Neutron scattering facility for continuous high magnetic fields up to 40 Tesla at Hahn-Meitner-Institut Berlin

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Abstract

The neutron scattering facility BENSC at Hahn-Meitner-Institut offers outstanding research opportunities to the international scientific user community. Experiments on an advanced suite of instruments can be performed in uniquely high magnetic fields up to 17.5 T at temperatures down to 30 mK simultaneously. To further extend the range of continuous magnetic fields for neutron scattering, HMI has proposed a new facility with resistive magnets up to 40 Tesla.

Key words: neutron scattering; sample environment in high magnetic fields; low temperatures

1. Introduction

Magnetism is a fundamental feature of all materials, including those considered to be non-magnetic in conventional terms. In very high magnetic fields in the range above 25 T the magnetic interaction gradually becomes significant in all materials at ordinary temperatures, and above 100 T the electronic states in matter start to be seriously modified. Thus the magnetic field is one of the fundamental thermodynamic parameters, just like temperature or pressure and investigating matter in high magnetic fields is a crucial part of the exploration of condensed matter (e. g. semiconductors or HT_C superconductors as examples of recent great significance).

The most conspicuous areas of research in which magnetic fields were used in the last decade include the broad field of magnetism in metals and semiconductors with emphasis on quantum hall effect or strongly correlated electronic systems for example, but also chemistry, biology, life sciences, biotechnology and medicine.

The Hahn-Meitner-Institut as a member of the 'Hermann von Helmholtz Gemeinschaft', hosts the Berlin Neutron Scattering Centre, BENSC (`http://www.hmi.de/bensc`), a user facility open to guest scientists from all over the world. BENSC is reputed for its modern neutron scattering instrumentation combined with excellent sample environment equipment, especially for uniquely high magnetic fields up to 17.5 T at a wide range of temperatures down to 30 mK.

2. The neutron scattering facility for high magnetic fields

The Hahn-Meitner-Institut now projects to combine for the first time two large scale facilities for the study of magnetic and related phenomena: a neutron source and a high magnetic field laboratory to extend the capabilities for neutron scattering experiments in continuous high magnetic fields up to 40 Tesla. This is made possible by the radically new concept of building up the neutron scattering instrumentation around the large immobile magnets with very limited access. Our approach is based on innovative neutron instrumentation concepts (time-of-flight chopper diffractometer, ballistic neutron guides and advanced neutron optics)

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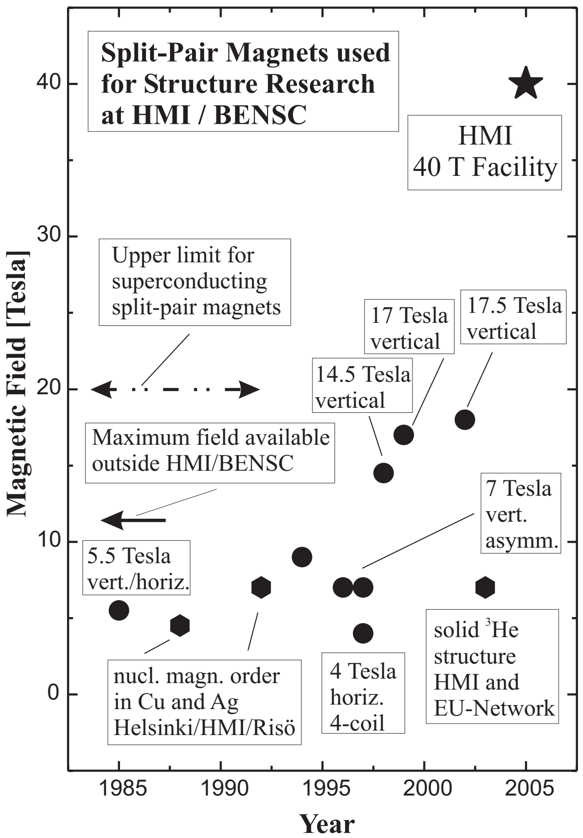

Fig. 1. Achievements at HMI in neutron scattering at high magnetic fields. All magnets can accommodate sample environment equipment for temperatures down to 30 mK.

developed and tested by HMI [1].

We plan a magnet station with 2 resistive magnets for neutron scattering (vertical and horizontal field), driven by a 40 MW power station and cooling circuit. Experimental use will be 4000 to 5000 h/year, which includes experimental setup, testing, calibration and measuring time. This new capacity will be made available to the international user community. With its extensive experience as the world leader in neutron scattering at high magnetic fields (see Fig. 1), HMI is well placed to provide expert scientific user support in this unique facility.

3. Scientific results and perspectives

The leading national high magnetic field laboratories in Europe, United States of America and Japan provide a variety of experimental research techniques to study matter in highest magnetic fields up to 45 T continuously and up to 65 T in long pulses of 1 to 10 msec. However, neutron scattering facilities all over the world offer, at present, research opportunities at magnetic fields not higher than 11 T with the exception of HMI/BENSC (world record of 17.5 T).

Neutron scattering studies in high magnetic fields at BENSC have already produced important breakthroughs, for example in HT_C superconductors. In $La_{2-x}Sr_xCuO_4$ [2] the coexistence of bulk superconductivity and magnetic field induced antiferromagnetism was observed at 14.5 T magnetic field. In La_2CuO_{4+y} [3] it was found, that the dependence of the spin-density-wave order parameter as a function of the magnetic field shows a non-linear behaviour. The magnetic field dependence provides a new probe of the interplay between superconductivity and spin-density-wave order.

In general high magnetic fields are crucial for the study of high temperature superconductors as materials with high technological potential. Theoretical predictions show that magnetic fields up to 40 T will open up new opportunities, although the BC_2 is still much higher. A particular challenge in the field of vortex matter is the search for supersolids.

Further fields of fundamental interest are new macroscopic quantum phenomena as well as highly correlated electronic systems with strong interactions and the search for a fundamental microscopic understanding of magnetically correlated phenomena (CMR-magnets, hard magnetic materials). The diamagnetic response in organic matter also becomes a significant coupling in such high magnetic fields.

The extension of neutron scattering capabilities to dramatically higher fields of 40 T will lead to breakthrough discoveries in virtually all fields of condensed matter research, including new materials like soft and biological matter. The broad field of applications and the mutually complementary nature with conventional high magnetic field experimental techniques make this project a fundamentally interdisciplinary one.

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