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超電導 Web21
Superconductivity

Superconductivity Web21

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Contents:

Top of Superconductivity Web21

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The 16th International Superconductivity Industry Summit (ISIS-16)

ISIS-16 conference hall

The 16th International Superconductivity Industry Summit (ISIS-16) was held in Philadelphia from August 29 to August 30. Some forty experts from Japan, the U.S., Europe, and Korea were in attendance. Philadelphia is a historical city. It was the first capital established by the U.S. after the Revolutionary War and the city where the Declaration of Independence was drafted and signed by the representatives of each state. It is also known as the setting for the movie *Rocky* starring Sylvester Stallone.

In the U.S., there is mounting criticism of the nation's over-dependence on foreign oil for its energy needs, particularly oil from the politically unstable Middle East, and debates are now arising over the need for various solutions from a national security standpoint. Moreover, coping with the problem of global warming is becoming an important political issue. The aging of electric power facilities is also a major problem. In the summit, the concept of a "modern grid" was presented as a guest lecture. This new type of power grid will be robust, reliable, economical, highly efficient, and environmentally friendly. From the standpoint of such a modern grid, superconducting technology is believed to be one of the most important options.

In the summit, reports on current and future developments and commercialization were presented from Japan, the U.S., Europe and Korea. Competition between Japan and the U.S. is intensifying over the development of next-generation HTS wire. In Europe, the Federal Ministry of Economics and Technology of Germany decided to secure additional development funds for the practical application of next-generation HTS wire. In the U.S., superconducting cable demonstration programs are now underway in Columbus, Ohio, Albany, New York, and Long Island, New York under the auspices of the Superconductivity Partnership Initiative (SPI) of Department of Energy (DOE). Japanese and European companies are also taking part in these projects, thus giving them a bit of an international flavor. The DOE is also trying to launch five new projects with a total budget of about US$100 million, targeting cables and FCL, in an effort to advance the U.S. HTS application technologies and to promote her power grid modernization. Furthermore, the Department of Homeland Security launched a new program for a robust power grid against sabotages, natural disasters, and other disruptions. The aim of the new program is the development of HTS power grid technology and its deployment to Con Edison's distribution network in New York City.

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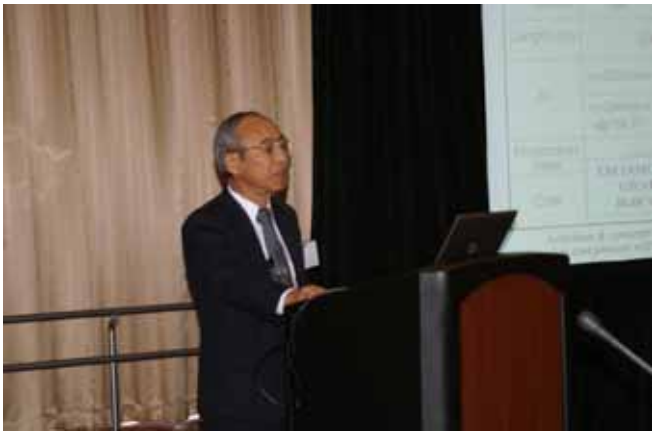
Furthermore, in the U.S. and Europe the steady progress is being made in developing superconductor related equipments including superconducting motors, and the related application technologies are also steadily advanced.


Japanese delegation at ISIS-16

In the field of electronics, the Japan's world-first successful demonstration of a switch for a high-speed router using SFQ-based superconducting circuits was a huge surprise for the electronics experts attending the summit.. The demonstration of the would-be-a-future-technology as a real solution seemed to have a great impact.

Energy is essential to our sustained development, but we are now in a new age where the unlimited use of energy is no longer acceptable. Global warming is beginning to threaten our daily lives. We must not forget that falls of ancient civilizations were sometimes due to depletion of energy resources. And a next fall of civilization might be on a global scale. Technologies for energy conservation and the use of green energy are what will guarantee our sustainable economic development. This is steadily becoming a global consensus regardless of political affiliation. The superconductor technology is one of the promising options. The investments made so far to the superconductor technologies are starting to bear fruits. When necessary, those involved in superconductor business must prepare to provide with answers to the near future problems, which should be economically rational and technologically appropriate. This was strongly recognized in this summit.

The next summit (ISIS-17) will be held in Japan.

(Akihiko Tsutai, Director, International Affairs Department, ISTEC)

(Published in a Japanese version in the October 2007 issue of *Superconductivity Web 21*)

Top of Superconductivity Web21

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New World Record in Gd123 Wire

Takashi Saitoh, Chief Engineer
Material Technology Laboratory
Fujikura Ltd.

Yttrium-based superconducting wire, which contains Gd123, is characterized by a high critical current density and high critical current under a magnetic field at the temperature of liquid nitrogen, and therefore, applications for it are expected in not only cables, but also in superconducting power storage systems, motors, electric generators, and transformers.

Latest Gd123 superconducting wire that was manufactured

In 2004, Fujikura succeeded in developing the world's first wire to exceed 100 m and a critical current of 100 A, and they have been conducting R&D toward achieving 500 m and 300 A, which is the objective of The Research and Development of Fundamental Technologies for Superconductivity Applications. The wire manufacturing process is known as the IBAD/PLD method, a combination of an intermediate layer manufacturing process using an IBAD method and a superconducting layer manufacturing process using a pulsed laser deposition (PLD) method.

In manufacturing this latest type of wire, Fujikura employed the fruits of research conducted at the SLR's Nagoya Coated Conductor Center to increase wire length using Gd123 superconducting material for which even higher critical current density and good magnetic field characteristics are expected. And, in addition to improving the degree of crystalline orientation and manufacturing an intermediate layer of high quality material, we revised the manufacturing conditions for the superconducting layer. To minimize variability wire manufacturing over the long term, we changed the target drive method and revised the control method for substrate heating.

After we formed a film coating over 500 m long and measured critical current every 0.7 m over the entire length, we found that out of the 750 measurement sites where the critical current generally ranged from 350 to 430 A, there were some 10 sites where there was a drop in the critical current. A critical current exceeding 300 A was achieved over an unbroken length of 368 m, and the I_c and L values (product of critical current times length) reached 112 and 166 Am, respectively. This new world record broke the previous record of 102 and 935 Am set by the U.S. company SuperPower in August 2007.

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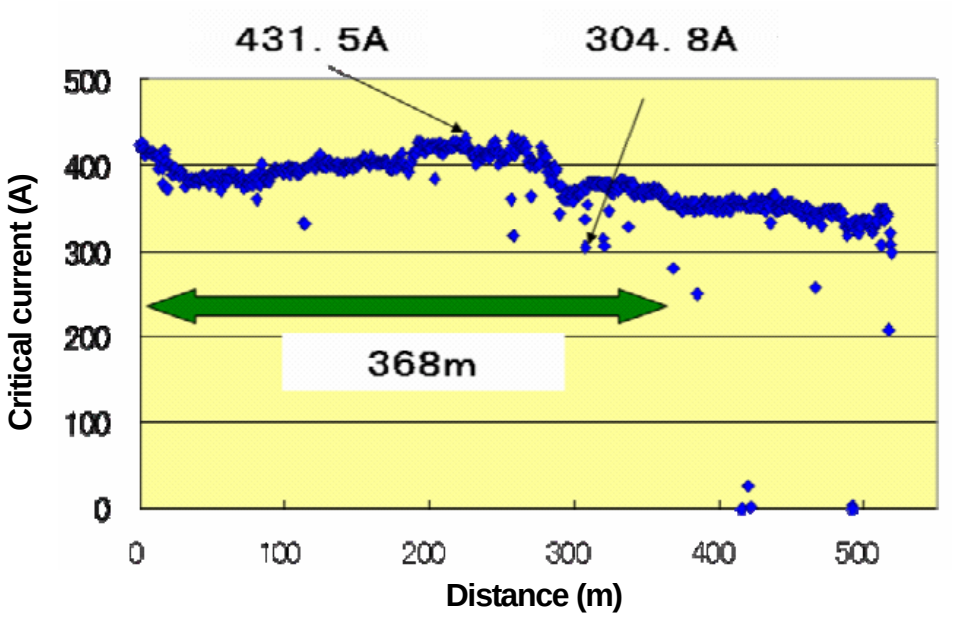

Critical current distribution for 500-m-long Gd123 wire

(Published in a Japanese version in the November 2007 issue of *Superconductivity Web 21*)

Top of Superconductivity Web21

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Developing a Liquid Nitrogen-Cooled Bismuth-based Superconducting Motor with the World's Highest Output

Kenji Takagi
Superconductive Ship Propulsion System Div.
IHI Corporation

The industry-academic group*A that is coordinated by IHI Corporation has succeeded in developing a 365 kW superconducting motor with the world's highest output through the use of liquid nitrogen cooling. An overview of this development follows.

In previously developed superconducting motors, the cryogens used have included liquid helium (7 K or approximately -266°C) and liquid neon (30 K or approximately -243°C). When helium and neon were used, a variety of problems arose, including difficulty in reducing motor size due to the large insulation structure required for cryogenics and high operating costs because compared to liquid nitrogen (77 K or approximately -196°C), helium and neon are respectively 10 and 100 times more expensive. As a result, research on using inexpensive liquid nitrogen as a cryogen has been underway, but due to its higher temperature compared with other cryogens, practical application has been seen as difficult because the flow of a large current over a coil produces a strong magnetic field, which affects the coil so much that it ends up being unable to carry the current any longer.

Under the concept of having a large current flowing over a coil without flux linkage, the industry-academic group developed a flux collector (FLC)[*B] for making magnetic flux pass through the center of a superconducting coil that uses bismuth-based superconducting wire (DI-BSCCO), and in 2005, they succeeded in developing the world's first liquid nitrogen-cooled superconducting motor with practical applications. Thereafter, they started working on increasing its size to make it commercially viable. Load tests on the 365 kW superconducting motor they most recently developed have already completed at the Kawasaki Plant, Fuji Electric Systems Co., Ltd.

The main features of the latest motor that was developed are as follows:

1. Other superconducting motors that have been developed have only achieved superconductivity on an DC coil (field coil), but the industry-academic group has employed an FLC to reduce the AC loss[*C] that results on AC coils (armature coils[*D]), allowing them to develop the world's first AC superconducting coil.

2. Using superconducting coils in parallel results in drift (a phenomenon in which current does not flow uniformly on a coil)[*E] on a superconducting coil where a large currently only flows on both ends. In response, a current regulator that could regulate the current on each coil for a uniform flow was developed.

3. On other superconducting motors, the shaft was used for the cryogen flow, but the industry-academic group achieved cooling without using the shaft by immobilizing the superconducting section (armature section). This made it possible to make both ends of the shaft connectable, thereby allowing multiple motors to be used in tandem for increased motor capacity.

The industry-academic group is now beginning to assemble a propulsion system that directly drives

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contrarotating propellers by connecting in tandem this superconducting motor (365 kW) and a superconducting motor (50 kW) that was developed last year on an experimental basis.

Future targets include the introduction of a 400 kW-class superconducting motor onto the market during 2008 to meet the expectations for energy conservation in the marine equipment market and plans call for continuing development toward a 2,500 kW version.

Motor specifications
Output: 365 kW, RPM: 250, Size: 1.2 x 0.8 m (diameter x length), Weight: 4.4 t

*A Industry-academic group (alphabetical order)
Fuji Electric Systems Co., Ltd.; Hitachi, Ltd.; IHI Corporation; Nakashima Propeller Co., Ltd.; Niigata Power Systems Co., Ltd.; Prof. Hidehiko Sugimoto, University of Fukui; Sumitomo Electric Industries, Ltd.; Taiyo Nippon Sanso Corporation

*B Flux collector (FLC)
A coil system in which a highly permeable material is inserted at the center of the coil to concentrate magnetic flux on the flux collection area. The use of this system enabled a large current to flow, even at the temperature of liquid nitrogen. As a result, it became possible to build a high capacity motor that was just 1/10 the size of conventional motors.

*C AC loss
Refers to the energy consumed within the superconductor due to fluctuations in the magnetic field and the flow of current. The industry-academic group has made it possible to retain the "no electrical resistance (loss)" advantage of superconductivity by AC loss by using an FLC.

*D AC superconducting coil
An AC coil consisting of double pancake coils using bismuth-based superconducting wire that were layered on top of each other. Employs a winding structure and coil immobilization method that can withstand electromagnetic force and mechanical vibration, and it features a structure that rapidly transfers AC loss to the cryogen.

*E Drift
Phenomenon in which differences or shifts in the size or phase of the currents flowing on each coil arise (current does not flow uniformly on the coils) when an AC current is flowing on superconducting coils arranged in parallel.

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Top of Superconductivity Web21

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What's New in the World of Superconductivity (November)

Power

American Superconductor Corporation (November 1, 2007)

American Superconductor Corporation (AMSC) has reported its financial results for the second quarter ending September 30, 2007. Revenues for the quarter increased 125% to US $21.6 million, compared with $9.6 million for the same quarter in the previous fiscal year. The gross margin increased to 26% of revenues, compared with 5% for the same period in the previous fiscal year. The net loss for the quarter was $6.7 million, compared with $7 million for the same period in the previous fiscal year. The company ended the quarter with $118.2 million in cash, cash equivalents, and short-term investments; this sum included $94 million that was raised by AMSC in a follow-on stock offering that was completed during July 2007. AMSC booked approximately $129 million in orders during the second quarter, increasing their total backlog of orders and contracts to approximately $180 million as of September 30, 2007. Greg Yurek, chief executive officer and founder of AMSC, reported, "Based on the growth in orders and backlog in the second quarter, we are poised to deliver solid revenue growth for the remainder of this fiscal year. Our backlog for recognition as revenue next fiscal year has continued to increase strongly and is now over $100 million. This supports our forecast to be EBITDAS positive in fiscal 2008. With accelerating growth in international orders and sales in the wind energy industry, our Power Systems business unit generated an operating profit in the second quarter. Our Superconductors business unit is successfully executing multiple projects, including Project HYDRA in Manhattan, and it remains on track to initiate volume production of 344 superconductors in December 2007." Revenue growth is expected to accelerate during the remainder of the fiscal year, with anticipated revenue for fiscal 2007 falling between $100 million to $110 million. Annual net losses have also been adjusted to between $27 million and $31 million as a result of restructuring costs and an anticipated increase in operating costs arising from the company's rapid growth.
Source:
"AMSC Reports Second Quarter Fiscal 2007 Financial Results"
American Superconductor Corporation press release (November 1, 2007)
http://www.amsuper.com/newsroom/pr.html?id=267

SuperPower Inc. (November 6, 2007)

SuperPower Inc., a subsidiary of Royal Philips Electronics NV, has reported a new world record performance for second-generation HTS wire. At ISS 2007, the company announced the successful production of a 790-m single piece of wire with a minimum critical current of 190 A/cm, resulting in a new world record of 150,100 A-m. This performance represents an improvement of 46% compared with the previous record of 102,935 A-m – also announced by SuperPower in January 2007. SuperPower also reported the successful production of 10 wires with complete 5-layer buffer stacks in lengths in excess of 1 km and the scale-up of SuperPower's Pilot MOCVD system to produce 155-m long wires with a minimum critical current of 320 A/cm at a speed of 70 m/h. SuperPower has now shipped their 2G HTS Wire™ to more than 35 customers around the world, several of whom have placed repeat orders.
Source:
"SuperPower Announces New World Record Performance in Second-Generation HTS Wire"
SuperPower press release (November 6, 2007)
http://www.superpower-inc.com/news.php?n=133

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Zenergy Power plc (November 12, 2007)

Zenergy Power plc, in conjunction with Converteam SAS, has provided an update regarding its design and engineering success within the UK's Department of Trade and Industry (DTI)'s project to develop an 8-MW direct-drive wind power generator using Zenergy's patented HTS materials and components. Parallel with this progress, Converteam has received its first commercial order, valued at more than 260,000 euros, for HTS coils and components to be utilized in the DTI project. These components will be utilized in the construction of a large-scale demonstration system of a high-power direct drive HTS wind power generator. The eventual 8-MW wind power generators being produced under this project are expected to reduce the cost of generating offshore wind power by 25%, thanks to their highly compact, lightweight, and efficient nature. These benefits of HTS technology are also expected to overcome some of the engineering challenges, specifically excessive weight, that have hindered the utilization of conventional copper machines with ratings in excess of 6 MW.

Source:
"Commercial Collaboration Update Department of Trade and Industry Wind Power Project"
Zenergy Power plc press release (November 12, 2007)
http://www.trithor.com/pdf/press-en/2007-11-12-Converteam-Coil-Order.pdf

American Superconductor Corporation (November 15, 2007)

American Superconductor Corporation (AMSC) announced its initial fiscal 2008 revenue outlook. AMSC previously reported anticipated revenue for fiscal 2007 in the range of US $100 million to $110 million. For fiscal 2008, AMSC is anticipating further revenue growth in excess of $150 million. The company also reiterated its expectation to achieve EBITDAS positive results in fiscal 2008. Greg Yurek, AMSC's founder and chief executive officer, commented, "Our growth today is being driven primarily by the wind energy market, and we expect this to continue next year. We are now also increasing our pipeline of business in the power grid sector as evidenced by recent orders for our new SVC product line. We believe the growth we are achieving both domestically and internationally in the wind and power grid markets will not only be strong enough to enable us to achieve EBITDAS positive results next fiscal year, but also to achieve our next goal, which is GAAP profitability, soon thereafter."

In related news, AMSC also reported that it was initiating the production of 344 superconductors, one month earlier than anticipated. The first 344 superconductors to be produced by AMSC's new manufacturing operation will be utilized in Project Hydra, which requires an initial shipment of 17,000 m by March 31, 2008. The first power cable to be fabricated using this wire shipment is slated for deployment in Consolidated Edison's midtown Manhattan power grid in early 2010.

Source:
"AMSC Provides Initial Fiscal 2008 Revenue Outlook and Initiates Production of 344 Superconductors"
American Superconductor Corporation press release (November 15, 2007)
http://www.amsuper.com/newsroom/pr.html?id=269

Material

SCI Engineered Materials, Inc. (November 7, 2007)

SCI Engineered Materials, Inc. announced their financial results for their third quarter ending September 30, 2007. Total revenues increased by 25% to US $2,589,938, compared with $2,064,497 for the same period in the previous fiscal year. As of the end of the third quarter, the company's backlog was

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$2.3 million. Gross profit increased to $489,633, compared with $469,007 for the same quarter in the previous fiscal year, while the gross profit margin decreased to 18.9% of total revenues, compared with 22.7% for the same period in the previous fiscal year. The latter decrease was mainly caused by a change in the product mix of certain high-value products with relatively lower gross margins. Dan Rooney, Chairman, President and Chief Executive Officer of SCI Engineered Materials, commented, “We are pleased with our performance for the three months ended September 30, 2007, the fifth consecutive quarter of profitability. The results included higher revenues and also reflected upfront investment in marketing, research, and manufacturing capabilities to enable expansion into new markets.”
Source:
“SCI Engineered Materials, Inc. Reports Third Quarter 2007 Results”
SCI Engineered Materials, Inc. press release (November 7, 2007)
http://www.sciengineeredmaterials.com/investors/ne/earnings/scci37.htm

Sensor

National Institute of Standards and Technology (November 8, 2007)

The National Institute of Standards and Technology (NIST) has published a new database on the properties of solid materials at temperatures ranging from 4 K to room temperature. The database, known as the NIST Standard Reference Data Database #152, the Cryogenic Materials Properties Database, will be available online, free-of-charge (www.cryogenics.nist.gov/MPropsMAY/material%20properties.htm). The database will contain information that may or may not have been publicly available previously. This information was collected from various organizations and was validated by NIST researchers prior to publication in the database. New materials and properties will be added to the database as they become known. The database will include a wide range of materials, including those used in the cryogenics and superconductivity industries.
Source:
“NIST posts online database of cryogenic materials properties”
National Institute of Standards and Technology press release (November 8, 2007)
http://www.nist.gov/public_affairs/techbeat/tb2007_1108.htm#cryo

Argonne National Laboratory (November 26, 2007)

Researchers at the U.S. Department of Energy’s Argonne National Laboratory, in collaboration with researchers in Turkey and Japan, have created a compact device that could lead to portable, battery-operated sources of terahertz radiation, or T-rays. Previously, T-rays could not be generated because of the physical limitations of semiconducting circuit components. The new device utilizes stacks of HTS Josephson junctions to produce an electromagnetic field that can be tuned by altering the applied voltage. In this manner, small voltages, around 2 mV per junction, can induce T-rays. To synchronize the signals from the Josephson stacks, some of the junctions were shaped into resonant cavities (similar to the principle used to produce lasers). Ulrich Welp of Argonne's Materials Science Division, explained, "Once you apply the voltage, some junctions will start to oscillate. If those have the proper frequency, an oscillating electric field will grow in the cavity, which will pull in more and more and more of the other junctions, until in the end we have the entire stack synchronized." By keeping the length and thickness of the cavities constant and varying the width, the researchers were able to generate frequencies between 0.4 and 0.85 terahertz at a signal power of up to 0.5 microwatts. They hope to expand this range and to increase the strength of the

signal by making the Josephson cavities longer or by linking them in arrays.

Unlike X-rays, T-rays do not have sufficient energy to "ionize" an atom by knocking loose one of its electrons; thus, exposure to non-ionizing T-rays will not lead to any cellular damage. Since T-rays are capable of penetrating many common materials, like fabric and paper, their potential application in airport or security scanners for not only the detection, but also the identification, of hazardous or illegal substances is promising. T-rays can also penetrate the human body by almost half a centimeter, enabling the detection and treatment of certain types of cancers, particularly skin and breast cancers, as well as dental imaging.

The research appeared in the November 23 issue of *Science*.

Source:
"New T-ray source could improve airport security, cancer detection"
Argonne National Laboratory press release (November 26, 2007)
http://www.anl.gov/Media_Center/News/2007/MSD071123.html

Quantum Computer

D-Wave Systems (November 12, 2007)

D-Wave Systems has conducted an online demonstration of an image matching application running on a commercial 28-qubit quantum computer. The demonstration was part of an invited talk on "Disruptive Technologies" at the SCO7 Conference. The new system builds on D-Wave's 16-qubit system that was introduced in February 2007. Herb Martin, D-Wave's CEO, commented, "Advancing the machine to 28 qubits in such a short space of time lends credibility to our claim of having a scaleable architecture. Our product roadmap takes us to 512 qubits in the second quarter of 2008 and 1024 qubits by the end of that year. At this point we will see applications performance far superior to that available on classical digital machines." The company plans to deploy their system in the last quarter of 2008 using an online service model, providing support for applications involving pattern matching, constrained searches, and optimization. Expected users of the online service may include customers from the government, military, academia, research, engineering, and life sciences as well as manufacturing, banking, and insurance groups. In addition to finding solutions in a significantly shorter period of time, the online system will also be capable of solving "intractable" problems.

Source:
"World's First 28-qubit Quantum Computer Demonstrated Online at Supercomputing 2007 Conference"
D-Wave Systems press release (November 12, 2007)
http://www.dwavesys.com/index.php?mact=News

Communication

Superconductor Technologies Inc. (November 9, 2007)

Superconductor Technologies Inc. (STI) has signed a binding definitive agreement to form a joint venture with Hunchun BaoLi Communications Co. Ltd. (BAOLI) to manufacture STI's SuperLink® interference elimination solution for the Chinese market. Under the terms of the agreement, STI will provide

an exclusive license in China for the enabling technology and BAOLI will provide the manufacturing expertise and financing. The new joint venture will be called Hunchun BaoLi Superconductor Technology Co. Ltd. and will be registered in Jilin Province. The sales and marketing division will be based in Shenzhen. BAOLI will hold 55% of the equity in the joint venture, and STI will hold the remaining 45% and will receive a royalty on sales. QiangHua Shao, General Manager of BAOLI, commented, "We believe our partnership with STI will enable cost reductions on a scale that makes SuperLink(r) competitive in the Asian marketplace. We will now forge ahead with our plans to capitalize on the benefits of combining STI's technology and our manufacturing and supply chain capabilities."
Source:
"Superconductor Technologies Signs Definitive Agreement for Venture With Hunchun BaoLi Communications"
Superconductor Technologies Inc. (November 9, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1075460&highlight

Superconductor Technologies Inc. (November 12, 2007)

Superconductor Technologies Inc. (STI) has announced their financial results for the third quarter ending September 29, 2007. Total net revenues amounted to US $4.1 million, compared with $5.9 million for the same quarter in the previous fiscal year. Net commercial product revenues totaled $2.3 million, compared with $4.9 million for the same period in the previous fiscal year. Government and other contract revenue amounted to $1.8 million, compared with $1.0 million for the same period in the previous fiscal year. The net loss for the third quarter was $2 million, compared with $2.1 million for the same period in the previous fiscal year. Jeff Quiram, STI's president and chief executive officer, commented, "We diversified our U.S. customer base earlier in 2007, which created the expanded foundation we have today for future growth. In the third quarter, we took steps to further extend our market reach to participate in the ongoing build out of 2G networks and the upcoming rollout of 3G networks in China."
Source:
"Superconductor Technologies Inc. Announces Third Quarter 2007 Results"
Superconductor Technologies Inc. (November 12, 2007)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle&ID=1076567&highlight

ISCO International, Inc. (November 13, 2007)

ISCO International, Inc. and Clarity Communication Systems, Inc., a private company that sells value-added applications for mobile networks and devices, have signed a Definitive Merger Agreement. ISCO also announced that it intends to file a proxy statement for its shareholders related to this proposed acquisition. Ralph Pini, Interim CEO of ISCO, commented, "This move is about product, market and customer synergies that we believe will be greater than the sum of its parts, help us accelerate the development of our complete digital adaptive interference management ("AIM") platform, and begin to address the OEM channels in both infrastructure and handsets... I believe that Clarity's unique product offerings in Push-to-Talk and Location Services will benefit from the multiplication of sales, marketing and customer support resources that will result by combining these teams." The proposed merger would involve the issuance of up to 40 million shares of ISCO common stock in exchange for all of Clarity's stock and satisfaction of employee rights and interests. Of this sum, 20 million shares would be issuable upon closing, 2.5 million would be issuable on each of the first and second anniversaries of the closing, and 15 million would be performance-based shares. The merger is subject to customary closing conditions and requisite shareholder and regulatory approvals.
Source:

"ISCO International and Clarity Communication Systems Sign Definitive Merger Agreement"
ISCO International Inc. press release (November 13, 2007)
http://www.b2i.us/profiles/investor/ResLibrary.asp?ResLibraryID=22293&f=1&BzID=826&Nav=1&LangID=1&s=0&

Accelerator

CERN (November 7, 2007)

CERN has reported that the last interconnection between the main magnet systems in the Large Hadron Collider (LHC) has been sealed. A small ceremony was held to mark this latest milestone in the commissioning of the LHC, the world's most powerful particle accelerator, and the end of the two-year program to install and connect all of the main dipole and quadrupole magnets. The next step will be to cool the various sectors of the ring. If the cooling proceeds according to schedule, the first beams may be injected into the LHC in May 2008, with circulating beams established by June or July. CERN's Director General, Robert Aymar, commented, "...there are inevitably hurdles to be overcome as we bring the LHC into operation. Every part of the system has to be brought on-stream carefully, with each sub-system and component tested and repaired if necessary. There have been no showstoppers so far. For a machine of this complexity, things are going remarkably smoothly and we're all looking forward to doing physics with the LHC next summer."
Source:
"LHC completes the circle"
CERN press release (November 7, 2007)
http://press.web.cern.ch/press/PressReleases/Releases2007/PR08.07E.html

(Akihiko Tsutai, Director, International Affairs Department, ISTEC)

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Top of Superconductivity Web21

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Feature Articles: Superconducting Digital Device Technology
- Latest Trends in Superconducting Digital Device Technology -

Major advances in the development of superconducting digital device technology have occurred in the past year. In Japan, the development and demonstration of a switch system using Nb-based low-temperature superconducting single-flux quantum (SFQ) devices and a desktop sampler using oxide high-temperature superconducting SFQ devices took place at the Superconductivity Research Laboratory (SRL) as part of the NEDO project entitled "Superconductor Network Device" project—this is the last year of the project—and this work has demonstrated the prospects for superconducting systems featuring performance that exceeds semiconductor devices. The details will be left for a separate article, but these results alone elicited quite a response when they were reported during invited lectures at the International Superconductive Electronics Conference (ISEC 2007) held in Washington D.C. in June. These demonstrations were very significant in the sense that the development of interface technology between room-temperature electronics and SFQ circuits that operate at super-high speed at a low temperature, as well as the development of cryo-packaging technology, has brought superconductivity to a level where it can be used almost regularly. Despite the issues of enlarging the scale and further improving performance, the demonstrations were highly acclaimed, even by system specialists.

A number of new projects related to SFQ devices are also being launched. It has already been pointed out that when SFQ devices are applied to high-end computers, the exchange of data with high capacity memory becomes a bottleneck, making it impossible to maximize the benefits of super high-speed SFQ processors. Meanwhile, in the field of scientific computation, a new architecture capable of rapid computation with minimal memory access is being devised by combining multiple floating-point calculation units with a switched network. This is an architecture truly suited to SFQ and it aims to eventually enable desk-side teraflop (Tflop) computers. The JST-CREST project (Nagoya University, Kyushu University, Yokohama National University, and SRL) aimed at developing the fundamental technology for SFQ processors based on this architecture commenced in October last year. In addition, a special research program at the Ministry of Education, Culture, Sports, Science and Technology, centering on SFQ device research using so-called MTS* materials such as NbN and MgB_2, launched at about the same time. Furthermore, in June this year, work started under NEDO's "Development of Next-generation High-efficiency Network Device Technology" project toward developing optical device technology and systemization technology for large-scale routers as well as the optical I/O technology and low-temperature packaging technology essential to increasing SFQ switch scale.

Based on the presentation and information provided at ISEC 2007, the development of a digital receiver (system that digitizes and processes analog radio signals in the microwave range) by HYPRES, which is supported by the military in the U.S., is proceeding smoothly. In addition, Northrop Grumman has successfully developed a technologically difficult 2^{nd}-order superconducting Σ-Δ A/D converter. In Europe, a group at Chalmers University of Technology in Sweden is using the HYPRES's Nb process to develop an SFQ digital signal processing circuit with 10,000 junctions for interference reduction processing on wireless communication base stations, and this year, they plan on mounting it on a cryocooler and giving a demonstration. The EU does not have a large budget, but the FLUXONICS network aimed at developing SFQ circuits has been set up between numerous universities in the EU, and specific universities are serving as foundries for manufacturing the circuit chips. A major factor for Japan's world-leading position in the field of superconducting digital devices, primarily SFQ devices, is its building of superior manufacturing

processes for both low and high-temperature devices. An extremely crucial issue will be whether Japan will maintain this position until full-fledged practical applications are achieved.

*MTS: Middle Temperature Superconductor

(Keiichi Tanabe, Director, Division of Electronic Devices, SRL/ISTEC)

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Top of Superconductivity Web21

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Feature Articles: Superconducting Digital Device Technology - Switch Demonstration Using a Low-Temperature SFQ Device and Future Prospects -

Low-temperature single-flux quantum (SFQ) circuits using niobium as a superconductor deliver both high speeds in excess of 100 GHz and low power consumption amounting to 0.1 μW per gate. Furthermore, high integration is possible with these devices, and a breakthrough in the current limit of existing technology is expected. Meanwhile, switches that rapidly switch data destinations based on addresses are the part of network routers that demand the fastest speed, and the super high-speed and low power consumption of SFQ circuits can be effectively utilized for such switches. In the NEDO's " Superconductor Network Device" project, the Superconductivity Research Laboratory built a superconducting switch prototype system using low-temperature SFQ circuits and conducted a successful video transfer test between four PCs on a local area network (LAN) that used this system. This showed that super lower-power network routers featuring superconducting switches are feasible.

The heart of this prototype system is a superconducting multi-chip module (MCM) that is cooled to a super low temperature (-269℃) using a cryocooler. It can access data at 10 billion bits per second (10 Gbps) using 32 electric signal lines starting from room temperature. The superconducting MCM is comprised of an SFQ switch chip and superconducting amp chip for output, and signals are transferred between the two chips using 10 Gbps SFQ pulses. The switch chip is comprised of a scheduler circuit for preventing packet collisions and a 4 x 4 (four inputs and four outputs) switch. Some 2,000 Josephson junctions are integrated in the switch chip, enabling the processing of data equivalent to 4.8 million A4 pages of text per second. Despite this enormous processing volume, power consumption is a mere 0.66 mW.

Fig. 1 shows the SFQ switch prototype system housing the superconducting MCM along with peripherals, including a power source and interface circuits, in a single rack. The superconducting MCM is housed in the red area at the center. This system along with four PCs forms a LAN, and we performed a video transfer test using standard Ether frames over Ethernet. Test results showed that video was properly transferred by the superconducting switch's collision prevention feature, even when one PC simultaneously requested

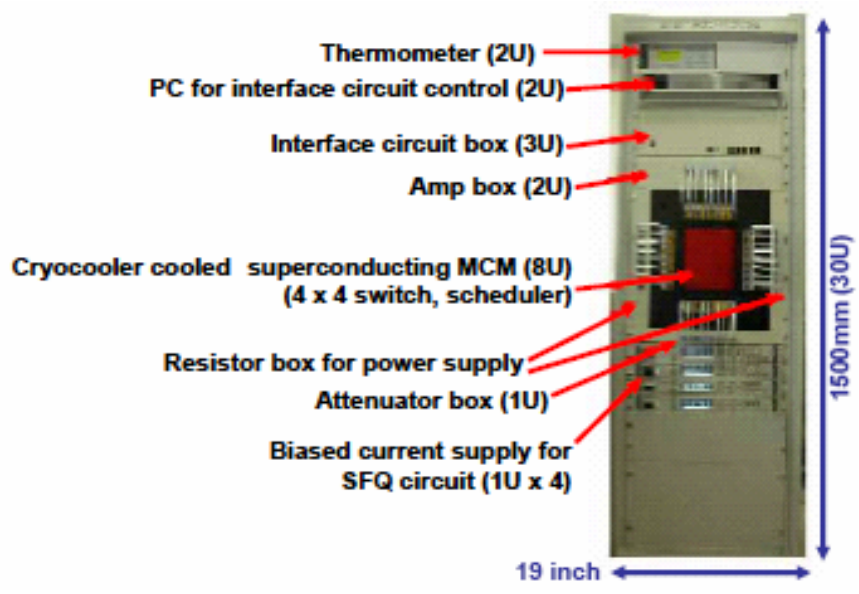

Fig.1 External view of SFQ switch prototype (the cryocooler compressor is separately housed)

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video transfers from multiple PCs. Fig. 2 shows an example of the video transfer demonstration. In a separate test, a bit error rate (BER) around 10^{-13} was achieved. Generally, a BER of 10^{-12} or less is required for devices used on networks, so this demonstrates that the reliability of our SFQ switch system is at a level that can be applied to networks.

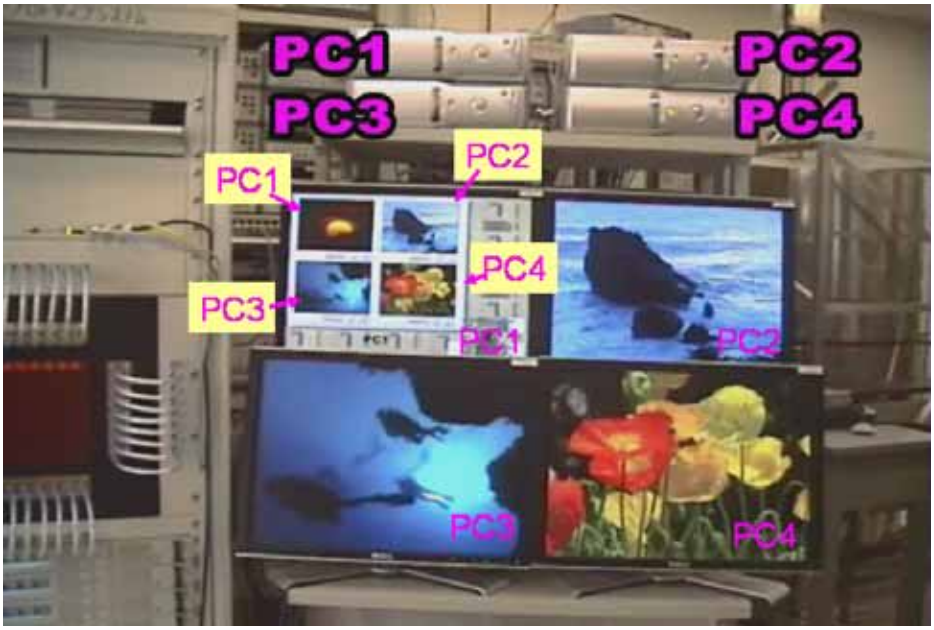

Fig. 2 Video transfer test between four PCs on a LAN using SFQ switches

This demonstration was able to show the high level of potential capacity of SFQ switches. Although the energy consumption of the SFQ chips on this prototype was less than 1 mW, the heat inserting into the cryogenic environment through the 32 high-speed electric signal lines was about 1 W, and almost all of the cooling capacity of the cryocooler was expended by this inflow of heat. If the system scale were increased, this inflow of heat would become an even bigger problem. Using optic fiber, which transmits almost no heat, to input and output data would be an effective way to solve this problem. Therefore, we need to implement optical-SFQ and SFQ-optical conversion at cryogenic temperatures. As part of the NEDO's "Next-generation High-efficiency Network Device Technology" project, we are currently developing packaging technology that includes optical I/O. This development work has fixed its sights on the large-scale superconducting routers of the future, but using this packaging technology, the early practical application of small SFQ systems is also expected.

(Mutsuo Hidaka, Director, Low Temperature Superconducting Device Laboratory, SRL/ISTEC)

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Top of Superconductivity Web21

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Feature Articles: Superconducting Digital Device Technology - Developing Fundamental Technology Aimed at High-Performance Superconducting Computers -

Nobuyuki Yoshikawa, Professor
Department of Electrical and Computer Engineering
Graduate School of Engineering, Yokohama National University

High-performance computers are required for all manner of scientific computations, and performance has been improving at a tremendous pace. Obviously, advances in semiconductor IC technology, which is based on CMOS, have played a major role. However, a look at development trends in recent semiconductor processors reveals changes in the way performance is being improved. Before, individual processor performance was improved by simply increasing clock speeds, but recently, improved performance is being achieved by the parallel use of multiple relatively low-performance processors. For example, the Cell processor developed by IBM, Toshiba, and Sony runs nine approximately 20 GOPS processors in parallel to achieve around 200 GOPS of performance. The Matrix processor developed by Renesas uses 2,000 2-bit processors operating at 200 MHz to achieve 40 GOPS of performance. The main factor behind this change in thinking about processor design is the increasing power consumption of CMOS. It is already difficult to improve the performance of individual processor by boosting clock speed due to the increased power consumption that results, and thus we now have multiple low speed processors with improved computational efficiency per energy consumed being operated in parallel. However, the application areas for such parallel processors are limited and the performance improvements by parallelization will eventually hit a wall. Consequently, the development of single processors featuring exceptional performance will always be necessary.

SFQ circuits, which employ single flux quantum (SFQ) within a superconducting loop as a single piece of information, operate at speeds 10 or more times faster than semiconductors, while consuming only 1/1000 or less the power. And since they are capable of ballistic propagation of SFQ pulses by using superconducting wiring, there is no drop in speed and no increase in energy consumption due to wiring. Consequently, the use of SFQ circuits makes it possible to realize processors with high processing performance per energy consumed that exceeds CMOS processors. With help from NEDO, we have been developing an SFQ processor jointly with Nagoya University. This article introduces the CORE processor we have developed thus far.

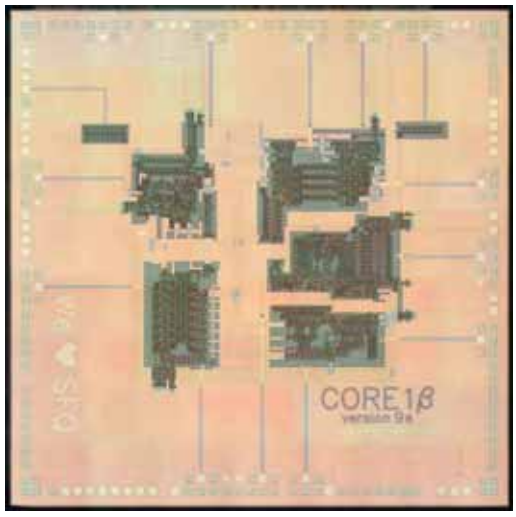

Fig.1 CORE1β ver.9 chip
Chip dimensions: 8 mm square

Fig. 1 is a photo of the CORE1β ver.9, the largest scale SFQ microprocessor for which we have successfully demonstrated operation. The CORE1β ver.9 is an 8-bit processor with 14 instructions, and it is comprised of 10,995 Josephson junctions. It was fabricated on an 8 mm chip using an SRL 2.5 kA/cm^2 Nb standard process with a minimum wire width of 2 μm.

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The chip operates at a clock frequency of 25 GHz, and the computational performance and power consumption at that speed are 1.4 GOPS and 3.4 mW respectively. The computational performance per unit of energy consumed exceeds 400 GOPS/W or three figures higher than with Blue Gene.

The architecture of CORE1β ver.9 is characterized by per-bit data processing (bit serial). This is done to reduce processor size. It has two cascade-connected ALUs, allowing it to execute two register computations with a single instruction. In addition, instruction processing is executed by a four-level pipeline stage. For pipeline control, a method known as one-hot encoding, which is suited to SFQ circuits, is used in an attempt to greatly simplify the circuit.

The circuit configuration of CORE1β ver.9 is characterized by the use of a magnetically strong cell library. All bias lines are covered in a superconducting shield layer to prevent the magnetic field caused by the bias current from affecting circuit operation. Furthermore, all circuit blocks are interconnected by superconducting wiring in an attempt to greatly reduce data transfer delay between circuit blocks and lower power consumption.

The successful demonstration of high-speed operation on these SFQ circuits exceeding 10,000 junctions led to the development of an Nb process with stable SRL and a cell library with a wide performance margin, but the dedicated efforts of the students at Nagoya University and Yokohama National University also played a major role.

The NEDO project ended in 2006, but subsequent projects, specifically "Single-Flux-Quantum Integrated Circuits based on Localized Electromagnetic Waves" which is part of the Grant-in-Aid for Scientific Research on Priority Areas funded by the Ministry of Education, Culture, Sports, Science and Technology, and JST/CREST's "Reconfigurable Low-Power High-Performance Processors Using Rapid Single-Flux-Quantum Circuits" have been launched. The former aims to achieve signal processing circuits exceeding chip performance of 1 TOPS, while the latter aims to establish the fundamental technology for realizing desk-side supercomputers capable of computational performance of 10 TGOPS.

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Top of Superconductivity Web21

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Feature Articles: Superconducting Digital Device Technology
- Developing a High-Temperature Superconducting Desktop Sampler -

Information technologies typified by the Internet, have been growing exponentially since we entered the 21 century, and the need for ever increasing network speed remain unabated. The 40 Gbps network systems have been started to be spread, and R&D on systems exceeding 100 Gbps have been underway. It is very likely that superconducting SFQ technology can be exploited as high-speed measurement technology for these systems, based on its high-speed performance and high sensitivity. In particular, superconducting samplers are seemed to be closest to the practical applications for high-temperature superconducting SFQ circuits because they can be fabricated by using small-scale integration technology with about ten junctions. At the Superconductivity Research Laboratory, R&D on a superconducting sampler had been conducted as part of NEDO's "Development of Low Power Superconducting Network Devices" project. The goal of our work was developing a prototype HTS sampler system with high-frequency characteristics, which had a desktop size comparable to other measurement instruments on the market as a practical-level system.

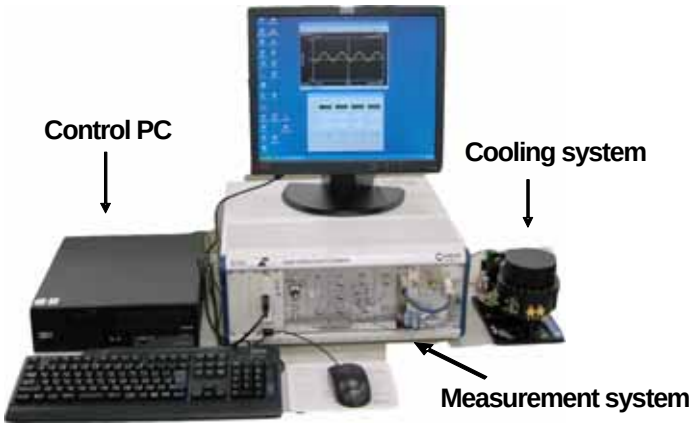

Fig. 1 High-temperature superconducting SFQ sampler system

Since high-temperature superconducting devices can operate near 50 K, cooling is possible using a small cryocooler. One advantage of this is overall system size can be downsized. There is, however, no practical example where such a system has been realized, except for superconducting filters, which are a passive device. Our latest goal was to develop a small cooling system with a high-temperature superconducting sampler chip along with the overall system that includes room temperature instruments for the sampler operation. Fig. 1 shows the portable desktop-sized high-temperature superconducting sampler we developed. To make this possible, we conducted R&D on chip fabrication, chip packaging, and the measurement section as follows:

1. Chip fabrication

In order to fabricate the sampler chip, we developed IC fabrication technology for high-temperature superconducting single-flux quantum (SFQ) circuits by means of ramp-edge surface-modified Josephson junctions (IEJ junctions) and multilayer thin-film technology. Fig. 2 is an example of a sampler chip we fabricated using the high-temperature superconducting IC technology. Since minimizing the leakage magnetic field and reducing

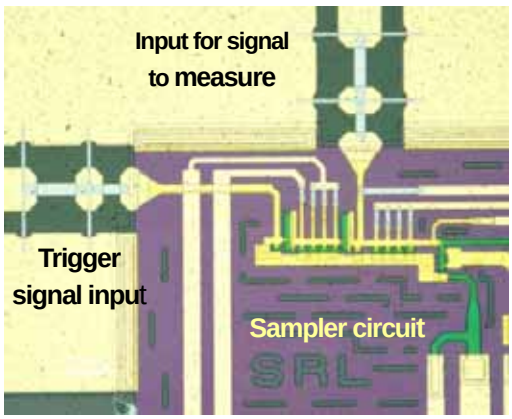

Fig. 2 High-temperature superconducting sampler chip

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inductance are necessary in fabricating sampler circuits, we developed technology for fabricating circuits on a superconducting ground plane. The chip's input section is a coplanar line, and we integrated matching resistance for reducing the reflection of high-frequency signals.

2. Packaging

Packaging technology, creating a portable system overall, including a cooling system, and reducing the cooling time were important issues for the development. The cooling system we developed reduced thermal inflow and thermal capacity by properly design the parts, such as the material selection, the design of high frequency module on which chip are mounted and shape of the signal lines. As a result, we were able to use a small one-stage Sterling cryocooler (cooling capacity: 1 W or more at 80 K, power consumption: 60 W). It also became possible to cool to 45 K within 60 minutes after power on. The high frequency module and chip mounting was developed along with Advantest Laboratories Ltd. The initial version weighed over 100 g, but in the final version, weight was reduced to about 25 g, thereby contributing to a shorter cooling time. The cooling system in which this sampler module was incorporated became small and light weight (Fig. 3), measuring only 140 mm x 150 mm x 200 mm (W x H x D) and weighing less than 4 kg.

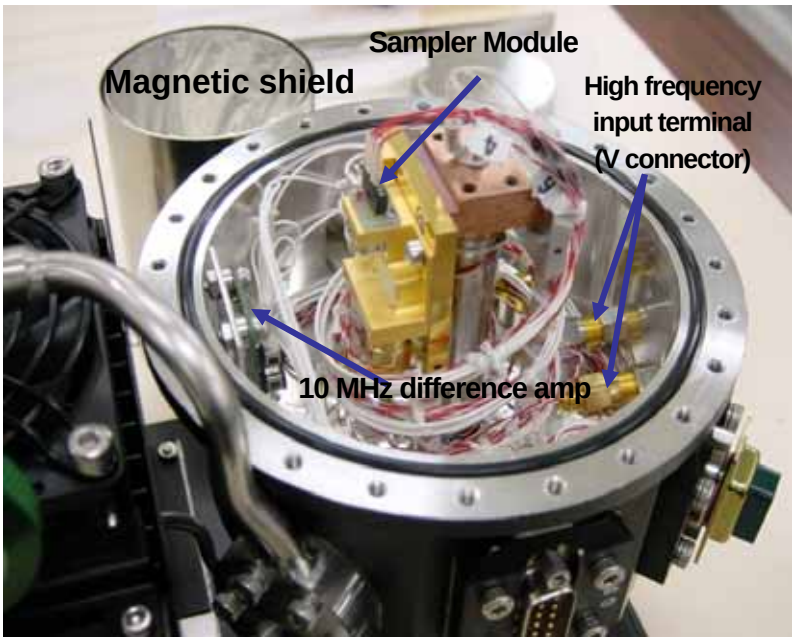

Fig. 3 Sampler cooling system using a small cryocooler (internal photo)

3. Measurement instruments

We also completely overhauled the measurement system and have developed one case-sized version based on PXI, one of the standards for instruments. We were able to house all the functional components necessary for the operation of a superconducting sampler, including a pulse generator, delay line, DC bias current, and A/D converter, in a 3U size PXI case (177 mm high) in a 19-inch standard rack. An electrical variable delay line that changes the timing of the sampling has been developed in place of a mechanical variable one which operated at a slower speed. We also made a two-order improvement in sampling frequency from 100 kHz to 10 MHz. As a result, the sweep speed for displaying observed waveforms was accelerated to several seconds or so, which is nearly comparable to instruments on the market. To improve the electrical performance, we developed a new method that uses 10 MHz sampling with a high slew rate and a synthesizer with a low phase noise as a master oscillator, reducing jitter from about 5 ps to 1 ps.

Fig. 4 is a 50 GHz waveform measured using the superconducting sampler system. The system succeeded in observing a clear waveform at unprecedented high sensitivity. The entire system developed

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by our latest efforts, including the PC that controls sampler operation, was reduced in size from the former single rack size to desktop size, which brings it to the practical level. At the test stage, we used a desktop PC, but a modular PC can be housed in the PXI case. Creating such a portable system that includes a cooling system is expected to be an important first step toward a practical system of the future.

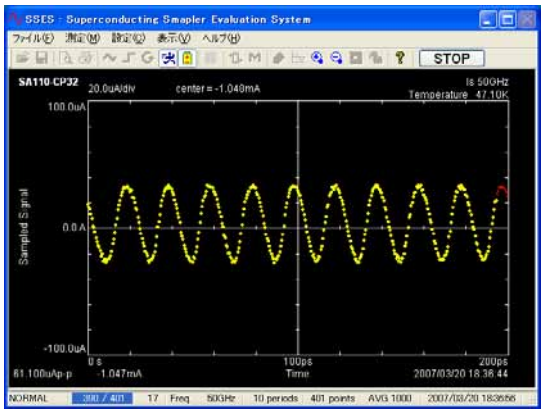

Fig. 4 50 GHz sine wave signal that was observed

Related Articles

1) Suzuki, Hideo, Superconductivity Web21, September 2004, p.4.
2) Suzuki, Hideo, Superconductivity Web21, October 2005, p.3.
3) Suzuki, Hideo, Superconductivity Web21, October 2006, p.12.

(Hideo Suzuki, Low Temperature Superconducting Device Laboratory, SRL/ISTEC)

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Top of Superconductivity Web21

Winter, 2008 Date of Issue: January 15, 2008
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Standardization Activities

Topics in October

- IEC/TC90 Holds First WG12 Meeting in Philadelphia, USA -

IEC/TC90 (Superconductivity) held the 1st meeting of WG12 on August 28, 2007 at the Marriot Hotel in Philadelphia, U.S. The meeting was a complete success, with 10 experts, including observers, in attendance.

IEC/TC90/WG12 was established on February 2, 2007 as a working group (WG12) by seven specialists from five different countries, with Prof. Toshiyuki Mito, Inter-University Research Institute Corporation National Institute for Fusion Science, National Institutes of Natural Sciences, as convener. The working group's objective is the creation of proposals for international standards relating to current leads for power supplies used in superconducting equipment at the International Electrotechnical Commission (IEC). The immediate work to be carried out by WG12 is the creation of the following standard proposal:

IEC 61788-14 Superconductivity
- Part 14: Superconducting power devices
- General requirements for characterization of current leads for powering superconducting devices

At the 1st WG12 Meeting, the following matters were discussed, with Prof. Takakazu Shintomi (Nihon University) presiding over the meeting in place of Prof. Toshiyuki Mito.
1. Introduction of IEC/TC90/WG12 members
2. Confirmation of an agenda of the 1st WG12
3. Explanation of the background behind the establishment of WG12 and introduction of the agenda and schedule
4. Discussion of the first working draft (1st WD) for the international standard created by the Japan National Committee (JNC)

The 1st WG12 Meeting ended up short on time because it was held at the same time as the 20th International Conference on Magnet Technology (MT20). As a result, an agreement was reached to respond as follows:

1. The chaired Prof. Takakazu Shintomi will summarize members' comments regarding the international standard draft (1st WD) created by the Japan National Committee (JNC) by September 28, 2007.
2. The 2nd WG12 Meeting will be held on November 5-7, 2007 at the International Superconductivity Symposium (ISS'07).

(Yasuzo Tanaka, Director, Standardization Department, ISTEC)

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Top of Superconductivity Web21

Winter, 2008 Date of Issue: January 15, 2008
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Standardization Activities

Topics in October

-' IEC/TC90's Fourth Panel Discussion on Superconducting Equipment' report -

Takakazu Shintomi, Professor
Advanced Research Institute for the Sciences and Humanities
Nihon University

Panel discussion hall

The Fourth Panel Discussion on Superconducting Equipment sponsored by IEC/TC90 was held on August 28 at the Marriott Hotel in Philadelphia, where the 20th International Conference on Magnet Technology (MT20) was also held. Despite being held at 8:00 PM after the MT20 session, some 30 experts were in attendance, and spirited discussions took place past 10:00 PM.

The panel discussion was carried out under the chairmanship of Dr. Kozo Osamura, professor emeritus at Kyoto University and Chairman of the TC90 National Technical Committee. The various panelists reported on and discussed the development status and future outlook of IEC/TC90, current leads, power cables, superconducting fault current limiters, and superconducting rotating machines among other topics.

Dr. Osamura (Research Institute for Applied Science) kicked things off by shedding light on the purpose of the panel discussion and then introducing the overall activity status of IEC/TC90 in superconductivity standardization and the standardization of test methods for superconducting materials and products for superconducting devices. A report was made that, as a result of the standardization activities for products, the general rules for characteristic test methods for current leads were brought up and a working group (WG12) for dealing with this was started at the beginning of this year. As for the next item to be brought up for discussion, some panelists believed the standardization of power cables would be a good choice.

Tom Taylor (CERN) reported on the development status of the design, manufacture, and testing of the 1,800 normal conducting and high-temperature superconducting (HTS) current leads, ranging widely from 60 A to 13 kA, that are to be used in the LHC superconducting accelerator being built in Europe. He also shared various lessons learned during the development process. One thousand HTS current leads are being manufactured in three different types (600 A, 6 kA, and 13 kA), and Taylor believes that they will become the de facto standard and that technologies for HTS wires developed by means of HTS current leads will initially be utilized in power cables.

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David Lindsay (Southwire Co.) discussed the features of power cables and reported about the current state of power cable projects currently underway in the U.S. and about planned development projects in Korea, China, and Japan. He brought up features that include lower electromagnetic field leakage, environmental friendliness due to such factors as high efficiency, five times the capacity of conventional power cables, and compactness. And during discussions, the need for advancing standardization of superconducting DC power transmission was voiced.

Kenichi Sato (Sumitomo Electric Industries) discussed the need for TC90 to remain in contact with the technical committees on power cables (TC20) within IEC/TC and other technical committees from the standpoint of standardization.

Next, Hye-Rim Kim (KEPCO) reported on the development project and status for superconducting fault current limiters in Korea. Two principal development projects are underway in the 21-Century Frontier Program. She reported that, currently, R&D is underway on a 22.9 kV/630 A three-phase and a 14 kV/630 A single-phase superconducting fault current limiters, with field tests to be conducted this fiscal year, and ultimately, they plan to make such devices (22.9 kV/3 kA three-phase and 154 kV/4 kA single-phase) available for practical application starting in 2012. She also mentioned that they could likely offer materials that could contribute to standardization.

Kenichi Sato giving his report

Michael Tomsic (Hyper Tech Research) reported on the recent development status of superconductor rotating machines in the U.S. He also reported on a 26.5 MW HTS motor for ship propulsion by AMSC and Northrop Grumman, a 40 MW DC/synchronous motor, the 1.3 MW motor ordered by the Air Force from GE, the world's first motor using BSCCO from RE, a DC homopolar motor from GA, the launch of power generation development by SuperPower, an LH_2 cooled 2 MW power generator from LEI, and the manufacture of a 2 MW rotor coil using MgB_2 by Hyper Tech.

At the latest MT20, there were numerous research reports on high-temperature superconducting materials and magnet technology that uses them, and it made us feel that technical developments in this area were advancing at a furious pace. The IEC/TC90, too, must keep a constant eye on technical trends. As for the standardization of products, the panel discussions were significant in the sense that there was a shared understanding.

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Top of Superconductivity Web21

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Standardization Activities

Topics in November

- Kaoru Yamafuji, Hitoshi Wada, and Teruo Matsushita Win Awards Relating to Superconductivity Standardization -

Kaoru Yamafuji (President, Fukuoka Institute of Technology) has won the International Electrotechnical Commission (IEC) 1906 Award, while Hitoshi Wada (Professor, Graduate School of Frontier Sciences, University of Tokyo), and Teruo Matsushita (Professor, Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology) have each won the FY 2007 METI Minister Awards for the promotion of Industrial Standardization.

The transfer ceremony for the IEC 1906 Award and the award ceremony for the FY2007 METI(Minister of Economy, Trade and Industry) Minister Awards for the promotion of Industrial Standardization were held on Monday, October 15, 2007 in the Ho-oh no Ma (Phoenix Hall) at the Toranomon Pastoral Hotel. These award ceremonies preceded the 2007 National Conference on Standardization and Quality Control, held by the Japanese Standards Association on October 15 and 16, 2007, and were attended by, among others, Yoshitaka Shindo, Senior Vice Minister, METI; Ishida Toru, Director-General, Industrial Science and Technology Policy and Environment Bureau, METI; Kyoichi Hirota, Deputy Director-General for Technical Regulations, Standards and Conformity Assessment Policy, METI; Hiroshi Shima, President, Japanese Standards Association; Mariko Sano, Secretary General, Japan Housewives' Association; and Eisuke Shoda, Vice Chair, Japanese Industrial Standards Committee.

The award ceremony opened with a greeting from Yoshitaka Shindo, Vice Minister, Senior Ministry of Economy, Trade and Industry, and then the Prime Minister Award for Industrial Standardization was presented to one recipient, the METI Minister Awards to 23 recipients and 7 groups, the Industrial Science and Technology Policy and Environment Bureau Director-General Award for Contributions to International Standards to 21 recipients, the Industrial Science and Technology Policy and Environment Bureau Director-General Award for Promoters of International Standardization to 13 recipients, and the IEC 1906 Award to 27 recipients. The conferment ceremony for the IEC 1906 Award was also held.

Kaoru Yamafuji, one of the winners of this year's IEC 1906 Award, was commended for his "extensive contributions to the smooth promotion of international consensus on IEC60050-815 and IEC61788 series international standardization and normalization." Hitoshi Wada was commended for his "efforts in establishing IEC standards while coordinating with research activities at VAMAS as the international convener of IEC/TC90 (superconductivity)/WG3 (critical current) and extensive contributions to standardization in the field of high-temperature superconductivity, including participation in the establishment of JIS standards for technical terms in the new field of superconductivity and for critical current measurement method for Bi oxide superconducting wire as chairperson of the national committee on critical current." Teruo Matsushita was commended for his "efforts in developing IEC standards relating to superconducting products and high temperature superconducting materials in new fields and in advancing the standardization of the residual resistance ratio test method for Nb-Ti and Nb_3Sn superconductors as convener of IEC/TC90 (superconductivity)/WG1 (terminology), as well as contributions to the establishment of JIS standards conforming to IEC standards and extensive contributions to the economic ripple effect of

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5-34-3, Shimbashi, Minato-ku, Tokyo 105-0004, Japan Tel: +81-3-3431-4002, Fax: +81-3-3431-4044

not only the development of the traditional superconductivity-related industry, but also the market introduction of the new high-temperature superconductivity-related industry."

Winners of the FY2007 METI Minister Awards for promotion of Industrial Standardization

Winners of IEC 1906 Award

(Editorial Office)

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Top of Superconductivity Web21