Topological Superconductivity

Scientists of the University of Twente and the University of Amsterdam now demonstrate a new property: the non-superconducting material bismuth shows lossless current conduction. [30]

A team of international scientists including Maia G. Vergniory, Ikerbasque researcher at DIPC and UPV/EHU associate, has discovered a new class of materials, higher-order topological insulators. [29]

A team of researchers from Japan, the U.S. and China, has identified a topological superconducting phase for possible use in an iron-based material in quantum computers. [28]

Physicists have shown that superconducting circuits—circuits that have zero electrical resistance—can function as piston-like mechanical quantum engines. The new perspective may help researchers design quantum computers and other devices with improved efficiencies. [27]

This paper explains the magnetic effect of the superconductive current from the observed effects of the accelerating electrons, causing naturally the experienced changes of the electric field potential along the electric wire. The accelerating electrons explain not only the Maxwell Equations and the Special Relativity, but the Heisenberg Uncertainty Relation, the wave particle duality and the electron's spin also, building the bridge between the Classical and Quantum Theories.

The changing acceleration of the electrons explains the created negative electric field of the magnetic induction, the Higgs Field, the changing Relativistic Mass and the Gravitational Force, giving a Unified Theory of the physical forces. Taking into account the Planck Distribution Law of the electromagnetic oscillators also, we can explain the electron/proton mass rate and the Weak and Strong Interactions.

Since the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements, as strongly correlated materials and Exciton-mediated electron pairing, we can say that the secret of superconductivity is the quantum entanglement.

Contents

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The Quest of Superconductivity

Superconductivity seems to contradict the theory of accelerating charges in the static electric current, caused by the electric force as a result of the electric potential difference, since a closed circle wire no potential difference at all. [1]

On the other hand the electron in the atom also moving in a circle around the proton with a constant velocity and constant impulse momentum with a constant magnetic field. This gives the idea of the centripetal acceleration of the moving charge in the closed circle wire as this is the case in the atomic electron attracted by the proton. Because of this we can think about superconductivity as a quantum phenomenon. [2]

Experiences and Theories

Topological material shows superconductivity—and not just at its surface

The special properties of topological materials typically occur at their surface. These materials, for example insulators that do conduct current at their surface, are expected to play a major role in future quantum computers. Scientists of the University of Twente and the University of Amsterdam now demonstrate a new property: the non-superconducting material bismuth shows lossless current conduction. What's even more special: it doesn't just occur at the surface but on the inside of the material as well. The scientists publish their findings in *Nature Materials*.

Topological materials have drawn increasing interest, especially after Thouless, Haldane and Kosterlitz won the Nobel Prize in Physics in 2016. These materials get their particular properties by playing with the order of energy levels. By 'twisting' these levels, a material that doesn't conduct any current under normal circumstances will suddenly become a conductor, but only at its surface. The phenomenon includes the transport of electrons and their spin – this describes the way the electron spins on its own axis and its magnetic properties.

Superconductivity

In their *Nature Materials* paper, the researchers now demonstrate a that the transport and spin of electrons are related,in a topological material. Thanks to this property, a non-superconducting material will even be able to conduct current without resistance. Majorana quasiparticles play a major role in this. Notably, this is not a property that can only be observed at the surface. Measurements show that superconduction also takes place inside the bulk of the material. This makes the properties less vulnerable to noise or pollution, for example.

Bismuth with a little antimony has become a model material for studying electronic properties. In bismuth, the number of electrons available for conduction is so low that it can hardly be called a metal. But the electrons in this 'semimetal' do move like particles at the speed of light. Applying superconducting electrodes made of niobium to a thin crystal flake of bismuth doped with antimony at a temperature of 10 milli Kelvin causes a superconducting current to flow through the material. In a superconductor, paired electrons, so-called Cooper pairs, are responsible for conduction. This is not the mechanism inside the bismuth: Here, Majorana particles are responsible. [30]

Bismuth shows novel conducting properties

A team of international scientists including Maia G. Vergniory, Ikerbasque researcher at DIPC and UPV/EHU associate, has discovered a new class of materials, higher-order topological insulators. Theoretical physicists first predicted the existence of these insulators, which have conducting properties on the edges of crystals rather than on their surfaces, and conduct electricity without dissipation. Now, these novel properties are demonstrated experimentally in bismuth.

The current flows without resistance and responds in unconventional ways to electric and magnetic fields. These unique properties have future applications in high-performance electronics and quantum computation.

Higher-order topological insulators

Recently, a new class of topological materials with novel conducting properties was predicted by a group of physicists from Donostia International Physics Center (DIPC), the University of the Basque Country (UPV/EHU), UZH, Princeton University and Max Planck Institute of Microstructure Physics. The researchers refer to it as a "higher-order topological insulator."

According to theoretical studies, the conducting edges are extraordinarily robust for higher-order topological insulators. The current of topological electrons cannot be stopped by impurities, and if the crystal breaks, the new edges automatically also conduct current. However, the most extraordinary property of these new materials is that they can theoretically conduct electricity without any dissipation, as superconductors do at low temperatures. This would be a specific property of higher-order class topological insulators.

Bismuth is topological

Now, it has been confirmed that bismuth, an element consistently described as bulk topologically trivial, follows a generalized bulk-boundary correspondence of higher-order, that is, hinges have topologically protected conducting modes instead of the surface of the crystal.

The special topological properties of this element were first identified by using symmetry arguments, topological indices, first-principles calculations, and the recently introduced framework of topological quantum chemistry.

This phenomenon was then verified experimentally. With scanning-tunneling spectroscopy, the unique signatures of the rotational symmetry of the one-dimensional states located at step edges of the crystal surface were proved. Using Josephson interferometry, scientists demonstrated their universal topological contribution to the electronic transport.

Finally, this work establishes bismuth as a higher-order topological insulator and opens the way to identify new ones. [29]

Topological superconductor phase may solve decoherence problem in quantum computers

A team of researchers from Japan, the U.S. and China, has identified a topological superconducting phase for possible use in an iron-based material in quantum computers. In their paper published in the journal *Science*, the team outlines their study of the phase, which, they claim, shows promise as a means for solving the decoherence problem in quantum computers.

As research surrounding quantum computers continues researchers confront a number of problems. One is the tendency of quantum states to degrade, resulting in computing errors—a problem known as decoherence. Experts suggest that the solution to the problem is to develop a material capable of protecting the quantum state by employing just the right topological properties. In this way, localized noise would not be able to disturb the quantum state. In this new effort, the researchers report on the identification of a topological superconducting phase that they believe could satisfy this requirement.

The researchers report that they were able to attain three key kinds of measurements believed to be necessary for analyzing the quantum phase of Fe(Te, Se) in sufficient detail, which they claim shows that the phase could prove suitable for protecting the quantum state in a system. They further report that the phase, once integrated into a suitable material, would be capable of supporting Majorana bound states (MBSs), which are quasiparticles so-named due to their discovery by Ettore Majorana. Prior research has suggested that a material capable of using Majorana properties might play a role in solving the decoherence problem.

The researchers note also that they were able to identify the helical spin polarization of the surface state and to measure the superconducting gap. They were also able to identify the surface state. Taken together, the results of their testing indicate that MBSs could be induced in a material by exerting a magnetic field to the Fe(Te, Se). If their predictions pan out, the new phase could wind up as part of the next generation of quantum computers, possibly paving the way for machines capable of manipulating more qubits than those currently in use. [28]

Superconducting qubits can function as quantum engines

Physicists have shown that superconducting circuits—circuits that have zero electrical resistance—can function as piston-like mechanical quantum engines. The new perspective may help researchers design quantum computers and other devices with improved efficiencies.

The physicists, Kewin Sachtleben, Kahio T. Mazon, and Luis G. C. Rego at the Federal University of Santa Catarina in Florianópolis, Brazil, have published a paper on their work on superconducting qubits in a recent issue of Physical Review Letters.

In their study, the physicists explain that superconducting circuits are functionally equivalent to quantum systems in which quantum particles tunnel in a double-quantum well. These wells have the ability to oscillate, meaning the width of the well changes repeatedly. When this happens, the

system behaves somewhat like a piston that moves up and down in a cylinder, which changes the volume of the cylinder. This oscillatory behavior allows work to be performed on the system. The researchers show that, in the double-quantum well, part of this work comes from quantum coherent dynamics, which creates friction that decreases the work output. These results provide a better understanding of the connection between quantum and classical thermodynamic work.

"The distinction between 'classical' thermodynamic work, responsible for population transfer, and a quantum component, responsible for creating coherences, is an important result," Mazon told Phys.org. "The creation of coherences, in turn, generates a similar effect to friction, causing a notcompletely-reversible operation of the engine. In our work we have been able to calculate the reaction force caused on the quantum piston wall due to the creation of coherences. In principle this force can be measured, thus constituting the experimental possibility of observing the emergence of coherences during the operation of the quantum engine."

One of the potential benefits of viewing superconducting qubits as quantum engines is that it may allow researchers to incorporate quantum coherent dynamics into future technologies, in particular quantum computers. The physicists explain that a similar behavior can be seen in nature, where quantum coherences improve the efficiency of processes such as photosynthesis, light sensing, and other natural processes.

"Quantum machines may have applications in the field of quantum information, where the energy of quantum coherences is used to perform information manipulation in the quantum regime," Mazon said. "It is worth remembering that even photosynthesis can be described according to the working principles of a quantum machine, so unraveling the mysteries of quantum thermodynamics can help us to better understand and interpret various natural processes." [27]

Conventional superconductivity

Conventional superconductivity can be explained by a theory developed by Bardeen, Cooper and Schrieffer (BCS) in 1957. In BCS theory, electrons in a superconductor combine to form pairs, called Cooper pairs, which are able to move through the crystal lattice without resistance when an electric voltage is applied. Even when the voltage is removed, the current continues to flow indefinitely, the most remarkable property of superconductivity, and one that explains the keen interest in their technological potential. [3]

High-temperature superconductivity

In 1986, high-temperature superconductivity was discovered (i.e. superconductivity at temperatures considerably above the previous limit of about 30 K; up to about 130 K). It is believed that BCS theory alone cannot explain this phenomenon and that other effects are at play. These effects are still not yet fully understood; it is possible that they even control superconductivity at low temperatures for some materials. [8]

Superconductivity and magnetic fields

Superconductivity and magnetic fields are normally seen as rivals – very strong magnetic fields normally destroy the superconducting state. Physicists at the Paul Scherer Institute have now demonstrated that a novel superconducting state is only created in the material $CeCoIn_5$ when there are strong external magnetic fields. This state can then be manipulated by modifying the field

direction. The material is already superconducting in weaker fields, too. In strong fields, however, an additional second superconducting state is created which means that there are two different superconducting states at the same time in the same material. The new state is coupled with an anti-ferromagnetic order that appears simultaneously with the field. The anti-ferromagnetic order from whose properties the researchers have deduced the existence of the superconducting state was detected with neutrons at PSI and at the Institute Laue-Langevin in Grenoble. [6]

Room-temperature superconductivity

After more than twenty years of intensive research the origin of high-temperature superconductivity is still not clear, but it seems that instead of *electron-phonon* attraction mechanisms, as in conventional superconductivity, one is dealing with genuine *electronic* mechanisms (e.g. by antiferromagnetic correlations), and instead of s-wave pairing, d-waves are substantial. One goal of all this research is room-temperature superconductivity. [9]

Exciton-mediated electron pairing

Theoretical work by Neil Ashcroft predicted that solid metallic hydrogen at extremely high pressure (~500 GPa) should become superconducting at approximately room-temperature because of its extremely high speed of sound and expected strong coupling between the conduction electrons and the lattice vibrations (phonons). This prediction is yet to be experimentally verified, as yet the pressure to achieve metallic hydrogen is not known but may be of the order of 500 GPa. In 1964, William A. Little proposed the possibility of high temperature superconductivity in organic polymers. This proposal is based on the exciton-mediated electron pairing, as opposed to phonon-mediated pairing in BCS theory. [9]

Resonating valence bond theory

In condensed matter physics, the resonating valence bond theory (RVB) is a theoretical model that attempts to describe high temperature superconductivity, and in particular the superconductivity in cuprate compounds. It was first proposed by American physicist P. W. Anderson and the Indian theoretical physicist Ganapathy Baskaran in 1987. The theory states that in copper oxide lattices, electrons from neighboring copper atoms interact to form a valence bond, which locks them in place. However, with doping, these electrons can act as mobile Cooper pairs and are able to superconduct. Anderson observed in his 1987 paper that the origins of superconductivity in doped cuprates was in the Mott insulator nature of crystalline copper oxide. RVB builds on the Hubbard and t-J models used in the study of strongly correlated materials. [10]

Strongly correlated materials

Strongly correlated materials are a wide class of electronic materials that show unusual (often technologically useful) electronic and magnetic properties, such as metal-insulator transitions or half-metallicity. The essential feature that defines these materials is that the behavior of their electrons cannot be described effectively in terms of non-interacting entities. Theoretical models of the electronic structure of strongly correlated materials must include electronic correlation to be accurate. Many transition metal oxides belong into this class which may be subdivided according to their behavior, *e.g.* high-T_c, spintronic materials, Mott insulators, spin Peierls materials, heavy fermion materials, quasi-low-dimensional materials, etc. The single most

intensively studied effect is probably high-temperature superconductivity in doped cuprates, e.g. $La_{2-x}Sr_xCuO_4$. Other ordering or magnetic phenomena and temperature-induced phase transitions in many transition-metal oxides are also gathered under the term "strongly correlated materials." Typically, strongly correlated materials have incompletely filled *d-* or *f*-electron shells with narrow energy bands. One can no longer consider any electron in the material as being in a "sea" of the averaged motion of the others (also known as mean field theory). Each single electron has a complex influence on its neighbors.
[11]

New superconductor theory may revolutionize electrical engineering

High-temperature superconductors exhibit a frustratingly varied catalog of odd behavior, such as electrons that arrange themselves into stripes or refuse to arrange themselves symmetrically around atoms. Now two physicists propose that such behaviors – and superconductivity itself – can all be traced to a single starting point, and they explain why there are so many variations.
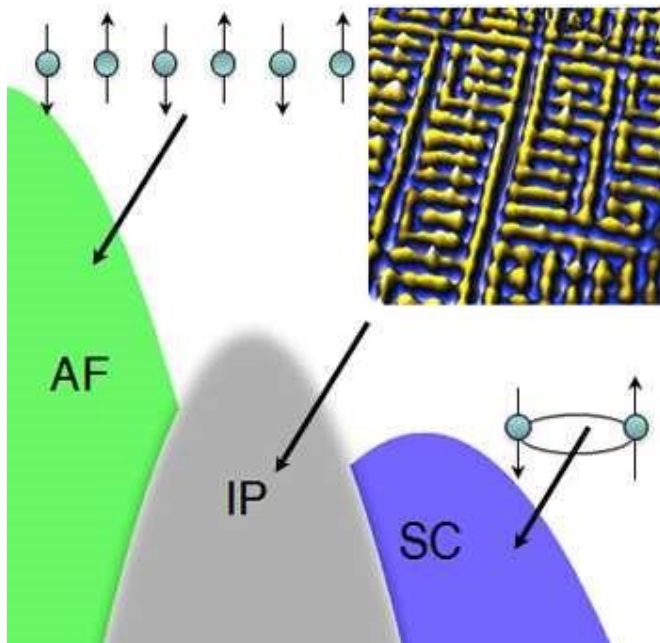
An "antiferromagnetic" state, where the magnetic moments of electrons are opposed, can lead to a variety of unexpected arrangements of electrons in a high-temperature superconductor, then finally to the formation of "Cooper pairs" that conduct without resistance, according to a new theory. [22]

Unconventional superconductivity in $Ba^{0.6}K^{0.4}Fe^2As^2$ from inelastic neutron scattering

In BCS superconductors, the energy gap between the superconducting and normal electronic states is constant, but in unconventional superconductors the gap varies with the direction the electrons are moving. In some directions, the gap may be zero. The puzzle is that the gap does not seem to

vary with direction in the iron arsenides. Theorists have argued that, while the size of the gap shows no directional dependence in these new compounds, the sign of the gap is opposite for different electronic states. The standard techniques to measure the gap, such as photoemission, are not sensitive to this change in sign.

But inelastic neutron scattering is sensitive. Osborn, along with Argonne physicist Stephan Rosenkranz, led an international collaboration to perform neutron experiments using samples of the new compounds made in Argonne's Materials Science Division, and discovered a magnetic excitation in the superconducting state that can only exist if the energy gap changes sign from one electron orbital to another.

"Our results suggest that the mechanism that makes electrons pair together could be provided by antiferromagnetic fluctuations rather than lattice vibrations," Rosenkranz said. "It certainly gives direct evidence that the superconductivity is unconventional."

Inelastic neutron scattering continues to be an important tool in identifying unconventional superconductivity, not only in the iron arsenides, but also in new families of superconductors that may be discovered in the future. [23]

A grand unified theory of exotic superconductivity?

The role of magnetism

In all known types of high-Tc superconductors—copper-based (cuprate), iron-based, and so-called heavy fermion compounds—superconductivity emerges from the "extinction" of antiferromagnetism, the ordered arrangement of electrons on adjacent atoms having anti-aligned spin directions. Electrons arrayed like tiny magnets in this alternating spin pattern are at their lowest energy state, but this antiferromagnetic order is not beneficial to superconductivity.

However if the interactions between electrons that cause antiferromagnetic order can be maintained while the actual order itself is prevented, then superconductivity can appear. "In this situation, whenever one electron approaches another electron, it tries to anti-align its magnetic state," Davis said. Even if the electrons never achieve antiferromagnetic order, these antiferromagnetic interactions exert the dominant influence on the behavior of the material. "This antiferromagnetic influence is universal across all these types of materials," Davis said.

Many scientists have proposed that these antiferromagnetic interactions play a role in the ability of electrons to eventually pair up with anti-aligned spins—a condition necessary for them to carry current with no resistance. The complicating factor has been the existence of many different types of "intertwined" electronic phases that also emerge in the different types of high-Tc superconductors—sometimes appearing to compete with superconductivity and sometimes coexisting with it. [24]

Concepts relating magnetic interactions, intertwined electronic orders, and strongly correlated superconductivity

Unconventional superconductivity (SC) is said to occur when Cooper pair formation is dominated by repulsive electron–electron interactions, so that the symmetry of the pair wave function is other than an isotropic s-wave. The strong, on-site, repulsive electron–electron interactions that are the proximate cause of such SC are more typically drivers of commensurate magnetism. Indeed, it is the suppression of commensurate antiferromagnetism (AF) that usually allows this type of unconventional superconductivity to emerge. Importantly, however, intervening between these AF and SC phases, intertwined electronic ordered phases (IP) of an unexpected nature are frequently discovered. For this reason, it has been extremely difficult to distinguish the microscopic essence of the correlated superconductivity from the often spectacular phenomenology of the IPs. Here we introduce a model conceptual framework within which to understand the relationship between AF electron–electron interactions, IPs, and correlated SC. We demonstrate its effectiveness in simultaneously explaining the consequences of AF interactions for the copper-based, iron-based, and heavy-fermion superconductors, as well as for their quite distinct IPs.

Significance

This study describes a unified theory explaining the rich ordering phenomena, each associated with a different symmetry breaking, that often accompany high-temperature superconductivity. The essence of this theory is an "antiferromagnetic interaction," the interaction that favors the development of magnetic order where the magnetic moments reverse direction from one crystal unit cell to the next. We apply this theory to explain the superconductivity, as well as all observed accompanying ordering phenomena in the copper-oxide superconductors, the iron-based superconductors, and the heavy fermion superconductors. [25]

Superconductivity's third side unmasked
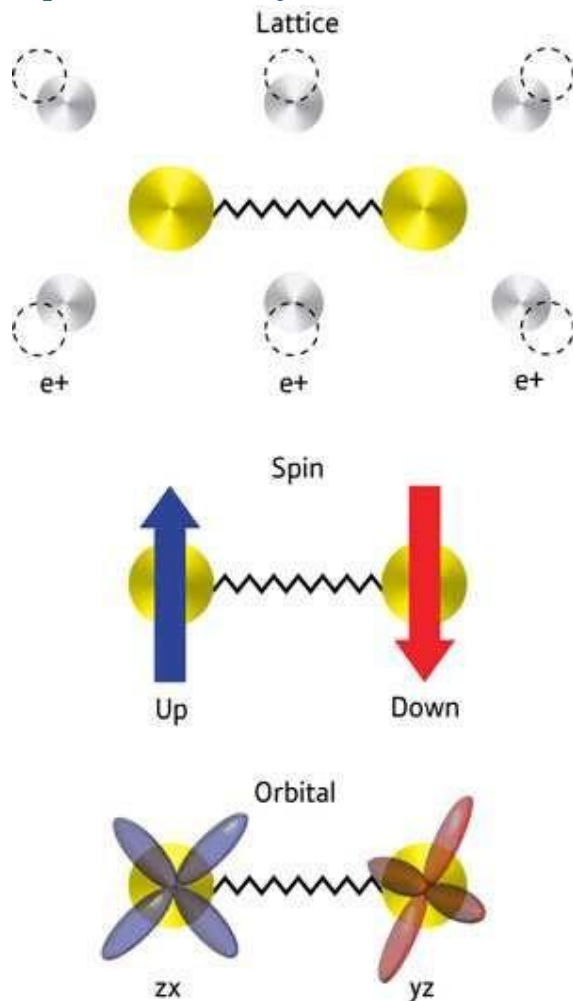
Shimojima and colleagues were surprised to discover that interactions between electron spins do not cause the electrons to form Cooper pairs in the pnictides. Instead, the coupling is mediated by the electron clouds surrounding the atomic cores. Some of these so-called orbitals have the same energy, which causes interactions and electron fluctuations that are sufficiently strong to mediate superconductivity.

This could spur the discovery of new superconductors based on this mechanism. "Our work establishes the electron orbitals as a third kind of pairing glue for electron pairs in superconductors, next to lattice vibrations and electron spins," explains Shimojima. "We believe that this finding is a step towards the dream of achieving room-temperature superconductivity," he concludes. [17]

Strongly correlated materials

Strongly correlated materials give us the idea of diffraction patterns explaining the electron-proton mass rate. [13]

This explains the theories relating the superconductivity with the strong interaction. [14]

Fermions and Bosons

The fermions are the diffraction patterns of the bosons such a way that they are both sides of the same thing. We can generalize the weak interaction on all of the decaying matter constructions, even on the biological too.

The General Weak Interaction

The Weak Interactions T-asymmetry is in conjunction with the T-asymmetry of the Second Law of Thermodynamics, meaning that locally lowering entropy (on extremely high temperature) causes for example the Hydrogen fusion. The arrow of time by the Second Law of Thermodynamics shows the increasing entropy and decreasing information by the Weak Interaction, changing the temperature dependent diffraction patterns. The Fluctuation Theorem says that there is a probability that entropy will flow in a direction opposite to that dictated by the Second Law of Thermodynamics. In this case the Information is growing that is the matter formulas are emerging from the chaos. [18] One of these new matter formulas is the superconducting matter.

Higgs Field and Superconductivity

The simplest implementation of the mechanism adds an extra Higgs field to the gauge theory. The specific spontaneous symmetry breaking of the underlying local symmetry, which is similar to that one appearing in the theory of superconductivity, triggers conversion of the longitudinal field component to the Higgs boson, which interacts with itself and (at least of part of) the other fields in the theory, so as to produce mass terms for the above-mentioned three gauge bosons, and also to the above-mentioned fermions (see below). [16]

The Higgs mechanism occurs whenever a charged field has a vacuum expectation value. In the nonrelativistic context, this is the Landau model of a charged Bose–Einstein condensate, also known as a superconductor. In the relativistic condensate, the condensate is a scalar field, and is relativistically invariant.

The Higgs mechanism is a type of superconductivity which occurs in the vacuum. It occurs when all of space is filled with a sea of particles which are charged, or, in field language, when a charged field has a nonzero vacuum expectation value. Interaction with the quantum fluid filling the space prevents certain forces from propagating over long distances (as it does in a superconducting medium; e.g., in the Ginzburg–Landau theory).

A superconductor expels all magnetic fields from its interior, a phenomenon known as the Meissner effect. This was mysterious for a long time, because it implies that electromagnetic forces somehow become short-range inside the superconductor. Contrast this with the behavior of an ordinary metal. In a metal, the conductivity shields electric fields by rearranging charges on the surface until the total field cancels in the interior. But magnetic fields can penetrate to any distance, and if a magnetic monopole (an isolated magnetic pole) is surrounded by a metal the field can escape without collimating into a string. In a superconductor, however, electric charges move with no dissipation, and this allows for permanent surface currents, not just surface charges. When magnetic fields are introduced at the boundary of a superconductor, they produce surface currents which exactly

neutralize them. The Meissner effect is due to currents in a thin surface layer, whose thickness, the London penetration depth, can be calculated from a simple model (the Ginzburg–Landau theory).

This simple model treats superconductivity as a charged Bose–Einstein condensate. Suppose that a superconductor contains bosons with charge q. The wavefunction of the bosons can be described by introducing a quantum field, ψ, which obeys the Schrödinger equation as a field equation (in units where the reduced Planck constant, $\hbar$, is set to 1):

$$i\frac{\partial}{\partial t}\psi = \frac{(\nabla - iqA)^2}{2m}\psi.$$

The operator $\psi(x)$ annihilates a boson at the point x, while its adjoint $\psi^\dagger$ creates a new boson at the same point. The wavefunction of the Bose–Einstein condensate is then the expectation value ψ of $\psi(x)$, which is a classical function that obeys the same equation. The interpretation of the expectation value is that it is the phase that one should give to a newly created boson so that it will coherently superpose with all the other bosons already in the condensate.

When there is a charged condensate, the electromagnetic interactions are screened. To see this, consider the effect of a gauge transformation on the field. A gauge transformation rotates the phase of the condensate by an amount which changes from point to point, and shifts the vector potential by a gradient:

$$\psi \rightarrow e^{iq\phi(x)}\psi$$

$$A \rightarrow A + \nabla\phi.$$

When there is no condensate, this transformation only changes the definition of the phase of ψ at every point. But when there is a condensate, the phase of the condensate defines a preferred choice of phase.

The condensate wave function can be written as

$$\psi(x) = \rho(x)\,e^{i\theta(x)},$$

where ρ is real amplitude, which determines the local density of the condensate. If the condensate were neutral, the flow would be along the gradients of θ, the direction in which the phase of the Schrödinger field changes. If the phase θ changes slowly, the flow is slow and has very little energy. But now θ can be made equal to zero just by making a gauge transformation to rotate the phase of the field.

The energy of slow changes of phase can be calculated from the Schrödinger kinetic energy,

$$H = \frac{1}{2m}|(qA + \nabla)\psi|^2,$$

and taking the density of the condensate ρ to be constant,

$$H \approx \frac{\rho^2}{2m}(qA + \nabla\theta)^2.$$

Fixing the choice of gauge so that the condensate has the same phase everywhere, the electromagnetic field energy has an extra term,

$$\frac{q^2 \rho^2}{2m} A^2.$$

When this term is present, electromagnetic interactions become short-ranged. Every field mode, no matter how long the wavelength, oscillates with a nonzero frequency. The lowest frequency can be read off from the energy of a long wavelength A mode,

$$E \approx \frac{\dot{A}^2}{2} + \frac{q^2 \rho^2}{2m} A^2.$$

This is a harmonic oscillator with frequency

$$\sqrt{\frac{1}{m} q^2 \rho^2}.$$

The quantity $|\psi|^2$ (=ρ^2) is the density of the condensate of superconducting particles.

In an actual superconductor, the charged particles are electrons, which are fermions not bosons. So in order to have superconductivity, the electrons need to somehow bind into Cooper pairs. [12]

The charge of the condensate q is therefore twice the electron charge e. The pairing in a normal superconductor is due to lattice vibrations, and is in fact very weak; this means that the pairs are very loosely bound. The description of a Bose–Einstein condensate of loosely bound pairs is actually more difficult than the description of a condensate of elementary particles, and was only worked out in 1957 by Bardeen, Cooper and Schrieffer in the famous BCS theory. [3]

Superconductivity and Quantum Entanglement

We have seen that the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements, as strongly correlated materials and Exciton-mediated electron pairing. [26]

Conclusions

Probably in the superconductivity there is no electric current at all, but a permanent magnetic field as the result of the electron's spin in the same direction in the case of the circular wire on a low temperature. [6]

We think that there is an electric current since we measure a magnetic field. Because of this saying that the superconductivity is a quantum mechanical phenomenon.

Since the acceleration of the electrons is centripetal in a circular wire, in the atom or in the spin, there is a steady current and no electromagnetic induction. This way there is no changing in the Higgs field, since it needs a changing acceleration. [18]

The superconductivity is temperature dependent; it means that the General Weak Interaction is very relevant to create this quantum state of the matter. [19]

We have seen that the superconductivity is basically a quantum mechanical phenomenon and some entangled particles give this opportunity to specific matters, like Cooper Pairs or other entanglements. [26]

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