J-Physics 2018 Program Overview

June 24 - 30, 2018

Summer School (24 Sun – 27 Wed) | **Workshop** (27 Wed – 30 Sat)

	24 (Sun)	25 (Mon)	26 (Tue)	27 (Wed)	28 (Thu)	29 (Fri)	30 (Sat)
8:30		Opening (8:50~)					
9:00		Lecture 1 Taka-hisa Arima 9:00 - 10:20	Lecture 5 Nicholas P. Butch 9:00 - 10:20	Lecture 10 Philip Brydon 9:00 - 10:20	Opening (9:00~) Exotic Superconductor 1 9:10 - 10:10	Exotic Materials 2 9:00 - 10:30	Crystal Growth 9:00 - 10:50
10:00		Break Lecture 2 Philip Brydon 10:40 - 12:00	Break Lecture 6 Morgan Trassin 10:40 - 12:00	Break Lecture 11 Nicholas P. Butch 10:40 - 12:00	Break Exotic Superconductor 2 10:40 - 11:50	Break	Break
11:00						Actinoide Materials 1 11:00 - 12:10	Chiral Materials 11:20 - 12:20
12:00		Lunch	Group Photo & Lunch	Closing (~12:10) Excursion 12:10 - 18:00	Lunch	Group Photo & Lunch	Poster Award & Closing
13:00					Exotic Materials 1 13:30 - 15:20		
14:00		Lecture 3 Taka-hisa Arima 14:00 - 15:20	Lecture 7 Alexandre Pourret 14:00 - 15:10			Poster Session 14:00 - 16:00	
15:00		Break Lecture 4 Morgan Trassin 15:40 - 17:00	Break Lecture 8 Ilya Seikin 15:30 - 16:40		Break Kondo Materials 15:50 - 18:20		
16:00	Registration 16:00 - 18:00		Break	Registration 16:00 - 18:00		Actinoide Materials 2 16:00 - 16:50	
17:00		Break Poster Session & Dinner 17:20 - 19:30	Lecture 9 Benoît Fauqué 17:00 - 18:10				
18:00	Get-Together 18:00 - 20:00			Dinner @Sea Aiga 18:00 - 20:00 http://www.awajishima-bbq.jp/		Japanese Puppet Show & Banquet 18:00 -20:00	
19:00							
20:00							

Non-reciprocal Flows of Quantum Particles Induced by Ferroic Order of Odd-Parity Multipoles

Taka-hisa Arima

Department of Advanced Materials Science, University of Tokyo RIKEN Center for Emergent Matter Science

A directional asymmetry of a particle/wave flow has been long attracting interests. The so-called p-n junction has been a key ingredient of the electrical circuit. The essence of the asymmetric flow across the p-n junction is the breaking of the space inversion and the energy dissipation.

Recently dissipationless asymmetric flows of a particle are attracting interest. From the viewpoint of symmetry, any particle or wave can exhibit directional asymmetry in a matter with the violation of space inversion and time reversal. In particular, extensive studies have been performed on the directional asymmetry in light propagation. A pioneering experimental work was performed by Hopfield and Thomas [1] more than half a century ago. They observed large ‘photon momentum effects’ of 2P exciton states in CdS of noncentrosymmetric wurtzite structure, when a magnetic field was applied perpendicular to the c-axis. The optical absorption by excitons exhibited a large asymmetry when reversing the light propagation direction.

If a noncentrosymmetric matter hosts a ferromagnetic moment, such an asymmetry may be observed in the absence of a magnetic field. Both the time reversal and space inversion can be broken by the emergence of a ferroic order of odd-parity magnetic multipoles including toroidal moments. In fact, directional asymmetries of electromagnetic waves in the meV to keV energy range were reported in polar or chiral matter in a magnetic field or with a spontaneous magnetization [2-6]. A similar directional asymmetry has been confirmed by a neutron inelastic scattering measurement of spin waves in a chiral magnet MnSi [7].

[1] J. J. Hopfield and D. G. Thomas, Phys. Rev. Lett. **4**, 357 (1960).
[2] G. L. J. A. Rikken and E. Raupach, Nature **390**, 493 (1997).
[3] T. Roth and G. L. J. A. Rikken, Phys. Rev. Lett. **88**, 063001 (2002).
[4] M. Kubota *et al*., Phys. Rev. Lett. **92**, 137401 (2004).
[5] I. Kézsmárki *et al.*, Phys. Rev. Lett. **106**, 057403 (2011).
[6] Y. Nii *et al.*, J. Phys. Soc. Jpn. **86**, 024707 (2017).
[7] T. J. Sato *et al.*, Phys. Rev. B **94**, 144420 (2016).

Pairing of J=3/2 fermions in cubic superconductors

Dr Philip Brydon, University of Otago, Dunedin, New Zealand

The microscopic pairing state of a superconductor is characterized by the relative angular momentum and spin state of the electrons. The two spin 1/2 electrons can bind into either a spin singlet S=0 or triplet S=1 state; this restricts the orbital state to be even and odd parity, respectively. The spin pairing states therefore represent a fundamental distinction in the microscopic description of the superconductivity, which is reflected in the macroscopic physical properties. Determining the spin state of the Cooper pair is a therefore an important goal in the study of any newly-discovered superconductor. Recently, however, superconductivity has been found in materials such as YPtBi, where the electrons possess an effective internal angular momentum of j=3/2. The j=3/2 nature of the electrons in this compound arises from two effects: strong spin-orbit coupling in the Bi atoms, and the cubic symmetry of the crystal, which does not completely quench the atomic orbital angular momentum. In this case, when constructing the Cooper pair wavefunction, one must consider quintet (J=2) and septet (J=3) pairing states, in addition to unconventional singlet (J=0) and triplet (J=1) pairing. This leads to remarkable new physics, which is the focus of the these lectures. We will examine three aspects of the physics.

- **Mixed singlet-septet pairing**: We will examine the case of YPtBi in detail, understanding the origin of the low-energy j=3/2 electrons and constructing the effective normal-state Hamiltonian. The available experimental data will be reviewed, and we will consider pairing states consistent with the observation of line nodes. An effective spin-1/2-like theory for the low-energy states will be developed. It will be shown that a key aspect of the physics is the absence of inversion symmetry, which means that even- and odd-parity pairing can coexist. This motivates a mixed singlet-septet pairing state as a minimal explanation for the pairing. Proposals for the origin of the pairing will be discussed.

- **Bogoliubov Fermi surfaces**: The five quintet states of j=3/2 electrons correspond to even parity pairing states, and hence one can consider unconventional orbital s-wave pairing. Despite the orbitally-isotropic pairing, these states display nodes at the Fermi surface, due to the interplay of the quintet state with the spin-orbit coupling. The high symmetry of the crystal requires that several of these states have the same critical temperature; this generically leads to their appearance in time-reversal symmetry-breaking combinations. Remarkably, the expected line or point nodes for the pairing state are replaced by Bogoliubov Fermi surfaces – a surface in momentum space where the excitation gap is vanishing. It will be shown that these Fermi surfaces are robust, and can be energetically favourable. Their microscopic origin will be explained in terms of interband pairing, and the appearance of a subdominant magnetic multipole order parameter.

- **J=3/2 physics beyond cubic superconductors**: Finally, we will discuss the relevance of j=3/2 physics in materials without cubic symmetry. We will in particular discuss the cases of UPt_3 and the iron pnictide superconductors.

These lectures will require only a graduate-level understanding of superconductivity and basic perturbation theory. Some familiarity with topology and unconventional superconductivity is desirable, but is not necessary. Homework will be given, along with suggested readings.

Introduction to Neutron Scattering Techniques for Quantum Materials

Nicholas P. Butch
NIST Center for Neutron Research
University of Maryland, College Park

This lecture will introduce different neutron scattering techniques that are commonly used to study quantum materials, such as powder diffraction, small angle scattering, and inelastic scattering/spectroscopy. We will begin with a discussion of the basic aspects of neutron scattering and comparison to other scattering techniques. Examples of measurements on quantum materials will illustrate the range of problems that neutron scattering can address. Students will learn what physical phenomena can be probed by neutrons and how neutron scattering complements other types of measurements that are performed on modern quantum materials.

Probing Ferroic States in Oxide Thin Films Using Optical Second Harmonic Generation

Morgan Trassin

Department of Materials, ETH Zurich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland;

Forthcoming low-energy consumption oxide electronics rely on the deterministic control of ferroelectric and multiferroic domain states at the nanoscale. In the first part of the lecture, I will address the recent progress dealing with electric field control of magnetization in multiferroic magnetoelectric thin film architectures and the potential of non-invasive optical second harmonic generation (SHG) for probing ferroic states in oxide thin films. For more than 50 years, SHG has served as an established technique for probing ferroic order in bulk materials. Here, I will present the specific new aspects introduced to SHG investigation of ferroelectrics and multiferroics by working with thin film structures. Taking multiferroic heterostructures as prototypical example, I will show how SHG can probe complex ferroic domain patterns non-invasively and even if the lateral domain size is below the optical resolution limit or buried beneath an otherwise impenetrable cap layer. Special attention is given to monitoring switching events in buried ferroic domain- and domain-wall distributions by SHG, thus opening new avenues towards the determination of the involved dynamics.

In the second part, I will show that by integrating SHG into the ongoing thin film deposition process, we can monitor the emergence of ferroic order and properties in situ, while they emerge during growth. I will focus on ultrathin ferroelectric and multiferroic based heterostructures to demonstrate how polarization can be designed at will, taking advantage of in situ diagnostic tools.

Lecture on :

Fermi Surface Instabilities in Highly Correlated Electron Systems

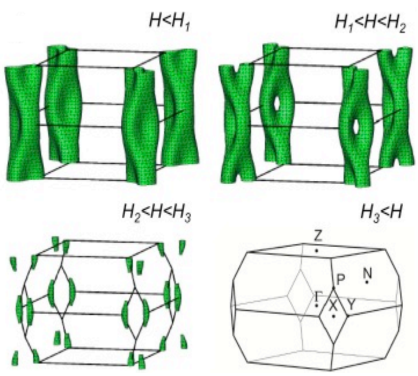
A.Pourret

Univ. Grenoble Alpes, CEA, INAC-PHELIQS, F-38000 Grenoble, France

Fermi surface (FS) instabilities have regained interest very recently with the discovery of materials where new exotic topological orders are expected to emerges close to a FS reconstruction. When the number of components of the Fermi surface changes under the influence of an external parameter such as chemical doping, pressure, or a magnetic field (H) the transition is called a Lifshitz transition (LT). LTs, known since the 1960, are continuous quantum phase transitions at zero temperature and are referred to in the literature as $2^{1/2}$ order phase transitions using the Ehrenfest terminology. At temperatures different from zero and in the presence of impurities such a FS reconstruction is often referred to as an electronic topological transition.

The magnetic field as a driving force of the LTs appeared among the experimental techniques very recently and its characteristics are still poorly discussed theoretically. Indeed, topological changes of the FS can occur under the effect of magnetic field only in systems where the relevant energy scales of the electronic system are of the same energy scale as the Zeeman energy, see Fig.1. Such a situation is given in heavy fermion compounds which are characterized by flat quasiparticle bands crossing the Fermi level. As a consequence, the Zeeman splitting of the energy bands close to the Fermi level can be strong enough to suppress continuously spin-split FS pockets leading to LTs.

In this lecture I propose to give first a short introduction to the different types of Lifshitz transitions in particular those induced by the magnetic field and their consequences on different transport and thermodynamic quantities. Then, I will present recent observations of FS instabilities in large variety of heavy fermion systems. In parallel, I will discuss the different quantum oscillation techniques to get the full topology of FS. Special focus will be given on thermoelectric quantum oscillation.



<u>Fig1:</u> Example of FS topological transitions in $YbRh_2Si_2$ induced by magnetic field. The corrugated cylinder located at the corner of the Brillouin zone collapse as the magnetic field increases.

Measurements of physical properties of strongly correlated electron systems under high magnetic fields.

I. Sheikin

LNCMI-EMFL, CNRS, UGA, Grenoble, France

In my lecture, I will give an overview of several experimental techniques commonly used in pulsed and steady high magnetic fields for the investigation of strongly correlated electron systems. These, techniques, however, are also useful for other classes of materials.

I will start by a brief introduction into high magnetic field generation. Then, I will discuss the two impacts of high magnetic fields on strongly correlated electron systems. Firstly, acting as a thermodynamic parameter, an applied field can induce phase transitions tuning a system through different ground states. This, combined with pressure and temperature, allows one to study the extremely rich phase diagrams of strongly correlated electron systems, and relate changes in different parameters to the appearance of new phases. Secondly, magnetic field gives rise to quantum oscillation effects (de Haas-van Alphen and Shubnikov-de Haas), which are unique tools for the direct exploration of the Fermi-surface and the dynamics of the charge carriers.

In the following, I will discuss in more details the major techniques used for studding strongly correlated electron systems in high magnetic fields. These include, among others, transport, specific heat, and magnetic torque measurements. I will also show several examples of recent results obtained in high fields using these experimental techniques.

Lecture on :

Superconductivity and correlated electronic grounds state induced by the magnetic field in low carrier metals

B.Fauqué

IPCDF, Collège de France, 75005 Paris, France and ESPCI ParisTech, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 6, LPEM, 10 rue Vauquelin, F-75231 Paris Cedex 5, France

In this lecture I will discuss the electronic ground states that can be found or be induced by an external parameters in metals with an electronic density several orders of magnitude smaller than in conventional metals.

In the first part I will focus on the case of the superconductor $SrTiO_{3-x}$. Strontium titanate is a wide-gap semiconductor avoiding a ferroelectric instability thanks to quantum fluctuations. This proximity leads to strong screening of static Coulomb interaction and paves the way for the emergence of a very dilute metal with extremely mobile carriers at liquid-helium temperature. The superconducting instability survives at exceptionally low concentrations and beyond the boundaries of Migdal-Eliashberg approximation. An intimate connection between dilute superconducting and aborted ferroelectricity is widely suspected. I will give a brief account of ongoing research on bulk strontium titanate as an insulator, a metal and a superconductor.

In the second part I will discuss the so-called *quantum limit* of a three dimensional metal, which is attained at a sufficiently strong magnetic field with only a few occupied Landau levels. Semi metals such as graphite or bismuth, which have a small Fermi surface, are ideal candidates to explore this limit. In the early 1980s, a sharp increase in the in-plane magneto-resistance of graphite at high magnetic field (typically B> 20 T) was discovered and attributed to a phase transition induced by the magnetic field. Numerous studies followed, and this phase transition is generally believed to be a density-wave instability triggered by the one-dimensional nature of the electronic spectrum and the enhancement of the electron-electron interactions in the quantum limit. Recent transport measurements up to 80 T revealed that not one but two successive field-induced instabilities are present. After a brief description of the quantum limit, we review the rich and complex field phase diagram of graphite as a function of temperature and magnetic field. I will discuss the possible electronic states associated with these instabilities.