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The new D23 diffractometer: working at high fields

D23 is a double-monochromator two-axis single-crystal diffractometer with a lifting detector installed on the thermal neutron guide H25. Its efficiency was increased in 2004 by the installation of a completely new non-magnetic, compact and versatile secondary spectrometer. Following this improvement, D23 is now ideal for all kinds of diffraction measurements that require high magnetic fields.

The CRG diffractometer D23

is, with IN22, one of the two machines transferred from the SILOE reactor (CEA-Grenoble) to the ILL (in 1995-96). It has been available to the neutron community since August 1999. It has two different configurations: unpolarised and polarised neutron modes. D23 is devoted to the determination of magnetic structures, magnetisation distribution maps and magnetic phase diagrams at low temperature, high magnetic field and/or under an applied pressure. The wavelength can be changed in the range 0.9-3 Å (unpolarised neutrons) and 1.2-2.4 Å (polarised neutrons). D23, as originally built, was suffering from its old mechanics mainly because it was highly magnetic, and therefore it was impossible to reach very high fields. For this reason, it was decided to replace the secondary spectrometer by a modern one more compact, rapid, non-magnetic and versatile.

All the studies and drawings were made in March 2003 by the company AZ-Systèmes and the mechanics were built at the end of 2003. The new machine (figure 1) was installed and successfully tested at the beginning of 2004, and was available to the community for 2.5 cycles (out of 3) during 2004. Several experiments at high fields were scheduled with both the CEA-12 T and the ILL-15 T cryomagnets, as illustrated in the next section. With this latter device, forces as low as 35 kg (horizontal) and 40 kg (vertical) were measured at 13 Tesla in the worst position [1], demonstrating that D23 is now one of the very few instruments at the ILL, safely supporting all the cryomagnets available. In addition, particular attention was paid to the positioning speed of the different movements. Typically, speeds as high as 6° per second can be reached, making D23 a particularly efficient machine, with an optimised ratio time actually spent counting over the total time of an acquisition (this is of particular importance on a diffractometer, when counting times are of the order of the second). Lastly, the machine is more compact and allows access to a wider angular range: roughly 125° on both sides in $2\Theta_B$, and ± 30° in ν (out of plane angle of the detector). The fact that the arc is symmetric permits working with all types of asymmetric magnets available at the ILL.

Figure 1: The new D23 secondary spectrometer with the 15 T ILL cryomagnet mounted.

What's next?

The new machine has been drawn to be evolutionary: polarised ^{3}He cells are thought of as an alternative to the existing Heusler alloy monochromator, to increase the flux in the polarised neutron mode. The detector can also be replaced for a polarisation analysis option (with an ^{3}He cell as a spin analyser "DECPOL"). All these options are of prime interest to provide the users with a three-dimensional polarisation analysis option as implemented in the new CRYOPAD device.

High Field study of URhGe

One of the first experiments performed at high fields on the new D23 diffractometer was devoted to the intermetallic compound URhGe. This compound is ferromagnetic below 9.5 K, and both ferromagnetic and superconducting below $T_S \sim 0.3$ K [2]. A similar behaviour is also found in the related ferromagnetic material UGe_2 between 11 and 16 kbar [3]. Here, the appearance of superconductivity occurs together with a first order reduction in the value of the ordered moment at 0 K [4,5]. A first order transition back to the larger moment phase can be induced by applying a magnetic field along the easy axis.

In URhGe there is also a field induced transition at $H_c \sim 11$ T visible in the high field magnetisation. However it differs from the metamagnetic transition seen in UGe_2, since the change now occurs for a field applied perpendicular to the ordered moment rather than parallel to it. At first sight, this transition could simply be a banal rotation of the moment towards the applied field direction: for d-metal ferromagnets such as iron, the magnetic moment prefers to lie along certain crystal directions in low fields and an applied field of sufficient magnitude can then rotate the moment towards the applied field direction. This physics is well understood when the anisotropy energy is much smaller than the exchange energy, and the magnitude of the ordered moment is conserved. However other measurements reveal that the transition in URhGe is in fact much more complicated, enhancing the importance of characterising the magnetic behaviour carefully. Neutron diffraction offers a big advantage for this, since it allows all the components of the magnetisation to be measured simultaneously, and can also test for the appearance of other orders, such as antiferromagnetism. The newly available field of 15 T has allowed us to investigate this interesting physics on the D23 diffractometer (figure 2).

In this experiment, the field was applied along the *b*-axis, whereas the zero field easy axis is the *c*-axis. Collecting a large series of peaks at $H = 0$ and above the critical field $H_c \sim 11$ T evidenced that the effect of the applied field H is to suppress the ferromagnetic moment along the *c*-axis, m_c, and to induce a moment parallel to H, m_b. A field dependence of 2 Bragg peaks was performed at $T = 2$ K up to 15 T: (i) the (002) peak, not sensitive to m_c, which therefore measures the induced moment parallel to the applied field, its field dependent part being proportional to m_b^2 ($m_b = 0$ at $H = 0$); (ii) the (200) peak, whose intensity, after subtraction of the nuclear part (measured at $H = 0$, $T = 15$ K), is proportional to the square of the total moment, $m_b^2 + m_c^2$. Assuming an isotropic form factor, the moment parallel to the easy axis can be deduced from the difference between the normalised intensities of these two peaks (corresponding to m_c^2). As seen in figure 2, m_c collapses at a metamagnetic field of about 11 T, with a corresponding increase in the induced moment parallel to the applied field, m_b. However, the measurements also show that the total moment does not increase monotonically, but has a dip at the 'metamagnetic' field. Either the form factors for the two moment directions are substantially different, or the total moment is reduced in the vicinity of the transition field, a reduction which remains to be explained.

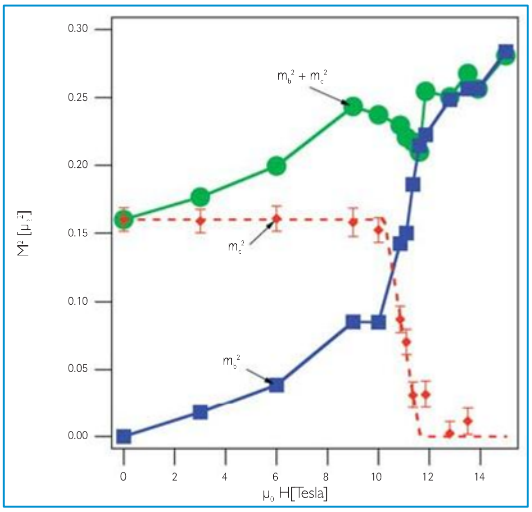

Figure 2: Field dependence of m_b^2, m_c^2 and of the square of the total moment $m_b^2 + m_c^2$ measured on D23 in URhGe at 2 K, in an applied field along the b-axis.

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