Research Matters

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Creating environments for physical sciences ISSUE 15 SUMMER 2002

Electrons Meet Helium

Dr. Keiya Shirahama meets Sir Martin Wood

Dr Keiya Shirahama, is the winner of the 2001 Sir Martin Wood Prize. Sponsored by Oxford Instruments Superconductivity, the Millennium Science Forum annually awards the Sir Martin Wood Prize to a young Japanese scientist carrying out his/her research in Japan, who has performed outstanding research in Condensed Matter Science. Dr Shirahama's prize winning research using 2D electron systems is presented below.

Liquid ^{3}He Free Surface Probed by the Wigner Crystal

Two-dimensional (2D) electron systems have contributed greatly to developments in fundamental physics, for example, in the discovery of the Quantum Hall effect. Electrons trapped on a free surface of liquid helium (He) offer an excellent high mobility 2D electron system.

Since the free surface of liquid He is extremely smooth, the mobility of electrons increases enormously at low temperatures. Due to this highly mobile nature, the electrons are very sensitive to elementary excitations, which disturb electron transport, and can be a powerful probe for the study of the He surface.

Due to strong Coulomb repulsion, surface electrons undergo a phase transition to a crystalline state called the Wigner crystal, predicted theoretically by the famous American physicist, Eugene Wigner, in 1934. The Wigner crystal is one of the possible ground states of strongly correlated electron systems.

Quantum Liquids

The Wigner crystal on liquid He has a unique feature; the electrons localised within the lattice put pressure on the liquid surface resulting in periodic corrugations (Figure 1). This is called the “dimple” structure. Not only does the dimple structure play a key role in the dynamic properties of the Wigner crystal, but it can be used as a tool for understanding liquid He, the fascinating quantum liquid.

The free surface of liquid He is an intriguing object of study. In particular, we have been interested in the surface of superfluid ^{3}He. The superfluid ^{3}He is a typical *anisotropic* Fermi superfluid, in which the Cooper pairs have nonzero spin- and orbital- angular momenta. Near the boundaries of the liquid, the

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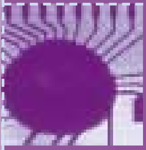
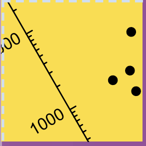
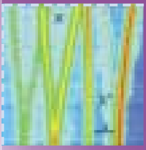
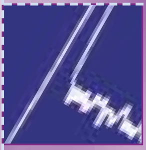








anisotropic nature may be greatly enhanced. A boundary is made by, for instance, a solid wall of a liquid helium container. The wall is usually very rough in a mesoscopic length scale, however, so it does not provide a good boundary. Conversely, the free surface of liquid helium is extremely flat in atomic length scale, with no impurities or defects. This offers an almost ideal boundary of the anisotropic Fermi superfluid where one may expect some peculiar elementary excitations called *quasiparticles*.

The superfluidity of liquid ^{3}He was discovered by Osheroff et al 30 years ago. Its surface properties have never been studied, because suitable experimental means were not available. Our study has established the utility of the surface electrons for understanding the surface properties of liquid ^{3}He.

We have conducted measurements of electron mobility on both liquid ^{3}He, and ^{4}He, a boson isotope, under various experimental conditions, in particular, for temperatures spanning four orders of magnitude from 1 Kelvin down to 200 microKelvin. The mobility measurement is a simple method, but it has provided a great deal of important information on electronic and surface properties.

The mobility shows a peculiar temperature dependence (figure 2). The most important is that mobility of the Wigner crystal is determined by the scattering of ^{3}He quasiparticles to the surface dimples. Below 930 microKelvin (the superfluid transition temperature of ^{3}He) the mobility greatly increases, obeying the Arrhenius law. This behavior is explained by the scattering of quasiparticles, which are thermally excited over the superfluid energy gap, and hit the corrugated surface in a ballistic way. This interpretation has been confirmed for the two different superfluid phases, the B phase, which possess an isotropic energy gap, and the A phase, in which the energy gap is highly anisotropic.

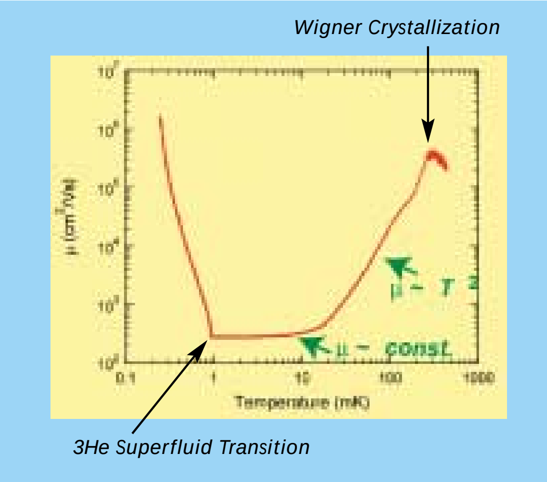


Figure 2: The electron mobility shows a peculiar temperature dependence

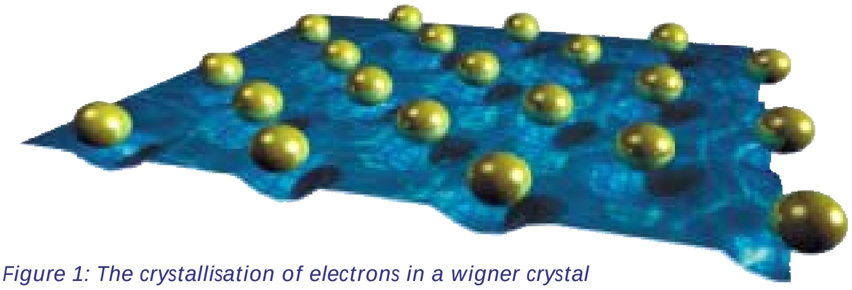


Figure 1: The crystallisation of electrons in a wigner crystal structure at the surface of the 3He superfluid

Novel physics in quasiparticle dynamics

Our study shows that the Wigner crystal and the dimples are sensitive to the quasiparticles of liquid ^{3}He. This fact enables us to study novel physics in quasiparticle dynamics and the gap structure of anisotropic superfluid, such as the Andreev type quasiparticle reflection. It also enables us to study quasiparticle states bound to the surface, and novel surface collective oscillation called surface zero sound.

Another intriguing property is nonlinear (nonohmic) electron transport, which appears only in the Wigner crystal state. We attribute the nonlinearity to the complicated collective dynamics both of the crystal and surface dimples. Above a certain driving force, the dimples may not follow the crystal motion, and this results in the collective sliding of the electrons out of the dimples. The Wigner crystal with surface dimples provides us with a model system exhibiting fascinating nonlinear electron transport phenomena.

In conclusion, the Wigner crystal on liquid helium acts as an excellent surface probe for quantum liquid He. The meeting point of the electrons and the helium is fertile, and it will produce a new interdisciplinary research field of ultralow temperature physics, low dimensional electron physics, and nonlinear physics.

*Contact: **K. Shirahama**,*
Department of Physics, Keio University,
Yokohama 223-8522, Japan
keiya@phys.keio.ac.jp

Sir Martin Wood Prize

The 2002 Sir Martin Wood Prize giving will take place on 30th October.

For further details on how to apply for the 2003 prize, please view: www.oxford-instruments.jp or www.msforum.jp/index.htm

The Prize consists of a ¥500,000 cash sum, and a certificate and gift awarded at a prize ceremony at the British Embassy. The prizewinner is also invited to lecture at British Universities.

Sponsored by Oxford Instruments Superconductivity, the Millennium Science Forum was launched in 1999 with the aim of motivating young scientists in the area of condensed matter science and to increase scientific dialogue between the UK and Japan. Each year it awards the Sir Martin Wood Prize to a young Japanese scientist performing outstanding research into Condensed Matter Science in Japan.

Multi-photon transitions between energy levels in a current biased Josephson tunnel junction

Research conducted by a team headed by Professor Alexey Ustinov and Dr Andreas Wallraff at the Physikalisches Institut III at the University of Erlangen-Nuremberg in Germany, is shedding light on quantum mechanics of macroscopic systems. Their study of superconducting devices may help to make use for computation the quantum phenomena, which are hindering the miniaturisation of conventional microchips. Superconducting junctions are now seen as the best candidates for replacing semiconductor transistors in future quantum computers.

Nanocomputers – hindered by quantum effects

Recent years have borne witness to the amazing growth rate in computer power. This rapid progress is mainly due to the continual miniaturisation of one of the most fundamental components of a computer, the transistor.

As the transistor size decreases, more can be integrated into a microchip to improve the computational power. This miniaturisation, however, is now approaching its limit. If microchips were smaller still, to a scale of tens of nanometres, their operation would be disrupted by the emergence of a variety of quantum phenomena. The tunnelling of electrons through barriers between wires occurs at this scale and the discreteness of the electrical charge represents a key problem.

To allow computational science to advance, an alternative to transistor technology must be found, where components function through quantum effects, rather than in spite of them.

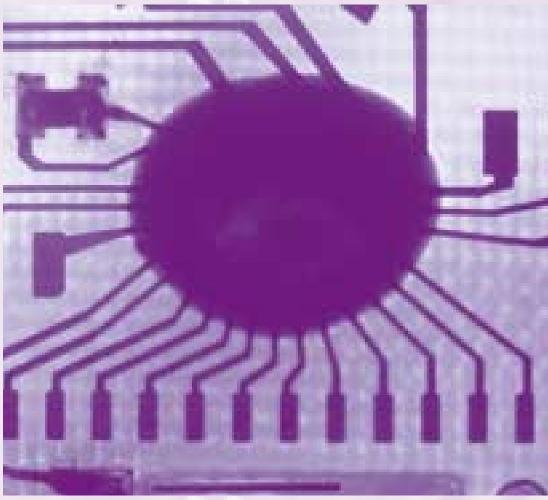
The researchers aims

Professor Ustinov and his team have tried to understand the quantum tunnelling effect for a macroscopic state using a superconducting Josephson junction. The team excited the junction with microwaves and measured the decay of its superconducting state in order to investigate the interplay between the single-photon and multi-photon transitions across the junction energy levels. Continuing these experiments with pulsed microwaves the team hopes to obtain information on phase decoherence – destruction of the coherence of a macroscopic quantum state – thought to be a major issue for quantum computing.

ULT a necessity

Macroscopic quantum tunnelling in a Josephson junction can only be observed below a cross-over temperature T*, which ranges for different junctions between 50 and 300mK. The experiments must be conducted at ultra low temperature (ULT), because, since only in the T<T* regime that quantum processes dominate over thermal fluctuations. To observe this macroscopic quantum tunnelling effect, the team used a Kelvinox™ 100 dilution refrigerator.

The dilution fridge was fitted with special electronic filters and attenuators mounted at the 1K-condensing stage. Low temperature performance, available space and the stability of the system allowed the team to perform this type of experiment. In addition, various rf filters at room temperature and at the 1K pot region are necessary to reduce external electromagnetic interference. In order to perform this experiment, cold dc magnetic shields, special wiring for dc lines (thermocoaxes and copper powder tubes) and several stages of cold attenuators in the microwave lines had to be mounted.



Conclusion - are excited electrons to blame?

In quantum information technology, coherent control of quantum bits (qubits) is required. As well as the qubits already demonstrated, for example, in ion-trap, cavity QED, and NMR experiments, several kinds of solid-state qubit implementations have been proposed for possible use in an integrated quantum circuit. The most promising have been so far Josephson junction circuits, which have been recently successfully tested by several groups as qubits in quantum information processing.

By exciting the Josephson junction state in a quantum well, through microwave frequencies 10 – 40 GHz, the Erlangen team have shown that single and multi-photon transitions were generated. This photonic absorption caused the current-biased junction to switch into a non-zero voltage state. These multi-photon transitions could be the additional cause of phase decoherence in microwave driven superconducting qubits. At the same time, they offer an opportunity to manipulate the quantum state of a qubit and hence the quantum information of the future quantum computer.

Contact: ***A. Usinov & A. Wallraff****,*
Physikalisaches Institut III, University of Erlangen-Nürenberg, Germany
wallraff@physik.uni-erlangen.de
ustinov@physik.uni-erlangen.de

Low temperature hyperpolarisation of xenon

Dr Neven Biškup's team at the Physics Department, University of Massachusetts, Amherst, USA, investigated brute force polarisation of xenon at high magnetic field and ultra low temperatures using an Oxford Instruments Superconductivity's dilution refrigerator, thermometer and temperature controller. Matter prepared with hyperpolarised nuclear spins such as ^{3}He and ^{129}Xe have important applications. This new method, significant in the field of physics, also has potential importance in medicine, for example, to polarise a broad range of contrast agents to improve resolution of MRI scanning techniques.

Background

An obstacle to brute-force polarisation of ^{129}Xe is the long spin-lattice relaxation time (T1), preventing bulk solid xenon from quickly reaching equilibrium polarisation. Surface nuclear spins in substances immersed in liquid ^{3}He, however, are rapidly relaxed by quantum tunnelling of ^{3}He atoms in the localised (solid-like) layer that forms near solid surfaces – a process that persists to arbitrarily low temperatures. The main constraints for this process is the need for a large surface area since quantum tunnelling polarisation transfer will appear only on the surface in direct contact with ^{3}He.

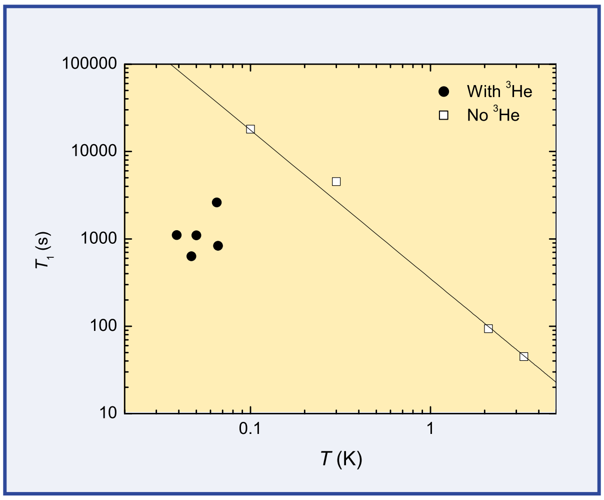


Figure 1: Spin lattice relaxation time T, measured for ^{129}Xe as a function of temperature and ^{3}He coverage

New solutions

Dr Biskup's team overcame this difficulty by plating xenon onto a silica gel substrate, with a very high specific surface area. A cell containing powdered silica gel with a sintered-silver heat exchanger, was cooled in a dilution refrigerator in an 8 Tesla NMR magnet. The silca gel was contained in an epoxy lower portion of the cell, extending into a small birdcage NMR resonator at 92 MHz, the Larmor frequency at 8T. The magnetic field could also be reduced to measure the ^{3}He NMR signal at the same frequency. ^{3}He liquid levels were monitored using a vibrating wire viscometer at the top of the cell.

Xenon was introduced using a heated fill line maintained at 90K. The volume condensed was typically 20% of the available pore space – corresponding to around three atomic layers on the silica surface.

Small angle tipping pulses, after either a magnetisation-inverting π pulse or a magnetisation-destroying comb of large angle pulses, was used to measure the spin-lattice relaxation of ^{129}Xe. Magnetisation was sampled from 0.1 – 40,000 s ensuring the inclusion of rapidly or slowly relaxing spin populations.

Findings

Addition of ^{3}He to the cell shortens T1 and changes the recovery curve from a stretched exponential, typically due to a wide distribution of T1 values for individual ^{129}Xe spins, to a simple exponential.

In the absence of ^{3}He, T1 is strongly temperature dependent. The mechanism of relaxation without ^{3}He is not known, although it may reflect interactions with the silica surface and/or adsorbed impurities. When ^{3}He is added to the cell, the relaxation time reduces to a temperature-independent value t1 ~1000 s (Figure 1).

Conclusion

Solid xenon can be brute-force polarised at dilution refrigerator temperatures using a ^{3}He-porous substrate method. Before becoming a practical method for the production of hyperpolarised ^{129}Xe gas, further obstacles need to be overcome. It may be necessary, for example, to switch off the relaxation process before removing the xenon sample to low B/T conditions. Addition of ^{4}He to the cell could provide such a switch, as ^{4}He preferentially occupies sites next to solid surfaces. Importantly, spreading of ^{4}He over the xenon surface occurs by superfluid film flow. Like the tunnelling process used to induce relaxation, this is a quantum process that proceeds at arbitrarily low temperatures.

*Contact: **N. Biškup**,*
Physics Department, University of Massachusetts, USA
biskup@ma.oxinst.com

Magneto µ-photoluminescence of Single self-assembled InGaAs Quantum Dots

Progress in semiconductor growth and fabrication has been accompanied by a steady shift of interest towards nanostructures with progressively reduced dimensionality. The fundamental limit of this progression has been reached with the development of fabrication techniques for zero-dimensional (0D) semiconductor heterostructures. These have unique optical and electronic properties, arising from the *complete* quantum mechanical confinement of the motion of the charge carriers (electrons - e and holes - h). Such 0D nanostructures termed quantum dots (QDs) can be considered the man-made analogue of atoms in the solid state. Their unique properties may enable a new generation of optoelectronic devices.

We are investigating the fundamental optoelectronic properties of self-assembled In(Ga)As-(Al)GaAs QDs using photoluminescence spectroscopy (PL). This technique is powerful when applied to the study of higher dimensional nanostructures such as quantum wells. However, as a consequence of their formation process, self-assembled quantum dots suffer from weak dot-dot fluctuations in size and composition that result in each dot absorbing and emitting light at a slightly different energy. This property complicates interpretation of conventional optical measurements since hundreds of thousands of QDs are probed simultaneously masking their true “atom-like” properties. This problem can be completely circumvented by investigating *single* quantum dots; a task that is complicated by the high areal density of QDs ($\sim 5.10^{10}$cm^{-2}). Single dot spectroscopy requires the development of sophisticated spectroscopic techniques that have extremely high spatial and spectral resolution. We have developed a low temperature microscope facilitating the study of individual QDs and allows access to a rich spectrum of the novel physical phenomena that occurs in these incredible systems.

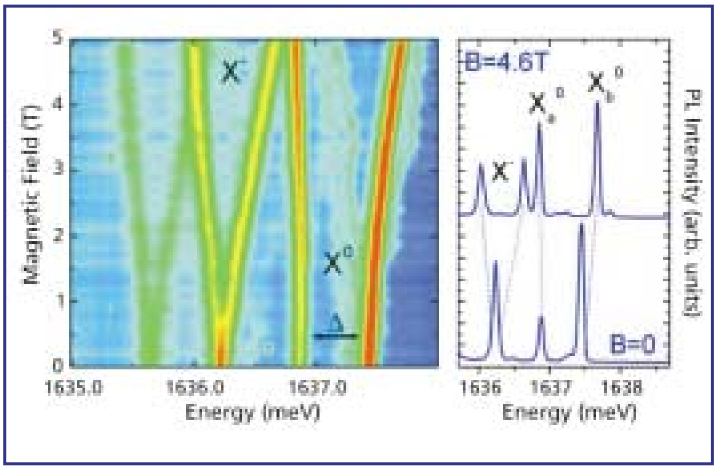


Figure 1 – Left: False colour image depicting magnetic field dependence of the photoluminescence spectrum from charge neutral (X^0) and negatively charged exciton (X^-) in a single asymmetric InAs-AlGaAs quantum dot. Right: PL spectra showing charge neutral and negatively charged exciton.

One example concerns the fine structure of the exciton, a correlated state consisting of a single electron (e) and hole (h). Normally, two flavours of exciton are possible: one comprising a spin up-electron and spin-down hole (↑e+↓h) and the second in which the spins of the electron and hole are inverted (↑e+↓h). In systems that possess cylindrical symmetry (i.e. when the shape of the QD is like a disc), these two excitons have exactly the same energy, i.e. are degenerate. When the shape of the QD becomes asymmetric, this degeneracy is removed due to the spin-spin exchange interaction between the electron and hole. In this case, the PL spectrum of a single exciton is expected to consist of *two* linearly polarised lines.

Figure 1 shows such a spectrum consisting of a linearly polarised doublet (X^0) as a function of magnetic field B=0-5T. At B=0, the two linearly polarised lines (X_a and X_b) are split by Δ~0.8meV, reflecting the extremely strong electron-hole exchange interaction strength in these QDs and the splitting increases with B due to the interaction of the spins with the magnetic field (Zeeman effect). Also evident is the negatively charged exciton (X-=2e+1h) in which the doublet fine structure at B=0 has vanished. This occurs since X- has two electrons, and in the ground state the electron spins “pair-up” forming a zero net electron spin state (e.g. ↓e↑e+↑h). The e-h exchange interaction vanishes completely and the two distinct (X^-) states are only revealed by the magnetic field (X_a^-, X_b^-).

Experiments are underway to investigate the possibilities to coherently control the spin and carrier population of the QD over a ps timescale. Such experiments are aimed at using the QD as a QBIT, the basic element in a quantum computer. When achieved, such complete coherent control of the QD quantum state using fast optical pulses may open up new possibilities to create optoelectronic devices that have true quantum functionality.

Contact: ***J. Finley, D. Mowbray, R. Oulton and M. Skolnick,***
Department of Physics and Astronomy, The University of Sheffield, Sheffield, S3 7RH, U.K.
jonathon.finley@wsi.tu-muenchen.de

Unravelling superconducting gap structure by low temperature STM

Dr Hermann Suderow and co-workers in the group headed by Prof. S. Viera at the Autonomous University of Madrid, Low Temperature Laboratory, are combining low temperature techniques with STM / STS (scanning tunnelling microscopy and spectroscopy) to study superconductivity at the surface of metallic compounds.

ULT as an enabling technology

The team employs Oxford Instruments Superconductivity's ultra low temperature (ULT) ^{3}He systems (HelioxVL) with dilution refrigerators (Kelvinox™ and home built dilution refrigerators) to cool their STM measuring device. To ensure the cooling of the experimental set up as well as the compound under study at temperatures below 1K, two very similar STM designs have been employed. One used a ^{3}He insert manufactured by Oxford Instruments Superconductivity, and the other used a lab-built dilution refrigerator. Several sample and STM tip preparation methods were also investigated and developed by the team. They explored very promising STM heads with superconducting tips. The superconducting tips enhance the overall sensitivity of STM detection. This high-energy resolution can, however, only be achieved when the system is cooled to the lowest temperature. Measurements are made by approaching the tip (of a normal, Pt-Ir or Au, or a superconducting, Pb or Al, material) into the vicinity of a superconducting sample. The differential conductance dI/dV is then measured as a function of the bias voltage V in different positions of the tip over the sample.

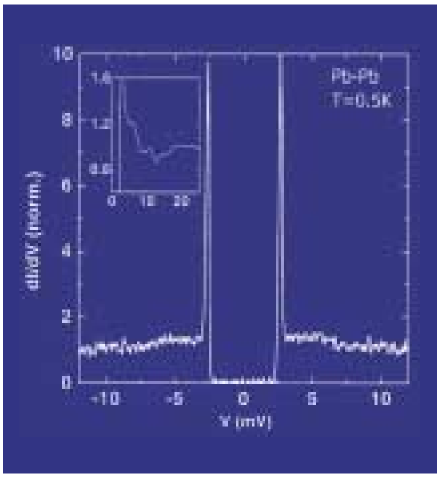


Figure 1: Two pronounced symmetric signals represents the peaks of quasiparticles

STM steps-up superconductivity studies

A review article by the team, published in Physica C[1] this year, presented interesting new experimental STM techniques. The enhancement of spectral resolution through the use of superconducting tips on the STM (rather than normal tips) was particularly striking and opens fascinating unexplored avenues in the study of superconductivity.

STM and surface scanning microscopy have been acknowledged as powerful investigative techniques offering potential in studying the physics of superconducting vortices. These techniques provide a means of studying the form of the superconducting energy gap and the properties of the electronic density of states at the atomic level.

The authors reviewed recent advances in very low temperature scanning microscopy in superconductors and profiled latest developments allowing high resolution measurement on superconductors. The researchers presented results on the newly discovered magnesium di-boride (MgB_2) superconductors and the borocarbide material $TmNi_2B_2C$. Magnesium di-boride is cheap to use to use and can be produced as filament wires. Researchers have found that the current flow through the new superconductor is not compromised by leaps made between separate grains in the compacted powder normally used to make wires. The borocarbide materials have the general formula RNi_2B_2C where R is a rare earth such as Lu, Y, Tm or Er. In borocarbide materials the interaction or competition of superconductivity with magnetic excitations makes very rich phase diagrams in an accessible temperature range (T_c between 6 and 16 K).

Tunnel exploration – Dr Suderow's findings

Using STM/STS with superconducting tips opens many new possibilities. For instance, interesting experiments can be made in one of the most prominent families of strongly correlated electron materials, heavy fermions, where several unconventional p-wave superconductivity modes have been unravelled. Their superconducting temperatures are, however, very low and significant experimental development at these low temperatures is necessary. The main attraction of using superconducting tips with STM/STS is to allow direct microscopic probing of the superconducting gap structure. This technique allows researchers to study the structure and the characteristic energy of the superconducting gap, D. For example, experiments in the new MgB_2 superconductor (T_c = 40K) the value of the superconducting gap is about one third of the expected value, based on estimations from BCS theory. This was possibly due to the presence of two different gaps.

STM spectroscopy allows a study of the local density of states at the atomic level. However the signal observed with STM is the convolution of the density of state value and the temperature of the system. At too high a temperature the signal becomes 'smeared' and the resolution is lost. Hence, ULT experimental equipment is required. An example is given in Dr Suderow *et al*.'s paper Physica C where a superconducting tip is used to study a lead (Pb) sample. At such a low temperature of 0.5K the two pronounced symmetric signals represent the peaks of quasiparticules and the gap in the middle of the graph is the superposition of the two superconducting gaps, (Figure 1).

Low temperatures, high impact

Dr Suderow and his team have presented very promising results using very low temperature STM spectroscopy. Preliminary results with Pb and Al have demonstrated the feasibility of tunnelling using a superconducting tip. This technique would enhance the resolution at the atomic level and would allow researchers to probe even deeper and with more insight into the structure of any superconducting gaps. These methods could open doors in the fundamental investigation of unconventional superconductors (heavy fermions such as UPt3) and a more thorough understanding of new superconductors properties (such as single crystalline MgB_2 and new borocarbides).

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Contact: ***H. Suderow**,*
Low Temperature Laboratory,
Autonomous Univbersity of
Madrid, Spain
herman.suderow@uam.es

Editor's column:

Your Problems: Your solutions

Welcome! "Your Problems:Your Solutions" will be highlighting the issues that face researchers today. If you have any comments or topics for discussion, please contact me at: vladimir.mikheev@oxinst.co.uk

V. Mikh

Vladimir Mikheev

About the editor:

Vladimir Mikheev, Consultant Engineer, Technical Development, Oxford Instruments Superconductivity was formerly a scientist in the Ukraine (FTINT, Kharkov). He is Professor of Physics in the field of Solid State Physics at ultra low temperatures. Vladimir Mikheev joined Oxford Instruments Superconductivity in1994, and has developed a number of ultra low temperature refrigerators. These include ^{3}He Heliox refrigerators, the KelvinoxAST dilution refrigerator and a ^{3}He refrigerator for scanning tunnelling microscopy (STM), which can travel within an ultra high vacuum environment.

PED Compliance

Thousands of pressure equipment products are now subject to new safety standards as a result of the European Pressure Equipment Directive 97/23/EC. Replacing product specific national rules, it applies to the design, manufacture and conformity assessment of pressure equipment and assemblies with a maximum allowable pressure of 0.5 bar or greater.

Products meeting these new standards can be sold throughout the European Union, the European Economic Arena, and EU candidate countries, which have transposed the directive into their national laws. This, argues the EU, will give manufacturers of pressure equipment easier access to the single market.

For more information on PED, view www.ped.eurodyn.com

Please write in with any comments or queries you may have on the directive.

ULT - new scope for research

It is a testament to man's ingenuity that the lowest temperatures on Earth are man-made – and can be found within Physics laboratories. Researchers are continually striving to push the limits of low temperatures in creating new research environments. We have, in this issue for example, featured the work of Suderow *et al* where low temperatures were vital in obtaining high resolution STM results.

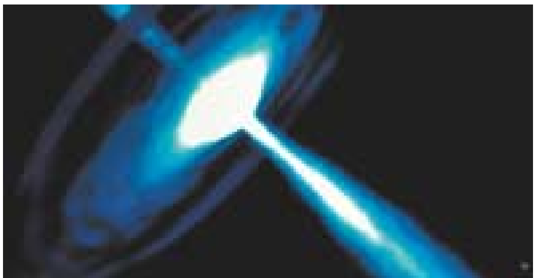
In addition, the work of Professor Fischer and his team at Geneva University provides a further example of achieving such STM results.

We can currently achieve temperatures in the milliKelvin range for practical use – and in some special cases microKelvin temperatures are possible.

So how low can we go? What are your applications? What novel low temperature research techniques are being developed?

Your problems: Your solutions - We look forward to hearing your views

Contact: vladimir.mikheev@oxinst.co.uk



Dark matter - the mystery of missing mass

Dark matter is thought to make up around 30 to 90% of the Universe. It does not emit electromagnetic radiation - so cannot be seen, but we know it exists. Theoretical predictions, and some observational evidence, on the mass of the Universe show that it is far larger than can be predicted from the visible Universe.

The amount of dark matter in is key to understanding the ultimate fate of the Universe. If the density of the Universe is below a critical value, the gravitational attraction between its parts will be unable to hold the Universe together and it will continue to expand. If, however, the mass exceeds the critical value, the initial “big bang” could reverse in a “big crunch”.

The composition of dark matter is uncertain. It includes objects that are known as MACHOs - massive (astronomical) compact halo objects - and includes baryonic matter such as dead or unborn starts, and black holes. However, most dark matter is now believed to be non-baryonic, an example of which, the axion, was proposed around 20 years ago. Each axion is thought to weigh just a few microelectron volts and there are thought to be as many as 106/cc. All attempts to visualise axioms have so far failed.

Dr Seishi Matsuki of Kyoto University is developing a new, highly sensitive way to detect axions using the Primakoff process. Here, axions are converted into microwave photons in a resonant cavity permeated by a strong magnetic field. Photons produced by this process can then be detected with Rydberg atoms. Dr Matsuki and his team have constructed an axion research system (CARRACK), incorporating an Oxford Instruments Superconductivity 7 T magnet with a 500 mm bore and a dilution refrigerator. The cryostat has optical and atomic beam access ports at the base beneath the magnet to prepare and utilize the Rydberg atoms. The group's research is now concentrating on detecting axions with masses of around 6 to 15 meV.

For more information, please contact:
Institute for Chemical Research, Kyoto University
matsuki@carrack.kuicr.kyoto-u.ac.jp

In Brief

Microgravity on Earth

Magnetic levitation is providing scientists with microgravity environments on Earth – conditions only previously possible in space. A collaboration between the University of Nottingham and Oxford Instruments Superconductivity has succeeded in levitating objects as diverse as water, flowers, tomatoes and pickled onions. Levitation can be sustained, giving scientists the chance to understand the effects of gravity, or the lack of it, for long periods of time.

The principle exploits diagmagnetism. This is induced by a magnetic field and since the magnet field acts on all electrons – it acts on all materials.

Researchers at Nottingham’s Department of Physics and Astronomy have levitated many objects inside a magnetic cylinder using Oxford Instruments Superconductivity’s minimum condensed volume (MVC) 16 Tesla magnet. To levitate a human being would require a much larger bore magnet of similar field strength.

Controlled gravity environments simulate weightlessness for materials and systems, and even people, destined to go into space – without the expense of launching a rocket.

For more information, please contact:
School of Physics and Astronomy, Nottingham University
physics-enquiries@nottingham.ac.uk

Winners of the Fritz Award

Prizes for the Fritz London Memorial Award will be presented at the 23rd International Conference (LT23) on Low Temperature Physics, Hiroshima, Japan. Oxford Instruments Superconductivity, sponsors, congratulates the winners who are being recognised for outstanding contributions to low temperature physics. They are:

- **Prof. Russell J. Donnelly** (University of Oregan, USA), for his contribution to low temperature fluid dynamics;
- **Prof. Allen M. Goldman** (University of Minnesota, USA), for his contribution to the physics of superconductors;
- **Prof. Walter N. Hardy** (University of British Columbia, Canada), for contributions in atomic and solid hydrogens.

Presented every three years, the Award is supported by Oxford Instruments Superconductivity and endowments administered at Duke University from the late John Bardeen, Horst Meyer, and the organising committee of LT23 and LT22.

Oxford Instruments Superconductivity

UK
Tubney Woods, Abingdon
Oxfordshire OX13 5QX
Tel: +44 (0)1865 393 311
Fax: +44 (0)1865 393 333

Germany
Otto-von Guericke Ring 10
D-65205 Wiesbaden
Tel: +49 6122 937 171
Fax: +49 6122 937 175

Italy
Via Leone Tolstoi 86
20098 San Giuliano
Milanese
Milan
Tel: +39 02 98 2531
Fax: +39 02 98 24407

Japan
Haseman Building
2-11-6 Tomioka, Koto-ku
Tokyo 135-0047
Tel: +81 03 5245 3261
Fax: +81 03 5245 4472

Spain
Avda Mata Piñonera, 2
28700 San Sebastian de los Reyes
Madrid
Tel: +34 91 659 0740
Fax: +34 91 654 6794

U.S.A.
130A Baker Ave. Ext.
Concord, MA 01742-2121
Tel: +1 978 369 9933
Fax: +1 978 369 6616

E-mail:
superconductivity@oxinst.co.uk

Visit our web site at
www.oxford-instruments.com

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