'Dressing' in superconductors: A new piece in the high-temperature superconductivity puzzle

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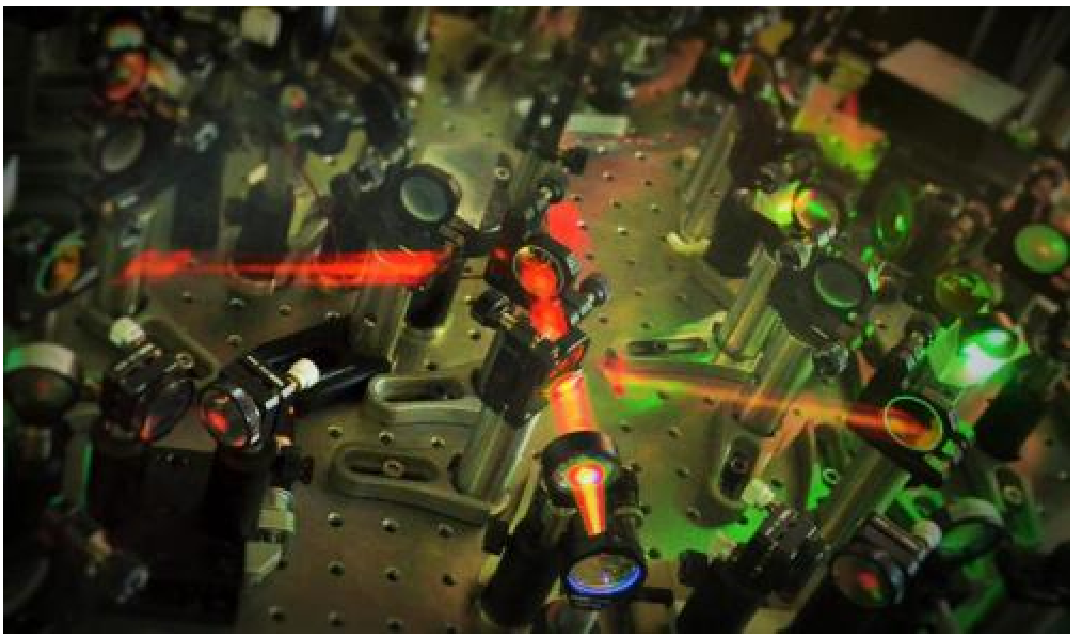

This image shows laser beams. Credit: SISSA

"Imagine a heavy ball rolling on an elastic net: what happens?" asks Daniele Fausti, researcher at Elettra Sincrotrone of Trieste and the University of Trieste. That's how Fausti explains the concept of "dressing" in physics: "the ball's movement is slowed down because each movement is accompanied by a deformation of the net: the sphere no longer behaves like a free sphere (i.e., that rolls on a rigid plane), but like a sphere that is 'dressed' by the net's deformation". Why is this "dressing" concept so important? "Because it's what physicists believe explains superconductivity in conventional superconductors, that is, those that work at very low temperatures".

"To continue with the metaphor, in these materials we have a situation in which there are two heavy spheres: by adjusting adequately the speed of movement, we can, for example, get another ball to move in the "wake" of the first one. The two spheres become 'coupled', travelling together and behaving as a single object". This gives an idea of what happens to electrons in the crystal grid of the superconducting material. "Two electrons would normally repel each other owing to their having the same charge, but in these conditions they are able to travel together, hence the superconductivity".

Superconductivity is a property of materials that can be exploited in many ways, for example in the medical field or even in transport. However, the difficulty handling these materials that superconduct at very low temperatures, close to absolute zero (-273°C) and therefore hard to attain, makes them quite unsuited to technological applications. More recently, scientists have identified other superconductor families (based on copper oxides, cuprates, for example) that exhibit their properties at substantially higher temperatures (-196° C) and therefore promise a greater ease of use. The mechanism at play in these new materials remains, however, a mystery. "There's no experimental evidence that dressing plays a part in this case", explains Fausti.

"But are we really sure?" the scientist asked himself. Together with Fabio Novelli, from Elettra and the University of Trieste first author of the study, and an international group of researchers, Fausti developed a new technique to "look directly at the dressing of excitations in complex systems". By using ultrashort light pulses at different frequencies, it is possible to study the reaction of the so-called "boson field" with which the electrons are coupled in a crystal of La2CuO4, progenitor of the cuprate family. If the electrons are the heavy spheres and the superconductor's crystal grid is the elastic net, the light pulses may be considered an oscillating force that pushes the electrons on the net. By changing the frequency of the light pulse the researchers directly observed the elastic net reaction, and at certain frequencies its reaction proved to be fast enough to "dress" the sphere.

"This observation can now drive research into the theory of high-temperature superconductors", comments Massimo Capone, a SISSA researcher who took part in the theoretical part of the study. "According to this result, the electrons definitely undergo a coupling process mediated by a net that holds them together despite the strong Coulomb repulsion". In addition to its experimental results, the study also introduced a new, promising method for the study of materials of the future.

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