Research Update: Government Laboratory and University News

From August 2010 *High Frequency Electronics*

Scientists Strive to Replace Silicon with Graphene on Nanocircuitry

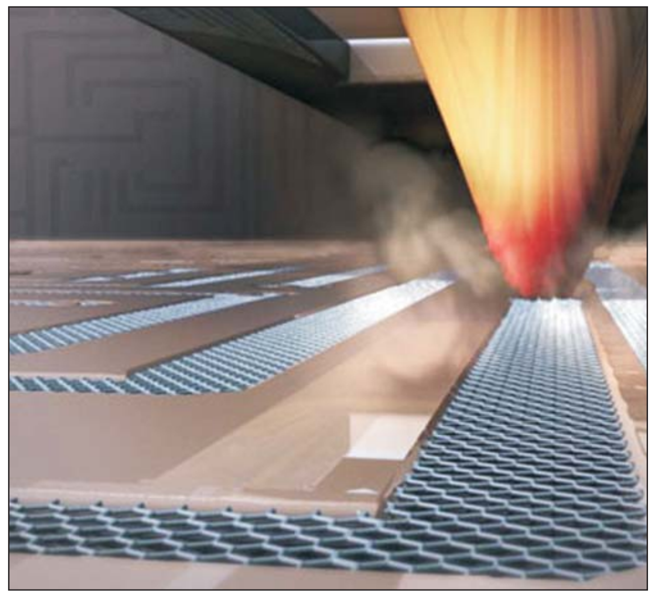
Scientists have made a breakthrough toward creating nanocircuitry on graphene, widely regarded as the most promising candidate to replace silicon as the building block of transistors. They have devised a simple and quick one-step process based on *thermochemical nanolithography* (TCNL) for creating nanowires, tuning the electronic properties of reduced graphene oxide on the nanoscale and thereby allowing it to switch from being an insulating material to a conducting material. The technique works with multiple forms of graphene and is poised to become an important finding for the development of graphene electronics.

Scientists who work with nanocircuits are enthusiastic about graphene because electrons meet with less resistance when they travel along graphene compared to silicon and because today's silicon transistors are nearly as small as allowed by the laws of physics. Graphene also has the edge due to its thickness—it's a carbon sheet that is a single atom thick. While graphene nanoelectronics could be faster and consume less power than silicon, until now, no one knew how to produce graphene nanostructures on such a reproducible or scalable method.

"We've shown that by locally heating insulating graphene oxide, both the flakes and epitaxial varieties, with an atomic force microscope tip, we can write nanowires with dimensions down to 12 nanometers. And we can tune their electronic properties to be up to four orders of magnitude more conductive. We've seen no sign of tip wear or sample tearing," said Elisa Riedo, associate professor in the School of Physics at the Georgia Institute of Technology.

On the macroscale, the conductivity of graphene oxide can be changed from an insulating material to a more conductive graphene-like material using large furnaces. The research team used TCNL to increase the temperature of reduced graphene oxide at the nanoscale, so they can draw graphene-like nanocircuits. They found that when it reached 130 degrees Celsius, the reduced graphene oxide began to become more conductive. The research team tested two types of graphene oxide—one made from silicon carbide, the other with graphite powder.

The research is a collaboration among Georgia Tech (www.gatech.edu), the U.S. Naval Research Laboratory (www.nrl.navy.mil) and the University of Illinois at Urbana-Champaign (www.uiuc.edu).



In a technique known as *thermochemical nanolithography,* the tip of an atomic force microscope uses heat to turn graphene oxide into reduced graphene oxide, a substance that can be used to produce nanocircuits and nanowires with controllable conductivity. *Image Credit: University of Illinois at Urbana-Champaign.*

THz Frequency Transceiver

Sandia National Laboratories (www.sandia.gov) researchers have taken the first steps toward reducing the size and enhancing the functionality of devices in the terahertz (THz) frequency spectrum. By combining a detector and laser on the same chip to make a compact receiver, the researchers eliminated the precision alignment of optical components formerly needed to couple the laser to the detector.

Terahertz radiation is of interest because some frequencies can be used to "see through" certain materials. Potentially they could be used in dental or skin cancer imaging to distinguish different tissue types. They also permit improved nondestructive testing of materials during production monitoring. Other frequencies could be used to penetrate clothing and possibly identify chemical or biological weapons and narcotics.

Since the demonstration of semiconductor THz quantum cascade lasers (QCLs) in 2002, it has been apparent that these devices could offer unprecedented advantages in technologies used for security, communications, radar, chemical spectroscopy, radioastronomy and medical diagnostics. Until now, however, sensitive coherent transceiver systems were assembled from a collection of discrete and often very large components. Similar to moving from discrete transistor to integrated chips in the microwave world and moving from optical breadboards to photonic integrated circuits in the visible/infrared world, this work represents the first steps toward reduction in size and enhanced functionality in the THz frequency spectrum.

The work, described in the current issue (June 27, 2010) of *Nature Photonics*, represents the first successful monolithic integration of a THz quantum-cascade laser and diode mixer to form a simple, but generically useful, terahertz photonic integrated circuit.

With investment from Sandia's Laboratory-Directed Research and Development (LDRD) program, the lab focused on the integration of THz QCLs with sensitive, high-speed THz Schottky diode detectors, resulting in a compact, reliable solid-state platform. The transceiver embeds a small Schottky diode into the ridge waveguide cavity of a QCL, so that local oscillator power is directly supplied to the cathode of the diode from the QCL internal fields, with no optical coupling path.

NIST Fellowship Announcement

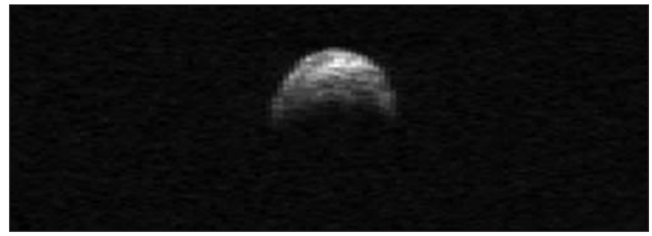
Applications for National Institute of Standards and Technology (NIST, www.nist.gov) measurement science and engineering fellowships—for graduate, post-doctoral and senior researchers—are now being accepted by the University of Maryland and the University of Colorado, which are administering the programs. In February 2010, NIST awarded a total of $19.5 million to the two institutions to implement and administer the fellowship programs, which were funded under the American Recovery and Reinvestment Act (ARRA) of 2009.

The University of Maryland-administered portion of the program will place successful applicants in positions at either NIST's campus at Gaithersburg, Md., or the Hollings Marine Laboratory (HML) in Charleston, S.C., which is a unique partnership involving NIST, the National Oceanic and Atmospheric Administration, and other of governmental and academic agencies. Fellows selected by the University of Colorado will be placed at NIST's Boulder, Colo., laboratories.

For information on the University of Maryland-administered portion of the program, go to: http://www.nistfellows.umd.edu/. For information on the Boulder laboratories fellowships managed by the University of Colorado, go to: http://www.colorado.edu/nistfellows/.

Radar Images Asteroid 2.3 Million km Away

Near-Earth asteroid 2005 YU55 was imaged by the Arecibo Radar Telescope in Puerto Rico on April 19. Data collected during Arecibo's observation of 2005 YU55 allowed the Near-Earth Object Program Office at NASA's Jet Propulsion Laboratory (www.jpl.nasa.gov) to refine the space rock's orbit, allowing scientists to rule out any possibility of an Earth impact for the next 100 years.



Radar imaging of asteroid 2005 YU55 was used to refine it's orbit and determine if it poses any threat to earth. *Image credit: NASA/Cornell/Arecibo.*

The space rock was about 2.3 million kilometers (1.5 million miles) from Earth at the time this image of the radar echo was generated. The image has a resolution of 7.5 meters (25 feet) per pixel. It reveals 2005 YU55 as a spherical object about 400 meters (1,300 feet) in size.

Not only can the radar provide data on an asteroid's dimensions, but also on its exact location in space. Using Arecibo's high-precision radar astrometry capability, scientists were able to reduce orbit uncertainties for YU55 by 50 percent. At one time 2005 YU55 was classified as a potential threat. After incorporating the radar data from Arecibo, impacts can be ruled out entirely for the next 100 years.

Australia-New Zealand Radio Telescope Network

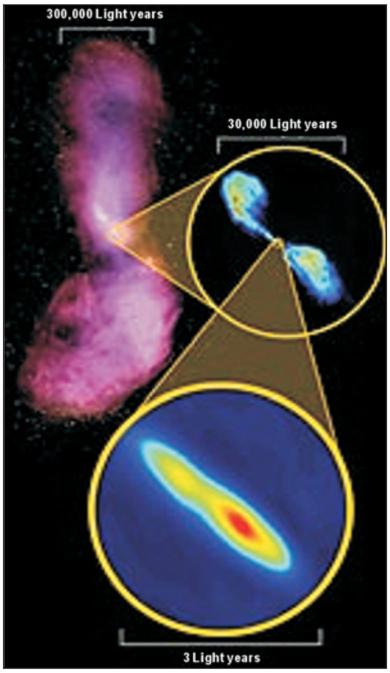
Six radio telescopes across Australia and New Zealand have joined forces to act as one giant telescope, linking up over a distance of 5,500 km. The link-up was a collaboration between CSIRO's (www.csiro.au) Astronomy and Space Science division, the International Centre for Radio Astronomy Research at Curtin University of Technology (www.curtin.edu.au) in Western Australia, and AUT University (www.aut.ac.nz) in New Zealand. The linked telescope has already been used to peer into the heart of the Centaurus A galaxy.

Showing Australia and New Zealand can link telescopes this way strengthens the two countries' joint bid to host the international Square Kilometre Array (SKA) telescope. The giant $2.5 billion SKA will have several thousand antennas, up to 5,500 km apart, working together as one telescope.

The newest additions to the Australasian telescope team are the New Zealand dish, near Warkworth in the hills of the North Island, and a new CSIRO dish in Western Australia's red dirt country, inland from Geraldton. The new CSIRO dish is the first antenna of the Australian SKA Pathfinder radio telescope. The other telescopes used in the link-up were three CSIRO facilities in New South Wales and a University of Tasmania dish near Hobart, Tasmania.

Data from New Zealand radio telescope were transferred from Warkworth directly to Australia using recently established 1 Gbps connectivity via the Kiwi Advanced Research and Education Network (KAREN).

One of the linked telescope's first projects has been to study the heart of a galaxy called Centaurus A. Lurking



A composite image zooms in to the heart of galaxy Centaurus A, at a distance of 14 million light-years. At the bottom is the innermost part of the galaxy, imaged by the new network of Australian and New Zealand radio telescopes.

Image credit— Whole galaxy: I. Feain, T. Cornwell & R. Ekers (CSIRO / ATNF); ATCA northern middle lobe pointing courtesy R. Morganti (ASTRON); Parkes data courtesy N. Junkes (MPIfR). Inner radio lobes: NRAO / AUI/NSF. Core: S. Tingay (ICRAR) / ICRAR, CSIRO and AUT.

there is a black hole that shoots out jets of radio-emitting particles at close to the speed of light. Observing the galaxy for 10 hours, the telescopes took a huge amount of data. The International Centre for Radio Astronomy Research at Curtin University of Technology provided the equipment for recording the data and also analyzed the data to make the image.

Advanced Spectrum Utilization Studies

The Berkeley Wireless Research Center at the University of California, Berkeley (www.bwrc.eecs.berkle-ly. edu) is pursuing a research initiative in *pervasive communications* or the end product of convergence. After 100 years of spectrum sharing based on fixed frequency allocations, the explosive growth of wireless communications over the last decade has made such communications pervasive. However, present methods of frequency allocation, combined with reliance on fixed infrastructure, threaten continued growth.

The BWRC research group will lay the theoretical foundation, develop the necessary systems knowledge, and demonstrate a prototype of a new kind of a wireless system, which will operate in a very broad frequency spectrum with bands of operation that can be dynamically allocated. Such a system would be able to reuse the frequency bands that primary users are not using at a particular time and a particular location. Demonstration of a wireless terminal prototype will be a centerpiece of this program. This wireless terminal would replace today's mobile phone and will interoperate with a "connectivity broker," a device that will ultimately replace access points, to support a diversity of radio technologies and innovative rules of cooperation. The concept of secondary use of the spectrum in combination with advanced cooperation between system components is revolutionary, and is enabled by advances in fundamental communications and networking theory and continued improvements in integrated circuit technology.