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

March 10, 2015 Vol. 29, No. 2

Bruker Earnings Show Good Year for BEST

Bruker Corporation's Energy & Supercon Technologies (BEST) segment realized revenues of $36.8 million in Q4 2014, a 21% decline from $46.6 million in Q4 2013. For FY 2014, BEST revenues reached $152.9 million, a gain of 3.7% over the $147.4 million reported for FY 2013.

BEST system and wire revenue during the fiscal year, which includes its superconductor sales, reached $148.8 million compared to $137.3 million in FY 2013, a gain of 8%. Operating income for BEST for the year was $3.4 million, a decline of 64.2% from $9.5 million the previous fiscal year. This decrease was due to the Rosatom license revenues that were realized in FY2013.

Frank Laukien, President and CEO of Bruker, commented in the earnings conference call that the year-over-year comparison for BEST was not the best yardstick, according to a transcript provided by the website *SeekingAlpha.com*: "BEST was able to deliver good growth, despite having about $10 million of revenue related to the Rosatom pilot line delayed into 2015. BEST also faced a difficult year-over-year comparison due to the Rosatom license fees recognized in 2013.

"The market for LTS wire remains healthy as BEST exited the year with strong new order bookings and backlog. We also expect its market for Big Science projects will remain attractive."

NMR Sales Lower for BioSpin

Much of the Bruker's earnings conference call was focused on reduced NMR demand at Bruker BIOSPIN and the rightsizing of that group. BIOSPIN generated revenue of $622.8 million in FY2014, which was a slight decline from the $624.4 million in revenue recognized in FY2013.

"Our BIOSPIN group reported flat revenues in FY2014 as a very good year from our pre-clinical imaging division was offset by the second half revenue declines in our NMR business," Laukien said. "NMR revenues declined in all three major geographic regions as demand for higher-field products continued to remain muted.

"Fundamentally, we believe that the NMR market remains healthy, but it is absorbing some of the investments made in higher-field systems over the past few years. We are seeing some incremental order opportunities as a result of Agilent's exit from the market, but it can take

up to a year before we see that the benefit of new orders effect our profit and loss statement. That being said, we're optimistic that NMR new order bookings will continue to improve over the next few quarters.

"During 2015 we are moving forward with our rightsizing and manufacturing footprint consolidation programs in BIOSPIN. We made our proposals to the workers' councils in Europe earlier this quarter and have proposed to reduce our headcount in BIOSPIN by approximately 9%, or slightly less than 200 positions.

"We're building a new division within the BIOSPIN group to pursue new opportunities for NMR technology in applied and clinical markets. We will provide additional information about this program once we complete our negotiations with the various workers' councils."

Performance Hurt by CAM Restructuring

Bruker realized $508 million of revenues for Q4 2014, a decline of 8% compared to Q4 2013 revenues of $552.1 million. Non-GAAP net income fell by 3.6%, to $50.3 million from $52.2 million.

For FY 2014, Bruker's revenues fell by 1.7% to $1.81 billion from $1.84 billion in FY 2013. Non-GAAP earnings were $127.7 million, a 0.4% gain from $77.1 million. On the day after the earnings announcement Bruker's share price fell by 3.1%, from $19.37 to $18.77, although the company slightly beat the consensus analyst earnings estimate.

Cash grew by 13.4%, to $497.5 million from $438.7 million at the end of FY 2013. The aggregate backlog declined by 4.8%, from $9.21 million to $8.77 million over the same period. Overall performance was hurt by the restructuring of the Chemical and Applied Markets (CAM) division product lines, including the divestment of products, the transfer of the remaining CAM product lines into the Daltonics division, and the closure of CAM's Fremont, CA manufacturing site.

Exchange Rates to Affect Performance in 2015

CFO Charles Wagner noted that earnings were adversely affected by exchange rates: "With about 80% of our revenues generated outside the U.S., changes in currency have a substantial effect on

our financial performance. The profit impact was primarily the result of the weakness of the yen versus the dollar during 2014. Since we have very little in yen denominated costs, the negative currency impact on yen revenues flows directly through operating margin and earnings per share.

"In recent months the dollar has strengthened against nearly every global currency, not just against the yen or euro. As a result, and with such a high percentage of our revenues outside the U.S., we expect changes in foreign exchange rates to lower our earnings per share by $0.09 year-over-year, which represents a double-digit earnings per share headwind in 2015."

After the release of the earnings report, Laukien bought 5,271 shares of Bruker stock at an average market cost of $18.95 per share, for a total transaction cost of $99,886. Following the completion of the transaction, the CEO directly owns 36,594,917 shares of the company's stock, valued at approximately $693,473,677.15. The acquisition was disclosed in a filing with the Securities and Exchange Commission (SEC). ❍

AMSC Q3 Gridtec Earnings Down 12.8% on D-VAR Sales

AMSC has announced that Q3 2014 revenues for its superconducting Gridtec segment fell by 12.8%, from $7 million in Q3 2013 to $6.1 million. Operating loss for the segment reached $7.1 million compared to a $4.7 million loss for the same period last year. In the quarterly earnings conference conference call, CFO David Henry attributed the reduced sales to lower shipments of non-superconducting D-VAR reactive compensation systems.

For the first three quarters of 2014 Gridtec revenues declined by 39.1%, from $24.9 million to $15.2 million. The operating loss rose to $20 million from $15.3 million.

McGahn: Navy SPS Contract Expected by the End of March

In the conference call, AMSC President and CEO Daniel McGahn noted that the company was focusing on two established products that are driving revenue, D-VAR and electrical control systems for wind turbines, and two disruptive HTS solutions, the resilient electric grid (REG) and the ship protection degaussing system (SPS). While incremental changes in Gridtec revenue will depend on how the D-VAR business is doing, the greatest growth is going to come from REG and SPS.

"Looking forward, we continue to believe that we will get a [SPS] order from the U.S. Navy by the end of this fiscal year," McGahn commented, according to a transcript provided by the website *SeekingAlpha.com*. "This order will be the next step in the commercialization of the technology."

AMSC Offering Two REG Applications

Regarding the REG system, McGahn said that AMSC is focused on the successful completion of the first phase of its Chicago project and moving on to the second phase (see *Superconductor Week*, Vol 28, No 1). In addition, the company is in discussions with a number of utilities over two distinct REG applications.

"One application is the interconnection of urban substations creating a ring like configuration," McGahn said. "We can also offer utilities a more cost effective and simplified solution to address urban load growth. Whereas the first application can be described as a ring, this application can be described as a branch.

"For the second application, a REG cable would connect an existing large suburban substation, with a new much smaller and more simplified substation within the city, at a lower cost. The smaller urban substation does not need large power transformers and takes up much less space, thereby significantly reducing real

estate, construction and other related costs in the urban area.

"The ring application is a system-wide upgrade for enhanced reliability and capacity. The branch application addresses specific problems that utilities are trying to solve right now."

Q3 2014 Aggregate Revenues Higher

AMSC reported that aggregate revenue for Q3 2014 for both the Gridtec and Windtec segments rose 3.4% to $21.3 million from $20.6 million in Q3 2013, but were 70% higher sequentially. Non-GAAP net losses were $9.6 million compared to a loss of $5.7 million during the previous year.

CFO Henry commented that over 60% of AMSC's revenues but only 40 to 50% of the associated costs were denominated in euros. The discrepancy led to a negative impact on the company's income statement due to a strengthening dollar.

For the first three quarters of 2014, AMSC revenues fell by 29.6% to $30.2 million from $42.9 million. Non-GAAP net losses were $33.2 million compared to $24.7 million over this period.

AMSC has Sufficient Funding for 2015 Operations

Cash, cash equivalents, and restricted cash totaled $37.6 million at the end of the quarter, compared with $38.2 million at the end of the previous quarter. Henry noted that the company generated net proceeds under its At-Market Sales Facility (ATM) of $1 million from the issuance of approximately 0.8 million shares of common stock at an average sales price of $1.22 per share.

In addition, AMSC received net proceeds of $9.1 million from a completed equity offering to a new investor of 9.1 million units of common stock at an offering price of $1.10 per common stock unit. Each unit consists of one share of common stock and 0.90 of a warrant to purchase one share of common stock, or a warrant to purchase in an aggregate of 8.2 million shares (see *Superconductor Week*, Vol 28, No 11). Henry stated that, as a result of these new financing arrangements, AMSC should now have sufficient available liquidity to fund its operations through December 31, 2015.

Gridtec Sales Likely Flat in Q4 2014

AMSC's backlog fell to $53 million sequentially from $68 million at the end of the previous quarter. The company is projecting that revenues in Q4 2014 will be in the range of $23 to $25 million for Q3 2014, with non-GAAP net loss at less than $7 million.

Henry commented during the conference call that Gridtec sales will be flat to slightly lower next quarter. The consensus estimate of the four analysts following AMSC is $24.6 million in revenues for Q4 2014.

The company has also narrowed the range of its projected revenues for 2014 to $68 to $70 million. The previous estimate during the Q2 2014 earnings call was $65 to $75 million.

AMSC has scheduled a special shareholders meeting on March 18 to seek approval for a range of potential reverse stock splits from 1-to-8 to 1-to-12 (see *Superconductor Week*, Vol 28, No 11). If approved, this would result in a higher share price that should permit the company to regain compliance with the NASDAQ minimum bid requirement. ❍

DOE, NCI Award $1.95 M for Lightweight Particle Beam Delivery Systems

The DOE Office of Science and the National Cancer Institute (NCI) have awarded $1.95 million over three years to Lawrence Berkeley Lab (LBNL), the Paul Scherrer Institute (PSI) in Switzerland, and Varian Particle Therapy, Inc. of Palo Alto, CA,

to develop a lightweight superconducting magnet technology to reduce the size and weight of particle beam delivery systems by an order of magnitude. The team will use technologies previously developed for the magnets of the Large Hadron Collider (LHC) to build and test a prototype designed specifically for cancer treatment. The funding was one of six grants announced by the NCI and DOE for innovation in particle-beam therapies for cancer treatment and laser technology as part of the DOE Office of Science Accelerator Stewardship program.

"The initial focus for this project is on a proton gantry, but we will make an effort to develop solutions that can be scaled to heavy ions (e.g. carbon), as well," said Soren Prestemon, Division Deputy of the Accelerator Technology and Applied Physics Division (ATAP) at LBNL. "The intent is to develop a solution that will reduce the overall cost of a proton beam radiation therapy (PBRT) system, but that will only be confirmed once the magnet system is further developed and engineered.

"We expect that for a proton gantry the final bend magnet will be reduced in weight by a factor of 5 to 10. This estimate is based on a preliminary analysis of the magnet cold mass and cryostat, and will be refined and confirmed as part of this project."

Magnet Analysis Capabilities Developed by DOE OHP to aid current project

The effort will be helped by previous work carried out by the DOE's Office of High Energy Physics (OHP) for accelerator research, most recently the U.S. LHC Accelerator Research Program (LARP), a collaboration between Fermilab, Brookhaven National Lab (BNL), and LBNL to develop high-field superconducting quadrupoles for the next LHC upgrade. In 2013 LARP began testing on the HQ02a, a 12 T superconducting Nb_3Sn high-field quadrupole magnet that demonstrated the technology for the LHC High Luminosity upgrade (see *Superconductor Week*, Vol 27, No 13).

"The LBNL Superconducting Magnet Group has been developing superconducting cables, coils, and magnet support structures for high-field accelerator magnets, as well as sophisticated simulation tools for magnetic and structural analysis and optimization," said Prestemon. "These capabilities, in particular our analysis capabilities, will serve the Stewardship project."

LBNL to Lead Overall Magnet Design

Prestemon specified the role each member in the collaboration would play: "PSI will provide guidance on medical therapy requirements for the gantry, operational modes, and optics designs. LBNL will lead the overall design, including magnet and optics optimization, cryostat design, magnetic and structural design, and cold-mass fabrication. Varian will fabricate the cryostat and support manufacturing engineering.

"We will be working closely with our partners to identify major performance drivers and risks, with the intent of addressing them in the design process. Weight and ultimately cost are primary goals, but other performance parameters may also impact the final design. We intend to facilitate technology transfer with the goal of enhancing access to proton therapy for the public." ❍

OI Installs High Field Magnet at HLD

Oxford Instruments (OI) has successfully developed and installed a compact, high-field, high stored energy superconducting magnet system at the Dresden High Magnetic Field Lab (HLD) at the Helmholtz Center Dresden-Rossendorf (HZDR) in Germany. The new magnet generates 19 T within a large magnet bore of 150 mm, operating at 4.2 K, the normal boiling point of liquid helium.

Until recently, such combinations of high

magnetic field and large bore size or sample space could only be achieved by super-cooling the magnet to 2.2 K using liquid helium. The magnet for HLD was specifically designed to accommodate HTS insert coils targeting even higher fields, in addition to a wide range of sample configurations for experiments such as the high field magnetization of magnetic materials.

Modelling and Construction Techniques Overcome Technical Obstacles

OI overcame two significant challenges in the design and manufacture of the superconducting magnet: the stresses within the magnetic coils and the management of the very high stored energy within the magnet. To manage the extremely large coil stresses, OI combined modelling with construction techniques in order to produce sufficiently reliable high-field Nb_3Sn superconductor coils.

The energy stored in such a magnet when at its full field is 5.7 MJ. For the HLD magnet, a new quench energy management system was developed and extensively tested before being proven on the full magnet system. In its research program, HLD already operates a number of OI superconducting magnet systems including a high-field research magnet generating 20 T at 4.2 K and 22 T at 2.2 K - presently the state of the art for LTS NbTi and Nb_3Sn wires.

An essential enabling factor in the creation of the high-field magnet has been Oxford Superconducting Technology's development of the rod restack process (RRP) Nb_3Sn conductor. The RRP conductor is a specialized high-performance product geared towards optimized performance for ultra-high field superconducting magnets. ❍

MIT Creates Larger, Denser, More Sensitive SNSPD Array

A research team from the Massachusetts Institute of Technology (MIT), Columbia University, the Jet Propulsion Lab, and IBM has built an array of superconducting nanowire single-photon detectors (SNSPD) on a silicon optical chip through a process that increases their sensitivity. Such arrays are a key component of devices that use photons to conduct quantum computations. The research was supported by the DARPA Information in a Photon program, the Army Research Office, through grant W911NF-10-1-0416, the National Science Foundation through grant ECCS-1128222, and the Air Force Office of Scientific Research (AFOSR) through MURI grant FA9550-14-1-0052.

"Our long-term goal is to build a chip-scale photonic quantum processor in which photons encode quantum states.," said Professor Dirk Englund of MIT. "For a fully-integrated system that allows a large number of photonic qubits to be efficiently measured, arrays of single photon sources and detectors are required.

"Scalability and high performance of these sources and detectors are therefore key. In this work, we focused on integrating high-performance single-photon detectors on a photonic chip. Using arrays of waveguide-integrated high-performance detectors, we managed to detect non-classical light on a photonic chip for the first time."

Fabrication Method Solves Instability Problem

Optical processors are considered a promising method of transmitting quantum information using entangled photons. However, SNSPDs made with traditional optical components can be very unstable and have a high failure rate, making it difficult to group them densely in large arrays.

The researchers developed a method for fabricating and testing the SNSPDs separately before transferring them to an optical chip that was built using standard processes. They grew a thin, flexible film of silicon nitride on a separate silicon chip, and then deposited superconducting

niobium nitride (NbN) on the film. At both ends of the chip they placed gold electrodes.

They then attached a droplet of silicone to one end of the film and pressed a tungsten probe against it. Using the probe, they peeled the film off the substrate and attached it to the optical chip.

"Two material properties are essential for our superconducting nanowire single-photon detectors: low defect density in the superconducting film, which increases detection efficiency, and high supercurrent density in the film, which is essential for the high speed of the detectors," Englund noted. "Currently, only thin NbN and NbTiN films can offer both properties, and are therefore the ideal materials for superconducting single-photon detectors. Single-photon detectors based on other promising materials, mainly amorphous superconducting films such as WSi and MoSi, are currently in development."

"The effective yield of the waveguide-integrated SNSPDs is 100%. If for some reason one of the detectors does not work, it can simply be replaced, or we can place another working membrane-detector in front of it."

20% of Single Photons Detected

This new approach not only yielded denser and larger arrays than traditional methods, but also increased detector sensitivity. The MIT team's array registered about 20% of the arrivals of single photons, which is more than an order of magnitude higher than previously possible. It is estimated that a practical quantum circuit should be able to detect 90% or more photons.

"The testing of the SNSPDs was performed in a cryogenic probe station using an optical probe, for illumination with 1550-nm-wavelength light, and an RF probe, to read out their electrical photodetection signal," Englund said. "The cryogenic probe station is essentially a cryostat operated at a 3 K base temperature.

"The 20% efficiency number includes external fiber-to-waveguide coupling losses and limited optical absorption of the SNSPD due to small coupling length. We can solve the first problem by integrating single-photon sources directly on the same chip as the detectors. The second problem can be addressed by increasing the detector-to-waveguide coupling length or by integrating the detector in a cavity."

Array Scalable for Smaller Quantum Systems

According to Englund, the array is appropriate for smaller systems: "For smaller quantum systems that require tens of SNSPDs our current method is sufficiently fast and scalable and offers a path to the integration of waveguide-SNSPD arrays. However, to integrate thousands of SNSPDs a larger amount of automation of the pick-and-place approach, which is currently done manually, is required.

"One way to address the problem is to improve the device yield of SNSPDs. This will very likely happen over time. When it does, one will be able to flip-chip bond larger membranes using arrays of SNSPDs onto the circuit."

The researchers have separately developed a scalable method to integrate single-photon sources with photonic chips. They are planning to bring single-photon detectors, single photon sources, and spin-based quantum memories onto the same chip to build small, scalable quantum systems. ❍

HPSTR, Carnegie Team Triples T_c through Carrier Switch

A team led by scientists from the Center for High Pressure Science and Technology Advanced Research (HPSTR) of Shanghai and the Geophysical Lab of the Carnegie Institution of Washington has demonstrated that the application of pressure can drive the iron pnictide KFe_2As_2

from hole-doped to electron-doped superconductivity, tripling the maximum T_c from its initial value of 3.5 K to 12 K (arXiv: 1501.00330). The findings suggest a new route to further improve superconductivity with high T_c enhancement through carrier switch.

Also participating in the study were researchers from the Institute of Crystallography of the Russian Academy of Sciences and the University of Science and Technology of China in Hefei. The study was supported by EFree, an Energy Frontier Research Center funded by DOE's Office of Basic Energy Sciences, the Natural Science Foundation of China, the Strategic Priority Research Program (B) of the Chinese Academy of Sciences, and the National Basic Research Program of China.

"This research is part of an ongoing project to use pressure to pursue a directed search and discovery of new superconductors, understand and exploit competing electronic phases, identify the essential interactions that give rise to high-T_c superconductivity, and find a route to synthesize superconductors with such higher T_c's at ambient conditions," commented HPSTR and Carnegie Researcher Xiao-Jia Chen. "Along these lines, we have successfully found superconductivity in highly efficient thermoelectric materials and topological insulators."

Pressure Changes Fermi Electronic Structure

Chen discussed the specific findings: "At a certain carrier concentration, a material begins to superconduct. The carriers can be electrons, with a negative charge, or holes, with a positive charge.

"The carriers of KFe_2As_2 are holes at low pressure. However, applying pressure can drive the carriers from holes to electrons and, after the carrier crossover, novel superconductivity appears.

"This means that pressure can change the Fermi surface electronic structure. The electron-doped KFe_2As_2 at high pressure possesses a much higher T_c than that at the ambient condition."

Compression Results in Collapsed Tetragonal Phase

High-T_c superconductors behave asymmetrically when chemically doped, with the maximum T_c generally higher for optimal hole-doping than for optimal electron-doping on the same parent compound. Researchers commonly tune the structural and physical properties by applying pressure to change the lattice of these compounds.

Experiments with iron pnictides have shown that heavy compression on the lattice drives these superconductors from an initial tetragonal to a collapsed tetragonal phase. In the latter phase, the material loses superconductivity, perhaps due to the absence of electronic correlations or the suppression of antiferromagnetic spin fluctuations.

Strong Electronic Correlations may Cause Novel SC

The research team found that KFe_2As_2 behaved differently. They subjected a single crystal of the material to various pressures of up to 30 GPa.

T_c reached a maximum of 12 K between 12.2 and 16 GPa. The results suggested that the strong electronic correlations in KFe_2As_2 might account for the unexpected enhancement of superconductivity in the collapsed tetragonal phase.

"Heavy compression on the lattice always drives the iron-based superconductors to change from the initial tetragonal to a collapsed tetragonal phase," Chen noted. "The dense collapsed phase has been found to lose superconductivity. However, these findings suggest that the modification of lattice structure into the collapsed tetragonal by film growth or element substation may actually favor higher T_c."

Chen discussed how the research team would build on these findings: "We plan to examine other compounds that exhibit a collapsed tetragonal structure. Our objective will be to see whether

similar higher T_C behavior can be observed through applying pressure." ❍

NIST Builds SC-Magnetic Spintronics Device

Scientists from the U.S.'s National Institute of Standards and Technology (NIST) report having developed and demonstrated a nanoscale superconducting-magnetic device that employs spintronic effects (DOI: http://dx.doi.org/10.1103/PhysRevApplied.3.011001). The cryogenic memory technology that they adopted addresses a key requirement in the quest to achieve superconducting computing. Their work received funding directly from NIST and through a National Security Agency (NSA) contract.

Device is an Element of the IARPA C3 Program

The NIST research is a component of the Intelligence Advanced Research Projects Activity (IARPA) initiative under the Cryogenic Computer Complexity (C3) program which is seeking to build a small-scale prototype with the goal of evaluating superconducting computing for scale-up (see *Superconductor Week*, Vol 28, No 12). NIST is responsible for evaluating the superconductor computing components developed by the three IARPA contract awardees - IBM Corp., Raytheon BBN Technologies, and Northrop Grumman Corp. - and is currently devising the necessary metrology and evaluation methods. However, NIST scientists have also been conducting research on a cryogenic memory system employing Josephson junction switches since well before the advent of the IARPA program.

"Developing cryogenic memory is one of the main elements of IARPA C3 program," NIST Researcher Burm Baek commented. "However, we need to understand the physics of superconducting-magnetic hybrid structures much better in the perspective on memory application.

"While contract awardees are focusing on developing actual devices based on different mechanisms, we are trying to provide a better understanding of relevant physics. For example, we have reported on important properties such as scalability and spintronic control in each of our latest papers."

Challenge of Balancing SC and Magnetism

Although superconducting-magnetic hybrid devices already exist, the NIST module is the first to employ spintronic effects for managing magnetic properties which, until now, have only been used for room-temperature magnetic devices. The team developed a modified Josephson junction consisting of an ellipse with 50 nm in minor and 100 nm in major axes. Between the two superconducting junction electrodes, they fabricated a multilayer barrier consisting of two different magnetic materials separated by a non-magnetic metal, NiFe/Cu/Ni and Ni/Cu/Ni.

Baek pointed out the challenges of employing spintronics in a nanoscale hybrid device: "We needed to achieve a balance between magnetism and superconductivity. Usually, superconductivity is easily destroyed by stronger magnetism, which limits the direct applications of well-studied spintronic technologies. We also have had to consider that our system is in a different regime regarding the temperature and materials systems."

Further Plans for Reducing Magnetic Switching I_C

In the device, the relationship between the polarity of the two magnetic layers, which can be aligned either the same (parallel) or opposite (anti-parallel), determines the magnitude of the supercurrent in the Josephson junction and whether there is zero or non-zero voltage across the junction. Using spin-transfer torque, a normal current with an even distribution of spins would pass through the fixed magnetic layer, which acts

as a filter such that the electrons emerging from it are spin-polarized. The angular momentum associated with that spin state is then transferred to the free layer, changing its magnetic alignment.

Baek outlined how the NIST team plans to continue its work: "The magnetic switching I_C must be reduced for these devices to be practical. We plan to explore different material systems to engineer the magnetic switching properties so it becomes more efficient and doesn't degrade the superconducting circuit performance." ❍

Princeton Views Cooper Pairs on Topological Superconductor

A Princeton University-led team of researchers has reported observing the helical Cooper pairing of Dirac electrons on the surface of a topological insulator (doi: 10.1038/nphys3139). Their findings may serve as a platform for testing fundamental physics predictions such as emergent supersymmetry and topological quantum criticality. Scientists from Pennsylvania State University, National Taiwan University, and the University of Illinois also participated.

Topological insulators are artificially fabricated structures that behave as an insulator in their interior but have unusual surface electronic states that conduct electricity. While ordinary superconductors have electrons that spin in both up and down directions, the electrons on topological insulators spin up when moving in one direction while spinning down when moving in the opposite direction.

Topological Insulator Expected to Host Majorana Fermions

As a result, only half of the electrons are available for what is known as helical pairing. Furthermore, the spin momentum that is locked into a topological insulator is expected to allow the surface states to host Majorana particles if superconductivity is induced. A topological insulator-based Marjorana is expected be a very robust, coherent particle for storing and transmitting quantum information.

"This has been the first observation of the helical pairing of Dirac fermions forming a superconducting condensate," commented Princeton Professor M. Zahid Hasan, who led the research team. "We have created a new model physical system for studying exotic phenomena like supersymmetry."

Supersymmetry to Illuminate Particle Physics Problems

Supersymmetry is the hypothesized extension of spacetime symmetry where bosons, which have an integer-valued spin, and fermions, which have a half-integer spin, can be converted into each other at very high energies. It is expected that this quantum state will shed light on many unresolved questions in particle physics.

Supersymmetry has not yet been observed, although there were high hopes that the Large Hadron Collider would find evidence for it. It has not done so to date.

"If our topological system were magnetically doped and the temperature brought down to the quantum critical point, we would be in new territory," Hasan said. "In that state bosons and fermions move in the same way and with the same speed. This may be [representative of] the physics of the twenty-first century."

Potential to Discover New Properties of SC

The Princeton team used angle-resolved photoemission spectroscopy (ARPES) to study the kinetic energy and spin direction of the Dirac electrons ejected from a sample of a bismuth selenide (Bi_2Se_3) topological insulator they had discovered previously on a niobium selenide substrate. The scientists plan to follow up on their findings by using a hybrid photoemission

spectroscopy technique on the topological system that combines tunnelling spectroscopy and electrical transport. They will attempt to identify a new type of Marjorana fermion and supersymmetry particles in the isolated helical Cooper pairs.

"While we would be working with a T_C that is very low, we may discover properties about superconductivity that were unknown in the past," Hasan commented. "This could be a route to finding higher-T_C superconductors and eventually new types of technologies that might be used in devices such as topological SQUIDS." ❍

U Tokyo Creates Theoretical SC Model for Iron-Based Compounds

Two University of Tokyo physicists have used a supercomputer to analyze an ab initio model for iron-based compounds that identifies the onset of superconductivity with the enhancement of electron-density fluctuations (doi: 10.1038/ncomms6738). Their work may assist experimentalists by providing guidelines for synthesizing higher-T_C superconductors. The study received financial support from the MEXT HPCI Strategic Programs for Innovative Research (SPIRE) and the Computational Materials Science Initiative (CMSI), and a Grant-in-Aid for Scientific Research (No. 22104010, No. 22340090, and No.23740261) from the Japanese Ministry of Education, Culture, Sports, Science and Technology.

"Although it is difficult to suggest precise expectations at this stage, it is plausible that experimental examinations of our theoretical findings will open a new path to reaching higher-T_C materials," commented Professor Takahiro Misawa of the University of Tokyo. "More immediately, experimentalists may use our findings to seek out the conditions for realizing electron density fluctuations."

Although iron-based superconductors were initially discovered in 2008, their mechanism of superconductivity has not yet been fully clarified. A major difficulty has been the lack of useful methods for deriving a theoretical model for this family of superconductors.

Misawa and his colleague, Professor Masatoshi Imada, adopted a new approach to this problem by enlisting the assistance of supercomputer K. The computer, named for the Japanese word *kei*, meaning 10 quadrillion (10^{16}), was manufactured by Fujitsu and is currently installed at the RIKEN Advanced Institute for Computational Science. In 2011, it was the first computer to reach a computational speed of 10 petaflops and is ranked by the TOP500 project as the fourth fastest computer in the world today.

By using experimental information of only lattice structures and elements for superconducting LaFeAsO, the two physicists succeeded in numerically reproducing the superconducting state from the principles of quantum mechanics and statistical physics. In addition, they isolated the origin of superconductivity by systematically controlling the electron-to-electron Coulomb interaction, a level of control that is difficult to achieve experimentally.

SC Related to Electron Density Fluctuations

Analyzing the theoretical model derived from the ab initio calculation, the two theorists found that the mechanism of superconductivity could be identified with enhanced uniform density fluctuations due to a one-to-one correspondence with the instability driven by first-order antiferromagnetic and nematic transitions. This result was surprising, considering the prevailing thinking that electron-density fluctuations had little bearing on superconductivity.

"We analyzed other iron-based superconductors and materials using the same theoretical method," Misawa said. "The important element involveed charge degrees of freedom, that

is, that the enhancement of uniform charge fluctuations plays a key role in stabilizing superconductivity."

"We are planning to examine whether the obtained mechanism is universal in high-T_C superconductors. To do so, we will perform ab initio calculations for other high-T_C materials such as the copper oxides." ❍

UBC Finds Charge Ordering in Electron-Doped Cuprates

Researchers from the University of British Columbia (UBC), The Canadian Light Source, the University of Maryland, the Max Planck Institute for Solid State Research, and the Canadian Institute for Advanced Research (CIFAR) have observed the onset of charge ordering in an electron-doped cuprate at a higher temperature than the pseudogap (doi: 10.1126/science.1256441). The findings demonstrate that charge ordering is a phenomenon found in all HTS cuprates. Understanding how it functions may help scientists to learn more about the specific superconducting mechanism in these materials.

The study was supported by the Max Planck-UBC Center for Quantum Materials, the NSERC's Steacie Memorial Fellowships, the Canada Research Chairs Program, the Natural Sciences and Engineering Research Council of Canada (NSERC), the Canada Foundation for Innovation (CFI), and CIFAR Quantum Materials. The x-ray experiments were performed at beamline REIXS of the Canadian Light Source, which is funded by CFI, NSERC, the National Research Council Canada, the Canadian Institutes of Health Research, the Government of Saskatchewan, Western Economic Diversification Canada, and the University of Saskatchewan.

Study Opens Parallel Avenue of Research

Within crystals, atoms and their electrons form highly organized periodic lattices. When charge ordering occurs, an instability causes some electrons to form new periodic patterns of charge that do not follow the underlying pattern of the atoms, preventing the formation of Cooper pairs. Charge order is a well-known phenomenon in hole-doped cuprates, where it appears to compete with superconductivity until a sufficiently low temperature ensures superconductivity's supremacy.

"This work demonstrates that charge ordering is truly universal," explained Professor Andrea Damascelli of UBC, who led the research team. "Our work last year showed it to be universal to all hole-doped cuprates (see *Superconductor Week*, Vol 28, No 2). Now we have discovered that electron-doped superconductors show the same phenomenology."

Eduardo da Silva Neto, the CIFAR Global Scholar who spearheaded the study, added: "Since understanding the mechanism for charge ordering formation is at the forefront of contemporary cuprate research, our discovery opens up a parallel avenue to learn about its microscopic origin. Specifically, we can now contrast what we know about charge ordering in both systems, hole- and electron-doped cuprates, in order to sort out which features are universal, and therefore elemental to charge ordering, and which are material-specific."

Charge Order at Higher Temperature than Pseudogap

The researchers conducted resonant x-ray scattering studies on $Nd_{2-x}Ce_xCuO_4$. They found that charge ordering occurs at a higher temperature than the pseudogap, countering the widely-held view that the pseudogap is a prerequisite of charge order.

"Our observations show that the charge ordering transition temperature is around 340 K, which is about 100 to 150 K higher than in the hole-doped cuprates," Damascelli said. "However,

it is more meaningful to compare the charge ordering temperature to the pseudogap temperature. This reveals a major discrepancy between hole- and electron-doped cuprates.

"Whereas in hole-doped materials the charge ordering temperature tends to be below or similar to the pseudogap temperature, in electron-doped cuprates it is more than twice the pseudogap temperature. The pseudogap phase was believed for the longest time to dominate this 'underdoped' regime of the cuprate phase diagram, at least at temperatures above T_c."

Damascelli and da Silva Neto outlined how further research would proceed: "At this stage we would like to perform in-depth measurements of different electron-doped cuprates. This would establish the commonalities and dissimilarities between the charge-ordering phenomenology in electron- and hole-doped cuprates." ❍

Study Proposes New Theoretical Descriptions for HTS

Researchers with the Max Planck Institute for Solid State Research, Stanford University, the Argonne National Lab, the University of Tokyo, and the Lorentz Institute for Theoretical Physics at Leiden University have published a study that concludes that new theoretical descriptions are necessary to resolve some remaining issues clouding current understanding of how HTS operates (doi: 10.1038/nature14165). In particular, the study looks at how string theory may be useful in advancing our understanding of HTS.

"We emphasize that the portfolio of theoretical methods different from string theory has been used quite successfully to demonstrate that superconductivity can be caused by repulsive electron-electron interactions," said Leiden Professor Jan Zaanen who co-authored the paper. "Since the energy scales of these microscopic interactions are large, the superconducting T_c's can be high, and therefore the problem of superconductivity at a high temperature is no longer regarded as a problem of principle. However, the normal state and especially the strange metal at optimal doping has evaded a reasonable explanation in terms of 'conventional' theory, and here string theory may make a big difference.

"We stress that AdS/CFT is not the only innovation on the theoretical side. Numerical methods such as DMRG and I-PEPs have been improving spectacularly over the last years. This profits from insights coming from quantum information theory.

"However, these are particularly suited to describe zero temperature properties and as such they have added significant insight to the physics of the pseudogap, intertwined order, and so forth. The dynamical mean field theory numerical method is, on the other hand, suited to address the finite temperature properties. This is, however, a bit of a black box and there are encouraging signs that these numerical results might eventually find an explanation in terms of the physics principles of the paper and pencil string theory."

String Theory Addresses Unconventional Matter

Zaanen touched on the importance of string theory to understanding unconventional HTS: "The way I see it, the arrival of string theory has moved high T_c research to a higher ambition level. The holographic duality of string theory addresses a very general physics problem: are there forms of matter that are completely different from the matter discussed in the text books of physics?

"It is well understood that the established mathematical methods fall fundamentally short in dealing with strongly interacting fermions at a finite density (the infamous 'fermion sign problem'). Holographic duality is the first mathematical method that can to a degree get around this mathematical obstruction, with holographic strange metals as the outcome. The

case can be made that this is genuine quantum matter in the sense that these strange metals are governed by highly collective quantum entanglement effects giving rise to completely novel physical behaviors.

"These in turn are surprisingly similar to the properties of the lab strange metals. Metaphorically, the copper oxide electron systems are the twenty-first century analogues of the gas-fluid system studied by van der Waals in the nineteenth century to prove the Boltzmann statistical physics view on matter.

"The difference is that the copper oxides are a test bed to find out what is happening in that part of reality that is not in the grip of Boltzmann's logic. This is about the very fundamentals of physics, having potential ramifications even for quantum gravity. Viewed from this perspective, the superconductivity itself is boring side show."

Unresolved Issues Cloud Understanding of HTS

While researchers have a qualitative understanding of the nature of the superconducting state itself, unresolved issues remain. These include the complexity of the phase diagram, the prominence of various forms of collective fluctuations, and the simplicity and insensitivity to material details of the 'normal' state at elevated temperatures.

"Perhaps the most striking prediction of holographic duality is precisely the complexity of the phase diagram," said Zaanen. "The basic view is completely different form what can be imagined departing from conventional theory.

"The strange metal is the central wheel. This exists at high temperature and the complexities of competing/intertwined order are 'born' in this strange metal state when temperature is lowered.

"The 'black holes' speak a clear language: the holographic strange metal is an intrinsically 'quantum frustrated' state that can go unstable in many directions. It can even be the birth place of a Fermi liquid. The highlight of this affair are surely the striking similarities between the 'black hole' strange metals and the normal state at elevated temperatures."

BCS Provides Model for LTS

Under BCS theory, superconductivity occurs at low temperatures when single electrons in a metal form Cooper pairs. Ordinary quantum theory suggests these paired electrons behave as one single particle with new properties.

BCS does not adequately describe the behavior of HTS cuprates. Under BCS, cuprates are expected to behave like normal metals with a certain amount of conductivity above the superconductivity threshold. However, the conductivity in HTS is much smaller than in simple metals.

String theory contains a number of dualities that offer different but equivalent description of a problem. One such duality is the AdS/CFT duality that connects quantum field theory with a theory of gravity. It suggests a holographic connection between the two, for which the field theory can be thought of as living on the boundary of an anti-deSitter space.

Study Builds on 2007 Research

In 2007, theoretical physicists began to approach holographic duality as a mathematical toolbox for use in the field of superconductors. It was found that certain phenomena, such as the behavior of strange metals, could be described as the holographic dual of a black hole.

"This is the magic of mathematics," said Zaanen. "It is for good reason that the AdS/CFT correspondence is generally regarded as the greatest mathematical result of string theory since it renders the equivalence of general relativity and the physics of strongly interacting quantum

systems to be mercilessly precise. It is actually the case that also conventional states of matter like superconductivity and Fermi liquids can be precisely enumerated in terms of Einstein equations, but these are now associated with the GR of stars instead of the black holes behind the unconventional metals.

"Holographic duality is just singular; it is a mathematical edifice of a complete new kind with powers that have no precedent elsewhere in the mathematics books of physics. It shares part of its machinery with the weak-strong (or Kramers-Wannier) duality of conventional quantum field theory/statistical physics..

"[This paper is an] encouragement [of the 2007 results], because it states that the condensed matter community should take holography seriously. At the same time it is as a review hopefully useful for string theorists to get a clear view on what matters most on the lab floor."

String Theory also to Benefit from HTS

String theory also benefits from the exchange of tools, especially in the field of quantum information. Regarding such topics as large-scale entanglement, there are many similarities with strongly correlated electron systems such as superconductors.

"String theorists need Eddington," added Zaanen. "Right now the status is that of suggestive resemblances between what is computed with AdS/CFT and what is measured in the lab. What is needed is the smoking gun: a highly counter-intuitive prediction that is miraculously confirmed in the lab.

"At present a concerted effort is unfolding in the holographic community aimed at such predictions. In fact, there is already a small portfolio of the kind lying ready but these invariably involve experiments that are difficult, if not impossible to realize in the lab.

"However, this field is now in a stage where active involvement of experimentalists starts to increasingly make sense. On the theoretical side, the AdS/CFT correspondence is still littered with mystery and the effort that started in 1997 to decode its real meanings is much helped by the condensed matter applications. Quantum information and the way it acts out in 'strange matter' is indeed crucial for the present advances on the theoretical frontier." ❍

Superconductivity Roundup

Events & Opportunities from Around the Industry

sw **Thomas Bachmann**, President of the **Bruker BioSpin Group** since August 2013, has submitted his resignation effective July 2015 in order to pursue other interests. He has reportedly accepted a position as President and CEO of the Eppendorf Group, headquartered in Hamburg, Germany, and will start in that position no later than August 1, 2015. Bachmann has been a member of the supervisory board of Eppendorf AG since 2013.

Bruker has agreed that Bachmann will continue as Bruker BioSpin group president that until the end of Q2 2015 to ensure management continuity. The company intends to initiate a search for a successor.

sw **MR Solutions** has announced the first installations of its 2G MRI cryogen-free magnet

technology at the National Institute for Health in Bethesda, Maryland; the University of Manchester, UK; the Korea Advanced Institute of Science and Technology; and the International Iberian Nanotechnology Lab in Portugal. Features of MR Solutions new technology include variable field operation , higher intrinsic magnetic field homogeneity, larger fields of view (FOV) elliptical in shape to better fit the subject, and automatic field ramping.

MR Solutions has also launched its new PreClinical Scan software which integrates MR Solutions' PET and SPECT technology. The company provides PET-MRI or SPECT-MRI imaging either for independent acquisition, sequential acquisition, or simultaneous acquisition. Optical and CT imaging capabilities are also possible.

sw **Transport Market Research Reports** has released a report entitled "More Electric Aircraft Market by Technology (Power Electronics, Thermal Management System, Safety Systems, and Advanced Material), by Platform (Commercial, Military, and UAV), by Geography - Forecast and Analysis to 2014 to 2020." The report predicts that the electric aircraft equipment market will grow at a CAGR of 4.62% from 2014 to 2020. Growth factors will include the need for optimized aircraft performance, decrease in operational and maintenance costs, reducing gas emissions and airport noise, and the increase in aircraft deliveries.

The aviation industry requires aircraft that are more fuel efficient than the current fleet. Superconducting technology offers a viable path to reach the power densities needed in airborne applications. The main issues involved in using superconductors for aero propulsion are the feasibility of superconducting electric propulsion and the integration of the technology into the aircraft.

sw **Superconductor Technologies Inc.** (STI) has entered into warrant exercise agreements with certain holders of outstanding warrants to purchase an aggregate of 916,857 shares of common stock. The warrants were originally issued as part of an underwritten public offering that closed on August 9, 2013. Under the terms of the agreements, the exercise price of the warrants was adjusted immediately prior to their exercise to $2.00 per share, down from $2.57.

STI expected to receive about $1.83 million from the warrant exercise. The company had previously forecast that its cash resources were sufficient to fund its planned operations well into Q1 2015.

With the proceeds of the warrant exercise, cash reserves are expected to be sufficient to fund the company's operations until well into Q2 2015. STI's share price declined by 19.4%, from $2.73 to $2.20, on the day that the warrant exercise agreements were announced.

sw The **U.S. FDA** recalled almost 13,000 **GE Healthcare** superconducting MRI systems due to employee error and in response to a safety incident in India. Such a Class I recall is issued when the unit could cause a death or serious harm to a patient. The FDA notice was not related to any manufacturing defect or product-related error.

The action instructs MRI customers to perform a five-minute check to ensure no one on site post-installation has disconnected the magnetic rundown unit (MRU), which is effectively an emergency off switch for the magnet. Once the check is confirmed, MRI operations can continue as normal.

sw **The 12th European Conference on Applied Superconductivity** (EUCAS 2015) has issued a call for abstracts. The conference will be held in Lyon, France, on September 6 to 10, 2015.

Abstract submission is open until March 27, 2015. Further information is available at http://www.eucas2015.org. First time papers accepted after peer review will be published in a special issue of the IEEE Transactions on Applied

Superconductivity in 2016.

sw The **2nd International Conference on Recent Trends in Nanomagnetism, Spintronics, and their Applications** (RTNSA) is being held at the Palacio de Barrena in Ordizia, Gipuzkoa, Spain, on June 30 to July 3, 2015. It will be followed by the **7th International Workshop on Magnetic Wires** (IWMW) at the same location on July 2 to 3, 2015. Further information about both conferences is available at: www.ehu.eus/en/web/rtnsa-iwmw2015/home.

sw **The International Conference on Magnet Technology** (MT24), will take place in Seoul from October 18 to 23, 2015. The conference will cover magnet technology ranging from large-scale magnets to magnets for home appliances.

Conference actvities will include a visit to the Korea Superconducting Tokamak Advanced Research (KSTAR) facilities which is operated by the National Fusion Research Institute. Early registration will begin on June 1. More information is available at http://www.mt24.org/

sw **Bruker Corporation** is sponsoring a workshop entitled "An Eye on the Future of Imaging" on March 18 at the European Molecular Imaging Meeting in T¸bingen, Germany.

The workshop will focus on the development, testing, and bringing-to-market strategies of contrast agents of multiple imaging disciplines, including MRI. Further information is available at: www.bruker.com/events/2015/mr/bruker-industry-workshop-at-emim-2015.html

sw **The Nanotechnology Forum for Indian Scientists** (NT Forum) has announced that **Arindam Ghosh** from the **Indian Institute of Science** (IISC) in Bangalore is the first winner of the Oxford Instruments (OI) Young Nanoscientist Award 2015. The NT Forum was formed in 2014 and launched the award to acknowledge outstanding research in the field of fabrication and characterisation of nano materials and structures in physical or bio nanotechnology.

The NT forum received 43 nominations for the award. Ghosh's winning nomination is titled: "Thermodynamic and Transport Properties of Emerging Low-Dimensional Materials."

sw **HEPTech**, together with the **French National Center for Scientific Research** (CNRS), the **French Atomic Energy Commission** (CEA), **Grenoble University**, the **Alliance of Nanoscience Energy Labs** (Lanef), and the **Laue-Langevin Institute** (ILL), in partnership with the **Center for European Nuclear Research** (CERN), the **University of Twente**, and **Rutherford Appleton Lab**, is organizing an **Academia Industry Matching Event on Cryogenics** in Grenoble at the Chamber of Commerced and Industry (CCI)on June 4 and 5, 2015. The event aims to explore the subject of cryogenics and its impact in society and research.

Topics that will be covered include:

- Cryogenic Systems for high energy physics at accelerators, neutron facilities, and related applications
- Cryogenics for astrophysics/high energy physics in space
- Industrial spin-offs, such as MRI, NMR. and energy-related applications

In addition, the First General Assembly of the new **Cryogenics Society of Europe** will take place during the first session. Registration will open during the first weeks of March. Further information is available at: inac.cea.fr/Phocea/Vie_des_labos/News/index.php?id_news=1317

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

~Insert~

March 10, 2015 Vol. 29, No. 2

Superconductivity Stock Index

Company Name	Symbol	Prices ending 31-Dec-2014	Prices ending 27-Feb-2015	Percentage change
American Superconductor	AMSC	0.74	0.83	12%
Oxford Instruments	OXIG.L	19.51*	17.94*	-8%
Superconductor Technologies	SCON	2.77	2.00	-28%
Bruker Corporation	BRKR	19.62	19.03	-3%
Furukawa Electric	5801	16.78**	17.72**	6%
Ion Beam Application	IBAB.BR	17.35***	21.38***	23%
Superconductor Index (12/31/12 = 100)		100.00	89.74	1%
Standard and Poor's 500		1848.36	2,058.90	10%

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

MRI Apparatus Using SQUIDs and Field-cycling

2014-09-16

U.S. Patent No. 8838200

There is described an MRI system in which the detection of the NMR signal is performed by a resonant input at a median field range above 100 gauss and where the main field is cycled to a low field of below 50% of the resonant frequency after the excitation of the NMR signal for a period sufficient to develop differences in magnetization. The advantage of this system is that images can be generated at much lower field intensities than prior art systems and is able to detect abnormalities in tissue such as cancerous tissues in a patient.

SC Quantum Circuit Having a Resonant Cavity

International Business Machines Corporation

2014-09-23

U.S. Patent No. 8841764

A quantum electronic circuit device includes a housing having an internal resonant cavity, a qubit disposed within a volume of the internal resonant cavity and a non-SC metallic material mechanically and thermally coupled to the qubit within the internal resonant cavity and contiguously extending to the exterior of the housing.

SC Rotating Machine Having Cooler for Rotator

Doosan Heavy Industries & Construction Co., Ltd.

2014-09-23

U.S. Patent No. 8841803

A SC rotating machine having a cooler for a rotator is provided. The SC rotating machine includes a rotator wound with a SC coil, a stator enclosing the rotator and separated therefrom by a predetermined gap, the cooler having a cold head directly attached to the rotator and at least one compressor connected with the cold head, and a flexible coupling disposed between the cold head and the compressor and enabling a cryogenic refrigerant to flow therein. The cold head is directly connected to the rotator, and the cold head and the compressor are

driven using the flexible coupling, so that it is possible to prevent vibration of the compressor and enhance cooling efficiency by thermally separating the cryogenic cold head from the compressor.

Wind Turbine with Sealed Off Stator Chamber
Envision Energy ApS
2014-09-30
U.S. Patent No. 8847424
A wind turbine having a wind turbine tower with a nacelle; a wind turbine rotor hub with at least one rotatably mounted wind turbine blade; a shaft coupled to the wind turbine rotor hub and a generator. The generator has a rotor with at least one SC rotor coil arranged rotatably relative to a stator having at least one stator coil. The rotor is arranged in a rotor housing and the stator is arranged in a stator housing, the housings being separated by a rotor-stator gap. The stator housing has a stator inner shell and a stator outer shell connected together by at least one stator housing end plate. The stator inner shell has a first inner shell element attached to a stator iron which is connected to a second inner shell element. A pressure plate is attached to the second inner shell element and the stator outer shell.

SFCL
Rolls-Royce plc
2014-09-30
U.S. Patent No. 8848323
A SFCL comprises a SC element having a plurality of SC portions and at least one connector. Each SC portion has end regions and each connector is connected to the end regions of adjacent SC portions to electrically and thermally connect adjacent SC portions of the SFCL together. Each connector provides a local reduction in the critical current and quench current of the end regions of the SC portions in contact with the at least one connector. This provides a phased transition of the SFCL in relation to the severity of a fault current.

HTS Magnet System
Babcock Noell GmbH
2014-09-30
U.S. Patent No. 8849364
The invention relates to a HTS magnet system, preferably for an insertion device for generation of high-intensity synchrotron radiation, consisting of the coil body, on the mantle surface of which poles with windings that lie between them are disposed, wherein at least one HTS strip is wound onto the coil body in one direction, and adjacent winding packages or sections are electrically connected with one another in such a manner that the current flow runs in opposite directions, in each instance. The solution according to the invention has the advantage of a simplified winding process, whereby individual coil pairs can be replaced, if necessary, by means of the modular arrangement. The scheme can be applied to every possible configuration of an insertion device, and is therefore also suitable for use in so-called free electron lasers and other light sources based on particle accelerators. Furthermore, complicated cooling is eliminated, so that safety problems caused by lack of cooling cannot occur.

Low Temperature Resistor for SC Circuits
Northrup Grumman Systems Corporation
2014-10-07
U.S. Patent No. 8852959
An integrated circuit and methods for fabricating the circuit are provided. The circuit integrates at least one circuit element formed from a material that is SC at temperatures less than one hundred mK and at least one resistor connected to the circuit element. The resistor is formed from an alloy of transition metals that is resistive at temperatures less than one hundred mK.

Systems and Methods for SC Flux Qubit Readout
D-Wave Systems Inc.
2014-10-07
U.S. Patent No. 8854074
Systems and methods for reading out the states of SC flux qubits may couple magnetic flux representative of a qubit state to a DC-SQUID in a variable transformer circuit. The DC-SQUID is electrically coupled in parallel with a primary inductor such that a time-varying (e.g., AC) drive current is divided between the DC-SQUID and the primary inductor in a ratio that is

dependent on the qubit state. The primary inductor is inductively coupled to a secondary inductor to provide a time-varying (e.g., AC) output signal indicative of the qubit state without causing the DC-SQUID to switch into a voltage state. Coupling between the SC flux qubit and the DC-SQUID may be mediated by a routing system including a plurality of latching qubits. Multiple SC flux qubits may be coupled to the same routing system so that a single variable transformer circuit may be used to measure the states of multiple qubits.

Metal Laminated Substrate

Toyo Kohan Co., Ltd.
Sumitomo Electric Industries, Ltd.
2014-08-26
U.S. Patent No. US8815777

A metal laminated substrate for an oxide SC wire is produced by removing, in a state where a copper foil to which rolling is applied at a draft of 90% or more is held at a temperature below a recrystallization temperature, an absorbed material on a surface of the copper foil by applying sputter etching to the surface of the copper foil; removing an absorbed material on a surface of a nonmagnetic metal sheet by applying sputter etching to the surface of the nonmagnetic metal sheet; bonding the copper foil and the metal sheet to each other by reduction rolls at an applied pressure of 300 MPa to 1500 MPa; orienting crystals of the copper by heating a laminated body obtained by bonding at a crystal orientation temperature of copper or above; and forming a protective layer on a copper-side surface of the laminated body by coating.

SC Coil Apparatus

Mitsubishi Heavy Industries, Ltd.
2014-08-26
U.S. Patent No. US8818471

It is desired to perform assemble, disassemble, maintenance and the like, especially of a large site SC coil device, in a short time. The SC coil device includes a plurality of coil units arranged in a circle circumference to form a toroidal shape. Each of the plurality of coil units includes a cryostat and a SC coil stored in the cryostat, and has a first surface parallel with a radius of the circle circumference and a second surface parallel with the radius of the circle circumference and arranged in a first direction side of the circle circumference to the first surface. The first surface contacts with the second surface of a coil unit adjacent in one direction among the plurality of coil units. The second surface contacts with the first surface of a coil unit adjacent in other direction among the plurality of coil units.

SC Magnet Apparatus

Samsung Electronics Co., Ltd.
2014-09-02
U.S. Patent No. US8823476

Provided are a SC magnet apparatus with a switch that automatically connects or disconnects an external power source to a SC coil, and a method of controlling the same. The SC magnet apparatus includes a SC coil that generates a magnetic field when an electric current from an external power source is applied thereto, and a switch that supplies or shuts off an electric current output from the external power source by connecting or disconnecting the SC coil to the external power source.

SC Switch

Rolls-Royce PLC
2014-09-16
U.S. Patent No. 8838192

This invention is a high voltage SC switch comprising: a length of SC having a switching portion located within an air gap; a magnetic circuit including at least one flux guide having ferrite pole pieces defining an air gap in which a switching portion of a SC can reside in use and at least one primary magnetic flux source located within the circuit so as to provide a quenching magnetic field across the air gap via the ferrite pole pieces.