# Chiral Faraday effect breakthrough, thanks to helices made of nickel

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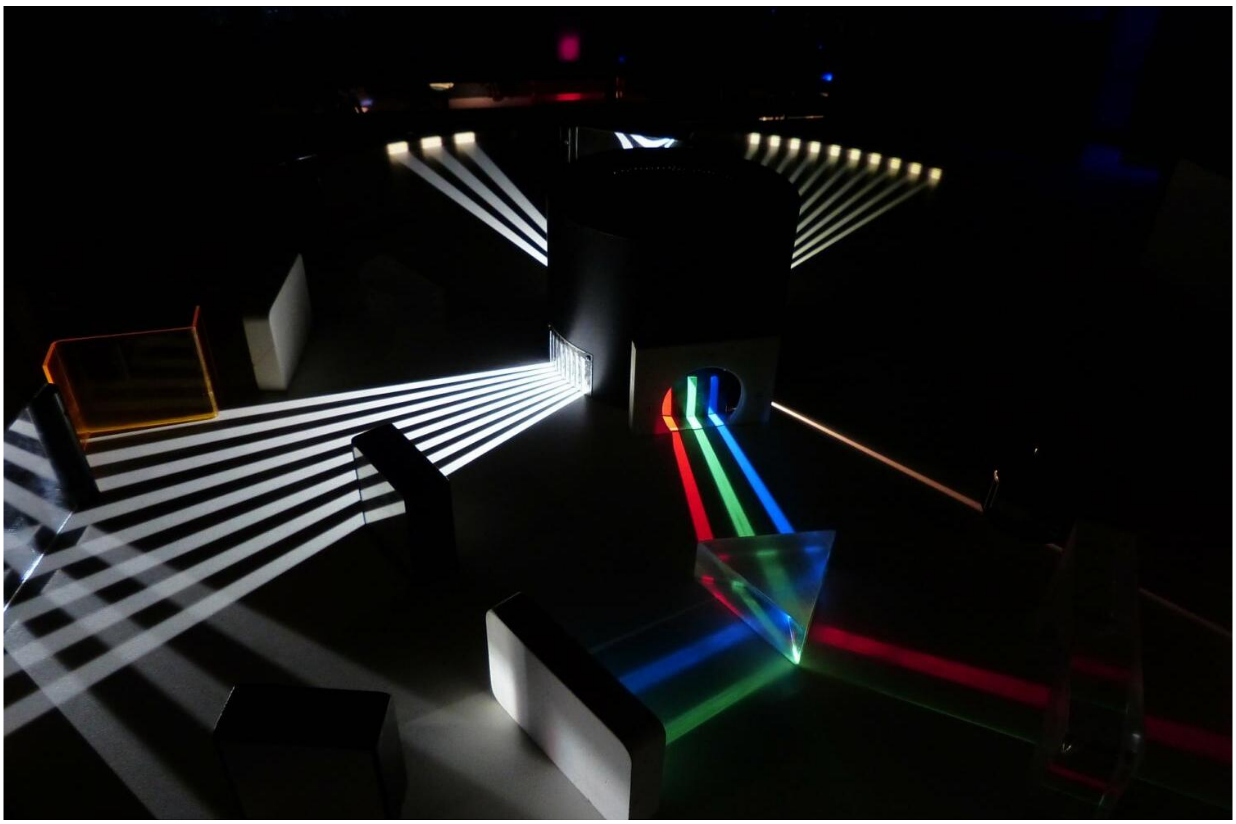

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Physicists at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) have for the first time been able to prove a long-predicted but as yet unconfirmed fundamental effect. In Faraday chiral anisotropy, the propagation characteristics of light waves are changed simultaneously by the natural and magnetic-field induced material properties of the medium through which the light travels. The researchers obtained proof that this is the case by conducting experiments using nickel helices at the nanometer scale. Their findings have now been published in the academic journal *Physical Review Letters*.

Light is transmitted as sine waves consisting of crossed electric and magnetic fields and interacts with matter. This interaction can be influenced, in particular, by external magnetic fields. One of the most well-known examples of this magneto-optical activity is the Faraday effect: if light is directed through a magnetic medium, such as a crystal, the polarization plane of the light waves tilts at a certain angle. This phenomenon is caused purely due to the magnetic field and becomes more pronounced if the light passes through the medium again in the opposite direction. The rotation effect can only be neutralized if the direction of the magnetic field is changed as well.

The opposite effect is seen in the natural optical activity of chiral mediums without a magnetic field, in which the rotation of the polarization plane is canceled out when the light passes through the medium once more in the opposite direction. Chiral means that molecules or figures have a mirror image which cannot be superimposed onto it simply by rotation. Examples are a human's left and right hands or snail shells with spirals running in opposite directions. Sugar molecules are also chiral. The way they interact with light can be used, for example, to determine the concentration of sugar in grapes.

## Following in the footsteps of Louis Pasteur

Scientists have been aware of both phenomena—natural and magnetic optical activity—for more than 150 years, and for almost the same time, scientists have been sure that a combination of the two must exist. "Even

Louis Pasteur, the famous French scientist, tried to prove a correlation using various different experiments," explains Vojislav Krsti, Professor of Applied Physics at FAU. "Of course, Pasteur didn't have the sensitive instruments for measuring frequency which we have today. But even using this technology, proof has still remained elusive, largely due to the fact that no one has designed a suitable experiment setup."

An international collaboration led by Vojislav Krsti has now succeeded where Pasteur and many other researchers have failed. They have become the first to confirm "Faraday chiral anisotropy' in an experiment, providing one of the last missing pieces in fundamental magneto-optical theory. Their success was due to a unique experiment setup based on nickel helices. The researchers produced spirals spiraling in a clockwise and and in an anticlockwise direction, similar in form to Italian fusilli pasta, at the nanometre scale by vaporizing nickel and bringing atoms back together on a revolving disk. "The rotation of the disk means that the nanostructures take on a screw shape instead of forming into pillars as is usually the case," explains Krsti.

## A 'forest' of helices as a chiral medium

For the experiment itself, a "forest" of magnetic nickel helices was set up on a layer of silver. In one part of the experiment, only anti-clockwise spirals were used, and in the second only clockwise ones. The helices acted as a chiral medium, and the layer of silver reflected the beam of light directed at it. "The fact that we reflected the light instead of simply directing it through the medium was a deciding factor," says Vojislav Krsti.

The idea behind the experiment was that if the light passes through the helices both on the outward and the return journey, and if the direction of the magnetic field is changed with a great degree of precision, then in theory the two fundamental effects should cancel each other out, no matter whether the helices are clockwise or anti-clockwise. If both phenomena influence each other, however, then a net signal should be left over which behaves in the opposite fashion for clockwise and anti-clockwise helices. Krsti notes, "We did indeed measure a net signal just like this, thereby proving the correlation of the chiral and magnetic effect. It was one of those 'Eureka!' moments every researcher dreams of."

## Astro research in the laboratory and impulses for quantum electronics

With their research, the researchers led by Vojislav Krsti have not only succeeded in providing experimental proof of a magneto-optics theory which has long been predicted. Their approach also means that researchers will be able to research certain astrophysical phenomena on Earth. It is thought, for example, that Faraday chiral anisotropy takes place in magnetized gas clouds in which certain astroparticles modify the light spectrum radiated out by galactic and intergalactic media. The findings could also give new impulses for further study of quantum technologies for electronic switches, as the described optomagnetic process is also found analogously during electronic excitation in solid bodies.

**More information:** José M. Caridad et al, Detection of the Faraday Chiral Anisotropy, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.126.177401

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