(idw)

idw - Informationsdienst Wissenschaft
Nachrichten, Termine, Experten

Pressemitteilung

Max-Planck-Institut für Struktur und Dynamik der Materie
Dr. Joerg Harms

02.04.2025
http://idw-online.de/de/news850070

Forschungsergebnisse, Wissenschaftliche Publikationen
Physik / Astronomie, Werkstoffwissenschaften
überregional

A new wave in Ultrafast Magnetic Control

Researchers at the Max Planck Institute for the Structure and Dynamics of Matter (MPSD) have developed an innovative method to study ultrafast magnetism in materials. They have shown the generation and application of magnetic field steps, in which a magnetic field is turned on in a matter of picoseconds.

Magnetic fields are fundamental to controlling the magnetization of materials. Under static or slowly varying conditions, a material's magnetization aligns with the external field like a compass needle. However, entirely new magnetization dynamics emerge when magnetic fields change on ultrafast timescales - faster than the material's response time. These rapid transients are of great interest for fundamental research into non-equilibrium states of matter and for potential applications in next-generation magnetic memory, where faster writing speeds are critical.

To address this challenge, the research team designed a novel superconducting device capable of producing ultrafast, unipolar magnetic field steps—sudden magnetic changes with picosecond-scale rise and super-nanosecond decay times. "Our goal is to create a universal, ultrafast stimulus that can switch any magnetic sample between stable magnetic states," says lead author Giovanni De Vecchi. "This breakthrough could drive advances in both fundamental science and technology."

Harnessing Superconductors for Ultrafast Magnetic Steps

The team, led by Andrea Cavalleri, achieved this feat by rapidly quenching supercurrents in a superconducting YBa▯Cu▯O▯ thin disc exposed to an external magnetic field. Supercurrents naturally form to expel magnetic fields from superconductors. "By abruptly disrupting these currents using ultrashort laser pulses, we could generate ultrafast magnetic field steps with rise times of approximately one picosecond—one trillionth of a second," says fellow co-author Gregor Jotzu.

"Devising a method to track these magnetic transients in real-time was a major challenge," explains co-author Michele Buzzi. The researchers placed a spectator crystal near the superconducting sample to achieve this. The crystal's optical properties change in response to the local magnetic field. This effect allows the team to track the magnetic field evolution by analyzing the polarization rotation of a femtosecond laser pulse. "With this approach, we achieved sub-picosecond resolution and unprecedented sensitivity," adds co-author Sebastian Fava.

Towards Ultrafast Magnetic Switching

While the current magnetic steps do not yet achieve complete magnetization switching, the researchers believe optimizing the device geometry could enhance the amplitude and speed of the magnetic field transients. "With suitable improvements, we envision applications ranging from phase transition control to complete switching of magnetic order parameters," says Andrea Cavalleri.

The Deutsche Forschungsgemeinschaft supported the study through the Cluster of Excellence CUI: Advanced Imaging of Matter. The MPSD is a member of the Center for Free-Electron Laser Science (CFEL), a joint enterprise with DESY and the University of Hamburg. The research was conducted in collaboration with Alexey Kimel, Professor at Radboud University.

wissenschaftliche Ansprechpartner:

Michele Buzzi
Phone: +49-40-8998-88115
michele.buzzi@mpsd.mpg.de

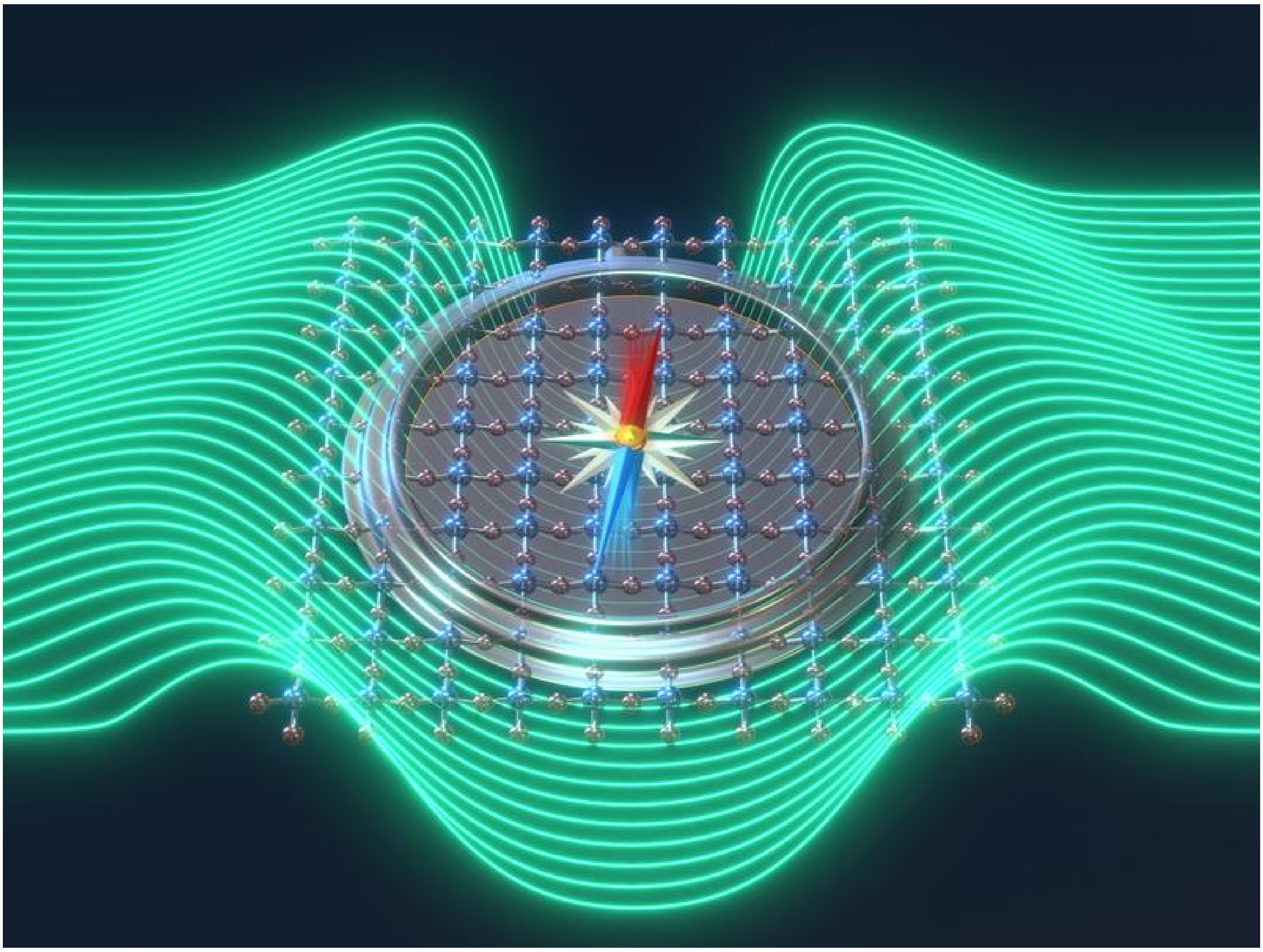
Giovanni de Vecchi
giovanni.de-vecch@mpsd.mpg.de

Andrea Cavalleri
Phone: +49-40-8998-88101
andrea.cavalleri@mpsd.mpg.de

Max Planck Institute for the Structure
and Dynamics of Matter / CFEL
Building 900 (MPSD)
Luruper Chaussee 149
22761 Hamburg / Germany

Originalpublikation:

Generation of Ultrafast Magnetic Steps for Coherent Control
G. De Vecchi, G. Jotzu, M. Buzzi, S. Fava, T. Gebert, M. Fechner, A. Kimel, A. Cavalleri
Nature Photonics, online (2025)
https://www.nature.com/articles/s41566-025-01651-y
https://doi.org/10.1038/s41566-025-01651-y



Ultrafast disruption of superconductivity in a YBa□Cu□O□ thin film triggers an abrupt magnetic field quench, setting off dynamics in a neighboring spin system.
Giovanni de Vecchi, Joerg M. Harms / MPSD