Abstract of Presentation

New challenges in iron-based superconductors: Understanding and tuning the electronic properties

Abstract :

A major challenge in condensed-matter research is to understand the exotic electronic properties, among which high-temperature superconductivity (HTS), of materials presenting strong electronic correlations, i.e., n-body physics dominated by Coulombian repulsion. While considerable experimental and theoretical progress has been made since the discovery of HTS in 1986, a fundamental understanding of this phenomenon has yet to be reached, especially in terms of the mechanism responsible for the formation of the Cooper pairs.

In this respect, the discovery in 2008 of HTS in layered iron-based compounds has ignited considerable interest. While this stemmed initially from apparent similarities of the phase diagram with that of the high-temperature superconducting cuprates, it has since then been shown that iron-based superconductors feature a unique set of properties, with a pronounced multi-orbital character, a semi-metallic behavior, an apparently unique superconducting state, and the possible role of a nested Fermi surface. Therefore, these new compounds offer an original playground in which to explore the links between strong correlations, HTS, and magnetic fluctuations.

Mastering knowledge of the intrinsic properties of new compounds constitutes the first step towards their tailoring and the development of innovative materials for applications. HTS holds considerable promise in this respect, with targets such as improved energy transport/use, and high magnetic fields for medical applications. Here again, iron-based superconductors are a system of interest, since they can feature very large (up to around 100 T) and reasonably isotropic upper critical fields, together with mechanical properties possibly suited to practical deployment.

Since 2008, Japanese and European research teams have deployed intensive activity around iron-based superconductors. To build on this work and develop scientific collaboration between Japan and the EU, the IFW Dresden together with Japanese and other European institutions are forming a preliminary network. With the participation of RIKEN (Japan, H. Takagi), the University of Tokyo (Japan, H. Wadati), the CNISM

Abstract of Presentation

institute (Italy, R. de Renzi), the Laboratoire Léon Brillouin (France, P. Bourges), and the IFW Dresden (Germany, B. Büchner), an extended array of powerful probes is available, including notably NMR, muSR, STM, ARPES, neutron diffusion, and photoemission spectroscopy. This is further supported by a strong synthesis activity.

The work done so far addressed for instance Fermi surface reconstruction effects [1], ground state coexistence and electronic inhomogeneities in the underdoped region of the phase diagram [2,3], the anomalous superconducting and normal states [4,5], the link between spin dynamics and superconductivity [6,7], and the interpretation of doping [8]. Of likely interest for future investigation are topics such as the variability of the phase diagram with respect to ground state coexistence, the tuning of properties through applied pressure, and the impact of Fermi surface properties on the superconductivity.

We are now looking for further opportunities for coordinated research between Japan and the EU, through establishment of a robust international network. This should help address outstanding issues about iron-based superconductors and more generally about unconventional superconductivity, while offering exchange and training possibilities for the involved researchers.

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