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What's New in the World of Superconductivity (December, 2011)

Shinya Hasuo, Senior Research Fellow
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Grid interconnection project

Tres Amigas (December 27, 2011)

Tres Amigas LLC has announced that Mitsui & Co., Ltd., has agreed to invest US$ 12 million in the Tres Amigas SuperStation, a national grid interconnection project that is being undertaken in the USA. In exchange, Mitsui will obtain an equity position and will actively participate in the project, thereby internationalizing their "Smart Green Information Technology" business model. Phillip Harris, chair, president and CEO of Tres Amigas, commented, "…the commercial operation of the SuperStation requires intensive use of information systems and technology, as well as management of large scale infrastructure. Mitsui's worldwide experience in these areas will be invaluable." Construction of the SuperStation is scheduled to being in 2012, with the start of Phase I commercial operations scheduled for 2015.

Source: "Tres Amigas Announces $12 Million Investment from Mitsui & Co., Ltd."
Tres Amigas press release (December 27, 2011)

Sensors

National Institute of Standards and Technology (December 6, 2011)

The world's largest submillimeter camera has been mounted on the James Clerk Maxwell Telescope on Mauna Kea (Hawaii); the camera will be used to scan the universe including faint and distant sectors that have never been seen before, thereby accelerating studies of the origins of stars, planets, and galaxies. National Institute of Standards and Technology (NIST) physicist Gene Hilton reported, "The submillimeter is the last frontier in astronomical imaging. It's been very difficult to develop cameras that work at this wavelength, so the submillimeter is largely unexplored." The camera utilizes more than 10,000 superconducting sensors developed at NIST. Each of these sensors functions as a single pixel in the camera, which precisely measures submillimeter radiation. The NIST instrument is the largest superconducting camera ever to be made. The sensor arrays are also packaged with superconducting amplifiers to boost the signal strength. These amplifiers greatly reduce the number of wires required between the cryogenic instruments and the room-temperature electronics used to compile the data, making this large-scale sensor array feasible.

Source: "Powerful NIST detectors on Hawaiian telescope to probe origins of stars, planets, and galaxies"
National Institute of Standards and Technology press release (December 6, 2011)
http://www.nist.gov/pml/div686/scuba2-array.cfm

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Aalto University (December 15, 2011)
Physicists at Aalto University (Finland) have used a nanomechanical oscillator to detect and amplify feeble radio waves or microwaves. This device enables measurements to be made with the least possible disturbance. The device consists of a nanomechanical oscillator that it comes in contact with a superconducting cavity resonator, which exchanges energy with the nanomechanical resonator. This setup enables the resonant motion to be amplified. The phenomenon is similar to that which occurs in a guitar, where the string and the echo chamber resonate at the same frequency. The device will have certain real-life applications, but further research will be required. The group's findings were recently published in *Nature*.

Source: "Aalto University researchers demonstrate an almost noiseless nanomechanical microwave amplifier"
Aalto University press release (December 15, 2011)
http://www.aalto.fi/en/current/news/view/2011-12-15/

Accelerator

CERN (December 13, 2011)
The status of the search for the Standard Model Higgs boson using the ATLAS*1 and CMS*2 experiments was recently presented at a CERN seminar. The results are based on the analysis of large amount of data sufficient to enable significant progress in the search for the Higgs boson, although further data is still required to make a conclusive statement regarding the existence or non-existence of the Higgs boson. The main conclusion is that if the Higgs boson exists, its mass will most likely be constrained within a range of 116 – 130 GeV (based on the ATLAS experiment) or 115 – 127 GeV (based on the CMS experiment).
While tantalizing hints have been seen in this mass region in both experiments, the observations are not yet sufficiently strong to claim a discovery. Fabiola Gianotti, spokesperson for the ATLAS experiment, added, "…over the last few weeks we have started to see an intriguing excess of events in the mass range around 125 GeV. This excess may be due to a fluctuation, but it could also be something more interesting. We cannot conclude anything at this stage. We need more study and more data. Given the outstanding performance of the LHC this year, we will not need to wait long for enough data and can look forward to resolving this puzzle in 2012."
*1 A Troidal LHC Apparatus
*2 Compact Muon Solenoid

Source: "ATLAS and CMS experiments present Higgs search status"
CERN press release (December 13, 2011)

Helium gas price

Air Products (December 15, 2011)
Air Products has announced a price increase for liquid and bulk helium gases in North America effective January 1, 2012. The price increase is the result of the ongoing severe shortage in the global helium market

that has arisen from an increasing demand worldwide. Air Products stated that the shortage has made it increasingly difficult to meet customer requirements, and the present situation is expected to continue well into the future. The Air Products team is attempting to manage this difficult situation on a day-by-day basis to maintain an uninterrupted supply to its customers.

Source: "Air Products Announces North America Price Increase for Liquid and Bulk Helium Gases"
Air Products press release (December 15, 2011)

Basics

National Institute of Standards and Technology (December 8, 2011)
Physicists at the National Institute of Standards and Technology (NIST) have discovered a way to manipulate the internal state of atoms using lasers, thereby dramatically influencing the interactions of the atoms in specific ways. These light-tweaked atoms can be used as proxies to study phenomena that would be difficult or impossible to observe in other contexts. Recently, the group demonstrated a new class of interactions that are thought to be important to the physics of superconductors in applications such as quantum computation. The group trapped rubidium-87 atoms using magnetic fields and then cooled the atoms to 100 nanokelvins. At this temperature, the atoms form a Bose-Einstein condensate and move sluggishly. Lasers were then used to 'dress' the atoms, mixing together different energy states. The condensate was then split, and the two parts were collided to see how they would interact. Whereas atoms that were not laser-dressed exhibited mainly simple, low-energy interactions, forming a uniform sphere, atoms that were laser-dressed tended to scatter in certain directions, forming interesting shapes that suggested the influence of more complicated interactions not normally seen in ultracold atom systems. The ability to induce such interactions opens up a whole new range of quantum phenomena that can be explored. In future studies, the researchers plan to modify the scheme so as to study ultracold fermions in the hopes of finding evidence of the Majorana fermion, a theoretical particle thought to be involved in superconducting systems and important to quantum computation. The group's most recent findings were published in *Science.*

Source: "Atoms dressed with light show new interactions, could reveal way to observe enigmatic particle"
National Institute of Standards and Technology press release (December 8, 2011)
http://www.nist.gov/pml/div684/atoms-dressed-with-light-show-new-interactions-could-reveal-way-to-observe-enigmatic-particle.cfm

Caltech (December 13, 2011)
Two chemists at Caltech have developed a hypothesis explaining the behavior of high-temperature superconductors and suggesting a means of fabricating even higher-temperature superconductors. Using a cuprate doped with strontium atoms (replacing lanthanum atoms) and modern quantum-mechanical calculations, the chemists have found that each dopant atom creates a four-center hole in the copper atoms surrounding the strontium; the chemists have called this unit a "plaquette". Electrons within the plaquettes form tiny pieces of metal, while those outside the plaquettes are insulating and behave like magnets. This result is completely opposite to prevalent assumptions about what happens when dopant atoms are added.

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After five years of study, the chemists have finally discovered how these holes in the plaquettes lead to superconductivity. The chemists hypothesized that when a sufficient amount of dopant atoms have been added, the plaquettes are able to create a percolating pathway that allows electrons to flow through the material. The magnetic electrons outside the plaquettes can interact with electrons traveling through the plaquette pathway. This interaction, in turn, leads to the electron pairing that results in superconductivity. Furthermore, the chemists hypothesized that the pseudogap phenomenon is related to the location of isolated plaquettes that cannot interact directly with other plaquettes. These isolated plaquettes have two distinct quantum states with equal energy. These two states can interact with nearby isolated plaquettes, at which point the two distinct quantum states become unequal in energy, and the difference in energy is responsible for the pseudogap. According to this hypothesis, the size of the pseudogap could thus be determined by simply counting the number of isolated plaquettes and determining their distances from each other. William Goddard III, a professor at Caltech, further explained, "The electrons involved in the pseudogap are wasted electrons because they do not contribute to superconductivity. What is important about them is knowing that, since the pseudogap comes from isolated plaquettes, if we were to control dopant locations to eliminate isolated plaquettes, we should be able to increase the superconducting temperature." The chemists have predicted that by carefully managing the placement of dopant atoms, it might be possible to fabricate materials that superconduct at temperatures as high as -73°C, which would represent a significant step toward the creation of truly high-temperature superconductors. The group's latest paper has been published in The Journal of Physical Chemistry Letters.

Source: "Caltech Chemists Propose Explanation for Superconductivity at High Temperatures"
Caltech press release (December 13, 2011)
http://media.caltech.edu/press_releases/13481

Harvard University (December 22, 2011)
Physicists at Harvard University have discovered a new way to cool synthetic materials using a quantum algorithm to remove excess energy. The discovery represents the first application of "algorithmic cooling" to ultra-cold atomic gases. The group has been studying quantum many-body physics, characterized by the exotic and complex behaviors that result when simple quantum particles interact. Such behaviors give rise to high-temperature superconductivity and quantum magnetism, with potential applications in quantum computers. Waseem Bakr, a graduate student, explained, "We simulate real-world materials by building synthetic counterparts composed of ultra-cold atoms trapped in laser lattices. This approach enables us to image and manipulate the individual particles in a way that has not been possible in real materials." Such observations, however, require extreme temperatures. In a proof-of-principle experiment, the team demonstrated that fluctuations constituting temperature can be actively removed, rather than waiting for evaporative cooling. This "orbital excitation blockade" allows excess atoms to be removed from a crystal until there is precisely one atom per site. The group's work has been reported in Nature.

Source: "Harvard physicists demonstrate a new cooling technique for quantum gases"
Harvard University press release (December 22, 2011)

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