Superconductor Week
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August 31, 2014 Vol. 28, No. 8

NIFS Tests 100 kA HTS GdBCO Coil

Researchers at the National Institute of Fusion Sciences (NIFS) in Japan, a subdivision of the National Institutes of Natural Sciences (NINS), have achieved an electrical current of 100 kA in a HTS GdBCO coil-shaped conductor sample. NIFS is developing the HTS coil for use in a magnetic confienment fusion (MCF) reactor magnet.

Funding for the project was provided by the Japanese government through NINS as Management Expenses Grants. NINS is an inter-university research institute under the Japanese Ministry of Education.

100 kA Record Current for HTS Conductor

"A conductor current of 100,000 A is sufficient for fusion magnets," said Nagato Yanagi, Professor at NIFS who was in charge of the coil's development. "Presently, ITER is equipped with 68 kA conductors. For the DEMO reactors, demonstration fusion reactors following ITER, 100 kA is the standard target.

"The record for current that has been applied to a superconducting conductor is 303 kA for a cable-in-conduit (CIC)-type conductor fabricated in 1990 using LTS strands of NbTi. Superfluid helium was used as coolant and the operating temperature was 1.8 K. This conductor was supposed to be developed for a large-scale superconducting magnetic energy storage (SMES) system.

"Compared to this record, our 100 kA is still lower, however ours is presently the world's highest among HTS conductors. Put differently, this is the world record for current conveyed through a superconductor at a temperature above 4 K. It is also notable that other HTS conductors being developed in the EU and U.S. have currents below 10 kA."

GdBCO Tapes Produced by Fujikura

The GdBCO tapes used in the coil were developed and produced in Japan. Fujikura Ltd. provided the tapes used in the experiment.

"Yttrium-based HTS wire has been intensively developed in Japan as part of a national project," said Yanagi. "The latest GdBCO tape produced by Fujikura achieves an

I_c >600 A at a 10 mm width and 77 K under self-magnetic field.

"We used multiple tapes to create a large-current capacity conductor to be used in large-scale magnets. This is the simplest configuration and the largest I_c that can be achieved by allowing a formation of non-uniform current distribution among the HTS tapes. Other types of HTS conductors developed mainly in the EU and U.S. employ twisting and transposition of HTS tapes.

"The twisting and transposition techniques are presently regarded as the standard method for making a large-current capacity conductor, which ensures uniform current distribution and low AC losses. This has been regarded as an indispensable method for making LTS conductors.

"We considered the idea that the HTS conductor could be fabricated without following this standard method, and thus chose a simple method of stacking the tapes. Since the helical fusion reactor will be operated in DC mode, we do not have to worry about the AC losses that are associated with tokamaks."

Stacking Eliminates Voids, Weak Points

Yanagi discussed the benefits of tape stacking: "The stacking of HTS tapes is the simplest way to make a large-current capacity HTS conductor. At the same time, one can make a mechanically strong conductor since there are no voids or weak points. Voids and weak points in the HTS tapes cannot be avoided via the twisting and transposition of tapes.

"We simply take HTS tapes and stack them in a copper and stainless steel jacket to form a large-current capacity conductor. With respect to the cost of such a conductor, the stacking method should be the cheapest one.

"A main target application for these YBCO tapes, other than use in fusion reactors, is use in transmission cables. Another target is small-scale magnets for electric devices, such as motors and transformers. MRI magnets and accelerator magnets used for cancer treatments are also being developed."

Prototype Tested at 20 K, J_c Exceeds Requirement for Fusion Magnet

NIFS developed the low-resistance joint technology used in the conductor joints in collaboration with Tohoku University. A prototype

Superconductor Week

Superconductor Week (ISSN 0894-7635) is published 12 times a year by **Peregrine Communications**

Publisher: Klaus Neumann

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conductor test carried out at 20 K realized an electrical current exceeding 100 kA. The overall J_c exceeded 40 A/mm^2, including the jackets.

"The maximum magnetic field during testing was 7 T using the maximum 9 T background field coil facility at NIFS," said Yanagi. "We are now constructing a new 13 T magnet facility. Another test of our HTS conductor sample will be carried out in 2015.

"We chose a mechanically connected lap-type joint. The alternate choice would be to apply solder. We confirmed that an equivalently low contact resistivity could be achieved with a mechanical joint.

"We achieved a low resistance of 2 nano-ohms with a mechanical joint. We applied a maximum stress of 100 MPa during the fabrication of the joint. Since we used an induction method to supply the sample current, a low resistance ensures a high current with a fixed change of the bias magnetic field.

"The prototype conductor was fabricated using bolts to form the stainless steel jacket. We need to use welding instead of bolts for the actual conductor to be used in fusion magnets. This type of conductor will have to be fabricated and tested in the near future."

Yanagi added that the current could be further improved: "We believe that a GdBCO or YBCO tape with a >1,000 A I_c will be produced in the near future. In the present experiment, the high I_c of the GdBCO tapes produced by Fujikura was the key technology for the achievement of 100 kA current.

"Note that if we had used other tapes with a lower I_c, we would need to use more tapes to achieve the same overall current. In that case, the conductor may have become too fat to be installed in the present facility and the experiment would not have been possible."

54 GdBCO Tapes used in the Conductor Sample

54 HTS GdBCO tapes were used to produce the conductor sample. Each tape is 10 mm in width and 0.2 mm in thickness, and the electrical current is limited to that area.

Together with an exceptionally strong and flexible substrate, the conducting area was surrounded by a copper jacket and a stainless steel jacket, while the electric current was induced by magnetic induction. The conductor length was ~3 m for the present sample.

"The stacked tapes can be produced in other dimensions," said Yanagi. "We can make smaller or bigger conductors by varying the number of tapes or the width of tapes.

"It all depends on the purpose and application. The substrate material used was Hastelloy.

"The advantage of sequentially connecting HTS conductors with short unit length is that huge and/or complex coils like the helical coils for the helical-type fusion reactor can be manufactured with the presently available technology. Furthermore, we do not need long unit lengths for the tapes. Generally, a higher I_c is obtained with a shorter unit production length." ❍

U.S. Navy Developing SC EMP Generator

The U.S. Navy recently patented a superconducting stator that enables a magnetic flux compression generator to produce an electromagnetic pulse (EMP) (see U.S. Patent No. US8723390 in the *U.S. Superconductivity Patents* section, this issue). The patent is jointly filed by scientists from the Naval Surface Warfare Center Dahlgren Division (NSWCDD) in Dahlgreen, VA, and the Naval Surface Warfare Center (NSWC) Carderock Division in West Bethesda, MD.

"Most conventional magnetic flux compression generators are explosively driven, dangerous to handle, and limited to one-time use," said Albert

Corda, NSWCDD Physicist. "The novel architecture of the generator described in this patent, however, is not explosive in nature. It's inherently safer to handle and potentially reusable."

Work on Stator Began in 2008

An EMP is characterized as a broad band signal with a frequency-power distribution ranging from a few hundred kilohertz to a few gigahertz. The magnetic flux compression generator is designed to generate a high voltage pulse output that can be incorporated into an EMP generator. Work on the magnetic flux generator began as NSWCDD and NSWC Caderock researchers collaborated at the Chief of Naval Operations Strategic Studies Group in 2008.

"The idea originated from a side-bar discussion that centered on the utility of HTS materials," said Jack Price, NSWC Carderock Scientist. "Someone posed a 'what if' question.

"We earnestly discussed all the possibilities and technical difficulties and the concept was born. The architecture provides elements of scalability and control not possible with conventional magnetic flux compression generator designs"

The concept resulted in a device designed to produce a short duration, highly localized electromagnetic pulse controlled by a SC stator that also enables multiple activations of the flux compression generator. Conventional magnetic flux compression generators have been in existence since the 1950s with initial work for the U.S. being carried out at Los Alamos, NM. Now, much smaller generators featuring high power pulses with very fast rise times can be made.

Price: SC Stator Practical, Affordable

"The proposed superconducting stator is potentially practical and affordable given the commercial availability of HTS materials that operate at liquid-nitrogen temperature," said Price. Military and industrial applications depend on the output configuration but can range from the production of broadband radio frequency transmissions to the rapid acceleration of physical mechanisms to high velocities.

"Each of the warfare center divisions has areas of expertise," said Blaise Corbett of the NSWCDD EMP Assessment Group. "NSWCDD has a history and expertise in pulsed power systems and applications. Carderock has expertise in HTS materials and applications, as evidenced by their development of a HTS degaussing system and motor."

In 2008, Researchers with NSWC Carderock and AMSC developed the first ship degaussing system to use HTS materials (see *Superconductor Week*, Vol 22, No 12). AMSC President and CEO Daniel McGahn recently indicated that he viewed securing a contract from the Navy for AMSC's degaussing ship protection system as a key milestone anticipated for FY2014 (see *Superconductor Week*, Vol 28, No 5). ❍

Dartmouth Develops Laser Based on SC Electrons

Researchers from Dartmouth College, the University of Nottingham, and the National Institute of Standards and Technology (NIST) have developed a laser that uses a single artificial atom to generate and emit particles of light and that is the first laser to rely exclusively on superconducting electron pairs. The laser may play a role in the development of quantum computing technology.

The majority of the funding for the work on the laser came from the National Science Foundation (NSF), with additional funding coming from the Defense Advanced Research Projects Agency (DARPA). The total amount of funding was on the order of $500,000 spread over multiple years.

"The fact that we use only superconducting pairs is what makes our work so significant," said

Alex Rimberg, Professor at Dartmouth who helped develop the new laser. "The artificial atom is made of nanoscale pieces of superconducting aluminum. The reason for using the artificial atom is that you can now make it part of an electrical circuit on a chip, something you can't do with a real atom, and it means that we have a much clearer path toward interesting applications in quantum computing."

Laser Could Transmit Data

The new laser converts electrical energy into light. That light has the potential to transmit information to and from a quantum computer.

"With a quantum computer you have to get the information from point A to point B," said Rimberg. "A computer that does a calculation but has no way of getting the information anywhere else isn't particularly useful. Our laser might offer an easy way of producing the kinds of weird quantum states of light that could be used to carry quantum information around.

"Lasers are useful [for transmitting information] because they are highly coherent. [In addition to quantum computing applications,] the laser could possibly also be used for high-precision, quantum-enhanced measurements. This assumes that the laser is less 'noisy' than a standard laser, something we hope is true but haven't proved."

SC Mirrors used to Minimize Losses

Light from the laser is produced by applying electricity to an artificial atom. This causes electrons to hop across the atom and, in the process, produce photons that are trapped between two superconducting aluminum mirrors.

The researchers placed the laser in a microwave circuit in order to measure its properties. However, the laser was the only device subjected to measurement, with the remainder of the circuit made of microwave amplifiers and other components.

"The mirrors had to be superconducting to minimize losses," said Rimberg. "We used a DC voltage to give energy to the Cooper pairs. We intentionally gave them just enough energy for them to emit a photon into the cavity.

"The energy conversion occurs when the Cooper pairs tunnel, since in order to do so they have to give up the extra energy they've been given. When that energy exactly matches the energy of a photon, tunneling is much more likely to happen."

Laser emits 100 Million Photons/Second

Rimberg added that it was not yet certain the volume of information the laser could transmit: "At the moment, the laser gives off photons at a rate of about 100 million photons/second, but I'm unsure how much information we can get into each photon. We could probably increase the rate of photon emission, though so far that hasn't been our focus.

"[In terms of its current operations] the laser is pretty stable, but it normally requires readjustment of the bias voltage every 30 minutes or so to continue emitting. That performance could easily be improved by use of a feedback loop. The next steps in the development of the laser are to try to determine more precisely what the quantum state of the laser light is and see if it in fact does have interesting properties, such as for instance less noise than is possible for a classical laser light." ❍

Elettra Synchrotron Leads Laser-based Study of Pseudogap

A research team led by scientists at the Elettra Synchrotron's T-ReX Lab, the University of Trieste, and the Catholic University of the Sacred Heart in Brescia, Italy, has used ultra-short light pulses to probe the pseudogap state in HTS cuprates. Understanding the pseudogap, a state above T_c in which some of the properties of superconductivity are preserved, has been a major challenge in understanding HTS in cuprates.

Other collaborators on the study include researchers from the University of Milan, the National Institute of Advanced Industrial Science and Technology in Tsukuba, Japan, the University of Minnesota, the University of Geneva, the University of British Columbia, the University of Duisburg-Essen, and the International School for Advanced Studies (SISSA) in Trieste. The over €1 million ($1.3 million) in funding for the research was provided by a variety of sources including:

- Internal support from the Elettra Synchrotron and the Catholic University of the Sacred Heart
- The EU's Seventh Framework Program (FP7 2007 to 2013) GO FAST Project
- The Italian Ministry of University and Research
- The European Research Council through FP7/ERC Starting Grant SUPERBAD
- The Mercator Research Center Ruhr
- DOE, Basic Energy Sciences
- The Alfred P. Sloan Foundation and Alexander von Humboldt Foundation
- The Natural Sciences and Engineering Research Council of Canada, the Canada Research Chairs Program, Canadian Institute for Advanced Research
- The Swiss National Science Foundation
- The Open Access has been funded by the Catholic University of the Sacred Heart and the Elettra Synchrotron

"We used two families of cuprates, $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi2212) and $HgBa_2CuO_{4+\delta}$ (Hg1201), because they have the same T_c despite having markedly different crystal structures," said Federico Cilento, Researcher at the Elettra Synchrotron who co-authored the study. "We also liked the fact that one [material], Hg1201, has a single-layer while the other, Bi2212, is a bilayer.

"This allowed us to state that the property we revealed, the photo-enhanced conductivity, is a universal feature among cuprates. In fact, Bi2212 was chosen because it is the only cuprate compound where photoemission gives consistent results, while Hg1201 was chosen since it is a single-layer compound with the same T_c as Bi2212. This choice therefore helped a lot when drawing the phase diagram."

Ultra-short Light Pulses Capture Properties Hidden at Equilibrium

The researchers used ultrashort light pulses to prepare a non-thermal distribution of excitations and capture properties that are hidden at equilibrium. Using a 0.5 to 2 eV probe, the scientists were able to track the dynamics of the dielectric function and unveil an anomalous decrease in the scattering rate of the charge carriers in a pseudogap-like region of the temperature and hole-doping phase diagram.

"We used light pulses for two reasons," said Cilento. "First, using ultrashort light pulses allowed us to gain access to the 'time domain,' the domain in which the relaxation dynamics of an excited system can be accessed. This provides information about the nature of the electron-phonon scattering processes that contributed to the re-equilibration of the excess energy injected into the system by the pump pulse.

"Second, a light pulse can create a k-space distribution of quasiparticles that is different from what can be achieved at equilibrium. This is the reason why we said the property we observed is hidden at equilibrium.

"We can also populate the anti-nodal region of the Brillouin zone, which is gapped. This is enabled because we used photons at 1.5 eV, the anti-nodal gap being ~40 meV, and the thermal kT being ~20 meV at the temperature at which the pseudo-gap closes."

First Use of TR-ARPES Measurements in Pseudogap

Cilento said the study followed up on previous research: “Our work is not the first example of ultra-short light pulses used to probe the pseudogap via time-resolved reflectivity. However, this is the first work where TR-ARPES measurements in the pseudo-gap are reported.

“More importantly, the optical measurements in reflectivity we reported are novel because we exploited a broadband probe pulse covering the 0.5 to 2 eV energy range. This probe pulse is a novelty and allowed us to reveal the decrease of the scattering rate. This rate decreases by a few attoseconds, given that the equilibrium value is a few fentoseconds.

“This information was not extracted from the time-domain, obviously, but from the probe energy domain, where a decrease in the scattering rate produces a peculiar spectral fingerprint. This technique allowed us to understand the microscopic origin of a signal that was already observed, but never really understood.”

Scattering Rate of Charge Carriers an Anomalous Behavior

Cilento added that the scattering rate provided information on anti-nodal quasi-particles: “This is the first time an effect similar to the scattering rate of the charge carriers has been measured. It is significant because it is an anomalous behavior.

“It tells us about the nature of anti-nodal quasi-particles, teaching us more about the nature of the pseudo-gap. It also tells us that we are photo-inducing a state of matter which is ‘more metallic,’ hence the term photo-enhanced conductivity.

“This is a novel result, however, there were some indications of a similar trend coming from the Cluster Dynamical Mean Field Theory (CDMFT) solution of the Hubbard model. The photo-induced decrease in the scattering rate, which we linked to a property of the anti-nodal quasi-particles alone thanks to photoemission measurements, tells us that the ground state of these anti-nodal quasi-particles is a state where strong electronic correlations that tend to localize carriers are present. We make these quasi-particles less localized and more metallic when we provide energy to them with a pump pulse.

“The temperature onset of this effect exactly matches the T* line in the phase diagram, drawn by other experimental techniques at equilibrium, telling us that the onset of the pseudo-gap phase coincides with the emergence of strong electronic correlations affecting the anti-nodal region of the BZ. Finally, our experimental results are confirmed by the prediction of the model, i.e., the solution of the 2D Hubbard model through CDMFT.”

Possibility of Controlling SC Characteristics via Laser Pulses

In addition to providing information on the pseudogap in cuprates, the study opens the possibility of controlling a superconductor’s characteristics by means of laser pulses. Cilento commented on how extensive this control could be: “The ultrafast control of superconducting properties is one of the main goals of our research on cuprate materials.

“This includes both the attempt to control, via quenching, the superconducting state, and the appealing attempt to photo-induce superconductivity via ultra-short light pulses. The Go-Fast Project, an FP7 Framework EU Project, is devoted to this topic is and has partly financed our research. In addition to the control of superconductivity by means of ultra-short light pulses, the next step in the study of cuprates via non-equilibrium spectroscopies is the development of a deeper understanding of and modeling the out-of-equilibrium properties of cuprates.” ❍

Cornell/BNL Team Finds Broken

Symmetry in Cuprate Pseudogap

Researchers with Cornell University and Brookhaven National Lab (BNL) have identified that previously observed density waves that seem to suppress superconductivity are linked to an unprecedented electronic broken symmetry, offering information as to why superconductivity doesn't happen at higher temperatures. The research is funded primarily by the DOE and the UK Engineering and Physics Research Council.

The work was conducted under the auspices of the Center for Emergent Superconductivity (CES), a DOE Energy Frontier Research Center (EFRC) based at BNL dedicated to the discovery of new superconducting materials (see *Superconductor Week,* Vol 23, Nos 8 & 10). Other project collaborators include researchers at Harvard University and Binghamton University.

State Never Before Experimentally Observed

"This exotic state has been predicted for decades," said J.C. Seamus Davis, Professor at Cornell and Director of the CES. "It's a pattern of electronic structure in a crystal that has never been seen experimentally before, in any material.

"$Bi_2Sr_2CaCu_2O_8$ and $Ca_{2-x}Na_xCuO_2Cl_2$ were chosen [for this study] because they are two representative cuprates whose various crystal lattice, dopant site, tunneling matrix, and other properties are extremely different. Any common characteristics of electronic structure (e.g. a d-form factor density wave) observed can then be deduced to be a fundamental and universal characteristics of cuprates."

The pseudogap is an intermediate phase between superconductivity and insulation in cuprates. It contains electrons that ought to be available to form Cooper pairs but instead appear to be absorbed by another electronic state. The pseudogap state often appears above T_c, and understanding how it relates to the emergence of the superconductive state is a major scientific and practical goal.

Many previous observations have shown that in the pseudogap state electrons in cuprates form density waves alternating rows of many or fewer electrons. Theorists suggest the these waves might block superconductivity.

The copper oxide layers in cuprates are made up of L-shaped cells consisting of a copper atom joined to two oxygen atoms, linked together in orderly rows. Another pseudogap phenomenon previously observed at Cornell is that the energy levels of the electrons are mismatched between east-west versus north-south bonds.

Study Employs New Approach

The recent study employed a new approach in which the researchers created separate images that showed the electronic structure of a cuprate just around the copper atoms, just around the oxygen atoms east and west of the copper, and just around the oxygen atoms to the north and south. They found that the asymmetry varies gradually from one unit cell of the crystal to the next, and a graph of the changes looks like the familiar sine wave, paralleling the observed density waves.

"You have to know your enemy to vanquish him," Davis said. "Here at last we reveal the identity of that enemy.

"That density wave is modulating the intra-unit-cell asymmetry. There are more electrons 'north' than 'west' of a copper atom at one location.

"As you pull back you see that this property is varying in space so that, after half a wavelength, there are more electrons 'west' than 'north' of their copper atom. After a full wavelength, there are more electrons to 'north' than 'west' once again. Then the cycle repeats.

"[Previous studies were unable to identify the broken symmetry present in the pseudogap state because that] required the visualization of the electronic structure inside each crystal unit cell. This technique was only invented three years ago and is unachievable for most research groups. The technique has great potential for future studies of complex electronic matter [and is not limited to studying the pseudogap in cuprates]."

Davis added that the results had been predicted: "Based upon our earlier work (http://www.sciencemag.org/content/315/5817/1380), these results were predicted by a raft of theorists. As far as we understand, these results are highly specific to cuprates. Now we need to explore the whole phase diagram using our ability to quantify the d-form factor density wave and understand where it exists and how it impacts superconductivity." ❍

SLAC Proposes Variable Coupler for 1.3 GHz SRF Cavities

Researchers with the Stanford Linear Accelerator Center (SLAC) have proposed a conceptual design for a variable coupler for 1.3 GHz SRF cavities without physical contact from the input waveguide and cavity receiver. The work was supported by DOE Contract No. DE-AC02-76SF00515.

"Current designs for superconducting RF couplers come in the form of RF waveguide or coaxial cable couplers," said SLAC Research Associate Chen Xu, who helped to design the new variable coupler. "Waveguide couplers are easy to manufacture but always provide for coupling in a fixed manner. This makes it harder to test a cavity and adjust the coupling, but waveguide couplers allow for a higher RF power to be transmitted than a coaxial cable coupler.

"Coaxial cable couplers have a central conductor, which makes it easy to adjust or change the coupling. However, in most cases the central conductor operates in a normal conducting state despite being made out of niobium. Cooling these couplers is quite difficult and vacuum windows are used for vacuum isolation.

"Coaxial cable couplers always generate higher static losses than waveguide couplers for this reason. If an accelerator is operated in continuous wave (CW) mode, the static loss ratio is minimized over the total loss ratio.

"However, particle collider accelerators such as International Linear Collider (ILC) are operated in pulse mode. Static loss reduction is thus one of the main goals for our proposed RF coupler/cyromodule design.

"Static loss in a RF coupler originates mainly from the contact between the cold part and warm parts of the coupler. Superconducting cavities are always operating within a cyro-module at temperatures around 2 K to 4 K. The cavities are surrounded by a helium vessel jacket while the RF power is guided into the cavities through couplers.

"A coupler has one end at 2 K while the other end endures temperatures of 300 K. With a relatively short length, there is a huge temperature gradient on the coupler. Cryogenic capability can easily be lost from this coupler segment because the other parts of the cavities are equipped with good temperature shielding."

Prototype of Coupler Under Construction

Xu said that a prototype coupler is under construction: "We are actually machining this coupler. We obtained a sapphire rod from a photonic band gap cavity from a pervious collaboration. SLAC has a state-of-art machine for cutting the copper for high-gradient S/X band cavities.

"The original coupler design was developed on-site for the Linac Coherent Light Source-II (LCLS-II) project. Because of the short time frame and the limited budget for fundamental R&D for LCLS-II, we are moving on to the future ILC project or any other SRF projects in Europe.

"It is fairly easy to adjust this coupler for different frequencies. However, it is not scalable in size. Moreover, it requires more tuning and adjustment regarding the shape of center sapphire rod and the outer conductor."

LCLS-II is an upgrade to the SLAC's LCLS project and is expected to come online in 2019. It will add two new x-ray laser beams and a room for additional new instruments, increasing the number of experiments carried out annually. LCLS currently produces x-ray pulses for the SLAC's 2-mile long linac.

Coupler Nearly Eliminates Static Heat Loss

The study seeks to improve a type of coupler known as a TTC-3 coaxial type input coupler. TTC-3 coaxial type input couplers generate a static heat loss of 0.02 W at 2 K and a dynamic heat loss of 0.06 W at a transmission average power level of 2 kW, figures that increase at 7 kW.

It has three cambers and each chamber has its own vacuum. The coupler primarily consists of three parts: a doorknob waveguide-to-coaxial transition, a center vacuum impedance match, and the top tip antenna to the cavities.

The main static loss in the TTC-3 design comes from the doorknob transition. The newly proposed couplers have no such doorknob design. Since the newly proposed coupler has no physical contact between the 300 K and 2 K areas via the doorknob transition, its static heat loss is trivial.

This is the advantage of the proposed coupler design and is achieved via considerable thermal isolation between the 2 K and 300 K sections by vacuum separation. The fact that the coupler allows only a single propagation mode at each section, meaning no energy is converted to high order mode, enables an almost full match without loss.

"We designed the coupler in sections and cascaded them together to adjust for the best match," said Xu. "The two end sections only have a circular waveguide.

"The radius can ensure that the higher order mode is beyond cutoff frequency where the microwave is evanescent. The central portion of the coupler is a sapphire load waveguide, and we chose the combination of waveguide and sapphire radius in order to avoid other higher-order HE11 modes.

"The two taper areas on both ends are used to force the field into the sapphire without leaking the RF power into the gap. However, when converting the TE11 circular waveguide mode into the HE11 mode in the sapphire loaded waveguide, there must be other modes converted that are in evanescent mode. With a fairly long transition length of both sections, finite element simulation ensures that there are no other HOM modes propagating out of these sections.

"The distance between the 2 K to 300 K sections is around 50 mm in length, leading to a gradient of 6 K/mm. In order to reduce the loss from RF, a low electric resistance surface must be used. In order to reduce thermal conductivity between 2 K and 300 K, a high thermal resistance bulk material must be used.

"To compromise between these conflicting needs, copper-coated stainless steel is used to build the outer conductor. Two bellows have been added to minimize the temperature gradient on the outer conductor and to increase the thermal length. In simulations conducted on the current LCLS-II TTC3 coupler, the max temperature occurs on the bellow and can reach 400 K at CW 7 kW power."

TTC-3 Design Product of International Collaboration

Xu also elaborated on the TTC-3 design and the collaboration that developed it: "TTC-3 is a product of the TESLA collaboration. The collaboration is aimed at the development of technology for SRF accelerators.

"The TTC collaboration contributes to concept development for the ILC. DESY in Germany has utilized the TTC design to build the FLASH Free Electron Laser (FEL) to serve as a light source facility. This FLASH linear light source has been upgraded into a European FEL after over five years in operation.

"The SLAC's LCLS-II project could be another beneficiary of the TTC-3. LCLS-II is using modified TTC-3 couplers for CW operation mode to deliver 7 kW RF power.

"The Cornell Energy Recovery Linac (ERL) project is also using modified TTC-3 couplers to construct another x-ray linear light source. Their current is a surprisingly high 200 mA and 55 MeV, and their total beam power is around 10 MW."

Electric Field Reduction not yet Focus of Coupler Design

There are two major areas of improvement on current TTC-3 designs: reducing static heat loss and minimizing electric field on vacuum windows. Xu said that minimizing electric field was also an important goal to be pursued for future couplers: "The heat loss from RF comes from the surface magnetic field and surface RF resistance. Thus surface magnetic field is the main focus in our proposed coupler.

"Surface electric field is another focus for more practical consideration, because it can cause field emission and multipacting. Both of those effects can limit the max power that these couplers can transmit. Field emission and multipacting effects can sometimes be serious if a system contains sapphire.

"Electric field is not an issue yet. However, the surface electric field can be enhanced in the sapphire body via the dielectric constant. High electric fields can cause the sapphire to crack.

"One solution is to make the sapphire transition section longer in order to involve fewer HOM modes and fewer trapped modes. The total length of this coupler would inevitably be longer and harder to fit into existing cryomodules. Current optimization is a balance between the length of the coupler and field minimization."

Researchers Seek S11 Variation from 0 to -20 db at 7 kW CW Power

The researchers sought to develop a variation of S11 from 0 to -20 db with CW power of 7 kW. The S11 parameter is used to determine the reflection characteristic in RF design. It is expressed as a ratio between forward voltage and reflected voltage on the input port.

S11 informs on the power loss from ohmic loss and reflection from the coupler. Another scattering parameter, S21, can be expressed as a ratio between the voltages on the output and input ports and is used to assess transmission.

The recent study provides analytical and numerical calculations for a two window variable coupler. Xu said that some practical issues still exist with the coupler design: "There are some issues that may prevent this coupler from mass production. The loaded sapphire is 60 mm long, and so far we have one 80 mm-long sapphire but little experience with sapphire rod production at such long lengths.

"However, the total length of the coupler is 100 mm, and that is longer than current TTC-3 couplers. In order to use this coupler in LCLS-II, a new cryomodule is required.

"Coupler manufacturing is ongoing and processing and testing of the coupler is planned. We are still progressing to optimize the coupler length and seeking possibilities for other low-frequency SRF applications. Meanwhile, we are open to any projects that seek a coupler with low static heat loss and coupling flexibility." ❍

Italian/French Team Proposes Design for SC Refrigerator

Researchers with the Institute of Nanoscience - CNR, CNRS, and the University of Grenoble Alpes have provided the design for a superconducting cascade electron refrigerator based on a combination of superconducting tunnel junctions. The refrigerator is designed for cooling microscopic objects to near 0 K. The research received partial funding from the Marie Curie Initial Training Action Q-NET No. 264034 and the EU Capacities MICROKELVIN Project No. 228464.

"The most novel aspect [of this system] is the fact that we used several superconductors with different T_c's and therefore different gaps," said Maria Camarasa-Gomez, Researcher at CNR who helped develop the new refrigerator. "We use the intermediate superconductor in the same role as the second stage outer superconductor to achieve lower values for the electronic temperature of the normal metal when we cool down. The most relevant improvement is that this method allows us to increase the range of operation of temperatures for superconductor-tunnel barrier-normal metal-tunnel barrier-superconductor (SINIS) refrigerators.

"There are plans to build this device and other, similar ones, in the coming months. Objects with a size on the order of 10^{-2} μm^3 can be cooled using this refrigerator, which is a standard size for current refrigerators and a feasible dimension to build this kind of device around."

SINIS Refrigerator Cools Normal Metal to 100 mK

Superconducting refrigerators are typically composed of superconductors, normal metals, and tunnel barriers that are arranged in a symmetric configuration. When a voltage is applied to the superconductors, hot quasiparticles in the normal metal tunnel through the tunnel barriers to the superconductors, cooling the normal metal.

The proposed design consists of a SINIS configuration with an additional superconducting tunnel contact on each end. A voltage is applied to a superconducting end contact, causing hot quasiparticles to first tunnel from the normal metal to the middle superconductor and then to the superconducting end contact.

Each tunneling event removes heat, resulting in a heat current that flows from the inside to the outside of the refrigerator. This allows for a normal metal to be cooled down to about 100 mK starting from a bath temperature of 500 mK.

Standard Techniques Used to Build Cooler

"This refrigerator is more efficient than the SINIS coolers in each range of low temperatures, even when using other kinds of metals or disordered alloys," said Camarasa-Gomez. "Its fabrication is not complicated, since the techniques used to build the cascade cooler are standard ones.

"We were able to increase the range of operation of temperatures thanks to the middle stage, where another superconductor is placed between the outer one and the normal metal. We designed a kind of SINIS, but we can play with the fact that the bath temperature is higher and achieve lower values for the electronic temperature in the normal metal. This allows the combination of typical superconductors to easily achieve lower electronic temperatures in normal metals."

System Operates Optimally with Vanadium, Aluminum

Camarasa-Gomez described the simulations used to test the proposed refrigerator: "The system was tested in simulations using vanadium and aluminum. We concluded that the combination of these materials, because of their T_c's, would lead to the best performance.

"The system can be implemented using disordered alloys such as aluminum-manganese or other superconductors, for instance, niobium. However, the optimum results are obtained by using vanadium and aluminum with no significant improvement when other materials are used.

"[There are] not actually [any technological difficulties in implementing this system]. An alternative design to the present implementation is given in the article, but the [simulated system allows for] fabrication using the simplest methods and techniques.

"This device opens a new branch in the design of superconducting refrigerators because of its innovative design and performance. These refrigerators can be integrated in macroscopic systems easily and open up new possibilities. The mechanism that enables this kind of refrigerator to work so efficiently can be studied more deeply to improve our results.

"In any case, this system opens the possibility of using different superconductors to widen the range of temperatures achievable by SINIS devices. This includes the use of aluminum, vanadium, and normal metals in an easy way and creates the option of cooling down normal metals from higher bath temperatures." ❍

Study Identifies Magnetism as Force in Cooper Pair Formation

Researchers at the University of Illinois, Chicago, Cornell University, and Brookhaven National Lab (BNL), have identified the microscopic mechanism responsible for the emergence of superconductivity in the heavy fermion material $CeCoIn_5$. By combining a newly developed theoretical formalism to the analysis of quasi-particle visualization experiments, they found that magnetic interactions lead to the bounding of electrons into Cooper pairs, the basic building block of superconductivity, in a highly directional manner. The research was funded by the DOE as part of a broader three-year research program.

Knowledge of Electronic Bandstructure needed to Confirm Hypothesis

The results confirm a thirty-year-old hypothesis regarding the origin of superconductivity in heavy fermion materials and the 'quantum glue' giving rise to the formation of Cooper pairs. The hypothesis states that superconductivity in heavy fermion materials arises from the strong anti-ferromagnetic interaction between the localized magnetic moments and that the quantum glue which is the basis of the superconducting pairing mechanism and provided by anti-ferromagnetic spin fluctuations.

"One of the main problems [in confirming the hypothesis] was that the form of the electronic bandstructure (the relation between the momentum and energy of the electrons) was not known," said Dirk Morr, Professor at U Illinois who co-authored the study. "This crucial piece of information has become available only recently through the invention of quasi-particle interference visualization for heavy fermions by the group of JC Seamus Davis of Cornell and BNL and a co-author of the study.

"Moreover, we were able to show that the form of the superconducting pairing interaction, which gives rise to the formation of Cooper pairs, can be determined from this bandstructure. Both pieces together, the bandstructure and the pairing interaction, then allowed us to make quantitative predictions regarding the properties of the superconducting state in $CeCoIn_5$."

Group Showed Quasi-particle Spectroscopy Reveals Fermion Bandstructure

Morr also commented on the use of quasi-particle visualization in the study: "Quasi-particle interference visualization had been used before not only in simple metals like copper, but also in the complex cuprate and iron-pnictide superconductors to determine the electronic bandstructure and the form of the superconducting gap. This technique was only introduced to the study of heavy fermion materials by the Davis Group about four years ago. My group showed theoretically that this technique indeed reveals the bandstructure in these complex materials, which was not clear from the outset due to the complex electronic structure of heavy fermion materials.

"$CeCoIn_5$ is one of the most interesting heavy fermion materials since it has one of the highest T_c's at 2.3 K. It is also part of the so-called 115 family of heavy fermion materials that possess the same type of complex phase diagram as the cuprate and iron-pnictide superconductors. $CeCoIn_5$ also has been widely studied by other experimental techniques, such that we could compare the predictions of our theory with a series of experimental results.

"$CeCoIn_5$ is also considered the hydrogen atom of heavy fermion materials, in the sense that understanding the microscopic origin of its unconventional superconducting state will also shed light on the mechanism in other superconducting heavy fermion materials and possibly also on that of cuprates and pnictides. Finally, the use of quasi-particle visualization in a material requires that one can create clean, almost perfect surfaces. $CeCoIn_5$ is one of the few heavy fermion materials where this is possible."

Morr elaborated on the significance of magnetism to the development of superconductivity in $CeCoIn_5$: "Our results show that the superconducting pairing mechanism in $CeCoIn_5$ arises from the strong anti-ferromagnetic interactions between the localized magnetic moments, and that $CeCoIn_5$ is an unconventional superconductor. This also suggests that the same pairing mechanism is present in other heavy fermion materials, which now, given the theoretical framework we have developed, can and will be tested in the future."

Theory to Enable Future T_c Enhancements

The observations led to the development of a series of calculations able to predict the superconducting properties of $CeCoIn_5$. Morr said that the team could now begin using the quantitative theory to investigate which new materials might possess a higher T_c: "The quantitative agreement between the predictions of our theory and experimental results demonstrate that magnetic interactions are the superconducting pairing mechanism. Since we now have a quantitative theory, we can start exploring theoretically how the parameters of a given material (for example, its bandstructure) need to be changed in order to increase T_c.

"Once we understand theoretically how the interplay between, for example, bandstructure and the strength of the magnetic interactions determines T_c, we will have an idea of how to design new materials with higher T_c's, hoping to eventually reach room-T_c superconductivity. In addition, we plan to apply our theory to other superconducting heavy fermion materials to test the idea that a magnetic mechanism of superconductivity is present in all heavy fermion superconductors." ❍

ISIS, HBNI Study Nb-oxynitride

Researchers with the STFC Rutherford Appleton Lab's ISIS Facility in Oxfordshire, UK, Hokaido University, and Homi Bhabha National Institute (HBNI) in Mumbai have concluded an investigation of a Si-doped Nb-oxynitride superconductor using muon spin rotation and relaxation. Funding for the research came from the Japanese Society for the Promotion of Science (Kakenhi (A) #21245047) and DAE (India) as a Raja Ramanna Fellowhip to J.V. Yakhmi at HBNI, and experimental beamtime was provided by STFC.

"A Si-doped Nb-oxynitride was chosen for its high T_c at 17 K," said Adrian Hillier, STFC Researcher who co-authored the study. "In addition, previous studies had shown that I_c at 5 K was ~2.5×10^4 A/cm^2, nearly four times higher than that using Mg and Al doping. We therefore began this study to try and understand the mechanisms for superconductivity.

"The high I_c and higher T_c may lead to some practical application. The I_c may change with the size of clusters introduced by Si, vacancy, and oxygen. The challenge would be controlling the size of these clusters, perhaps via the chemical composition and annealing.

"The 'Uemura Plot' classifies this superconductor with the HTS organics and heavy fermions. This suggests that the mechanisms for superconductivity may not be entirely conventional.

"Despite this, the previous results and ours suggest that it has a singlet isotropic gap. The material may potentially offer further insights to HTS, but further study is required."

Research Part of Broader Study

Hillier said the research is part of a broader study of the class of materials: "We are planning a broader study of these types of materials. Transition metals can change their valency to keep charge neutrality in the Nb-oxynitride crystal lattice. They do not leave any cationic vacancy effective for the flux pinning.

"An aspect of transition metals is the thermal metastability of their chemical bonds against nitrogen. Nitrides are thermally unstable in combination with the transition metals having a large number of d electron because of their anti-bond chemical bonding nature. We succeeded in keeping some amount of manganese, but nickel metal was not stabilized in the lattice and was present as an impurity.

"The manganese-doped Nb-oxynitride did not show an affirmative effect on the flux pinning. We will publish the experimental results shortly and will continue our experiments on the Si-doping in superconducting Nb-oxynitrides possessing different chemical compositions."

There is no evidence of time-reversal symmetry breaking and the temperature dependence of the magnetic penetration depth is consistent with an isotropic singlet s-wave ground state. The magnetic penetration depth is 218(5) nm and the BCS ratio is 4.6.

The superelectron density and effective mass were found to be 8.7×10^{27} m^3 and 15 me, respectively. Hillier said the next steps in the research involved expanding the study by testing the material with different dopants and under different pressures. ❍

Superconductivity Roundup

Events & Opportunities from Around the Industry

SW **UCLA** Researcher Ni Ni has received **DOE** funding to lead a superconductivity research program entitled: "Exploring Superconductivity at the Edge of Magnetic or Structural Instabilities." The program is being funded $150,000 annually over five years via the **Early Career Research Program.**

SW **Modutek Corporation** of San Jose, CA, which specializes in chemical process equipment, has selected **Vycom**'s Flametec materials for use in a project with **Michigan State University**'s **Facility for Rare Isotope Beams** (FRIB). Modutek has created a 33 ft.-long precision cleaning line made with Vycom's Flametec PVC-C and Kytec PVDF material to clean FRIB's SRF resonators.

The $730 million FRIB is being designed and established by MSU as a DOE Office of Science national user facility supporting the mission of the Office of Nuclear Physics. It is designed to accelerate certain elements in a superconducting linac and create rare isotope beams.

Built to MSU's specifications over a 6-month period, the precision cleaning line is designed to purify the accelerator's metal niobium tubes. The unit's Flametec cabinet and bench are designed to hold up to constant exposure to acids and harsh chemicals.

Construction on the FRIB began earlier this year (see *Superconductor Week*, Vol 28, No 3). Project completion is anticipated for no later than June 2022.

SW On August 27th **AMSC** EVP James Maguire sold 149,424 shares of AMSC stock on the open market at an average price of $1.80 for a total value of $268,963.20. Following the sale, the EVP now directly owns 422,332 shares in the company valued at approximately $760,198. The sale was disclosed in a legal filing with the SEC.

SW The $1.9 billion, 4.75 MW **Tres Amigas Superstation** in Clovis, NM, part of a planned project to link the three U.S. Grids with superconducting HVDC cables, was more than a month late in paying **Curry County** its $35,000 annual franchise fee. The fee was due to the county on July 15 under a contract negotiated last year. Tres Amigas CFO and Senior VP Russell Stidolph later stated that the fee had been sent to the county, and that the late payment was an oversight.

Tres Amigas is working to secure the funding necessary to break ground on the Superstation (see *Superconductor Week*, Vol 28, No 3). The groundbreaking, originally planned for July 2012 and as recently as December slated for March 2014, has undergone numerous delays (see Superconductor Week, Vol 26, No 12 & Vol 27, Nos 15 & 20). As of June, the first, $550 million phase of the Tres Amigas project was 75% financed.

Tres Amigas CEO David Stidham was quoted this spring stating that the groundbreaking of the facility will still occur in 2014 due to contractual agreements with utilities and other companies. Construction should take place over eight years and occur in three phases.

In addition to funding delays, Tres Amigas is in ongoing negotiations with officials of the Electric Reliability Council of Texas (ERCOT), the private power grid which powers Texas, concerning connecting to their grid. ERCOT officials said last month they were conducting a liability study.

SW The **Bruker Corporation** is planning to divest or restructure several of its business units, a move that could result in a corporate head count reduction of 200 to 250 employees. Bruker has 6,400 employees worldwide. According to a regulatory filing, the company's board has approved a plan to divest certain assets and implement a restructuring program in the company's Chemical & Applied Markets (CAM) division.

The CAM division, which does not focus on superconductivity device development, generated ~$100 million in 2013 revenue. Bruker believes that the division will be unable to achieve acceptable financial performance in the next two years. The divestment and restructuring actions are expected to lead to one-time charges of $35 million to $45 million to be incurred in the second half of 2014 and the first half of 2015.

SW **Indiana University**'s (IU) **Cyclotron** and **Proton Therapy Center** will close by 2015 once the roughly 30 current patients finish their treatments. First constructed in 1975, the cyclotron was originally used for physics research.

In 2004 it began providing proton beam radiation therapy (PBRT) treatments, becoming the third location in the U.S. to use proton beams for focused radiation treatments. However, the facility never became consistently profitable.

The center and cyclotron operated at a deficit for FY2013. Recently, an increase in PBRT facilities throughout the U.S., advances in cancer treatment, decreasing insurance reimbursement rates for proton therapy, and aging equipment led to fewer patients and low revenue.

PBRT is recognized as a preferred option for treating children and some spinal and cranial cancers (see *Superconductor Week*, Vol 27, No 19). However, for more common forms of cancer it is not certain that PBRT leads to better outcomes than cheaper, more common forms of radiotherapy.

A recent study by the Center for American Progress identified Medicare and Medicaid spending on PBRT treatments for prostate cancer as wasteful (see *Superconductor Week*, Vol 28, No 6). The study suggests that a $125 million PBRT center has to treat 2,000 patients per year and generate more than $50 million in annual revenue to turn a profit, driving the push to treat patients with more common forms of cancer. According to the IU center, patient numbers have been as high as 75 at a time but that 30 has been a more typical figure.

SW **University of Houston** Assistant Professor Jakoah Brgoch has been awarded a Robert A. Welch Professorship in HTS and Chemical Materials from the **Texas Center for Superconductivity at the University of Houston** (TcSUH). The Robert A. Welch Foundation created the professorships to recruit and retain outstanding faculty, research faculty and visiting scientists. The two-year appointment is effective Sept. 1.

Brgoch's research involves the investigation of new materials with energy-related applications, including improving the efficiency of light conversion compounds called phosphors that are critical for solid state-lighting devices. Additional research areas include magnetic materials required for wind turbines, materials with excellent wear-resistance, and gold-based catalytic compounds.

SW ITER's **European Domestic Agency** has awarded a four-year, multimillion-euro engineering contract for the integration of diagnostic instruments into ITER vacuum vessel ports to **IDOM**'s **Advanced Design and Analysis** division (IDOM ADA), a multinational specialized in engineering, architecture, and consultancy services based in Spain. The company will work to deliver an engineering design that integrates approximately 20 diagnostic instruments into five of the ports that give access to the ITER plasma. The contract also covers the design of in-vessel metallic containers to protect the diagnostic instruments from extreme temperature and to shield other components from neutron radiation.

SW The concrete for the basement of the **ITER** tokamak complex has been poured. The foundation, referred to as the B2 slab, will support some 400,000 t of building and equipment, including the 23,000-t superconducting tokamak. The foundation is installed on seismic columns and has a capacity for lateral movement of up to 10 cm in any direction.

The 1.5-metre-thick slab will serve as the first basement level of the Diagnostic, Tokamak and Tritium buildings. Five large drain tanks, supports for the base of the cryostat, and the building walls will be positioned directly on it. Concrete pouring for the 9,300 m^2 B2 slab began in December 2013.

Completion of the B2 slab marks the conclusion of the preparatory phase of the construction site begun in August 2010 and represents an investment of some €100 million ($132 million). Work is underway installing formwork to frame out the lower walls of the Diagnostic Building. Work will soon begin on the walls of the Tokamak Complex and the first 60 m-tall pillars will be set into place for the adjacent Assembly Building.

Superconductor Week
Commercialization · Markets · Products
Business Developments · R&D · Cryogenics
~Insert~
August 31, 2014 Vol. 28, No. 8

U.S. Superconductivity Patents

(RE) $Ba_2Cu_3O_{7-\delta}$ Thin Film SC
Superconductor Technologies, Inc.
2014-05-06
U.S. Patent No. US8716187
The films of this invention are HTS thin films specifically optimized for microwave and RF applications. In particular, this invention focuses on compositions with a significant deviation from the 1:2:3 stoichiometry in order to create the films optimized for microwave/RF applications. The RF/microwave HTS applications require the HTS thin films to have superior microwave properties, specifically low surface resistance, Rs, and highly linear surface reactance, Xs, i.e. high JIMD. As such, the invention is characterized in terms of its physical composition, surface morphology, SC properties, and performance characteristics of microwave circuits made from these films.

Structure to Reduce Electroplated Stabilizer Content
SuperPower, Inc.
2014-05-06
U.S. Patent No. 2014-05-06
A SC article includes first and second stacked conductor segments. The first stacked conductor segment includes first and second SC segments and has a nominal thickness t_{n1}. The second stacked conductor segment includes third and forth SC segments and has a nominal thickness t_{n2}. The SC article further includes a joint region comprising a first splice connecting the first and third SC segments together and a second splice connecting the second and forth SC segments together. The first splice is adjacent to and bridged portions of the first and third SC segments along at least a portion of the joint region, and the second splice is adjacent to and bridged portions of the second and forth SC segments along at least a portion of the joint region. The joint region has a thickness t_{jr}, wherein t_{jr} is not greater than at least one of $1.8t_{n1}$ and $1.8t_{n2}$.

Method of Producing SC Oxide Material
National Institute of Advanced Industrial Science and Technology; The Japan Steel Works, Ltd.
2014-05-06
U.S. Patent No. US8716189
A method of producing a SC material involves the step of applying a solution of an organic compound of metals, oxides of the metals forming a SC material, onto a support body to be subsequently dried, a provisional baking step of causing organic components of the organic compound of the metals to undergo thermal decomposition, and a main baking process step of causing transformation of the oxides of the metals into the SC material, thereby producing an epitaxially-grown SC coating material, wherein at the time of irradiation of a surface of the support body coated with the solution of the organic compound of the metals for forming the SC material, and/or of a surface of the support body, opposite to the surface coated with the solution of the organic compound of the metals, with the laser light, during a period between steps.

SC Switching Arrangement
Rolls-Royce PLC
2014-05-06
U.S. Patent No. US8718732
The invention relates to a SC switching arrangement, including: a SC having a plurality of first connection zones and at least one second connection zone, the first and second connection zones being connectable by at least one SC path in use, a quenching device which is operable to selectively quench portions of the SC so as to remove the SC path between at least two of the first connection zones and the at least one second connection zone.

SFCL Recovery System

Varian Semiconductor Equipment Associates, Inc.
2014-05-06
U.S. Patent No. US8718733
A SFCL recovery system includes a SFCL, a shunt electrically coupled in parallel with the SFCL, and a bypass path also electrically coupled in parallel with the SFCL. The bypass path enables a load current to flow through the bypass path during a bypass condition. Thus, load current may be quickly reestablished to serve loads after a fault condition via the bypass path while a SC of the SFCL has time to return to a SC state after the fault condition.

Flux Compression Generator
The United States of America as Represented by the Secretary of the Navy
2014-05-13
U.S. Patent No. US8723390
A flux compression generator (FCG) is provided for producing an electromagnetic pulse (EMP). The FCG includes an environmental case, a reactive load, a dielectric core, a SC stator, an electric energy source, a load switch, and a transition device. The reactive load transmits the EMP in response to an electric current pulse. The dielectric core has proximal and distal ends within the case, with the stator disposed coaxially around the core that provides structural support. The case contains the electrical energy source, the stator, the core and the transition device. The energy source connects to the stator at the proximal end and powers the transition device. The load switch connects the reactive load to the stator at the distal end. The energy source initially provides an electric current to the stator. The device upon activation heats at least a portion of the stator to reversibly transition the portion from a SC state to a non-SC state. The stator transfers the electric current as the pulse to the reactive load upon the portion's transition to the non-SC state. The stator can be a SC helical coil that wraps around the core connected to a SC conductor disposed coaxially within the core. Alternatively, the stator can be a stack of SC rings disposed coaxially along the core. The SC coil and rings can preferably be composed of a HTS material on a metal substrate.

Magnetic Field Sensor Device
Yeda Research and Development Company Ltd.
2014-05-13
U.S. Patent No. US8723514
The invention is a magnetic sensor device performing direct magnetic field imaging, comprising a probe having a conical tip portion which is configured as a sensor having two SC separated by a thin non-SC layer (such as a Josephson junction based sensor), where the non-SC layer is located at the apex portion of said conical tip, thereby defining electron tunneling region(s) at said apex portion. The technique of the present invention enables the sensor device to be very small and to be brought very close to the sample surface.

SRF Coil Array
Time Medical Holdings Company Limited
2014-05-13
U.S. Patent No. US8723522
A SRF coil array which may be used in whole body MRI scanners and/or in dedicated MRI systems. Some embodiments provide a SRF coil array for at least one of receiving signals from and transmitting signals to a sample during magnetic resonance analysis of the sample, the SRF coil array comprising a thermally conductive member configured to be cryogenically cooled, and a plurality of coils elements comprising SC material, wherein each coil element is thermally coupled to the thermally conductive member and is configured for at least one of receiving a MR signal from a spatial region that is contiguous with and/or overlaps a spatial region from which at least one other of the plurality of coil elements is configured to receive a signal and transmitting a RF signal to a spatial region that is contiguous with and/or overlaps a spatial region to which at least one other of the plurality coil elements is configured to transmit a RF signal.

SC Filter with Disk-shaped Electrode Pattern
Fujitsu Limited
2014-05-13
U.S. Patent No. US8725224
A filter includes a dielectric substrate; an electrode layer

continuously formed covering a first side of the dielectric substrate; a disk-shaped electrode pattern provided on a second side of the dielectric substrate, the disk-shaped electrode pattern and the electrode layer holding the dielectric substrate therebetween; a ground slot having an opening that is formed asymmetrically with respect to the center of a circular area included in the electrode layer and exposes the dielectric substrate, the circular area and the disk-shaped electrode pattern holding the dielectric substrate therebetween.

Adjustment Method of a MRI Apparatus
Hitachi Medical Corporation
2014-05-20
U.S. Patent No. US8726489
An adjustment method of a MRI apparatus has a cooling and excitation step in which work of transporting a SC magnet to a facility different from a facility where the SC magnet is to be installed, cooling a SC coil of the SC magnet with a refrigerant, and supplying a current from an external power supply for excitation is repeated until a predetermined rated current flows; a demagnetization and transportation step of demagnetizing the SC coil and transporting the SC magnet to the facility where the SC magnet is to be installed in a state where the SC coil is cooled by the refrigerant; and an installation step of installing the SC magnet in the facility where the SC magnet is to be installed and supplying a predetermined rated current from an external power supply to the SC coil in order to excite the SC coil.

Supported SC Magnet
Siemens plc
2014-05-20
U.S. Patent No. US8729990
A supported SC magnet has a SC magnet arranged within an outer vacuum container and a support structure bearing the weight of the SC magnet against a support surface. The support structure has a tubular suspension element between the magnet and the support surface, the element retaining the magnet in a fixed relative position with reference to the outer vacuum container by means of complementary interface surfaces arranged to transmit the weight of the SC magnet to the support structure. The element is arranged about a vertical axis, and supports a solenoidal magnet structure which is arranged about a horizontal axis.

RF Cavity Fabrication Method
The United States of America as represented by the Secretary of the Navy
2014-05-20
U.S. Patent No. US8731628
The present invention's RF cavity device comprises a rigid frame and plural flexible tiles. The frame includes walls of substantially uniform thicknesses that describe a hollow pillbox shape. The tiles are approximately equally thick, each tile being of substantially uniform thickness. Each tile includes a flexible metallic substrate and an HTS coating atop the substrate. The tiles are attached via their corresponding substrates to the inside wall surfaces of the frame so that their HTS coatings are interiorly exposed. The attached tiles conform to curved surface areas, are set with narrow seams therebetween, and cover approximately the entirety of the frame's inside wall surfaces. A filler material is applied to the seams. The tile configuration is characterized by approximate levelness of the exposed HTS coating surfaces and the filled seams.

Device for HTS Degaussing System Junction Box
American Superconductor Corporation
2014-05-20
U.S. Patent No. US8731629
A junction box is provided which allows serial connection of the individual conductors of at least one HTS wire bundle. The junction box includes an electrical interface device disposed within a junction box housing. The interface device is configured receive both ends of each conductor of each HTS wire bundle, and to provide a SC electrical connection between respective first ends of conductors to respective second ends of other wire bundle conductors to form at least one SC multi-turn electromagnetic winding.