Physicists develop novel concept for detecting chiral molecules

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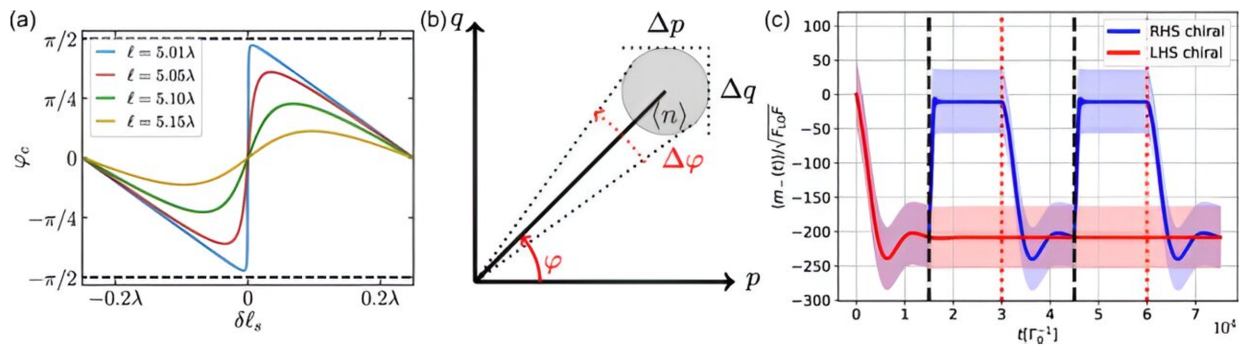

Chiral sensing. (a) Cavity phase versus small perturbations of the cavity length for different cavity lengths. (b) Illustration of phase uncertainty in phase space for a coherent state. (c) Homodyne detection signal for (ideal) right- and left-handed chiral scatterers passing through a RCP cavity with corresponding shot noise shown as shaded area. The dashed black line indicates the entry of a particle into the cavity and the dotted red line indicates its exit. Credit: *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.043602

In contrast to conventional mirrors, light can be reflected on surfaces known as metasurfaces without changing its polarization. This phenomenon has now been proven by physicists at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and the Max Planck Institute for the Science of Light (MPL). The discovery enables circulating light to be used to reliably detect chiral molecules.

The researchers have published their study in the journal *Physical Review Letters*.

Chiral molecules occur frequently in nature. Known as enantiomers, they are mirrored twins—like the right and left hands of humans. "Enantiomers usually have the same function," says Dr. Michael Reitz, who gained his doctoral degree in 2023 in the research group at MPL led by Dr. Claudiu Genes. "However, they can have completely different effects, especially when they come into contact with other chiral molecules."

This can have a serious impact, for example in pharmacology. Whereas one of the enantiomers might provide the cure for a certain disease, the other could be harmful to the body.

The ability to precisely detect and distinguish chiral molecules is thus of particular interest, not only in pharmacological research. Light is an ideal candidate for research as photons themselves can also be chiral. "It is possible to generate light as a spiral in a corkscrew shape," explains Nico Bassler, joint doctoral candidate of Claudiu Genes, head of the independent research group Cooperative Quantum Phenomena at MPL and Prof. Dr. Kai Phillip Schmidt, Chair of Theoretical Physics V at FAU. "Depending on the direction in which the spiral turns, it interacts either with left-handed or with right-handed enantiomers."

To maximize this interaction, however, the light field must be spatially confined, for example by circulating it between two mirrors. The problem here is that when light is reflected using a conventional mirror, it changes its polarization—the spiral then rotates in the opposite direction and would interact with the "wrong" enantiomer.

Double layers of atoms used as a mirror

The physicists at FAU and MPL solved this problem with a novel concept: Instead of using conventional mirrors, they use something known as metasurfaces comprised of double layers of atoms. "We combine two single-layer stacks of atoms that each possess electrical dipole moments," explains Genes. "Dipole moments can be regarded as the charge direction along an axis."

The decisive factor for the function of metasurfaces is the orthogonal orientation of the stacks of atoms, that is, ensuring that they are at 90 degrees to each other. "This trick from the field of quantum physics means that the photons are reflected, but still maintain their polarization," explains Prof. Dr. Kai Phillip Schmidt.

This allows for a completely new type of chiral sensor: While enclosed between two metasurfaces in a very small space, circulating light can detect chiral molecules reliably and with extremely high sensitivity. The researchers expect their discovery will help to speed up the development process for materials with relevant functions, particularly in the fields of biochemistry and pharmacy.

More information: Nico S. Baßler et al, Metasurface-Based Hybrid Optical Cavities for Chiral Sensing, *Physical Review Letters* (2024). DOI: 10.1103/PhysRevLett.132.043602

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