LNCMI-Grenoble

Field induced phase transitions in quantum materials

Summary

Strong magnetic fields are a modern tool used to discover, explore and control new states of matter. In combination with very low temperature, close to absolute zero, they provide access to unexpected phenomena. We propose to study such phenomenon with ultrasound measurements at low temperature in two classes of materials: 1) graphite a semi metal which undergoes a sequence of phase transitions of unknown origin at high magnetic field 2) high temperature cuprate superconductors which shows a kind of transition towards an exotic charge density wave order. The study of those two materials deal with two fundamental questions of modern condensed matter physics: the fate of a 3D electron wave function when confined by a large magnetic field and the ground state of cuprate superconductors.

Detailed subject

Ultrasound measurements involve the determination of two quantities: sound velocity and ultrasound attenuation. Both are Kramers-Kronig related and directly linked to an acoustic phonon dispersion and lifetime respectively. While sound velocity is a thermodynamic probe that can detect the most subtle phase transitions a material can undergo, ultrasound attenuation is a transport coefficient that can be related to the low frequency conductivity in a metal.

We use this technique in high magnetic field in order to uncover new phase boundaries in the phase diagram of highly correlated materials, where confinement, frustration and competition between ground state leads to exotic many-body phenomena. Such physics occur in two materials of our interest: graphite and high temperature superconductor. In the case of graphite we use ultrasound measurement in order to understand the nature and origin of a newly discovered sequence of phase transitions in high magnetic field that are likely to be related to a 3D weakly topological phase, with very surprising anisotropic transport properties that might be a signature of conducting surface states [1]. In the case of cuprate high temperature superconductors, we use ultrasound measurements in order to understand the role a very unconventional charge order in the phase diagram [2]. Cuprate materials are insulating and yet with the addition of a few extra doping atoms they become the best conductors available on earth. The charge order has been discovered recently and we now try to understand better how this charge modulation can affect, promote or reduce superconductivity [3].

The student will be involved in the development of part of a recent experimental set up, in the preparation of samples and experiment, data acquisition and analysis. Cryogenics and vacuum techniques, radio-frequency and DC electronics will be used.

Publications linked to the theme

[1] http://www.condmatjournalclub.org/jccm-content/uploads/2014/08/JCCM_AUGUST_2014_01.pdf

[2] http://www.toulouse.lncmi.cnrs.fr/spip.php?rubrique149&lang=fr

[3] D. LeBoeuf *et al.* Nature Physics **9** 79 (2013)

Background and skills expected : motivation for experimental work, collaborative skills, curiosity, bricolage, labview, data analysis, electronics, and a background in condensed matter physics

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