Topological insulators become a little less 'elusive'

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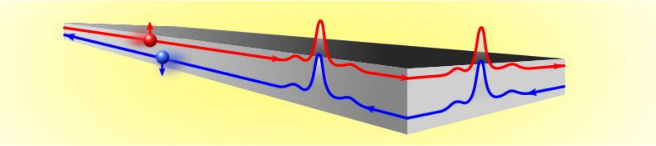

They are 'strange' materials, insulators on the inside and conductors on the surface. They also have properties that make them excellent candidates for the development of spintronics ('spin-based electronics') and more in general quantum computing. However, they are also elusive as their properties are extremely difficult to observe. Now a SISSA study, published in *Physical Review Letters*, proposes a new family of materials whose topological state can be directly observed experimentally, thus simplifying things for researchers.

"What interests us of topological insulators is not so much that their being insulators but that they exhibit conducting states on their surface" explains SISSA researcher Massimo Capone. "This features makes them unique, as none of the other insulating or conducting materials exhibits this dichotomy. Unfortunately, the characteristics that describe these materials are very subtle, such that they are truly difficult to identify and study". The latest paper by Capone and co-workers published in *Physical Review Letters* explains how such characteristics could be found in materials with more evident properties, thus simplifying research in this field and opening up new possibilities.

The mathematical explanation of why some materials are insulators and others are conductors was one of the first tangible results of the theory of quantum mechanics. Quantum mechanical models postulate that, in solids, the atoms making up the material may only have certain energy states ("positions" where the electrons spin around the nucleus) but not others. "Possible and impossible states alternate in a band pattern", explains Capone. "In insulators some bands are completely "occupied", and others are empty, whereas in conductors some empty places remain within a band". Topological insulators resemble normal insulators, with the difference that the energy states are inverted. "It's as if the bands contained artificial holes", continues Capone.

Conduction in these materials is strange for another reason as well. "The electrons contained in the energy layers have a spin, which we can think of as a direction of rotation around their axis. In a metal (a conductor), the electrons driven by an electrical field normally move in the same direction, independent of their spin, whereas in these topological insulators electrons with opposite spin propagate in opposite directions", says Adriano Amaricci, another SISSA researcher involved in the project. "This feature makes them attractive for spintronics". In fact, in electronics the information is encoded in sequences or strings of 0's and 1's, which correspond to "on" and "off" states, whereas in spintronics the 0's and 1's correspond to the type of spin, which may be only "up" or "down". Topological insulators could constitute the material basis for this alphabet.

The feature distinguishing topological insulators from a normal metal is very abstract and elusive. "To have an idea, try to compare this situation with the difference between a magnetic and non-magnetic state. The latter is a difference that can easily be measured", explains Amaricci.

The properties of topological insulators are instead abstract and mathematically defined, so it is difficult to know when we are dealing with such a material. "Through the use of a mathematical model and simulations, we demonstrated that new topological insulators can be found in materials that exhibit 'spectacular' features that are easily detected owing to strong electron-electron interactions" continues Amaricci. "This way, it will be easier to identify these materials experimentally, to then better investigate this important field of research".

Very important indeed, according to Capone: "the scientist who discovered these materials, in 2007, was Laurens Molenkamp who, according to rumours circulating in the research community, is a likely candidate for a future Nobel Prize". Molenkamp works at the University of Würzburg, which took part in the current study. Together with colleagues in Würzburg, and in particular Sangiovanni and Trauzettel, it might be possible to involve Molenkamp himself in the future developments of this research project.

More information: First-Order Character and Observable Signatures of Topological Quantum Phase Transitions, dx.doi.org/10.1103/PhysRevLett.114.185701

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