TT 45: Focused Session: 100 Years of Superconductivity

Time: Thursday 10:30–12:40 Location: HSZ 03

Invited Talk TT 45.1 Thu 10:30 HSZ 03
Pairing fermions with population imbalance — •Peter Fulde — Max-Planck-Institut für Physik komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden

Cooper pairing of fermions starts usually from the premise that the two species forming pairs have equal populations, i.e., that their particle numbers are the same. That need not always be the case, though, and examples to the opposite are known. They concern metals, as well as dense quark matter, nuclear matter or ultracold atoms.

The simplest case is that of a superconductor when a Zeeman term is added to the Hamiltonion. We will show that the Zeeman energy may result in breaking of translational invariance and hence in inhomogeneous superconducting ground states. They are often referred to as FFLO states, since they were first suggested by Fulde and Ferrell and independently by Larkin and Ovchinnikov. Simple arguments will be presented which explain the origin of the symmetry breaking.

The inhomogeneous states are paralleled by the ones caused by a magnetic field acting on the electron orbits, i.e., Abrikosov vortex states. While it took only a few years to verify Abrikosov vortices after they had been predicted, it has taken nearly 40 years to proof the existence of inhomogeneous states caused by population imbalance. In the meantime experiments on $CeCoIn_5$, and the two-dimensional organic superconductors κ-$(BEDT\text{-}TTF)_2 \cdot Cu(NCS)_2$, λ-$(BETS)_2$ $FeCl_4$, λ-$(BETS)_2$ $GaCl_4$ and β-$(BEDT\text{-}TTF)_2$ $SF_5CH_2CF_2SO_3$ provide very strong evidence in some cases, and still disputed ones in others that a FFLO state is forming in high magnetic fields. However, the most important realization of FFLO-like states is found in pi junctions, which seem to be on the verge of important technical applications. We will briefly describe progress which has been made here, based on ideas of Bulaevskii, Buzdin, Demler and others and realized by Ryazanov, Feofanov, Ustinov and others.

Invited Talk TT 45.2 Thu 11:00 HSZ 03
Unconventional Superconductivity - Aspects of Symmetry and Topology — •Manfred Sigrist — ETH Zürich, Zürich, Switzerland

Unconventional superconductors form coherent states of Cooper pairs whose internal structure gives rise to most intriguing and complex properties. Since the discovery of superfluid He-3 and the early heavy Fermion superconductors this fascinating field has evolved into one of the most active topics of condensed matter physics and has been stimulated by many discoveries of new materials, such as the cuprate and Fe-pnictide high-temperature superconductors, ruthenates and many heavy Fermion compounds. New theoretical insights based on the symmetry and topology of the superconducting order parameters and proposals of novel pairing mechanism enlarge our scope of superconductivity enormously. In this presentation I will give a brief overview on some of the most important concepts and ideas which have emerged during the recent era of research on unconventional superconductivity.

10 min. break

Invited Talk TT 45.3 Thu 11:40 HSZ 03
Large Scale Applications of Superconductors and the Challenges that they have posed — •David Larbalestier — National High Magnetic Field Laboratory, Florida State University

Already in 1913 Onnes envisioned using superconductors to create 100 kGauss fields well beyond any possibility provided by cooling Ag or Cu with liquid helium. Only some "bad places" in his Hg and Pb wires seemed to impede his first attempts at this dream, one that he imagined a short ongoing effort would quickly resolve. In fact, resolution required 50 years, understanding the subtle effects of alloy and compound superconductivity, closure of the theory-experiment gap and inspired experiments with Nb_3Sn. Suddenly in 1961, it all came together and Onnes's dreams of 100 kGauss magnets were soon comfortably surpassed. In the last 45 years virtually all superconducting magnets have been made from just two Nb-base materials, Nb-Ti and Nb_3Sn, operating in liquid He. In 1987 cuprates with $T_c > 100K$ suggested that superconducting applications could leave liquid helium behind, and extend well beyond the science to the electrical engineering market. However, making conductors from complex cuprates posed many more challenges than envisaged in 1987 (echoes of Onnes in 1913?). Now that these challenges have largely been met in $REBa_2Cu_3O_7$ coated conductors, it is time to talk too about practical requirements for new superconductors. At 100, one can still be sure that the "right" new superconductor will find broad application and the ubiquity of superconductivity in materials phase space suggests that many new applications lie ahead in the 2nd superconducting century.

Invited Talk TT 45.4 Thu 12:10 HSZ 03
Weak Superconductivity and Superconductor Electronics — •Konstantin Likharev — Stony Brook University, Stony Brook, NY 11794-3800, U.S.A.

I will review the discovery and studies of the Josephson effect and related macroscopic quantum phenomena (including the single-Cooper-pair tunneling), and the development of their electronics applications. The main focus of the talk will be on digital superconductor devices and circuits (such as the latching logic, parametric quantron, and RSFQ technology), but I will also briefly mention the development and current status of superconductor analog devices for dc voltage and current standards, ultrasensitive magnetometry, and electromagnetic wave detection.