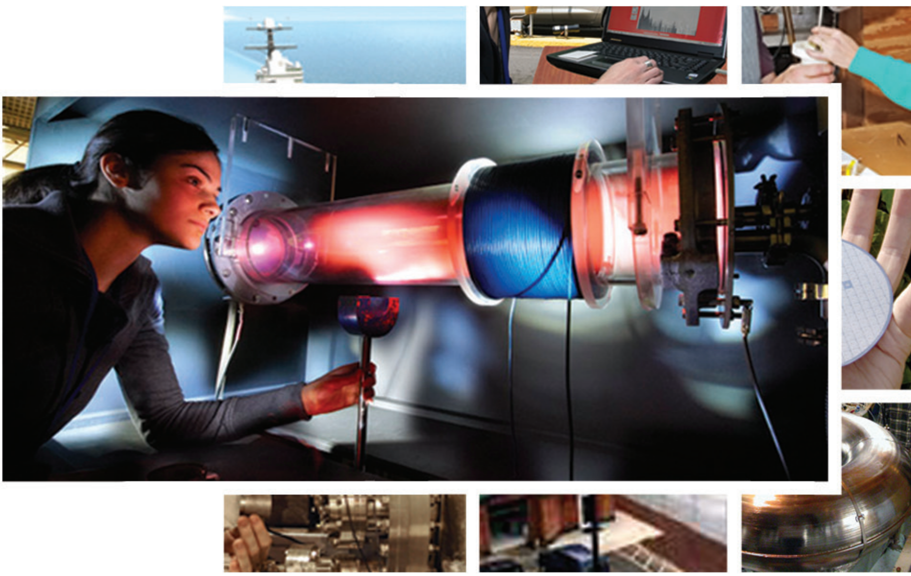
FusionCommunicationsGroup

Fusion Spinoffs



making a difference TODAY

The transfer of technology to private industry, academic institutions, other federal laboratories, and general consumers is one of the missions of fusion energy research facilities supported by the U.S. Department of Energy. As a technology resource, fusion and plasma physics institutions provide their unique expertise to solve a broad range of scientific and technological problems.

Fusion energy offers the promise of a safe, clean, and plentiful power source. While technological challenges remain in harnessing fusion as an energy source, significant advances have been made, including the development of new technology with applications beyond fusion energy.

Plasma, a hot gas of electrically charged particles, is the fuel for fusion energy production. Plasmas make up most of the visible universe, comprising all the stars in the cosmos.

Fusion — the same process that powers the Sun and other stars — occurs when two light atomic nuclei join within a plasma at very high temperatures. When they fuse, matter is converted into energy, which can be converted to heat for the generation of electricity.

In fusion experiments, scientists use powerful magnets to confine and shape plasma in a vacuum chamber and study its behavior. For use as a practical source of fusion energy, 100-million-degree plasmas must be contained within magnetic vessels for long periods of time.

This brochure highlights fusion and plasma physics technology accomplishments from DOE National Laboratories and facilities that conduct fusion and plasma physics research. These examples demonstrate how technology developed by DOE-supported fusion research is transferred to the commercial marketplace or has potential commercial value.

Cover Photo: ***Training the ITER generation of scientists. A physics student at the U.S. Department of Energy's Princeton Plasma Physics Laboratory studies plasma, the fourth state of matter. (Photo by Peter Ginter)***

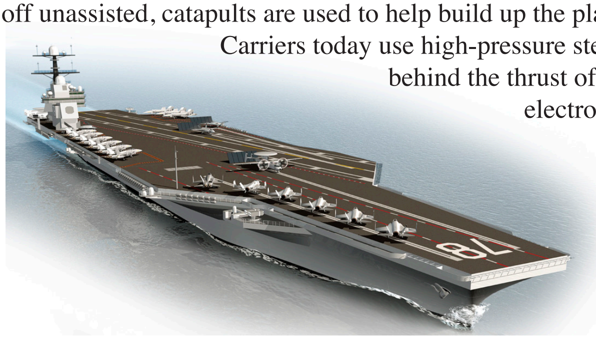
What's inside

Electromagnetic Aircraft Launch System

Catapulting the Navy into the 21st century

Early work in magnetic fusion energy has led General Atomics, a San Diego-based innovation firm, to help improve power systems for government and commercial customers. Technological advances include the Electromagnetic Aircraft Launch System (EMALS), an electromagnetic catapult that will replace steam catapults used on prior generations of aircraft carriers.

Because the flight deck of any aircraft carrier is too short for a plane to take off unassisted, catapults are used to help build up the plane's speed quickly. Carriers today use high-pressure steam to provide the force behind the thrust of the catapult. Using an electromagnetic pulse instead will lower operating costs, require fewer people to operate, improve catapult performance, and expand the range of manned and unmanned aircraft that the aircraft carrier can launch.



CVN-78, to be commissioned USS Gerald R. Ford, will use the General Atomics Electromagnetic Aircraft Launch System

EMALS will be installed on the U.S. Navy's new Gerald R. Ford-class aircraft carrier, CVN-78. A full-scale, shipboard representative catapult has been installed at the Navy's System Functional Demonstration Site at Joint Base McGuire-Dix-Lakehurst, N.J. Commissioning with dead-loads is under way, and aircraft launches will be demonstrated at this site.

EMALS is a multi-megawatt electric-power system involving generators, energy storage, power conversion, a 100,000-horsepower electric motor, and an advanced-technology, closed loop control system with diagnostic health monitoring. In addition to building EMALS power conversion and motor equipment, General Atomics provides the power system integration and logistics.

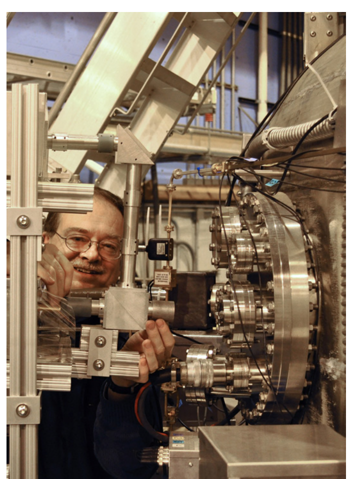
The MilliWave Thermal Analyzer

Going to extremes

Fusion energy research requires advanced technologies to monitor the extreme environment created by a hot plasma confined within a vacuum chamber. MIT's Plasma Science and Fusion Center has successfully adapted fusion energy diagnostic technologies for monitoring materials in the high-temperature and corrosive environments necessary for the production of glass, metal, and other industrial products.

The MilliWave Thermal Analyzer, developed in conjunction with Pacific Northwest National Laboratory and Savannah River National Laboratory, can monitor the properties of materials in the extreme conditions inside a glass melter or process reactor. This technology was designed to withstand previously inaccessible conditions created by high temperatures, corrosive fluids, melting materials, and radioactive or biologically contaminated environments.

Winner of a 2006 R&D 100 Award, the MilliWave system is the only thermal analyzer that uses millimeter-wave electromagnetic radiation to probe the temperature/chemical changes, as well as physical changes, of materials inside the melter in real time; the conventional method requires that someone periodically take small samples for outside analysis. The MilliWave technology can simultaneously measure temperature changes caused by chemical reactions, phase transitions, or physical movements in materials or melts. These key parameters can indicate the chemistry, stability, and quality of a material such as glass, slate, or metal during the manufacturing process. This new ability to measure industrial processes can lead to greater efficiency, better quality, and new product development.



Senior research engineer Paul Woskov works on a dual receiver millimeter-wave system used for plasma and chamber measurements in conjunction with a magnetic fusion experiment at MIT's Plasma Science and Fusion Center. (Photo by Paul Rivenberg)

Superconducting Technologies

Creating a more efficient electric grid

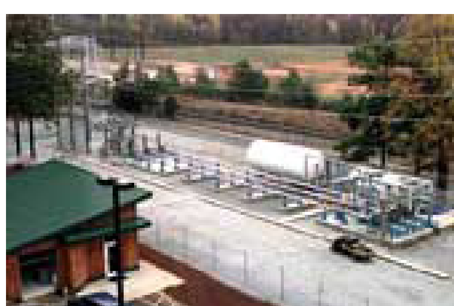
The power grid of the future likely will include devices made from high-temperature superconducting (HTS) wires based on a technology developed jointly by Oak Ridge National Laboratory and industry. ORNL fusion energy researchers have worked with staff from Georgia's Southwire Company to develop, design, and fabricate the world's most compact superconducting power cable. This technology can help electric utilities deliver more power with greater voltage control at high current densities, resulting in less need for additional transmission towers or new underground rights-of-way.

HTS cables offer much less resistance to the flow of electricity than conventional copper lines and can conduct up to five times as much current as a copper cable of the same size. Because an HTS cable loses little energy as heat, it can cut electrical transmission losses roughly in half (from about 8 to 4 percent). An HTS cable also is more environmentally friendly, because it is cooled with safe, inexpensive liquid nitrogen rather than oil-impregnated paper insulation, which may leak oil. It also can be installed in an existing underground duct, where the cable is better protected against natural, accidental, or deliberate threats.

The partnership with Southwire represents ORNL's largest and longest-running applied superconductivity project. The superconducting cable was initially installed, tested, and utilized in facilities at Carrollton, Ga. Southwire, ORNL, American Supercomputer, and American Electric partnered to produce an urban power distribution project that has been delivering electric power to some 8,600 homes and businesses in Columbus, Ohio, since 2006.

Southwire's HTS Triax™ is the most compact, high-power-density cable in the world. The three alternating-current phases are concentric and contained in a single cryostat.

This technology has been recognized with awards from the Federal Laboratory Consortium and DOE's Office of Electricity Delivery and Energy Reliability.



The Southwire Company facility in Carrollton, Ga., was the site of the first installation of the HTS cable. (Photo courtesy of Southwire)

The Miniature Integrated Nuclear Detection System

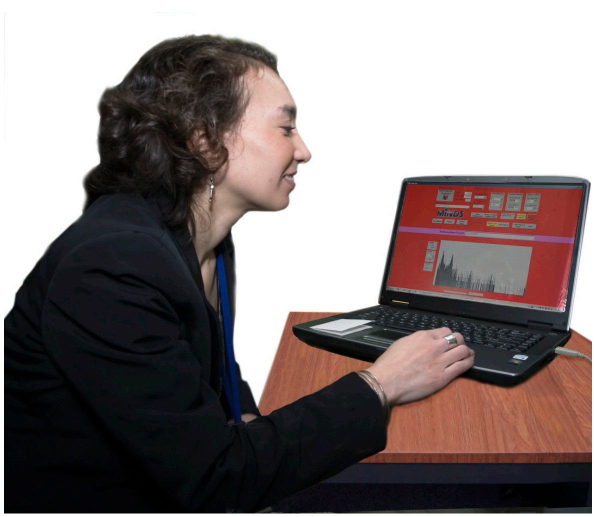
Making the world a safer place

The Miniature Integrated Nuclear Detection System (MINDS) was developed by engineers at DOE's Princeton Plasma Physics Laboratory while working on decommissioning the Tokamak Fusion Test Reactor. After 9/11, its developers realized they had also come up with a technique to detect and identify nuclear materials in real time for homeland security applications. For transportation and site security, MINDS is used to scan moving vehicles, luggage, cargo vessels, and the like for specific nuclear signatures associated with materials employed in radiological weapons.

This anti-terrorism device combines many off-the-shelf components with specific nuclear detection software and can detect X-rays, soft gammas, gammas, and neutrons. It is designed to identify, in real-time, gamma-emitting radionuclides at levels slightly above background and in radiologically noisy environments. Radionuclides can be recognized and differentiated from one another since each has a distinctive energy signature or "fingerprint." The system compares the energy spectrum of the detected radionuclide with the spectra of particular radiological materials that might be used in weapons.

MINDS is currently deployed at a major commuter rail station, at a military base, at workplace entrances, and at commercial shipping ports to detect the transportation of unauthorized nuclear materials.

MINDS technology has been licensed for commercial development.



Software engineer Dana Mastrovito tests the device, located near the underside of a car, at the PPPL guard booth near the entrance to the laboratory. (Photo by Denise Applewhite)

The Compact Synchrocyclotron

Making a valuable cancer treatment more available

The effort to develop advanced superconducting coils for magnetic fusion experiments at the MIT Plasma Science and Fusion Center (PSFC) has led to a new coil design that allows cyclotrons to be very compact, an advance that could make a valuable cancer treatment more available.

A cyclotron accelerates particles to high energies in a circular motion using magnetic fields. Cyclotrons are widely used in basic science research, including fusion, and have security and medical applications. They are currently used to help treat cancer with proton beam radiotherapy (PBRT). In traditional radiotherapy, the process of irradiating a tumor damages surrounding tissue. Proton beams, however, can be more precisely shaped to the size and thickness of the tumor, leaving surrounding tissue unharmed. Although PBRT is in demand, a typical cyclotron is so massive (around 1000 tons) and expensive to build (around $100 million), that there are currently only five PBRT centers in the U.S.

The PSFC is developing a compact high-field synchrocyclotron that is about 40 times smaller, lighter (about 25 tons), and orders of magnitude less expensive than the equivalent machine built using conventional magnet technology, making it possible for many more hospitals to provide PBRT. Single-treatment-room systems are now being commercialized.

The availability of a compact, low-cost cyclotron can also lead to advances in other fields that use cyclotrons. The PSFC is working on cyclotrons for point-of-use positron emission tomography and single photon emission computed tomography, as well as for screening of baggage and containers.

This floating coil magnet has been the heart of the LDX plasma physics experiment. The novel superconductor and coil design developed under this project has now been successfully adapted to a new class of high-power, very compact superconducting cyclotrons for cancer treatment using proton radiotherapy. A start-up company is now licensing this magnet technology from MIT for this medical application.

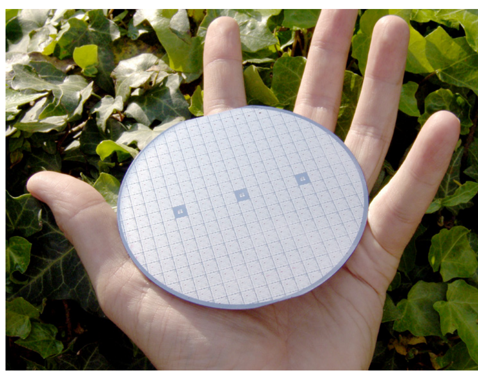
Semiconductor Inspection

Enabling rapid detection of chip defects

Oak Ridge National Laboratory fusion researchers helped develop an award-winning direct-to-digital holographic (DDH) microscopy technology. This technology can rapidly find small defects in deep-lying contacts and trenches in semiconductor wafers, thus exceeding the defect detection sensitivity and wafer throughput of conventional inspection systems.

In the semiconductor industry, manufacturers start with a silicon wafer to produce the tiny computer chips pervasive in many products. The DDH technology can help meet the industry's pressing need for high-aspect ratio inspection. The technique significantly extends the resolving power of optical systems.

The DDH technology is more sensitive than diffraction-limited, intensity-based techniques. It also requires little laser energy, provides volumetric detection rather than surface-area measurements, and has a higher throughput than is possible with other optical surface profile imaging techniques. Direct-to-digital microscopy is the only technology that can optically detect submicron defects within printed surface features having aspect ratios of greater than 10 to 1.



Silicon semiconductor wafer.

This patented inspection system, which has been commercially licensed, has the capability to help keep chip production costs low and contribute to maintaining the United States semiconductor industry's competitive edge.

Polymer-Electrode Bonding

Developing more realistic artificial muscles

Princeton Plasma Physics Laboratory scientists are collaborating with a research chemist to develop a method using plasma to improve polymer-electrode bonding in electro-active materials. This could lead to creating superior artificial muscles, benefiting people with disabilities.

Prosthetics should be realistic in appearance and movement. Ras Labs, a New Jersey small business research lab, is investigating contractile electro-active polymers in prostheses, particularly for the hand and arm. Ras Labs envisioned artificial muscles comprised of an electro-active polymer gel containing embedded electrodes, all encased in a flexible coating that acts as a kind of skin. The electrodes provide the electric stimulus, much like a nerve, and also attach the polymer to a mechanism, like a tendon attaches muscle to bone. When the electrodes are energized with direct current, the polymer contracts or expands, depending on material and electrical polarity. The artificial muscle then relaxes to its original shape and size when the current ceases, or it can be put through contraction-expansion movements by switching the electrical polarity back and forth, acting much like real muscle tissue responding to the brain's neural impulse.

Ras Labs developed polymers that respond quickly to electricity, but after repeated cycles, the polymers often detached from the electrodes. Researchers considered plasma treatment to improve polymer adherence. Through a Cooperative Research and Development Agreement, Ras Labs joined with PPPL to test ways to improve metal-polymer interface by plasma treating the actuator electrodes. Using PPPL's plasma equipment, the team treated metal samples with plasma, studying different ions to find a suitable metal and plasma combination that solved the detachment problem. The tests provided insight into the mechanisms responsible for improved adhesion of the polymer, leading to superior electro-active actuators and lifelike muscle movement.

PPPL Tech Transfer Head Lewis Meixler and Ras Labs chemist Lenore Rasmussen prepare materials for plasma treatment. (Photo by Elle Starkman)

Produced by the

FusionCommunicationsGroup

The goal of the Fusion Communications Group is to increase awareness of the potential of magnetic fusion energy as one of the important, practical solutions to the world's long-term energy needs.

For more information contact:
Patti Wieser, pwieser@pppl.gov or Bonnie Hébert, hebertb@ornl.gov