A. Exploring the electronic structure and superconductivity of iron-based superconductors under strain

This project will investigate the response of quantum materials, especially iron-based superconductors, to applied lattice strain. The fundamental reason to do this is that in these materials there are many electronic processes that occur simultaneously, which can be difficult to disentangle when looking at the unstressed system alone. One can gain much more information by understanding how elastic lattice distortion, applied through hydrostatic, biaxial, or uniaxial stress, affects the electronic properties of a material. For example, lattice strain may be used to suppress an electronic instability, or to enhance one or more of the processes in the material. One major area of interest in the iron-based compounds is the electronic nematicity, a form of electronic order which breaks rotational but not translational symmetries. Nematicity may play an important role in high-temperature superconductivity. Uniaxial stress can be used to increase nematic polarisation in a material, by adding to the orthorhombic lattice distortion associated with nematic order.

This project is an experimental study aim to understand the electrical resistivity under applied strain in iron-based superconductors. A suitable candidate will perform experiments as function of strain, temperature and magnetic field. The candidate will solve experimental problems and have a strong background in condensed matter physics. Good computational skills, such as Matlab and Python would be valuable for the project. We are looking for a candidate interested to pursue a MPhys project and a PhD project in condensed matter physics. To apply for this project please send your CV and a cover letter to justify your interest in the proposed topic to amalia.coldea@physics.ox.ac.uk.

Further reading:

1. The key ingredients of the electronic structure of FeSe
https://arxiv.org/pdf/1706.00338v1.pdf

2. Emergence of the nematic electronic state in FeSe, https://arxiv.org/abs/1502.02917
Strong Peak in Tc of Sr2RuO4 Under Uniaxial Pressure
https://arxiv.org/ftp/arxiv/papers/1604/1604.06669.pdf

3. Quantum oscillation studies of the Fermi surface of iron-pnictide superconductors,
http://iopscience.iop.org/article/10.1088/0034-4885/74/12/124507

4. Transport properties of FeSe epitaxial thin films under in-plane strain
https://iopscience.iop.org/article/10.1088/1742-6596/1054/1/012023

B. Quantum oscillations of novel quantum materials with Dirac dispersions

Topological Dirac-semimetals are electronic materials with strong spin-orbit interaction that have topologically protected electronic properties originating from Dirac-band dispersions either of the bulk and unusual topological surfaces. In ordinary materials, backscattering, in which electrons take a turn back owing to collisions with crystal defects, effectively degrades the current flow and increases the resistance. On the surface of topological protected systems, backscattering processes are completely suppressed (forbidden), so charge transport is in a low-dissipation state with exceptional transport mobility and reduced energy consumption, which due to their long life and low maintenance costs are extremely attractive for semiconductor devices.

This project aims to probe to establish the Fermi surfaces and the topological signatures in quantum oscillations of novel Dirac materials using high magnetic fields and low temperatures. A suitable candidate should have a strong background in condensed matter physics and advanced computational skills, such as using Matlab and Python. The student will compare existing experimental data with band structure calculations using Wien2k. http://susi.theochem.tuwien.ac.at/

We are looking for candidates interested to pursue an MPhys project and a PhD project in condensed matter physics. To apply for this project please send your CV and a cover letter to justify your interest in the proposed topic to amalia.coldea@physics.ox.ac.uk. For further questions please email amalia.coldea@physics.ox.ac.uk

Further reading:

Linear magnetoresistance caused by mobility fluctuations in the n-doped Cd3As2
Phys. Rev. Lett. 114, 117201 (2015)

Topological surface electronic states in candidate nodal-line semimetal CaAgAs
https://arxiv.org/abs/1708.06484

Quantum Oscillations in Nodal Line Systems
https://arxiv.org/abs/1801.02733

C. Optimizing tunnel diode oscillator technique to probe skin and penetration depth in superconducting and Dirac materials

This project aims to optimize the sensitivity of an existing experiment using the tunnel diode oscillator technique to probe the skin depth and penetration depth of novel materials. Tunnel diode oscillator based-technique is known to be sensitive to the London magnetic penetration depth in superconducting materials and can probe the transition temperature and the upper critical field. This technique also measures the skin depth of conducting materials and give access to quantum oscillations in high magnetic fields.

A suitable candidate should have a strong background in condensed matter physics and basic knowledge of electronics. Computational skills, such as using Matlab and Python would be useful. We are looking for candidates interested to pursue a MPhys project and a PhD project in condensed matter physics. To apply for this project please send your CV and a cover letter to justify your interest in the proposed topic to amalia.coldea@physics.ox.ac.uk.

For further questions please email amalia.coldea@physics.ox.ac.uk

For further reading consult:

https://arxiv.org/pdf/1003.5233.pdf
https://arxiv.org/ftp/cond-mat/papers/9904/9904026.pdf
https://arxiv.org/abs/1403.0844

D. Modelling vortex dynamics inside novel superconductors in magnetic fields

This project aims to understand the complex vortex dynamics inside two-dimensional superconductors in the presence of different defects and impurities. This is crucial for the implementation of high-temperature superconductors in applications as the vortex pinning on defects help to maintain very large critical currents. Simulations will rely on time-dependent Ginzburg Landau theory already implemented in the commercial software package COMSOL Multiphysics. In this project, simulations of vortex lattice and relevant superconducting parameters will be perform using realistic parameters in order to understand the presence of large critical currents in novel iron-based superconductors. This project will be performed in the new Oxford Centre for Applied Superconductivity (CfAS).

A suitable candidate should have a strong background in condensed matter physics and strong computational skills, such as COMSOL, Matlab or Python. We are looking for candidates interested to pursue further projects in condensed matter physics.

To apply for this project please send your CV and a cover letter to justify your interest in the proposed topic to amalia.coldea@physics.ox.ac.uk.

For further reading see:

1. COMSOL Multiphysics https://www.comsol.com/comsol-multiphysics
2. https://www.comsol.com/blogs/modeling-superconductivity-ybco-wire/

3. Time-Dependent Ginzburg — Landau Simulations of the Critical Current in Superconducting Films and Junctions in Magnetic Fields

4. See also the video of simulations on http://www.cfas.ox.ac.uk/discover

E. Implementing ultrafast data acquisition for testing superconducting properties of materials

We are looking for an enthusiastic student with good computational and electronics skills to implement a new fast and cheap acquisition system in our experimental laboratory for measuring transport and superconducting critical current densities. The acquisition system is based on different tools developed by Redpitaya http://redpitaya.com/. This project will be performed in the new Oxford Centre for Applied Superconductivity (CfAS). The aim is to integrate the new acquisition system within our current software written in Python or Matlab but there is also a scope for developing a complete new system such that the acquisition speed is not compromised.

A suitable candidate should have strong computational and electronics skills. To apply for this project please send your CV and a cover letter to justify your interest in the proposed topic to amalia.coldea@physics.ox.ac.uk.

For further reading please visit http://redpitaya.com/.