Researchers attempt to explain superconductive phenomenon

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Superconductivity with a high critical temperature (high Tc) presents a theoretical mystery. While this phenomenon is experimentally well established, science has not explained its mechanism. In the late 1990s, the British physicist Anthony Leggett proposed a scenario based on Coulomb energy. Today, researchers at the University of Geneva (UNIGE), Switzerland, in collaboration with Leggett and his group, tested this scenario. Their findings challenge Leggett's conjecture, opening new avenues for the explanation of high Tc superconductivity. These results are available in the journal *Physical Review X*.

Superconductivity is at the heart of intensive research in physics, in particular because of its remarkable electronic properties, such as the absence of electrical resistance. Its properties make it an indispensable element for applications in medicine, as well as in transportation and energy storage.

The conjecture proposed by Prof. Leggett of the University of Illinois presented a scenario for high Tc superconductivity in cuprates, materials consisting primarily of copper and oxygen. In his scenario, the transition of the material into the superconducting state is a direct consequence of a decrease of that part of the Coulomb energy associated with long wavelengths and mid-infrared frequencies. It remained to be tested experimentally; optical spectroscopy is a suitable technique for probing this part of Coulomb energy.

The team of Dirk van der Marel, professor at the Department of physics

of quantum matter of UNIGE Faculty of Science, has addressed this issue and the many challenges associated with it. "We have set up an experimental device and a protocol for measuring the long range Coulomb energy. By varying the temperature and the light frequency applied to several superconducting samples, we observed the subtle influence of superconductivity on the Coulomb energy," explains Dirk van der Marel.

The importance of chemical doping

Based on cuprate superconductors, UNIGE physicists have observed that the behavior of the Coulomb energy at the superconducting transition depends on the doping—i.e. the lack (or excess) of electrons. For some doping values, the energy decreases, but for others it stagnates or even increases. Changes in temperature of the Coulomb energy appear linked to the doping of the sample. "There is a critical doping below which the observed behaviour is opposite to Leggett's scenario," says the physicist.

These experimental advances still do not explain high Tc superconductivity in cuprates, but they advance the understanding of the phenomenon and adapt existing theories having foundations in common with Leggett's scenario. They can be extended to the measurement of the Coulomb energy in other superconducting materials, to other phenomena such as magnetism, to other methods, and provide directions for the development of experiments which will further advance the understanding of superconductivity and other quantum phenomena.

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