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UNIGE and BioSpin Build 25 T Superconducting Magnet

Physicists from the University of Geneva (UNIGE) and an R&D team from Bruker BioSpin have successfully developed and tested a superconducting coil that reached a magnetic field of 25 T, the highest magnetic field reached with a superconducting magnet at a European academic facility. Their work is a significant step towards developing important commercial ultra high field NMR products. The research was partially funded by the Swiss National Science Foundation (SNSF).

NMR magnets that are currently available, including those manufactured by Bruker BioSpin, are capable of producing magnetic fields of up to 23.5 T. This limit is related to the physical properties of LTS materials used to generate the magnetic field. However, a number of research fields, especially biomedical research, would benefit from stronger magnets with the capability of producing better resolutions of molecular structures.

HTS Insert Coil Increases Field by 4 T

UNIGE and Bruker BioSpin established their collaboration in 2012 with the goal of reaching a European record for magnetic field intensity of 25 T using HTS materials. To create this higher field, they combined a Bruker lab outsert magnet producing a 21 T magnetic field, which was already installed at UNIGE, with a superconducting insert coil that increased the field by an additional 4 T, bringing the combihned field to well beyond the 23.5 T previously reached.

"The outsert is a NbTi-Nb_3Sn magnet developed in the frame of a previous Bruker-UNIGE collaboration," commented Professor Carmine Senatore of UNIGE. "It generates magnetic fields of up to 19 T at 4.2 K and up to 21 T if sub-cooled to 2.2 K."

REBCO ($REBa_2Cu_3O_{7-x}$) coated conductors are used in the superconducting insert coil, which must be cooled with liquid helium to 4.2 K. In these conductors, a thin steel tape is covered with a 1 µm-thick layer of superconductor, which is then wound onto a cylindrical support to build the coil. The coil uses 140 meters of 3 mm-wide tape.

SuperPower REBCO Tape Used

"We are exploiting the high field potential of HTS that is realized only at very low temperatures," Senatore said. "The conductor chosen for the insert was a commercial REBCO tape from SuperPower. The selection of the tape was made taking into account not only the

electrical performance, but also the electromechanical and thermophysical tolerances compatible with the operating conditions of our insert."

In the preliminary design phase, the team studied and tested many types of commercially available superconducting tapes in order to understand and control their electrical, magnetic, mechanical, and thermal properties. They sought to find a superconductor that could carry high currents without dissipation, endure the winding process without degradation, and withstand the magnetically generated mechanical stresses.

"We studied REBCO coated conductors," Senatore noted. "We tested material from AMSC, BEST, Fujikura Ltd., SuNAM Co. Ltd., SuperOx ZAO, and SuperPower Inc."

The 25 T coil will remain at UNIGE for basic and fundamental research uses. Although it is not a commercial product, the technology developed for its design and manufacture suggests a path forward for creating NMR systems with commercial applications.

"It is the intention of UNIGE and Bruker BioSpin to continue this partnership," Seantore said. "The coil developed within this collaboration is still far from a typical NMR magnet. However, the successful test of the 25 T coil represents a positive test-bench of ideas that are being developed for next-generation HTS-based NMR magnets." ❍

Mitsubishi Electric-led Team Builds and Tests Compact HTS MRI Scanner

Mitsubishi Electric Corporation, working with Kyoto University and Tohoku University, has announced the development of a compact 3 T HTS MRI scanner that can be cooled using liquid nitrogen. Researchers used the new system to successfully image a 25 mm mouse fetus under a 3 T magnetic field, the first time HTS coils have been used for MRI imaging. The work was carried out under the Japanese Ministry of Economy, Trade, and Industry (METI) and Japan Agency for Medical R&D (AMED) project "Fundamental Technology Development for HTS Coils," which seeks to incorporate HTS coil technology into various electrical instruments.

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Publisher: Klaus Neumann

Executive Editor: Klaus Neumann
Staff Writer: Doug Neumann

Editorial Contact: editor@superconductorweek.com

Customer Service: service@superconductorweek.com
tel +31-614-056-532

Superconductor Week
P.O. Box 86345
Portland, OR 97286 USA

www.superconductorweek.com/cms

Existing commercially available MRIs use LTS wires with a round or square cross section of 2 to 3 mm. In contrast, HTS wire is commonly about 0.2 mm thick and 4 to 5 mm wide and is wound several hundred times to create a pancake coil. Small discrepancies in the thickness and width of the wire give the coil an uneven height that can disrupt the magnetic field and distort imaging.

Mitsubishi Achieves Winding Accuracy of 0.1 mm

Mitsubishi Electric achieved such a strong, stable 3 T magnetic field by increasing the precision of the coil winding. The company solved the problem of discrepancies in thickness by using laser displacement meters to measure the coil height and then adjusting it with correction sheets. This process realized a winding accuracy of 0.1 mm for pancake coils with an outer diameter of about 400 mm, thereby achieving the magnetic field homogeneity usually considered necessary for commercial imaging.

The small model has an imaging space 25 mm in diameter with a field homogeneity of less than two-millionths, the same level required for a 230-mm diameter by 650 mm cylinder in a commercial-size MRI. Mitsubishi Electric used YBCO wire wrapped in copper leaf foil manufactured by Fujikura, Ltd. for the superconducting coils.

Team Plans to Construct Half-size MRI Scanner

In carrying out the work, Tohoku University measured and estimated how to reduce magnetic field turbulence through magnetization. Kyoto University developed the imaging system for the device and conducted research and analysis on reducing magnetic field turbulence. Mitsubishi Electric designed and manufactured the HTS coils, as well as carrying out the MRI imaging

The collaborators plan to increase the size of the system to a half-size MRI scanner by 2020 and to commercialize a full-size version in 2021. Mitsubishi Electric noted that a key challenge to scaling the technology is incorporating the winding technique used for the small model so as to avoid degrading the superconducting performance. ❍

Houston Creates TFM Fields in Contradiction to CSM Theory

Physicists at the University of Houston (UH) have created full strength trapped field magnets (TFMs) in a superconductor with a pulse field of only 1.0 times the TFM force (http://dx.doi.org/10.1063/1.4945018). The finding is not consistent with long accepted theory, suggesting that TFMs might potentially be used to develop more efficient and powerful devices.

"There are a huge array of applications which require magnets," commented UH Professor Roy Weinstein. "Because superconducting magnets must be cooled below T_c, there is an 'overhead' in any HTS application due to the cost of cooling. This results in superconducting magnets being used mainly for large applications, and for applications in which ultra-high fields are essential, such as ship motors, municipal pumping stations, magnetic separators, blood component separators, transportation, and wind-tower generators."

"The use of TFMs in motors has been limited due to the difficulty of activating them. We started a review of the activation process in 2009, and it continues today. The major difficulty has been the need to generate a very large pulse of magnetic field."

CSM Theory Suggests High Pulse Necessary for TFM

More than 50 years ago C.P. Bean, a scientist at General Electric, developed a theoretical model known as the Bean Model or Critical State Model (CSM) that explains how a magnetic field could be applied to a superconductor using a pulse field

magnet after the material is cooled. The CSM predicts, and later experiments confirmed, that in order to push as much magnetic field as possible into a superconductor the pulsed field must be at least twice, and more typically over 3.2 times, as strong. The magnetized superconductor then becomes a TFM, effectively a permanent magnet.

The CSM severely restricted the utility of TFMs. Producing a pulse field of more than 12 T is expensive and difficult, which limits TFMs that can be employed in applications to a maximum of 3.75 T.

The performance of a device based on magnets improves as the strength of the magnet increases, up to the square of the increase. If a TFM field within a device were 12 T instead of 3.75 T, the device's performance could range from 3.2 to 10.2 times better, which could lead to more efficient or powerful devices. Many potential applications could benefit, especially MRI and NMR equipment.

This low maximum magnetic strength has made TFMs impractical for many types of magnets. Instead, most superconducting magnets are electromagnets made from wrapping coils of superconducting wire to produce extremely high, variable magnetic fields. However, these electromagnets suffer from a major drawback, the high cost of superconducting wire.

CSM Internally Inconsistent due to Flux Creep

The Houston researchers investigated minor problems that had been discovered with the CSM shortly after it was published by applying pulsed-zero field cool magnetization to bulk YBCO. They determined that Bean's model was inaccurate for certain constraints on a magnetic pulse, since a significantly different spatial distribution of field occurred. Where Bean's model predicted a steady, slow increase in field, the team observed sudden, great increases instead.

"The CSM predicts the position which the magnetic flux quanta will occupy during and after activation," Weinstein said. "However, 'flux creep' occurs upon activation, and the fluxoids can move.

"The effect of the movement is very low. Nevertheless, the existence of this movement makes CSM internally inconsistent, even if only by a small amount. We planned a more complete study of flux-pumping, multi-pulsing, and high-field effects to see if we could find a useful or basic hole in the CSM armor."

The sudden field increases were repeatable and controllable. Weinstein said that the team created a record TFM field of 10 T: "At that field, the TFM crystal cracked under magnetic pressure.

"Other groups in Japan, Germany, and the UK have worked to solve the cracking problem and have successfully trapped over 17 T. However, these achievements were all activated by a method called field cool, which is impractical for use in most applications. It is very expensive and requires a great expenditure of energy."

Team to try to Increase J_c by Lowering Temperature

The Houston researchers plan to tweak several variables to determine whether they can achieve better results. If they are able to gain funding, they should be able to complete a study of all known variables within a year, which will shed light on the underlying physics.

"We are studying the design variables to learn where the optimum is, how much the design parameters can be varied to accommodate the needs of various applications, and the nature of the exact physical process which leads to the giant flux leaps we observe," Weinstein commented. "We have already disproven our initial ideas.

"At the moment we want most to study lowering temperature in order to increase J_c. The ratio of pulse height needed to achieve a maximum trapped field, in our work, clearly

decreases as J_c increases. At 77 K in YBCO, the ratio has dropped to 1.0 for the highest J_c available to us.

"If J_c is increased by cooling, we want to know if the ratio goes below 1.0. This is physically allowed; it is magnetic flux that is conserved, not field. But this would certainly be an additional shock to find that activation can be a field multiplier." ❍

Grid Segment Powers AMSC Q4 Revenue Growth

AMSC has announced that Q4 FY2015 revenues grew by 9.5%, from $25.1 million in Q4 FY2014 to $27.5 million. Non-GAAP net loss fell from $6.4 million to $3.8 million. AMSC's share price declined by -6.5%, to $9.77 from $10.45 on the day of the earnings report.

For FY2015, AMSC revenues rose by 36.1% from $70.5 million to $96 million in FY2014. Non-GAAP net loss declined to $26.2 million compared to $39.6 million over the same period last year.

BASF Agreements Augmented Q4 Grid Segment Revenues

Q4 FY2015 revenues for the Gridtec segment rose by 85.4% to $7.6 million from $4.1 million in Q4 FY2014. These included $3.2 million recognized under AMSC's agreements with BASF (see *Superconductor Week*, Vol 30, No 3). Of this total, $3 million was received under the license agreement, which was paid and recognized in full in Q4 FY2015, and $200,000 was recognized under the joint development agreement.

"We were paid the first installment of $2 million under the joint development agreement in Q4 FY2015," commented CFO David Henry in the conference call. "The remainder of this payment was recorded as deferred revenue and will be recognized as revenue ratably through Q3 FY2016."

For FY2015, Gridtec revenues reached $27.1 million, 41.2% higher than $19.2 million reported over the same period last year. The operating loss was reduced by 44.8% to $14.8 million from $26.9 million. The revenue growth was primarily driven by higher non-superconducting D-VAR sales.

AMSC also reported an approximately $300,000 gain from the sale of its minority investment in Tres Amigas in the quarter. The total sale price is $650,000, with the remaining proceeds to be paid once certain financing conditions are met. The company has fully written off its investment in Tres Amigas (See *Superconductor Week*, Vol 29, No 7).

AMSC Developing Second Version of Ship Protection System

AMSC President and CEO Daniel McGahn provided an update during the earnings conference call on AMSC's work with the U.S. Navy on a superconducting ship protection system: "We believe the best near-term market opportunity is for the Navy to order an engineering change to a new ship being built with an existing design. We like this business because it has the potential to provide an annuity-like revenue stream once we are designed into a ship. To this end, we expect to deliver a beta version of the second ship protection system product to the U.S. Navy and begin qualification efforts during FY2016."

The CEO noted that the expected revenue from a small ship such as a littoral combat ship could be $3 million to $5 million, a medium ship such as a destroyer or an amphibious assault ship from $5 million to $15 million, and a large ship such as an aircraft carrier from $20 million to $25 million. In addition, use of ship protection systems in additional applications might add revenues of $5 million per ship.

Positive Operating Cash Flow for Quarter

Cash, cash equivalents, and restricted cash totaled $40.7 million at the end of the quarter, compared to $37.7 million reported at the end of

Q3 FY2015. AMSC reported positive free cash flow for the quarter for the first time since its problems with Sinovel emerged (see *Superconductor Week*, Vol 25, Nos 6 & 15).

"With respect to cash, collections have been strong thus far in Q1," Henry said. "As a result we expect to end Q1 with a balance of cash, cash equivalents and restricted cash greater than $35 million."

AMSC's 12-month backlog at the end of the quarter was approximately $89 million compared with $41 million at the end of FY2014. The increase was primarily due to a long-term supply agreement for the Wind segment completed with the Indian company Inox Wind during Q3 FY2015, as well as a stronger D-VAR backlog.

Company Projects Seasonally Lower Revenues in Q1 FY2016

McGahn highlighted four operation goals for AMSC in FY2016, two of which involve superconducting initiatives: "We aim to, one, complete a license agreement with Inox for a 3 MW wind turbine design; two, generate continued growth in our D-VAR business; three, complete the $3.7 million phase of our Resilient Electric Grid (REG) program with the Department of Homeland Security (DHS) and enable a decision on the program's next steps; four, deliver the beta version of a second Ship Protection System product and begin qualification efforts for this product with the U.S. Navy.

"Q1 FY2016 revenues will be negatively impacted by historical seasonality in our revenues from Inox, compounded by what has been described by Inox as a near-term working capital constraint," McGahn said. "Based on discussions with our customers, revenues in our Wind segment are currently expected to return to a more normal level in Q2."

For Q1 FY2016, AMSC expects that its revenues will be in the range of $12 million to $14 million. The company anticipates a net loss of less than $13 million.

Excluding unusual items, non-GAAP net loss is projected to be less than $12.5 million. Henry noted that cash flow is expected to approach neutral, resulting in a balance of cash, cash equivalents, and restricted cash at the end of Q4 FY2015 that is roughly the equivalent to the balance at the end of Q3 FY2015. ❍

OI Cuts Costs and Raises Profits

Oxford Instruments plc, (OI) has announced that aggregate revenues for FY2015/2016 fell by 3.8% to £361.6 million ($519.6 million) compared to £380.1 million ($546.2 million) in FY2014/2015. Adjusted operating profit rose by 4.2% to £44.6 million ($64.1 million), compared to £42.8 million ($61.5 million) the previous year.

The adjusted operating profit margin grew to 12.3%, reflecting OI's success in cutting costs. OI's share price rose by 3.8%, from £6.51 ($8.58) to £6.76 ($8.91), on the day of the announcement.

"Over the previous financial year our NanoTechnology Tools and Service sectors have both delivered improved profit performances against an uncertain macroeconomic background," commented Ian Barkshire, OI's recently appointed CEO. "In our Industrial Products sector, industrial analysis has shown improved performance as a result of management actions, despite challenging industrial end markets. However, our superconducting wire business has suffered from a structural change in the market, which has reduced demand from our MRI customers."

Orders in the year were £380.8 million ($546.6 million). NanoTechnology Tools orders grew by 4%, offsetting a decline of 3% in Industrial Products orders. At the end of its fiscal year, OI's backlog stood at £140.4 million ($201.8 million), 12.1% higher than the £125.2 million ($179.9 million) backlog the previous year.

MRI Pricing Pressures Continue

The revenues of the Industrial Products sector, which comprises the industrial analysis, magnetic resonance, and superconducting wire units, declined by 7.2%, to £96.6 million ($138.8 million) from £104.1 million ($149.6 million), in the first half of the previous year, or by 11.4% on an organic constant currency basis. Sector operating profit fell by 29.7% to £4.5 million ($6.5 million) from £6.4 million ($9.2 million).

"Our superconducting wire business...continues to be affected by the pricing pressures exerted on us by the MRI system manufacturers and the reduced demand for wire from our OEM customers," Barkshire said. "The effect of this reduced MRI pricing will be somewhat offset by signed contracts to supply Nb_3Sn conductor for the High Luminosity upgrade to the Large Hadron Collider project at CERN (see *Superconductor Week*, Vol 29, No 11)."

Improved Margins for Nanotechnology Tools

Revenues for the Nanotechnology Tools sector, which consists of OI's highest technology products primarily for research customers and includes superconducting magnet systems, declined by 11.3%, to £187.4 million ($303.5 million) from £211.2 million ($303.5 million), or by 2.5% on a constant currency basis. Operating profit rose by 2.9% to £21.3 million ($30.6 million) from £20.7 million ($29.7 million).

"We continue to see strong demand for our ultra low temperature systems in line with the growing interest in understanding the fundamentals of quantum science and the associated industrial applications," Barkshire noted. "Quantum sensors are receiving increased amounts of funding and have the potential to offer unparalleled speed and sensitivity to the measurement of electrical current, magnetic field, and even time. This can enable the development of platforms that can be applied in a wide range of situations from environmental sensing to medical imaging, such as sensitive brain scanning."

Prior to the earnings announcement, OI announced that Chairman Nigel Keen would retire after the company's annual general meeting on Sept. 13 after 17 years with the company. Alan Thomson has been appointed as a Non-executive Director and Chairman Designate. ❍

York Instruments Launches New MEG Device

The UK company York Instruments Ltd. has announced the development of a new magnetoencephalography (MEG) device that employs technology licensed from the University of York and Royal Holloway University of London. MEG is considered the world's most sensitive functional brain imaging device. The York MEG uses an improved sensor called a hybrid quantum interference device (HyQUID) that requires no cryogens and incorporates LTS technology.

The HyQUID is much more sensitive and has a lower noise floor than the traditional superconducting quantum interference device (SQUID) sensors that have been used in MEG systems to date. HyQUIDs are suitable for all applications where SQUIDs would be employed as sensors; however, they have substantially less low-frequency noise, allowing for recordings of slow wave activity for resting state studies. This makes them especially suitable for clinical applications where slow waves are symptomatic of underlying pathology.

Increased Sensitivity Muliplies Potential Uses for HyQUIDs

This increased sensitivity would allow the new MEG device to be more widely used than traditional MEGs, especially in the areas of traumatic brain injury and post-traumatic stress disorder. At the other end of the spectrum, ultra-

high frequency oscillations of very low amplitude would also be easily measurable. The company has cited Alzheimer's, epilepsy, and neuromodulation as fields that would especially benefit from HyQUID technology.

In addition, the HyQUID does not suffer from flux trapping. It can be operated in a wide range of background magnetic fields and is resistant to RF interference, allowing great versatility in siting a lab. In addition, it is also simple to fabricate and calibrate.

"The company intends to offer full featured research and clinical software using the latest tech," commented James Petite, President of York Instruments. "The electronics have been designed to be modular and keep noise levels to a minimum."

HyQUIDs Cooled with Helium-free Cooling System

The device's cooling system is a liquid helium-free technology developed in collaboration with Oxford Instruments. It uses a vibration tube to cool the LTS HyQUIDs without interference. This results in a system that is more compact, has lower operating costs, can be turned off and on in hours instead of over days, is potentially transportable, and can be installed in locations where it might be difficult to ensure a regular liquid helium supply.

York Instruments was established earlier this year and specializes in magnetic measurements and their healthcare applications. The company recently introduced the new MEG at both the American Clinical MEG Society Annual Conference and MEG UK 2016 Conference. The commercial launch will occur later this year, with pricing that will be based on a specific set of options and the configuration required by the customer. ❍

Google Develops Digital Tuning to Control Qubit Interactions

Researchers from Google, Inc., the University of the Basque Country, and the University of California at Santa Barbara have developed a prototype device that blends analog and digital approaches to control qubit interactions while avoiding decoherence due to random noise (doi:10.1038/nature17658). The system offers a novel approach towards building quantum computers that can be scaled to greater numbers of qubits. The work received partial funding from grants under the EU Seventh Framework Programs "Propagating Microwaves in Strongly Coupled Environments" (PROMISCE) and "Scalable Superconducting Processors for Entangled Quantum Information Technology" (ScaleQIT) projects.

Google has been involved in the research and development of quantum computing since 2011. In collaboration with NASA, the company established the Quantum Artificial Intelligence Lab (QuAIL) at NASA's Ames Research Center in 2013. Google obtained a 512-qubit D-Wave Two quantum computer created from D-Wave Systems the same year (see *Superconductor Week*, Vol 27, No 7).

In late 2014, Google hired the John Martinis research team from the University of California, Santa Barbara to develop hardware to transform quantum computing into a practical technology (see *Superconductor Week*, Vol 28, No 9). In September 2015, D-Wave reached an agreement with the QuAIL consortium for the installation of its 1152-qubit 2X system, along with a succession of future quantum computers, at the Ames site.

AQC Approach Difficult to Scale

D-Wave uses an analog approach in its quantum systems known as adiabatic quantum computing (AQC). AQC is a subclass of quantum annealing that involves the evolution of a simple Hamiltonian, an operator corresponding to the total energy of the system, into a final Hamiltonian that encodes the computational problem.

However, errors cannot be corrected using the AQC method as systematically as with digital circuits. This limitation introduces a scalability problem, since random noise generated by AQC causes more errors as the system increases in size.

Digital quantum computing is a complimentary approach, which enables the construction of arbitrary interactions and is compatible with error correction. It splits up a problem to be resolved in terms of quantum logic gates in a way that is similar to that of a conventional computer.

Qubit Interactions Controlled with Voltage and Current Pulses

The researchers overcame AQC's shortcomings by combining analog and digital approaches to error correction. They worked with a row of nine solid-state qubits made from strips of aluminium placed on a sapphire surface. The aluminium was cooled to 0.02 K, below its T_c of 1.2 K and where thermal fluctuations are well below the qubits' energy.

"Aluminium is a superconducting metal that lends itself well to use in qubits," said Google Researcher Rami Barends. "The materials-related losses are low, and Josephson junctions can be built easily using the native oxide as a tunnel barrier."

The scientists controlled the interactions between neighboring qubits with 1,000 logic gates that digitally steer the qubits into a state that encodes solutions to problems. They used short voltage and current pulses to tune the resonance frequency of each individual qubit to that of a neighboring one. By adjusting qubit frequencies towards or away from each other, they could start or end interactions.

"The logic qubits are elementary operations on the information in the qubits," Barends said. "Some consist of a single microwave pulse that swaps information inside a qubit, much like a classical NOT operation."

System Protected from Effects of Noise

This digital tuning approach could potentially serve as a general-purpose algorithm that could be scaled to a larger quantum computer. Each quantum bit and interaction added to a system can create additional noise which, without mitigation, puts a limit on scalability. But due to the system's compatibility with existing methods for quantum error correction, it can be protected from the effects of environmental noise.

"The number of logic gates relates to the algorithm," Barends said. "An algorithm can be implemented by combining many logic gates, much in the same way buildings are constructed by many bricks. The more gates, the more complicated the algorithm."

In their paper the research team suggested how their research would proceed: "We need to improve the superconducting quantum hardware. We hope that, in parallel with other academic and industry groups, we can improve the hardware and make headway with noise reducing decoupling techniques and reducing algorithmic complexity." ❍

Rice Investigates SC in 2D Boron

Theoretical physicists at Rice University have determined that 2D boron is an intrinsic LTS (DOI: 10.1021/acs.nanolett.6b00070). This characteristic might make 2D boron an attractive material for developing superconducting nanocircuits. Their study received financial support from the Office of Naval Research and the DOE's Office of Basic Energy Sciences.

2D boron had not been previously tested for superconductivity, although it has qualities that make it an attractive candidate. The material is relatively light, due to its small atomic mass, and is metallic in its 2D form.

"2D boron is the only existing monoelemental,

one-atom-thick metal," commented Rice Research Scientist Evgeni Penev. "Its' in-plane stiffness is high, about half that of graphene, but it is very flexible, with a bending rigidity that is just a fraction of graphene's. Graphene needs to be doped to induce metallicity; therefore superconductivity is not an intrinsic property of the material.

"Boron also has the advantage of being the lightest element among possible 2D materials with strong interatomic bonding. These properties are favorable for a material to have a higher T_c."

Two Labs Recently Synthesized 2D Boron

The discovery of MgB_2 as a high-T_c electron-phonon superconductor more than a decade ago hinted towards the potential of superconducting boron. Scientists agree that superconductivity in MgB_2 is due to the boron layer, with the magnesium serving to dope the material.

Until recently 2D boron, known as borophene, was only a hypothetical material. However, at about the same time that the Rice team released its paper two groups, one led by Argonne National Lab and the other by the Chinese Academy of Sciences, separately synthesized samples. The existence of these samples offers a means for experimentalists to test the theory proposed by the Rice scientists.

Polymorphs may allow Tuning of Boron's Conductivity

The Rice team calculated that 2D boron has a T_c in the range of 10 to 20 K. Boron atoms can make more than one pattern when coming together as a 2D material.

These patterns, known as polymorphs, may allow researchers to tune the material's conductivity. The researchers suggested that isolating 2D boron between layers of inert hexagonal boron nitride might help stabilize the material's superconductor phase.

"The interaction between electrons and lattice vibrations is affected by the arrangement of hexagonal holes in the underlying triangular B lattice," Penev said. "In this sense, tuning might be achieved by targeting the synthesis of specific polymorphs."

"Our calculations revealed really interesting features in the electronic structures of some of the 2D boron polymorphs, suggesting the existence of other non-trivial phenomena in this material. This is something that we may pursue in the future." ❍

Grenoble Fabricates Quantum Dot Electron Turnstile

Researchers from the University of Grenoble have developed a single quantum dot junction that serves as an electron turnstile between two superconductors, permitting only one electron through at a time (Phys. Rev. Lett. 116, 166801). The device could be used in quantum metrology applications and electronic analogues of quantum optics experiments. The work received funding from the EU Seventh Framework Program INFERNOS (FP7/2007- 2013), which seeks to establish quantitative thermodynamic constraints on the operation of quantum detectors, and the Nanosciences Foundation under the auspices of the Joseph Fourier University Foundation.

Controlling the flow of a current at the level of a single electron has been a key feature of applications ranging from nanoelectronics to electron optics. In electron optical systems, electrons typically travel in single file along a conductor due to the repulsive Coulomb force between the electrons.

"Superconductors are extremely useful for controlling energy selective tunneling processes," commented Grenoble researcher David van Zanten. "This is due to the superconducting quasi-particle spectrum, where the density of states goes from literally zero to infinite over an extremely narrow energy range at the gap edge. In aluminum, this range is less than 1 neV, which is

an incredibly sharp spectroscopic feature for a condensed matter system."

Unwanted Electrons Cause Increased Error Rate in SINIS Turnstiles

Scientists commonly use superconducting single-electron transistor (SINIS) turnstiles for this type of electron tunneling. SINIS turnstiles contain a metallic region connected to two superconducting leads via insulating tunnel junctions.

In a SINIS turnstile, researchers control electron tunnelling by varying the voltage that permits an electron to tunnel first into the metallic region and then onward to the superconductor. The Coulomb force should ensure that the electrons flow in single file. The gaps in the electron energy distribution of superconductors help to limit tunneling, but the continuum of energy levels in the metal allows unwanted electrons to slip through, which increases the error rate of SINIS junctions.

"Since SINIS turnstiles can be made using conventional techniques, the yield is orders of magnitude larger, which makes them much more suitable for scaling and hence for metrological applications," van Zanten noted. "The dimensions of the island in SINIS devices are much larger, and it can easily be coupled to other devices. With a single level turnstile device, these two issues remain an open challenge."

Electromigration used to Create SQS Junctions

The Grenoble device, a superconductor-quantum-dot-superconductor (SQS) turnstile, is the first where electrons at only a single quantum level are able to transit. The dot's quantum energy states are widely spaced, so that electrons only occupy the dot's ground level.

The researchers fabricated the SQS junctions by using electromigration to insert nanometer-sized fractures in superconducting constrictions. They randomly dispersed gold nanoparticles of about 5 nm diameter to bridge the fractures, serving as the quantum-dot junctions.

"These devices are extremely difficult to make; having a quantum dot fall into the junction is a totally random process, much more than with SINIS," van Zanten noted. "This is why, without another breakthrough in the fabrication yield, our turnstiles might remain scientists' toys rather than metrologist devices.

"Electromigration is a statistical process which is not well suited for scaling. However, one could also fabricate a quantum dot turnstile using a semiconducting quantum dot, provided that it is tunnel-coupled to superconducting leads with a hard-gapped density of states. But this last point turns out to be very difficult, although researchers in Copenhagen and Helsinki are making progress."

Error Rate Below 1% Realized

The team observed a steady stream of electrons shuffle through the SQS turnstile, all at the same fixed energy. The rate of error was less than 1%, indicating that additional electrons were not squeezing through the dot.

Van Zanten outlined the team's future course of work: "Until now, we can only operate our devices as a turnstile; the electrons go in the direction of applied bias. Calculations show that the devices can also be operated as a true electron pump in which the electrons are being transported against the applied bias.

"Also, we are optimizing the design of the devices to withstand higher magnetic fields, such that we can lift the spin-degeneracy without deteriorating the turnstile operation. Under these conditions the turnstile devices will become spin-selective resulting in a single spin current." ❍

TIT Induces SC in FeSe Via

Electrostatic Carrier Doping

Researchers at the Tokyo Institute of Technology (TIT) have employed electrostatic carrier doping to realize superconductivity in an iron selenide (FeSe) thin epitaxial film. The findings suggest a novel means for investigating superconductivity in a material exhibiting insulator-like behavior without using chemical doping. The research received financial support from Japan's Ministry of Education, Culture, Sports, Science, and Technology (MEXT) through the Element Strategy Initiative to Form Core Research Center.

"Our strategy was inspired by the superconductivity in high-T_c cuprates; that is, an insulating parent phase with strong electron correlation should exhibit HTS if high-density carriers are successfully doped," commented Professor Hidenori Hiramatsu of TIT. "We focused on very thin FeSe epitaxial films that exhibit an insulator-like behavior even though bulk FeSe is a superconductor with a T_c of ~8 K.

"High-density carrier doping using an electric double-layer transistor (EDLT) suppresses charge and magnetic ordering, which is related to the strong electron correlation. However, we have not observed clear experimental evidence for the ordering at present."

EDLT Avoids Structural and Carrier Transport Degredation

Strong electron correlation in an insulating parent phase is believed to enhance the T_c of a superconductor in a doped phase due to a strengthening of the binding energy of Cooper pairs. Impurity doping is the most common means of inducing superconductivity in the insulating phase.

However, conventional carrier doping, such as chemical substitution, can degrade the structure of the material and carrier transport. An EDLT with an ionic liquid gate insulator offers a method to avoid these drawbacks. Although researchers have achieved direct induction of superconductivity from an insulating phase experimenting with EDLTs using the iron-based insulator $T_1Fe_{1.6}Se_2$ and single crystals of (Li,Fe)OHFeSe, the method had not previously been employed with EDLTs using iron-based layered pnictides or selenides.

Maximum VG of 5.5 V

The TIT team applied a gate voltage (VG) of 5.5 V to an EDLT structure in order to induce superconductivity in thin epitaxial films of FeSe with a thickness of 10 nm. They fabricated the EDLTs using a thin insulating FeSe layer, with the ionic liquid DEME-TFSI as the gate insulator.

The achieved T_c of 35 K was more than four times higher the T_c of bulk FeSe. The researchers suggested that an extremely dense accumulation of electrons on the film's surface had the effect of raising the material's T_c.

"T_c increases with increase in the VG," Hiramatsu explained. "However, the maximum VG is limited to 5.5 V because chemical reaction between the FeSe channel and the ionic liquid occur at higher VGs. This causes the FeSe channel layer to disappear, leading to the destruction of the EDLT device.

"It may be difficult to raise the T_c of a material that already becomes a superconductor because the electronic structure of such a material is metal, not insulator. However, I expect that this method would be very effective for exploring possible candidates for superconductivity because it can be used to continuously control the carrier density of electrons and holes by applying positive and negative gate voltages."

Team to Apply Structures to Other Insulators

Hiramatsu outlined some of the directions the team's continuing research will take: "We plan to investigate the relationship between the surface state of FeSe channels and the superconducting

properties of the EDLT devices. The device operation, the modulation of the drain current by applying gate voltages, is quite sensitive to the surface of the FeSe channel. Thus, we have to employ an in-situ fabrication process without exposure to air in order to induce this high T_c in the FeSe channel.

"We will seek to induce a sharper superconducting transition by improving the growth technique for the FeSe channel and the fabrication process for the EDLTs. In addition, we will apply the EDLT structures to other insulating materials in order to explore new HTS." ❍

Chicago-led Team Traps Electrons Above Superfluid Helium

Researchers from the University of Chicago, Argonne National Lab, and Yale University have isolated and trapped electrons that they levitated just above the surface of liquid helium (Phys. Rev. X 6, 011031). Their work may constitute a step towards manipulating a single electron that could be employed as a qubit for quantum computing. The research received financial support from an NSF CAREER grant, the University of Chicago, the NSF's MRSEC program, and the David and Lucile Packard Foundation.

"This is an important step in a program we proposed back in 2010 (Phys. Rev. Lett., 105, 040503 (2010))," commented Professor David Schuster of the University of Chicago. "The basic idea is that the spin of an electron on helium is nearly the ideal qubit. It has two states, 'up' and 'down,' and because it is 'levitated' in a vacuum it can preserve its state in a very pristine manner."

Helium Electrons less Affected by Environmental Noise

Electrons used as qubits that are subject to environmental disturbances generally lose coherence. However, liquid helium has a different effect: the electrons levitate just above the surface without being affected by the atomic fluctuations below them.

This phenomenon occurs because the helium produces a mirror image of the electron. The electron and the image carry opposite charges, which pull them together. Combined with quantum mechanical effects that would cause the electron to move away from the helium, equilibrium is reached, which holds an electron at about 10 nm above the helium surface.

Electrons Trapped in SC Resonator

The team used a superconducting coplanar waveguide resonator structure, consisting of a niobium layer on a bed of sapphire, to hold the electrons in place. A microwave photon was bounced between the ends of the resonator hundreds of times until it became strong enough to interact with the trapped electrons to produce a qubit.

The researchers first flooded their sample with superfluid helium at a temperature slightly above absolute zero. The electrons came from the tungsten filament of a miniature toy light bulb. They were thrown off from the bulb after it became heated, and moved to the surface of the helium.

"We operated our system as low as 0.02 K," Schuster said. "Interestingly, when the light bulb is activated to produce the electrons it is heated to several thousand kelvin, but because it is small and as this is done only briefly it only heats the system to about 0.1 K, after which it cools back down in about 10 to 15 minutes."

Team Controlled Electrons Flowing from Trap

The scientists observed the microwave photons emerging from the resonator, monitoring them as they allowed electrons to leak from the device. By modifying the strength of the trap, they affected how strongly the electrons interacted with the resonator, controlling how they poured out.

"We started with about 250,000 electrons and went down to about 50,000 before pouring the rest of them out," Schuster noted. "Using a similar technique we could probably resolve the number down to about 1000 electrons."

Schuster pointed out that the researchers were already proceeding with the next phase of their research: "We have built a new device which has a specially designed trap that can hold just a few electrons, from one to perhaps twenty electrons at most. We will trap a large number using the technique demonstrated in this work and then transfer just a few to the small trap. We also hope to be able to demonstrate the interaction between a single electron and the superconducting circuit." ❍

Physicist Wei Proposes Particle Teleportation

In a recent comment (Phys. Rev. E 93, 066103 (2016)), Chinese Physicist Yuchuan Wei has suggested that particle teleportation is a new observable relativistic effect in quantum mechanics, offering a straightforward explanation for superconductivity. Using this new concept in quantum mechanics, superconductivity could be viewed as the teleportation of electrons from one side of a superconductor to another. Wei is not currently affiliated with a research institution and last worked with Wake Forest University.

"Teleportation is a method of particle motion," said Wei. "Particle teleportation alters our thinking on microscopic particles.

"There are two equations that can result in particle teleportation, the relativistic and fractional Schrödinger equations. One can easily reach the former from the standard Schrödinger equation by replacing classical kinetic energy with relativistic kinetic energy.

"The latter was introduced in 2001, but the source term in the probability continuity equation was missing. It is this term that leads to particle teleportation. The mistake has not drawn much attention because in our world there are no particles with fractional kinetic energy."

Study Relevant to SC Research

"The existence of particle teleportation is important to superconductivity research in general," emphasized Wei. "Superconductivity cannot be explained before we can describe it correctly.

"Few people can understand the BCS theory for LTS because of its complexity, and there exists no well-recognized HTS theory. Currently, superconducting electrons are understood to pass through a Josephson junction via quantum tunneling, but an open question is how a supercurrent can flow through the non-superconducting metal in an SNS junction without dissipation. I think, the only reasonable explanation is that the electrons can teleport from one side of the junction to the other, i.e. they do not physically pass the normal metal layer in the junction."

Wei outlined some experiments that could be conducted to experimentally observe particle teleportation: "We can observe the teleportation of helium atoms in a superfluid experiment. When a superfluid flows through a capillary tube, the flow rate and velocity can be measured. If the flow rate is bigger than it should be with a certain measured velocity, there is teleportation; otherwise no teleportation exists. Scattering experiments can also be used to detect particle teleportation." ❍

Zhejiang U Finds SC and Ferromagnetism Coexist

Scientists at Zhejiang University and the Zhejiang University of Science and Technology have reported that superconductivity and ferromagnetism coexist in the iron arsenide $RbEuFe_4As_4$ (Phys. Rev. B 93, 214503). The finding suggests that the general

antagonism between the two phenomena could be suppressed. This research received financial support from the National Science Foundation of China and the Fundamental Research Funds for the Central Universities of China.

Superconductivity and ferromagnetism generally do not coexist. A superconductor expels magnetic fluxes below T_c while a ferromagnet magnetizes itself below the ferromagnetic transition temperature. However, researchers have considered a few material systems as candidates for ferromagnetic superconductivity, although bulk superconductivity and full ferromagnetism have rarely been observed simultaneously.

"In general, ferromagnetism and superconductivity are mutually antagonistic," commented Professor Guang-Han Cao of Zhejiang U, who led the research team. "In iron-based systems, especially in the present intergrowth structure, however, they may be compatible. There definitely exists interplay between superconductivity and ferromagnetism."

Phosphorus-doped $EuFe_2As_2$ is one compound that has shown some evidence of both superconductivity and ferromagnetism. Superconductivity emerges at 26 K and the Eu spins become ferromagnetically ordered at about 20 K. However, debate has persisted as to whether the Eu spins are fully ferromagnetically ordered.

In their work, the research team synthesized a 1144-type material by replacing every alternate Eu layer with a layer of the alkali metal rubidium (Rb), yielding the compound $RbEuFe_4As_4$. The new material crystallized in an intergrowth structure of $RbFe_2As_2$ and $EuFe_2As_2$, which drastically changed the physical properties.

The material demonstrated bulk superconductivity at 36.5 K in the FeAs layers and ferromagnetism at 15 K in the Eu sublattice. The observation of robust superconductivity suggests that mechanisms exist that could minimize the commonly observed mutual suppression between superconductivity and ferromagnetism.

"At present, I am mostly interested in how superconductivity coexists with ferromagnetism," said Cao. "Is there a Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) state, as was theoretically predicted over 50 years ago?" ❍

Superconductivity Roundup

Events & Opportunities from Around the Industry

sw Researchers at the DOE's **Brookhaven National Lab** (BNL) have completed **preliminary tests** of a 20-ton **superconducting cylindrical magnet** intended to be part of an upgrade to the **Relativistic Heavy Ion Collider** (RHIC). The tests were needed to ensure that the superconducting solenoid was in working order after having sat idle for 8 years and then traveling cross-country from California to Brookhaven last year (see *Superconductor Week*, Vol 29, No 1).

The magnet was formerly part of the BaBar experiment at SLAC National Accelerator Lab and may find new life in bending the trajectories of charged particles emerging from proton and ion collisions at RHIC, a DOE Office of Science User Facility for nuclear physics research. The BaBar solenoid magnet was originally built in the 1990s,

tested in 1997 to 1998, and operated at SLAC from 1999 to 2008.

Inspections have so far identified and repaired two leaks in the magnet system and adapted a quench detection system originally designed for the LHC for use with the magnet. Researchers have also upgraded the magnet's power supply and some of the controls.

In the initial testing, the magnet was cooled and tested at 1, 10, 50, and 100 A. No problems with the magnet were identified in the initial testing, though further tests are needed to verify the magnet for its expected operating field of 1.4 T at 4,600 A.

sw **Arthur Freeman**, the first **Associate Director** of **MIT's National Magnet Laboratory** (NML) from 1962 to 1967, **passed away** on June 7 at the age of 86. Freeman is regarded as having been instrumental in bringing new physicists with backgrounds in superconductivity and magnetism, both theoretical and experimental, to the NML. Freeman himself was a pioneer in the development of first-principles quantum simulation methods for complex magnetic and superconducting materials, including their structural, electronic, magnetic, optical, and mechanical properties.

sw A team of physicists including researchers from the **University of Innsbruck** in Austria have performed the **first full simulation of a high-energy physics experiment**, the creation of pairs of particles and their antiparticles, **on a 4-qubit quantum computing system** (doi:10.1038/nature.2016.20136). If the team can scale it up, the technique promises access to calculations that would be too complex for an ordinary computer to deal with. Quantum computers are expected to be particularly useful for situations in which calculations are too difficult to allow predictions based upon first principles.

sw **ReportsWeb** has released a **study** entitled "**The Global Superconductor Consumption 2016 Market Research Report**." The report analyses the superconductor consumption industry size, share, and growth and forecasts the market through 2021.

sw **IBM** is allowing researchers and scientists to **run experiments using its quantum processor**, which consists of 5 qubits made with superconducting metals on a silicon chip. IBM asserts that the superconducting chips can be designed and manufactured using standard silicon fabrication techniques.

IBM has opened access to the system through the **IBM Quantum Experience**, which runs on the IBM Cloud and allows users to run algorithms and experiments on the quantum processor; work with individual qubits; and explore tutorials and simulations on the possibilities opened up by quantum computing. Users will be allowed to contribute and review their results in the community hosted on the IBM Quantum Experience. IBM plans to add more qubits and different processor arrangements over time.

sw **Ion Beam Applications S.A.** (IBA) has announced the promotion of **Jean-Marc Bothy** to **Chief Strategy Officer** and the appointment of **Soumya Chandramouli** as **Chief Financial Officer**. Both have been with IBA for several years, with Chandramouli having joined the company in 2004 and Bothy prior to 2001.

sw German superconductor provider **THEVA Dunnschichttechnik GmbH** has secured **€6.4 million ($7.1 million) in financing** from investors including eCapital, the Bavarian Growth Fund, Target Partners, and the Bayerische Beteiligungsgesellschaft (BayBG). Target Partners and BayBG have been THEVA shareholders since participating in a 2012 financing round.

The lead investor in the current round of funding was Munster-based eCAPITAL, which specializes in technology-focused growth industries. Co-investor the Bavarian Growth Fund is administered by Bayern Kapital GmbH, which was set up in 2015 by the Bavarian state government with €100 million ($110 million) of state money. Co-investments by private risk capital investors are intended to boost this to several hundred million.

THEVA is the third investment of the eCAPITAL IV Technologies fund, which was formed earlier this year. The goal of the fund is to build a portfolio of about 15 investments with a total volume of about €100 million invested in high growth, innovative companies in the fields of software & IT, cleantech, automation/industry, and new materials.

sw **Google** is reportedly **experimenting** with security systems intended to secure its Google Chrome software against **quantum computer encryption hacking**. Google is attempting to encrypt some of its connections through post-quantum cryptographic methods to ensure that they cannot be retroactively accessed after quantum computers develop the capability to work around current cryptographic methods.

Google is utilizing the New Hope algorithm, which was designed last year by researchers at Ege University, Radboud University, the Center for Mathematics and Computer Science in Amsterdam, and Infineon Technologies AG. The experiment is currently enabled in Chrome Canary, an experimental branch of Google Chrome.

sw **The EcoSwing project**, a consortium building the largest wind turbine with superconductor technology intended for actual operation, has announced that it **plans to begin tests** on its generator next year. The generator, to be included in a turbine near Thyboron, Denmark, will be rated for 3.6 MW in a direct drive configuration. The generator is expected to have an outer diameter of no more than 4 m.

The EcoSwing consortium includes THEVA Dunnschichttechnik, which is delivering the rotor coils for the project, Envision Energy (Denmark) Aps, ECO 5 GmbH, Jeumont Electric SAS, Delta Energy Systems GmbH, Sumitomo Cryogenics of Europe, Ltd, DNV GL Renewables Certification, and the Fraunhofer Institute for Wind Energy and Energy System Technology (IWES). In addition, University Twente will assemble the superconductive rotor.

sw **Technifab Products Inc.**, a custom cryogenic equipment manufacturer, has **expanded its current manufacturing facility** for added engineering capabilities and to meet expected future demand.

The latest building design, which has added 20% in square footage to Technifab's original site, combines new equipment, advanced fabrication processes, and improved technology. The increased capacity will enable Technifab aims to expand its product offering into larger diameter pipe production, generate large scale projects, and ramp up production.

sw **Market.biz** has released a market **research report** entitled "**The Global HTS Industry 2016**." The report includes analysis of major manufacturers including Bruker, SuperPower, Southwire, AMSC, Oxford Instruments, Furukawa Electric, and Superconductor Technologies.

sw **Superconductor Technologies Inc.** (STI) has effected a **one-for-fifteen reverse split** of its common stock. STI implemented the split for the purpose of regaining compliance with the Nasdaq Stock Market's listing maintenance standard that requires STI to maintain at least a $1.00 per share minimum bid price.

The reverse split will reduce the number of outstanding shares of STI common stock from approximately 41,748,218 shares as of July 18, 2016 to approximately 2,783,214 shares outstanding post-split. Correspondingly, the initial trading price of STI common stock is expected to proportionately increase immediately following the reverse split. STI stock was trading at $0.19 as of June 30, but closed at $2.86 on July 19, the day after the reverse split.

Superconductor Week
Commercialization · Markets · Products
Business Developments · R&D · Cryogenics

~Insert~

July 23, 2016 Vol. 30, No. 6

Superconductivity Stock Index

Company Name	Symbol	Prices ending 31-Dec-2015	Prices ending 30-June-2016	Percentage change
American Superconductor	AMSC	6.37	8.44	32%
Oxford Instruments	OXIG.L	11.33*	9.48*	-16%
Superconductor Technologies	SCON	0.21	0.19	-10%
Bruker Corporation	BRKR	24.27	22.74	-6%
Furukawa Electric	5801	2.13**	2.29**	8%
Ion Beam Application	IBAB.BR	16.83***	47***	19%
Superconductor Index (12/31/14 = 100)		100.00	99.41	-1%
Standard and Poor's 500		2043.90	2,071.50	1%

The Superconductivity Stock Index is a market value index as is the S&P500. It is generated by Peregrine Communications. The year-to-date percentage change is based upon the change in market value of the companies in the index. Market value is determined by the share price times the number of shares outstanding at the end of the measured period.

* Figures are derived from closing rates on the London Stock Exchange, converted from UK Pounds to U.S. Dollars
** Figures are derived from closing rates on the Tokyo Stock Exchange, converted from Japanese Yen to U.S. Dollars
*** Figures are derived from closing rates on the Brussels Stock Exchange, converted from Euros to U.S. Dollars

U.S. Superconductivity Patents

Apparatus for the Generation of Light Pulses

Helmholtz-Zentrum Dresden-Rossendorf e.V.
Feb. 23, 2016
U.S. Patent No. 9268151

Extremely ultrashort and short-wave light pulses are generated with the aid of the traveling-wave Thomson scattering process. Dispersive elements are arranged between an electron, particle, or radiation source, which is synchronized with a laser system, and an optical element that focuses in a direction. The device is used to superpose a pulse-front tilted light pulse of high power with an ultrashort pulse of relativistic electrons in a laser-line focus. By varying the laser pulse-front tilt, narrow-band radiation pulses in a wide wavelength range from EUV to x-ray wavelengths and having a high number of protons are obtained, and the bandwidth and coherence properties can also be modified. The system can be used, among other things, in EUV lithography, in the planning and optimal design of laser systems and electron sources, in material analysis by phase contrast imaging, and in SC research. The assembly is smaller and cheaper than current comparables.

Magnetic Structure for Circular Ion Accelerator

Ion Beam Applications S.A.
Feb. 23, 2016
U.S. Patent No. 9271385

A magnet structure for use in a circular ion accelerator, such as e.g. a synchrocyclotron comprises a cold-mass structure including SC magnetic coils, at least one dry cryocooler unit coupled with the cold-mass structure for cooling the latter and a magnetic yoke structure with a return yoke configured radially around said coils. The return yoke comprises an opening in which said dry cryocooler unit is received so as to be in thermal contact with said cold-mass structure.

Coil Capable of Generating a Magnetic Field

Centre National de la Recherche Scientifique
Mar. 1, 2016
U.S. Patent No. 9275780

Method for manufacturing a coil for generating an intense magnetic field when an electric current passes through it. Turns are formed in a cylindrical tube

made of conducting or SC material. At least one indentation is formed in an edge of at least one turn. Insulating material is positioned between the turn including the indentation and an adjacent turn. The recess forms with the insulating material a channel between the interior and the exterior of the tube when the coil is stressed.

Low Resistivity Joints

General Electric Company
Mar. 15, 2016
U.S. Patent No. 9287485

Method for joining wires using low resistivity joints is provided. More specifically, methods of joining one or more wires having SC filaments, such as MgB_2 filaments, are provided. The wires are joined by a low resistivity joint to form wires of a desired length for applications, such in medical imaging applications.

HTS Magnetic Sensor

International Superconductivity Technology Center
Mar. 8, 2016
U.S. Patent No. 9279863

A HTS magnetic sensor having SC layers formed on a substrate, a SQUID being formed on the SC layers, the HTS magnetic sensor includes: a pickup coil that is formed on the SC layer and is connected to an inductor of the SQUID; and an input coil that is formed on the SC layer, is connected to the inductor of the SQUID and the pickup coil to form a closed loop, and is magnetically coupled with the inductor of the SQUID. In planar view, at least one turn of the input coil surrounds the inductor of the SQUID, or is surrounded by the inductor of the SQUID. The width of the SC forming the inductor of the SQUID is 10 μm or less.

Compensating for Field Distortion in an MRI

General Electric Company
Mar. 8, 2016
U.S. Patent No. 9,279,871

A magnet apparatus for a MRI system includes a vacuum vessel, a helium vessel disposed within the vacuum vessel and a thermal shield disposed between the vacuum vessel and the helium vessel. A set of passive compensation coils are disposed within the vacuum or helium vessel and used to compensate for magnetic field distortion from mechanical vibrations within the magnet apparatus.

SC Multi-bit Digital Mixer

Hypres, Inc.
Mar. 1, 2016
U.S. Patent No. 9276615

A SC multi-bit digital mixer, designed using RSFQ logic, for multiplying two independent digital streams, at least one of these comprising a plurality of parallel bit lines, wherein the output is also a similar plurality of bit lines. In a preferred embodiment, one of the digital streams represents a local oscillator signal, and the other digital stream digital RF input from an analog-to-digital converter. The multi-bit mixer comprises an array of bit-slices, with the local oscillator signal generated using shift registers. This multi-bit mixer is suitable for an integrated circuit with application to a broadband digital RF receiver, a digital correlation receiver, or a digital RF transmitter. A synchronous pulse distribution network is used to ensure proper operation at data rates of 20 GHz or above.

Josephson Junction Memory Cell

Northrop Grumman Systems Corporation
Mar. 8, 2016
U.S. Patent No. 9281057

One embodiment describes a memory cell. The memory cell includes a phase hysteretic magnetic Josephson junction (PHMJJ) that is configured to store one of a first binary logic state corresponding to a binary logic-1 state and a second binary logic state corresponding to a binary logic-0 state in response to a write current that is provided to the memory cell and to generate a SC phase based on the stored digital state. The memory cell also includes a SC read-select device that is configured to implement a read operation in response to a read current that is provided to the memory cell. The memory cell further includes at least one Josephson junction configured to provide an output based on the SC phase of the PHMJJ during the read operation, the output corresponding to the stored digital state.

Systems, Devices, and/or Methods for Solar Cells

K Tube Technology LLC
Mar. 8, 2016
U.S. Patent No. 9281426

Certain exemplary embodiments can provide a method,

which can comprise fabricating a system. The system can comprise a light amplification element and a charge transport element. Each of the light amplification element and a charge transport element can comprise one or more of a graphene layer, graphene oxide, graphene nano platelets, functionalized graphene, graphene/SC composite, tubular shaped nano carbon, semiconductor powder, thin film, nano wire, and nano rod.

Atomic Layer Deposition of Tunnel Barriers

Intermolecular, Inc.

Mar. 8, 2016

U.S. Patent No. 9281463

Metal oxide tunnel barrier layers for SC tunnel junctions are formed by atomic layer deposition. Both precursors include a metal (which may be the same metal or may be different). The first precursor is a metal alkoxide with oxygen bonded to the metal, and the second precursor is an oxygen-free metal precursor with an alkyl-reactive ligand such as a halogen or methyl group. The alkyl-reactive ligand reacts with the alkyl group of the alkoxide, forming a detached by-product and leaving a metal oxide monolayer. The temperature is selected to promote the reaction without causing the metal alkoxide to self-decompose. The oxygen in the alkoxide precursor is bonded to a metal before entering the chamber and remains bonded throughout the reaction that forms the monolayer. Therefore, the oxygen used in this process has no opportunity to oxidize the underlying SC electrode.

Compact Proton Therapy System

Varian Medical Systems, Inc.; Varian Medical SYstems Particle Theraby GMBH

Mar. 15, 2016

U.S. Patent No. 9283407

Systems and apparatuses for providing particle beams for radiation therapy with a compact design and suitable to a single treatment room. The radiation system comprises a stationary cyclotron coupled to a rotating gantry assembly through a beam line assembly. The system is equipped with a single set of dipole magnets that are installed on the rotating gantry assembly and undertakes the dual functions of beam energy selection and beam deflection. The energy degrader may be exposed to the air pressure. The beam line assembly comprises a rotating segment and a stationary segment that are separated from each other through an intermediate segment that is exposed to an ambient pressure.

Pulsed Charge Cooling of a Component of a Tokomak

L'Air Liquide Societe Anonyme Pour L'Etude Et L'Exploitation Des Procedes Georges Claude

Mar. 15, 2016

U.S. Patent No. 9285141

The invention relates to a method and device for pulsed charge cooling of a component of a tokamak. The method uses a refrigeration device that subjects a working fluid such as helium to a work cycle including: compression, cooling, and decompression, as well as heat exchange with the member and heating. The refrigeration power produced by the refrigeration device is increased to a relatively high level when the tokamak is in a plasma generation phase and is decreased to a relatively low level when the tokamak is no longer in a plasma generation phase. The increase in refrigeration power produced by the refrigeration device is automatically triggered in response to a signal produced during a step for starting plasma in the tokamak.

Optical-microwave-quantum Transducer

Northrop Grumman Systems Corporation

Mar. 29, 2016

U.S. Patent No. 9296609

An optical-microwave-quantum transducer can include a first nanophotonic slab and a second nanophotonic slab. Each of the first and second nanophotonic slabs can include an optical region and a SC region. The first nanophotonic slab can include a pair of torsional beams anchored to a substrate to allow relative rotation between the first and second nanophotonic slabs about an axis of rotation.