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# Superconductivity Web21

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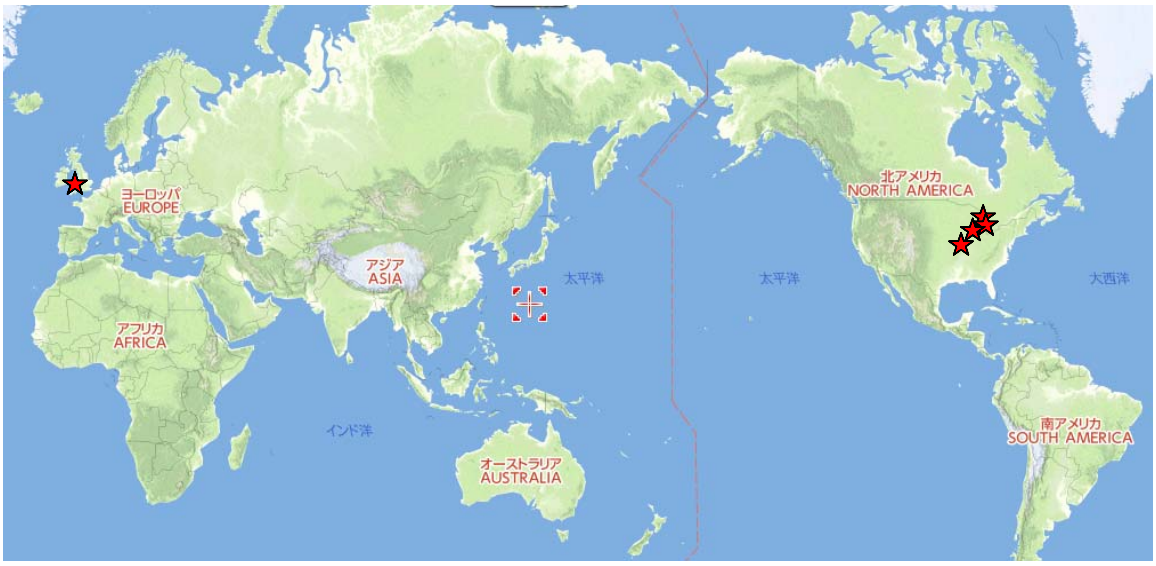
## What’s New in the World of Superconductivity

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

## ▸Magnet

### New 21Tesla Ultra-High Field MRI

**Bruker Corporation (17 Sep, 2014)**

BioSpec 210/11 is a new 21 Tesla ultra-high field MRI with Buker’s latest CryoProbe™. This system provides increases in sensitivity and resolution, giving a significant boost to cellular and molecular research and the potential for gaining new insights in preclinical research.

The instrument scanner is based on Bruker’s proven 21 Tesla 11 cm UltraShield™ (USR) magnet technology, successfully employed in FT-mass spectrometry. USR reduces stray magnetic fields and Bruker’s active magnet refrigeration technology almost eradicates the need for cryogen top-ups, limiting downtimes and user maintenance costs.

Wulf I. Jung, Ph.D., President of Bruker's Preclinical Imaging Division, commented, "The level of discrimination that we can now deliver with the 21Tesla MRI has not been possible with previous systems. I am very pleased that Bruker's latest CryoProbe technology, together with our ultra-high field magnets and unique software packages, can provide the quality of data needed to push back the boundaries of research."

Source: "Bruker's new 21Tesla Ultra-High Field MRI with CryoProbe allows in vivo Investigation to shift from Organ and Tissue Imaging to Cellular and Molecular research"
(17 Sep, 2014)
http://www.bruker.com/news-records/single-view/article/brukers-new-21tesla-ultra-high-field-mri-with-cryoprobe-allows-in-vivo-investigation-to-shift-fro.html
Contact: Dr. Thorsten Thiel, Thorsten.thiel@bruker.com

## ▸Power Application

### New D-VAR® Contracts in Canada, UK, and US

**AMSC (29 Sep, 2014)**

AMSC has announced 3 new D-VAR® STATCOM contracts in Canada, United Kingdom, and United States. Daniel P. McGahn, President and CEO, AMSC is quoted as saying, "AMSC's D-VAR STATCOM system enables renewable energy plants to safely and efficiently connect to the electric grid. It also helps utilities to enhance grid utilization on existing power systems and protects industrial facilities from voltage instability". All systems are expected for delivery in 2014.

The D-VAR system provides dynamic voltage control and power factor correction to stabilize and prevent events such as voltage collapse occurring in the power grid. The systems are classified are as Static Compensators, or "STATCOMs," a member of the FACTS (Flexible AC-Transmission System) - power electronic solutions for alternating current (AC) power grids. The systems are designed to simultaneously and instantaneously compensate for voltage disturbances by dynamically introducing reactive power into the power grid.

The D-VAR systems enable developers the efficient interconnection of generated renewable energy to the power grid in addition to the safety standards. Senvion SE (formerly REpower) based in the UK will employ D-VAR system to connect the Strathy North Wind Farm to the power grid. Currently the wind farm is under construction and will be made up of 33 Senvion MM82 wind turbines. It is expected to be fully operational by the end of 2015. In the USA, the D-VAR system will connect the Route 66 Wind Farm (currently under construction) in Amarillo, Texas to the Electric Reliability Council of Texas (ERCOT) power market. This will be AMSC's second project with First Wind, an independent US-based wind energy company. It is expected to generate 150 megawatts (MW) of renewable energy. In Canada, a D-VAR system to be installed near a port and rail facility will be designed to reduce flicker violations caused by the starting of large electric motors at the facility.

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Source: “AMSC Announces New D-VAR® System Contracts in Canada, United Kingdom, and United States”
(29 Sep, 2014)
http://ir.amsc.com/releases.cfm
Contact: Kerry Farrell, kerry.farrell@amsc.com

## ▸Wire

### New Insulator TiO2 for HTS Magnets

**North Carolina State University (4 Sep, 2014)**

Research from North Carolina State University shows that modified titania, offers potential as an electrical insulator for superconducting magnets, allowing heat to dissipate while maintaining the electrical current path. The chemical composition of the titania remains proprietary information. The development and characterization of this material was a joint effort between NC State and nGimat LLC, based in Lexington, Kentucky.

Dr. Sasha Ishmael, a postdoctoral researcher at NC state and lead author of a paper describing the work, says “Changing the current inside the superconductor is important for many applications, but this change generates heat internally. The magnets will operate much more safely if the electrical insulators are able to shed any excess heat. Otherwise, the higher temperatures could destroy the superconductor. This titania-based material is up to 20 times better at conducting heat than comparable electrical insulators. It has characteristics that are very promising for use as electrical insulators for superconducting technologies.”

“We’re now looking at the effect of radiation on this material, to determine if it can be used for high energy physics applications, such as particle colliders,” says Dr. Justin Schwartz, senior author of the paper and Kobe Steel Distinguished Professor and head of the Department of Materials Science and Engineering at NC State.

The paper, “Thermal conductivity and dielectric properties of a TiO2-based electrical insulator for use with high temperature superconductor-based magnets,” is published online in the journal *Superconductor Science and Technology*.

Source: “Titania-Based Material Holds Promise as New Insulator for Superconductors”
(4 Sep, 2014)
http://news.ncsu.edu/2014/09/schwartz-superconductor-insulator-2014/
Contact: Dr. Justin Schwartz

## ▸Basics

  

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## Two-dimensional Electron Liquids for Novel Superconductivity

**Joint Quantum Institute (18 Sep, 2014)**

Truly two-dimensional objects have quantum interactions that can lead to new phenomena. Two examples are grapheme, which has exceptional mechanical, electrical, and optical properties and a two-dimensional electron gas (2DEG), which allow the observation of the quantum Hall effect and the spin Hall effect.

A relatively new example of studying 2D matter is being led by James Williams, a new fellow at the Joint Quantum Institute (JQI), where he is also an assistant professor of physics at the University of Maryland. The aim here is to investigate planar collections of electrons at the surface of transition-metal-oxide (TMO) materials, which are a 2D liquid rather than as a 2D gas. The high electron densities in these materials give rise to interactions that are stronger than those found in semiconductors.

Prior to joining the University of Maryland, Prof. Williams was at Stanford University, where he and his colleagues performed tests on a thin sample STO, patterned with a 50-nm-wide gate electrode is wetted by an electrolyte gel. An unseen electrode draws off the negative ions in the electrolyte. The positive electrolyte ions remain on the STO surface, where they induce a dense 2D layer of electrons to form directly beneath. The transport of these electrons can be controlled by applying a voltage to an overlying electrostatic gate, in a similar fashion to FETs.

It was Williams and his colleagues at Stanford and Santa Barbara, who were the first to discover that bulk strontium titanate (a common TMO) that was simultaneously superconducting and ferromagnetic, a characteristic that can be tuned by changing the density of electrons in the sample. At low voltages (electron densities of less than 8 x 10^12 electrons per sq. centimeter) the barrier material is an insulator. At a medium voltage and electron density leads to quantum tunneling. At higher voltages (above 5 x 10^13 electrons per sq. centimeter) miniature conducting zones materialize allowing superconducting currents to flow freely, much greater than found in existing FETs.

The studies being conducted now are interested in seeing how normal and supercurrents flow through tiny channels from one superconducting STO panel to another. The channel dimensions are equivalent to electron wavelengths and it is expected that quantum effects will occur. Thus the superconducting STO material is quantized and the conductivity of Cooper pairs should only occur at certain levels, namely multiples of 2e^2/h, where e is the charge of an electron and h is Planck's constant. However, the current versus gate voltage demonstrate that the conductivity can also occur at multiples of e^2/h. The combination of the high electron density and their interactions has not been observed in other materials and the enforced quantum behavior through the tiny passage may be producing a new kind of electron transport in which the degrees of electron spin are broken.

The material becomes superconducting as the electron density is increased outside the quantum point contact. Studying the transmission of Cooper pairs (electrons with opposite spins) across the quantum point allowed researchers to ascertain that their transmission across the quantum point prevents electrons with opposite spins. The question is then as to how do Cooper pairs make it through the quantum point? The present understanding is that Cooper pairs in this particular TMO may not pair in a conventional way. Their experimental findings are reported online in the journal Nature Physics published August 31, 2014.

  

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Source: "Two-dimensional electron liquids/LOOKING FOR NOVEL FORMS OF SUPERCONDUCTIVITY" (18 Sep, 2014)
http://jqi.umd.edu/news/two-dimensional-electron-liquids
Contact: Phillip Schewe, pschewe@umd.edu

## Quest for Room-temperature Superconductor using 'Solid Light'

**Princeton University (8 Sep, 2014)**

Researchers at Princeton University have begun crystallizing light to answer fundamental questions about the physics of matter. Their research, reported online Sept. 8 in the journal Physical Review X, is transforming light into crystals by locking photons into place, in an effort to develop exotic materials such as room-temperature superconductors. Photons obey the rules of quantum mechanics, where multiple particles become linked and can affect each other over long distances, a behavior called "entanglement".

In their experiment, at first, photons travel easily between the two superconducting sites producing the large waves. After a time, the scientists cause the light to 'freeze,' trapping the photons in place. Fast oscillations demonstrated are evidence of the new-trapped behavior. Their findings are an effort to answer fundamental questions about atomic behavior by creating an experimental device that can simulate the behavior of subatomic particles.

Additionally, the team was approaching to build a machine that directly simulates quantum behavior and answering important questions regarding the creation of a general-purpose quantum computer. Researchers created a system structure made of superconducting materials containing 100 billion atoms, specifically engineered to act as an "artificial atom." They placed the artificial atom close to a superconducting wire containing photons. Typically photons do not interact with each other, but in the Princeton device, the researchers were able to create new behavior in which the photons interacted like particles. The current device has only two sites where an artificial atom is paired with a superconducting wire. However, by expanding the device and the number of interactions will enable the researches to simulate more complex systems from a single molecule to an entire material. The team hopes that a future device with hundreds of sites will lead them to observe exotic phases of light such as superfluids and insulators.

Mohammad Hafezi, an assistant professor of electrical and computer engineering at the University of Maryland, is quoted as saying, "Quantum nonequilibrium systems are difficult to describe theoretically, but their experimental investigation could shed light on fundamental questions about how quantum systems thermalize and even the formation of the early universe".

Source: "'Solid' light could compute previously unsolvable problems" (8 Sep, 2014)
http://www.princeton.edu/engineering/news/archive/?id=13459
Contact: Martin Mbugua, mmbugua@princeton.edu

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# Feature Article: Refrigeration and Cryogenic Technologies - Current Progress of Brayton Refrigerators

Norihisa Nara
Superconductivity Project, Tsukuba Laboratories
Taiyo Nippon Sanso Corporation

High-temperature superconducting (HTS) power equipment is considered as one vital component required for energy saving technology, and to this aim, the research and development of practical superconducting cables and superconducting fault current limiters currently has entered the final feasibility phase. Amongst these studies, the needs of refrigeration systems suitable for HTS power equipment are crucial. Compulsory refrigeration specifications applicable for HTS power equipment include 1) operational temperature control and cooling capacities able to sustain stable superconductivity characteristics, 2) highly reliable long-term continuous operation, 3) high cooling efficiencies (low running costs), 4) system compactness (compact footprint), and 5) low maintenance costs.

The operating temperatures of refrigeration systems overall employed for cooling HTS power equipment ranges between 20 and 80 K, however, superconducting cables in particular require 5-10 kW at 70 K operation. Current commercially available compact cryocoolers only provide cooling capacities of around 1 kW at 80 K operation, and moving parts in the system typically require regular maintenance once per year. On the other hand, cryogenic air separation units and large-scale cryogenic systems such as helium liquefiers have expansion turbines comprising of non-contact bearings, which have proven durability qualities. However, the cooling capacities of such systems far exceed that required by HTS power equipment. To address this discrepancy, a turbo-Brayton refrigerator prototype was developed using neon as the working gas, under NEDO's "Technological Development of Yttrium-based Superconducting Power Equipment" project.

A cooling system comprising the prototype refrigerator consisted of a cold box, a turbo compressor and a liquid nitrogen sub-cool heat exchanger unit. Later, the system was commercialized as an integrated refrigerator, where all the components were packaged onto a single platform. Of great significance was the sub-cool heat exchanger, which was housed in a cold-box and thus eliminated the need for a sub-cool heat exchanger unit. Figure 1 shows a 3D-image of a 2 kW neon turbo-Brayton refrigerator launched in the market last year. The main heat exchanger and sub-cool heat exchanger are housed in a centrally located cold box, with the expansion turbine installed in the upper part of the cold-box. A turbo compressor used to compress the neon refrigerant is installed adjacent to the cold-box. In a system similar to the prototype, the adoption of magnetic bearings in the turbo compressor and in the expansion turbine eliminates moving parts, thereby realizing maintenance-free operation. Furthermore, feedback control of the sub-cool liquid nitrogen temperature regulates the turbo compressor revolutions and thereby controlling the cooling capacity of the refrigerator. The system is integrated into a compact package including a buffer tank for neon gas storage and peripherals such as control console, permitting easier transportation and installation at the final site.

  

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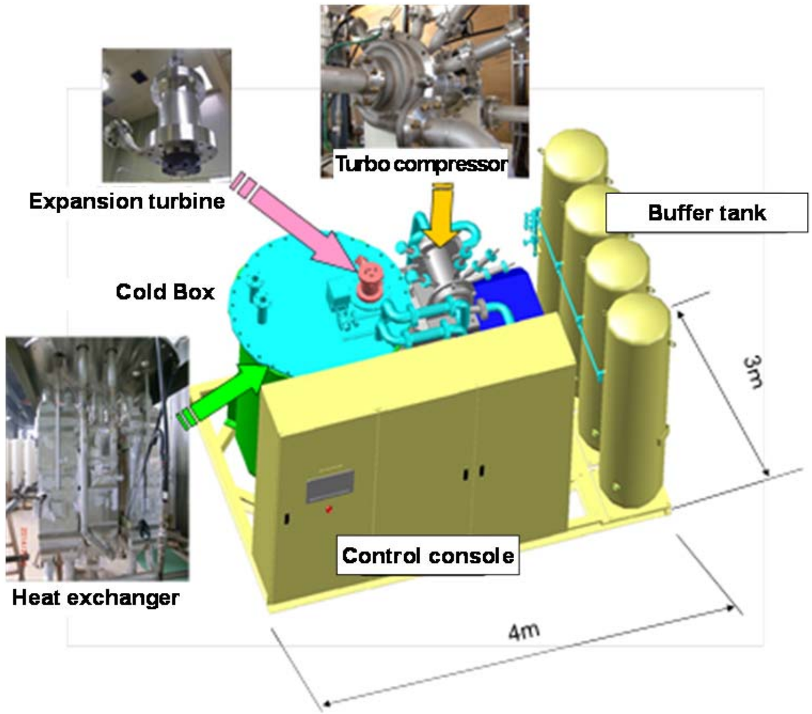


Fig. 1 2 kW-class neon turbo-Brayton refrigerator

Whilst demonstration studies of HTS power equipment has been undertaken on a practical scale, larger refrigerators with even greater cooling capacities are required. The developments of 5 to 20 kW-class prototype systems are now progressing at respective research institutions. Figure 2 shows the conceptual schematic of a 10 kW-class refrigerator currently developed at the Taiyo Nippon Sanso Corporation. A main heat exchanger is housed in a horizontally positioned cold box, and a turbine compressor is installed in the upper part of the cold box. A neon gas buffer tank and control console is also installed onto a common platform. The performance characteristic trials of prototype 10 kW-class refrigerators are planned during 2014.

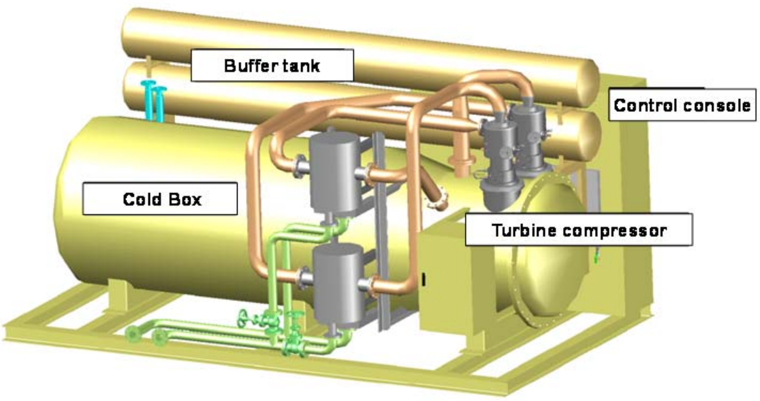


Fig. 2 10 kW-class neon turbo-Brayton refrigerator (conceptual schematic)

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# Feature Article: Refrigeration and Cryogenic Technologies - Demonstration Results of Cryogenic Cooling System for High-temperature Superconducting Cable

Naoko Nakamura
Vice Research Fellow, Research and Development Center
Mayekawa MFG. Co., Ltd.

A project initiated by NEDO entitled, "Demonstration project of high-temperature superconducting (HTS) cable", signified the connection of a HTS cable system to the grid on 29 October 2012, completing over one year of verification trials as of 25 December 2013. There were no significant cooling system issues during the trials, thereby confirming its performance merits and the promising findings are a step closer towards realizing practical HTS cables in future. The author introduces a summary of the trial results herewith:

The cooling system for the HTS cable comprised of a refrigerator, a circulating pump and a reservoir tank equipped with a pressure control device (Figure 1). The HTS cable was cooled continuously by circulating sub-cooled liquid nitrogen, taking into consideration the homogeneous cooling and electrical insulation attributes of the cable. Each component was selected by its track record and choices being, a 1kW-class Stirling cycle refrigerator and a centrifugal circulating pump. A total of six refrigerators and two circulating pumps were employed after contemplating variations in thermal loss and redundancy of HTS cables. An unattended demonstration of the HTS cable system were conducted at the Asahi Substation of the Tokyo Electric Power Company with remote supervision of the operational status of both liquid nitrogen and every component, sending warnings to substation monitoring centers and project managers of any impending issues.

Fig. 1 Cooling system for HTS cable demonstration trials

  

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Adjusting the reservoir tank pressure and changing the number of refrigerators in operation automatically regulated the cable supply temperature, continuously supplying sub-cooled liquid nitrogen. Unattended operation of this system requires the recirculation of sub-cooled liquid nitrogen in a closed cycle without the liquid nitrogen needing to be topped-up. The cable remained sub-cooled during these trials amidst seasonal and daily fluctuations of thermal loss and phased liquid nitrogen temperatures changes varying between 69K and 75K. Thus, the operation was successfully undertaken without liquid nitrogen needing to be top-up. However, after three months of continuous operation in the grid, deterioration in the refrigeration cooling performance was observed. Investigations concluded that a refrigeration gas leak into the vacuum chamber was the main culprit behind this. Despite this, it was still possible to sustain a certain level of cooling capability by regular vacuum pumping, however, the refrigerator required maintenance before and after 8000-hrs of continuous operation. The author and her research team confirmed that sustaining refrigerator performance characteristics over long periods and extending maintenance intervals were significant hurdles to be resolved in realizing HTS cable for practical use. The first step in the development of the 5kW-class Brayton cryocooler (Figure 2), undertaken in parallel with cable verification trials, was to aim for greater efficiencies (COP0.1). The equipment design took into consideration maintenance intervals and working characteristics, with important goals such as having greater reliability than typical refrigerators employed in industrial applications.

Fig. 2 5kW-class Brayton cryocooler planned for demonstration trials at the Asahi Substation

The current project concluded in February 2014. The next project phase currently planned at the Asahi Substation for the 5kW-class Brayton Cryocooler involves demonstration trials to be conducted for more than a year. Successful outcomes from this phase of the project will ultimately lead to the potential application of HTS cables into grid system. Thus, the author and her team hope for a positive outcome.

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