Stanford University's SLAC National Accelerator Laboratory.

"Researchers have been working hard to understand what happens when you blast a magnet," said Iacocca, lead author of the new study and a research associate in the Department of Applied Mathematics. "What we were interested in is what happens after you blast it. How does it recover?"

In particular, the group zeroed in on a short but critical time in the life of a magnet—the first 20 trillionths of a second after a magnetic, metallic alloy gets hit by a short, high-energy laser.

Iacocca explained that magnets are, by their nature, pretty organized. Their atomic building blocks have orientations, or "spins," that tend to point in the same direction, either up or down—think of Earth's magnetic field, which always points north.

Except, that is, when you blast them with a laser. Hit a magnet with a short enough laser pulse, Iacocca said, and disorder will ensue. The spins within a magnet will no longer point just up or down, but in all different directions, canceling out the metal's magnetic properties.

"Researchers have addressed what happens 3 picoseconds after a laser pulse and then when the magnet is back at equilibrium after a microsecond," said Iacocca, also a guest researcher at the U.S. National Institute of Standards and Technology (NIST). "In between, there's a lot of unknown."

It's that missing window of time that Iacocca and his colleagues wanted to fill in. To do that, the research team ran a series of experiments in California, blasting tiny pieces of gadolinium-iron-cobalt alloys with lasers. Then, they compared the results to mathematical predictions and computer simulations.

And, the group discovered, things got fluid. Hoefer, an associate professor of applied math, is quick to point out that the metals themselves didn't turn into liquid. But the spins within those magnets behaved like fluids, moving around and changing their orientation like waves crashing in an ocean.

"We used the mathematical equations that model these spins to show that they behaved like a superfluid at those short timescales," said Hoefer, a co-author of the new study.

Wait a little while and those roving spins start to settle down, he added, forming small clusters with the same orientation—in essence, "droplets" in which the spins all pointed up or down. Wait a bit longer, and the researchers calculated that those droplets would grow bigger and bigger, hence the comparison to oil and water separating out in a jar.

"In certain spots, the magnet starts to point up or down again," Hoefer said. "It's like a seed for these larger groupings."

Hoefer added that a zapped magnet doesn't always go back to the way it once was. In some cases, a magnet can flip after a laser pulse, switching from up to down.

Engineers already take advantage of that flipping behavior to store information on a computer hard drive in the form of bits of ones and zeros. Iacocca said that if researchers can figure out ways to do that flipping more efficiently, they might be able to build faster computers.

"That's why we want to understand exactly how this process happens," Iacocca said, "so we can maybe find a material that flips faster."

**More information:** E. Iacocca et al, Spin-current-mediated rapid magnon localisation and coalescence after ultrafast optical pumping of ferrimagnetic alloys, *Nature Communications* (2019). DOI: 10.1038/s41467-019-09577-0

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