7th Superconductivity Summer School

5–8 July 2022
Wolfson College, Oxford, UK

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Tuesday 5th July

12:00 – 13:00	**Registration and Lunch**
	Chair
13:00-13:15	**Welcome and Introduction** Dr. Ziad Melhem, Oxford Quantum Solutions Ltd, Oxford, UK Ziad.melhem@oxqsol.com
13:15-14:00	Invited Special Topic Talk 1 **Superconducting Technologies and Zero Emission Targets** Dr. Mark Husband from GKN Aerospace mark.husband@gknaerospace.com
14:00-14:45	**Superconducting Fundamentals and Theory** Prof. Stephen Blundell, Clarendon Laboratory, University of Oxford, Oxford, UK s.blundell1@physics.ox.ac.uk
14:45-15:30	**Basics of Superconducting Materials** Prof. Susannah Speller, Materials department, University of Oxford, Oxford, UK susannah.speller@materials.ox.ac.uk
	Chair
15:30-16:45	**Coffee and Tea Break** **And Attendees contributions (Posters/Short Talks)**
16:45-17:30	**Superconducting Applications** Dr. Martin Wilson, Consultant, Oxford, UK martnwil@gmail.com

17:30-18:00	Panel Session (1)
18:00-19:00	**Dinner**
19:00	Invited Public Talk (2) **Can superconductors help us save the planet?** *This will be followed by Launching A Materials Science Guide to Superconductors and How to Make Them Super by* Prof. Susannah Speller, Materials department, University of Oxford, Oxford, UK susannah.speller@materials.ox.ac.uk

Wednesday 6th July

07:45- 8:30	**Registration and Refreshments**
	Chair
8:30-9:15	**Superconducting Conductors for Science and Engineering Applications** Prof. David Larbalestier, ASC-NHMFL, Florida State University, Tallahassee, USA larbalestier@asc.magnet.fsu.edu
09:15-10:00	**Electronic and superconducting properties of iron-based superconductors** Prof. Amalia Coldea, Clarendon Laboratory, University of Oxford, Oxford, UK amalia.coldea@physics.ox.ac.uk
10:00-10:45	**Superconducting Materials Chemistry** Prof. Simon Clarke, Chemistry Department, University of Oxford, Oxford, UK simon.clarke@chem.ox.ac.uk
10:45-11:15	**Tea and coffee break**
	Chair
11:15-12:00	**Bulk Superconducting Materials**

	Prof. John Durrell, Engineering Department, Cambridge University, Cambridge, UK jhd25@cam.ac.uk
12:00-12:45	**Ginzburg-Landau Theory for High Magnetic Field Applications** Prof. Damian Hampshire, Physics Department, Durham University, Durham, UK d.p.hampshire@durham.ac.uk
12:45-13:45	**Lunch**
	Chair
13:45-14:30	**Design Principles of Superconducting Magnets – Part I** Dr. Martin Wilson, Consultant, Oxford, UK martnwil@gmail.com
14:30-15:15	**Superconducting Applications – Cables: Principles, large scale applications and Power transmission** Dr. Joe Minervini, Plasma Dept, MIT, Boston, USA minervini@psfc.mit.edu
15:15-15:45	**Tea and Coffee**
	Chair
15:45-16:30	**Multiphysics Modelling of a Superconductor close to its Critical Current** Dr. Nathaniel Davies, COMSOL, Cambridge, UK
16:30-17:15	**Modelling of SC Applications using SIMULIA Opera** Dr. Ben Pine, Dassault Systemes UK Limited | 3DS Oxfordshire, Langford Locks, Kidlington | OX5 1LH Oxfordshire | United Kingdom Ben.PINE@3ds.com
17:15-17:45	Invited Special Topic Talk 3 **The Challenge of Cryogenics for Superconducting Applications** Dr. Bruce Strauss, IEEE-CSC

	nbti@aol.com
17:45-18:15	**Panel Session (2)**
18:30-20:00	**Dinner/Barbecue**

Thursday 7th July

7:45 -8:30	**Registration/Refreshments**
	Chair
8:30-9:15	**Superconducting circuits for quantum information processing** Prof. Martin Weides, James Watt School of Engineering, University of Glasgow, Glasgow, UK Martin.weides@glasgow.ac.uk
9:15:10:00	**Nanoscale SQUIDs for a closer look at brain functions** Dr. Thilo Bauch, Chalmers University of Technology - se-412 96 Gothenburg, Sweden thilo.bauch@chalmers.se
10:00-10:30	**Tea and Coffee Break**
	Chair
10:30-11:15	**Technology Roadmap for Superconductor Electronics** Prof. D. Scott Holmes, IEEE Council on Superconductivity (CSC) - International Roadmap for Devices and Systems (IRDS) d.scott.holmes@ieee.org
11:15-11:45	Invited Special Topic Talk 4 **UK National Quantum Computing Centre (NQCC)** Dr. Michael Cuthbert – NQCC, STFC UKRI, Oxfordshire, UK michael.cuthbert@stfc.ac.uk
11:45-12:15	**Panel session (3)**

12:15-13:15	**Lunch**
13:15-14:00	Travel to Oxford Instruments
14:00-16:00	**Oxford Instruments Talk and Tour at Tubney Woods** (visit by coach) Dr. Andrew Twin, Oxford Instruments, Tubney Woods, OX13 5QX, Abingdon, UK TWIN Andrew Andrew.TWIN@oxinst.com
16:00-16:30	**Return to Oxford**
	Chair
19:00- 20:30	**Summer School Dinner** **(7pm prompt)**

Friday 8th July

7:45 -8:30	**Refreshments**
	Chair
8:30-9:15	**Superconducting Technology for High Energy Physics and Accelerators** Dr. Luca Bottura, CERN, Geneva, Switzerland luca.bottura@cern.ch
9:15- 10:00	**Superconducting Technology for Fusion** Dr. Joe Minervini, MIT, Boston, USA minervini@psfc.mit.edu
10:00-10:30	Invited Special Topic Talk 6 **HTS Technology for Spherical Tokamaks** Dr. Greg Brittles, Tokamak Energy, UK greg.brittles@tokamakenergy.co.uk

10:30-11:00	**Tea and Coffee Break**
	Chair
11:00-11:45	**Cryogenics for Superconducting Applications** Mr. Charles Monroe, Monroe Brothers Ltd, Oxford, UK cmonroe@monroebrothers.co.uk
11:45:12:30	**Design Principles of Superconducting Magnets – Part II** Dr. Martin Wilson, Consultant, Oxford, UK martnwil@gmail.com
12:30-13:30	**Lunch**
	Chair
13:30-14:15	**Superconducting Applications – MRI** Dr. M'hamed Lakrimi, Siemens Magnet Technology, Oxford, UK mhamed.lakrimi@siemens.com
14:15-15:00	**Superconducting Electrical Machines** Dr. Mark Ainslie, Cambridge University, Cambridge, UK mark.ainslie@eng.cam.ac.uk
15:00-15:30	**Tea and Coffee Break**
15:30-16:00	Invited Special Topic Talk 5 **European Magnetic Field Laboratory (EMFL): Science and Technologies** Prof. Amalia Patane, Nottingham University, Nottingham, UK Amalia.patane@nottingham.ac.uk
16:00-16:30	**Panel Session (4)**
16:30-16:45	**Closing Remarks** Dr. Ziad Melhem, Oxford Quantum Solutions Ltd, Oxford, UK ziad.melhem@oxqsol.com

Superconducting Technologies and Zero Emission Targets

Dr Mark Husband, GKN Aerospace

The aerospace industry has agreed emission targets and these are driving new aircraft towards zero emission solutions. A significant increase in electrification, including delivering propulsion power, and new fuels are some of the key levers to achieving significant emissions reduction. Meeting short range airplane platforms can be achieved with developing existing technology. GKN believe an all-electric approach using hydrogen fuel cells offers the optimum solution to meet short-range aircraft. Critically to meet aerospace needs liquid hydrogen storage is preferred. Through an ATI funded project called H2Gear, GKN is developing cryogenic cooled power and propulsion technology based on more traditional tube and wing airframes. Given the significant high power density and efficiency requirements for longer range aircraft platforms, a number of step-changes are required. This includes new more efficient airframes, enabled by an all-electric, and new electrical technologies of which superconductivity is seen as key. Potential power density and efficiency targets are provided assuming new airframe benefits are delivered. The high-level aerospace industry risks of adopting superconductivity are also discussed but the potential for superconductivity is very exciting.

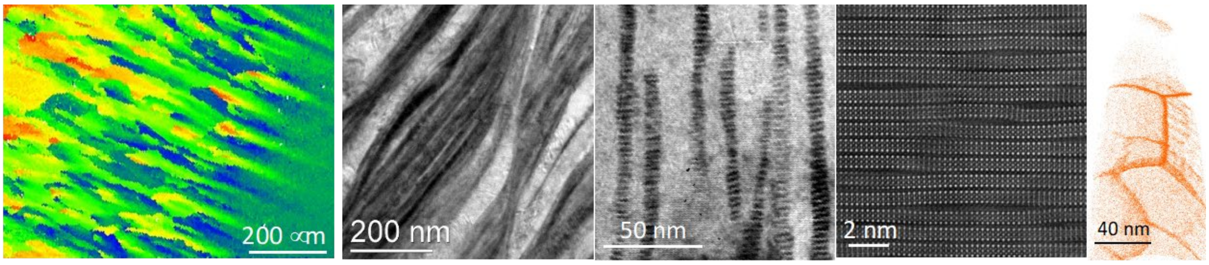
Superconducting Fundamentals and Theory

Stephen Blundell, University of Oxford, UK

I will give an overview of the theories that have been constructed to describe superconductivity in materials. This will include the London equations, the BCS model and the Ginzburg-Landau approach, and I will also highlight unsolved issues.

Superconducting Materials I

This lecture will introduce type II superconductors and magnetic flux lines and will focus on the basic principles of optimising materials performance by controlling microstructure. Various case studies will be used to explore how advanced materials engineering is used to obtain high performance low temperature and high temperature superconductors for practical applications. The main focus is on materials capable of carrying high current densities, but we will also touch upon thin film superconductors for small-scale device applications.



Susie Speller is a Professor of Materials Science at the University of Oxford and a Fellow at St Catherine's College. She has spent over 20 years researching superconducting materials in Oxford, originally working on high temperature cuprate superconducting thin films for microwave device applications, before diversifying into a wider range of superconductors including coated conductors, iron-based superconductors, low temperature superconductors and MgB_2. In collaboration with industrial partners, recent projects have included the development of superconducting joints for MRI and NMR applications, bulk superconductors for compact magnet applications and radiation damage of coated conductors for fusion magnets. Susie is currently Letters Editor of *Superconductor Science and Technology* and has recently written a book called *"A Materials Science Guide to Superconductors: and how to make them super,"* aimed at introducing superconductors materials to the general public.

Applications of Superconductivity

Dr Martin Wilson, Consultant, Oxford, UK

The School features many lectures on the application of superconductivity – both electronics and heavy current applications. In this brief introduction I will present the overall scene on heavy currents and then give some attention to those applications not covered by other speakers. Market surveys show that activity in superconductivity worldwide is dominated by magnets and high current applications, with superconducting electronic devices so far claiming only a small share of the market. Scientific research was the first application to use superconductivity, with NMR spectroscopy becoming the first area for commercial products. This research naturally led to the use of NMR for medical imaging, now known as MRI, and MRI scanner magnets now dominate the market sector with ~ 75% of the total worldwide business in superconducting products, still predominantly low temperature superconductors LTS. Large scale applications are dominated by particle accelerators and thermonuclear fusion. Other heavy current applications include magnetic separation, maglev, induction heating, bearings, power generation, energy storage, transformers and fault current limiters.

Some 36 years after their discovery, high temperature superconductors HTS have finally started to make a commercial impact and their use is now growing. Prospects for the application of HTS will be discussed.

Can superconductors help us save the planet?

Prof. Susannah Speller, Materials department, University of Oxford, Oxford, UK

As global energy demand continues to rise at an alarming rate, and the devastating environmental impacts of guzzling fossil fuels like oil and coal are increasingly evident, decarbonisation of the economy is of utmost importance to our future. For this reason, governments around the world are setting ambitious targets for reaching “net zero” and are investing heavily to increase renewable energy production, develop new technologies like nuclear fusion and make the transition to electric vehicles. So how might superconductors be able to help? Superconductors are very special materials that can carry huge amounts of electricity without losing any energy at all in the process. Harnessing this amazing property could not only lead to dramatic savings in the cost of distributing energy around the countryside and storing electricity that has been generated by renewables, but can also enable us to make the really high strength magnets needed to replicate on Earth the nuclear fusion process that powers the stars. In this public lecture, Susie Speller will use live demonstrations to show the extraordinary properties of superconductors, and will explore the practical challenges of deploying these very complex materials in revolutionary technologies.

Superconducting Materials in Conductor Forms

David C Larbalestier

Of many hundreds, perhaps thousands of materials known to be superconducting, only 6 are available industrially. By far the largest production is of Nb47wt.%Ti followed by Nb_3Sn, both in multifilamentary form. Together they account for well over 90% of all superconductor made because they can supply high critical current density $J_c(4.2K)$, well over 1000 A/mm^2, in fields of up to about 8 T for Nb-Ti and up to ~16 T for Nb_3Sn. Thus well over 95% of all superconducting magnets have been made with Nb-base materials. Three cuprate superconductors have been made in conductor forms, first $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi-2212), later $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$ (Bi-2223), then coated conductors of $REBa_2Cu_3O_{7-x}$ (REBCO). For any superconductor to become viable, it must be available in an affordable, quench-protectable and strong enough conductor form to be suitable for magnet construction, a task well fulfilled by Nb-Ti and Nb_3Sn in magnets with fields up to 23 T. HTS materials, notably Bi-2212 and REBCO have allowed demonstration magnets above 30 T. Recently a small REBCO insert coil has achieved 14.5 T in a 31 T background field to achieve a new world record of 45.5 T for DC field. Many believe in REBCO coated conductors as the future commodity superconductor because of its capability to operate at temperatures well above liquid helium temperatures, perhaps even as high as 65-77 K. A major development in late 2021 was the successful test of a prototype toroidal field tokamak coil which generated a peak field of 20 Tesla while cryo-cooled to 20 Kelvin. Bi-2212 also offers intriguing options since it is the only HTS conductor available with high J_c in round, isotropic and multifilament form, while Bi-2223, also multifilament, though in strongly coupled and high aspect ratio tape format, has found wide use in prototype electric utility devices. All three cuprate conductors are expensive which has allowed MgB_2 conductors to enter small-scale production as a low field (~0-3 T), medium temperature (~10-30 K), potentially cheaper alternative uses not served by Nb-Ti.

Due to time constraints I will only be able to explicitly discuss a subset of these conductors, but I hope to do so in a way that will be provide general value for those interested also in the conductors that I do not have time to discuss.

Electronic and superconducting properties of iron-based superconductors

Professor Amalia I. Coldea, Clarendon Laboratory, University of Oxford, Oxford, UK

Iron-based superconductors are a new family of high temperature superconductors with large critical temperatures that can exceed nitrogen liquid temperatures and extremely high and isotropic upper critical fields.
In this talk, I will discuss their superconducting properties which originate from the details of their electronic structure and the unconventional pairing interaction. I will also present upper critical studies up to 90T, the magnetization studies to determine the critical current densities and magnetotransport data under strain and pressure to characterize new single crystals [1,2,3,4,5]. I will also describe efforts to develop powders for wire fabrication [6]. Another exciting discovery for this class of materials is the high temperature two-dimensional superconductivity of a monolayer of FeSe on a doping substrate. I will discuss the progress made to develop thin flakes devices from single crystals of FeSe [7]. This work is supported by the Oxford Centre for Applied Superconductivity.

[1] A.I. Coldea, Frontiers in Physics, **8**, 528, (2021);
[2] M. Bristow, et al., Phys. Rev. B **101**, 134502 (2020);
[3] M. Bristow, et al., Phys. Rev. Research **2**, 013309 (2020);
[4] S. J. Singh et al., Phys. Rev. Materials **2**, 074802 (2018);
[5] P. Reiss et al., Nature Physics **16**, 89 (2020);
[6] M. Ghini et al., Phys. Rev. B **103**, 205139 (2021);
[7] S. J. Singh et al., Supercond. Sci. Technol. **33** 025003 (2020);
[8] L. Farrar et al., npj Quantum Materials, **5**, 29 (2020);

The Synthesis and Chemical Control of New Superconductors

Prof Simon J Clarke

[1]Department of Chemistry, University of Oxford, Inorganic Chemistry Laboratory, South Parks Road, Oxford, OX1 3QR, UK.

The chemistry of a range of systems displaying superconductivity will be surveyed briefly. The main focus will be on the factors controlling superconductivity in iron arsenide and selenide superconductors, but the chemical ideas will be extended to the control of superconductivity in other systems, particularly layered chalcogenides. Synthetic methods for realising members of the class of iron based superconductors, and other classes of superconductor will be described. In particular the focus will be on compounds containing iron selenide layers with electropositive metals and small molecules such as ammonia in the interlamellar space, which have been characterised using neutron diffraction investigations [1,2] and *in-situ* X-ray powder diffraction investigations carried out during synthesis [2]. The control of the physical properties through chemical transformations including absorption of small molecules [2,3] will be described, and the interplay of magnetism and superconductivity as a function of composition will be compared with that of the iron arsenide members of the class [4]. These will be related to measurements on iron selenide films. Further new results relating to the use of detailed characterisation to correctly identify the superconducting phase in structurally complex mixtures will be discussed in the context of superconductors derived from bismuth selenide [5].

References

[1] M. Burrard-Lucas et al., Nature Materials 12, 15 (2013)
[2] S. J. Sedlmaier et al., J. Am. Chem. Soc. 136, 630 (2014)
[3] H. Sun et al. Inorg. Chem., 54 1958–1964 (2015)
[4] D. R. Parker, et al., Phys. Rev. Lett. 104, 057007 (2010)
[5] M. E. Kamminga, *et al.* Communications Materials 1 82 (2020)

Bulk superconductors – an introduction

Prof. John Durrell, Engineering Department, Cambridge University, Cambridge, UK

The obvious application of superconducting materials is in the form of wires, and this has been the subject of much materials research effort. However, it is also possible to employ superconductors in bulk form. Just as superconductors in wire and tape form can replace conventional copper conductors, bulk superconductors can be used as replacements for rare-earth permanent magnets, but with trapped magnetic fields an order of magnitude larger. In addition, bulk superconductors can be used to provide passively stable magnetic levitation, by exploiting their flux pinning properties. It is this latter property which is often encountered in popular demonstrations of superconductivity, often coupled with an entirely incorrect explanation for stable levitation involving the Meissner effect.

In this summer school talk I will provide a broad overview of the materials science of bulk superconductors and key factors affecting their performance and suitability for applications. I will then review some of the key active areas of current research in the material science of bulk superconductors. My talk will conclude with a review of the applications of bulk superconductors, which range from the highly speculative, such as motors for long distance air travel, to the fully commercialised, such as bearings for high speed centrifuges.

Title: Ginzburg-Landau Theory and Pinning in High-Field Superconductors/Applications

Prof. Damian Hampshire – University of Durham, UK.

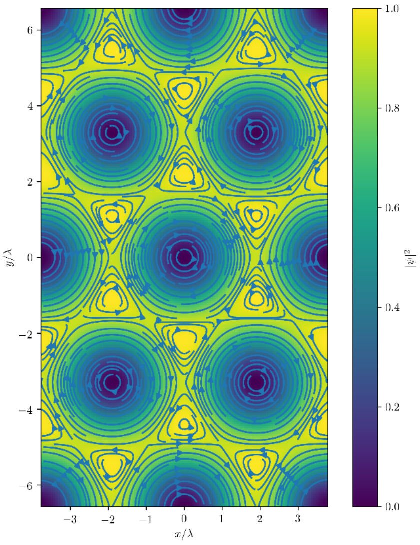


Figure 1: The density of superelectrons in the flux-line-lattice calculated using Ginzburg-Landau theory [A Blair thesis, Durham 2020]

Abstract:

Ginzburg-Landau (GL) theory describes the properties of all known superconductors in magnetic fields. It provides the framework for the two classes of superconductors (Type I and Type II), as well as a detailed description of the low-field Meissner state and the high-field mixed state that includes the flux-line-lattice [1].

In this lecture, we will consider the assumptions and predictions of GL theory. Visualisations of GL theory will be provided that show how the flux-line-lattice is established, and the central ideas and experimental data that lead to our current understanding of flux pinning and the extraordinarily high critical current density that superconductors can carry. We conclude by considering recent research [2].

[1] D. P. Hampshire **A derivation of Maxwell's equations using the Heaviside notation. *Phil. Trans. R. Soc. A* 20170447 (2018) – Open Access**.
[2] A. I. Blair and D. P. Hampshire **Critical current density of superconducting-normal-superconducting Josephson junctions and polycrystalline superconductors in high magnetic fields**, Phys. Rev. Research **4**, 023123, 16 May 2022

Design Principles of Superconducting Magnets - part I: Magnetic Configurations and Quenching.

Dr. Martin Wilson, Consultant, Oxford, UK

Because they have no Ohmic dissipation, superconducting magnets are able to reach high fields, but unlike conventional electromagnets they cannot use an iron yoke to shape the field because iron saturates at ~ 1.8T. In the absence of iron, the field must be shaped entirely by the winding configuration. The different winding shapes needed to produce solenoid, dipole and toroidal fields will be described, together with the electromagnetic forces and resulting stresses produced in the windings and their supporting structure.

Quenching occurs when a point within the magnet windings goes from superconducting to resistive state. Intense Ohmic heating ensues and the resistive zone grows by thermal conduction so that the magnet current decays via the growing internal resistance. If the current does not decay quickly enough, the temperature at the point where the quench started may be high enough to destroy the magnet. Methods of calculating quench behaviour and of protecting against damage by quenching will be described. The resistive zone in an HTS winding grows much more slowly than in an LTS winding, which makes the quench protection problem much more difficult and requires new ideas to protect the magnet from damage.

Multiphysics Modelling of a Superconductor close to its Critical Current

Dr. Nathaniel Davies, COMSOL, Cambridge, UK

In this talk, we will explore the capabilities of the COMSOL Multiphysics® software for modelling of superconductors, including user stories and worked examples. The talk will focus on electromagnetic modelling of superconductors close to the critical point and will discuss other aspects such as thermal and structural modelling.

Superconductivity Modelling

Dr. Ben Pine, Dassault Systemes UK Limited | 3DS Oxfordshire, UK

The simulation of superconducting materials operating in ideal conditions and in isolation is relatively straighforward - the fields can be calculated by solving the Biot-Savart equations. However, real life is rarely so straightforward. Superconducting materials may be inside a cooling system or vacuum tank, or near other conducting or permeable materials. If the temperature, electromagnetic field or current of part of the superconductor goes beyond its critical limit then the superconductor will return to its resistive state - it will quench.

For normal superconductors quench is an avalanche process - once a quench has started it will continue and the consequences must be dealt with in a safe and predictable way. A system can be trained to limit the number of operational quenches and reach design operating conditions. For high temperature superconductors the situation is more complex, and some current sharing between superconductor and substrate can be expected at all conditions.

If a quench does occur the current flowing through the superconductor will divert into the substrate, raising its temperature quickly. The current will fall, inducing eddy currents and forces on nearby conducting materials. This process can be extremely destructive. It is important to anticipate and mitigate quench events by detecting them early, spreading the quench to other nearby conductors to avoid localized damage and divert current to protection circuits.

Simulation tools have been used extensively to model the behaviour of superconductors. They can calculate the fields produced by superconducting materials with extreme accuracy, but can also model the full quench process including electromagnetic fields, transient temperature effects, forces and protection circuits.

In part due to these tools, superconductors have been successfully used for many decades in particle accelerators, MRI scanners and prototype fusion machines. In recent years, novel material types with superconducting transition temperatures above the temperature needed for liquid nitrogen (77 K) have become available. This far less challenging temperature has opened up new developments for superconductors in highly efficient electric motors and lossless transmission lines.

Cryogenics and Other Considerations for Real Superconducting Systems

Dr. Bruce Strauss, IEEE-CSC

As superconducting projects move from the design table or the laboratory bench to real applications it is useful to carefully consider assumptions regarding cryogenics and other systems reliability issues. This talk will take a lookback as to where projects have failed due to faulty assumptions and engineering.

Superconducting circuits for quantum information processing

Prof. Martin Weides, James Watt School of Engineering, University of Glasgow, Glasgow, UK

Quantum technologies based on on-classically interacting qubit states allow experimental realizations ranging from fundamental tests to quantum simulation & computing achieving a quantum advantage. Today, realizing the second quantum revolution appears feasible, with superconducting quantum circuits having matured over the past years to one of the leading platforms with an unprecedented variety of implementation and application schemes. For instance, superconducting quantum simulators and computers can now tackle problems that are hard to solve.

In this talk, an introduction to the field will be given, including a view on technological challenges such as quantum circuit materials and their processing and scale-up. Exemplary quantum simulation applications such as the dynamics in ultra-strongly coupled systems or multi-state Landau Zener transitions are discussed.

Nanoscale SQUIDs for a closer look at brain functions

Dr. Thilo Bauch, Chalmers University of Technology - se-412 96 Gothenburg, Sweden

Recent advances in nano-patterning of high critical-temperature (high-T_c) superconductors have yielded superconducting quantum interference device (SQUID) magnetometers that are simpler to fabricate, enable more flexibility in design, and are more sensitive to magnetic fields as compared to the state-of-the-art. There are two state-of-the-art approaches to low-noise high-T_c SQUID magnetometers: bicrystals and step-edges. While both have been developed and refined since the 1980s, they require multilayer and/or multi-chip configurations in order to reach high sensitivity. Such technical challenges limit fabrication yield and design flexibility. As such, widespread utilization of high-T_c SQUIDs has been limited, especially when compared to their low critical temperature (low-T_c) counterparts. Our recent development of a new high-T_c SQUID fabrication process, namely grooved Dayem-bridges, overcomes these limitations because it consists of patterning of a single high-T_c film while meeting—or exceeding—the low-noise capabilities of the state-of-the-art. The elegantly simple fabrication approach enables unique design flexibility. It furthermore lends itself to volume production for beyond state-of-the-art single- and multi-channel magnetometer systems that can meet the market need in non-destructive evaluation, geomagnetism, and biomagnetism. The latter is of high relevance for medical imaging, such as neuroimaging with magnetoencephalography (MEG).

The neuroimaging advancement is enabled by the moderate (T~77 K) operating temperature of our highly-sensitive SQUIDs such that they can be placed in close (within 1 mm) proximity of the head surface where neuromagnetic signals are stronger and imaging resolution is improved. The state-of-the-art in MEG today is based on low-T_c SQUIDs: as the name implies, such sensors operate at extreme cryogenic temperatures (T~4 K) and therefore require significant overhead in terms of thermal insulation and expensive liquid helium. The sensors inside MEG systems on the market today are roughly 2 cm from the head surface and systems consume some 100 litres of liquid helium per week. Because the magnetic fields generated by neural activity decay rapidly as a function of distance from the sources (i.e., the electrical activity of neurons in the brain), MEG systems suffer from low signal levels and spatial resolution. By densely packing our highly sensitive magnetometers around the scalp surface, we expect to detect stronger signals with improved spatial sampling. We can furthermore replace expensive and scarce liquid helium with cheap and abundant liquid nitrogen. As such, we can achieve a quantum leap in neuroimaging capabilities—at a lower cost—as compared to the state-of-the-art.

Establishing a new National Laboratory: NQCC purpose and progress

Dr. Michael Cuthbert – NQCC, STFC UKRI, Oxfordshire, UK

The National Quantum Computing Centre will help translate UK research strengths into innovation, by enabling the understanding, development and integration of quantum computing technology, to help build a resilient future economy. As an independent trusted authority, the NQCC's vision is for the UK to harness the potential of quantum computing to solve some of the most complex and challenging problems facing society, having addressed the key scaling challenges – in technology as well as user adoption. In this talk the NQCC Director will update on progress being made against the goals of the Centre to create workforce readiness, technology capability and state of the art infrastructure.

Superconducting Technology for High Energy Physics and Accelerators

Dr. Luca Bottura, CERN, Geneva, Switzerland

Superconducting magnet and RF technologies are fundamental ingredients that fuel advances in High Energy Physics (HEP), and more in general particle accelerators for scientific, industrial and medical applications. In this lecture we will review the reasons why superconductivity is necessary in frontier accelerators such as the LHC, or for future realizations such as lepton and hadron colliders. We will then enter into the details of superconducting magnets for beam lines and detectors, and superconducting RF cavities. A special focus will be given to recent advances and perspective of future developments, e.g. high field LTS and HTS magnets and high-gradient RF structures.

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