Superconductor Week

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AMSC Revenues 33.1% Lower for Q1

AMSC has announced that its Q1 FY2017 revenues fell by 33.1%, to $8.9 million from $13.3 million in Q1 FY2016. Net loss rose to $15.3 million from $8.7 million over the same period.

The company's earnings exceeded analyst expectations, and the share price rose by 11.1%, from $2.97 to $3.30, the day after the earnings release. Cash, cash equivalents, and restricted cash at the end of the quarter totaled $37.7 million, compared with $27.7 million at the end of the previous sequential quarter.

Grid Revenues Fall by 13.4%

AMSC's Grid and Wind segments both contributed to the revenue decline. Q1 FY2017 revenues for the Grid segment declined by 13.4%, from $7.6 million to $6.6 million. Operating losses rose to $8.2 million from $5.3 million the previous year.

"Our financial performance in Q1 was at the top of our expected range," said Daniel McGahn, AMSC President and CEO. "We remain focused on executing on our objectives for the fiscal year. We understand the changing dynamics of the Indian wind market and believe that our Wind and Grid segments revenues will improve in the second half of FY2017."

Navy Accounts for 35% of Total Revenues

The Grid business unit accounted for 74% of total revenues for Q1 FY2017 compared to 57% for the same three months in the previous year. The decline in Grid segment revenues were primarily due to lower non-superconducting D-VAR system sales, partially offset by higher revenue from the U.S. Navy. Superconductor-related U.S. Navy revenues constituted 35% of total revenues for the quarter, compared to a negligible percentage in Q1 FY2016.

"In May 2017 we announced a contract worth up to $8.4 million for engineering and technical services from the Naval Surface Warfare Center (see *Superconductor Week*, Vol 31, No. 5)," McGahn noted during the earnings conference call. "The sole source contract was entered into to support the U.S. Navy's insertion of AMSC's HTS-based ship protection systems into the surface fleet including interface hardware for testing and training systems.

"We believe our May 2017 sole source contract for engineering and technical services is a clear indicator that the Navy is ready to integrate AMSC's HTS-based Ship Protection Systems (SPS) into the surface fleet. The current administration has the desire to expand the U.S. Navy fleet by nearly 30%. Every additional vessel added to the Navy's build plan increases our addressable market for SPS."

REG Negotiations Continue

McGahn offered little new information about developments regarding AMSC's Resilient Electric Grid (REG) initiatives with a number of U.S. utilities: "Our negotiations with ComEd for a commercial contract continue and we will report progress with ComEd as we are able to announce it. We continue to be in discussions with other cities and other utilities for our REG product."

For Q2 FY2017, AMSC expects that its revenues will be in the range of $9 to $13 million. The company's net loss is expected to be less than $14 million. A cash burn of $7 to $8 million for the quarter is projected. ❍

BEST Drives Bruker Q2 FY2017 Growth

Bruker Corporation announced revenues of $414.9 million for Q2 FY2017, 11.6% higher than Q2 FY2016 revenues of $371.7 million. Excluding a 1.8% negative effect from changes in foreign currency rates and the impact of acquisitions, the company's year-over-year organic revenue growth was 7.6%. Net income for the quarter rose by 61.4% to $23.4 million from $14.5 million.

For the first half of FY2017, Bruker's revenues rose by 7.1% to $799.8 million, compared to $747.1 million in the first half of FY2016. Net income reached $45 million, 18.1% higher than the $38.1 million realized over the comparable period last year. Bruker's share price fell by 2.1%, from $28.47 to $27.88, on the day following the earnings announcement.

"We are pleased with our 11.6% year-over-year revenue increase in Q2 FY2017, which included 7.6% organic growth, albeit in comparison to a relatively weak Q2 a year ago," commented Frank Laukien, Bruker's President and CEO. "Our Q2 revenue growth included mid-single digit organic growth in our Scientific Instruments (BSI) segment, and very strong organic and inorganic growth in our BEST segment, which has inherently lower gross margins than our BSI segment.

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"Our Q2 FY2017 year-over-year order growth marks three consecutive quarters of positive bookings momentum in Europe, and we now also see evidence of improvements in industrial demand. We expect accelerated annual organic revenue growth in 2018 in support of our long-term margin expansion objectives."

BEST Income more than Doubles

Bruker's Energy & Supercon Technologies (BEST) segment increased revenues by 89.5%, from $28.5 million in Q2 FY2016 to $45 million in Q2 FY2017. The increase resulted from the Oxford Instruments Superconducting Wire LLC (OST) acquisition, which was completed in Q4 FY2016 (see *Superconductor Week*, Vol 30, No 11), and organic revenue growth caused by an acceleration of shipments of superconductors to large MRI customers.

BEST's system and wire revenue, which includes LTS and HTS wire and superconducting devices, including magnets, linear accelerators and RF cavities, rose by 92.4%, from $27.7 million to $53.3 million. The segment realized operating income of $3 million in Q2 FY2017, 114.3% higher than the $1.4 million in earnings in Q2 FY2016.

For the six-month period, BEST revenues rose by 68.9%, to $94.1 million from $55.7 million. System and wire revenue reached $92.4 million, 70.8% higher than the $54.1 million achieved during the first half of FY2016. Segment operating income was $2.5 million, a gain of 78.6% over the $1.4 million in operating income reported during the first half of FY2016.

BEST Contributed 13% to Aggregate Bruker Revenues

"BEST had over 40% organic revenue growth, as well as significant inorganic growth from our OST acquisition last November," Laukien said during Bruker's earnings conference call. "To give you perspective, in Q2 FY2017 BEST contributed about 13% of Bruker's overall revenues compared to about 8% of revenues in Q2 FY2016.

"As a reminder, BEST has significantly lowered gross margins than our core BSI business, something that is inherent in the advanced superconducting materials business model. However, we have multi-year productivity and innovation efforts underway to further increase BEST operating margins."

Laukien predicted that the BEST segment would continue to perform well. He noted that some of segment's MRI OEM customers have ordered more superconductor wire in the weeks after the end of the quarter.

BIOSPIN Experiences Continued NMR Demand

The BIOSPIN Group delivered low-single digit revenue growth due to continued steady demand for NMR systems and an improvement in the preclinical imaging business (PCI), although with lower margins. This was due to a Q2 FY2017 mix with more low-field NMR and PCI revenue compared to more high-field NMR revenue in Q2 FY2016. Laukien noted that BIOSPIN no longer expects to have any one gigahertz systems revenue in 2017 as the expected timing of installations has shifted to mid-2018.

Bruker has adjusted its 2017 revenue growth and earnings outlook to reflect changes in foreign currency rates and the year-to-date performance. For FY2017, the company now expects revenue growth of 4.5% to 6%, including organic growth of 1.5% to 2%, growth from acquisitions of 3.5% to 4%, and a headwind from foreign currency rates of -0.5% to 0%. Bruker continues to project an increase in FY2017 operating margin of 40 bps to 70 bps year-over-year, including approximately 40 bps of headwind from recent acquisitions. ❍

Saarland U Creates Thin, Flexible Superconductor Film

Researchers at Saarland University have developed a thin nanomaterial with superconducting properties that can be woven into an ultrathin flexible film (doi.org/10.1088/1361-6668/aa544a). The film has the potential for use in novel coatings for applications ranging from aerospace to medical technology. The study received financial support from the German Research Foundation (DFG) and the Volkswagen Foundation.

"Our research focuses on the investigation of the superconducting properties of HTS materials, including powder, thin films, and nano-materials," commented Saarland U Researcher Xian Lin Zeng. "The results we reported are part of our research on superconducting nanowire network samples prepared via the electrospinning method."

Electrospinning Technique Low Cost and Scalable

Electrospinning is usually used in the manufacture of polymeric fibers. A liquid material is forced through a very fine nozzle known as a spinneret to which a high electrical voltage has been applied, producing nanowire filaments of about 300 nm or less. The mesh of fibers is then heated to create superconductors of a specific composition.

"The electrospinning technique is low-cost compared to conventional bulk, thin film, or tape samples, as electrospinning has the advantage of a high-yield fabrication of nanowires," Zeng said. "The production can be upscaled to produce large area samples, which is not possible with any other method to produce HTS materials."

Film Weighs 100 Times Less than a Conventional Superconductor

The characteristics of the material developed at Saarland contrast with the rigidity and brittleness of superconducting cuprate ceramics. The new film is a woven fabric of plastic fibers and HTS nanowires.

With a density of only 0.05 grams per cubic centimeter, the film weighs about a hundred times less than a conventional superconductor. This increases its attractiveness for applications where weight is an issue, such as in space technology. The material might also be used to provide low-temperature screening from electromagnetic fields, in flexible cables, or to facilitate friction-free motion.

FCLs a Potential Application

The team used $Bi_2Sr_2CaCu_2O_8$ (Bi-2212) as its superconducting material. They employed two different precursors to grow the nanowires, a Pb-doped one and a Cu,Ca-enriched one. Although T_c was similar for both systems, with the Pb-doped one at 84 K and the Cu,Ca-enriched one at 76 K, the magnetization loops and the resistance data demonstrated that the Cu,Ca-enriched precursor yielded samples with better superconducting properties.

"Currently we are mainly focusing on the basic properties of the superconducting nanowire networks," Zeng noted. "In our opinion, the most promising application would be in fault current limiters, which require a high J_c and light weight. Another application is magnetic shielding, where the foil samples can shield irregular shapes due to their flexibility."

Team Seeking Commercial Partners

The research team exhibited their superconducting film at the Hannover Messe. They are seeking commercial and industrial partners with whom they can develop their system for practical applications.

"We are planning further basic investigations of the properties of the superconducting nanowires and their networks and want to improve the preparation method," Zeng said. "An important step forward will be the use of a basic superconducting material with a higher T_c to enable operation at 77 K. At that temperature, many applications, such as a superconducting carpet upon which magnetic objects can be levitated, will become possible.” ❍

KIT Enhances SC in NbN Nanowires

Researchers from the Karlsruhe Institute of Technology (KIT), the German Aerospace Center (DLR), the French National Center for Scientific Research (CNRS), and the Russian Academy of Sciences have found that NbN nanowires prepared using negative electron-beam lithography with positive-tone poly-methyl-methacrylate (PMMA) resist demonstrate improved performance metrics over those prepared using positive lithography with the same PMMA resist (arxiv.org/abs/1706.01289). The study highlights the potential of the technology to enhance applications such as superconducting nanowire singe-photon detectors (SNSPDs). The research received financial support from the joint German Research Foundation and French National Agency for Research (DFG/ANR) project SUPERSTRIPES SI 704/11-1.

Numerous efforts have been made in recent years to increase SNSPD detection efficiency (DE) at longer wavelengths and to decrease timing jitter and dark count rate (DCR). Research has been pursued in several directions, including in fields such as optics, solid state physics, and thin-film technology, with the search for optimal materials and the improvement of the quality of superconducting nanowires among the most straightforward.

Process Produces Smaller Width, Less Edge Roughness

KIT Researcher Ilya Charaev pointed out that negative electron-beam lithography is a promising path for producing improved superconducting nanowires, but it requires a more difficult process: “Negative electron-beam resists are more expensive, more delicate in handling, and have a higher requirements in terms of environmental conditions and surface quality. However, nanowires with smaller widths and reduced edge roughness have been obtained in a reproducible manner via negative-PMMA lithography with positive resist.”

The KIT-led research team demonstrated that nanowires with a thickness 5 nm and widths under 100 nm prepared using negative lithography had a 5% higher T_c and 30% higher J_c at 4.2 K than those prepared using positive-PMMA lithography. The improved cooling efficiency of the negative-PMMA nanowires resulted in 20% higher values for the retrapping current density. For SNSPDs, an increase in the cooling efficiency should result in a lower DCR and latching probability.

Damage to Nanowire Edges Affects Superconductivity

In addition, the ratio of the experimental I_c to the depairing I_c was found to be larger for the nanowires prepared using negative PMMA. The researchers suggest that the enhancement of superconducting properties was associated with the difference in the degree of damage that nanowire edges sustain in the lithographic process.

“It is predicted by theory and has been confirmed experimentally that an increase of the ratio of experimental I_c to the depairing I_c, for example via optimization of stoichiometry of NbN films or layout of the detector, results in an extension of the spectral range of SNSPD operation towards the infrared,” Charaev noted. “In the paper we report on the roughness of edges which was found to be larger for the strips made via the positive-PMMA lithography.

“Further details on this topic will be presented and discussed in another paper which will be submitted soon. We plan to combine our recent achievements in the optimization of material properties of thin NbN films, geometry and configuration of nanowire, optical coupling, readout chain, etc., to develop of the next generation of SNSPD-based devices and detection systems." ❍

ANL, LBNL Build Superconducting Undulators for LCLS-II Project

Argonne National Lab (ANL) and Lawrence Berkeley National Lab (LBNL) researchers at the Advanced Photon Source (APS) have designed, built, and tested two prototype superconducting undulators (SCUs) with the potential to make x-ray lasers more powerful, versatile, compact, and durable. They demonstrated that a SCU could be used as a free electron laser amplifier for x-ray free electron lasers (FELs). The work received funding from the U.S. DOE's Office of Science.

SCUs enable scientists to probe the properties of matter at ever smaller and faster scales. They create stronger magnetic fields than conventional permanent magnetic undulators of the same size. These fields then produce higher-energy laser light without increasing the electron beam energy. An SCU equivalent in length to a permanent magnetic undulator could produce light that is at least two to three times and up to 10 times more powerful, and could also access a wider range of x-ray wavelengths.

SCUs Offer Advantages Over Permanent Magnets

"The development and construction of SCUs require significant, multi-year investment commitments," commented ANL Researcher Efim Gluskin. "ANL maintained these commitments for almost a decade.

"The result is the successfully developed technology that already benefits APS and in the future will benefit other synchrotron and FEL light sources. This technology will be transferred to an industrial partner."

The SCU development was motivated by the Stanford Linear Accelerator Center (SLAC) National Accelerator Lab's upgrade of its Linac Coherent Light Source (LCLS), the only x-ray FEL in the U.S., through the LCLS-II project. X-ray FELs currently use permanent magnetic undulators to produce x-ray light by manipulating high-energy bunches of electrons in alternating magnetic fields produced by a sequence of permanent magnets.

Superconducting undulators have no macroscopic moving parts, so they could conceivably be tuned more quickly with high precision. Superconductors also are far less prone to damage by high-intensity radiation than permanent-magnet materials, a significant concern with high-power accelerators such as those that will be installed for LCLS-II.

ANL Built and Tested NbTi SCU

The APS scientists built and tested a 1.5-meter-long prototype SCU magnet that utilized NbTi superconducting wire in its magnetic coils. It was designed to meet FEL undulator technical requirements, such as high-precision field quality and consistency all along the magnet. The APS SCU team used in-house-developed cryogenic systems and magnetic measurement techniques to validate the SCU performance.

"The SCU was benchmarked against permanent magnet (PM) undulators," Gluskin noted. "The SCU delivers stronger fields, i.e. exceeds PM device performance and at the same time meets all the other challenging magnetic specs."

LBNL Undulator Uses Nb_3Sn

The LBNL researchers used Nb_3Sn in their 1.5-meter-long prototype undulator. It set a record in magnetic field strength for a device of its design during testing in September 2016.

The NbTi used in the ANL SCU has a lower maximum magnetic field strength than Nb_3Sn, but has been more thoroughly investigated. The

Nb_3Sn used at LBNL is a brittle material that cannot be drawn into a wire. For practical use, a pliable wire which contains the components that will form Nb_3Sn when heat-treated at 920 K is used for winding the undulator coils.

The LBNL team wound the Nb_3Sn wire around a steel frame to form tightly wrapped coils in an alternating arrangement. After the heat treatment, the superconducting coils were placed in a mold and impregnated with epoxy to hold them in place. A quench-protection system was engineered to detect the occurrence of quenching within a couple thousandths of a second and shut down its effects within 10 thousandths of a second.

"SCUs will be the technology we go to eventually, whether it's in the next 10 or 20 years," commented SLAC's Paul Emma, Accelerator Physics Lead for LCLS-II. "They are powerful enough to produce the light we are going to need.

"I think it's going to happen. People know it's a big enough step, and we've got to get there." ❍

Harvard Builds Quantum Antiferromagnet System

Harvard University physicists have created a quantum antiferromagnet using the ultracold gas of hundreds of lithium atoms (10.1038/nature22362). The system will enable them to study the physics of antiferromagnets, and especially how they influence superconductivity in cuprates. The research received financial support from the Air Force Office of Scientific Research, the Army Research Office, the Gordon and Betty Moore Foundation's Emergent Phenomena in Quantum Systems (EPiQS) Initiative, the Harvard Quantum Optics Center, the National Science Foundation, and the Swiss National Science Foundation.

In traditional magnets, the electron spins in a material are aligned so that they work in unison. In an antiferromagnet, however, electron spins are arranged in a checkerboard pattern. One spin may be pointed north, while the next is pointing south, and so on. Past experiments have suggested that antiferromagnetism may be a precursor to the pseudogap and superconducting phases in cuprates.

"Antiferromagnetism appears in most cuprates before the transition to superconductivity," commented Harvard Researcher Daniel Greif. "A better understanding of this phase could enable us to better study the Hubbard model. We hope eventually to start with antiferromagnetism in order to build an unconventional superconductor."

Atoms Used in place of Electrons

The Harvard antiferromagnet provides a much-needed tool for studying the phase transitions of cuprates. Scientists have been successful in simulating the quantum properties of atoms, and some simple materials. However cuprates, among other compounds, are too complex to be modeled accurately by conventional computers.

The Harvard team created the antiferromagnet by trapping a cloud of lithium atoms in a vacuum and using a method they called entropy redistribution. This process cooled the atom cloud to 10 billionths of a degree above 0 K in a square lattice of approximately 80 sites.

Team Controls All Parameters

The system they built essentially functions as a special-purpose quantum computer that can simulate the physics of antiferromagnets. The researchers control all the parameters, so they are able to observe directly how specific tuning might help or suppress superconductivity.

"The antiferromagnet uses atoms as charge carriers in place of electrons," Greif noted. "We can control each atom to a very high level, to a point where we can identify the effects that result from changing one parameter. This will help us identify how specific tuning might stimulate or suppress superconductivity in cuprates."

Research to Continue at Lower Temperatures

This degree of control has enabled the Harvard researchers to map the system to the level where they can extract information about individual atoms. They can also change the atomic density of the antiferromagnet and observe its effects.

"We plan to lower the temperature further through more advanced cooling schemes," said Greif. "This will provide a new way for looking at the system. Besides observing its effects on superconductivity, we hope to study other quantum phases, such as the pseudogap and stripe ordering." ❍

Team Demonstrates SC Kinetic Inductance Nanoscale Memory

Researchers with the University of Illinois at Urbana-Champaign and Stony Brook University have demonstrated that the winding number of the order parameter of a closed superconducting loop, or its vorticity, can be used for realizing a nanoscale nonvolatile memory device. The research is a step towards the development of nanoscale superconducting memory technology for computing applications. The work was supported by the National Science Foundation (NSF) under Grant No. ECCS-1408558.

"Although previous experiments showed that nanoscale superconducting loops can sustain different vorticity states, our work is probably the first demonstration of a complete control of the vorticity," said Alexey Bezryadin, Professor at U Illinois who co-authored the research. "Our study includes writing the desired memory state and reading out the information with a demonstration of 100% fidelity in one test device. To the best of our knowledge, ours is the first device based on the kinetic inductance of nanowires, which allows for reliable information storage and recovery."

Memory to Enable Low Power-consuming Supercomputers

The demand for low-dissipation nanoscale memory devices is as strong as ever, in part in order to enable low power-consuming supercomputers. As part of this objective, research is ongoing to develop information processing circuits out of superconductors.

To date, however, digital superconducting circuits have not demonstrated their potential. One reason is that a dense superconducting memory technology is not yet available.

The miniaturization of traditional SQUIDs is difficult below a few micrometers because their operation relies on the geometric inductance of the superconducting loop. Magnetic memories do allow nanometer-scale miniaturization, but are not purely superconducting.

"Geometric inductance is dependent on the size of the device," said Bezryadin. "If the device is small then the inductance is small too. This fact make miniaturization difficult.

"The reason is that to achieve metastable states in traditional SQUIDs one needs to achieve at least two metastable states, which is possible if the inductance is sufficiently large. In traditional SQUIDs, the geometric inductance has to be larger than the superconducting flux quantum divided by the I_c of the device.

"Therefore, the lower limit on the size of SQUID-based memory cells is typically above a few micrometers. In our case, the kinetic inductance is the main player.

"The lower limit gets bigger when the wire is made thinner because it is inversely proportional to the cross-section area of the wire. Our smallest superconducting memory loop was approximately 150 nm in width, which is roughly an order of magnitude smaller than what was possible with traditional SQUIDs."

Two Designs for SC-

Magnetic Memory Devices

Bezryadin elaborated on how superconductivity is used in the memory device developed by his team: "In superconductor-magnetic memory devices one can distinguish two types of designs. In the first approach, a magnetic layer is inserted into the dielectric of the junction. In such cases one can achieve a memory effect because the magnetic layer can be magnetized in different directions, changing the magnetic flux through the junction.

"The I_c of the junction follows the Fraunhofer pattern as the flux is changed. This means that by changing the magnetization one can achieve a memory effect.

"In the second approach, two magnetic layers are present in the junction and the I_c is dependent on the two layers being magnetized parallel to each other or antiparallel. The exchange interaction, and not magnetic interaction between the layers, plays the key role in this configuration.

"In the first configuration the magnetic field can have adverse effects on practical systems where many memory cells are integrated. In the second configuration the layer thickness has to be very precisely controlled, probably with a precision of better than one nanometer, and because of this fabrication is difficult and could be costly.

"The miniaturization is limited by the process runout, which means that the dimensions of the etched device can be smaller than expected in an unpredictable way. Both types of magnetic memory may be promising, but so far the test devices were on the order of one micron in size, to the best of our knowledge.

"The reading and writing functions of the magnetic devices required changing the magnetic field. However, in our smallest device we could reliably write and read the states by changing the bias current at a constant and fixed magnetic field."

Researchers Developing Kinetic Inductance-based Memory Cells

The Illinois-Stony Brook team is working to develop nanometer scale memory cells based on the kinetic inductance, instead of geometric inductance, of superconducting nanowire loops. Kinetic inductance-based memory cells have shown promise in previous studies.

"The kinetic inductance is inversely proportional to the I_c," said Bezryadin. "But the I_c is given by a product of the J_c and the cross-section area. This means that decreasing the cross section area of the nanowire used in the SQUID memory device will raise the inductance. Miniaturization below one micron is therefore possible, as we demonstrate, because by making thinner nanowires we achieve higher kinetic inductance and thus achieve multiple metastable states.

"One key requirement to obtain a memory device is the presence of multiple metastable states. For this purpose, we estimate that the length of the nanowire loop must be at least eight times larger than the coherence length. A typical coherence length is 5 or 10 nm.

"The loop radius should thus be at least 10 or 20 nm. Note that a high-T_c material has a much smaller coherence length and if used can result in a memory cell that is even smaller.

"At this stage, the nanowire-based kinetic inductance memory is much slower [that SQUID-based systems] because a DC current or a low frequency AC current was used to write and read the memory states. Preliminary results were previously published by our team showing that the vorticity can be also determined by performing microwave measurements on superconducting loops coupled to microwave cavities. It should therefore be possible to cut the operation time of our memory devices to a fraction of nanosecond."

Possible to Develop Memory that Operates without Dissipation

In the recent study, the research team demonstrated how to alter the vorticity in a controlled fashion by applying calibrated current pulses. A reliable read-out of the memory was also demonstrated, alongside arguments that such memory can be developed to operate without energy dissipation.

"One challenge is to develop an algorithm allowing us to read out information as well as write the information into a large ensemble of such memory devices," said Bezryadin. "Another challenge is to increase the T_c above the liquid helium temperature of 4.2 K.

"We hope to develop a SQUID based on NbTi nanowires, which has a higher T_c than the $Mo_{75}Ge_{25}$ that we currently use. We have also developed a method that allows us to control the memory cell exclusively via the bias current.

"The memory cell still needs to possess multiple states. The idea is to design a system and choose the external parameters in such a way that a pair of metastable states is degenerate by energy. Then, so-called macroscopic quantum tunneling can be used to change the vorticity as desired.

"Quantum tunneling occurs without dissipation, so it should be possible to achieve memory functions with a very low memory dissipation. Another approach would be to change the relative energies of the memory states adiabatically.

"Using that approach, if the system is allowed to jump between states many times while being driven by its thermal fluctuations then the energy release can be very small. Our kinetic inductance devices should be helpful in for the realization of such energy-efficient adiabatic computation."

Team to Operate Kinetic Inductance Memory using Microwave Electromagnetic Pulses

Bezryadin described the next steps in his team's research: "The next step is to operate our kinetic inductance memory using microwave electromagnetic pulses. Both reading and writing can be done at high frequencies, in the GHz range.

"The attempt frequency of phase slips is high, in the range of ~100 GHz, so a high-speed operation should be possible. In order to switch the memory, just one Little's phase slip is needed.

"Additionally, to be more efficient the memory should function without involving any magnetic fields, either for its reading or writing. We expect this will be possible if the loop is made of two different wires. So far, we have been able to demonstrate the readout and the writing functions at a constant magnetic field.

"The magnetic field can be completey eliminated as a control parameter because the kinetic inductance memory phase shifts of the superconducting condensate in the loop, associated with Little's phase slips, define the behavior of the memory cell. Such phase shifts and slips are controlled by voltage pulses and do not require magnetic fields.

"The final goal will be to develop an integrated system with the large numbers of memory cells needed to make it practically useful. The cross-talk between the kinetic inductance memory cells is expected to be low since they do not produce magnetic field of any significant strength due to their low geometric inductance." ❍

Cornell Team Wins Grant to Develop Topological SC

A multidisciplinary team from Cornell University has received a $1 million, 3-year grant from the W.M. Keck Foundation to build on their past work to create a specific topological superconducting material. The project is entitled "A Materials-by-Design Approach to an Odd-Parity Topological Superconductor" and aims to develop a material that might contribute to a stable and scalable quantum computing technology.

The Cornell team is led by Engineering Professor Darrell Schlom, an expert in molecular beam epitaxy (MBE). Other team members and their areas of expertise include: Physical Sciences Professor J.C. Seamus Davis, who developed a precise spectroscopic imaging scanning tunneling microscope (SI-STM), Physics Professor Kyle Shen, an expert in angle-resolved photoemission spectroscopy (ARPES), Applied and Engineering Physics Professor Craig Fennie, an expert in materials-by-design, and Physics Professor Eun-Ah Kim, whose expertise is correlated electron theory.

Cornell to Create Non-Abelian Anyons

The group's proposal involves creating an artificial material in which pairs of ground-state non-abelian anyons could be braided in two dimensions. An anyon is a type of quasiparticle that occurs only in 2D systems but with properties much less restricted than fermions or bosons. If transported around another anyon, it develops a quantum phase that can take on any value depending on the type of anyon.

Davis explained the value of an anyon that is transported around another anyon: "It depends on the symmetry of the fundamental phase of the electrons. For example, quasiparticles of fractional quantum Hall states have many different possible values of the quantum-phase winding, according to which quantum Hall state they emerge from."

Successfully utilizing anyons in a quantum system could be a means of overcoming the problem of qubit instability and retention of information. Since an anyon does not enter an excited state, it does not suffer decoherence.

Physicists first suggested about 15 years ago that non-abelian anyons could be used to construct a topological quantum computer. Experimental evidence of their existence has only recently been presented and is not considered conclusive.

Team to use Moore CONQUEST Facility

The team will make use of the Moore Creation and Observation of Novel Quantum Electronic Structures (CONQUEST) facility, which was funded by a three-year, $4.13 million grant from the Gordon and Betty Moore Foundation in 2013. The facility houses an oxide MBE and ARPES in one lab, which are connected to the SI-STM in an adjoining lab. It is expected to be up and running by the end of 2018. ❍

Israeli-led Team Measures Vortex Dynamics in SC

Researchers with the Weizmann Institute of Science, the Hebrew University of Jerusalem, the University of Antwerp, the University of Liege, the University of Colorado Denver, the Ukrainian Academy of Sciences, and Old Dominion University have reported the first direct visual observation and measurement of ultra-fast vortex dynamics in superconductors (doi:10.1038/s41467-017-00089-3). The technique could contribute to the development of new practical applications in electronics for superconductors by optimizing their properties.

"The technique allows for the visualization of vortex flow, which is a limiting factor and a source of dissipation in practical superconducting devices," said Eli Zeldov, Professor at the Weizmann Institute who co-authored the research paper. "We used lead thin film for convenience, but in principle any superconductor can be similarly studied."

Understanding Vortice Movement Focus of Significant Research Push

Superconductivity is generally suppressed in the presence of magnetic fields. A family of superconductors known as type-II superconductors can withstand much higher magnetic fields than typical superconducting materials thanks to their ability to allow the magnetic field to thread through them in a quantized, local tubular-shaped form called a vortex.

Unfortunately, in the presence of electric currents these vortices experience a force and may begin to move. This motion of vortices allows for electrical resistance.

Understanding when and how vortices will move or remain localized is the focus of much scientific research. Until now, addressing the physics of fast moving vortices experimentally has proven extremely challenging. This is because most of the existing imaging techniques lack the required combination of sensitivity, spatial resolution, and noninvasiveness needed to visualize vortex motion at practical applied fields.

Team Deploys SQUID-on-tip Microscopy Technique

The research team used a novel microscopy technique called scanning SQUID-on-tip to measure the movement of the vortices. SQUID-on-tip allows magnetic imaging at a resolution of about 50 nm and high magnetic sensitivity. The technique was developed over the last decade at the Weizmann Institute and is currently also being developed at the Hebrew University.

"The SQUID-on-tip can be fabricated from various superconducting materials including Al, Nb, Pb, and In," said Zeldov. "In this study we used a SQUID-on-tip made of Pb due to its superior properties.

"In the presented study of vortex dynamics the SQUID-on-tip has a substantial advantage over the other techniques. SQUID-on-tip microscopy can be utilized for a wide range of nanoscale magnetic imaging studies of superconductors and magnetic materials."

Vortices Travel Faster than Supercurrent Driving Them

Using the SQUID-on-tip microscope, the researchers observed vortices flowing through a thin superconducting film at rates of tens of GHz and traveling at velocities of up to about 72,000 km/hr, faster than previously thought possible. Their speed exceeds the pair-breaking speed limit of superconducting condensate; a vortex can travel 50 times faster than the speed limit of the supercurrent that drives it.

"The situation is similar to a sailboat that cannot sail faster than the wind if it moves along with the wind's direction," said Zeldov. "But if the sailboat is steered to move close to being perpendicular to the direction of the wind it can in principle move at speeds well above the wind velocity. The vortices essentially move perpendicular to the flow of the condensate and are hence are not limited by the condensate velocity."

The researchers also found that as the vortices move, they tend to follow each other. The results are considered surprising as vortices normally repel each other and try to spread out as much as possible.

"There could be a number of mechanisms that cause vortex tailgating," said Zeldov. "We believe the dominant mechanism is local heating in the wake of a moving vortex that attracts the following vortex. The collective vortex dynamics and the resulting dissipation in devices is affected by the specifics of the vortex flow characteristics."

1 THz Frequency Gap Desirable for Applications

Simulation results conducted as part of the study suggest that with proper sample design and improved heat removal it may be possible to reach even higher velocities. In that regime, the calculated frequencies of penetration of vortices may be pushed to the technologically desired THz frequency gap.

"[The vortices will need to travel] about 50 times faster to reach 1 THz," said Zeldov. "This is the frequency range that is important for nondestructive evaluation and security inspection and is not readily achievable with current technologies

"[Our current research into vortex movement] is specific to type II superconductors. The next interesting things we would like to study are vortex dynamics in HTS materials and dynamic phase transitions of vortex matter." ❍

NIST Devises Efficient Small SNSPD Cooling System

Scientists at the National Institute of Standards and Technology (NIST), along with Front Range Engineering, LLC, have developed a prototype hybrid system for cooling superconducting nanowire single-photon detectors (SNSPD) that is much smaller than those currently in use and does not use liquid helium as a cryogen (doi: 10.1109/TASC.2017.2657682). Their work may expand the use of SNSPDs to applications that currently require higher voltage energy sources.

The design phase of the study was funded by the National Security Agency (NSA). The project is currently being supported by a Small Business Innovation Research grant from the Defense Advanced Research Projects Agency (DARPA) and under a cooperative R&D agreement (CRADA) with the Michigan startup Quantum Opus.

"This type of architecture has a niche for very small cooling capacity, compact applications," commented NIST Researcher Vincent Kotsubo. "It is already being used for spaceflight coolers. It may, in the future, be used for Josephson junction noise thermometry, and carbon nanotube bolometers."

Development Driven by Lower Power Draw

Past models of SNSPDs have used liquid helium cooling systems, which in recent years have become much more costly. This has generated interest in finding more cost-effective cooling alternatives.

'SNSPD's are presently being cooled with closed cycle Gifford-McMahon coolers, with a sorption cooler if they need to get to lower temperatures," Kotsubo said. "Gifford-McMahon coolers are significantly oversized for this application, with the smallest available unit requiring 1.5 kW of power. So the driver for this development was lower wall power draw and a more compact footprint."

Architecture Combines JT Cryocooler with PTR

The NIST team's prototype device relies on a hybrid cooling system comprising a Joule-Thomson cryocooler (JT) and a pulse-tube refrigerator (PTR). A gas is alternately compressed and then allowed to expand, shedding thermal energy to an exchanger that removes heat from the system, which is completely closed.

The PTR has reached temperatures as low as 6.4 K, although the heat load from the JT causes the temperature to rise to about 7.5 K. After precooling, the JT can operate below 2 K. Substituting helium-3 for helium-4 should result in even lower temperatures, approaching 1 K.

The complete system consisting of cooler, drive, control electronics, and instrumentation is 0.31 m high and 0.61 m long. When all the engineering work is completed, the scientists believe that it will easily fit in a standard electronics rack.

Complete System to Require less than 250 W

A fully optimized system is projected to consume less than 250 W of wall power draw, including other elements such as drive and control electronics and cooling fans. Future work includes development of the Joule-Thomson compressor, drive and control electronics, and further optimization of the pulse tube and Joule-Thomson coldheads.

"The 250 W is projected from PTR test data, along with assumptions on JT compressor power, plus estimates on electronics power consumption," Kotsubo said. “We operated the pulse tube with 150 W input power and we expect the JT compressor to consume 30 W, so the mechanical coolers themselves consume 180 W. Since 250 W is already a low number, there isn’t too much of a drive to keep the total system power low.

“Our largest challenge is the reliability of the JT system. It is very sensitive to contamination, so the question remains as to whether the contamination generation by the compressor will be low enough, and whether or not we can adequately remove whatever contamination is being generated.” ❍

Nanjing U Investigates $Sr_xBi_2Se_3$ as Topological Superconductor

Researchers at the Center for Superconducting Physics and Materials at Nanjing University have detected two-fold symmetry in the superconductor $Sr_xBi_2Se_3$, providing evidence that the material might be a topological superconductor (doi: 10.1007/s11433-016-0499-x). Their findings suggest that Majorana fermions might be discovered in $Sr_xBi_2Se_3$, and that the compound may hold promise for use in quantum computing. The work was supported by the Ministry of Science and Technology of China and the National Natural Science Foundation of China.

“The early interest in $Sr_xBi_2Se_3$ has been about the topological surface state,” commented Nanjing U Professor Hai-Hu Wen. “Theory now predicts that there might be a kind of complex pairing order parameter with a two fold symmetry in this system.

“Our experiment illustrates that the two-fold symmetry of the order parameter is consistent with earlier NMR and specific heat measurement. The finding requires further research on similar high quality samples. If two-fold symmetry is shown to be a common feature, it would be an important step in the search for topological superconductivity.”

Doping-induced superconductors from topological insulators are expected to possess robust, gapless excitations on the boundary or surface of a topological insulator. Their zero energy excitations are suitable for the presence of Majorana fermions, which theorists predict could function as stable qubits for quantum computation.

Two-fold Symmetry Observed

The Nanjing team used high-quality $Sr_xBi_2Se_3$ single crystals in their work. $Sr_xBi_2Se_3$ has a T_c of about 3.5 K. The researchers performed the c-axis resistivity measurements with an angle-dependent, in-plane magnetic field on four $Sr_xBi_2Se_3$ samples with a Corbino-shaped electrode.

The observations were consistent with earlier experiments by NMR and angle resolved magnetocaloric measurements. The two-fold symmetry features in all the angular dependent resistance measurements at low magnetic fields and temperatures, indicating the nontrivial topological order of the superconductivity in $Sr_xBi_2Se_3$.

“We are growing more $Sr_xBi_2Se_3$ samples of the best quality and will conduct further experiments to check for topological superconductivity. The next step will be searching for Majorana fermions and modes in this system, which would be a natural consequence of topological superconductivity.” ❍

Chinese Team Runs HHL Algorithms on Quantum Processor

Researchers from the Chinese Academy of Sciences, Zhejiang University, and the University of Science and Technology of China, Hefei, have used a four-qubit superconducting quantum processor to solve a 2D system of linear equations using the HHL algorithm (Phys. Rev. Lett. 118, 210504).

Their results highlight the potential of superconducting quantum circuits for applications in solving large-scale linear systems. The study received financial support from the Chinese Academy of Sciences, the National Bio Resource Project of China (NBRP), the National Natural Science Foundation (NSFC), and the Fundamental Research Funds for the Central Universities of China.

The HHL algorithm was proposed in 2009 as a means for quantum computers to solve linear systems exponentially faster by calculating the expectation value of an operator associated with the solution. Based on this algorithm, several practical applications of quantum computation have been suggested, including data processing, numerical calculation, and artificial intelligence. However, the algorithm has previously only been demonstrated with parametric down-converted single photons and liquid NMR, neither of which are considered to be easily scalable to large numbers of qubits.

For their experiment, the Chinese team used a superconducting quantum circuit, which past studies had suggested would offer improved coherence, scalability, and high-fidelity and fast control. In addition, they compiled versions of various quantum algorithms that have been successfully tested on this platform on a small scale.

"The whole calculation process takes about one second," Xiaobo Zhu of the University of Science and Technology noted. "It is hard to directly compare the current version to the classical methods. In this work, we showed how to solve the simplest 2×2 linear system, which can be solved by classical methods in a very short time.

"The key power of the HHL quantum algorithm is that when solving an 's-sparse' system matrix of a very large size, it can gain an exponential speed-up compared to the best classical method. It would be much more interesting to show such a comparison when the size of the linear equation is scaled to a very large system."

"Our future research will focus on improving the hardware performance, including longer coherence times, higher precision logic gates, larger numbers of qubits, lower crosstalk, and better readout fidelity," Professor Haohua Wang of Zhejiang University said. "Based on these improvements we will demonstrate and optimize more quantum algorithms to really show the power of the superconducting quantum processor." ❍

Superconductivity Roundup

Events & Opportunities from Around the Industry

SW **AMSC** has delivered the beta version of its **HTS Magnetic Influence Mine Countermeasure Payload System** to the **U.S. Navy** for on-the-water testing and evaluation. The system is a deployable mine countermeasure system designed to operate in concert with multiple U.S. Navy vessel platforms.

AMSC, the U.S. Navy, and the Office of Naval Research have collaborated on AMSC's HTS-based Ship Protection Systems (SPS), which include HTS Advanced Degaussing Systems (see *Superconductor Week*, Vol 22, No 12) in addition to the Mine Countermeasure Payload System. The core components of AMSC's SPS are common and transferable to other applications being targeted for ship implementation.

sw Researchers with the **University of Saskatchewan** and **El-Shorouk Academy** in Egypt have conducted a **dynamic simulation study of superconducting fault current limiters** (SFCLs) used to mitigate the impact of synchronous machine (SM)-based distributed generation (DG) integration on existing radial fuse-recloser protection infrastructure (doi: 10.1049/iet-gtd.2015.1156).

The study compares the performances of two different SFCL types. The results indicate that the presence of SFCLs prevented any excessive fault current contribution from SM-based DG sources, and as a result restored the fuse-recloser coordination and recloser sensitivity adequacy.

sw Researchers with the **STFC Rutherford Appleton Lab**, the **National Institute of Advanced Industrial Science and Technology** (AIST), and **IMRA Material R&D Company, Ltd.** have concluded a **study** of the superconducting and magnetic properties of **$CaKFe_4As_4$** (doi.org/10.1103/PhysRevB.95.140505). $CaKFe_4As_4$ belongs to a newly discovered family of high-T_c Fe-based superconductors, $A_eAFe_4As_4$ where A_e=Ca, Sr, Eu and A=K, Rb, Cs.

The researchers studied the superconducting and magnetic properties of $CaKFe_4As_4$ using muon spectroscopy. Zero-field muon spin relaxation studies carried out on the superconductor did not show any detectable magnetic anomaly at T_c or below, implying that time-reversal symmetry is preserved in the superconducting ground state.

The temperature dependence of the superfluid density of $CaKFe_4As_4$ was found to be compatible with a two-gap s+s-wave model with gap values of 8.6 and 2.5 meV, similar to the other Fe-based superconductors. The presence of two superconducting energy gaps is consistent with theoretical and other experimental studies on the material. The value of the penetration depth at T=0 K was determined to be 289 nm.

sw **Oxford Instruments** (OI), the **National Physical Lab**, and the **National Graphene Institute** at the **University of Manchester** have completed a project to develop, verify, and test a graphene-based, **cryogen-free quantum measurement system** operating at low magnetic fields. The system enables primary resistance calibrations with unprecedented accuracies and is intended for use by national metrology labs and industrial companies.

"This demonstrates the industrial feasibility of using graphene and 2D materials to commercialize quantum measurement systems and enable solutions in standard measurements and 2D materials characterization," said Ziad Melhem, Alliances Manager from OI NanoScience. The project was partially funded by Innovate UK.

sw **HTF Market Intelligence** has released a new report entitled "**Superconductors - Global Market Outlook (2016 to 2022)**" in which it forecasts that the global market for superconductors will reach $2.71 billion by 2022. The global superconductor market was valued at $820 million in 2015, and the report projects that it will grow at a CAGR of 18.6% over the period analyzed. The report includes analysis of major providers including AMSC, Evico GmbH, Hyper Tech Research, Inc., Siemens AG, Sumitomo Electric Industries Ltd., STI, Bruker Corporation, Ceraco Ceramic Coating Gmbh, Deutsche Nanoschicht Gmbh, Fujikura Ltd., and Furukawa Electric Co. Ltd.

sw The **Hungarian Ministry of Agriculture** has selected Bruker collaboration partner **Diagnosticum** to implement a new program to **authenticate and identify Hungarian wines** using Bruker's NMR FoodScreener Technology. Diagnosticum and Bruker will form the Hungarian Wine Consortium and develop a Hungarian wine model. Wine Profiling by NMR relies on the acquisition of the spectroscopic fingerprint specific of each individual sample.

sw **York Instruments, Ltd.**, a subsidiary of **Croton Healthcare, LLC**, has **signed agreements to place MEG systems** at three neuroscience research universities in the UK and Germany. The

University of York and the University of Glasgow in the UK and Germany's University of Konstanz will partner with York Instruments to develop the technology, as well as pursue potential new applications using the company's MEG technology.

The agreement expands on a development partnership started in 2015. By first incorporating MEGSCAN core control electronics, the universities' MEG researchers will achieve an improved SNR using low noise electronics. With the full MEGSCAN system, the universities will end their reliance on liquid helium and have the ability to measure healthy and pathological brain signals with unprecedented sensitivity.

Later this year, the universities will install the first stage of control electronics, which will allow for higher levels of functional brain imaging. In addition to offering low levels of electronic noise interference, the systems have a higher level of reliability, lower power consumption, and will be upgradable.

sw **HTF Market Intelligence** has released a research report entitled "**Global High Temperature Superconducting Wires Market 2016 to 2020**" in which it projects that the HTS wire market will grow at a CAGR of 4.8% over the analyzed period. The report includes analysis of major industry players including AMSC, SUNAM, Superconductor Technologies, and SuperPower.

sw **AMSC** will **move out** of its Devens, MA offices to save a total of $4 million to $5 million annually. The company plans to move by next April to a nearby location. AMSC doesn't expect the relocation to affect employees or product deliveries.

AMSC's current 355,000 square foot site is larger than necessary, President and CEO Daniel McGahn first told investors this spring. The site was intended to be used for a first-generation manufacturing process to create a scale of wire that the company has never actually created. AMSC also doesn't require as much office space after laying off 30 employees in the spring, an 8% reduction in the company's workforce. The company owns the building, which it values at $23 million to $25 million.

sw **Patrick Adair Designs** has begun selling **rings made out of discarded superconducting wire**. The ring currently being sold by the design company incorporates LTS NbTi wire and sells for $700.

sw **Global Market Insights, Inc.** has published a market report entitled "**Superconducting Materials Market Size - Industry Share Report 2024**" in which it forecast that the superconducting materials market will exceed $2 billion by 2024, growing at a 17% CAGR. Some companies analyzed in the report include Siemens AG, Evico GMBH, American Superconductor, Hyper Tech Research Inc., Hitachi Ltd., and STI.

sw The **UMCG** and the **MAASTRO Clinic** have been **awarded a grant** of over **€1.5 million** ($1.8 million) by the **Dutch Cancer Society KWF** for a program to set up **research infrastructure for proton therapy** (ProTRAIT). HollandPTC in Delft, all the university medical centers in the Netherlands, the Netherlands Cancer Institute/Antonie van Leeuwenhoek, and the Princess Maxima Center are also involved in the program.

The centers will set up a joint database to store the data of all patients treated with proton therapy in the Netherlands. The data will initially be gathered and stored by the individual centers, and then linked through an advanced IT structure. It will then be incorporated into an existing national database for cancer research (TRAIT).

Proton therapy will be available in the Netherlands from late 2017 onwards in Groningen and Delft. In 2014,the Dutch government approved the construction of four proton therapy centers in Amsterdam, Delft, Groningen, and Maastricht.

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August 31, 2017 Vol. 31, No. 7

Superconductivity Stock Index

Company Name	Symbol	Prices ending 30-Dec-2016	Prices ending 31-July-2017	Percentage change
American Superconductor	AMSC	7.37	3.19	-57%
Oxford Instruments	OXIG.L	9.04*	13.85*	53%
Superconductor Technologies	SCON	1.23	1.46	19%
Bruker Corporation	BRKR	21.18	28.68	35%
Furukawa Electric	5801	30.38**	45.17**	49%
Ion Beam Application	IBAB.BR	43.82***	35.41***	-19%
Superconductor Index (12/31/14 = 100)		100.00	130.15	30%
Standard and Poor's 500		2,238.83	2,470.30	9%

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

Aluminum Smelter with SC Material

Rio Tinto Alcan International Limited
Mar. 21, 2017
U.S. Patent No. 9598783

An aluminum smelter has a series of electrolytic cells, designed for the production of aluminum, forming one or more rows, a supply station designed to supply the series of electrolytic cells with an electrolysis current, the said electricity supply station comprising two poles, a main electrical circuit through which the electrolysis current flows, having two extremities each connected to one of the poles of the supply station, at least one secondary electrical circuit comprising an electrical conductor made of SC material through which a current flows, running along the row or rows of electrolytic cells, characterized in that the electrical conductor made of SC material in the secondary electrical circuit runs along the row or rows of electrolytic cells at least twice in such a way as to make several turns in series.

HTS Films

Ambature, Inc.
Mar. 21, 2017
U.S. Patent No. 9601681

Operational characteristics of an HTS film comprised of an HTS material may be improved by depositing a modifying material onto appropriate surfaces of the HTS film to create a modified HTS film. In some implementations of the invention, the HTS film may be in the form of a “c-film.” In some implementations of the invention, the HTS film may be in the form of an “a-b film,” an “a-film” or a “b-film.” The modified HTS film has improved operational characteristics over the HTS film alone or without the modifying material. Such operational characteristics may include operating in a superconducting state at increased temperatures, carrying additional electrical charge, operating with improved magnetic properties, operating with improved mechanic properties or other improved operational characteristics. In some implementations of the invention, the HTS material is a mixed-valence copper-oxide perovskite, such as YBCO. In some implementations the modifying material is a conductive material that bonds easily to oxygen, such as chromium.

Active Compensation of Quantum Processor Elements

D-Wave Systems Inc.

Mar. 28, 2017

U.S. Patent No. 9607270

Apparatus and methods enable active compensation for unwanted discrepancies in the SC elements of a quantum processor. A qubit may include a primary compound Josephson junction (CJJ) structure, which may include at least a first secondary CJJ structure to enable compensation for Josephson junction asymmetry in the primary CJJ structure. A qubit may include a series LC-circuit coupled in parallel with a first CJJ structure to provide a tunable capacitance. A qubit control system may include means for tuning inductance of a qubit loop, for instance a tunable coupler inductively coupled to the qubit loop and controlled by a programming interface, or a CJJ structure coupled in series with the qubit loop and controlled by a programming interface.

Substrate for SC Thin Film

Furukawa Electric Co., Ltd.

Mar. 28, 2017

U.S. Patent No. 9608191

A SC thin film having excellent I_c characteristics has a substrate that includes a substrate body having a main surface in which the root mean square slope $R_{\Delta q}$ of a roughness curve is 0.4 or less.

Cooling System and Method

Sumitomo Heavy Industries, Ltd.

Apr. 4, 2017

U.S. Patent No. 9612062

A cooling system for cooling a SC device by a low-temperature fluid has a flow generator for producing a flow in the low-temperature fluid. The low-temperature fluid flowing through the SC device is heated. The flow generator is used to produce a flow in the heated low-temperature fluid. The low-temperature fluid is cooled and supplied to the SC device.

LTS Device for Measuring Gravity

Institute of Electrical Engineering, Chinese Academy of Sciences

Apr. 4, 2017

U.S. Patent No. 9612356

A LTS device for measuring gravity, includes a low-temperature container, a cryocooler, a rotor chamber, a SC rotor, an upper levitation coil, a lower levitation coil, an upper electrode, an intermediate electrode, a lower electrode, a magnetic shielding chamber and a SQUID. By cooling the whole LTS device using a cryocooler, the intermediate electrode disposed in the body of the magnetic shielding chamber will generate an output voltage when the SC rotor is displaced due to a change of gravity. Thus, the SQUID can make the SC rotor return to the central balance position by adjusting the operating current of the upper levitation coil or the lower levitation coil. A change of gravity can be determined based on the operating current fed back to the upper levitation coil or the lower levitation coil.

Memory System with SC Memory

Microsoft Technology Licensing, LLC

Apr. 4, 2017

U.S. Patent No. 9613699

A memory system has a content addressable memory with an array of content addressable memory elements including a plurality of rows of content addressable memory elements and a plurality of columns of content addressable memory elements is provided. Each of the content addressable memory elements further includes a first SQUID and a second SQUID, where an input bit to each of the content addressable memory elements is compared with: a first state of the first SQUID and a second state of the second SQUID to generate an output signal. The memory system further includes a Josephson magnetic random access memory (JMRAM), coupled to the content addressable memory.

SC Magnet Device

Hitachi, Ltd.

Apr. 11, 2017

U.S. Patent No. 9620272

A permanent current switch device of a refrigerator cooling-type SC magnet includes a SC coil cooled by solid thermal conduction and a permanent current switch. A heat transfer member is thermally connected to a cooling stage and is structured to be inserted into and removable from a former of the permanent current switch. Due to differences in thermal expansion between the heat transfer member and the former, a permanent current mode can be stably maintained.

Silicon Dielectric for SC Devices
Intermolecular, Inc.
Mar. 14, 2017
U.S. Patent No. 9593414
Amorphous silicon (a-Si) is hydrogenated for use as a dielectric (e.g., an interlayer dielectric) for SC electronics. A hydrogenated a-Si layer is formed on a substrate by CVD or sputtering. The hydrogen may be integrated during or after the a-Si deposition. After the layer is formed, it is first annealed in an environment of high hydrogen chemical potential and subsequently annealed in an environment of low hydrogen chemical potential. Optionally, the a-Si (or an H-permeable overlayer, if added) may be capped with a hydrogen barrier before removing the substrate from the environment of low hydrogen chemical potential.

Liquid Nitrogen Cooled MRI Coils
The University of Houston System
Mar. 14, 2017
U.S. Patent No. 9594131
New method of cooling of MRI coil and resonators is disclosed and described. MRI coil designs showed in the disclosure are based on the use of copper tube elements filled with liquid nitrogen. Inside the conducting tubes at rf frequency there is no RF electric field, thus the liquid nitrogen presence inside such coils will not have any influence on MRI coil dielectric losses and on the resonant frequency modulation. Liquid nitrogen cooled coils, when in the coil noise regime, demonstrate two to three gain of SNR comparing with room temperature equivalent coils. Methods for making and using SC and normal metal MRI coils and/or arrays in such configurations are also disclosed.

Increasing Fabrication Yield in SC Electronics
Hypres, Inc.
Mar. 14, 2017
U.S. Patent No. 9595656
An improved microfabrication technique for Josephson junctions in SC integrated circuits, based on the use of a double-layer lithographic mask for partial anodization of the side-walls and base electrode of the junctions. The top layer of the mask is a resist material, and the bottom layer is a dielectric material chosen so to maximize adhesion between the resist and the underlying SC layer, be etch-compatible with the underlying SC layer, and be insoluble in the resist and anodization processing chemistries. The SC is preferably niobium, under a silicon dioxide layer, with a conventional photoresist or electron-beam resist as the top layer. This combination results in a substantial increase in the fabrication yield of high-density SC integrated circuits, increase in junction uniformity and reduction in defect density. A dry etch more compatible with microlithography may be employed.

Field Rotor of SC Rotating Machine
Kawasaki Jukogyo Kabushiki Kaisha
Mar. 14, 2017
U.S. Patent No. 9595860
A field rotor of a SC rotating machine including: a rotation shaft; a supply shaft that supplies a refrigerant to the rotation shaft at one end of the rotation shaft; an input/output shaft provided at the other end of the rotation shaft so as to integrally rotate with the rotation shaft; and a SC coil held on a circumferential surface of the rotation shaft to be cooled by the refrigerant, wherein the supply shaft and the input/output shaft are fixed to each other so as to rotate integrally with each other, and the rotation shaft and the supply shaft are at least partly brought in contact with each other in order to allow the rotation shaft to be supported by the supply shaft and in order to be slidably fitted to each other in a circumferential direction of the rotation shaft and in an axial direction of the rotation shaft.