Spring, 2013 Date of Issue: April 15, 2013

# Superconductivity Web21

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# Topics: Reporting on the 21st International Superconductivity Industry Summit (ISIS-21)

Toru Okazaki, Director
International Affairs Division
ISTEC

Scene of ISIS-21

The 21st International Superconductivity Industry Summit (ISIS-21) was held between 4th (Thurs) – 6th (Sat) October 2012, in Portland Oregon, located close to Seattle in the west coast of USA. Portland is well known as the most environmentally friendly city in the USA. Last year's participants at ISIS-20 were the usual countries that included Japan, USA, Europe, New Zealand and Korea. At this summit however, Russia participated for the first time as regular member, which felt, according to the author, as an expansion of the superconductivity industry. The numbers of participants per country were: 16 from the host country, USA, 11 from Japan, 4 from Europe, 3 from New Zealand and Korea, and 1 from Russia.

Reflecting upon the expansion of the superconductivity community, there was no particular theme for this summit, but instead each country reported their current status. The summit was also an opportunity for active discussions on how ISIS could play a role in the future promotion of the superconductivity industry.

At the opening of the summit Dr. Alan Lauder from the USA provided a historical background to ISIS, as well as announcing the passing of two great pioneers in the field of superconductivity, Professor Shoji Tanaka and Dr. Jens Mueller. A silent prayer was offered to their memories. Following this, the aims of this summit were presented to mutually disclose and discuss PJ developments in high temperature superconductors from each country under the backdrop of a world recession, and also deliberate potential future opportunities.

Reports from New Zealand included, Mr. Tye Husheer, Co-CEO of HTS110, and Dr. Robert Buckley, Group Manager of IRL, a research institute funded 100 % by the government. In a small country such as New Zealand, it has steadily progressed its business activities, gaining confidence in successfully promoting a niche market and thereby creating a profitable business. Main markets for their targeted applications are magnets and NMR systems.

  

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Dr. Joachim Bock, from NEXANS in Europe, reported on the steady progress of a cable and fault current limiter (FCL). A commercially installed FCL was mainly reported. High-capacity FCLs employ Y-based wires for their operation. A cable project named Ampacity was addressed for the considerable amount of wire required for the project. However, they reported that wire volumes were not an issue as there were many suppliers able to deliver on this project.

Dr. Tabea Arndt, from Siemens, reported about various other project plans, in particular, the newly launched wire development project called EUROTAPES, a €20bn investment over 4 and half years, targeted at wire development for various applications. Sensors are also thought to emerge as promising future applications.

Dr. Victor Pantsyrny, from Russia reported on various PJs in his country. Cables, FCLs, transformers, SMES, motors and power generators have all been thoroughly developed for conventional applications. Amongst these, the planned installation of a 2.5 km-class AC and DC cable in St. Petersburg drew particular attention at the summit.

Japan introduced its conventional project plans and reported on the current status of four cable companies. Recent electronics-related applications were also reported.

Korea, like Russia, has thoroughly targeted various specific applications. Professor Minwon Park reported on the necessary details required for superconducting wind turbine generators, sparking a heartfelt passion for this field.

The USA reported that due to no further DOE funding for new superconductivity-related projects from 2012, many projects would still continue but cease by the end of 2013. The author could not help envisaging the low-key stance undertaken by the USA compared to other counties. Nevertheless, plans connecting New York and Washington using Maglev and a superconducting aircraft dream project are forthcoming.

During general discussions it was debated whether ISIS should launch a transnational PJ. However, it was concluded that the present structure of ISIS should be maintained owing to the difficulty of initiating such a project straightaway. Whilst research budgets in the USA have been cut due to government policies, new PJs have been launched worldwide producing a sense of the different positions taken by the USA and the rest of the world.

In accordance with scheduling the next ISIS conference will take place in Japan and is to be sponsored by ISTEC. ISIS will be followed by the International Superconductivity Symposium (ISS2013), which is to be held on 18th (Mon) – 20th (Wed) November 2013.

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# Topics: Reporting on the EnerSol-WSEF in Tunis

Ryohei Kondo
Managing Director/Secretary General
ISTEC

EnerSol WSEF Venue

## 1. About EnerSol-WSEF

The first EnerSol-WSEF (World Sustainable Energy Forum) took place in Tunis in 2012, and was derived from recommendations made at the solar power generation seminar of the United Nations Industrial Development Organization in 2002. The forum aims to facilitate exchanges in the latest information between a wide range of participants including industry-academia-government and the general public regarding government policy, science technology and projects centered on renewable energies. In particular, the focus was to make contributions to African and Middle Eastern countries, which are expected to experience future dynamic development.

## 2. Event Overview

EnerSol-WSFF 2012 was held over three days from 14th – 16th November, at the Kram Exhibition Park located in eastern part of Tunis. The entire event consisted of more than 100 exhibitions by various corporate entities and forums of government policy/science technology/business. The sponsors expected more than ten thousand visitors to the exhibitions, with the forum attracting around 100 participants from around ten countries. Salah El HNNACHI, President of EnerSol, is well known in political circles in Tunisia and a Japanophile, having been posted as an ambassador to Japan for ten years. It seemed that his personal relationships also helped attracting guests to this event.

Prime Minister, Hammadi JEBALI, was invited to attend the first day of event, which attracted large numbers of media. Tunisia was where the "Jasmine Revolution" took place, and was also considered the first of a series of revolutions named the "Arab Spring". The constituent assembly in Tunisia presently consists of a Prime Minister and a President, with JEBALI supervising the entire government as the Head of

  

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Government. Being a physicist, he was well acquainted with renewable energies and earnestly toured the exhibition.

Prime Minister (Center) on a tour and surrounded by many visitors, media, and SPs

### 3. Forum Contents (Policy & Business, Science & Technology)

On behalf of Prime Minister JEBALI, the Tunisian Minister of Industry made a passionate speech in French at the opening address at the forum. A summary of the forum follows herewith.


Opening address by the Tunisian Minister of Industry
(fourth from right) and sponsor (third from right)

- The main themes from a few reports were on the mega-scale solar project in the Sahara desert. The EU reported that they wanted to achieve 2GW-class power generation by employing Sahara PV (Photovoltaic Power Generation) and transport the electricity to Europe. Additionally, it was conveyed that the EU expected electric power transmission by integrating PV/wind power energy policy in MENA (Middle East and North Africa regions). Japan's involvement with the Sahara Solar

  

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Breeder Project has been significant with reports on the substantial potential of PV and the possibility of increasing desert greening by PV power production using solar panels fabricated from desert silica. Japan also reported the feasibility of DC superconducting power transmission cables laid across the Mediterranean Sea. Evaluating the overall system performance along with the requisite cooling system was deemed important.

- There were interesting reports on renewable energies emphasizing the importance of grid strengthening, greater efficiencies afforded by the combinations of either "PV and geothermal heat pump (HP) system" or "PV and solar power generation". Power supply systems without the requirements of battery storage, achieved by combining PV and diesel power generation were reported as well. The "numbers of employers (person/kw)" research report addressed by Tunisia reflected the local economic situation of "wind power>PV>gas/coal". The author reported on the current status of Japan's renewable energy policy after the Great East Japan Earthquake.

**4. Other matters**

The author visited "Revolution Avenue (Avenue Bourguiba)" during the spare moments of the forum, however, was warned by the administrative office lady to take extra attention because of a demo planned for that day. Nevertheless, male staff members reassured me to convey a message to the Japanese people to *"Come to Tunis, it's absolutely safe"*. The day in "Revolution Avenue" passed by with no issues; it was crowded with ordinary folk going about their business and with only a handful of demonstrators singing songs. However, armored troop carriers were posted at the center of the street, highlighting traces of the revolution.

Central reservation at the west end of "Revolution Avenue"
(barbed-wire and armored troop carrier seen behind the cars)

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# Topics: "Participating at the 25th Anniversary Symposium of both Inauguration of the TcSUH (the Texas Center for Superconductivity at the University of Houston) and the Discovery of YBCO

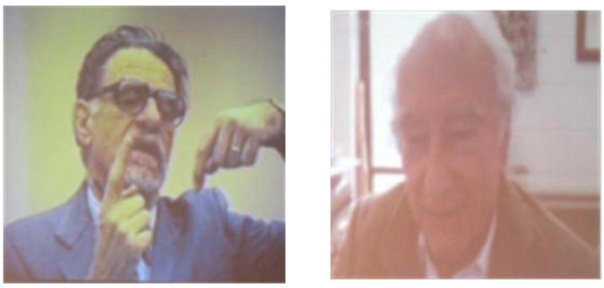
Yuh Shiohara
Director General
SRL/ISTEC

TcSUH 25th Anniversary Symposium
Hilton University of Houston, Shamrock Ballroom
4800 Calhoun Road, Houston, TX 77004

The 25th Anniversary Symposium of both inauguration of the TcSUH (the Texas Center for Superconductivity at the University of Houston) and the discovery of YBCO, sponsored by TcSUH, took place on 19th November 2012 with panel discussions on future research expectations and reflections on the past 25 years. Prior to the panel discussions, six Nobel Prize winners opened the plenary lectures with each giving a 20-minute lecture, including Dr. K. Alex Mueller, discoverer of oxide superconductors and Prof. Leon Cooper, one of the scientists behind the proposed BCS theory of superconductivity, both appearing via a video link. The Nobel laureates' joining in the celebrations of the 25th anniversary of the discovery of YBCO, and also being held on USA soil made the symposium even more momentous. Hosting an equivalent event in Japan would be unimaginable. The author was overwhelmed to participate and attend these extraordinary plenary lectures.

Prof. Annette Bussmann-Holder (University of Basel) introduced Dr. Alex Mueller's research into solid-state physics that led to the discovery of high temperature superconductors after being posted at IBM Zurich Research Laboratory in Switzerland in 1963, and also presented the current research undertaken by Dr. Alex Mueller. A video message from Dr. Mueller was also included as part of the presentation.

Also appearing via video-link was Prof. Leon Cooper, Nobel Prize winner for work on BCS theory, who gave a historical account of the research that led to the now well-accepted BCS theory. He explained that his initial efforts in trying to understand and explain the energy gap using Feynmann Diagrams and renormalization methods were unsuccessful, because he was unable to account for the small-digit energy gains usually associated with a superconductivity transition at the origin. Whilst phonon exchanges already alluded to electron attraction, he found problems associated with phonon exchanges with electrons on a Fermi surface. He went on to comment that at time he had a direct sense that an overlapping cooper pair would not simply lead to a Bose-Einstein Condensation. He concluded with a congratulatory message for the 25th anniversary.



Prof. Allex Mueller (left) and Prof. Leon Cooper (right) presenting their 20 minute lectures and congratulatory messages, appearing via video link during the morning plenary lectures.

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Following this, there were two lectures related to superfluidity in helium-3 which closely linked to superconductivity. Superconductivity is a phenomenon leading to a sudden decrease to zero electrical resistance in materials when they are cooled to cryogenic temperatures. Similarly, the superfluidity phenomenon occurs when a liquid is cooled, losing its viscosity abruptly and producing a flow of liquid without any hydrodynamic resistance. This behavior has been observed in helium-4 but was long thought impossible
in helium-3. However, in 1972, Prof. D.M.Lee *et al*., discovered superfluidity in helium-3 at 34 atmospheres of pressure and at a temperature of 0.0026 K (2.6 mK). Prof. Lee presented his discovery of superfluidity in helium-3 at this symposium. The transition temperature of helium-3 under ordinary atmospheric pressures is around 1mK, much lower compared to helium-4. Helium-3 is a fermion consisting of three nucleons (odd number). The superfluidity transition temperature of helium-3 is much lower than helium-4 because a fermion system does not reach its condensation state by itself. However, when two helium-3 particles are paired they become bosons, potentially triggering a Bose-Einstein Condensation. Superfluidity in helium-3 can be considered to occur when pairs of helium atoms form a condensation state. In accordance with BCS theory, fermion pairs have zero spin, however superfluidity of helium-3 exhibits internal degrees of freedom. BCS theory explained that electrons formed pairs because of attractions triggered by electron- phonon reciprocal interactions, however for helium-3, it was contemplated that the attractions occurred via spin fluctuations. Prof. A.J.Leggett presented with the aid of detailed diagrams, pairing interactions caused by spin fluctuations.


Prof. Anthony James Leggett (left) and Prof. David Morris Lee (right) presenting lectures on helium-3 superfluidity
Source: Wikipedia: Nobel Laureate Sir Anthony James Leggett in 2007.jpg、
Nobel Laureate David Morris Lee in 2007.jpg

Following this, Prof. Robert F. Curl, Jr. presented his lecture on fullerene C60. He confirmed the formation of large carbon chains or clusters by vaporizing an appropriate graphite target using laser irradiation. He focused his experimental results on the mass peak of 720 (corresponding to C60 atoms) and the mass peak of 840 (C70 atoms) followed, which led to his discovery and concluded its stability under an array of conditions. This experimental finding established the formation of C60, but was unable to resolve structural information. However, with repeated experiments he determined that C60 had to be spherical, but it was not known precisely how C60 aligned to form a sphere. The Montreal Expos exhibition, with its hemispherical dome that contained geometrical pentagons and hexagons, allowed Prof. Harry W. Kroto, co Nobel-Prize winner with Prof. Robert F. Curl, Jr., to contemplate the structure of C60 and the alignment of carbon atoms. Today, C60 is well known as Buckminster Fullerene or *Bucky balls*. Other cage structures such as elliptical shaped C70 were discovered and the family of structures referred to as “fullerenes”.

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Prof. Robert Floyd Curl, Jr. presenting his lecture on fullerene C60
Source: Rice University · James A. Baker III Institute for Public Policy

Prof. Samuel C.C.Ting, who received the Novel Prize in Physics in 1976 for the discovery of the J/ψ meson together with Prof. Burton Richter, presented the last plenary lecture at the session. Their experiments involved irradiating a target using a strong proton beam, and by employing complex and precise instrumentation they successfully detected showers of particles, leading to the discovery of new elementary particles. Prof. Richter's group named this new particle as a ψ particle, and Prof. Ting's group named it a J particle. The Greek character Ψ was chosen to represent the particle because its tracks resembled the psi shape. One story tells that the 'J' was chosen because of its similarity to the Chinese character "丁" of Ting. Despite this, both names have been adopted and it is now commonly referred to as the J/ψ meson. The lectures emphasized that experiments were equally important as theory.

The following summarizes the plenary session program, listing the session chairs, names of presenters and lecture themes.

**MORNING SESSION**

**Creativity & Innovation in Frontiers of Materials, Science, and Technology**

*This special session provides a unique opportunity to hear renowned scientists share their personal insights on major discoveries in materials, science and technology.*

*Chairs will provide 2-minute introductions of each speaker, and speakers will have 15 to 18 minutes for each talk, with presentations pre-loaded before the session begins. Each speaker block is thus shown as 20 minutes. Brief speaker bios will be printed in the official program.*

**Session Chairs**

**Prof. David Pines**, *Founding Director, Institute for Complex Adaptive Matter (ICAM); Distinguished Professor of Physics at UC Davis, and Research Professor of Physics/Professor Emeritus of Physics and Electrical and Computer Engineering in the Center for Advanced Study, University of Illinois at Urbana-Champaign*

**Prof. Dr. Øystein Fischer**, *Professor, Département de Physique de la Matière Condensée (DPMC); Founder and Director, Swiss National Center of Competence in Research (NCCR); Initiator, Geneva Creativity Center, University of Geneva, Switzerland*

**Thoughts on the Discovery of the First High Temperature Cuprate Superconductor** *9:15 – 9:35*

**Dr. K. Alex Mueller** *(greetings/video lecture), IBM Zürich Research Laboratory, Ruschlikon, and Department of Physics, University of Zürich; 1987 Nobel Prize in Physics for superconductivity in ceramic materials. Introduction by* **Prof. Dr. Annette Bussmann-Holder**, *Department of Physics, University of Basel, and Max Planck Institute for Solid State Research, Stuttgart, Germany*

  

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**Origin of the Theory of Superfluid He3 and Superconductivity** *9:35 – 9:55*
**Prof. Sir Anthony J. Leggett**, *John D. and Catherine T. MacArthur Professor, and Center for Advanced Study Professor of Physics at the University of Illinois at Urbana-Champaign; 2003 Nobel Prize in Physics for the theory of superconductors and superfluids*

**The Discovery of Superfluidity in He3 and its Implications for Science and Technology** *9:55 – 10:15*
**Prof. David M. Lee**, *Distinguished Professor of Physics, Physics & Astronomy Department, at Texas A&M University; 1996 Nobel Prize in Physics for the discovery of superfluidity in helium-3*

**The Development of the BCS Theory, The Most Comprehensive Microscopic Theory of Superconductivity, and its Impact on Physics** *10:15 – 10:35*
**Prof. Leon N. Cooper**, *(video lecture), Thomas J. Watson, Sr. Professor of Science and Director of the Institute for Brain and Neural Systems at Brown University; 1972 Nobel Prize in Physics for the BCS theory of superconductivity*

**Discovery of $C_{60}$ and the Beginning of the Nanoscience and Technology Era** *10:35 – 10:55*
**Prof. Robert F. Curl, Jr.**, *University Professor Emeritus, Pitzer-Schlumberger Professor of Natural Sciences Emeritus, and Professor of Chemistry Emeritus, Rice University; 1996 Nobel Prize in Chemistry for the discovery of fullerenes*

**The Discovery of the J-Particle and the Search for Dark Matter** *10:55 – 11:15*
**Prof. Samuel C. C. Ting**, *Thomas D. Cabot Professor of Physics, Massachusetts Institute of Technology; 1976 Nobel Prize in Physics for discovering the subatomic J/ψ particle*

Following the plenary lectures in the morning, the 25th Anniversary Luncheon was held with the following congratulatory messages and speeches.

Ms. Sheila Jackson Lee, Texas-elected Congressman (US House of Representative) attended the luncheon. She praised the achievements and past research findings of TcSUH, also stressing the importance of science and technology as well as future expectations of high temperature superconductors. Additionally, messages were read on behalf of two US Senators, Kay Bailey Hutchinson and John Comyn. After the address, representatives from the Governor of the state of Texas and Mayor of Houston city, Prof. Neal F. Lane (Rice University), made a speech on behalf of the USA's Science Community. At the conclusion, the author representing the International Community presented his congratulatory message celebrating the 25th anniversary, reflecting on 25 years of superconductors and future expectations. The lectures proved to be very fruitful.

Ms. Sheila Jackson Lee, US House of Representative, presents awards after her congratulatory message.
From the left, Prof. R.N. Bose (Vice Chanceller, University of Houston), Prof. C.W.Chu、
Prof. Allan J.Jacobson (Director, TcSUH), Ms. Sheila Jackson Lee (US House of Representative)

  

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Lecture and congratulatory message by the author (Shiohara), looking back over 25 years since the discovery of YBCO

**Friends of TcSUH 25th Anniversary Luncheon**

November 19, 2012 — 11:30 a.m. – 1:30 p.m.

Hilton University of Houston Hotel – Waldorf Ballroom

| | |
|---|---|
| 11:30 **Welcome** | **Allan J. Jacobson**, Director, TcSUH |
| | **Rathindra N. Bose**, Vice Chancellor/Vice President for Research and Technology Transfer, University of Houston |
| 11:33 **Introductions** | **Alan Lauder**, Executive Director, Coalition for the Commercial Application of Superconductors; President, Allan Lauder, Inc. (Master of Ceremonies) |
| | **Corbin J. Robertson, Jr.**, CEO, Quintana Minerals; Chair, TcSUH Advisory Board |
| | **Paul C. W. Chu**, Founding Director and Chief Scientist, TcSUH |
| 11:40 – 12:00 | **GREETINGS** |
| United States House of Representatives | **The Honorable Sheila Jackson Lee** Congressional District 18 |
| United States Senate | **Jason Fuller**, Regional Director, Office of the Honorable Kay Bailey Hutchison, United States Senate |
| | **Jay Guerrero**, Regional Director, Office of the Honorable John Cornyn, United States Senate |
| Office of the Governor, State of Texas | **Brett Perlman**, CEO, Vector Advisors; Former Public Utility Commissioner, State of Texas |
| Office of the Mayor, City of Houston | **Alfred Moran**, Director of Administration and Regulatory Affairs, City of Houston |
| Scientific Community | **Neal F. Lane**, Malcolm Gillis University Professor, Professor of Physics and Astronomy, and Senior Fellow, James A. Baker III Institute for Public Policy, Rice University |
| International Community | **Yuh Shiohara**, Director General, Superconductivity Research Laboratory (SRL), International Superconductivity Technology Center (ISTEC), Senior Managing Director, Industrial Superconductivity Research Association (iSTERA), Tokyo, Japan |

During the afternoon sessions the following four panel discussions were held.

  

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1:30 – 6:20 **TcSUH 25th ANNIVERSARY SYMPOSIUM** – *Continued in Shamrock Ballroom*

**AFTERNOON SESSION:**

**Frontiers of Materials, Science, and Technology: Creativity, Innovation, and Education**

**Note:** *There will be no formal break during the sessions. Beverages will be provided in the foyer throughout the session.*

**Session Chairs**

**Dr. Maw-Kuen Wu**, *President, National Dong Hwa University, Taiwan*

**Dr. Larry R. Faulkner**, *President Emeritus, The University of Texas at Austin; President Emeritus, Houston Endowment; TcSUH Advisory Board member*

*Note: The afternoon session will consist of panels. Renowned scientists will share their personal insights on HTS science, materials, applications, and science and technology policy. One hour and five minutes has been allotted to each panel for discussion of the topics listed below. Each speaker has 6-8 minutes to share his/her personal perspective on what is exciting, with time at the end for a few questions from the audience. If necessary, one or two viewgraphs may be used, and we ask that they be turned in at the registration table for loading prior to the session. The Chair will briefly introduce panel members at the beginning of each session. A brief bio for each speaker will be included in the printed program. There will be 5 minutes between sessions for panel changes.*

*1:30-2:35* **PANEL 1: High Temperature Superconductivity: PRESENT SCIENCE & MATERIALS RESEARCH**

- **Dr. Ivan Bozovic**, *Senior Scientist and Leader, Molecular Beam Epitaxy Group, Brookhaven National Laboratory*
- **Prof. Richard L. Greene** (Chair), *Alford L. Ward Professor of Physics, and Director Emeritus, Center for Superconductivity Research, University of Maryland*
- **Dr. T. K. Lee**, *Distinguished Research Fellow and Director, Institute of Physics, Academia Sinica, Taiwan*
- **Dr. Igor Mazin**, *Materials Science and Technology Division, Naval Research Laboratory*
- **Dr. James L. Smith**, *Materials Technology: Metallurgy, and Laboratory Fellow, Los Alamos National Laboratory*

*2:40-3:45* **PANEL 2: High Temperature Superconductivity: APPLIED RESEARCH, DEVELOPMENT & APPLICATIONS**

- **Dr. Amit Goyal**, *UT-Battelle Corporate Fellow, Battelle Distinguished Inventor and an ORNL Distinguished Scientist, Materials Science and Technology Division, Oak Ridge National Laboratory*
- **Prof. David C. Larbalestier** (Chair), *Francis Eppes Professor of Superconducting Materials, Department of Mechanical Engineering, and Director of the Applied Superconductivity Center, Florida State University; Chief Materials Scientist, National High Magnetic Field Laboratory*
- **Dr. Marty Nisenoff**, *M. Nisenoff Associates; IEEE Council on Superconductivity*
- **Dr. Horst Rogalla**, *National Institute of Standards and Technology (NIST)*
- **Dr. Bruce P. Strauss**, *Program Manager, High Energy Physics, Office of Science, U.S. Department of Energy*

*3:50-4:55* **PANEL 3: High Temperature Superconductivity: THE FUTURE**

- **Prof. Øystein Fischer**, *Professor, Départment de Physique de la Matière Condensée (DPMC); Founder and Director, Swiss National Center of Competence in Research (NCCR); Initiator, Geneva Creativity Center, University of Geneva, Switzerland*
- **Prof. Laura H. Greene** (Chair), *Swanlund Professor of Physics and Center for Advanced Study Professor of Physics, University of Illinois at Urbana-Champaign; Associate co-Director, Center for Emergent Superconductivity, an Energy Frontier Research Center; TcSUH Advisory Board Member*
- **Dr. Peter D. Johnson**, *Chairman, Condensed Matter Physics and Materials Science Department, Brookhaven National Laboratory*
- **Prof. Shin-ichi Uchida**, *Professor, Department of Physics, Graduate School of Science, The University of Tokyo*
- **Dr. Harold Weinstock**, *Program Manager, Air Force Office of Scientific Research (AFOSR)*

  

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*5:00-6:05* **PANEL 4: PERSPECTIVES ON SCIENCE & TECHNOLOGY POLICY**

- **Prof. Dr. Kristian J. Fossheim**, *President, Royal Norwegian Society of Sciences and Letters; Professor Emeritus, Institute for Physics, Norwegian University of Science and Technology, Trondheim*
- **Dr. Mary L. Good**, *Special Advisor to the Chancellor for Economic Development, Founding Dean and Dean Emeritus, Donaghey College of Engineering and Information Technology, University of Arkansas at Little Rock; former Under Secretary for Technology, Technology Administration, Department of Commerce; former President, American Chemical Society*
- **Dr. Koichi Kitazawa**, *Counselor to the President, Japan Science and Technology Agency (JST), Tokyo; former President, JST; Head, The Independent Investigation Commission on the Fukushima Daiichi Nuclear Accident*
- **Prof. Neal F. Lane (Chair)**, *Malcolm Gillis University Professor, Professor of Physics and Astronomy, and Senior Fellow, James A. Baker III Institute for Public Policy, Rice University; Former Director of the National Science Foundation, Assistant to the President for Science and Director of the White House Office of Science and Technology Policy; TcSUH Advisory Board Member*
- **Prof. H. D. Yang**, *President, National Sun Yat-Sen University, Taiwan; representative on behalf of the Taiwan Comprehensive University System (TCUS); former Vice Chair, National Research Council, Taiwan, ROC*

*6:05-6:20* **Concluding Remarks – Prof. Paul C. W. Chu**

Prof. Kitazawa (left) and Prof. D. Larbalestier (right) presenting lectures during the afternoon panel discussions

Prof. C.W.Chu (right), Prof. Kitazawa (middle), and the author (left) at the Banquet

Invited participants from Japan included, Professor Koichi Kitazawa (JST), Shinichi Uchida (University of Tokyo) and the author.

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## Topics: The 25th International Symposium on Superconductivity (ISS2012)

Toru Okazaki, Director
Public Relations Division
ISTEC


Opening remarks by the Chairperson of the ISS Organizing Committee, Kitazawa

The International Superconductivity Technology Centre (ISTEC) hosted the 25th International Symposium on Superconductivity (ISS2012) at the Tower Hall Funabori (Edogawa-ku, Tokyo) between 3rd(Mon) - 5th(Wed) December 2012. ISS is held annually to facilitate R&D discussions and foster international exchanges in superconductor technology in both Japan and overseas. It is primarily aimed at the development of a superconductor industrial technology, its promotion and diffusion as well as educating the general public. This year marks the 25th symposium. There were 507 participants in total, including 125 overseas participants from eighteen countries. Although the numbers of participants has slightly decreased, the numbers of countries participating has increased with the addition of three more countries compared to previous years, increasing sentiment of a broadening of superconductivity technology.

There were a total of 411 presentations, almost the same level as last year, and included 73 invited talks, 125 oral presentations and 286 poster presentations. Articles from the presentations are to be published in Physics Procedia and a special issue of Physica C (both by Elsevier) after a peer review process. In parallel, an exhibition showcasing superconductor-related materials products and technologies took place with nine corporates/institutions participating. In particular, new demonstrations included one by Tohoku University of a seismic isolator, which employed the Meissner effect of bulk superconductors, as well as demonstrations of science educational tools.

The first day was a special lecture session - the Professor Tanaka Memorial Day, dedicated to Professor Shoji Tanaka, founder of ISTEC who passed away at the end of last year. This followed addresses by Koichi Kitazawa, Chairperson of the ISS Organizing Committee, and a congratulatory message from invited guest, Keiichi Kawakami, Deputy Director-General for Industrial Science and Technology and Environment, on behalf of the Ministry of Economy, Trade and Industry. The following are brief accounts of the presentations (titles omitted).

  

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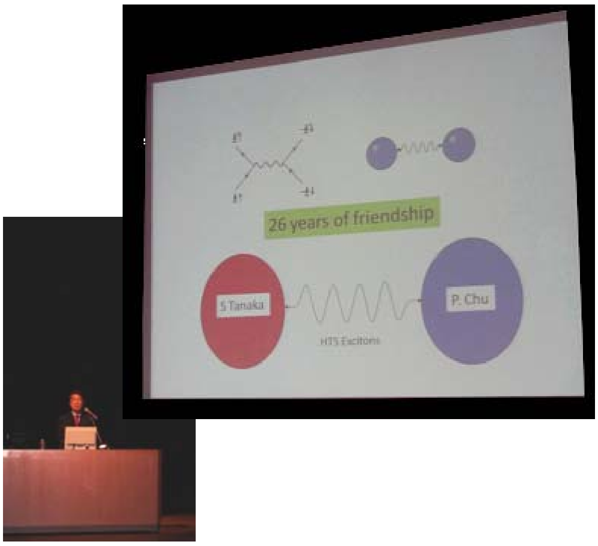
There were three special plenary lectures, the first entitled “Fukushima and electric power sharing in 23rd century” by Koichi Kitazawa (Japan Science and Technology Agency); “Possible evidence for interface-enhanced $T_c$ in Fe-pnictides and -chalcogenides) by Paul Ching Wu Chu (University of Houston); “From Curprate to Iron-based Superconductors” by Zhongxian Zhao (Chinese Academy of Sciences).




Special plenary lecture “26 years of friendship just like cooper pairs”

There were seven plenary lectures and included, “Over 20 years’ R&D of HTS and LTS electronic devices at SRL-ISTEC” by Keiichi Tanabe (ISTEC); “Superconducting devices to probe basic properties” by Tord Claeson (Chalmers University of Technology); “Human levitation with bulk high temperature superconductors” by Masato Murakami (Shibaura Institute of Technology); “Innovative roles of HTS in this century – Development of DI-BSCCO-“ by Ryosuke Fukuda (Chubu University); “Does the electric power grid need a room temperature superconductor?” by Alexis P. Malozemoff; “R&D of REBCO processing at ISTEC; from bulk single crystals to coated conductors –In memory of Prof. Shoji Tanaka–“ by Yuh Shiohara (ISTEC); “Contributions by Prof. Tanaka for the development of superconducting power systems” by Shirabe Akita (Central Research Institute of Electric Power Industry).

The second and third days of the symposium saw oral presentations from four categories sub-divided as: physics · chemistry/magnetic flux physics; wires · tapes/property evaluation; thin film•devices; system applications and large-scale system applications. There were also two poster sessions, allowing related reports and discussions to be exchanged. The evaluation of conventional bulk · characteristics were classified into two categories dependent on their contents.

The closing session on the afternoon of third day summarized the categories; physics · chemistry · magnetic flux physics reviewed by H.H.Wen (Nanjing University); wires · tapes reviewed by H.C.Freyhardt (University of Goettingen); thin film · devices reviewed by Keiichi Tanabe (ISTEC); large scale system applications was to be summarized by P.Masson, however he was unable to attend the symposium. Instead, the secretary briefly reported only the number of presentations made in that category. Finally, the Steering Committee Chairperson of ISS2012, Yutaka Kiyokawa (Executive Director of ISTEC) made the closing remarks.

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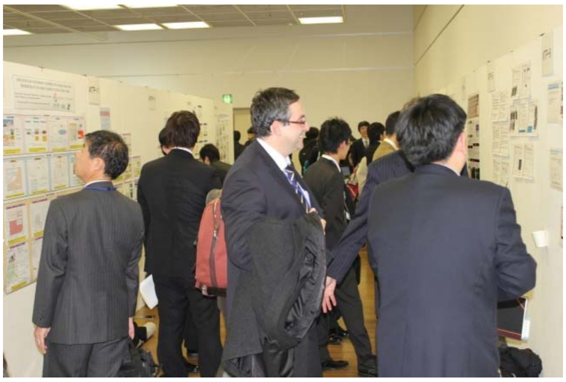
The next ISS meeting, ISS2013, will take place at Tower Hall Funabori (Edogawa-ku, Tokyo), for three days between 18th (Mon) – 20th (Wed) November 2013.

Oral session



Poster session

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# Topics: ISTEC Exhibition at "Eco-Products 2012"

Minako Oka, Assistant Manager
Public Relations Division
SRL/ISTEC


Demonstration of bulk superconductor levitation (movie)

The 14th "Eco-Products 2012," sponsored by Nikkei Inc., was held at the Tokyo Big Sight (Ariake, Koto-ku, Tokyo) over three days from 13th – 15th December 2012. The sponsor reported that the exhibition was well participated with 178,501. Although the number of visitors did not reach previous year's total of 181,487, the exhibition was very dynamic with visitors ranging from elementary and junior high school students on field trip excursions, to families and businessmen.

ISTEC exhibited at the "Smart Community Zone" last year. Last year's exhibition format contained a cartoon used to explain and promote superconductivity. It received positive reviews and comments such as, *"very easy to understand"* and *"gained familiarity in superconductivity"*. For this year's exhibition we have adopted a touch-panel style quiz, aimed at increasing public awareness of "the meaning of superconductivity, improving their understanding, and increasing their retention of what superconductivity is".

Additionally, characters such as "Cho-den-ger (superconducteranger) and Suzu-chan, were introduced in order to draw interests from children. Quiz questions were aimed at higher grades of elementary school students as well as junior high school students. Quiz participants were awarded "member certificate" stickers as a memento of their involvement.


Quiz question challenge

  

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Demonstrations of superconductors were present at previous exhibitions. However at this year's exhibition, superconducting levitation produced using superconducting wires was presented, and with tongs allowed the public to *experience* and *feel* the phenomena of superconducting levitation for the first time. The demonstrations had positive reviews with comments such as *"I understood the concept of superconductivity,"* and *"this is the only place to experience such demonstrations, which are otherwise typically only exhibited in a corporate showcase."*


Quiz participants awards - "Timeranger Member Certificate"

The ISTEC booth too proved attractive to not only children but also grown-ups, with large crowds and participants exceeding 2,000.

ISTEC first participated at "Eco-Products," Japan's largest environmental exhibition, in 2007, with this being ISTEC's 6th event. Questions from attendees were more specific, *"how eco-friendly can we become by utilizing superconductivity?"* and "*what future applications can be realized using superconductors?"* Only a few questions related to, *"What is superconductivity?"* A teacher attending the exhibition listened attentively; he was going to teach superconductivity to his class.

Showing interest during the superconductivity demonstrations


Very popular booth

Experiencing superconductivity demonstrations

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# World Project Now for Superconductor

## Save Earth by Superconductor

This year ISTEC has started special features on the current world projects for HTS superconductor and its application.

This month, Dr. A. P. Malozemoff, introduces the US activity.

We hope that our readers of Web21 will be initiated by this article not only for the research work but also for a business plan.

ISTEC
Yutaka Yamada

  

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# U. S. Activity in Superconductor Technology for Power Grid

A. P. Malozemoff,
37 Walnut St., Lexington MA 02421

## Abstract

Projects for enhancing superconductor wire performance and carrying out technology demonstrations of electric power grid equipment continue actively in the U. S., involving a number of wire, cable, motor and transformer manufacturers and utilities, with support from several U. S. government agencies. The U. S. leads the world in supplying commercial second generation high temperature superconductor wire, principally from AMSC and SuperPower, and a number of other entrepreneurial wire development efforts are under way. But U. S. activity in superconductor wire and power grid technology was significantly impacted by the termination of the U. S. Department of Energy's program on superconducting power equipment, which had for almost two decades been the center point of the U. S. effort in this area. Ongoing focus on applications, both government-supported and commercial is still needed, assisting the growing U. S. (and worldwide) industry in bridging to a future flourishing commercial superconductor power equipment market.

## Introduction and Overview

This report summarizes the status and future prospects for U. S. activity in superconductor electric power grid technology, building on a recent major report by Wolsky, [1] which provides a thorough review of both companies and specific projects in this area.

The focus here is on power grid technology based on high temperature superconductor (HTS) wire using the cuprate superconductors[2], particularly first generation (1G) $Bi_2Sr_2Ca_2Cu_3O_{10}$ (BSCCO-2223) and second generation (2G) $RE_1Ba_2Cu_3O_7$ (REBCO-123, where RE stands for rare earths and yttrium), and to a small extent on $MgB_2$ wire , which is being considered for fault current limiter and rotating machine applications. Although all these types of superconductor wires can address magnet applications, like magnetic resonance imaging, high energy physics and high field research magnets, such applications will not be considered here except insofar as they provide an additional market pull for superconductor wire.

Seen as a whole, the U. S. activity in superconductor grid technology leads the world in its scope and level of sophistication. It has the world's two leading suppliers of second generation (2G) high temperature superconductor (HTS) wire, AMSC and SuperPower. The world's most advanced HTS cable installation, the LIPA cable, which has operated since 2008 in the Long Island grid and originally used 1G wire, is now introducing 2G wire in one of its three phases. The world's most advanced HTS rotating machine, a 36 MW ship propulsion motor, was demonstrated by the U. S. Navy's Office of Naval Research (ONR) already in 2008. Major projects are under way to install the world's first fault current limiting cable in the New York City grid and to develop a 5 MW current limiting transformer. These and many other presently active projects are summarized in **Table I**.

AMSC, Boeing, Emerson Electric, General Electric, Southwire, Varian Power Systems and Waukesha Electric Systems are the main U. S.-headquartered industrial participants, along with smaller companies, some focused on wire such as Grid Logic, Hyper Tech Research, MetOx, Superconductor Technologies Inc. (STI) and 3G-HTS, and some focused on coils and systems, such as Advanced Magnet Lab, BEW Engineering, Empirical Systems Aerospace, and Tai-Yang. The main participating U. S. utilities are American Electric Power, Con Edison, the Long Island Power Authority (LIPA) and Southern California Edison. Governmental funding support is provided by the U. S. Departments of Defense, Energy and Homeland Security and by NASA. The U. S. activity is further enhanced by relevant R&D in several national laboratories (Argonne, Brookhaven, Los Alamos and Oak Ridge) and in many universities, particularly the Applied Superconductivity Center and Center for Advanced Power Systems at Florida State University, and the Texas Center for Superconductivity at the University of Houston. Superconductor power applications are studied and promoted by the Coalition for Commercial Applications of Superconductivity (CCAS), EPRI's Program 36 on Underground Transmission and the IEEE Working Group on Fault Current Limiter Testing.

Of course it should be recognized that a significant portion of the present U. S. activity is conducted by U. S. companies owned by foreign companies (SuperPower Inc. now owned by Furukawa Electric Co. of Japan and TECO-Westinghouse owned by TECO of Taiwan - Republic of China), by U. S. divisions of foreign companies (ABB of Switzerland), directly by foreign companies (Nexans and Air Liquide of France), or by partially foreign-owned joint ventures (Ultera, a joint venture of Southwire Company of the U. S. and nkt cables of Denmark).

**Challenges**

Nevertheless, some clouds have arisen in recent years around the future of U. S. superconductor grid technology. One was the termination of the almost two-decade-long U. S. Department of Energy (DOE) program, by its Office of Electricity, on superconductor power equipment, which promoted in an organized way the development of HTS wire and the formation of vertically integrated industrial teams to demonstrate in-grid superconductor power equipment. This program supported the key LIPA, Columbus-Bixby and Albany cable demonstrations (the first still active, Albany long since decommissioned, and Columbus-Bixby project expected to conclude at the end of 2012). It also supported the development of fault current limiter technology, culminating in the successful demonstration of a single phase transmission voltage fault current limiter by Siemens, Nexans and AMSC. One reason for the termination of the program was the sense that the technology was sufficiently established to allow industry to carry forward commercialization without further government support.

While this may be true for superconductor AC cable and fault current limiter technology, it is not true for some other major commercial opportunities such as superconductor generators for wind turbines, transformers and DC cables for long distance power transmission. Furthermore, while HTS and $MgB_2$ wire have reached performance levels adequate for commercial-scale power equipment demonstrations, further improvement in wire properties and reduction in cost could significantly assist commercialization and could benefit by on-going co-ordinated, government-sponsored research.

Another program supported by the U. S. Air Force Office for Scientific Research (AFOSR), the MURI program on underlying materials science of HTS wire technology, was also terminated several years ago, while a new AFOSR program was started to search for higher temperature - ideally room temperature - superconductors. Similarly at DOE, as their power equipment program terminated, a new Energy Frontier Research Center (EFRC) program was started to search for and characterize new superconductors - the

  

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Center for Emerging Superconductivity (CES) supported by DOE's Basic Energy Sciences Department. One of the underlying rationales for this new focus on discovery of higher temperature superconductors, both by AFOSR and EFRC-CES, was the idea that truly successful grid application required a room temperature superconductor so as to eliminate refrigeration cost and complexity. This perspective has been challenged by those who believe that present HTS materials are already well on their way to successful commercial grid application. In fact questions have been raised, not only about the difficulty of discovering a room temperature superconductor, but also about the practicality of such a superconductor, even if it could be found, on the general grounds that very short coherence lengths and thermal activation would increase grain boundary barriers and enhance flux creep, thus suppressing critical current.[3] More recently, CES introduced a new effort to understand flux creep and enhance critical current in the cuprates, with particular focus on operating conditions of a wind generator.

Another disappointment has been that the U. S. Navy put on hold superconductor motor development for electric ships, delaying, perhaps indefinitely, the opportunity to test the successfully laboratory-tested 36 MW ship propulsion motor on a ship. Interest persists at a low level in the U. S. Air Force in a high-speed ultra-compact generator for all-electric aircraft.

Finally, perhaps the biggest disappointment has been the lack of any truly commercial U. S. power project to date. Recognizing that the wire price is still quite high and that refrigeration systems are also costly and complex, utilities nevertheless may benefit commercially from the unique benefits of HTS power equipment. For example, superconductor AC cables, such as the LIPA cable, have now been well demonstrated and tested around the world. In urban environments with dense underground infrastructure, these cables offer a way to install compact, higher power underground links, allowing utilities to avoid major costs in digging up city streets and rerouting existing underground infrastructure. Reasons for the delay in taking advantage of this new technology for such applications can be many. The Great Recession and the ensuing weak recovery temporarily slowed growth of power demand and hence the urgency in the need for higher power urban links. The utilities' unfamiliarity with the technology is surely a factor, though in-grid installations such as the LIPA and Bixby cables are beginning to provide demonstrations of feasibility and long-term reliability. Cost tradeoffs are also a significant issue – installation savings must be substantial enough to outweigh the presently higher cost of the HTS cable itself with its refrigeration infrastructure. Similar issues apply to other applications such as rotating machinery and fault current limiters. And the technology for wind generators, transformers or DC cables, as mentioned above, is still insufficiently developed or demonstrated; these applications call for renewed focus.

## Projects

Nevertheless, a variety of important programs continue in the U. S., as summarized in **Tables I and II**. On the wire side, both AMSC and SuperPower maintain active in-house and collaborative R&D to support and enhance their commercial wire production, and their sales are steadily growing. For instance, AMSC continues to deliver 2G HTS wire on its 2010 order from LS Cable (Korea) for 3 million meters (delivery spread out over several years), which is the world's largest wire order to date. Hyper Tech Research is delivering $MgB_2$ wire to a 12 kV fault current limiter project of Rolls Royce and Applied Superconductivity Ltd. in the U. K. Several new wire development and manufacturing efforts are underway at Grid Logic (MgB2), MetOx (2G HTS), STI (2G HTS) and 3G-HTS (round wire with YBCO). Although these latter companies are far behind AMSC and SuperPower in establishing viable 2G HTS production, they claim long-term advantages to their 2G HTS wire processes; time will tell.

  

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Several U. S. government projects support U. S. companies in wire development (**Table II**). ARPA-E, a relatively new branch of DOE supporting innovative energy technologies, has a series of projects developing enhanced or novel HTS wire. The EFRC-CES program, mentioned earlier, works with AMSC and SuperPower. While these programs are helpful, they can hardly replace the co-ordinated effort sponsored by DOE's superconductor power equipment program, supporting major efforts at Oak Ridge and Los Alamos National Laboratories which have now all but disappeared.

In the area of applications (see **Table I**), perhaps most significant is the Hydra project by AMSC and Con Edison to install a fault current limiting AC cable linking two substations in New York City at the distribution voltage (13.8 kV) level. This project is supported by the Department of Homeland Security with the goal of increasing security for critical assets like New York's financial district by providing alternative energy links to the substation powering a given district. The cable is being fabricated by Ultera and refrigeration system by Air Liquide. Two other projects target DC cable: a Navy project led by the Center for Advanced Power Systems (CAPS) to study and build a prototype DC cable for on-board ship power distribution, and the commercial Tres Amigas project to link the three main asynchronous U. S. power grids with DC cables (in the first stage with conventional technology, only later with HTS).

Another major project is the Fault Current Limiting Superconducting Transformer project led by Waukesha Electric Systems, with SuperPower and Southern California Edison (SCE) as partners. The 28 MVA (69 kV/12.47 kV) system features compactness, fault current limiting and avoidance of oil for enhanced fire safety. It will be tested in the SCE grid. A standalone superconducting resistive fault current limiter is also being developed in an internal program at Varian Power Systems. AMSC and Nexans are teaming to offer distribution level superconductor fault current limiters for the U. S. market.

Wind generator technology is supported by DOE's Energy Efficiency and Renewable Energy (EERE) department in a multi-party program led by Advanced Magnet Lab (AML). GE, including its recently acquired Converteam subsidiary in the U. K., also has ongoing internal interest in superconductor generator technology. Unfortunately no U. S. program is yet applying the most advanced rotating machinery technology, which was demonstrated in the Navy's ONR 36.5 MW ship propulsion motor, to high power wind generators.

A project led by ABB, including Brookhaven National Lab and SuperPower and supported by ARPA-E, is developing a magnetic energy storage system (SMES). The goal is storage of intermittent wind and solar energy, though the presently funded phase of the project is limited to design and a coil demonstration. A frequently cited application of SMES is voltage dip and sag protection to sensitive grid and industrial grid sites, but over a decade ago AMSC had fielded nine in-grid commercial SMES systems (using LTS) for this purpose; these were in fact the world's first commercial superconductor products for the power grid. But AMSC finally terminated this product in favor of a now widely used and lower cost power-electronic solution providing just reactive (out-of-phase) power. One other energy storage project at Boeing, supported by ARPA-E, focuses on flywheel storage using superconducting bearings.

Several other non-grid-focused U. S. government programs provide market pull for superconductor wire: the DOE High Energy Physics program supporting HTS wire development for future particle accelerators, the National Institutes of Health interest in ultra-high field HTS-based NMR, and the National Science Foundation's 32 T HTS-based user magnet for the National High Field Magnet Laboratory.

  

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## Conclusion

In conclusion, over the last two decades, U. S. companies and government have made huge investments developing superconductor wire and power grid equipment in expectation of a major commercial market and need for such superconductor power equipment. The wire is now available and many applications are well demonstrated. The industry is poised to grow. Government support is still very important to help perfect the wire and demonstrate other important applications, helping the industry bridge to the opening of that commercial market.

Table I. Sponsored U. S.-Based Power Systems Projects

| Project Sponsor | Application | Title | Technical Targets | Status, Target | Member | Budget, Period | Source |
|---|---|---|---|---|---|---|---|
| DOE OE | Cable | LIPA HTS Cable I and II | 138kV/2.4kA, 600m 3-phase cable system in-grid, Phase I with 3 1G HTS cables, Phase II with 1 2G HTS cable | In operation since 2008, Phase II complete 2012 | AMSC(lead),Nexans, Air Liquide, LIPA | $49 M, 2003-2011; $0.2 M, 2012 | Wolsky 2012 |
| DHS | Cable | Resilient Electrical Grids (Project Hydra) | 13.8 kV/4 kA, 170 m, 3-phase coaxial fault-current-limiting cable to be installed in NYC grid. | 25m test completed, full cable being fabricated | AMSC (lead), Con Edison, Ultera, Air Liquide, Altran, ORNL | $29 M, 2007-2014 | Wolsky 2012 |
| Tres Amigas LLC | DC Cable | Tres Amigas Super Station | DC power transfer between 3 main U. S. interconnects; first phase not superconducting | Raising funds | Tres Amigas LLC | TBD | Wolsky 2012; http://www.tresamigasllc.com/location.php |
| DOD ONR | DC Cable | Superconducting DC Cable | Study of helium-cooled DC superconducting cable for warship power; demo of 1 kV 30 m monopole cable | Underway | CAPS, Southwire, NSWC | $5M, 2007-2013 | Wolsky 2012 |
| DOE Smart Grid | Trans-former | Fault Current Limiting Superconducting Transformer | 28MVA, 3-phase (69kV/12.47kV) with current limiting, 2G HTS wire, Smart Grid commun./control, in-grid test starting by end 2013 | Design under develop-ment | Waukesha (lead), SuperPower, SCE, ORNL, TCSUH | $21.5M ($10.7M from DOE), 2010.2.1-2015.1.31 | Wolsky 2012, http://www.smartgrid.gov/sites/default/files/waukesha-oe0000244-final.pdf |
| DOE EERE | Wind gene-rator | Fully Superconducting Direct-Drive Generator for Large Wind Turbines | Performance tests of specific drivetrain components, build and demonstrate a sub-scale system and complete detailed design for 10 MW, using $MgB_2$ conductor | case study | AML, Emerson Electric, Argonne, Creare, BEW Engineering | Phase I $0.7 M, Phase II $2.5 M, 2012-2014 | Wolsky 2012 |
| NASA | Rotating machine | High-Fidelity Sizing Model for Superconducting Rotating Machines | Model for high-power superconducting machines for electrical generators and turbo-electric propulsion fans. | Started | AML, Boeing, Empirical Systems Aerospace | $0.9 M, 2011.6.13-2014 | Wolsky 2012 |
| DOE ARPA-E | SMES | Magnetic Energy Storage System | Storage using ultra high field HTS magnets, for storing intermittent wind and solar power, technology demonstration only in first phase | first wire delivered, coil trial begun | ABB (lead), Brookhaven Nat'l Lab, SuperPower | $4.2M, 2010.10.1-2013.9.30 | Wolsky 2012, http://arpa-e.energy.gov/?q=arpa-e-projects /magnetic-energy-storage-system |
| DOE ARPA-E | Flywheel | Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS) | In-grid demonstration of flywheel energy storage system with advanced fiber technology and superconducting bearings | Design complete, assembly underway, June 2012 | Boeing Research & Technology | $2.3 M, 2010.10.1-2013.9.30 | Wolsky 2012, https://www.uaf.edu/files/acep/BoeingFlywheelOverview_06_20_2012.pdf |

  

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Table II. U. S. Sponsored Wire Projects

| Project Sponsor | Application | Title | Technical Targets | Status, Target | Members | Budget, Period | Source |
|---|---|---|---|---|---|---|---|
| DOE ARPA-E | Wire | Improved Superconducting Wire for Wind Generators | Higher current 2G HTS wire (RABiTS™-MOD process) with several fold reduction in cost and minimal rare earth, for direct drive wind generators | Started | BNL (lead), AMSC | $1.5 M, 2012.1.1-2013.12.31 | http://arpa-e.energy.gov/?q=arpa-e-projects /improved-superconducting-wire-wind-generators |
| | Wire and Coils | Low-Cost Superconducting Wires for High Power Wind Generators | Engineer nanoscale defects in superconducting film: focus on IBAD-MOCVD REBaCuO films, quadruple current relative to today's wire [3000 A/12mm-width (30K, 2.5T), $36/kAm] | Started | UH(lead), SuperPower, TECO, Tai-Yang, NREL | $3.1 M (phase I, 80% funded), 2012.2.22-2014.12.31 | http://arpa-e.energy.gov/?q=arpa-e-projects/low-cost-superconducting-wire-wind-generators |
| | Wire | Low-Cost High-Temperature Superconducting Wires | Novel wire process using fine superconducting $MgB_2$ particles in metal matrix | Announced 2012.12.19 | Grid Logic | $3.8 M | http://arpa-e.energy.gov/?q=arpa-e-news-item/arpa-e-awards-130-million-66-transformational-energy-technology-projects |
| DOE BES | New Supercon-ductors and Wire | Center for Emergent Super-conductivity: an Energy Frontier Research Center | Finding new superconducting materials, understanding mechanism of HTS, controlling vortex matter to raise 2G HTS critical current | Ongoing | BNL (lead), ANL, UIUC, LANL, AMSC, SuperPower | $22M (phase I), 2009-2013 | http://science.energy.gov/bes/efrc/centers/ces/; Wolsky 2012 |

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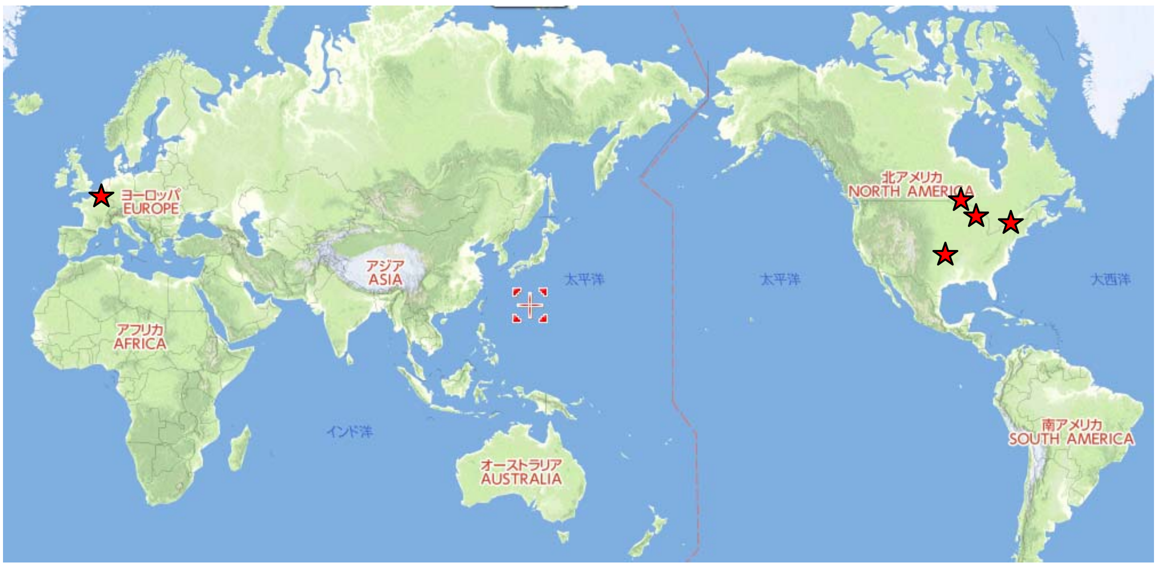
## What's New in the World of Superconductivity (February, 2013)

초전도 뉴스 −세계의 동향−
超电导新闻 −世界的动向−
**chāo diàn dǎo xīnwén - shìjiè de dòngxiàng-**

**Yutaka Yamada, Principal Research Fellow**
**Superconductivity Research Laboratory, ISTEC**




★News sources and related areas in this issue

### ▸Power Application 전력응용 电力应用 [diànlì yìngyòng]

**$30 Million Order From Inox Wind**

**AMSC (February 11, 2013)**
AMSC has received an order for wind turbine electrical controls systems (ECS) from Inox Wind Limited (India) valued at over US $30 million. AMSC expects to begin shipments during the current fiscal quart er, with the last delivery occurring in 2014. The order is the fifth, and largest, that AMSC has received from Inox

since Inox began volume production of its 2-MW wind turbines, which were licensed from AMSC in May 2009. The ECS consist of an integrated, high-performance suite of power electronic systems that include the wind turbine power converter cabinet, an internal power supply, and various controls, enabling reliable, high-performance operation by controlling power flow, regulating voltage, monitoring system performance, and controlling the pitch of the wind turbine blades and the yaw of the turbines to maximize efficiency.

**Source:** "AMSC Receives $30 Million Follow-On Order From Inox Wind"
AMSC press release (February 11, 2013)
URL:
http://files.shareholder.com/downloads/AMSC/2362775124x0x634754/e7d6063e-46e5-43e9-a7cc-22318be33dd2/AMSC_News_2013_2_11_Commercial.pdf
Contact: Kerry Farrell, kerry.farrell@amsc.com

▸**Wire** 선 재료 线材料 **[xiàn cáiliào]** ▸**Basics** 기초 基础**[jīchǔ]**

SUPERCONDUCTOR TECHNOLOGIES INC.

## IBAD, SDP, RCE-CDR Machines for 2G Wire Now in Operation

**Superconductor Technologies Inc. (February 21, 2013)**
Superconductor Technologies Inc. (STI) has completed the installation of its equipment suite required for the production of Conductus® 2G HTS wire at its Advanced Manufacturing Center of Excellence facility in Austin, Texas. All the 2G HTS wire pilot production equipment is now operational and is in various stages of process implementation. The three machines required to produce HTS wire are operational and achieving the expected functional milestones: the IBAD system is presently being used at full production and had achieved record results as of January 2013, the SDP system has been used to complete initial pilot production runs of 50-m lengths and 10-cm widths, and the RCE-CDR system has been installed and its first process run was completed in February 2013. The first Conductus wire to be completely fabricated at the Austin facility was recently shipped and is now being used to test a superconducting motor application. In January, STI achieved the product requirements for a low-temperature, high-infield superconducting magnet application by achieving a performance of more than 2500 A/cm at 4 K. Successful testing at magnetic field strengths of greater than 14 T has also been achieved.

**Source:** "STI Conductus 2G HTS Wire Pilot Production Equipment Now Operational"
Superconductor Technologies Inc. press release (February 21, 2013)
URL: http://phx.corporate-ir.net/staging/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1787327&highlight
Contact: Investor Relations, Cathy Mattison or Becky Herrick of LHA for Superconductor Technologies Inc., invest@suptech.com, ; HTS Wire, Mike Beaumont of STI, mbeaumont@suptech.com

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## Engineered Multilayer pushes up Critical Current

**University of Wisconsin-Madison (March 3, 2013)**

Researchers at the University of Wisconsin-Madison, Florida State University, and the University of Michigan have artificially engineered a unique multilayer material that could lead to breakthroughs in both superconductivity research and real-world applications. The researchers have been able to tailor a material that seamlessly alternates between metal oxide layers to achieve extraordinary superconducting properties, such as the ability to transport much more electrical current than non-engineered materials. Specifically, the researchers engineered and measured the superlattice properties of pnictide superconductors. A superlattice is a complex, regularly repeating geometric arrangement of atoms in layers of two or more materials. The new material created by the r esearch team co nsists of 24 la yers alternating between a pnictide superconductor and a layer of o xide strontium titanate. The group was a ble to achieve an atomically sharp interface at each region where the two materials meet, with each atom in each layer precisely placed, spaced, and arranged in a regularly repeating crystal structure. The resulting material exhibited improved current-carrying capabilities. As the superlattice was grown, the researchers intentionally added a small amount of oxygen to create vertical and planar defects every few nanometers; these defects, in turn, act as vertical and planar pinning centers, since vortices created by magnetic fields can occur in many different orientations. Chang-Beom Eom, a professor at the University of Wisconsin-Madison, hopes to expand on the success achieved thus far, commenting, "There's a ne ed to engineer superlattices for understanding fundamental superconductivity, for potential use in high-field and electronic devices, and to achieve extraordinary properties in the syst em." This material offers those possibilities." The group's work has been published in the advance online edition of *Nature Materials*.

**Source:** "Man-made material pushes the bounds of superconductivity"
University of Wisconsin-Madison press release (March 3, 2013)
URL: http://www.news.wisc.edu/21555
Contact: Renee Meiller, meiller@engr.wisc.edu

## Vortex Pinning Leading Superconducting Breakthroughs

**Argonne National Laboratory (February 12, 2013)**

An international team of r esearchers from Argonne National Laboratory and institutions in Russia, Spain, Belgium, and the U.K. has a nnounced findings that may represent a breakthrough in superconductivity applications. The group has discovered a method of efficiently stabilizing tiny magnetic vortices that interfere with superconductivity, potentially removing a significant roadblock to advances in superconductor technology. The group applied a hi gh magnetic field to a ver y thin (50 nm) low-temperature superconducting wire capable of only accommodating a sin gle row of m agnetic vortices, causing the vortices to crowd together in long clusters and stop moving. Further increases in the magnetic field restored the material's superconductivity, rather than destroying it. The group then carved a superconducting film into

  

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an array of holes so that only a few vortices could squeeze between the holes, where they remained captures and unable to interfere with the current. As a result, the resistance of the superconductor dropped dramatically at temperatures and magnetic fields at which no one has ever been able to pin vortices before. The results were described as "quite striking", and the team is now considering applying this approach to other types of superconductors. The group's results have been published in *Nature Communications*.

**Source**: "Vortex pinning could lead to superconducting breakthroughs"
Argonne National Laboratory press release (February 12, 2013)
URL: http://www.anl.gov/articles/vortex-pinning-could-lead-superconducting-breakthroughs
Contact: Louise Lerner, media@anl.gov

## ▸Basics 기초 基础[jīchǔ]

### First Three-year Results of LHC Running

**CERN (February 14, 2013)**
The Large Hadron Collider (LHC) has successfully completed its first 3-year running period during which it has enabled major advances in physics, including the discovery of a new particle thought to be the long-sought Higgs boson (as announced in July 2012). As of the last weeks of its run, over 100 petabytes of data had been stored in the CERN mass-storage systems, a data volume equivalent to roughly 700 years of full HD-quality movies. The LHC will now begin its first long shutdown period, known as LS1, during which major consolidations and maintenance work will be performed. The LHC will also be readied for higher energy running, and the experiments will undergo essential maintenance. Operation is scheduled to resume in 2015. Steve Myers, CERN's Director for Accelerators and Technology, commented, "There is a great deal of consolidation work to do on CERN's whole accelerator complex, as well as the LHC itself. We'll essentially be rebuilding the interconnections between LHC magnets, so when we resume running in 2015, we will be able to operate the machine at its design energy of 7 TeV per beam". The LHC exceeded expectations during its first three-year run, producing significantly more data than initially foreseen. As of the last recording of high energy proton-proton data in December 2012, the ATLAS and CMS experiments had each recorded around 30 inverse femtobarns of data. Much of this data will be analyzed during LS1. During the first weeks of its operation in 2013, the LHC was used to collide protons with lead ions as part of a program to understand matter as it would have existed immediately after the Big Bang.

**Source:** "First three-year LHC running period reaches a conclusion"
CERN press release (February 14, 2013)
URL:
http://press.web.cern.ch/press-releases/2013/02/first-three-year-lhc-running-period-reaches-conclusion
Contact: press.office@cern.ch

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# Feature Articles: Technological Development of Superconducting Power Equipment
# - Trends of Superconducting Power Equipment Development

Takeshi Ohkuma, Director
Electric Power Equipment Division
SRL/ISTEC

In Japan, the research and development of superconducting power equipment has been progressed mainly by projects sponsored by the Ministry of Economy, Trade and Industry and the New Energy and Industrial Technology Development Organization (NEDO). Current undertakings include the "Technological Development of Y-based Superconducting Power Equipment (M-PACC: Material and Power Applications of Coated Conductors)" project (FY2008-FY2012) and the "High Temperature Superconductor Cable Verification Project," which employs Bi-based superconducting wires (FY2007-FY2013). FY2012 marks an important year for those projects in Japan.

For the "High Temperature Superconductor Cable Verification Project", the construction of not only the cable itself, but also a 66 kV 200 MVA-class cable system that integrates technologies from both Bi-based superconducting wires and refrigeration is targeted. A verification test utilizing an actual 66 kV power grid network has been planned to comprehensively verify the integral reliability of the entire superconducting power cable system, including operation and maintenance. This marks Japan's first demonstrations of a superconducting cable operating in actual power grids, which commenced on 29 October 2012.

The "Technological Development of Y-based Superconducting Power Equipment" project ultimately aims to supply cities with large amounts of stable electricity using superconducting power equipment. Based on the process technology established to fabricate Y-based superconducting wires, the project has been progressed towards the realization of superconducting magnetic energy storage (SMES) devices, transmission power cables and transformers applications. 2012 marks the final year of the project. Whilst the establishment of a reliable and tolerant coiling technology is planned for SMES, system feasibility trials are scheduled for both the transmission power cables and transformers.

Overseas R&D efforts in this area has seen the USA has advanced SMES development as part of the DOE ARPA-E project, leading towards the development of a 3.4 MJ-class SMES employing Y-based superconducting wires, which has been ongoing since 2011. In 2012, China also launched a 4-year SMES project involving Y-based superconducting wires.

For superconducting cables, the LIPA project in the USA plans to replace one of the three phases of a 138kV/2.4kA-600m-class single-core type Bi-based demonstration test cable with a Y-based superconducting cable. In the HYDRA project for example, a 13.8kV/4kA-170m-class three-phase tri-axial Y-based superconducting cable has been developed and plans to test this cable in a live grid in 2014. In Korea, the DAPAS project has demonstrated testing of a 22.9kV/1.26kA-410m-class three-cores in one pipe type, Y-based superconducting cable in live grids. Future plans are the development of an 80kV/3.12kA-500m-class DC cable and a 154 kV-1km-class AC cable, to be installed to a live grid. A 1.3kV/10kA-360m-class DC cable based on Bi superconducting wires has been undergoing testing at a site in the Henan province of China. The AmpaCity project in Germany has developed a 10kV/2.3kA-1km-class

  

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three-phase tri-axial cable (including cable-to-cable joint), and proposals for its installation to live grids combined with a Y-based fault current limiter are planned for 2013. Russia plans to demonstrate testing of its 20kV-2.5km-class DC cable at a substation in Moscow.

One development of a superconducting transformer is the Smart Grid Demo project sponsored by the DOE, USA, which plans to develop a 69kV/12.47kV-class three-phase Y-based superconducting transformer equipped with fault current limiting capabilities and install this to a live power grid.

With regards to fault current limiters, Nexans has developed a 12kV/1kA-class resistive fault current limiter based on Bi-based wires, and performed demonstration tests in live grids as part of Europe's ECCOFLOW project. The future plans are demonstration tests in live grids of a 16.5kV/1kA-class as well as 24kV/1kA-class resistive fault current limiter employing Y-based coated conductors instead. The AmpaCity project has been developing a 10kV/2.3kA-class resistive fault current limiter based on Y-based coated conductors and proposals to combine it with the superconducting cable and install the entire system to a live grid are planned for 2013. Whilst Italy has been developing a 9kV/220A-class resistive Bi-based fault current limiter and performed demonstration tests in live grids, Germany has developed a 6.4kV/13MVA-class magnetic shield type Y-based single-phase fault current limiter. It now plans to develop a three-phase current fault limiter and install this into a live grid. Korea's DAPAS project has also performed demonstration testing of its 22.9kV/630A-class fault current limiter in a live grid. Their future plans are to develop a 154kV/2kA-class fault current limiter and install this to a live grid. Innpower, China, has developed and performed demonstrations in live grids of a 35kV/1.5kA-class as well as a 220kV/800A-class saturated-iron-core-type Bi-based fault current limiter.

This report serves as the main summary of the recent trends in superconducting power equipment in Japan and overseas. The current development statuses of individual equipment under the "Technological Development of Y-based Superconducting Power Equipment" project are introduced in the following feature articles.

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# Feature Articles: Technological Development of Superconducting Power Equipment
# - Progress in the Development of High Voltage Superconducting Power Cable Technology

Masashi Yagi
Power Transmission Group, HTS Project Team,
FURUKAWA ELECTRIC Co., Ltd.

As a part of the M-PACC project, since 2008, we have been developing YBCO superconducting cables exhibiting high electrical capacity equivalent to 275 kV-3 kA overhead transmission lines. The project goals are to achieve low losses less than 0.8 W/m and to keep the external diameter less than 150 mm, which are far more compact than XLPE cables that are typical conventional ones. Compared to the three lines of 275 kV XLPE cables, the 275 kV superconducting cables only need a single line at the same capacity, whereas the transmission losses are 1/4~1/5 of those of the XLPE cables, even including refrigerator power losses.

A two-layer conductor consisted of 60 pieces of narrow 3 mm-wide YBCO superconducting tapes that were obtained through a laser-slitting and copper-plateing to improve their stability. A single-layer shield, on the other hand, consisted of 43 pieces of 5 mm-wide copper-plated YBCO tapes. The YBCO layer in the superconducting tapes was based on TFA-MOD process, confirming its reliability by measurements of critical current ($I_c$) distribution in the longitudinal direction as well as measurements of each $I_c$ over the entire 50 m-length. The 50 m cable was fabricated assembling these YBCO tapes, as shown in Figure 1. The $I_c$ in the conductor and shield layer were expected to be around 6000A at 77.3K, thereby having sufficient AC capacity of 3000A (4242A at peak). The cables with lengths of 30 m and 20 m were used for the long-term verification tests and for various electrical tests, respectively.


Fig. 1 The structure and outline of 275kV-3kA YBCO superconducting cable

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Short-length cables from 20 m for electrical tests were used to confirm $I_c$, withstand voltage and over-current characteristics. The measurements of $I_c$ showed the expected designed performance, with conductor and shield $I_c$ of 6440 A and 5920 A, respectively. Testing of the withstand voltage confirmed that the cables were partial discharge free at the voltage of 310 kV and withstood 400 kV for 30 minutes. Also the testing of over-current of 63 kA-0.6 sec, which was the worst case in the 275 kV systems, did not cause $I_c$ degradation.

The 30 m superconducting cable, two terminations, an intermediate joint and three XLPE cables that were used for the flowing current of 3 kA were constructed in Shenyang Furukawa Cable Ltd. located in China, as shown in Fig. 2. The rapidly increasing energy demands in East Asian countries have focused attention on superconducting technologies. Thus, testing in China was planned with the aim of increasing Japan's international cooperation and contributions to the world.

The $I_c$ of the 30 m cable was measured after its transportation and installation, confirming 6800A for the conductor and 7000A for the shield at 77.3 K under atmospheric pressure, demonstrating no $I_c$ degradation. The long-term test has started since November 2012.
(The long-term tests had successfully completed at the end of December 2012, which verified 30-years performance.)

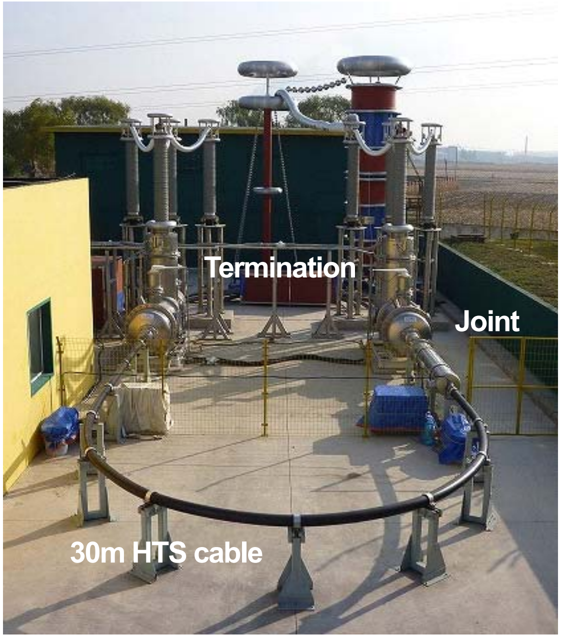


Fig. 2 Placement of the 275kV-3kA superconducting cable

This research was commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

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# Feature Articles: Technological Development of Superconducting Power Equipment - Japan's First Operation of "High Temperature Superconducting Cable Systems" in Live Grids

Takato Masuda
Superconductivity Technology Department
Sumitomo Electric Industries, Ltd.

66 kV-class superconducting cable (at Asahi Substation)

Under the "High Temperature Superconducting (HTS) Cable Demonstration Project," undertaken by commission from New Energy and Industrial Technology Development Organization (NEDO), Tokyo Electric Power Company, Sumitomo Electric Industries, Ltd., and Mayekawa Manufacturing Co., Ltd. launched Japan's first HTS cable demonstration in live grids at Tokyo Electric Power Company's Asahi Substation based in Yokohama.

The project aims are to develop an innovative, highly efficient transmission technology by undertaking demonstration tests of a HTS cable system operating in live grids, and verifying the total system reliability including its construction, operation and maintenance.

The HTS cable developed in this project is a 66 kV, 200 MVA-class compact 3-in-One HTS cable. The cable system, constructed at the Asahi Substation, consists of a 240 m-long superconducting cable, cable terminations, cable-to-cable joint and a cooling system.

Employing lower-AC loss DI-BSCCO wire developed by Sumitomo Electric Industries, Ltd., the project has performed AC-loss verification trials of short lengths cable, including system reliability testing in the case of a power grid failure. Technological development has also been performed on the high currents connections of the system such as cable terminations and cable-to-cable joint. Tokyo Electric Power Company has designed and constructed the HTS cable system and operations/monitoring systems on-site, together with

  

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construction of a protection/shut down system, allowing the connection and disconnection of HTS cables to the existing power grid. Mayekawa Manufacturing Co., Ltd. was responsible for the design and construction of the cooling system, as well as investigations into maintenance methods during its operation.

On the basis of the above-mentioned outcomes, a HTS cable system including its cooling system was constructed back in 2010-2011. After completion of the system, cooling tests were repeatedly performed to confirm the performance characteristics of both the cable and cooling system. The system was successfully connected to a live power grid on October 29, 2012. A ceremony was held to mark the occasion with participants involved in the project on that day (Photo). After the ceremony, Japan's first ever operation in a live power grid was launched with the HTS cable connected between the transformer and the 66kV bus at the substation.

The Ceremony

Operations in a live grid will be undertaken for one year or more and will involve verification trials of the cable's operability, reliability and stability.

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# Feature Articles: Technological Development of Superconducting Power Equipment - Progress in the Technological Development of Superconducting Transformers

Hidemi Hayashi,
Power Storage Engineering Group Leader & Superconducting Transformer Sub-Leader,
Research Laboratory, Kyushu Electric Power Co., Inc.

As part of the Yttrium-based superconducting power equipment technology development project (hitherto, Y-based project), investigations of superconducting transformer technology has been undertaken by Kyushu Electric Power Co., Inc., which leads a consortium collaboration between Kyushu University, Iwate University, International Superconductivity Technology Center (ISTEC), Fujikura, Showa Cable Systems Co., Ltd, Fuji Electric Co., Ltd, Taiyo Nippon Sanso Corporation and Japan Fine Ceramics Center (JFCC). Research collaborations in com ponent and system tec hnologies have been progressed between the periods of 2008-2012. The project has focused upon: (1) superconducting transformer wire development, (2) wire-winding technological development, (3) cryogenic system tech nological development, (4) technological development of fault-current limiting functionality, and (5) demonstration of a 2MVA-class superconducting transformer prototype. The technological development in e ach category has steadily progressed towards its final aims and objectives as highlighted in Table 1.

Categories (1) and (4) of the Y-based project, which terminates in February 2013, were reported previously by the author (Web 21, November 2011 issue). This article reports the current status of categories (3) and (5), which have now entered a crucial manufacturing and verification test stage.

Table 1 Ultimate Goals of the Superconducting Transformer Technology Development

| Technology Development Category | Final goals |
|---|---|
| (1) Superconducting transformers wire development | ・Stable manufacturing, Improvement of process technology (yield Improvement) |
| (2) Wire-winding technological development | ・Establishment of a 2kA-class wire winding technology<br>・Wire windings with low AC loss of ≦1/3 (cf. wire fabricated without a thinning process) |
| (3) Cryogenic system technological development | ・Cooling capacity: 2kW@65K<br>・Coefficient of performance (COP): 0.06@80K |
| (4) Technological development of fault-current limiting functionality | ・Operational demonstration of several-hundred kVA-class transformer equipped with current limiting function (Suppression of excess current less than three times rated) |
| (5) Demonstration of a prototype 2MVA-class superconducting transformer | ・Demonstration of a prototype 66/6.9kV-2MVA transformer with electric current application |

  

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## (3) Development of Cooling System Technology

It is deemed appropriate that a refrigerator operating between the ranges of 40-80 K with a cooling capacity of around 2-10 kW @ 80 K, is suitable to cool a superconducting transformer (Figure 1). The agreed goals for the Y-based project are shown in Table 1, and technological progression of the cooling system achieved using neon as the coolant gas (Figure 2).

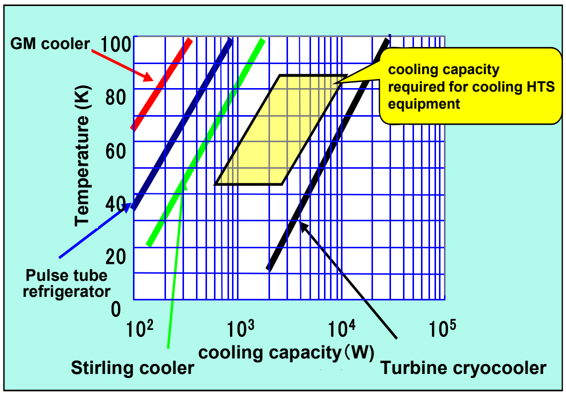


Fig. 1 Refrigerator cooling capabilities

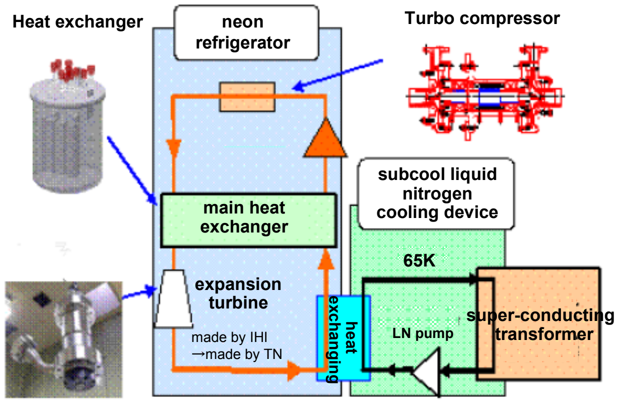


Fig. 2 Outline of cryogenic system

Thus far, efforts have focused upon the development of a new turbo-compressor, which forms the main component of the r efrigerator, improving the expansion turbine and investigating refrigeration processes. The results have confirmed that both the compressor and the expansion turbine efficiency have exceeded the target value of 65 %, set at an interim period over 2 ye ars ago (Figure 3). Additionally, a final test undertaken just recently achieved a 2.17 kW cooling capacity at 65K and a COP=0.06 at 80 K (Table 2). One major attribute of this ref rigerator is the r ealization of a mainten ance free refrigerator by a dopting magnetic bearings in the compressor and expansion turbine, thereby eliminating any moving parts.

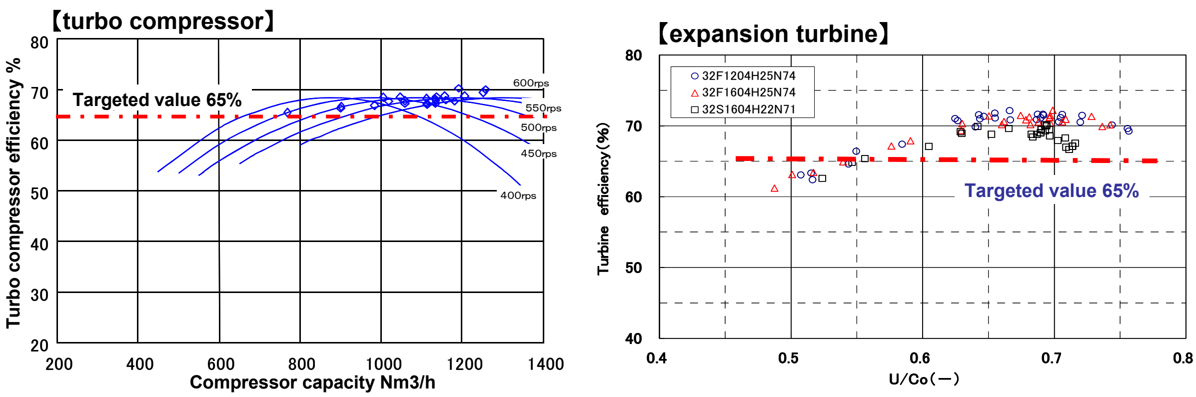


Fig. 3 Results of efficiency measurements taken from turbo compressor and expansion turbine

  

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Table 2 Performance test results of prototype cooler

| | | |
|---|---|---|
| Temperature (K) | 80 | 65 |
| Cooling capacity (kW) | 2.93 | 2.17 |
| Input power（kW） | 51.1 | 51.4 |
| Coefficient of performance (COP) | 0.06 | 0.04 |
| Compressor efficiency (%) | 70～72 | |
| Turbine efficiency (%) | 72～74 | |

October last year, the refrigerator completed single-unit performance evaluation testing and pre-operation evaluation of the 2MVA transformer cooling system, including the subcool system and cryostat (Figure 4). Final testing planned for the future involves combining it with a 2MVA transformer.

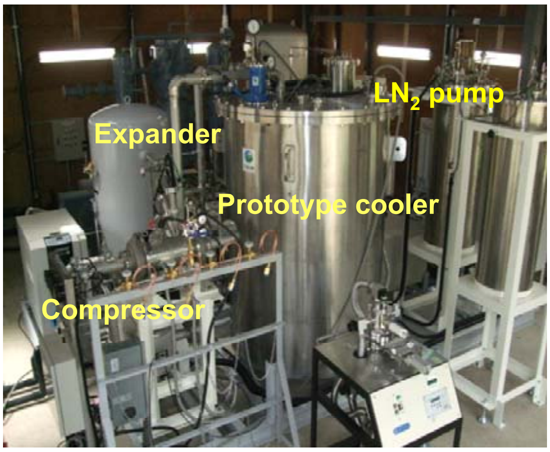


Fig. 4 Cryogenic system for the 2MVA transformer

### (5) Verification of a Prototype 2MVA-class Superconducting Transformer

The ultimate goal of the Y-based project is to fabricate and verify the performance of a 2 MVA-class superconducting transformer with an aim to realize a 20 MVA-class superconducting transformer in the future. To foresee the characteristics and fabrication technology required for the superconducting transformer with the combination of a cooling system, a goal of 2 MVA was set as it forms a minimum wire-winding capacity with the necessary equivalent voltage required for practical equipment.

The 2 MVA-class superconducting transformer prototype comprises of a 2 MVA-class superconducting transformer wire winding as shown in Figure 5, a cryostat as shown in Figure 6, and the above-mentioned transformer cooling system. A number of experimental trials involving the wire windings assembled into a cryostat are being currently performed (Figure 7).

In particular, the I-V characteristics shown in Figure 8 reveal favorable secondary wire winding attributes, fabricated by employing a complex three-filaments wire winding process, suggesting that the system

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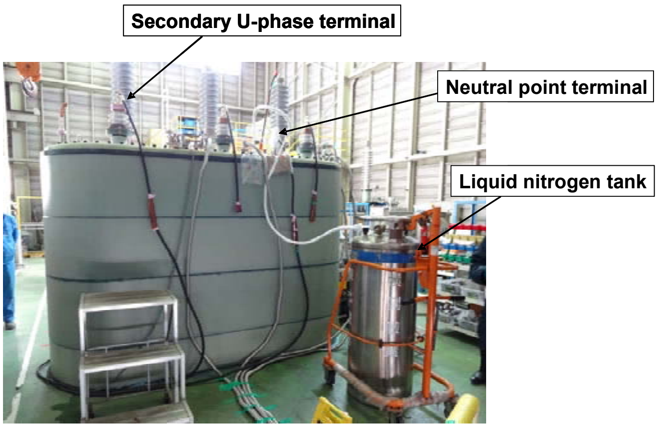
remains reliable even if cu rrents exceed the specified voltage of 2 60 A ( peak value of 167 A r ated secondary current x1.1).

W-phase V-phase U -phase

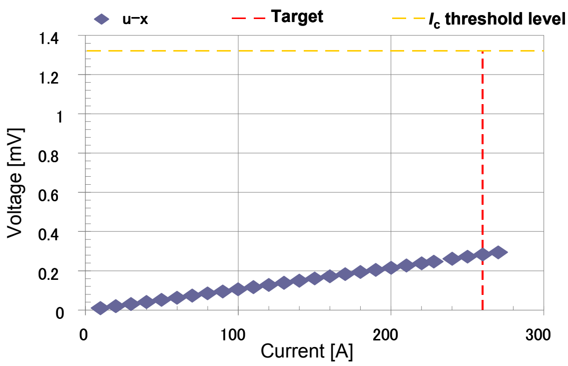
Fig. 5 2MVA-class superconducting transformer wire winding

Fig. 6 Testing a single unit cryostat




Full view of transformer
(Secondary U-phase/Neutral point connection)

Fig. 7 Testing the prototype 2 MVA transformer




U-phase secondary wire winding

Fig. 8 I-V characteristics (Secondary), U-phase secondary wire winding

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## Future Plans

Tests planned for February next year aims to combine the 2MVA-class superconducting transformer prototype with a cooling system. Steady research outcomes under Y-based project are targeted and further investigations will proceed to determine its adaptability and economic performance attributes, allowing detailed future plans to be drawn up for the design of a promising practical 20MVA-class superconducting transformer.

Additionally, the technology gained from the Y-based project can be applicable to various types of superconducting transformers. Therefore, an array of potential future applications is considered, such as transformers for power generation as shown in Figure 9, as well as industrial and transportation applications as shown in Figure 10. The outcomes from this project are thus expected to contribute significantly in the future development of superconducting transformers.

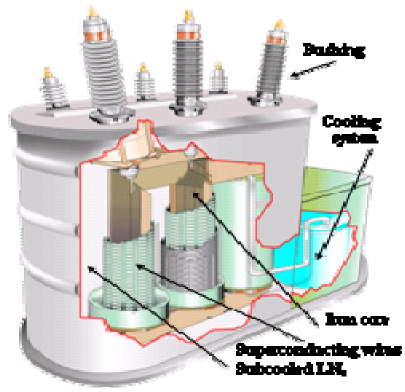


Fig. 9 Conceptual design of a 20 MVA-class superconducting transformer

Operational demonstration of several-hundred kVA-class transformer equipped with current limiting function (Suppression of excess current less than three times rated)

. Demonstration of a prototype 66/6.9kV-2MVA transformer with electric current application

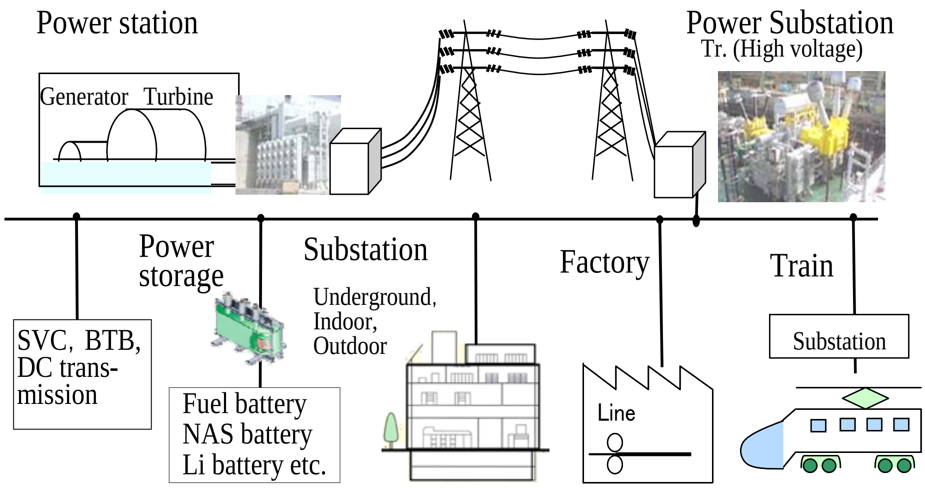


Fig. 10 Examples of superconducting transformer applications

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# Feature Articles: Superconducting Microwave/Terahertz Wave Device Technology
# - Recent Trends in Superconducting Microwave Device Technology

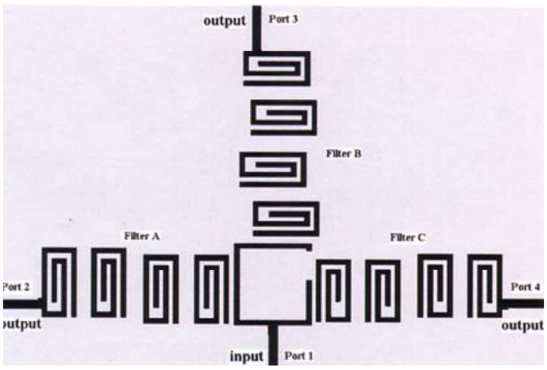
Shigetoshi Ohshima, Professor
Graduate School of Science and Engineering, Yamagata University

The international conferences (ASC, EUCAS, ISEC, HTSHFF etc) have seen many presentations related to superconducting microwave devices over the past 1-2 years, and focused mainly on 1) the design and evaluation of 0.5-25GHz band superconducting filters, and 2) theoretical and experimental analysis of the microwave characteristics of superconducting thin films. Japan, China, Taiwan, Canada have made exciting presentations relating to point 1), whereas the USA, Italy and UK have made contributions to point 2). This article focuses on the recent trends of point 1), and introduces China's progress of superconducting filter development, and simulation studies undertaken in Australia into "the advantage of installing superconducting filters at mobile phone base stations".

### 1. New development of superconducting filter research in China

The development of superconducting filter systems for mobile telecommunication base stations in China seems to have come to a pause for the time being. However, Professor Bisong Cao's research group based at Tsinghua University have recently launched a development project (total budget of 2,800,000 Chinese Yuan) of a new superconducting filter system, to run over four years between 2012-2015. The project is aimed at performance enhancements of current superconducting filter systems (filter and cooling system) that operate at telecommunication stations, with a long-term plan to develop new applications. The author aims to introduce potential new innovations when they become available.

The HE YuSheng group from the Chinese Academy of Science and the XU Zhang group from Nankai University recently reported on a superconducting duplexer. There are many research activities targeting practical applications in China, however, since there are no specific details regarding potential applications, the author can only conjecture that they are aimed at the realization of practical devices. Figure 1 shows the layout and the experimental results obtained from the triplexer designed and developed at the XU Zhang group, showing the superior characteristics of the compact superconducting duplexer.



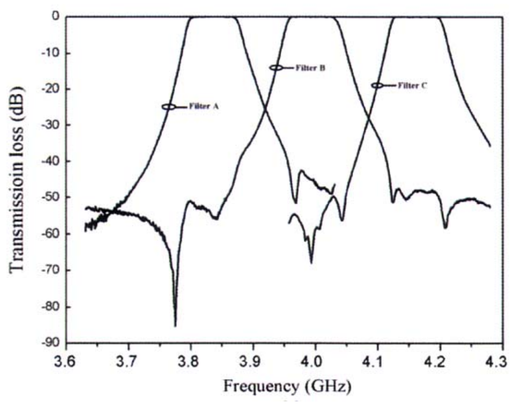




Fig. 1 Triplexer Layout (a) and its characteristics (b), (Source: XU Zhang)

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## 2. Investigati ons of superconducting filter systems for telecommunication base stations based in Australia

Countries such as th e USA and China, where superconducting filters have been installed at mobile telecommunication base stations, report advantages such as, 1) increased coverage range, 2) improvements in telecommunication quality and, 3) increased mobile-phone battery-life. Australia too has attempted to simulate what advantages could be assumed when employing superconducting filter systems at mobile telecommunication base stations. A report produced by Professor Janina Mazierska from James Cook University, as lead-researcher, is summarized herewith (Refer to the following).

Investigations into adjacent channel interference in 800 MHz spectrum allocations due to LMS
Possible effects on LTE and 3G.
Janina Mazierska (James Cook University, Australia)

The author of this report and his group made simulations under various conditions on any mutual interference effects when an LMS base station is tu ned to an 800MHz-band mobile unit, which are the norm in Australia. As shown in Figure 2, during the UPLINK, it assumes that the wave interference arrives at the mobile unit base station from the LMS, wh ilst the wave interference emanating from the LMS b ase station transmits directly to mobile units during the DOWNLINK. The simulations were an attempt to understand if any interference would occur or whether the guard band could be narrowed if a superconducting filter system was installed at a mobile phone base station. The simulation showed that the installation of a superconducting filter system at a base station was able to minimize interference in addition to narrowing the guard band. (Please email the author for detailed documentation. ohshima@yz.yamagata-u.ac.jp).

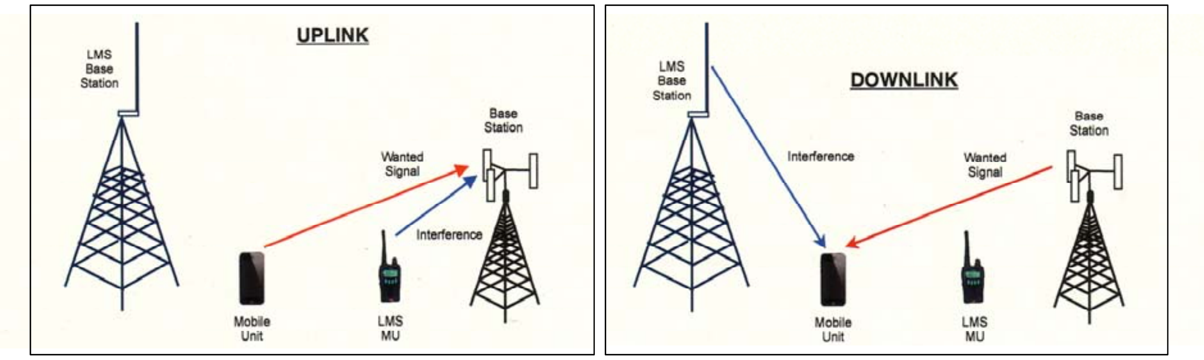


Fig. 2 Schematic diagram showing the interference between a Mobile Unit and LMS MU

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# Feature Articles: Superconducting Microwave/Terahertz Wave Device Technology
# - Development of a Microwave Kinetic Inductance Detector for an Imaging Fourier Transform Terahertz Spectrometer

Seiichiro Ariyoshi
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Chiko Otani
RIKEN Advanced Science Institute

Two-dimensional terahertz spectroscopy offers potential opportunities in material science research into soft materials for example, and industrial application development. The author and his group has progressed the development of a Microwave Kinetic Inductance Detector [1)] (hitherto MKID) array operating with a cryogen-free $^4$He refrigerator, and exhibiting both superior detection sensitivity of greater than one digit or more compared to conventional semiconductor bolometers, and greater speed response. Such an array aims to realize the application of a 2D-Fourier transform terahertz spectrometer. The targeted performance of each pixel of the detector is to have a frequency coverage of more than 1-5 THz, a response time of less than 100 μsec and noise-equivalent power of less than $10^{-14}$ W/√Hz. This new type of MKID has been fabricated and miniaturized using a Niobium Nitride (NbN) film, and designed to operate over a wide frequency range. The evaluation of performance characteristics of this MKID has been ongoing.

Figure 1 shows a schematic of an MKID (spiral-MKID) designed to operate both as a terahertz antenna having wideband characteristics and a high-Q microwave resonator [2)].
The MKID design concept is based upon its operation as a resonator with a natural microwave resonant frequency, occurring when the numbers of turns in a broadband terahertz antenna are made approximately ½ the wavelength of microwaves. This leads to characteristics that do not interrupt the performance of the terahertz antenna.

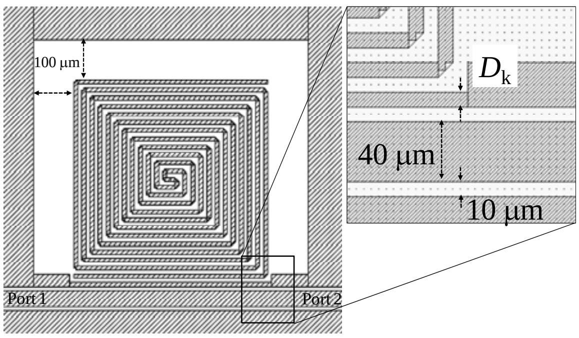


Fig. 1 Schematic of a typical spiral-MKID

  

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Fabricating NbN thin films onto various single crystal substrates were investigated as well as monitoring factors affecting the superconducting transition temperatures ($T_c$), by varying the nitrogen gas concentration during Nb DC-magnetron sputtering. The results confirmed a favorable thin film exhibiting a relatively high $T_c$~13 K (film thickness 150 nm) grown on a R-plane sapphire substrate [3]. By making a photomask of a 25-pixel array spiral-MKID a prototype MKID was fabricated using photolithography and reactive ion etching. Figure 2 shows the NbN spiral-MKID array fabricated onto a 10 mm-square R-plane sapphire substrate.

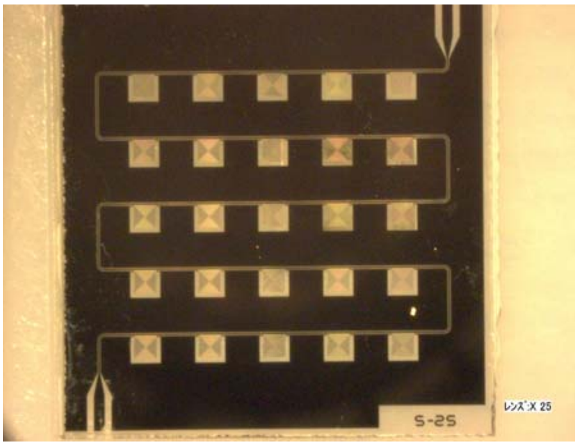


Fig. 2 5x5 pixel array of prototype NbN spiral-MKID fabricated onto a 10 mm-square sapphire substrate

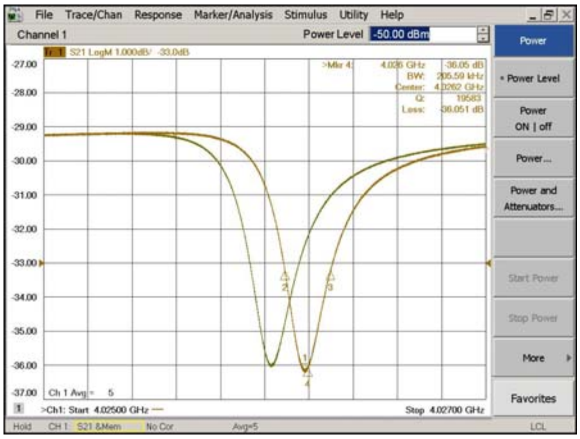


Fig. 3 Terahertz radiation responses of the spiral-MKID @3.5 K (around 0.2 MHz frequency shift was observed by utilizing an MKID with a resonant frequency of 4.026 GHz)

The prototype MKID chip was later installed in a $^4$He refrigerator and its microwave resonance characteristics measured when the terahertz radiation window was closed (equilibrium temperature 3.0 K). The measurements results confirmed favorable electrical characteristics and a Q factor of around 20,000 (dip 14 dB). When opening the terahertz radiation window (3.5 K), terahertz radiation experiments using two blackbody targets, each with different temperatures (300 K, 77 K), showed a clear distinction between their microwave resonance characteristics (Figure 3)[4]. The future plans are to advance terahertz spectra acquisition by utilizing a Fourier Transform Terahertz Spectrometer, undertake electromagnetic analysis of the array, and optimize the detection sensitivity including peripheral optical systems.

Acknowledgements
This research has been supported by the Japan Science and Technology Agency (Development of Systems and Technology for Advanced Measurement and Analysis).

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## Feature Articles: Superconducting Microwave/Terahertz Wave Device Technology
## - First-Light from the Band-10 SIS Receiver at the Atacama Large Millimeter/submillimeter Array (ALMA)

Yoshinori Uzawa
Advanced Technology Center
National Astronomical Observatory of Japan

Fig.1 Final construction stage of the ALMA telescope. Source NAOJ (National Astronomical Observatory of Japan).

The Atacama Large Millimeter/submillimeter Array (ALMA) - the largest ground-based radio-astronomical telescope constructed in the Atacama desert, 5000 m above sea level in north region of Chile, South America, has been hosting a joint international project involving East Asia, led by the National Astronomical Observatory of Japan (NAOJ), North American Union, led by the National Radio Astronomy Observatory (NRAO), and Europe, led by the European Southern Observatory (ESO). The location is not influenced by wave-absorbing water vapours and being vastly flat is a most ideal location on earth to site 66-unit parabolic antennas (54 antennas measuring 12 m in diameter + 12 antennas measuring 7 m in diameter). An aperture synthesis method allows antennas to collect potential millimeter/submillimeter wavelength astronomical signals (current plans are to observe frequency ranges between 31.5 GHz to 950 GHz), having superior sensitivity and greater resolutions of more than 1 order of magnitude and resolution compared to the performance characteristics of existing telescopes. At present 54 antennas have been constructed, entering the final stage of construction, which began in 2002[1)]. Figure 1 is a photo of the Antenna Operation Site (AOS) located on the plateau, 5000 m above sea level. It is difficult to capture the entire antenna area with a single camera shot. Assembly, fine-tuning and maintenance of the antennas are

  

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also undertaken at the Operations Support Facility, located 2900 m above sea level. Preparations are ongoing towards the completion of ALMA, with an inauguration ceremony to be held March 13, 2013.

Japan's role in the ALMA construction is the development and manufacturing of antennas (4 antennas, 12m diameter + 12 antennas, 7-m diameter) for the Atacama Compact Array (ACA) and their correlators, together with Band-4 (125-163 GHz), Band-8 (385-500 GHz), and Band-10 (787-950 GHz) superconducting receivers to be installed together with all the antennas. Japan joined the ALMA project two years late, and with this handicap has been making substantial efforts to catch up, with the production of only superconducting receivers remaining. Amongst these manufacturing processes, the Band-10 receiver is regarded as the most difficult to produce, with the series-production of nearly 30-units of the planned 73-units (the number of antennas + 7 spares) having been so far completed. The left side of Figure 2 shows a picture of the Band-10 receiver. The receiver has 4K, 15K, 110K cooling plates (gold plated copper) and a vacuum sealing plate (stainless) at room temperature. The input optics including the ellipsoidal mirrors, polarization grid and corrugated horns, as well as the SIS mixers and the IF amplifiers is arranged on the 4K plate [2)]. The right side of Figure 2 shows the noise temperature performance characteristics of 28 receivers (corresponding to 56 SIS mixers) that have completed manufacturing and testing. The average values from these receivers are sufficiently low and within ALMA specifications. The noise increase at approximately 800GHz was attributed to excess noise from a local oscillator (LO) provided by NRAO. A minimum receiver noise temperature of 123K was within the frequency range and correspondes to around three-times the quantum noise $h\nu/k_B$. The results imply that the SIS junction itself operates closely at the quantum noise limits, verifying the superiority of superconductivity technology at terahertz frequencies.

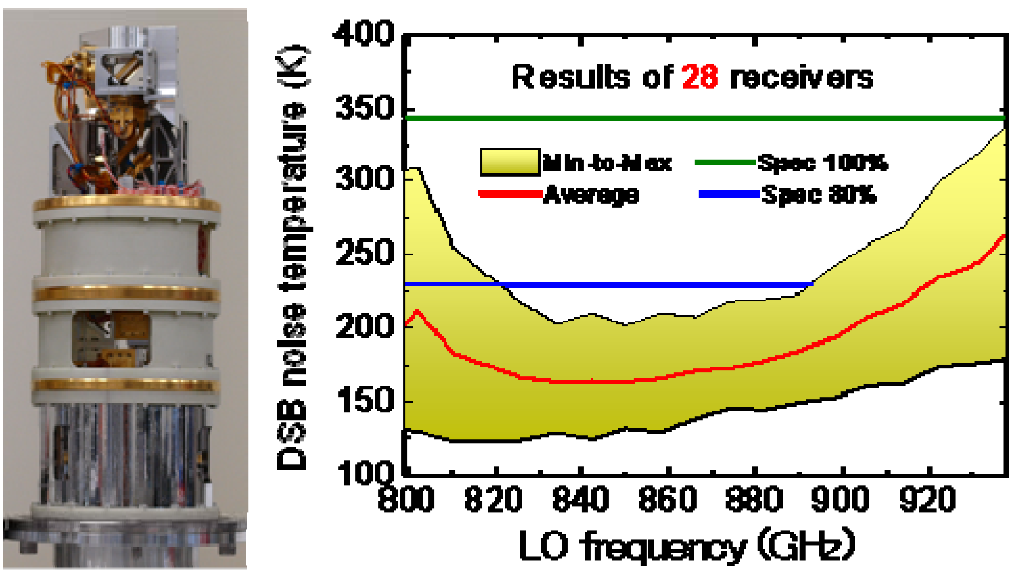


Fig. 2 Photo of the Band-10 receiver (left) and a graph showing the noise temperature results of 28 "series-produced" receivers (right). The results are from 56-unit SIS mixers since two SIS mixers are installed into a single receiver for orthogonal polarization reception.

The first set of Band-10 receivers reported in a previous feature article last year [3)] were installed in the ALMA cryostat supplied by ESO, located in the integration center of NRAO, as per schedule. After

  

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undergoing performance tests at the center the receiver was sent to the OSF in Chile. November 2012 saw the first, long-awaited spectra of an astronomical radio wave, successfully acquired using the Band-10 receiver installed into an antenna. The radio wave source was the Sagittarius the Archer B2 (Sgr B2). Despite having significant amounts of water vapor present at OSF, a clear spectrum was obtained as shown in Figure 3. These results clearly reveal the superior performance afforded by the Band-10 receiver and also imply the stability of its operation in the environmental conditions surrounding the OSF. The signatures on the spectrum are from those members involved in the Joint ALMA Observatory (JAO), and portray the delightful sense of satisfaction felt by the group in seeing this “first-light”. Although astronomy is a small field of science, the author felt that efforts undertaken in superconductivity contribute to the world. The next milestone is producing the world-first terahertz interferometer test with several Band-10 receiver units. Towards the installation of our receivers into all the antennas, our future plans are to contribute to the development of astronomical science with our best efforts, by not only advancing the series production of receivers, but also pursuing R&D targeted towards new superconductivity technology.

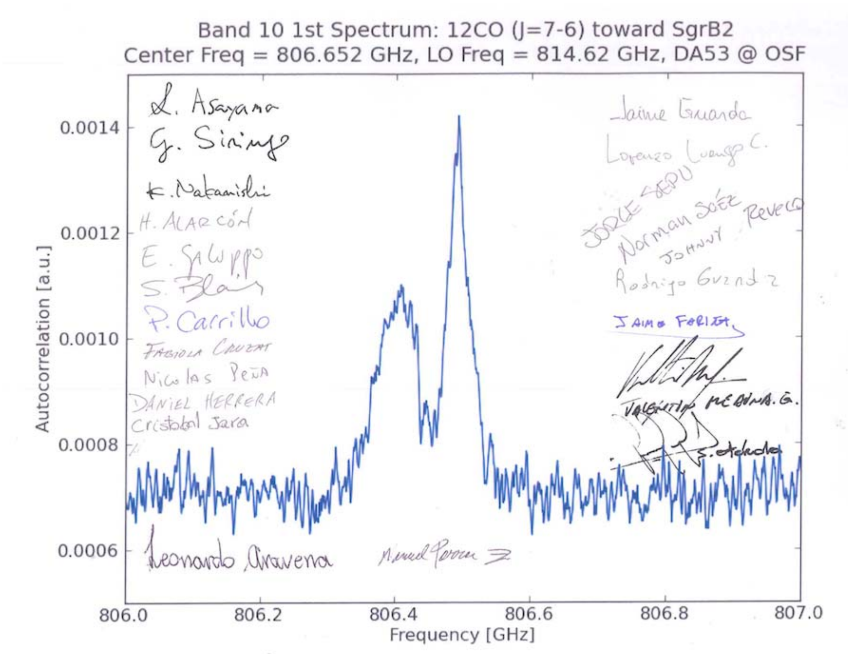


Fig. 3 The first spectrum acquired by the Band-10 receiver installed in the ALMA antenna

The advancements of this research and development have been made possible by the Japanese and overseas ALMA group of researchers, the National Institute of Information and Communications Technology, Osaka Prefecture University, Purple Mountain Observatory etc. The author would like to take this occasion to thank those researchers involved.

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