超電導 Web21
Superconductivity

Spring, 2011 Date of Issue: April 15, 2011

Superconductivity Web21

Published by International Superconductivity Technology Center
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"The 2nd Japan-Korea Superconductivity Workshop" was held

Takanobu Kiss, Professor
Graduate School of Information Science and Electrical Engineering
Kyushu University

Group photo at Japan-Korea Superconductivity Workshop

From October 26 to 27, 2010, "The 2nd Japan-Korea Superconductivity Workshop 2010 (JKSW 2010) – Green Innovation opened up by Superconducting Technologies -" was held in Fukuoka City. Chairperson: Yuh Shiohara (Superconductivity Research Laboratory); Organizing Committee Chairperson: Takanobu Kiss (Kyushu University); Supported by: Industrial Superconductivity Technology Research Association, International Superconductivity Technology Center, Japan Society of Applied Physics, Kyushu University/Research Institute of Superconductor Science and Systems; Sponsor: K-MEM R&D Cluster (Korea); Cosponsors: Kyushu University/Department of Electrical Engineering - Systematic graduate school education reform promotion program "Nurturing doctoral candidates by creating a synthesis of five comprehensive abilities," and Cryogenic Association of Japan.

This workshop was inaugurated as a place for information exchange mainly for researchers engaged in the study of Yttrium-based superconducting wires in Japan and Korea, both of which are making remarkable research advancement centering on national projects. The first workshop was held in Pusan, Korea, in February 2010, followed by this workshop that was the first one to be held in Japan. Taking the opportunity of CCA 2010 being held in Fukuoka, the workshop was held one day before CCA also in Fukuoka and attended by 59 participants (38 from Japan, 21 from Korea, including 35 students and young researchers).

Invited lecture (Dr. Izumi, SRL-ISTEC)

Particularly this time, cooperation with Asia was emphasized while exploiting the features of the Kyushu area where many researchers and high-level research facilities in the superconductivity field are accumulated. In addition, the workshop was carried out with assistance provided by the Industrial Superconductivity Technology Research Association and academic communities etc., aiming at nurturing young engineers and researchers who will lead the next generation of the superconductivity field. In addition to invited lectures by renowned Japanese and Korean researchers who are leading pioneering research and development, a special session was held for students and young researchers from Japan and Korea; for excellent researches among those presented at the session, 13 researchers were awarded including one Best Young Researcher Award

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(Arkadiy Matsekh, Kyushu University). The special session was comprised of short lectures and poster presentations. While there was a moderate sense of tension during short lectures, the question and answer session at the poster presentations was very active. The educational effect was better than expected and the participants expressed favorable opinions. The judges evaluated the presentations using an evaluation sheet that had been carefully prepared, which included items such as preparation, presentation style, information transfer, and discussion. For more objective/multi-faceted evaluation and exchange of opinions, Korean judges evaluated Japanese presenters while Japanese judges evaluated Korean presenters. For the students, we felt that it provided them with a good stimulus and experience as an introduction to international conferences. The lecturers' research subjects covered a wide range supporting areas from material process, measurement/characterization, to system applications, allowing us to foresee further advancement of this field for the future in both countries.

Award winners of Japan-Korea Superconductivity Workshop

The next workshop is scheduled to be held in Seoul and will be led by Professor Yoo of Seoul University and Professor William Jo of Ewha Womans University.

Details of this workshop can also be found on the workshop website:

(Published in a Japanese version in the December 2010 issue of *Superconductivity Web 21*)

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Exhibited at "Eco-Products 2010"

Minako Oka, Assistant Manager
Public Relations Division, ISTEC

From December 9 to 11, 2010, "Eco-Products 2010," hosted by the Nikkei, was held at Tokyo Big Sight, Ariake, Koto-ku, Tokyo. Up to last year, the International Superconductivity Technology Center (ISTEC) exhibited as "Superconductivity EXPO" or "Superconductivity Pavilion" along with related companies. This year, however, we exhibited jointly with the Industrial Superconductivity Technology Research Association (ISTERA).

At the ISTEC/ISTERA booth, we introduced superconducting technologies by panel explanation, model exhibition of future society with applications of superconductivity, as well as an experience corner for superconducting magnetic levitation.

The panel explanation introduced the overview of ISTEC and results of the latest research and development, while also explaining the basic properties of superconductivity, such as "zero electric resistance," "flux quantization," "generation of strong magnetic field," and "high-sensitivity detection of magnetic field and shielding of magnetic field." In addition, ISTERA introduced the "Overview of ISTERA" and "Development Project for Rare Metal Substitute Materials."

In the corner to introduce superconductivity applications, superconducting cables (three-core, single core), SMES, superconducting pod motor ship, wind power generation, and applications of superconducting elements to medical devices were displayed along with their models, while also showing related moving images.

In the corner of superconducting magnetic levitation, a disk 60-cm in diameter and approx. 75 kg, which is packed with neodymium magnets, was set afloat on a superconductor cooled by liquid nitrogen, and those who were interested experienced the feeling of levitation. This demonstration was a great success, attracting many people even gathering outside the booth.

Experiment of superconducting magnetic levitation (video)

The number of visitors to "Eco-Products 2010" clearly shows that people have a high level of interest in ecology. Looking back at previous years, the number of visitors has been increasing year after year: 164,903 in 2007, 173,917 in 2008, 182,510 in 2009, and 183, 140 this year.

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There were a wide variety of visitors at the ISTEC booth, including business persons, students visiting for extracurricular activities, and families with children, as well as visitors from abroad.

At the booth, visitors asked questions such as "Why does superconductivity relate to ecology?" and "How does superconductivity serve our daily living environment?" making us realize the high level of interest in superconductivity. Also, children were peeping into the magnetic levitation device and asked serious questions such as "Why is the disk floating?" and "Why does it need to be cooled?" which researchers attempted to explain using easy-to-understand terms.

This time, we also distributed "visitors' questionnaires" and collected about 1,000 replies. From the replies, we felt that people's understanding is deepening and the interest in superconductivity is heightening.

ISTEC/ISTERA Booth

(Published in a Japanese version in the January 2011 issue of *Superconductivity Web 21*)

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What's New in the World of Superconductivity (January and February, 2011)

Akihiko Tsutai, Director
International Affairs Division, ISTEC

Power

American Superconductor Corporation (January 4, 2011)

American Superconductor Corporation (AMSC) has received an initial order valued at more than US $10 million for wind turbine electrical control systems from Doosan Heavy Industries and Construction Company, Ltd. (South Korea). Doosan plans to use the systems in onshore and offshore 3-MW full-conversion wind turbines. Shipment of the electrical control systems to Doosan is scheduled to begin during the summer of 2011. Doosan represents AMSC's seventh customer to place a volume production order for wind turbine control systems or components in the last 12 months. Greg Yurek, founder and chief executive officer of AMSC, commented, "Doosan has decades of experience in the power and offshore arenas, which will serve them well as they grow their green energy business globally. With the offshore wind market in Asia now entering a phase of rapid growth, we expect multi-megawatt wind energy systems such as Doosan's WinDS3000 will be in increasingly high demand."

Source:
"AMSC Receives Volume Wind Turbine Electrical Control System Order from Korea's Doosan Heavy Industries"
American Superconductor Corporation press release (January 4, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1512314&highlight

American Superconductor Corporation (January 11, 2011)

American Superconductor Corporation (AMSC) has licensed several of its proprietary AMSC Windtec™ wind turbine designs to Beijing JINGCHENG New Energy Co., Ltd. (JCNE), which has been producing wind turbines since 2006 and has an operations base capable of producing 2000 MW annually. AMSC has granted JCNE licenses to manufacture, market, and sell AMSC Windtec 2-MW, 3-MW, and 5-MW full-conversion wind turbine models as well as a 3-MW SuperGEAR™ wind turbine model. As part of the contract, JCNE will also purchase the electrical control systems and core electrical components for these turbines exclusively from AMSC. Production of the 2-MW and 3-MW full-conversion wind turbines is scheduled to begin in 2011, with the production of the other wind turbine designs beginning thereafter. Greg Yurek, founder and chief executive officer of AMSC, commented, "The Chinese wind energy market is expected to continue growing strongly over at least the next decade and remains a core focus for AMSC. JCNE has generated early momentum in the wind industry, and we believe they are well positioned to play a much more prominent role in the years ahead with our AMSC Windtec turbine designs, extensive customer support, and best-in-class power electronics and controls. With six Chinese wind turbine manufacturing customers now going to market with wind turbines 'Powered by AMSC,' we expect to continue growing our market share for wind turbine power electronics and controls both in China and worldwide."

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Source:
"AMSC Licenses Multiple Wind Turbine Designs to a Sixth Wind Turbine Manufacturing Customer in China"
American Superconductor Corporation press release (January 11, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1514827&highlight

American Superconductor Corporation (January 18, 2011)

American Superconductor Corporation (AMSC) has received two orders for its proprietary D-VAR reactive compensation solution for wind farms from Nordex UK Ltd. (United Kingdom). The two D-VAR solutions will be used to extend wind farms located in Scotland, enabling them to meet local grid interconnection requirements. Dan McGahn, AMSC President and Chief Operating Officer, commented, "The United Kingdom's wind power market continues to grow strongly as the country strives to meet its objective of deriving 15% percent of its total energy consumption from renewables by 2020. Nordex is a key enabler of this emerging market. We are pleased to partner with this leading company to help the United Kingdom to meet its clean energy objectives."

AMSC's D-VAR solutions are now being used to interconnect more than 70 wind farms with local power grids in six different countries worldwide. Orders for the solution reached a new record in 2010, more than doubling the orders received in 2009. AMSC expects this portion of their power grid business to continue to grow, given the increasing demand for clean, zero-emission energy.

Source:
"AMSC Announces Additional D-VAR® Orders for Grid Interconnection of Wind Farms in the United Kingdom"
American Superconductor Corporation press release (January 18, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1516607&highlight

American Superconductor Corporation (January 25, 2011)

American Superconductor Corporation (AMSC) has received a follow-on order valued at US $9 million for the supply of wind turbine electrical control systems from Inox Wind Limited (India). Previously, Inox placed an order with AMSC for 17 wind turbine electrical control systems in August 2010. The electrical control systems are being used in a 2-MW doubly fed induction wind turbine that Inox is manufacturing under a global licence from AMSC Windtec™. Greg Yurek, AMSC founder and Chief Executive Officer, commented, "India is expected to be a major market for clean technology solutions, and Inox Wind is well positioned to be a leader in this sector. Inox has rapidly established a wind turbine manufacturing capacity of 800 MW per year and, with this new $9 million order, Inox is becoming one of our key wind turbine manufacturing customers."

Source:
"AMSC Announces Additional D-VAR® Orders for Grid Interconnection of Wind Farms in the United Kingdom"
American Superconductor Corporation press release (January 25, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1519423&highlight

American Superconductor Corporation (February 1, 2011)

American Superconductor Corporation (AMSC) has reported its financial results for the third quarter of fiscal 2010, ending December 31, 2010. Revenues for the third quarter increased by 42% to US $114.2 million, compared with $80.7 million for the same period in the previous fiscal year. The gross margin for the quarter was 40.7%, compared with 37.5% for the same period in the previous fiscal year. The net income for the third quarter was $16.0 million, compared with $5.2 million for the same period in the previous fiscal

year. The non-GAAP net income was $19.8 million, compared with $9.1 million for the same period in the previous fiscal year. At the end of the quarter, AMSC had $260.5 million in cash, cash equivalents, marketable securities, and restricted cash, compared with $131.2 million at the end of the previous quarter (September 30, 2010). This increase was driven by a follow-on stock offering in November 2010. The reported backlog as of December 31, 2010, was $883 million. Greg Yurek, AMSC's founder and chief executive officer, commented, "In the third quarter - our sixteenth consecutive quarter of sequential revenue growth - we generated record power grid-related revenues of approximately $20 million. Sales in the wind energy market, particularly in Asia, are expected to continue to be the growth engine for our company in the near term. At the same time, sales of our grid-related products, including D-VAR, D-VAR RT, SolarTie, Amperium wire and superconductor cable projects, are expected to become a much bigger contributor to our growth going forward."
Source:
"AMSC Reports Third Quarter Fiscal Year 2010 Financial Results"
American Superconductor Corporation press release (February 1, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=86422&p=irol-newsArticle_Print&ID=1522219&highlight

Superconductor Technologies Inc. (February 1, 2011)

Superconductor Technologies Inc. (STI) has successfully produced second-generation wire samples that meet the customer-specified requirements for HTS AC power cable, superconducting fault current limiter (SFCL) and HTS wind turbine applications. Delivery of the sample wires to customers for testing is expected to begin shortly. STI's strategic 2G HTS wire program utilizes a specialized HTS material deposition process and volume manufacturing expertise to produce energy efficient, cost-effective and high-performance HTS wire. Jeff Quiram, STI's president and chief executive officer, commented, "Achieving our goal of completing all three wire samples is an enormous accomplishment for STI's 2G HTS wire initiative. Each application has demanding technical requirements and our team worked very hard over the recent months to meet these wire performance objectives. We look forward to building on this success as we move closer to establishing future commercial relationships with our valued customers."
Source:
"Superconductor Technologies Inc. Produces 2G HTS Wire Samples for Superconducting High Power Transmission Cable, Fault Current Limiter, and Wind Turbine Generator Applications"
Superconductor Technologies Inc. press release (February 1, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1522189&highlight

Superconductor Technologies Inc. (February 9, 2011)

Superconductor Technologies Inc. (STI) has announced high-magnetic field test results for its second-generation HTS wire. Together with the Los Alamos National Laboratory (LANL), STI has produced a second-generation HTS wire with excellent in-field critical current values, demonstrating the effectiveness of STI's HTS fabrication process for producing wire that meets the demanding requirements of applications such as superconducting fault current limiters and high-power wind turbine generators. Using a LANL template, STI produced a second-generation HTS coated conductor sample that exhibited a minimum critical current of 228 A at a temperature of 65 K in an applied magnetic field of 3T, corresponding to a value of 256 A per cm-width. The maximum critical current (at 65 K) exceeded 404 A per cm-width for a 3-T magnetic field oriented parallel to the coated conductor's surface; however, this current value was limited by the amount of current that could be supplied by the measurement apparatus. At 5 T (and 65 K), the coated conductor had a minimum and a maximum critical current of 143 A per cm-width and 322 A per cm-width, respectively. The measurements were performed at LANL. Dr. Brian Moeckly, Director of Materials

Research and Development at STI, commented, "Achievement of this level of current-carrying capability in high magnetic field is a critical milestone in our development of 2G HTS wire. In addition, we fabricated this sample using a straightforward HTS structure; we did not need to add additional elements or so-called artificial pinning centers to the coated conductor to obtain this result. While these measurements were performed on a small sample, we believe that the outstanding properties of this wire can be maintained upon scale-up of our processes to long-length 2G HTS wire production."
Source:
"Superconductor Technologies Announces 2G High Temperature Superconductor Wire Critical Current Performance Achievement"
Superconductor Technologies Inc. press release (February 9, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1526771&highlight

National Institute of Standards and Technology (February 10, 2011)

Researchers at the National Institute of Standards and Technology (NIST) have discovered a method of making thinner and more flexible HTS cables than those demonstration cables installed in the power grid at present. The new cables are capable of carrying the same or higher current than that carried by demonstration HTS cables presently in use. Such compact cables have potential applications in the electric grid as well as for scientific and medical equipment and may also enable HTS power transmission for military applications. The new method involves winding multiple HTS-coated conductors in alternating directions around a multi-strand copper "former," or core. One prototype cable has an outer diameter of 6.5 mm and can carry a current of 1,200 A, while a second cable has an outer diameter of 7.5 mm and carry a current as high as 2,800 A. Thus, these cables are approximately one-tenth of the diameter of typical HTS cables that are presently being demonstrated in the power grid. The major innovation in these cables is the tolerance of the new HTS conductors to compressive strain, enabling the use of the unusually slender copper formers. Although the prototype cables were wound by hand, several manufacturers have suggested that mass production is feasible. NIST researchers are now developing prototype compact HTS cables for military applications.
Source:
"Compact high-temperature superconducting cables demonstrated at NIST"
National Institute of Standards and Technology press release (February 10, 2011)
http://www.nist.gov/pml/electromagnetics/htc-021011.cfm

Zenergy Power plc (February 11, 2011)

Zenergy Power plc has completed a review of its business and strategic options involving their main business lines and an assessment of the long-term viability of their overall strategy. Zenergy has a patented portfolio of intellectual property (IP) in the area of high-temperature superconductivity, which has been incorporated into numerous industrial power applications including a magnetic billet heater and an HTS fault current limiter (FCL). The company's Board of Directors concluded that Zenergy's superconductor technology solutions possess significant value. Nevertheless, the Board has determined that the investment required to scale-up the technology required for the commercialization of their HTS wire process (a continuous chemical process) is too great for Zenergy to fund on its own. Furthermore, while FCL applications have a large long-term potential market, it will likely be a number of years before FCLs achieve significant market penetration. In addition, sales of magnet billet heaters have been at lower volumes and on a significantly more protracted time scale than originally predicted. In view of these factors, the funding required to finance Zenergy through the period required to commercialize its technology would be substantial. As such, the Board has decided to seek a purchaser for the company, so that Zenergy's

business may be developed as part of a larger group with access to the necessary funding and commercial relationships needed to enable the commercialization of Zenergy's IP and products.
Source:
"Review of Group's business, strategic options and commencement of offer period"
Zenergy Power plc press release (February 11, 2011)
http://www.zenergypower.com/images/press_releases/2011/2011-02-11-zenergy-power-strategic-review-clean.pdf

Converteam (February 21, 2011) and Zenergy Power (February 22, 2011)

Converteam has successfully completed static testing of the essential elements for its 1.7-MW HYDROGENIE generator, the world's first HTS hydro generator. Converteam is manufacturing the generator using 28 HTS coils from Zenergy Power as part of a European Union-funded project for a commercial installation at E.ON Wasserkraft GmbH's hydroelectric power plant in Bavaria, Germany. The superconducting HYDROGENIE will enable size and weight reductions of up to 70% in addition to large increases in efficiency, compared with conventional solutions. Derek Grieve, Director of Technology at Converteam, commented, "The recent critical milestone in the testing of HYDROGENIE was the successful passing of current (in this case 70A) through the rotor coils when they were cooled to below the superconducting transition temperature. This was achieved with only half the defined cooling power applied to the coils, and confirms the thermal and electrical design of the coils, cooling and insulation systems. HYDROGENIE looks set to change the fundamental economics of the renewable energy industry with generator efficiency reaching up to 99%." The HYDROGENIE is scheduled for commissioning in the summer of 2011.
Sources:
"Converteam's HYDROGENIE superconducting generator successfully completes landmark testing in the quest for clean energy sources"
Converteam press release (February 21, 2011)
http://www.converteam.com/converteam/4/doc/News_2011/20110221_6_HYDROGENIE_tests.pdf
"Superconducting coils from Zenergy Power successfully operating in the landmark testing at Converteam for the E.ON Wasserkraft hydro generator"
Zenergy Power press release (February 22, 2011)
http://www.zenergypower.com/images/press_releases/2011/2011-02-22-hydrogenie-static-test.pdf

Superconductor Technologies Inc. (February 16, 2011)

Superconductor Technologies Inc. (STI) has reported that its second-generation HTS wire samples have met the customer requirements for current carrying performance at the desired temperature and magnetic field strengths necessary for superconducting 2G HTS wire applications for large rotating machines. Adam Shelton, STI's vice president of product management and marketing, commented, "This customer validation is a significant milestone towards our goal of obtaining market acceptance for our 2G HTS wire. Our efforts remain focused on large, emerging addressable markets including superconducting rotating machines, which are enabled by the availability of high-performance, economical 2G HTS wire. Our HTS materials development team worked extremely hard over the past year to meet this customer's challenging wire specifications. Demonstrating our superior current carrying performance in high magnetic field is an important achievement on STI's road to commercial success with 2G HTS wire."
Source:
"Superconductor Technologies Inc. Meets Customer Current Carrying Performance Requirements of 2G HTS Wire for Superconducting Applications in High Magnetic Field"

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Superconductor Technologies Inc. press release (February 16, 2011)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1529456&highlight

NMR

Bruker (January 12, 2011)

Bruker has received an order valued at over US$7.5 million from the University of Minnesota for an ultra-high field Avance™ III 900 and an Avance™ III 850 NMR spectrometer. The two spectrometers will be installed in the university's new Nuclear Magnetic Resonance laboratory and will form the core equipment of this facility, which will be used for a wide range of biomedical research. The Avance™ III 850 NMR spectrometer is based on Bruker's 850-MHz Ascend™ magnet, which utilizes advanced superconductor technology, enabling significant reductions in magnetic stray fields and the use of a much smaller cryostat.
Source:
" Bruker Announces Large Ultra-high Field NMR Order from the University of Minnesota"
Bruker press release (January 12, 2011)
http://www.bruker-biospin.com/pr110112.html

Quantum Computer

National Institute of Standards and Technology (February 23, 2011)

For the first time, researchers at the National Institute of Standards and Technology (NIST) have coaxed two beryllium atoms in separate locations to take turns vibrating while swapping quanta of energy. This technique for directly linking the motions of two physically separated atoms could be used to simplify information processing in future quantum computers and simulations. The coupling can be tuned, affecting the speed at which the energy is exchanged as well as the amount of energy that is exchanged, with the exchange of a single quantum of energy possible. The experiments were made possible by a novel one-layer ion trap that was cooled to -269°C in a liquid helium bath. The demonstration suggests that similar interactions could be used to connect different types of quantum systems; for example, a trapped ion could act as a "quantum transformer" between a superconducting qubit and a qubit made of photons. The group's work has been published in the Feb. 23 edition of *Nature*.
Source: "Quantum hot potato: NIST researchers entice 2 atoms to swap smallest energy units"
National Institute of Standards and Technology press release (February 23, 2011)
http://www.nist.gov/pml/div688/quantum-022311.cfm

Nuclear Fusion

Oak Ridge National Laboratory (January 14, 2011)

Scientists and engineers at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) are working with the U.S. ITER Project Office at ORNL, the Japanese Atomic Energy Agency, and the ITER Organization to resolve issues with a critical component of ITER, an experimental fusion facility. The

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VULCAN Engineering Diffractometer at the Spallation Neutron Source (SNS) at ORNL is being used to examine superconducting cables for ITER's central solenoid magnet, which is used to produce the electrical current required to confine and shape the plasma inside the reactor. The scientists are attempting to reduce the degradation of the superconducting strands in the superconducting cables, thereby improving the cable performance. In late 2010, a sample test showed that the superconducting cables were losing their current-carrying capacity over time to an extent beyond that observed in an earlier ITER model coil test. The strong magnetic field generated by the cables and the resulting electromagnetic force is known to cause some degradation over a period of constant magnetic cycling. However, the exact cause of the degradation in the conductor sample is unknown. The manufacturing of the sample or a particular sensitivity of the wires to the loads is also possible causes of the degradation. To determine the cause, small sections have been cut from the cable and will be examined at SNS using neutron scattering. Such examination will provide detailed data about the structure of the cable sections without destroying or altering them. Xun-Li Wang, a VULCAN instrument scientist, commented, "Neutron diffraction is a well-known technique for mapping strain or stress in engineering materials. With VULCAN we will be able to determine the deformation induced by the Lorentz force. On a fundamental level, we can also study in detail how the critical current in a superconducting wire responds to applied stress and develop a predictive model for the wires." The Japan Atomic Energy Agency and the ITER organization are now developing a plan for future study.

Source:
"Neighbor lends a hand"
Oak Ridge National Laboratory press release (January 14, 2011)
http://www.ornl.gov/info/features/get_feature.cfm?FeatureNumber=f20110114-00
Used with permission of the U.S. Department of Energy

Accelerator

CERN (January 31, 2011)

CERN has announced that the Large Hadron Collider (LHC) will run through to the end of 2012 with a short technical stop at the end of 2012. Furthermore, the beam energy for operation in 2011 will be 3.5 TeV. This operation schedule should provide a good opportunity for the discovery of new physics within the next two years before the LHC enters a long shutdown period to prepare for operation at a higher energy level, beginning in 2014. Steve Myers, Director for Accelerators and Technology at CERN, commented, "If the LHC continues to improve in 2011 as it did in 2010, we've got a very exciting year ahead of us. The signs are that we should be able to increase the data collection rate by at least a factor of three over the course of this year." Even if no new physics is discovered in the energy range currently being explored by the LHC, operation throughout 2012 will at least provide the data needed to fully explore this energy range before the start of experiments at a higher energy level.

Source:
"CERN announces LHC to run in 2012"
CERN press release (January 31, 2011)
http://public.web.cern.ch/press/pressreleases/Releases2011/PR01.11E.html

Basic

University of Illinois at Urbana-Champaign (January 13, 2011)

Researchers at the University of Illinois at Urbana-Champaign have observed a new fractional vortex state in an unconventional superconductor (strontium ruthenium oxide [SRO]). The observations may provide the first glimpse of an exotic matter state, known as a half-quantum vortex, first predicted theoretically more than 30 years ago. This state can be thought of as a 'texture' that arises from the spin phase of the superconducting order parameter. Such states could provide the basis for a novel form of quantum computing. The observations were made using state-of-the-art nanofabrication methods and a highly sensitive cantilever-based magnetometry technique. This technique enabled the observation of minute fluctuations in the magnetism of tiny rings of SRO, the fabrication of which was crucial to the experiment. Anthony J. Leggett, a noted physics professor, commented, "Strontium ruthenium oxide is a unique and fascinating material, and the half-quantum vortices that have been conjectured to exist in it are particularly interesting. It is believed that these half-quantum vortices in SRO may provide the basis for topological quantum computing. If this novel form of computing is eventually realized, this experiment will certainly be seen as a major milestone along the road there." The group's research was published in the January 14 issue of *Science*.

Source:
"U of I physicists observe exotic state in an unconventional superconductor"
University of Illinois at Urbana-Champaign (January 13, 2011)
http://engineering.illinois.edu/news/2011/01/10/researchers-observe-half-height-magnetization-steps-sr2ruo4

University of Oxford (January 14, 2011)

Researchers at the University of Oxford, in collaboration with colleagues in Germany and Japan, have succeeded in transforming a non-superconducting material into a superconductor using a strong burst of infrared laser light. The non-superconducting material that was used is closely related to high-temperature copper oxide superconductors, but the arrangement of its electrons and atoms normally prevent any electronic current. The burst of laser light perturbed the positions of some of the atoms, causing the material to instantaneously become a superconductor for a fraction of a second before relaxing back into its normal state. Professor Andrea Cavalleri of the Department of Physics at Oxford University and the Max Planck Department for Structural Dynamics (Hamburg), commented, "We have shown that the non-superconducting state and the superconducting one are not that different in these materials, in that it takes only a millionth of a millionth of a second to make the electrons 'synch up' and superconduct. This must mean that they were essentially already synched in the non-superconductor, but something was preventing them from sliding around with zero resistance. The precisely tuned laser light removes the frustration, unlocking the superconductivity." The discovery has provided a new way to probe how superconductivity arises in high-temperature superconductors. The group's research was published in the journal Science.

Source:
"Light touch transforms material into a superconductor"
University of Oxford press release (January 14, 2011)
http://www.ox.ac.uk/media/news_stories/2011/111401.html

Rutgers University (January 20, 2011)

Researchers from Rutgers University and the University of Tokyo have reported that a new, exotic ytterbium-based superconductor (YbAlB4, also known as YBAL) possessing unusual properties is able to reach a point where seemingly contradictory electrical and magnetic properties coexist. This point, which is

known as a "quantum critical," can be reached without requiring massive changes in pressure, magnetic fields, or chemical impurities; thus, the new material is the first to exhibit quantum criticality in its natural state. Piers Coleman, a professor of physics and astronomy at Rutgers, commented, "This is a completely unexpected result. It could be the first example of what physicists describe as a 'strange' metallic phase of matter, manifesting itself intrinsically, without any tuning of the material's properties." Intriguingly, the beta-structure of YBAL may reveal an exotic new phase of matter known as the "critical strange metal" phase. In this phase, a material would be able to shift among conventional electrical behavior, superconducting behavior, and a condition resembling neither (known as "strange metal" behavior). While strange metal behavior has been observed in superconducting materials, whether it occurs only in the vicinity of a quantum critical point or can exist over an extended range of physical conditions, which would make it a phase of matter, remains uncertain. While the idea of strange metal phases is controversial, the present experiments may provide more evidence—potentially changing our basic understanding of materials.
Source:
"University of Tokyo, Rutgers physicists unveil unexpected properties in superconducting material"
Rutgers University press release (January 20, 2011)
http://news.rutgers.edu/medrel/research/rutgers-researchers-20110120

University of Texas at Dallas (January 24, 2011)

Researchers at the University of Texas at Dallas have invented a new technology to produce, weavable, knittable, sewable, and knottable yarns containing large amounts of otherwise unspinnable powders. With this technique, a small amount of host carbon nanotube web holds "guest" powders within highly conducting scrolls without altering their performance, potentially enabling high-tech applications ranging from electronic textiles to superconducting cables. The technique, known as "bi-scrolling," involves the placement of a uniform layer of the guest powder on the surface of a carbon nanotube web, followed by the twisting of this two-layer stack into a yarn. The carbon nanotube webs are extremely strong and extremely light. Depending on the type of powder that is imbedded in the web, a large variety of applications become feasible including "superconducting yarns" for potential applications in magnets and electrical transmission. The group's work was published in the Jan. 7 issue of *Science*.
Source:
"UT Dallas Researchers Spin Nanotech Breakthrough"
University of Texas at Dallas press release (January 24, 2011)
http://www.utdallas.edu/news/2011/1/24-8251_UT-Dallas-Researchers-Spin-Nanotech-Breakthrough_article.html

Oak Ridge National Laboratory (February 7, 2011)

Researchers at the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) have suggested that the key magnetic interactions responsible for high-temperature superconductivity in iron-based materials may occur between next-nearest neighbor orderings of atoms, rather than adjacent atoms. The group's conclusions were based on the use of neutron scattering analysis to perform spin-wave studies of magnetically ordered iron chalcogenides and a comparison of the new data with that for magnetically ordered pnictides, another class of iron-based superconductors. Pengcheng Dai, who has a joint appointment with ORNL's Neutron Sciences Directorate and the University of Tennessee, commented, "There are theories suggesting that it's the second nearest neighbor that drives the superconductivity. Our discovery of similar next-nearest-neighbor couplings in these two iron-based systems suggests that superconductivity shares a common magnetic origin." The research was made possible by the

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high-intensity neutron beams created at ORNL's Spallation Neutron Source (SNS), the world's most powerful pulsed neutron source.
Source:
"Neutron analysis reveals '2 doors down' superconductivity link"
Oak Ridge National Laboratory press release (February 7, 2011)
http://www.ornl.gov/info/press_releases/get_press_release.cfm?ReleaseNumber=mr20110207-00

Brookhaven National Laboratory (February 13, 2011)

Researchers at Johns Hopkins University and the U.S. Department of Energy's Brookhaven National Laboratory have used terahertz spectroscopy to measure fluctuations in superconductivity across a wide range of temperatures. This technique enables the visualization of fluctuations lasting down to picosecond time scale. The measurements have revealed that such fluctuations disappear in cuprates at 10–15 K above the critical temperature, unlike the situation in conventional superconductors. These results suggest that the transition to the non-superconducting state is driven by a loss of coherence among electron pairs. Ivan Bozovic, a physicist at Brookhaven, explained, "…unlike in conventional superconductors, the transition in cuprates is not driven by electron (de)pairing but rather by phase fluctuations. The hope is that understanding this process in full detail may bring us one step closer towards cracking the enigma of high-temperature superconductivity." The group's work was published in the online version of *Nature Physics* on February 13, 2011.
Source:
"Fleeting fluctuations in superconductivity disappear close to transition temperature"
Brookhaven National Laboratory press release (February 13, 2011)
http://www.bnl.gov/bnlweb/pubaf/pr/PR_display.asp?prID=1231

University of Illinois at Urbana-Champaign (February 14, 2011)

Researchers at the University of Illinois at Urbana-Champaign have reported the first observations of some unusual physics that occur when superconductors and graphene are connected. The researchers developed a method for isolating individual electron-hole pairs in a normal metal, known as Andreev bound states (ABS), by connecting superconducting probes to tiny quantum dots (nanoscale flakes of graphene). This method enabled the ABS to be restricted to discrete energy levels within the quantum dots, allowing researchers to measure and manipulate the superconducting ABS on an individual level. Greater understanding of ABS is expected to contribute to applications such as superconducting transistors or qubits for quantum computers. The group's research has been published in the journal *Nature Physics.*
Source:
"Physicists isolate bound states in graphene-superconductor junctions"
University of Illinois at Urbana-Champaign (February 14, 2011)
http://news.illinois.edu/news/11/0214conductivity_NadyaMason.html

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Feature Article: ISS2010 Topics

- The 23rd International Symposium on Superconductivity (ISS2010)

Masaharu Saeki, Director
Public Relations Division, ISTEC

Opening Ceremony

For three days from November 1 (Mon.) to 3 (Wed.), 2010, the International Superconductivity Technology Center (ISTEC) held the 23rd International Symposium on Superconductivity 2010 (ISS2010) at the Tsukuba International Conference Center. ISS, which was the 23rd holding this year, has been held every year with the aim of facilitating the development and practical application of industrial superconducting technologies, as well as promotion and enlightenment for the general public, through international exchange and by publicizing the results of research and development related to superconductivity at home and abroad. This symposium turned out to be a very successful meeting, with 681 participants in total (192 from overseas) and 23 participating countries. The total number of presentations was 494, including 76 by invited lecturers, 120 oral and 374 poster presentations. The dissertations of the lectures are scheduled to be published as a special edition of the collected papers "Elsevier Physica C." At the same time, exhibitions of products, technologies, and superconductivity-related materials were held by nine companies and groups.

On the first day, an opening speech was given by Shoji Tanaka, Director Emeritus of ISTEC Superconductivity Research Laboratory, and a guest felicitation was read by Mr. Shunichi Uchiyama, Director of the Kanto Bureau of Economy, Trade and Industry, on behalf of Mr. Akihiro Ohata, Minister of Economy, Trade and Industry, followed by two special plenary lectures and six plenary lectures hosted by two program chairpersons, Dr. Atsushi Ishiyama (Waseda University) and Dr. D. Cardwell (Cambridge University). At the special plenary lectures, Dr. K. Seong (Korea Electro-technology Research Institute) delivered a lecture entitled "The Present State and Future of Superconducting Technology Development in Korea" and Dr. Keiichi Tanabe (ISTEC Superconductivity Research Laboratory) delivered a lecture entitled "Progress of Josephson Junction Technology and the Latest Trends of Electronics Applications in Japan." At the plenary lectures, Dr. Shin Shiku (Tokyo University) delivered a lecture entitled "Research on Laser ARPES (Photoelectron Spectrometry System) using Superconductors," Dr. Mitsuru Izumi (Tokyo University of Marine Science and Technology) - "About High-temperature Bulk Superconductors," Dr. K. D. Irwin (National Institute of Standards and Technology, USA) - "Superconducting Detectors for Sub-millimeter and Millimeter Signals," Dr. Yasuhiro Iijima (Fujikura Ltd.) - "Progress of Coated Conductors by means of IBAD-PLD Method," Dr. V. Selvamanickam (University of Houston) - "Development of Coated Conductors based on IBAD-MOCVD Method," and Dr. Kenichi Sato (Sumitomo Electric Industries, Ltd.) - "About S-Innovation Project on Superconducting Systems." A banquet was held in the evening to provide a place for active exchanges among the participants.

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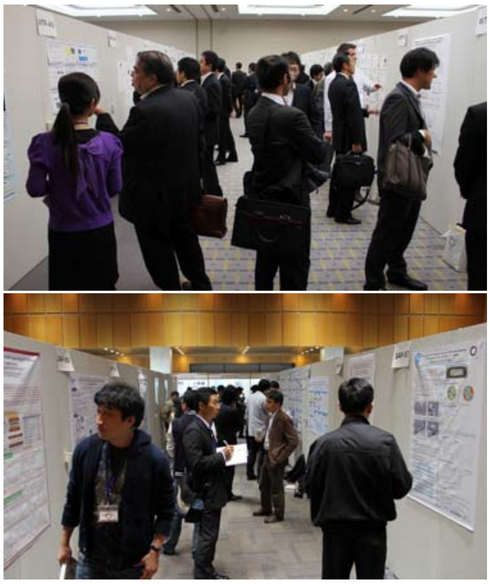
On the second and third days, oral presentations were given and two poster sessions were held. Oral presentations were divided into five fields: Physics/Chemistry/Magnetic Flux Physics, Bulk/Characterization, Wires/Tapes/Characterization, Thin films/Devices/System Applications, and Large System Applications, in each of which, ardent reports and discussions took place.

In the physics/chemistry field, the latest topics were discussed such as new superconducting materials and clarification of the superconducting mechanism. In the bulk field, the latest topics and research results were reported and discussed, including researches on fabrication methods aimed at upsizing and improvement of critical current, as well as characterization techniques toward practical applications. In the wires/tapes field, research reports were presented and active discussions took place, including the achievements in cutting-edge technology developments related to Y-based high-temperature superconducting wires and tapes in Japan, the US, and Europe, characterization techniques for current density and AC loss of tape wires, as well as applications in the power device field. In the thin films/devices field, reported topics included the development of SQUID and filters using Y-based high-temperature superconductors and the development results of Nb-based low-temperature superconductors aiming at high-integration devices, such as AD converter, router, and SFQ processor, and ultra-fast/low-energy-consumption servers. In the large system applications field, the development progresses including demonstration experiments were reported, such as industrial applications of superconducting coil, magnet, motor, and power generator, and power system applications of cable, SMES, transformer, and current limiter.

Oral Session

At the closing in the afternoon on the third day, Dr. P.J. Hirschfeld (University of Florida) summarized the presentations in the physics/chemistry/magnetic flux physics field, Dr. P. Vanderbemden (University of Liege) summarized the bulk field, Dr. V. Selvamanickam (University of Houston) summarized the wires/tapes field, Dr. K. D. Irwin (National Institute of Standards and Technology, USA) and Dr. Michio Naito (Tokyo University of Agriculture and Technology) summarized the thin films/devices field, and Dr. S. J. Dale (Florida State University) summarized the large system applications field. At the end, ISS2010 steering committee chairperson Mr. Yutaka Kiyokawa (Executive Director, ISTEC) gave a closing speech to wrap up the symposium, which turned out to be a successful meeting, while expressing the desire to meet again at ISS2011 scheduled to be held next year for three days from October 24 (Mon.) to 26 (Wed.) at Tower Hall Funabori, Edogawa-ku, Tokyo.



Poster Session

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Feature Article: ISS2010 Topics - Physics/Chemistry/Vortex Physics

Noriko Chikumoto, Assistant Director
Advanced Materials & Physics Division, SRL /ISTEC

Presentations in this field included 32 oral (incl. one plenary lecture) and 93 poster presentations. When classified by materials, presentations on iron-based materials accounted for about 40 % of the total (for oral, 23 out of 32 presentations), indicating that this research field is becoming increasingly active.

As for iron-based materials, two years have passed since the discovery, and many research reports on these materials were presented due to the fact that various groups became capable of growing high-quality crystals, particularly with $BaFe_2As_2$ (Ba122), and that three types of doping (hall, electron, and equivalent doping) are possible by means of K substitution of the Ba site (BaK122), Co substitution of the Fe site (BaCo122), and P substitution of the As site, respectively. From the aspect of clarifying the mechanism of iron-based superconductors, interests are drawn to how spin fluctuation contributes to superconductivity. First, Dr. Shin of the University of Tokyo pointed out in his plenary lecture that orbital fluctuation is also important in addition to the spin fluctuation for the appearance of superconductivity from ARPES of the BaK122 single crystal. Meanwhile, Dr. Ishida of Kyoto University hinted that, based on NMR, the contribution of spin fluctuation is important because the spin fluctuation reaches the maximum at the point where T_c reaches the highest value in P-doped Ba122. Dr. Shamoto (Japan Atomic Energy Research Institute) described that, based on the result of neutron scattering, the spin fluctuation disappears in the over-doped region of 1111-based materials. Regarding the coexistence of the anti-ferromagnetism (AF) phase and superconducting phase, Dr. Kamihara of Keio University described that they may not coexist in 1111-based materials, whereas Dr. Johrendt (Ludwig-Maximilans-Univ. München) explained that they may coexist in Ba122-based materials.

As for electronic structures, Dr. Hirschfeld (University of Florida) showed the result of theoretical calculation of the adulterant effect, and pointed out that small changes such as doping bring about a great change in electronic structures. Dr. Onari (Nagoya University) carried out a study on the superconducting mechanism using a 5-orbit Hubbard-Holstein model, and reported that gap symmetry is A1g, some systems have sign inversion, and that the node structure of anisotropical $s_{\pm}$ is sensitive to small changes in electronic structure caused by the height, distortion, and defect of pnictogen. Dr Carrington (University of Bristol) performed theoretical calculation based on the data of the dHvA effect and described that the Fermi surface is reduced and effective mass is increased as superconducting correlation becomes stronger, and that the effective mass disperses at the SDW quantum critical point. Dr. Tsukada (Central Research Institute of Electric Power Industry) explained that, from the Hall measurement result of FeTe-based materials, the reason for FeTe not exhibiting superconductivity is that the Hall mobility is restricted in the AF phase, whereas it exhibits superconductivity when electron mobility is improved by Se displacement. Dr. Vekhter (Louisiana State University) discovered that a line node exists adjacent to Γ-M due to the fact that the thermal conductivity of Ba122 is dependent on the magnetic field angle, and reported that Co doping changes the existence and nonexistence of the note. Dr Lee(Brookhaven National Laboratory) succeeded in STM/STS measurement of CaCo122 for the first time in the world and discovered that a "nematic" order is observed in the banded SDW phase. Regarding the improvement of T_c, Dr. Nohara (Okayama University) showed that T_c is improved up to 37 K by Pt substitution of the Fe site of $CaFe_2As_2$, and pointed out that the control of Fe deficiency holds the key to higher T_c.

Meanwhile, as for non-iron-based materials, Dr. Kubozono of Okayama University reported that a

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maximum superconductivity of T_c＝30 K (Rb doping) can be obtained by doping K, Rb, or Ca into a picene. In addition, Dr. Bollinger (Brookhaven National Laboratory) discovered that a superconductivity of T_c=37 K is exhibited when stacking La_2CuO_4, which is an insulator, on the $La_{1.55}Sr_{0.45}CuO_4$, which is an over-doped phase (non-superconducting phase), and explained that it is due to the charge transfer occurring at the interface.

Regarding vortex physics, Dr. Movshovich (LANL) hinted that, from the result of the impurity doping effect of the heavy electron system ($CeCoIn_5$), SDW and FFLO interact with each other in the low-temperature/high-magnetic-field region, and Dr. Ikeda of Kyoto University gave it a theoretical consideration. Regarding critical current properties of iron-based materials, Dr. Holtzapfel reported on the J_c angle scaling of BaCo122 thin film, Dr. Chikumoto (ISTEC) reported on the peak effect of the BaCo122 single crystal, and Dr. Tamegai (Univ. of Tokyo) reported on the anomalous flux creep behavior of BaCo122 in the low magnetic field.

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Feature Article: ISS2010 Topics
- Bulk/Characterization Field

Koichi Nakao, Senior Research Scientist
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The bulk/characterization field included six invited lectures including one plenary lecture, four general oral presentations, and 28 poster presentations. The total number is approximately the same as it was last year. Classifying them by substances, copper-oxide-based materials were overwhelmingly predominant with 32 presentations, while MgB_2-based and iron-pnictide-based materials were three for each. As expected, 123-based material was overwhelmingly predominant among copper-oxide-based materials with 29 presentations, 247-based and 124-based materials were one for each, and 214-based material was one. The following briefly summarizes the contents of some presentations.

At the plenary lectures, Izumi (Tokyo University of Marine Science and Technology) presented an extensive review covering the fabrication method for 123-based bulk material, pinning properties, magnetizing method, magnetic levitation, and various applications etc. Specific application examples include magnetic bearing, rotating machine, marine vessel, and medical applications. He touched upon almost all application examples that had been proposed up to now, as well as refrigeration technologies required for such applications.

At the invited lectures on the second day, Akase (Tohoku University) reported an observation result of electron beam holography performed on flux pinning in a YBCO bulk material containing the 211 phase. He confirmed the state where quantized flux was pinned in the 211 phase.

If an AC external magnetic field is applied in the perpendicular direction when a superconductor traps magnetic flux, the trapped flux gradually decreases. While this phenomenon had been known previously, the process is not necessarily understood completely. Vanderbemden (University of Liege) carried out an experiment and also proposed a model for the numerical analysis of this phenomenon.

Pompeo (Roma Tre University) delivered a lecture on the characterization method for the pinning property of bulk material by means of microwave. By microwave irradiation, information that is unobtainable by direct current or low frequency can be obtained, regarding those parameters that determine the motion of quantized flux.

Tsuda (Tohoku University) introduced a method for applying magnetic levitation force, which is produced by means of YBCO bulk material and permanent magnet, to biaxial quake-absorbing structures.

Kii (Kyoto University) described an application of bulk material to an undulator, which realizes a periodic magnetic field required for free electron laser etc.

Eisterer (Vienna University of Technology) introduced a method to separately measure the values of intra- and inter-grain critical current density in a sintered material by measuring the residual magnetization after removing the magnetic field that had previously been applied. This time, the measurement method was applied to an iron-pnictide-based Sm1111 sintered material.

Regarding bulk applications, it seems that almost all possible application examples had already been proposed; however, this ISS saw several novel ideas for characterization methods etc.

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Feature Article: ISS2010 Topics - Wires/Tapes/Characterization Field

Teruo Izumi, Director
Superconducting Tapes & Wires Division, SRL/ISTEC

In this report, "Wires, Tapes, and Characterization" session is overviewed. At the SPL (special plenary lectures), Dr. Seong (KERI) introduced the latest, fast-advancing trends in Korea along with applications. At the plenary lectures, two companies, Fujikura Ltd. (Dr. Iijima) and SuperPower (UH, Dr. Selvamanickam) reported on the development progress up to now and the present status. There were 25 oral and 105 poster presentations, among which YBCO coated conductors were overwhelmingly predominant with 97, followed by MgB_2-based (17) and Bi-based wires (13). The following summarizes the trends regarding the development of YBCO coated conductors.

One of the biggest topics at this ISS was that the value of the IcL product was updated after a long interval. It was the first update since August 2009 when SuperPower reported on an IBAD-MOCVD tape with the property of 1,065 m-282 A/cm width, IcL=300 kAm. Dr. Iijima (PL-4) reported that they have succeeded in fabricating an IBAD-PLD tape of 615 m-609 A/cm width (375 kAm). In addition to the development of an IBAD-MgO substrate, he explained that the company has also succeeded in developing a hot-wall PLD method, which led them to the practical result of thick-film/ high-I_c tape. Regarding TFA-MOD tapes, which have been under development as a low-cost process, the highest value was 500 m-300 A/cm width (150 kAm) developed by Showa Cable Systems. This time, AMSC reported a higher value of 540 m-466 A/cm width/252 kAm (Dr. Rupich: WT-1). SuNAM Electric of Korea appears to be breaking into the above mentioned development competition. After obtaining technology transfer from KERI, the company has been rapidly producing fruitful results this year, and reported at this symposium that they have succeeded in fabricating a wire of 500 m-310 A/cm width (Dr. Moon: WT-3). The company also supplies tapes for motor development in Korea, and attentions are drawn to their future activities.

The above mentioned IcL value is a conventional development index and is still a currently progressing development axis; however, another trend to note is the tape development with strong awareness for applications. The first is the development of tapes suitable for in-magnetic-field applications, such as motor and SMES. Improvement of in-magnetic-field properties is already underway, including the introduction of an artificial pinning centers on a short-length basis; however, the improvement is now accelerating. As reported by Dr. Obradors (IMSB: WT-22), Dr. Yoshizumi (ISTEC: WT-19), Dr. Maiorov (LANL: WT-23), and Dr. Mele (Kyushu Institute of Technology), the development of microstructure control is advancing, while the development is also starting for long-length tapes. According to Dr. Selvamanickam (PL-5), SuperPower and the University of Houston reported that they have obtained up to 100 A/cm width @ 1 T and up to 20 A/cm width @ 3 T at 75 K as the stable properties in the magnetic field for production-level tapes by optimizing the additive amount of Zr and ratio of Y/Gd method to introduce BZO rods into the YGdBCO superconducting phase. Regarding Japan, as the result by ISTEC (WT-8), the author reported a property of 33 A/cm width @ 77 K, 3 T with a 50-m GdBCO tape, which was fabricated by means of the PLD method, while increasing the film thickness under a high-speed film forming condition, which realizes low cost.

In addition to the above, for low-AC-loss tapes aiming at AC applications including a cable and transformer, active discussions took place for the reports on thinning tapes (WT-18, and Dr. Amemiya: WT-16) and Roebel conductors (Dr. Gldacker: WT-14), which are also another big theme. A noteworthy topic regarding loss reduction was introduced by Dr. Iwakuma (Kyushu University: WT-15). It is a newly discovered phenomenon in YBCO coated conductors. At present, although the manifestation condition is

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limited, hysteresis loss drastically decreases in coated conductors of high orientation. Further confirmatory experiments are required, but it implies a great potential for future applications.

As information with awareness for applications, what was characteristic this time was that many researchers referred to the price of tapes. SuperPower aims to reduce the price to approximately $50/kAm by about 2015, compared with the current price of $400/kAm. Fujikura Ltd. is also planning to offer approximately the same level of price at 3,000 yen/m (6 yen/Am) for 500 A tapes by about 2015. Meanwhile, SuNAM also introduced their long-term vision that they are planning to reduce the current price of $220/kAm to $80/kAm by 2015 and to $25/kAm by 2023.

As a general conclusion, while the development of long-length/high-performance tapes is still progressing, at the same time, activities are intensifying in the technology development of additional features (properties in magnetic field, low loss, etc.). In addition, the fact that prices have started to be revealed indicates that wires are getting one step closer to practical applications.

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Feature Article: ISS2010 Topics
- Thin Films, Junctions, Electronics Devices Field

Mutsuo Hidaka, Director
Low Temperature Superconducting Device Lab, SRL/ISTEC

At the special plenary lectures, Dr. Tanabe of ISTEC introduced Japan's progress in fabrication technologies for the Josephson junction and its applications to electronics. Among metal-based low-temperature superconductors, the Nb/AlOx/Nb junction exhibits the best properties, and is used for SQUIDs, SIS mixers, STJ detectors, and digital applications. Particularly in digital applications, Japan has achieved a high level of fabrication techniques; for example, a processor fabricated by nine Nb layers, using over 10,000 Nb/AlOx/Nb junctions, operates at 45 GHz. As for oxide-based high-temperature superconductors, ISTEC developed a Y-based modified interface barrier ramp edge junction with superior properties. Apart from these superior properties, a multilayer SQUID using this junction also has high robustness to external noises and is used for various applications, including non-destructive test systems.

At the plenary lectures, Dr. Irwin of NIST described the arraying of superconducting detectors. While they are used as high-sensitivity detectors with an unrivaled ability for various applications, including astronomical observation and material analysis, he emphasized that enlargement of the detection area by arraying of detectors is indispensable to facilitate their use.

As for iron-based superconducting thin films, Prof. Ikuta of Nagoya University reported T_c^{on}=56 K and T_c^{end}=52 K using CaF_2 substrates. This is a world record for iron-based thin films. Prof. Naito of the Tokyo University of Agriculture and Technology, meanwhile, reported T_c^{on}=52 K and T_c^{end}=48.6 K using LAO substrates. Both used the MBE method. Dr. Katase of the Tokyo Institute of Technology reported on the grain boundary junction and SQUID using iron-based thin films. Although the modulation was small, at 1.4μV, it is the world first iron-based SQUID.

As for quantum bits for quantum computers, Prof. Martinis of UCSB introduced a method that uses a superconducting resonator for the tunable coupling of quantum bits. The use of this method allows a scalable increase in the number of quantum bits.

Prof. Fujimaki of Nagoya University uses SFQ circuits to read out from superconducting detectors; however, to use it for this application, the power consumption of the SFQ circuit must be further reduced. He reported on the simulation result of the SFQ circuit when the bias voltage is decreased to reduce the power consumption. The bias voltage is now 2.5 mV, but it still operates normally, even when the voltage is decreased to 0.1 mV. The operating speed, however, is adversely affected; hence the balance with speed must be considered.

Dr. Khabipov of PTB introduced a π junction using ferromagnets. They are also developing an Nb-CuNi-Nb junction with the aim of applying it to SQUIDs, quantum bits, and SFQ circuits. The critical current is reduced in SFQ circuits, which are used at the same cryogenic temperatures as quantum bits, meaning considerable inductance is required for the SFQ loop, and leading to a problem of increased circuit size. The use of this π junction as part of the inductance allows the circuit to be downsized.

Dr. Satoh of ISTEC introduced a fabrication process for Integrated Cryogenic Current Comparator (ICCC). The CCC is a high precision current comparator that is even used as a standard; however, it is an individually handcrafted device, which cannot be mass-produced. Furthermore, there used to be a problem that the upper limit of the current multiplication ratio was about 10,000. They are aiming at resolving these problems by diverting the niobium fabrication process, which was developed by ISTEC for digital circuits, in order to convert an analog circuit CCC into an on-chip ICCC. The first device was fabricated using a

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planarization multilayer process and its CCC operation was confirmed. Henceforth, they will pursue approaches to enhance accuracy.

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Feature Article: ISS2010 Topics
- Large Scale System Applications

Takeshi Ohkuma, Director
Electric Power Equipment Division, SRL/ISTEC

The large scale system applications field included 26 oral and 98 poster presentations for a total of 124 presentations. When classified into applied fields, the number of presentations on cables was 20, current limiters 14, SMES 13, transformers 6, rotating equipment 10, magnets 26, magnet applications 23, and others applications 12. Compared with last year's total of 110, there were more presentations on SMES, rotating equipment, and magnets this year.

At the special plenary lectures, projects in Korea were reported. The DAPAS (Development of the Advanced Power system by Applied Superconductivity technologies) project, which started in fiscal 2001 and ends in fiscal 2010, is now in Phase 3 (fiscal 2007 to 2010), where the development of power devices is underway, such as 154kV/1GVA cable, 154kV/100MVA transformer, 154kV/4kA and 22.9kV/3kA current limiters, and 5 MW rotating equipment. Also introduced as Korea's first actual power grid demonstration was the GENI project (2008 to 2011) led by the Korea Electric Power Corporation (KEPCO). This project is developing 22.9 kV/50 MVA/500-meter three-core in one cryostat cables and 22.9 kV/630A current limiters, and there are plans to perform a system linkage experiment involving cables and current limiters in 2011 at the Ichen 154 kV substation. Aside from this, KEPCO is also planning the development and experiment of superconducting cables and current limiters as part of the smart grid experiment (phase 1: 2012 to 2016, phase 2: 2017 to 2021) that is scheduled for implementation on Jeju Island.

As for cables among oral presentations, projects in the US were introduced. LIPA II of the LIPA project features plans to implement a system linkage experiment of 138 kV/2.4 kA/600 m cables using 2G wires in 2011, while also planning a demonstration of cables equipped with a current-limiting function. Also introduced were the Southwire project that is currently implementing a system linkage experiment, HYDRA project's cables, equipped with a current-limiting function, and the Tres Amigas project's 5 GW/2-mile cable plan. As for projects in Japan, topics presented included those such as the status of Bi-based superconducting cable demonstration project and the development status of high-voltage cables in the technology development project for Y-based superconducting power devices.

As for rotating equipment, development statuses were reported regarding Siemens' 4 MVA-class, Korea's 5 MW-class, and Denmark's 5 MW-class equipment. For all of these, the application of superconductivity is indispensable, and, recently in particular, there has been an increase in the number of devices and equipment, such as the above, targeted for use in wind power generation.

As for transformers, projects in the U.S. were introduced. Among them, there are plans underway to link the 28 MVA/3-phase transformer (70.5 kV/12.4 kV), equipped with a current-limiting function, with a smart grid, and develop superconducting power application devices, along with cables and current limiters, for use in the smart grid.

As for current limiters, projects in the U.S. and Europe were introduced. From the U.S., topics introduced included the demonstration experiment featuring 12-kV current limiters, the development status of 138 kV current limiters by Zenergy Power, and the development status and demonstration experiment of 115 kV current limiters by AMSC. From Europe, the development status of 6.4-kV current limiters was introduced.

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Feature Article: Superconducting Electronics, Communications, Detectors field
- Technological Trends of Superconducting Microwave/Optical Devices

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This year marks exactly one century since the discovery of superconductivity. As superconductivity was discovered at Leiden University, Netherlands, on April 4th, 1911, the university plans to hold

"CELEBRATION: 100 Years of Superconductivity"

on the same day this year, in which I, also, would really like to participate. This is also the 25th year since the discovery of high-temperature superconductors. It is deeply moving for me to review the technology trends of superconducting microwaves/optical devices in such a memorable year.

Superconducting devices for controlling and sensing electromagnetic waves from microwave to light regions include: (1) a superconducting band-pass filter, (2) a terahertz wave detector, (3) an X-ray detector, (4) a neutron ray detector, and (5) a radiation detector, etc. Among these devices, the superconducting band-pass filter and X-ray detector have already been put into practical use and are widely used. A terahertz wave detector, neutron ray detector, and radiation detector have also drawn attention as promising practical devices, and are currently being actively researched. This special feature also includes articles describing the development of superconducting filters for weather radar (Mr. Kayano, Toshiba) and the TES X-ray detector (Mr. Mitsuda, JAX-ISAS), etc. Please refer to individual articles for these devices. As Mr. Ohkubo of the National Institute of Advanced Industrial Science and Technology explains about superconducting detectors elsewhere, I would like to describe the following two types of superconducting microwave devices:

1. New application of a superconducting filter – superconducting band-pass filter for UWB communication

3000 MHz – 10000 MHz

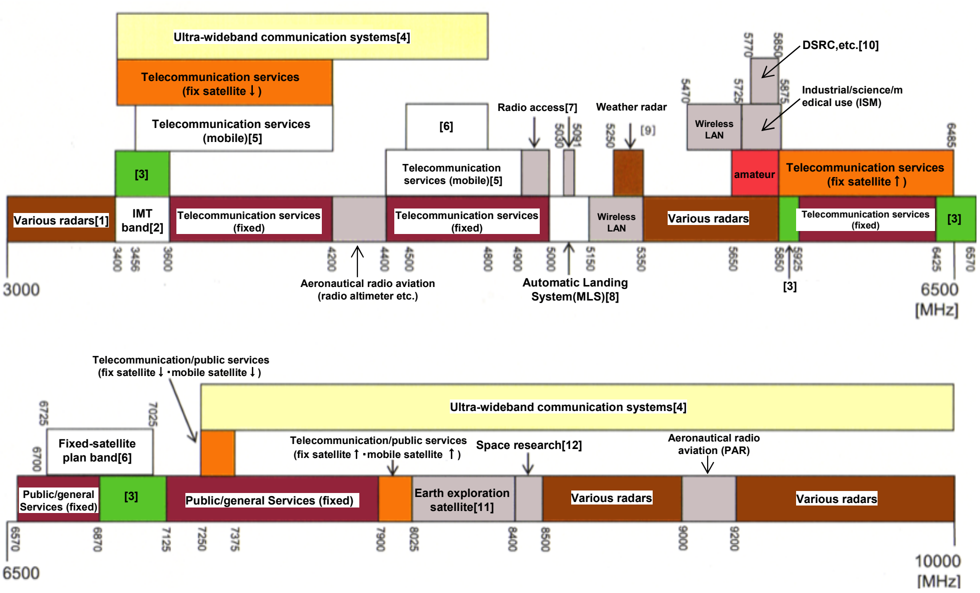

Fig. 1: Frequency utilization status of 3,000–10,000-MHz bands in Japan

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The Federal Communications Commission of the US determined that commercial uses of Ultra Wide Band (UWB) communication should be allowed, although this was formerly only approved for military use. Accordingly, an international standard of UWB communication was proposed and approved. In Japan, the frequency bands for UWB communication were allocated to 3.4-4.8 GHz and 7.25-10.25 GHz (Fig. 1)[1]. However, other radio communication systems are already operating in these frequency bands, meaning interference with such systems must be prevented. In addition to its low-loss property and superior frequency selectivity, the superconducting filter allows the design of compact wide-band filters, hence various types of UWB communication filters are proposed at present. Figure 2 shows the characteristics of the UWB filter as reported by Professor Ma *et al.* of Saitama University[2]. This is an ultra-wideband band pass filter that exhibits superior properties.

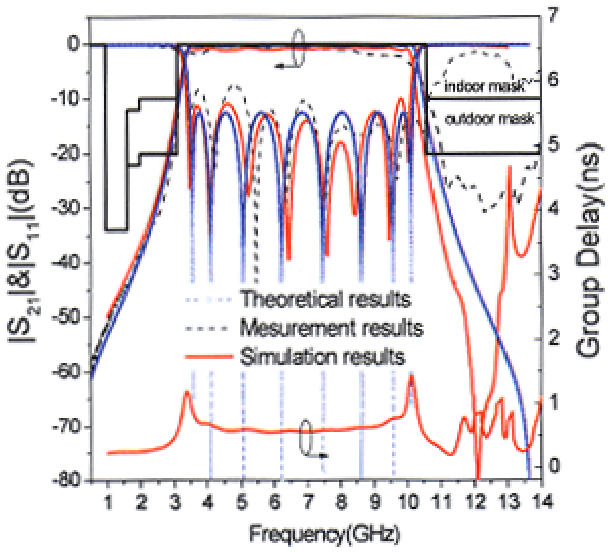

Fig.2 the characteristics of the UWB filter

2. Microwave Kinetic Inductance Detectors (MKIDs)

Increasing research is being carried out on MKIDs as devices to detect photons from light to X-ray regions. Recently, in particular, MKIDs are drawing attention as terahertz wave detectors. The principle is that when photons are injected into a resonator, the Cooper pair is destructed, its resonance frequency fluctuates, and photons from light to X-ray regions are detected by measuring the fluctuations in the resonance frequency. The structure is simple and the measurement is easy since the only requirement is to configure GHz resonators. We, as researchers of microwave resonators, also have a considerable interest in MKIDs. Lumped Element Kinetic Inductance Detectors (LEKIDs) are of particular interest, because they can be designed using the same technique as superconducting filters. Figure 3 shows the equivalent circuit of LEKIDs as reported by S. Doyle *et al.*[3] The basic structure is a resonator, comprised of a meander-concentrated L and comb-structured C. They reported that the filter has a resonance frequency of 6.5 GHz, a small size of approx. 0.3 mm square, and that it allows easier arraying.

Some superconducting microwave and optical devices have already been put into practical use, while others remain in the state where practical applications are promising for the future. To really target practical applications, however, these devices must have superior performance, operability, and price etc. compared with other competing devices. Although this is the biggest challenge, I hope new practical devices will emerge by overcoming such challenge.

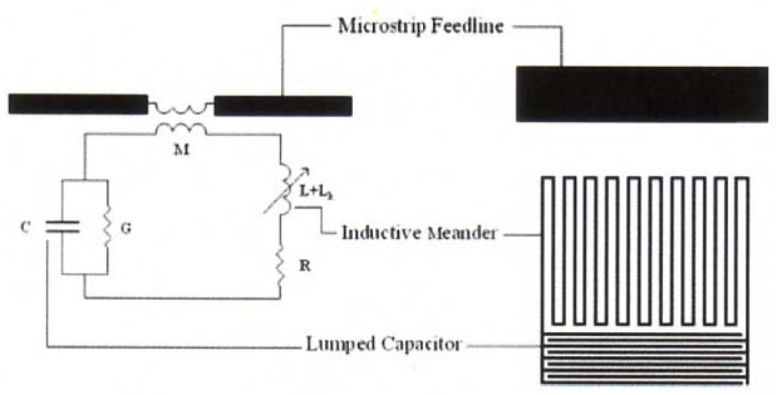

Fig.3 Equivalent circuit of MKIDs using an LC lumped circuit

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2. Zhewang Ma *et al*, " New Progress in the Development of Compact High-Performance Microwave Ultra-Wideband (UWB) Filters, 2009 IEEE International Symposium on Radio-Frequency Integration Technology (RFIT2009)
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Feature Article: Superconducting Electronics, Communications, Detectors field
- Development of a microwave-band noise source using a superconducting tunnel junction

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Institute of Astronomy, University of Tokyo

A cooled low-noise amplifier for the microwave band is a key component located in the first or second stage of detectors used for radio astronomy. Development is underway by many research institutes worldwide, targeting bandwidth expansion and noise reduction. Currently, an amplifier exists that exhibits super low-noise characteristics as low as a few K of equivalent temperature. The advancement of noise reduction, however, also results in a relative increase of measurement error, causing yet another problem.

Generally speaking, measurement of the noise factor (noise temperature), which indicates the performance of amplifiers, is carried out by inputting reference signals of two different power levels (equivalent temperatures) in the amplifier and evaluating the response to the same. It is desirable for the power level of the reference signal to be equivalent to the minimal noise of the amplifier, and the existing method generates reference signals by reducing the output of the avalanche diode to approximately 1/100 via an attenuator. There is a problem, however, of considerable error (more than 10 %) due to the loss caused by the attenuator and cable between the avalanche diode and amplifier, as well as the physical temperature of the attenuator. Therefore, the method sought is one allowing direct connection between the reference signal source and amplifier, which is not dependent on physical temperature.

When a voltage is applied to a superconducting tunnel junction (hereinafter "SIS junction"), it outputs a minimal shot noise in proportion to the bias voltage, which holds the potential for use as a reference signal source. The use of an SIS junction as a reference signal source allows noise to be measured with a high degree of accuracy (error 3 %) because it can be connected directly to the amplifier and is not dependent on the physical temperature. Moreover, it may also be used to evaluate the amplifier linearity because the output power can be controlled by voltage adjustment.

With this in mind, we carried out the development of the reference signal source using an SIS junction. Figure 1 shows the reference signal source which we fabricated, which comprises an SIS element and housing.

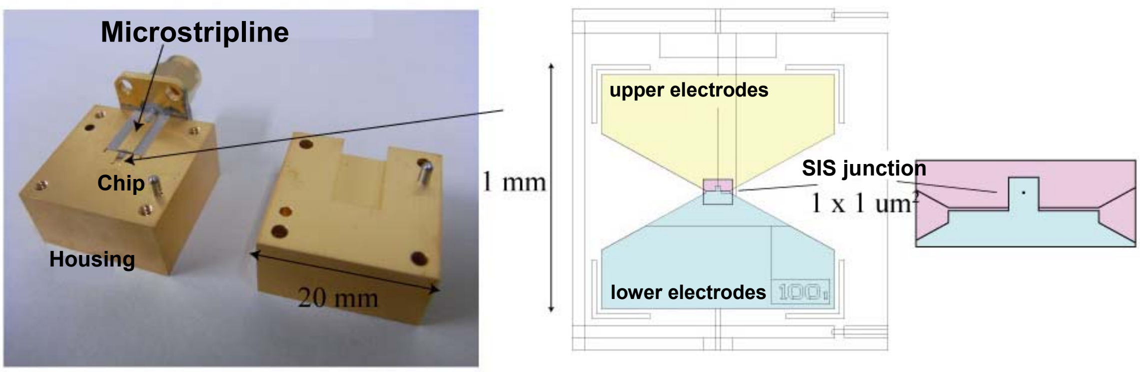

Fig. 1: A reference signal source we developed. (Right) Housing and SIS chip. (Left) SIS chip. The SIS chip comprises upper and lower electrodes, and an SIS junction.

During the design phase, we exercised extra caution to ensure the shot noise generated in the SIS junction was sent to the amplifier without any loss or reflection. The SIS junction adopted an Nb-Al/AlOx-Nb junction, and the size was set to 1 x 1 um^2 in order to restrict the geometric capacity of the junction itself. In addition, the normal state resistance was set to 50 Ω by adjusting the oxidizing condition of barriers in order to maintain the matching with the measured object.

Using the fabricated SIS noise source, we carried out characterization of the cooled low-noise amplifier, and compared the result with the existing method using a room-temperature diode noise source and cooled attenuator (Fig. 2). Due to the direct connection to the measured object and the lack of dependence on physical temperature, the measurement error is far smaller with the SIS noise source (red) than with the existing method (green). The result obtained showed an estimated noise temperature of about 1.5 K higher systematically when using the SIS noise source. We consider this difference to be attributable to the difference in physical temperatures between the external and internal conductors in the coaxial-type cooled attenuator used for the existing method.

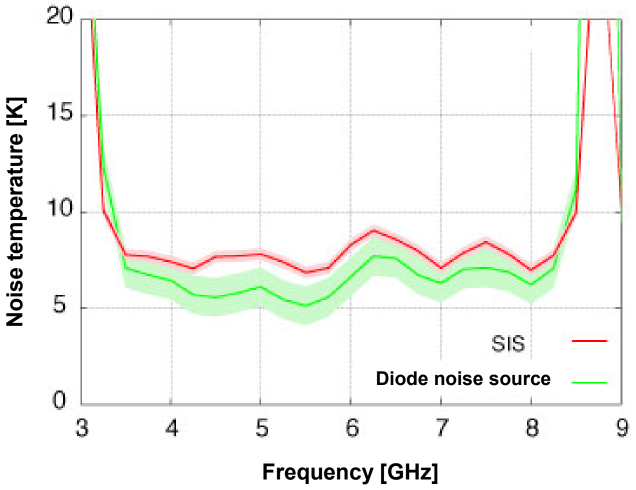

Fig. 2: Characteristics comparison between cooled amplifiers. The result with an SIS reference signal source (red) and the result with a diode noise source (green). The band indicates the measurement error.

We are now upgrading this SIS reference signal source to higher frequencies to achieve the operation in millimeter wavebands. If such a reference signal source is also achieved in millimeter wavebands, various applications can be expected, including the temperature calibration of astronomical signals in the radio astronomy field.

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Feature Article: Superconducting Electronics, Communications, Detectors field
- Development of Superconducting Receive Filters for 5 GHz band Weather Radars

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In recent years, the use of radio-wave devices has been expanding, such as digital television, mobile phone, and wireless LAN, and demand for the construction of a future high-speed communication network is also increasing. Alongside this trend, it is becoming increasingly important to ensure a proper radio-wave utilization environment by effectively utilizing limited frequency resources. Particularly in the 5 GHz band, there is an urgent need to ensure effective frequency utilization due to the recent explosive growth in the utilization of wireless LAN. In our company, we are advancing research and development to reduce the bandwidth of neighboring 5 GH-band weather radar systems, while assuming the frequency band expansion of 5 GHz-band wireless LAN. The current weather observation system uses a meteorological satellite for wide-range cloud observation; AMEDAS for the point observation of precipitation; and weather radars for short-term observation of wind and rain (see Fig. 1).

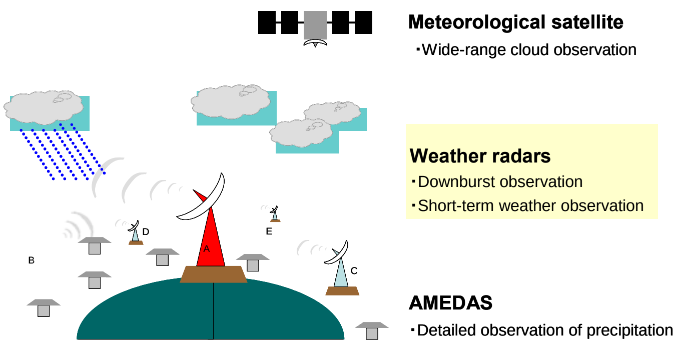

Fig.1 Weather observation system

The technology developed this time is a narrow-band superconducting receive filter, which is used to operate many weather radars with fewer frequency bands, targeting the construction of a weather radar network. The use of this filter allows only the target signal to be captured without interferences, even when narrow-band signals are densely allocated on the frequency axis.

As shown in Fig. 2, in terms of a filter that cuts out system bandwidth like a conventional filter, it was possible to achieve one with sufficient low-loss property, even with the use of a cavity resonator, which is a conventional technology. A narrow-band filter is required for

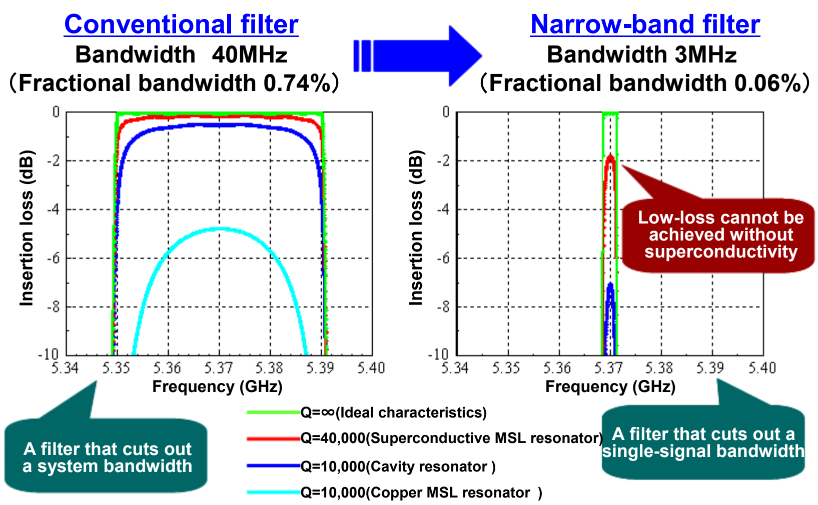

Fig. 2 Advantages of superconducting filter

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picking up a signal without interference from signals densely allocated on the frequency axis; however, a low-loss filter cannot be achieved without using the low-loss property of superconducting materials. We used to prototype filters using hairpin-type superconducting resonators, and have advanced our research given the increasing needs for further loss reduction. Subsequently, we developed a filter using a coupled superconducting microstrip line resonator, which eliminates the problem at the bend section of a hairpin-type resonator (see Fig. 3). The unloaded Q value (Qu), which is a performance parameter for resonators, was doubly improved and the filter insertion loss was halved to about 1 dB (see Fig. 4)[1]. This filter is capable of separating only the target signal and suppressing neighboring interference waves by over 30 dB, even when the system is operated at a signal density four times higher (2.5 MHz interval) than the conventional level.

At present, alongside the development of this receive filter, we are also advancing the technological development of a narrow-band transmit filter with high-power durability in the order of kW, which can be applied to the sending side.

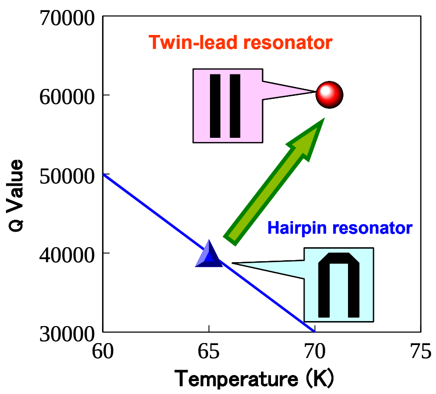

Fig. 3 Q value comparison of resonators

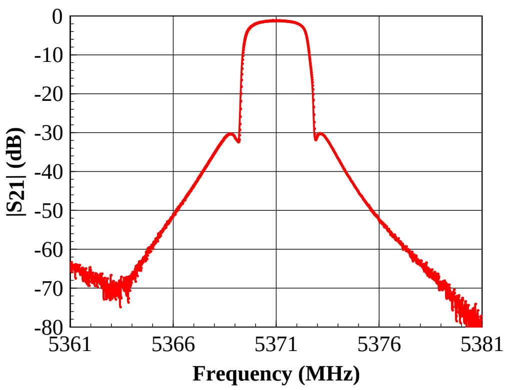

Fig. 4 Frequency characteristics

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Feature Article: Superconducting Electronics, Communications, Detectors field
- Trends in Advanced Measurement Technologies Equipped with Superconducting Detectors

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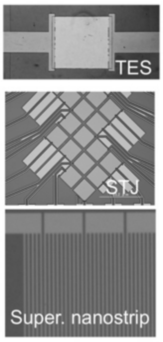
1. Introduction

For measurement techniques using the superconducting phenomenon, well-known devices include SIS mixers used for electromagnetic wave detection and SQUIDs used for magnetic field measurement. These devices can be classified into a category called "coherent detectors." Leaving explanation of coherent detectors to other excellent reports, this paper describes trends in "direct-type superconducting detectors" that have been progressing in recent years. While coherent detection measures physical quantities such as field strength and magnetic flux, direct detection is sensitive to quanta such as photons and phonons, and can detect particles one by one including photons, atoms, and molecules with a detection sensitivity of nearly 100 %. Direct detection also allows high-precision measurement, which is impossible with conventional techniques, such as photon energy ($h\nu$) from infrared to γ-ray and kinetic energy ($1/2\ mv^2$) from atomic molecules to giant molecules such as proteins. These detection capabilities surpass the limits of conventional techniques, and it is high time to promote popularization by IEC standardization that incorporates both coherent and direct detections so as to accelerate green innovation, life innovation, and security.

2. Types of superconducting detectors

The development of superconducting direct detectors started in the early 1980s, and has been rapidly advancing over the last 10 years. The direct detectors are in general classified into 2 types: the thermal detector and the quantum detector. The thermal superconducting detector is a calorimeter that measures temperature increase caused by, for example, absorption of a single photon, with the use of acute superconducting transition as a thermometer. The thermometer is called a "superconducting transition-edge sensor (TES)." The quantum detector directly converts radiation incidences into electric signals, and measures quasi-particles generated by the destruction of Cooper pairs by means of a superconducting tunnel junction (STJ). In addition to these detectors, many other types of superconducting detectors have been developed, including a junction that uses a normal conduction metal on one electrode (normal-insulator-superconductor: NIS), the microwave kinetic inductance detector (MKID) that uses surface resistance fluctuations caused when quasi-particles are generated, the metallic magnetic calorimeter (MMC) that uses the temperature dependence of paramagnetic magnetization of materials, and the nano-strip detector (superconducting single-photon detector: SSPD or superconducting nano-stripline detector: SSLD) that uses the transition of the superconducting nanostructure into a normal conduction state. Table 1 summarizes the spectral resolution, time response, and operation temperature of these superconducting detectors. Roughly speaking, TES has superb spectral resolution but the response is slow, STJ has high spectral resolution and the response is fast, and SSPD has no spectral resolution but is extremely fast. At first, the nano-strip was limited to photon detection in the infrared region, but recently, its application has been expanded to other observable objects such as biomolecules, electrons, and plasmons.

Table 1 Spectral resolution, time response, and operation temperature of superconducting detectors



Type	Spectral resolution (photons)	Time response	Operation Temp.
Carolimeter (TES, SPT, MMC)	Extremely high (1.2 eV@ 6 keV) (0.15 eV@ 1 eV)	Slow (1 ms)	< 0.1 K
Junction (STJ, NIS)	High (12 eV@ 6 keV) (0.14@ 2.5 eV)	Fast (1 μs)	0.3 K
Nanostrip (SSPD, SSLD)	N/A or Low (0.55 eV @ 1eV)	Extremely fast (1 ns)	> 4.2 K

3. Applications of superconducting direct detectors

As shown in Table 1, the operation temperatures of superconducting direct detectors are 4 K or below in most cases, and a very low thermal environment of 0.1 K is required in some cases. Compared with coherent detectors that can operate at 4 K to 77 K, it was very difficult for general users to use them with ease. Recently, however, thanks to the advancement of peripheral technologies, such as a cooling technique that does not require liquid helium supply, it can be mentioned that we are shifting from the research stage of studying the operating principles of superconducting detectors into the application stage of analyzing specimens by means of superconductivity.

As an application example, Figure 2 shows the mass spectrometer equipped with superconducting molecule detectors developed by us. Using this device, for example, 0.3 K can be obtained without the supply of liquid helium by creating 3 K with a GM cryocooler (or pulse tube cryocooler) while liquefying and depressurizing ^{3}He in a closed cycle. It is capable of continuous operation while maintaining 0.3 K for several days, and even when all the liquid ^{3}He has evaporated, 0.3 K can again be obtained several hours later. As the cooling cycle is automated, the user does not have to undertake the cumbersome cooling of detectors. The MALDI ionization method allows ionization without decomposing biomolecules, and the ions, which fly over a certain distance after they have been accelerated at a constant voltage, are detected by the superconducting detectors. The flight time and kinetic energy of the ions are simultaneously measured by means of digital signal processing (DSP) based on a field-programmable gate array (FPGA). Conventional mass spectrometry is unable to determine *m* uniquely, because ions are separated depending on the mass/charge number ratio (*m/z*). The use of a superconducting detector allows the determination of *z* from the kinetic energy, leading to achievement of a true mass spectrometry that can determine *m* uniquely. National Institute of Advanced Industrial Science and Technology (AIST) posts on their website a number of mass spectrometers equipped with superconducting detectors (listed in the “Nano Measurement” section at: http://open-innovation.jp/ibec/device/). They are open to the public.

Other examples of analysis techniques using superconducting detectors include: electron-beam-excited x-ray analysis, fluorescent x-ray analysis, fluorescent yield x-ray absorption fine structure (XAFS) spectrometry, α-ray spectrometry, and γ-ray spectrometry, which are used for scanning electron microscopes and transmission electron microscopes. Apart from analysis instruments, superconducting detectors are also utilized for advanced measurements in the telecommunications field and basic science field, such as quantum cryptographic communication, x-ray space observation, dark matter search, and neutrino physics. In the future, superconducting sensors are expected to accelerate innovation by eliminating measurement bottlenecks in the basic science and industrial measurement fields.

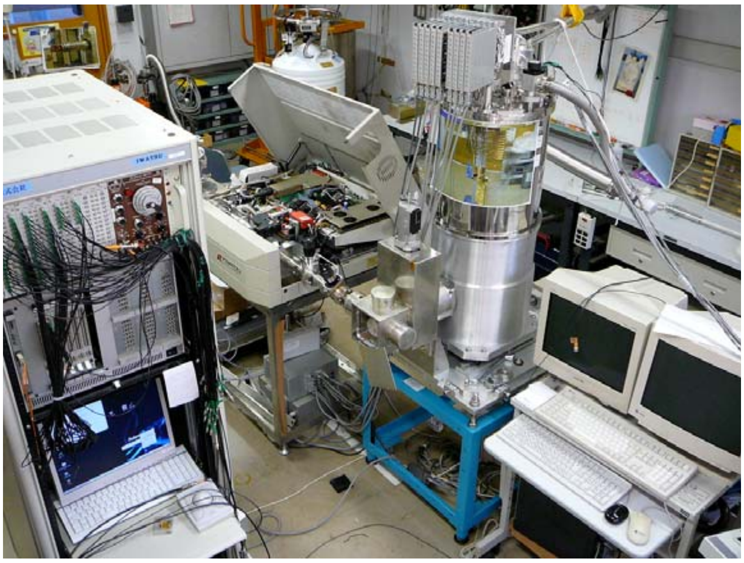


Fig. 2 Mass spectrometer for biomolecule analysis equipped with a superconducting molecule detector, a cryogen-free cryostat, and a signal process system

4. Conclusion

For the latest development on superconducting detectors, please refer to the proceedings of the International Workshop on Low Temperature Detectors.[1)-4)] There are a wide variety of superconducting detectors, and they have matured into the application phase. As a result of the discussion at the Superconducting Electronics Committee in Japan operated by ISTEC, superconducting sensors will be taken up as a target for standardization at the International Electrotechnical Commission (IEC/TC90 Superconductivity), with the aim of improving convenience for users of superconducting detectors. The proposal of the establishment of an ad-hoc group 4 for superconducting sensors has been submitted to the TC90 Subcommittee of the 2010 Seattle IEC Plenary Meeting, and obtained approval from participating countries. With IEC standardization, the popularization of superconducting detectors will be facilitated, measurement bottlenecks will be eliminated in many R&D fields by advanced analytical instruments equipped with superconducting detectors, and innovation will be accelerated significantly.

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Feature Article: Superconducting Electronics, Communications, Detectors field
- Space Observation Opened Up by TES X-ray Microcalorimeters

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Department of High Energy Astrophysics, Institute of Space and Astronautical Science (ISAS)
JAXA

The term "celestial body" would make many people imagine stars and interstellar gases, as well as galaxies composed of them. These celestial bodies, which can be observed at optical wavelengths, are only about 10 % of the normal-existence forms of substances (= baryonic matter, which accounts for only 4 % of the material energy in space, and the remainder is unidentifiable dark matter and dark energy). In the universe at present, the majority of remaining normal substances are assumed to be spreading widely in cosmic space as high-temperature gases at x-ray-emitting temperatures from 1 million to 0.1 billion degrees. These high-temperature gases contain heavy elements that have been produced by stars from the early universe when the first celestial body was created up to the present age. These highly ionized ions radiate emission lines that are unique to such ions. Spectroscopic observation of these emission lines with high sensitivity and high energy resolution will enable us to reveal the history of space structure formation and the history of element synthesis from the early universe to the present universe. For this purpose, observation with high energy resolution is required, and TES microcalorimeters are expected as the most promising detectors that allow imaging spectrometry by means of arraying and its energy resolution of several eV, which is more than 50 times higher than that of semiconductor detectors.

1. TES microcalorimeter

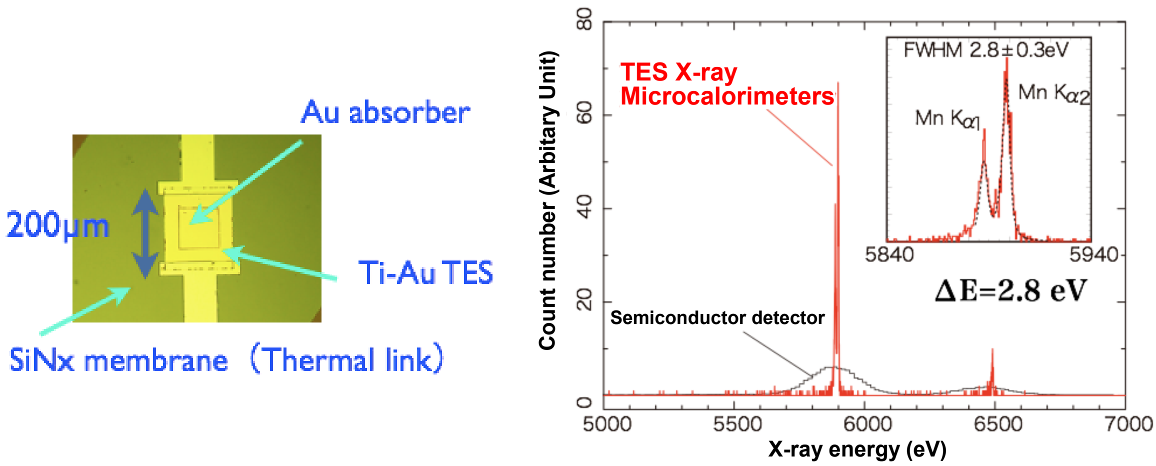

Fig. 1: Example of TES x-ray calorimeter developed by our research group of ISAS and TMU. With the element shown in the figure, a FWHM of 2.8 eV was obtained for Mn Kα lines emitted from the 55Fe isotope. Kα1 and Kα2 lines, which are separated from each other by about 10 eV, are clearly resolved.

Our research group, mainly led by the Mitsuda/Yamasaki Lab. of ISAS, JAXA and the Ohashi/Ishizaki Lab. of Tokyo Metropolitan University (TMU), has been conducting the research and development of the TES

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microcalorimeter and its readout system, for future space observations. Figure 1 shows our in-house fabricated device and an example of an x-ray spectrum obtained by this detector. We obtained a full width half maximum (FWHM) of 2.8 eV for Mn Kα lines (approx. 5.9 keV).[1)] A gold thin film of 120 microns square and a 1.5-micron thickness absorbs the x-rays, and the temperature increase caused by this absorption is detected by TES (transition-edge detector) composed of a bi-layer membrane of gold and titanium (beneath the gold). The heat capacities of many substances become very small at cryogenic temperatures compared with room temperatures. The heat capacity of this element, which is the sum of the gold x-ray absorber and the TES, is in the order of 1 pJ/K at an operation temperature of about 100 mK. When a single x-ray photon of 1 keV is absorbed, the temperature will increase by an order of 1 mK. Therefore, if the temperature increase can be measured with an accuracy of 1 micro K, the energy of x-ray photons can be measured with an acuuaracy of an order of 1 eV. To prevent the absorbed heat from escaping before the temperature has been measured with a high accuracy, the TES element is mounted on a self-supporting silicon nitride thin film of about 1-micron thickness.

2. Imaging device and signal multiplexing

Historically, the development of x-ray microcalorimeters started with semiconductor microcalorimeters that used semiconductor thermistors as their thermometers. The semiconductor microcalorimeter developed by the group of the NASA Goddard Space Flight Center has achieved a resolution of 4 eV for x-rays with 5.9 keV, and will be employed in the Japan's x-ray astronomy satellite, ASTRO-H. The greatest benefit of the TES type over the semiconductor type is the capability of signal multiplexing, which exploits the wider frequency bandwidth of the SQUID, which is used for the front-end readout circuit, than that of the TES signal. This benefit expands the potential of imaging spectrometry observation. We are also developing a large-format TES microcalorimeter array in which elements are closely packed, and we have obtained a resolution of 4.4 eV with a 256-pixel array of a 16 x 16 format. This resolution, however, is a result obtained by connecting a signle measuring circuit per pixel.

In case of a ground experiment, a cooling capacity of over 1 W at 4 K can be obtained by a GM or pulse tube cryocooler. For the observation of x-rays that do not reach the Earth's surface, we need to go into outer space by means of a satellite, etc. As available electric power is limited in satellites (several 100 watts may be used for observation devices), the obtainable cooling capacity is only about 20 mW at 4 K. Therefore, the number of wires must be reduced between the TES microcalorimeter array, which operates at about 100 mK, and the room-temperature electronic circuit. For this reason, signals from multiple TES microcalorimeters need to be multiplexed into a single signal channel in the stage of cryogenic temperatures from 100 mK up to 4 K, before sending the signals to the room-temperature stage. We have been conducting research on frequency-division which utilizes the difference between the frequency bandwidths of the SQUID (>1 MHz)and the TES microcalorimeter (several 10 kHz). . Different pixels are drived with AC bias of different frequencies, then the AM-modulated signals are applied to a single SQUID. To achieve our target of "signal multiplexing of about 20 pixels" with this method, these pixels need to be driven at a frequency of about 5 MHz. Operating the SQUID in a normal FLL (flux-locked loop) feedback circuit will cause oscillation due to signal delay occurring in the wiring from the cryogenic temperature stage to the room temperature stage (1 meter or more is required for a space cryocooler). For this reason, we have been developing a driving circuit by means of baseband feedback that, after demodulating the original signal, re-modulates the signal with a carrier wave whose phase has been adjusted by the amount equivalent to the delay that occurred in the feedback loop including the SQUID and circuit system, and returns the signal back to the SQUID (Fig. 2).[2)] We have demonstrated the basic operation and performance of the driving circuit, and are now developing a system that multiplexes signals from 4 pixels.

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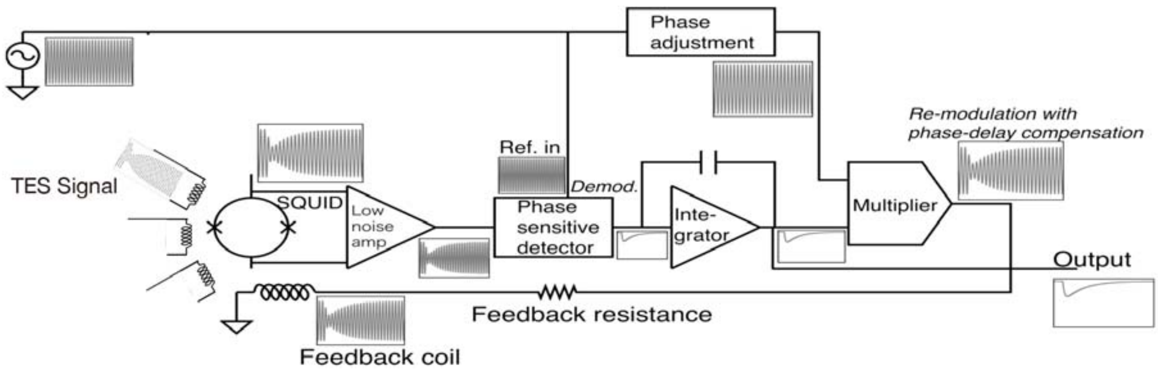

Fig. 2 Conceptual diagram of the frequency-division multiplexing system under development by our group. The AC-driven signals from TES are connected to the SQUID that has multiple input coils. (Although the figure shows only 3 inputs for simplicity, we have developed a SQUID that has 8 input coils.) The TES signals are retrieved by the phase sensitive detector, and the signals are re-modulated by a phase-adjusted carrier wave, before sending the signals back to the feedback coils of the SQUID. In this way, we were able to operate the SQUID stably even with a carrier wave of 5 MHz. An 80-stage SQUID array amp is used between the 8-input SQUID and the low-noise amp, which is not shown in this figure.

3. Future plans

The first cryogenic temperature detector that performs space x-ray observation in orbit will be a semiconductor microcalorimeter onboard ASTRO-H that does not use superconductivity. As future missions following that, we are actively discussing spectrometric imaging observation using TES microcalorimeters. Specifically, these plans include the small satellite DIOS[4] that is led by Japan with the aim of detecting missing baryon,[3] the mid-sized satellite Origin that is under consideration by Europe, Japan, and the US with the aim of revealing the history of element synthesis from the early universe to the universe at present, and the large satellite IXO[5] (US, Europe, and Japan) that aims to observe the first black hole and the first galaxy cluster created in universe as the primary observation objects. Including the small satellite DIOS, all the projects are considered to be undertaken with cooperation among scientists of research institutes in Japan, US, and Europe who are advancing the research and development of TES microcalorimeters, while aiming to have them participate in international missions in the late 2010s to the early 2020s.

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Feature Article: Superconducting Electronics, Communications, Detectors field
- Materials Science with Synchrotron Radiation Opened Up by STJ X-ray Detectors

Shigetomo Shiki, Masahiro Ukibe, Masataka Ohkubo
National Institute of Advanced Industrial Science and Technology

Yoshinori Kitajima
High Energy Accelerator Research Organization

As x-ray absorption fine structure (XAFS) can reveal the bond distance and electron state of elements, it is an indispensable technique for analyzing advanced materials. In various advanced materials, such as energy-saving semiconductors, ceramics, polymers, and catalysts, trace light elements including B, C, N, and O play an important role in the functional expression of these materials. While the fluorescent yield method is suitable for the XAFS spectrometry of trace light elements, the characteristic x-ray (Kα line) of trace elements is 2 keV or less, and this region contains K lines from light elements in matrix constituents and L and M lines from various elements; therefore, screening and analyzing of trace light elements are difficult with the capabilities of existing semiconductor detectors used for energy dispersion spectrometry. In addition to this, as light elemensts have a small fluorescence efficiency of 10^{-2} to 10^{-3}, wavelength-dispersive spectrometers cannot provide sufficient sensitivity even when a synchrotron radiation is used for the x-ray source. To resolve these problems, we are developing an XAFS spectroscopic instrument equipped with a superconducting tunnel junction (STJ).[1] As STJ can support up to a high count rate and provide higher energy resolution than semiconductor detectors and higher sensitivity than wavelength-dispersive spectrometers, it allows improvement both of the element screening capability and the sensitivity at the same time.

The fluorescence yield XAFS spectroscopic instrument is a combination of a 100-pixel STJ array detector, a 100-channel preamplifier, a 100-channel DSP pulse-height analyzer using FPGA, a cryogen-free ^{3}He cryostat, which can refrigerate to 0.3 K with the application of power, a vacuum analyzing chamber, and a load lock for specimen exchange (Fig. 1). At present, we are carrying out a performance test at KEK PF BL-11A. The target performance is a solid angle of 10^{-3} sr, an energy resolution of 10 eV, and a photon count rate of 1 M cps.

Fig. 1 Fluorescence yield XAFS spectroscopic instrument for light elements equipped with superconducting detectors

We are now at the stage where the following have become possible:

automatic cooling, obtaining DSP pulse height spectrums for 100 channels, and obtaining XAFS spectrums in tandem with a beamline monochromator. The ^{3}He cryostat provides an operationg temperature of 0.320 K, 40 hours of cooling time from room temperature to the operating temperature, and over 60 hours of holding time. Re-condensation of ^{3}He can be performed in a few hours. The feature of the cryocooler is that it does not require cryogen or cooling water, as it combines an air-cooled compressor and a cryogen-free pulse tube cryocooler, and that it allows automatic cooling. The detector adopts a structure that is particularly suitable for soft x-rays, such as a thickened upper electrode so as to show a single peak for a monochromatic light.[2)] The array detector has achieved a usable low leak current with about 90 out of 100 pixels. Currently, we are operating 16 pixels simultaneously. The actual measurement value of energy resolution for an oxygen Kα line (525 eV) is 14 to 22 eV (FWHM), and all 16 pixels have achieved 2- to 3-fold superior performance over the limit of silicon drift detector (SDD) (Fig. 2). Within fiscal 2010, we expect to achieve 100-channel operation by preparing preamplifiers, which are insufficient at present.

Multichannel operation improved the throughput. For example, the time required for oxygen K absorption edge XAFS spectrometry of α-Al_2O_3 with a single pixel is about 6 hours, which is comparable to wavelength-dispersive spectrometers using diffraction grating. By using 16 pixels simultaneously, a spectrum with the same statistical precision is obtained in about 30 minutes, and extremely high sensitivity can be achieved compared with wavelength-dispersive spectrometers.

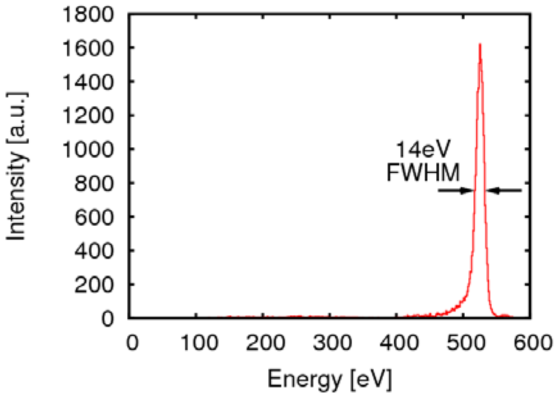

Fig. 2 Pulse-height spectrum when a 525-eV oxygen Kα line is irradiated to the STJ detector

Along with the device development, we are attempting to measure samples provided by users. This attempt is scheduled to be opened widely to the public from next fiscal year.

Acknowledgments:
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Feature Article: Superconducting Electronics, Communications, Detectors field
- Mass Spectrometry with STJ Molecule Detectors

Masataka Ohkubo, Masahiro Ukibe, Shigetomo Shiki, Koji Suzuki, Kaori Chiba, Tatsuya Kitazume
Super-Spectroscopy System Research Group, Research Institute of Instrumentation Frontier
National Institute of Advanced Industrial Science and Technology

1. Introduction

Mass Spectrometry (MS) is one of the most important analytical methods in a wide range of fields including the environment and life sciences. Mass spectrometry performs molecule identification by accelerating ionized atoms or molecules to a few keV and separating them spatially or temporally depending on the mass/charge number ratio (*m/z*) of the ions. It is still fresh in our memory that Mr. Koichi Tanaka and Mr. Fenn won Nobel prizes for the invention of the soft laser desorption method and the invention of electro-spray ionization, both of which allow the ionization of biological polymers without decomposition. In recent years, a widely spread method is matrix-assisted laser desorption/ionization (MALDI) that was evolved from the soft laser desorption. Conventionally, MS can only analyze low-molecular-weight molecules with molecular weights of a few up to 5,000; however, thanks to the emergence of these ionization methods, it can now be applied to protein with a molecular weight of 100,000 or more, leading to a rapid spread of mass spectrometers to life sciences.

MS, however, has two limitations due to its principle. One limitation is that the physical quantity, that can be determined by MS is *m/z*, but not as mass (*m*). Contrary to its name, mass spectrometry cannot determine the mass uniquely. It means that an uncertainty of the *z* value always exists, because the response of ions to electromagnetic force is determined by *m/z*. For example, $^{14}N^{+}$ and $^{14}N_2^{2+}$ are at m/z = 14 and, in principle, they cannot be separated even when an instrument having the highest mass resolution is used. Also, for Si with a slightly different mass, it is not easy to separate Si^{2+} and N^{+}. Another limitation of MS in its principle is that it can only analyze ions, because it uses electromagnetic force for separation. It cannot distinguish between different neutral molecules. This limitation is called “neutral loss” in the ion reaction and molecular structure analysis methods using tandem mass spectrometry (MS/MS). MS/MS is a method used for molecule identification and molecular structure analysis; it ionizes a specimen in which multiple molecules are intermixed, selects parent ions in the first MS, turns them into an unstable state by atomic collision or electron capture to dissociate them in the instrument, and analyzes the fragments in the second MS.

2. Overcoming the limitations of mass spectrometry by superconducting molecule detectors

Among MSs, the type that separates molecules according to their *m/z* values in accordance with their time of flight is called time-of-flight MS (TOF MS). Conventional molecule detectors used for MS include the microchannel plate (MCP) and the secondary electron multiplier.[1)] These detectors can detect the arrival of molecules as electric signals by multiplying secondary electrons that are emitted when molecules impact on the detector surface. Detection sensitivity is determined by the secondary electron emission efficiency (quantum efficiency). There are only a few secondary electrons emitted in a collision of a single ion with several KeV, and when it comes to the molecular weight of protein, the quantum efficiency drops to nearly zero. Therefore, counting loss occurs in the high-molecular-mass region. What can be known using the conventional detectors is only that molecules or atoms have arrived. This type of measurement is called the “ion counting mode.” In addition, the measurement of detector current can be performed when a large number of molecules impact on the detector; but this paper does not refer to it. Even when counting loss occurs, however, the overall detection sensitivity of MS can largely surpass other spectroscopic analytical methods.

MS instruments have no capability to determine the *z* value at any stages such as the ion source, separator, and detector. For this reason, MS can only measure *m/z*. What can be done to overcome this limitation? After being imparted with charges at the ion source, molecules are accelerated by a constant voltage potential difference. At this time, ions obtain a kinetic energy of *z x e*. Therefore, a true mass analysis can be achieved, when we can determine *m/z* and *z* values independently. The *m* value is obtained uniquely, if there is a detector that can measure the kinetic energy of ions in addition to the arrival time. Is there such a detector?

The use of superconductivity can realize the kinetic energy measurement of a single particle of several keV. Reference 2 summarizes the applications of superconducting detectors to mass spectrometry up to 1999. At that time, however, there were no reports of overcoming the limitations in the principle of MS. Figure 1 shows the mechanism of comparison between conventional molecule detection and superconducting molecule detection.[2)] While a high-energy α-ray can penetrate deep into a substance and easily excite electronic carriers, molecules and atoms of a few keV will stop at the detector surface and adhere only. In such a case, the secondary electron (or ion) emission is the only molecule detection mechanism, which is used in conventional detectors. Meanwhile, superconductors are known to be sensitive to phonons. As the energy gap of the superconductor is smaller than the Debye energy (the maximum energy of phonons), Cooper pairs are destroyed by phonons. Therefore, even for soft impact of a large molecule, which would stop at the surface of a superconductor, the molecule can be detected via phonons generated by the impact. The energy imparted to the superconductor can be determined based on the amount of destroyed Cooper pairs. While there are only a few secondary electrons with conventional molecule detectors, the number of quasiparticles generated by the break of Cooper pairs is extremely large, as many as 10^6, which is roughly equal to the number derived from dividing the kinetic energy by the superconducting energy gap. Without amplification, superconducting molecule detectors allow the same amount to be obtained as the final output charge amount of the secondary electron multiplier. In addition to allowing kinetic energy measurement, the large number ofquasiparticles means that molecules can be detected with an efficiency of 100% without counting loss. In principle, a degradation of the detection efficiency will not occur up to molecular weights of 10,000,000 or more.

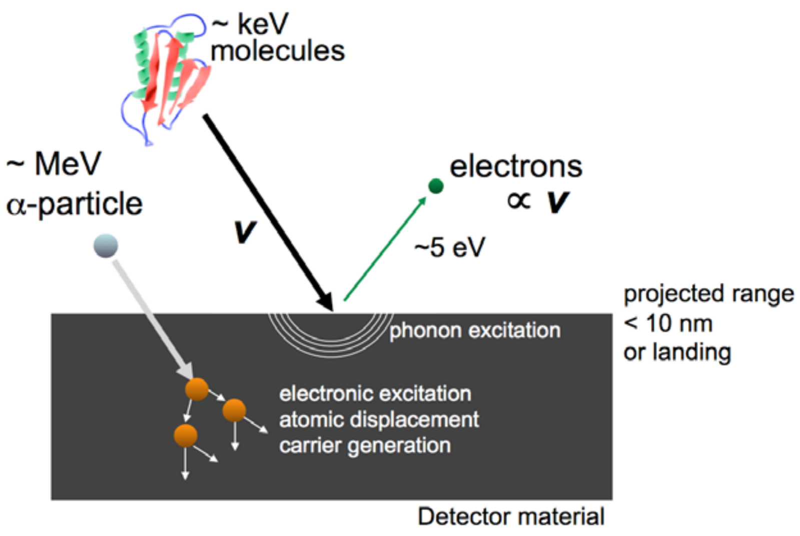

Fig.1 Comparison between conventional molecule detection and superconducting detection. For reference purposes, also shown is the case when α-rays (nuclei of helium), which are high-energy particles, have been injected.[2)]

A tunnel junction is used to read out the quasiparticles generated by the destruction of Cooper pairs. To prevent thermal excitation of quasiparticles , the junction is cooled down to 0.3 K, and it is then biased in the sub-gap region, while applying several 10 G of magnetic field in parallel with the junction to maintain the

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state in which the DC Josephson current is suppressed. In this state, when molecules impact on the surface of the junction electrode, quasiparticles are generated via phonons and the tunnel current increases. The superconductor then returns to the original state according to the lifetime of the quasiparticles. Therefore, for a single molecule impact, a current pulse with a fall time of 1 to 3 μs is generated. To read out this current pulse using a semiconductor amplifier, the quality of the tunnel junction must be much higher than the quality required for applications of the Josephson effect (SQUIDs or SIS mixers). The leak current must be lowered by 3 digits compared to the conventional junction applications. Furthermore, a large sensing area is important for detector applications to detect a sufficient number of molecule impacts. The 3-digit-lower leak current must be achieved with a junction area of a few 100 μm and an array of 100-element scale. To achieve this quality, we optimized the layer structure, film deposition condition, and etching process and the mask design.

When the ion source is MALDI, the measurement in mass spectrometry is performed by obtaining *m/z* from the time difference between the laser trigger and the current pulse. The determination of *z* is performed from the current pulse height. Figure 2 shows a measurement example of an enzyme, "lysozyme." The horizontal axis is *m/z* and vertical axis is kinetic energy. Tne dot corrensponding to each molecule impact is plotted according to the TOF value and the pulse height (called a "scatter plot"). Reference 5 reports the data when N^+ and N_2^{2+} were distinguished for the first time by performing kinetic energy measurement. This experiment was also reported in the online news of the American Chemical Society.[6)]

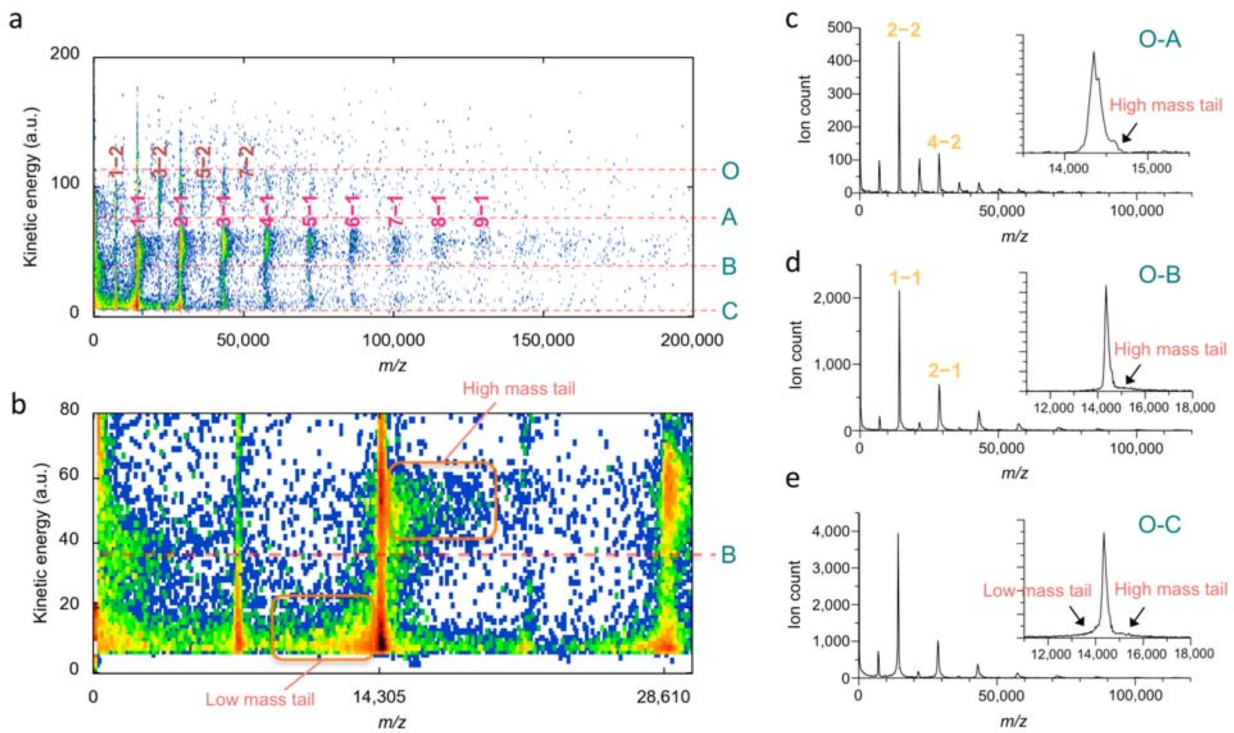

Fig. 2: Measurement of lysozyme by means of a mass spectrometer equipped with superconducting molecule detectors. The ionized and accelerated biomolecules exhibit decomposition during the free flight duration (called "post-source decay: PSD"). The fragments are produced by the PSD, and have the same TOF as the precursor ions. Because the kinetic energy is proportional to the molecular weight of the fragments, the events are seen vertically at about the same *m/z*, as shown in b, Since most of the ions, however, are detected without the PSD, for example, the mass spectra only for doubly-charged ions can be retrived by, selecting those events between O and A.[4)]

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Superconducting detectors can also resolve the problem of neutral loss observed in MS/MS. The problem of neutral loss occurs during electron capture dissociation. For example, electron capture for singly-charged ions generates excited neutral molecules. The fragments generated by the dissociation of the excited-state are all neutral. It is difficult to directly measure this type of dissociation reaction with conventional MS instruments. As the original kinetic energy is distributed according to the masses of the neutral fragments, different neutral fragments can be distinguished if we can measure the kinetic energies. The validity of this analysis method was confirmed by using a double-focusing mass spectrometer as the first MS, and the kinetic energy measurement of neutral fragment molecules, which are dissociated by the electron capture from a noble gas atom, as the second-stage MS (Fig. 3)[7].

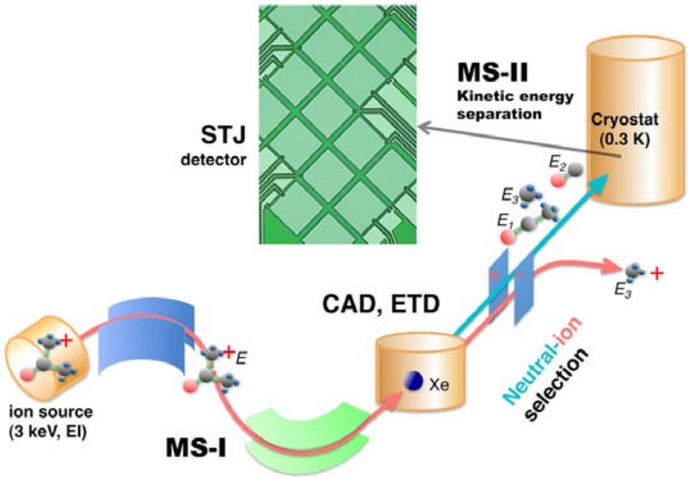

Fig. 3 Mass spectrometer equipped with superconducting detectors that resolved the problem of neutral loss.[7]

As described above, superconducting molecule detectors can overcome the limitations of conventional MS. The response speed, however, is restricted by the lifetime of quasiparticles, i.e., in the order of μs. This means that the accuracy of the TOF measurement time is restricted and the next molecule cannot be detected during that μs. Recently, a superconducting nano-stripline molecule detector was developed to solve this problem.[8] Conventionally, the superconducting single photon detector (SSPD), which was made of NbN superconducting nano-striplines of a few nm in thickness and a few 100 nm in width in an area of a few 10 square μm, was used for the detection of a single photon in the infrared region. This detector can achieve a time resolution better than 1 ns. An the size of only a few 10 μm, however, did not allow mass spectrometry because almost no molecules impact events occurs. To solve this problem, we adopted a device design called "parallel arrangement," and a time resolution better than 1 ns has been achieved even with a 1-mm detector size.[9)-11)] In recent years, this type of superconducting nano-stripline detector has been expanding to the detection of nanoparticles,[12)] plasmons,[13)] and electrons,[14)] in addition to photons and biomolecules.

3. Conclusion

The difficulties in fabricating the superconducting detectors are the perfectness of the tunnel barrier with a 1-nm thickness or the uniformity of the nano-stripline with a width of 1 μm or less. Furthermore, the detector size must be at least 1 mm or more. The recent progress in nanofabrication technologies made this fabrication possible. The progress of refrigeration technologies is also favorable for the application of superconductivity. The superconducting molecule detectors require cryogenic temperatures from 0.3 K to 4 K. Automatically controlled cryostats using a mechanical refrigerator can be utilized for this purpose. Users of mass spectrometers can get benefit from the high performance of superconductivity, even when they do not have the knowledge to handle the liquid helium.

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Standardization Activities

Topics in December

- Professor Kazuo Funaki Receives the FY2010 METI（Ministry of Economy, Trade and Industry）Minister's Award for the Promotion of Industrial Standardization

On October 18 (Mon.), 2010, Professor Kazuo Funaki, Graduate School of Information Science and Electrical Engineering, Kyushu University, received the METI Minister's Award as a person of merit for industrial standardization in the superconductivity field. The award ceremony was held in Cosmo Hall on the third floor of Toshi Center Hotel, hosted by Mr. Kaname Tajima, Parliamentary Secretary for METI, on behalf of Mr. Akihiro Ohata, Minister of METI. At the award ceremony, the Prime Minister's Award was given to one person, the METI Minister's Awards were given to nineteen people including Professor Kazuo Funaki and three organizations for the promotion of industrial standardization, the Director-General of Industrial Science and Technology Policy and Environment Bureau Awards for persons of merit in international standardization were given to twenty-four people, the Director-General of Industrial Science and Technology Policy and Environment Bureau Awards for promoters of international standardization were given to four people, the IEC1906 Awards were given to twenty people, the Standardization Contribution Awards were given to five people, and a Special Standardization Contribution Award was given to one organization.

Ceremonial photograph of the METI Minister's Award winners
(Prof. Kazuo Funaki, the fifth person from the right in the rearmost row)

Since 1999, Professor Kazuo Funaki has been acting as the convener of IEC/TC 90/WG9 (Superconductivity/AC Loss Test Methods), and played a central role in the establishment and revision of "AC loss measurements - Total AC loss measurement of round superconducting wires exposed to a transverse alternating magnetic field at liquid helium temperature by a pickup coil method", and "AC loss measurements - Magnetometer methods for hysteresis loss in Cu/Nb-Ti multifilamentary composites". Also in the same year, he assumed the position of JIS (Japanese Industrial Standards) draft creation

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commissioner, and served as the committee chairperson from 2003 to 2004. He has made great contributions to standardization activities at home and abroad in the superconductivity field, including his valuable efforts in the conversion of international standards into JIS standards.

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