Research Matters SPRING 2004

Resonant magnetic X-ray scattering under high magnetic fields

The control of thermodynamic variables such as temperature, magnetic field, electric field and pressure is essential for the determination of the complex relationship between correlated microscopic properties of materials. Experiments under extreme sample environment conditions have often led to unexpected and exciting science. Investigations on the properties of matter at low temperatures by Heike Kamerlingh Onnes led to the discovery of superconductivity. More recently, high magnetic fields have been the key factor for the discovery of the quantum Hall effect and of a new form of quantum fluid.

For some time, neutron scattering has been the technique of choice for the investigation of microscopic interactions in solids. Similar sample environments for X-ray magnetic scattering represent a major challenge. The possibility to carry out experiments under such extreme conditions would provide unique research opportunities for the study of a broad range of phenomena in condensed matter. The combination of high magnetic field and Resonant X-ray Scattering (RXS) would be of substantial value for investigating strongly correlated electron systems such as high temperature superconductors, non-Fermi liquid and heavy-Fermion systems, colossal magnetoresistance compounds, structural, magnetic and quantum phase transitions, frustrated and lowdimensional systems.

Here we present a project to extend the capabilities of the ESRF ID20 beamline by the addition of a continuous magnetic field environment of up to 10 Tesla, for low-energy resonant X-ray diffraction experiments in the temperature range from 1.6 to 300 K. This project includes the development of the cryomagnet itself, a high-load diffractometer built from nonmagnetic materials, and the construction of a new experimental hutch to accommodate these instruments. The project is well on its way: the construction of the new hutch was undertaken in autumn 2002 (see Figure 1).

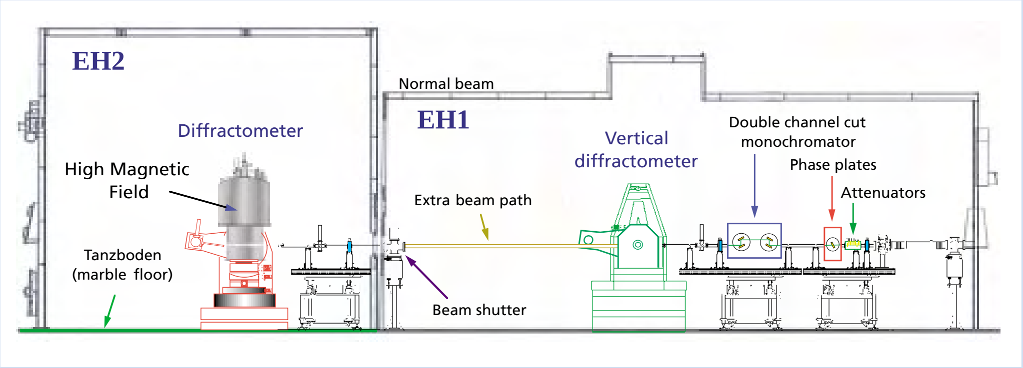

Figure 1: The new experimental hutch for the ID20 beamline

Split-Coil Superconducting Cryomagnets for X-ray Diffraction

In the case of scattering experiments, access to the sample is achieved using split pair magnet geometry. The coils have to be split into two parts, separated by a strong mechanical structure (wedge type spacer for X-ray or aluminium rings for neutrons), as there are strong attractive forces between the coil halves. The upper limit of the magnetic field is defined both by the split dimensions and the type of superconducting materials used for the wires. The dimensions of the Split-Coil Superconducting Cryomagnet (SCSCM) also have to be compatible with the load capacity of the diffractometer on which it is installed. The latter has to be built with non-magnetic materials, because the SCSCM creates a stray magnetic field, which decays with distance and can influence the steelmade materials as well as the electronic devices and detectors. Moreover, the presence of steel in close proximity to the magnet can cause excess force on the cryostat components, leading to damage to the internal magnet support system, or poor cryogenic performance.

An important technical point, which is specific to the RXS method, is defined by the working photon energies. These fix two main physical limitations for the construction of a SCSCM for X-ray diffraction: wide opening angles to perform magnetic diffraction, and low absorption windows. These specifications impact on the internal custom design of the magnet and on the maximum magnetic field strength obtainable.

Finally, a large sample space increases the versatility of the SCSCM to perform experiments using devices such as a uniaxial pressure stick, low temperature devices (^{3}He or dilution cryostats), or an additional stick with an extra rotation stage (to rotate and tilt the sample around the scattering vector).

Figure 2 shows the cross-section of the future 10 Tesla split-pair cryomagnet that will be installed at ID20 in the new experimental hutch. The cryomagnet will be constructed by Oxford Instruments and delivered at the ESRF in 2004. The

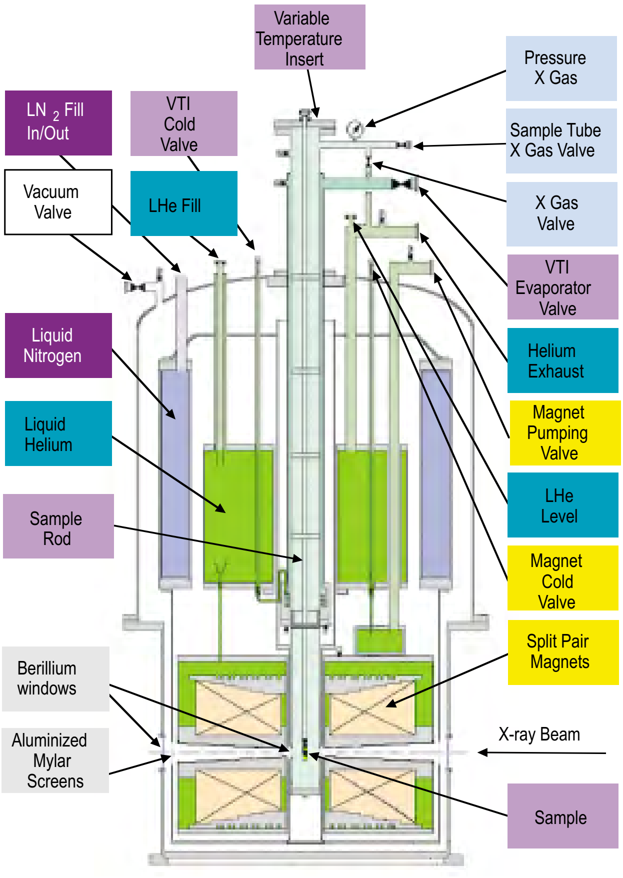

Figure 2: Cross-section of the new 10 T Split-pair cryomagnet

upper part of the SCSCM is a standard design in many superconducting magnet systems for neutron scattering experiments. A variable temperature insert (VTI), capable of reaching 1.8 K at the sample position, could be replaced in future with a high cooling power (> 40 mW) ^{3}He insert to reach temperatures below 1 K. The bottom part of the SCSCM is a completely new custom design, with a very large angular access to the photon beam and low absorbance beryllium windows and aluminised Mylar thermal screens. Due to the asymmetric distribution of the wedge type spacers, the maximum magnetic field cannot exceed 10 T at 4.2 K. This limit is also fixed by the close proximity of the new experimental hutch’s iron wall and the load capabilities of the new diffractometer. The latter will be adapted for the horizontal geometry (“normal beam” diffractometer).

The future capability to exert a high magnetic field on the new diffractometer will allow the RXS technique to be applied to some of the most exciting fields of condensed matter physics. This project, expected to be complete by the end of 2004, will overcome present limitations, and will allow researchers to fully exploit the potential of the ID20 beamline.

Reference:

1. S.W. Van Sciver and K.R. Marken, Physics Today, August 2002, p. 37.

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