National High Magnetic Field Laboratory

The National High Magnetic Field Laboratory at Los Alamos develops for use in basic research the world's most powerful pulsed electromagnets, more than a million times stronger than Earth's magnetic field. It is one of the three campuses of the National High Magnetic Field Laboratory consortium, supported by the National Science Foundation, the State of Florida and the Department of Energy. Researchers worldwide visit to perform experiments on a wide range of materials, including high-temperature superconductors.

High magnetic fields

Research in high magnetic fields allows scientists to study matter at the molecular level. Improved understanding of materials, chemistry, physics, and biological structures through research with high magnetic fields has led to a range of enhanced modern technologies, many of which are now taken for granted. Among them are computers, motors, plastics, high-speed trains and magnetic resonance imaging or MRI.

Pulsed magnets

The collaborating campuses at Florida State University and the University of Florida concentrate on continuous fields, magnetic resonance and ultra-low temperatures at high magnetic fields. The Pulsed Field Facility at Los Alamos focuses on pulsed magnets that reach much higher magnetic fields but are only energized for relatively short durations (microseconds to seconds). The energy used to push these magnets to extreme fields comes from either capacitor banks (1.6 mega joules of stored energy), or a 1.4 billion-watt motor generator large enough to power the state of New Mexico.

Two main types of magnets are produced at the Pulsed Field Facility, nondestructive and destructive. Nondestructive magnets can be used over and over again, providing field strengths up to 65 tesla, and soon up to 100 tesla. Destructive magnets use explosives to drive the field up to incredible strengths (850 tesla), but destroy the magnet and the sample in the process. However, a new project at the NHMFL is the development of a single-turn coil magnet, which will reach fields of 300 tesla for about 4 microseconds and, although the magnet will be partially vaporized, the sample and cryostat will remain intact.

Design and construction

The high stress of pulsing magnets to such extreme fields day in and day out wears heavily on the materials used to build such magnets. Therefore, new materials are constantly being developed and tested in order to build bigger and stronger magnets.

Choosing specific types of wires to create the coil is also difficult. Usually a good conductor of electricity, ordinary copper wire does not have the strength to handle the stress the magnetic field applies to the magnet. The high-tech wires used instead are a combination of copper strengthened by fine filaments of aluminum, silver or niobium.

The typical pulsed magnet's central component, its coil, is formed when the wire is wrapped around a cylinder for about 300 turns. A huge surge of electricity pushed through the coil induces a burst of magnetic field, creating stress of many hundreds of tons in the process.

The annual budget of approximately $12 million at the National High Magnetic Field Laboratory supports 35 technical and support staff and 15 students and postdoctoral fellows.

Inspecting the generator that is the largest among the magnet laboratory's magnetic-power sources.

High Magnetic Field Research

The National High Magnetic Field Laboratory is a consortium of Los Alamos, the University of Florida and Florida State University for high magnetic field research and user facilities, supported by the National Science Foundation, the State of Florida and Department of Energy. The Pulsed Field Facility of the NHMFL, located at Los Alamos, is home to a wide variety of experimental capabilities in pulsed magnetic fields as well as some of the most important condensed matter physics research in the world.

Research at the Pulsed Field Facility probes the fundamental properties of materials in harsh environments, such as rapidly changing high magnetic field, very low temperatures and extreme pressures. NHMFL scientists work to develop unique techniques and instrumentation in order to overcome the limitations of these extreme conditions. They also invite scientists from around the world to make use of these rare experimental capabilities. Understanding magnetism and superconductivity in materials not only answers fundamental questions in physics but also can lead to better metals and materials for use in everyday life.

Recently, a team led by NHMFL researchers Fedor Balakirev and coworkers found evidence to support leading theories of the nature of high-temperature superconductors. NHMFL custom-designed instrumentation allowed this team to take Hall Effect measurements that showed an anomaly, indicating evidence of a possible phase transition at quantum critical point, the point where superconductivity is strongest in a specific material. Such measurements could help explain why some materials become superconductors at critical temperatures and may lead to more common uses of such materials. Results were published Nature Magazine on July 20, 2003 (figure 1).

NHMFL researchers recently demonstrated the first example of a new, magnetic-field-induced, ordered state in a magnetic metal. This metal is unique because of its unidentified and heretofore unexplained lowest energy state. The newly found ordered state could play a critical role in explaining these properties. This metal, and metals in which electrons have many strong interactions, are the focus of much cutting-edge research and could improve knowledge of superconductivity and magnetism. These results were published in Physical Review Letters on March 7, 2003 (figure 2).

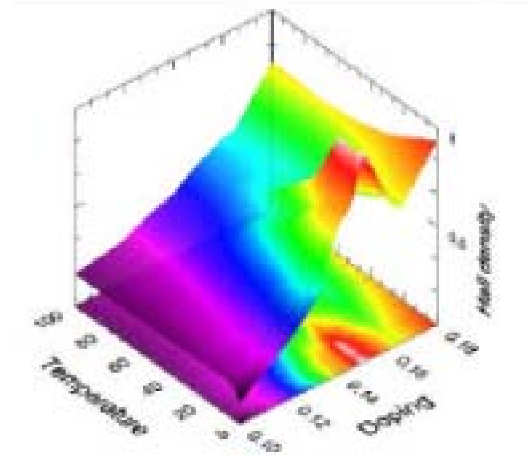

Figure 1: Normal state Hall Density as a function of temperature and number of charge carriers. The anomalous peak in the Hall Density indicates a phase transition.

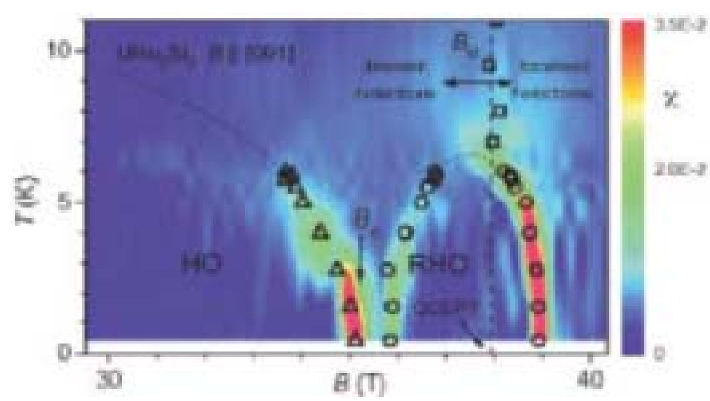

Figure 2: Color intensity plot of the high magnetic field phase diagram of URu2Si2, as featured on the cover page of Physical Review Letters.