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What's New in the World of Superconductivity

초전도 뉴스 –세계의 동향–

超导新闻 –世界的动向-

chāo dǎo xīnwén - shìjiè de dòngxiàng-

Yutaka Yamada, Principal Research Fellow
Superconductivity Research Laboratory, ISTEC

★ News sources and related areas in this issue

▸Power Application

Nexans, LS Cable, RWE Deutschland AG and STI Jointly Exhibit Solutions at CIGRE 2014

STI, Nexans, LS Cable, RWE Deutschland AG (25 Aug, 2014)

Superconductor Technologies Inc. ("STI"), together with Nexans, LS Cable and RWE Deutschland AG, showcased the attributes of superconducting fault current limiters (SFCLs) and high power superconducting cables (HPSCs) at STI's CIGRE.

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The joint goal is to leverage the collective expertise of the companies and share the value proposition of SFCLs and HPSCs with companies poised to develop the infrastructure, electricity transmission and distribution industries. This aims to support decision makers with critical planning network, broadening the market appeal of future infrastructure to optimize existing power systems and improve the stability and reliability of the grid.

Adam Shelton, STI's VP on Marketing and Product Line Management, said *"Superconducting wire is a key component of the overall solutions. In conjunction with our plan to begin producing our Conductus® wire in commercial volumes later this year, we are working closely with our SFCL and HPSC customers to optimize performance and improve capacity to meet industry demands."*

Source: "Nexans, LS Cable, RWE Deutschland AG and STI Jointly Exhibit Solutions at CIGRE 2014"
STI Press Release (25 August, 2014)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle_Print&ID=1960572&highlight
Contact: Cathy Mattison invest@suptech.com

▸Wire

750km/year Throughput of the 100mm wide and 1km long Wire

STI (7 August, 2014)

Superconductor Technologies Inc. (STI), reported their results for the second quarter ending June 28, 2014. STI's net revenues for second quarter 2014 were $75,000 compared to $389,000 in the first quarter of 2014 and $555,000 in the second quarter of 2013, mainly from legacy wireless products. Over this period, STI recognized a one-time gain of $3.5 million from its investment in Resonant Inc. For the six-month period ending June 28, 2014, total net revenues were $464,000, compared to $1.3 million for the first half of 2013.
In the second and third quarter, the company shipped 11 orders; six for Stage 1 customers conducting performance evaluation and five for Stage 2 customers testing simulated devices for commercial deployment. Their customers are employing Conductus wire for multiple applications such as superconducting fault current limiters, high performance magnets, power cables and nuclear magnetic resonance equipment. Five of the 11 shipments were to new customers. Also, during the same period, the company received five new orders and project commitments. STI reports the shipping of 20 Conductus wire orders over the past year.

STI's president and chief executive officer, Jeff Quiram, stated, *"The company has completed the installation and calibration of characterization equipment that allows STI to test their Conductus wire that has reported performance attributes of up to 1,000 Amps on 1 km lengths."* The company aims the transition from pilot plant equipment to 1km production equipment that is designed to produce 750 kilometers of Conductus wire at widths of 100mm annually. After delay of their original plan, commercial volume production is still expected in the fourth quarter and the ramp to full capacity to being early 2015.

Source: "STI Reports 2014 2Q Results"

STI Press Release (7 August, 2014)
http://phx.corporate-ir.net/phoenix.zhtml?c=70847&p=irol-newsArticle_Print&ID=1956390&highlight
Contact: Cathy Mattison invest@suptech.com

▸NMR

Portable NMR

Harvard School of Engineering and Applied Sciences (4 August, 2014)

A research team led by Donhee Ham, Gordon McKay Professor of Electrical Engineering and Applied Physics and his student Dongwan Ha, based at the Harvard School of Engineering and Applied Sciences (SEAS), together with the Schlumberger-Doll Research Center in Cambridge, Mass., and the University of Texas, Austin, have created a portable nuclear magnetic resonance (NMR) spectroscopy device. The research team successfully managed to shrink the electronic spectrometer components onto a silicon chip. By combining this with a compact permanent magnet, the spectrometer is the smallest device currently able to perform multidimensional NMR spectroscopy, as Ham states, *"one of the most powerful analytical tools to determine molecular structures at atomic resolution."*

Current state-of-art NMR systems employ large superconducting magnets for interrogating the structure of complex molecules. However, Ham says, *"In many circumstances-for example, many experiments in biochemistry or organic chemistry, quality control in production lines, or chemical reaction monitoring – you're doing NMR on smaller molecules, and for those applications the big superconducting magnets may be avoided."* Permanent magnets are weaker than superconducting magnets, but still perform satisfactorily to resolve small-to-medium size hydrocarbons, drug compounds, and biomolecules. Stability concerns associated with permanent magnets due to thermal effects have been overcome by calibrating using statistical distance minimization and entropy minimization to estimate the magnetic field drift.

Ham and Ha also see other potential portable applications combining this tiny spectrometer chip with a larger superconducting magnet to speed-up the analysis of complex molecules by performing many NMR spectroscopy experiments simultaneously. Ham says, *"Using a hundred of these cheap and small spectrometer chips in parallel within a superconducting magnet bore could counter the intrinsic slowness of NMR spectroscopy, enabling a high-throughout paradigm for pharmaceutical screening and structural biology. One year of testing could be completed in a few days. We have already started investigating this angle."* The research team has filed for a provisional patent on the miniature NMR spectrometer. Together with Harvard's Office of Technology Development (OTD), they are currently exploring potential avenues for commercialization with pharmaceutical companies involved in drug discovery, as well as from companies poised to deliver next-generation equipment for spectroscopy applications.

A research paper highlighting the NMR system comprising a compact permanent magnet was published in the *Proceedings of the National Academy of Sciences* (*PNAS*).

Source: "Minuscule chips for NMR spectroscopy promise portability, parallelization"

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STI Press Release (4 August, 2014)
http://www.seas.harvard.edu/news/2014/08/minuscule-chips-for-nmr-spectroscopy-promise-portability-parallelization
Contact: Caroline Perry

▸Basics

Large Grant of $1.9 million for the HTS mechanism

Brookhaven National Laboratory (12 August, 2014)
Ivan Bozovic, a Brookhaven physicist and an Adjunct Professor at Yale University has been awarded a grant of $1.9 million over five years by the Gordon and Betty Moore Foundation as part of the foundation's Emerging Phenomena in Quantum Systems (EPiQS) initiative. The grant is aimed at unlocking the secrets of high-temperature superconductivity, particularly investigating the fabrication and manipulation of superconducting thin films and exploring factors that lead to the ability of certain materials to carry electricity with no energy loss.
Bozovic quoted, *"I am very grateful for this grant, which recognizes the importance of methodical work that slowly but steadily improves materials synthesis techniques and sample quality."*

A bespoke molecular-beam epitaxy (MBE) machine has been built by Bozovic, allowing the fabrication of enhanced superconducting thin films, an atomic layer at a time. More than 2,000 thin film samples have been fabricated, together with hundreds of scientific experiments conducted. The atomic-layer-by-layer synthesis technique enabled Bozovic to make a series of discoveries that bring interface superconductivity to the forefront of research in condensed matter physics. The findings have demonstrated that a superfluid can be confined to a single atomic layer at the interface of two materials, neither of which is superconducting. Additionally, it was ascertained that electron pairs exist on both sides of the superconductor-to-insulator transition, which provide an important insight to the high-temperature superconductivity phenomenon.

Source: "New Grant to Aid Search for the Secrets of Superconductivity"
BNL Media & Communications Office (12 August, 2014)
http://www.bnl.gov/newsroom/news.php?a=25024
Contact: Karen McNulty Walsh

Role of Magnetism in Iron-based Superconductors

ORNL (21 August, 2014)
Researchers based at the Department of Energy's Oak Ridge National Laboratory and Vanderbilt University are challenging the current knowledge of superconductivity and magnetism in iron-based superconductors. Previous thinking was that magnetism and superconductivity could not coexist since

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superconductors conventionally repel magnetic fields. Experimental evidence using a combination of scanning transmission electron microscopy and electron energy loss spectroscopy to characterize the magnetic properties of individual atoms shows that rapid fluctuations of local magnetic moments is correlated with a high critical temperature, and can influence the performance of iron-based superconductors.

The team undertook a comprehensive four-year study that analyzed several families of iron-based superconductors, revealing universal trends among the compounds. They determined the total number and distribution of electrons in atomic energy levels that determine the local magnetic moments, concluding that the number of electrons doesn't change, but what changes are the positions and distribution of electrons in different levels and thus why the magnetic moments differs across families.

This research was conducted in part at the Center for Nanophase Materials Sciences, a DOE Office of Science User Facility. The research at ORNL was supported by the DOE's Office of Science. Idrobo and Zhou based at Vanderbilt University were supported by the National Science Foundation. The research is published as "Orbital occupancy and charge doping in iron-based superconductors" in Advanced Materials.

Source: "ORNL scientists uncover clues to role of magnetism in iron-based superconductors"
ORNL News Release (21 August, 2014)
http://www.ornl.gov/ornl/news/news-releases/2014/ornl-scientists-uncover-clues-to-role-of-magnetism-in-iron-based-superconductors-
Contact: Morgan McCorkle

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Feature Article: Forum on Superconductivity Technology Trends 2014 - High-temperature SQUID Application to Natural Resources Development and Non-destructive Testing

Keiichi Tanabe, Director General
SRL/ISTEC

A magnetic sensor utilizing a superconducting quantum interference device (SQUID) exhibits high magnetic field sensitivity in the femtotesla range (fT = 10^{-15}T), leading to the commercialization of clinical equipment including magneto-encephalogram and magneto-cardiogram having more than 50-100 channels of so-called low-temperature SQUID sensors fabricated from niobium thin films. Such equipment can perform high precision measurements with a magnetically shielded enclosure that completely shields it from the effects of geo-magnetism. High-temperature SQUID sensors on the other hand, comprising of RE123 high-temperature superconducting thin films, have the additional advantage of being easily cooled using liquid nitrogen, which is readily available around the world. Demonstrations with such sensors undertaken in recent years have shown their effectiveness in practical field applications, without the need for magnetic shielding e.g. in natural resource exploration, and therefore has broadened their appeal for an array of applications. The progress in sensor technology has been realized by undertaking advanced mount technology, including efficient cooling and external noise suppression, in addition to the improved sensitivity performance and magnetic field tolerance characteristics of high-temperature SQUID sensors.

The International Superconductivity Technology Center (ISTEC), has developed a high-temperature SQUID magnetometer for the next-generation transient electro-magnetic system (SQUITEM 3), aimed at the exploration of metal resources, and commissioned by the Japan Oil, Gas and Metals National Corporation from 2010 to 2012. The system induces an eddy current deep underground from a coil located at the ground surface. The magnetic field attenuation of the induced current is measured and analyzed by a SQUID magnetometer installed at the center of the coil, enabling depth profiles and the distribution of specific resistance variations in underground to be determined. The SQUID magnetometer is very compact as shown in Figure 1, and allows a day's exploration to be performed with only 1ℓ of liquid nitrogen. The SQUID sensor is fabricated from ISTEC-developed multilayer thin film technology, attaining both the high magnetic field sensitivity and flux-trap tolerance characteristics required for such an application. SQUITEM 3 can

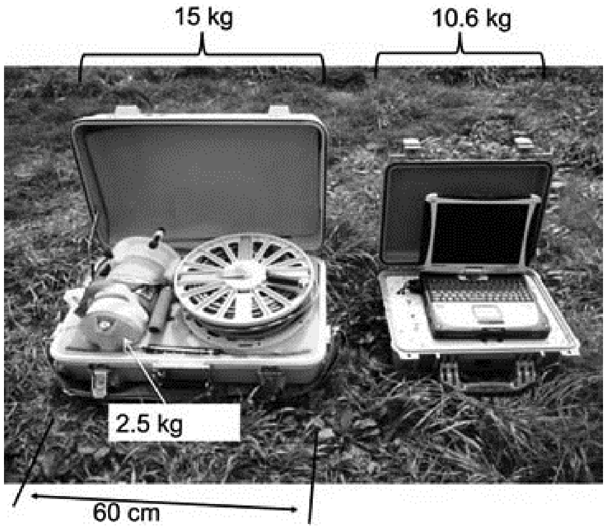

Fig. 1 SQUITEM 3 developed by JOGMEC's commissioned development projects. The cylinder on the left is the ISTEC-developed magnetometer; right is the receiver developed by Mitsui Mineral Development Engineering Co., Ltd.

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respond to rapid field variation with the application of a coil current an order of magnitude larger compared to a conventional system. Performance attributes of SQUITEM 3 are not only due to the enhanced sensor performance, but also contributed by electromagnetic shielding housing the magnetometer, which effectively shields unwanted noise frequencies of more than 100 kHz during measurements.[1),2)] Demonstration field trials of this system have been undertaken at a mining district in Australia, allowing the verification of its superior exploration depth capabilities compared to electromagnetic exploration systems utilizing conventional sensors such as flux gate and induction coils. From 2013 onwards, the system was employed for actual exploration in South America and other areas.

ISTEC has been developing SQUID sensor technology aimed for monitoring CO_2, which was injected into the oil layer for enhanced oil recovery (EOR), commissioned by the Oil & Gas Upstream Technology Unit, JOGMEC since 2012. Here, utilizing differences in specific resistivity of CO_2 and water-repellent oil layers, the distribution of specific underground resistivity in the horizontal direction is evaluated by similar methods usually undertaken by electro-magnetic systems for metal resources exploration.[3)] However, since the oil layer is located 2000-3000m below the surface it is necessary to operate each magnetometer and coil in the borehole drilled. This means that it is required that the SQUID sensor operate and withstand the extreme environments found inside a borehole, which can typically include pressures of 30-70 MPa and temperatures of around 200°C, as well as operate in restricted space. Additionally, the steel pipe casing that is also inserted during borehole drilling rapidly attenuates high frequency magnetic signals. Thus, the high sensitivity characteristics of SQUID sensors even at low frequencies are seen as an advantage. Under the "Technical Solutions Project 2013" conducted by JOGMEC, ISTEC was responsible for the development of the SQUID magnetometer component technology. A pressure and thermal tolerant plastic enclosure having a small external diameter of about 80mm has been fabricated, offering less impact on electro-magnetic measurements compared to metals. A demonstration trial confirmed its pressure and thermal tolerant characteristics. As shown in Figure 2, the magnetometer was injected into water and placed 50m deep into a trial borehole containing a steel pipe casing that was drilled into the Kashiwazaki test field of JOGMEC. The low-noise operational characteristics of the SQUID sensor and receipt of a coil signal from more than 100m has been successfully realized. Over the next couple of years, the research team aims to establish fundamental technology that will enable the SQUID magnetometer to operate safely and reliably in borehole depths of more than 1000m. This technology is also anticipated for the exploitation of other resources, including geothermal prospecting and submarine resource exploration in the future.

Fig. 2 Injection of the SQUID magnetometer into a trial borehole containing a steel pipe casing

Similarly, for non-destructive testing applications the high sensitivity performance characteristics of the

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SQUID sensors at low frequencies can prove to be advantageous. For example, when a SQUID is employed in an eddy current test (ECT), a method typically employed to detect surface defects in metals components, detection will be made possible at much greater material depths, such as detecting defects on the rear section of a pipe. Fundamental experiments demonstrating such capabilities have been undertaken in aluminum and Inconel multilayer samples, confirming a certain level of performance attributes to detect deep-level defects.[4)] Furthermore, other applications anticipated include areas with potentially significant needs in maintaining industrial infrastructure such as chemical and power generation plants, where corrosion and thinning of heat insulating pipes can occur. The current issues with regards to non-destructive testing are requiring a clear view of the target and also to demonstrate the significant superiority afforded by a SQUID sensor over conventional methods. Typically, non-destructive testing locations experience greater noise sources and testing accessibility is often limited. This overturns the conventional wisdom and wide held view concerning conventional SQUID sensors. However, the author considers that the utilization of assembly component technology developed during studies for resource applications will pave the way for their practical use.

Research introduced in this forum, was partially undertaken under the JOGMEC's commissioned development projects including "Technical Solution Project 2013" and the "Development of Next Generation SQUITEM Equipment and SQUID Magnetometer 2010-2011". We would like to express our gratitude to persons concerned in JOGMEC.

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1) JOGMEC NEWS, vol. 34, p. 8, Sept. 2013.
2) T. Hato, A. Tsukamoto, S. Adachi, Y. Oshikubo, H Watanabe, H. Ishikawa, M. Sugisaki, E. Arai, and K. Tanabe, Supercond. Sci. Technol., vol. 26, p. 115003, Nov. 2013.
3) JOGMEC, Annual report of Oil Engineering Development, p.110 , 2012.
4) J. Kawano, T. Hato, S. Adachi, Y. Oshikubo, A. Tsukamoto, and K. Tanabe, IEEE Trans. Appl. Supercond., vol. 21, p. 428, June 2011.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Application of High-temperature SQUID Magnetometers for Measuring Magnetic Variations Associated with Earthquakes

Kan Okubo, Associate Professor
Information Communication Systems, Faculty of System Design
Graduate School of System Design, Tokyo Metropolitan University

The author and his research group have relentlessly conducted field studies investigating the Earth's magnetic field. Amongst the observations include the direct and dynamic magnetic signals emanating from earthquake rupturing, measured successfully for the first time in Japan/abroad when the Iwate-Miyagi Nairiku Earthquake struck on 14 June, 2008.[1)] The observations revealed a gradual but clear magnetic variation from the onset of the earthquake.

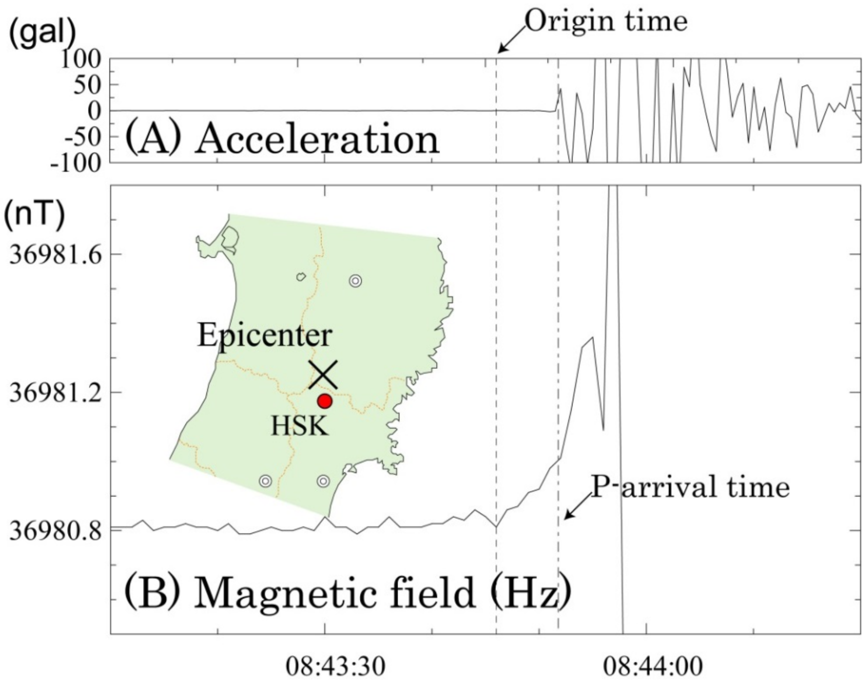

Fig. 1 Seismic waves detected at the Hosokura Observation site (HSK) in Miyagi prefecture, at the onset of the Iwate-Miyagi Nairiku Earthquake (A) Acceleration, (B): Magnetic field in the vertical direction

Magnetic variations were observed prior to the seismic wave reaching the observation site, and thus, the assumption is that the magnetic field begins to change in the epicentral area simultaneously with the onset of earthquake rupturing.

Magnetic variations can be transmitted to the observation site at almost the speed of light. Therefore, it is proposed that direct magnetic signals variations from earthquake rupturing enables the prompt detection of earthquakes, potentially offering the development of a new system providing "ultra" early warning of

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destructive earthquakes with the combined magnetic and seismic measurements.

However, to realize this system an outstanding issue remains to be solved, i.e. the sensor sensitivity used in magnetic field observations. The degree of magnetic variations observed during the Iwate-Miyagi Nairiku Earthquake was around several 100 pT, measured at the Hosokura observation site, situated at a distance of 26km from the epicenter of the earthquake. In fact, the levels of magnetic signals vary according to geographic influences including distance, angle, and depth from the epicenter. Thus, in some cases, this implies that the degree of magnetic variations measured could be much smaller, and therefore suggests that ultra-high sensitive magnetometer technology are inevitable to continuously undertake observational studies towards the realization of practical system in the future. In other words, pico-tesla class highly sensitive magnetometers are required to clearly observe the degree of magnetic signals associated with earthquake rupturing.

The author and his research group have progressed the development of a high-temperature SQUID (HTS-SQUID) magnetometer system specifically aimed for studying the Earth's magnetic field. The characteristics of an HTS-SQUID magnetometer are considered advantageous because; (1) three components of magnetic fields can be measured with greater sensitively; (2) extremely good temperature characteristics, and; (3) operating costs are minimal since superconductivity can be sustained using liquid nitrogen. In particular, long-term observation of terrestrial magnetism is required. Sustaining superconductivity utilizing liquid nitrogen is therefore advantageous from the viewpoint of multi-observational sites required in the future. Thus, this offers greater promise in realizing practical systems.
The author and research group has established the Iwaki observation site (IWK) at Iwaki City, (Fukushima prefecture), to enable continuous observation of the Earth's magnetic fields using a HTS-SQUID magnetometer. Constant observation is now ongoing (Figure 2, Figure 3). Currently, the system operation is stable and has acquired some magnetic variations associated with earthquakes. Further data accumulation studies is planned to determine the future feasibility of this system for practical use.

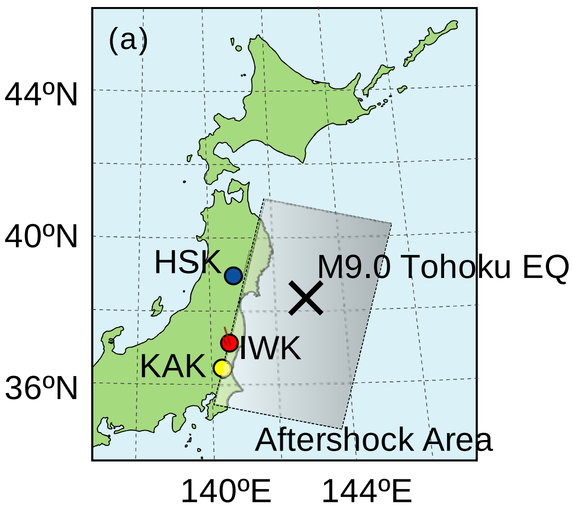

Fig. 2 Observational sites and the map of Japan

Fig. 3 HTS-SQUID magnetometer for terrestrial magnetism observation studies

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1) K. Okubo, *et al*., "Direct magnetic signals from earthquake rupturing: Iwate-Miyagi earthquake of M 7.2, Japan, EPSL 305, 1, pp. 65, 2011.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Superconducting Sensor Applications for Astronomical Observations – ALMA International Project

Yoshinori Uzawa, Director
Terahertz Collaborative Research Center
Terahertz Technology Research Center
National Institute of Information and Communications Technology

Fig.1 ALMA telescope constructed in the Atacama Desert, 5,000m above sea level (photo of mountaintop facility)

The Atacama Large Millimeter/submillimeter Array (ALMA) located in the Atacama Desert, 5,000m above sea level, in north region of Chile, South America, is the largest ground-based radio-astronomical telescope jointly constructed in a project involving East Asia, North America and Europe (Figure 1 shows the "AOS" mountaintop facility). Amongst the millimeter and submillimeter wavelengths heterodyne receivers to be installed in all of the 66-unit parabolic antennas that make up the telescope, the National Astronomical Observatory of Japan has been developing and manufacturing superconducting receivers designed for Band-4 (125-163 GHz), Band-8 (385-500 GHz), and Band-10 (787-950 GHz). The development of the Band-10 receiver covering the highest frequency ranges of those receivers at ALMA was launched in 2005, with manufacturing/testing for all the receivers completed in 2013. This article presents the summary outcomes from the viewpoint of the author based at the National Astronomical Observatory, who was in charge as leader of development of the Band-10 receiver.

The most challenging performance specifications required by the ALMA project was the receiver noise temperature, (which had to be less than five times the quantum noise). Band-10 exceeds the gap frequency of niobium (Nb), which has been conventionally utilized in such applications. The author and his development team have therefore developed a new niobium titanium nitride (NbTiN) superconducting material that has led to the successful demonstration of a SIS-mixer, exhibiting the world's lowest noise performance characteristics. All 73-unit receivers (including spares) that were shipped to Chile, have satisfactory demonstrated the challenging specifications required by ALMA. Figure 2 shows the minimum noise at each frequency measured by those receivers, which measured around three times the quantum noise, thereby virtually attaining the performance characteristics equivalent to conventional Nb receivers operating at lower frequencies. Furthermore, AOS has seen the world's first successful terahertz interferometer test using 2-unit antennas, each of which is equipped with a Band-10 receiver (Figure 3). The superior receiving performance attributes have been verified.[1)]

Reference:

1) http://alma.mtk.nao.ac.jp/j/

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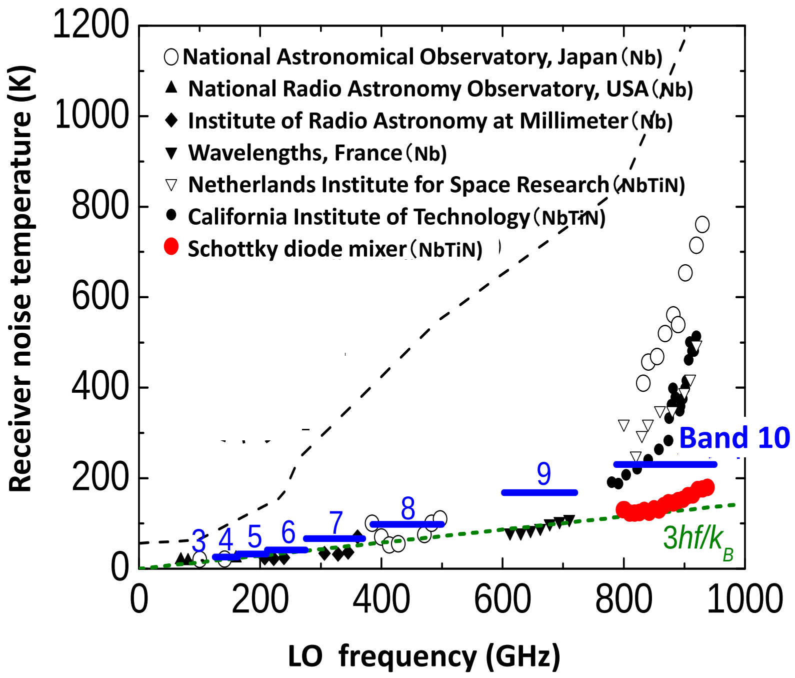

Fig. 2 ALMA noise specifications (blue line) and its actual performance demonstrated (red circle)

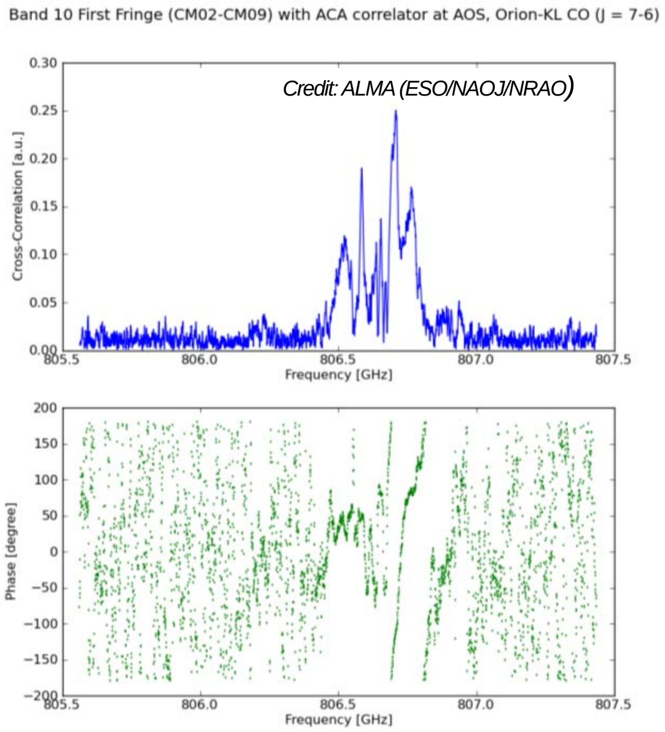

Fig. 3 Spectrum (above) and phase (below) captured from Orion KL

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Exploring Novel Superconducting Materials

Junichi Shimoyama, Associate Professor
Department of Applied Chemistry
School of Engineering, The University of Tokyo

A desire to explore novel superconducting materials has always been at the forefront of the research agenda throughout the more than 100-year history of superconductivity, which began with mercury. The trend continues into today, passing through several periods of research fevers. World records of critical temperatures (T_c) have been continually broken, first by elements followed by metal carbides, nitrides, alloys, intermetallic compounds, and finally copper oxides. Currently, at atmospheric pressure the highest T_c is 138K, while a zero resistance measured at a maximum of 153K has been realized under higher pressures. Figure 1 shows the transition of critical temperature of superconductors. Initial studies focused on whether superconductivity could be realized by cooling existing elements and alloys. Attempts gradually shifted towards intentionally fabricating materials exhibiting similar structures and compositions, i.e. new materials were fabricated in order to explore novel superconductors.

A report by Hardy and Hulm published in 1953 [1], listed 30 types of silicon and germanium alloys that were fabricated. Amongst these, eight compounds demonstrated superconductivity, reporting a maximum T_c of 17 K achieved in V_3Si, a record at that time. However, soon after an A15-type V_3Si crystal structure gathered attention, where a measured T_c=18 K was observed in Nb_3Sn [2]. Thus, superconductor research fever entered a phase investigating A15-type intermetallic compounds. A series of copper oxide-based superconductors were discovered consecutively from 1986 onwards. Here, all materials exhibited new chemical compositions and crystal structures apart from La_2CuO_4 doped with alkaline earth metals. Figure 1 shows that a rapid increase in world-breaking T_c's coincided with the research fever of copper oxide superconductors. In particular, the T_c record was enhanced more than 50 K by $YBa_2Cu_3O_y$, and its T_c value 92 K exceeded the boiling point of liquid nitrogen (77 K). It was during this period that the term "high-temperature superconductivity" was established. This remarkable increase in T_c exceeded the predictions of many researches at that time and was questionable soon after the initial press releases. However, within one month, a 90K-class high T_c emerged worldwide and this led to consecutive discoveries

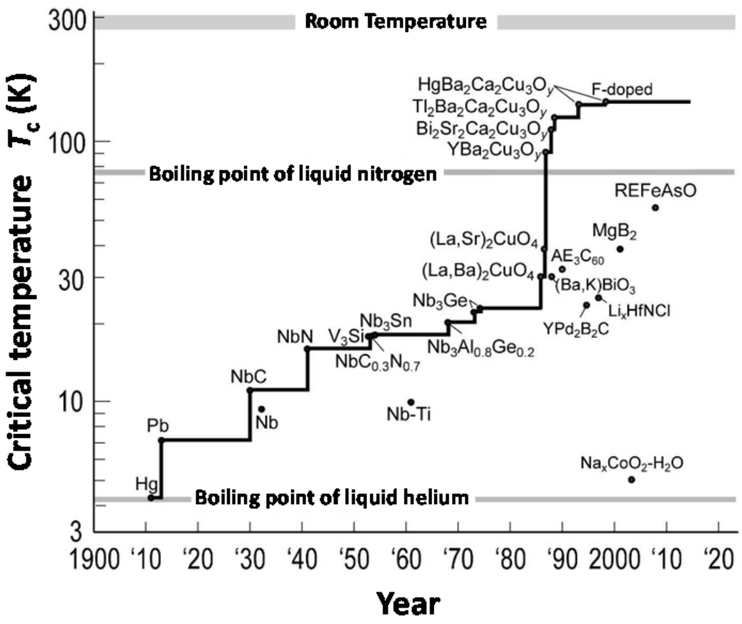

Fig. 1 The transition of critical temperature (T_c) of superconductors

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of superconductors in related material systems.
Superconductivity in MgB_2 was realized in 2001, which was an already known and commercially available material. Since 2008, many new breeds of iron-based superconductors were consecutively discovered. Even now, discoveries of new superconductors are being reported. Although T_c's of 39 K and 55 K for MgB_2 and in iron-based superconductors, respectively are not very high, these superconductors are anticipated as potential superconducting materials without requiring liquid He for cooling.

Although superconductivity has such a long history, there is no royal load to discoveries of novel superconducting materials. A very large number of fabricated material systems unintended for superconductivity and unexpected material choices have unpredictably demonstrated superconductivity. It is assumed that the theory behind the superconductivity phenomenon was almost been established. However, it was barely utilized for exploring novel superconducting materials. Thus, currently, we cannot make even low-level predictions as to whether novel material selections will demonstrate superconductivity or not, and what the measured T_c will be. In other words, in a similar fashion to the exploration of novel superconducting materials undertaken 100 years ago, an element of joy (dream) like *"we don't know anything until we try!"* still remains today. Of course, nothing is strange if room temperature superconductors (superconductor exhibiting T_c at around room temperature) is coincidentally discovered somewhere in the world today. Even if room temperature superconductors were to be discovered, this will probably not be a superconducting material that can be practically used at room temperature. A superconductor available at room temperature is truly a high temperature superconductor.

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1) G.F. Hardy and J.K. Hulm, *Phys. Rev*. **89** (1953) 884.
2) B.T. Matthias, T.H. Geballe, S. Geller, and E. Corenzwit, *Phys. Rev*. **95** (1954) 1435.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - High Field Magnets

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The commercialization of high temperature superconducting wires has led to the worldwide development and progression of superconducting device applications utilizing such wires. Specifically, rare earth high temperature superconducting, $REBa_2Cu_3O_y$ (RE123) coated conductors exhibit superior mechanical and high in-field critical current density characteristics. Since its conception, an expectation towards high field magnet applications has remained high on the research agenda. Currently, the National High Magnetic Field Laboratory (NHMFL) in the USA is progressively developing a 32 T-superconducting magnet, and is being followed by worldwide developments of high field superconducting magnets [1]. On the other hand, challenges associated with tape-shaped high temperature superconducting materials with high critical temperature characteristics have been raised, having issues that were not apparent in conventional materials. Problems included burnout caused by hotspots, and degradation attributed to the delamination of RE123 multilayers. Several methods designed to resolve these issues have been proposed and the realization of high temperature superconducting high field magnets is anticipated. In this article the author highlights several major developments of high temperature superconducting high-field magnets, in particular the development of cryogen-free, 25 T superconducting magnets and the proposed 50 T hybrid magnet, which have also been led by the Institute for Materials Research, Tohoku University.

Figure 1 shows the magnetic field generated by liquid helium cooled superconducting magnets (SM) and cryogen-free superconducting magnets (CSM) which have been developed since 1990. The material names as shown in the Figure are for the innermost coil. Since 2000 onwards, a change of superconducting materials from metalic superconductors to high temperature superconductors is clearly observed. As of 2014, the maximum magnetic fields generated by superconducting magnets stand at 24 T and 20 T for helium cooling and cryogen-free, respectively. The symbols in the brackets of the figure relate to the test results using compact coils, performed in a water-cooled copper magnet back-up field (19 T or 31 T) at NHMFL. A maximum magnetic field of 35 T has been successfully realized in these tests. It has been reported that the high performance characteristics of high temperature superconducting materials has finally been demonstrated, although they are not a whole superconducting magnet. High temperature superconducting materials therefore have to be capable of generating magnetic fields greater than 35 T. A 25 T cryogen-free superconducting magnet developed at the Institute for Materials Research, Tohoku University, and a 32 T superconducting magnet developed at the NHMFL consist of outer NbTi and Nb_3Sn superconducting magnets and RE123 inner magnets. Both magnets are designed with a strong electromagnetic stress of around 450MPa, using the advantage of the superior mechanical properties of RE123.

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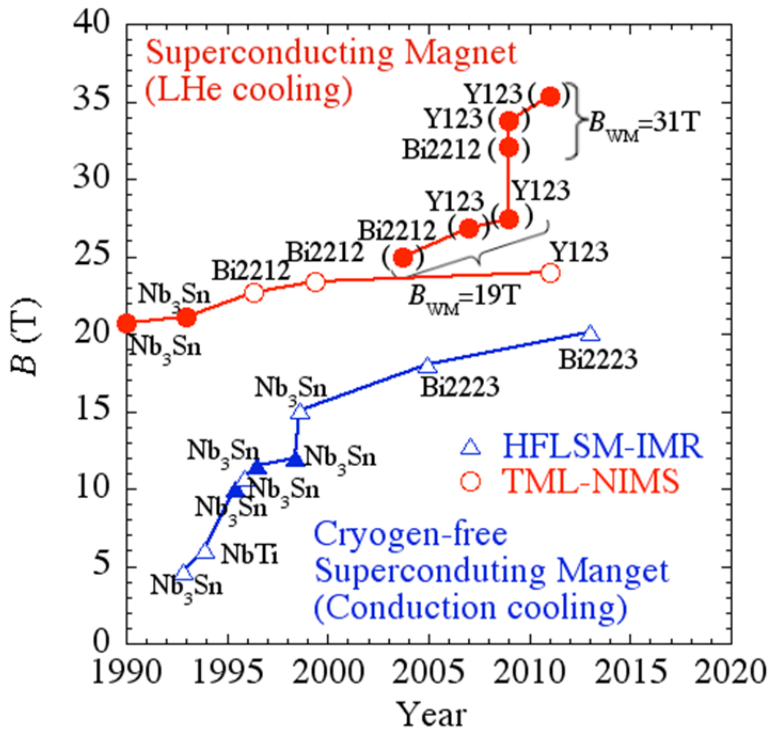

Fig. 1 The transition in the magnetic fields generated by liquid helium cooled magnets and cryogen-free superconducting magnets. White triangles indicate results from High Field Laboratory, Institute for Materials Research, and the white circles relate to the results obtained by NIMS

Reference:

1) D. Markievicz *et al*., IEEE TAS 22 (2012) 4300704.
2) S. Awaji *et al*., IEEE TAS 24 (2014) 4302005.

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Feature Article: Forum on Superconductivity Technology Trends 2014 - Overview of Projects Undertaken Worldwide

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The research and development field has accelerated with globalization and it has become vital to understand worldwide trends and the efforts of each county. Every year, ISTEC hosts the International Symposium on Superconductivity and actively supports the International Superconductivity Industry Summit. Leading researchers form around the world working in the superconductivity field provided an overview of country trends, which were published last year in ISTEC's on-line journal "Superconductivity Web21". Additional information allowed the editing office to publish *"Current worldwide projects"* in an easy to understand table format [1)] (table below). Each member corporate, institution and other researchers have effectively utilized this information for their R&D activities as well as preparing their project-planning drafts.

In this article, the author introduces major worldwide projects. The projects conducted in Japan were excluded on this occasion since these were introduced in other lectures.

The following provides an overview of the major projects conducted by each country:

EU: EUROTAPES-Pj (wire development) was launched involving many research institutions. However, wire characteristics such as length and I_c are not comparable to past records set by Japan and USA. On the other hand, the world's longest 1km-class high-temperature superconducting cable (AmpaCity-Pj: Essen, Germany) has entered the final stage (final year 2016). There are four ongoing research studies focusing on wind power applications (amongst these, only Hydornenie Pj of GE has completed. Others as shown in the table), Suprapower Pj employs low cost MgB_2 wires. Columbus Superconductors, a leading superconducting wire venture based in Italy, has a significant presence.

USA: Similar to Europe, investigations focusing on wind power applications have increased. MgB_2 can be easily fabricated into long wires, and investigations of potential equipment applications utilizing these wires have begun. Coiling development for high-field applications have launched in Florida. The author considers that this could be the first large-scale coil employing YBCO coated conductors, similar to a coil developed by Tohoku University. The investigations have been aiming for the design of a practical system, able to cope with electromagnetic forces as well as having quench protection. Further information is expected for the future development of large-scale coils.

Korea: Whilst conventional wire development Pj (DAPAS) has concluded, demonstration projects (AD, DC cables) for renewable energy applications, including wind power and photovoltaic power generation are now being advanced under JEJU-Pj.

Russia: Superconductivity development has intensified recently. Demonstrations of the world's longest 2.5km cables have taken place in St. Petersburg, as well as wire development projects advancing under the Superconducting Industry Project, together with other developments undertaken at other institutions.

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ROSATOM and the Federal Grid Company have led the trials. Russia has a strong interest in energy from a national characteristic viewpoint.

China did not participate at ISIS2013, and thus latest information is not available. Using 2012 data published in Web21, the author selectively highlights the topics.

Reference:
1) http://www.istec.or.jp/web21/pdf/14_03/all.pdf （ISTEC Web21 March, 2014 issue）

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World Project at a Glance (as of 2014 August)

Country	Project (Pj) Name (*not official name)	Contents					
		Devices, Wire	Summary of Target	Status (- unknown)	Institutes involved	Budget, Term, other data (- unknown)	references/origin
EU	EUROTAPES Pj	Wire (Y)	ABAD, RABiTS Substrates, YBCO Wire and Processes: length of 500m, the cost of 100€/kAm, round wire and others	Started in 2012 200m-250A（BRUKER)	20 Institutes such as Bruker, Nexans, Theva….(8 companies, 6 Universities, 5 National Institute, 1 Technical Center in 9 countries)	€20M, since 2012.9 with 54 month	ISS2013 http://eurotapes.eu/
	ECCOFLOW Pj	Current Limiter	16.5kV/1kA class、24kV/1KA class, Y-FCL in a real grid planned (2013)	12kV/800A class (2011)、12kV/1kA class (2012) Resistive FCL set in substation. 24kV/1kA class FCL completed in 2012 End. Now for preparing	Nexans	—	ISIS2013
	AmpaCity Pj	Cable, Current Limiter	10kV/2.3kA class FCL (Y), 10kV/2.3kA-1km 3 phase cable (Bi)	Operation started in Essen (2014)	Nexans, KIT, Siemens	2011-2015	ASC2014, ISIS2013
	Italian RSE/a2a Pj*	Current Limiter	12 kV/4.6 MVA, 2-year Operation and Upgrade	Success of 2-year Operation (Bi). 9kV/15.6	RES, a2a Reti Elettriche	2012-2014+	ASC2014, Exco 2013 Milan
	Suprapower Pj	Wind Generator	over 10MW HTS Generator without Gear system, MgB_2, Cooling R&D (KIT)	in designing of 10MWmachine（Weight 30%reduction, efficiency more than 95%)	tecnalia, Acciona, Columbus, Oerlikon-Leybold, Univ. of Southampton, KIT	2012Dec-2016	ISIS2013
	INNWIND.EU Pj	Wind Generator	10-20MW machine, high efficiency, for off-shore windmill	—	Siemens、Suzlon、Gamesa、DTUほか27 Institutes	€ 13.8M, 2012-2017	ISIS201 3
	HTS-Geno Pj	Wind Generator	YBCO large field winding and test system	Winding technique for large Coil and other R&D	KIT, Siemens	€4M, 2011-2014	ISIS201 3
	DC Cable Pj*	DC Cable	kA-class cable	tested at 1.5-15kA, 150-500kV	Nexans	—	ISIS201 3

Note: Here only posted the EU part while you can see other area's projects in Aian, US, Korea and China.