Experimental Report SI 556

Spin Structure of Fcc-Fe/Cu(001) Superlattices

The aim of this experiment was the investigation of magnetic ordering in γ - Fe films on Cu(001) at low temperatures by nuclear resonant scattering (NRS) and to search for antiferromagnetism in γ - Fe by looking for magnetic superlattice reflections.
To stabilize a sufficiently large amount of fcc - Fe we have grown Fe/Cu superlattices with a large number of bilayers where the individual Fe layer thickness did not exceed the critical thickness for transformation into the bcc phase. The crytalline quality of the sample was checked in our labs and appeared to be very promising for this experiment.
From this observation we have derived the countrate estimates given in the proposal that were in the range of 1 Hz. However, we could not achieve these values in the experiment. This is most probably related to the surface roughness of the sample that partially destroyed the spatial phase coherence between the individual Fe layers in the multilayer. This, however, is mandatory for a superlattice reflection to build up. The previous x-ray diffraction experiments in the lab just showed the average structure factor of the individual Fe layers. Due to this effect, we could not reach a resonant countrate from the sample that allowed to obtain information about the magnetic structure of fcc Fe.
Instead, we investigated a related system. γ - Fe and γ - Fe_2O_3 can be stabilized in nanoparticle precipitates in a Cu matrix [1]. We have prepared the latter sample for comparative studies. In the remaining beamtime we could perform a forward scattering experiment, investigating the superparamagnetic relaxation of these nanoparticles. The experimental data are shown in the subsequent pictures. Fig. 1 shows time spectra of NRS as a function of temperature, showing the transition to a magnetically ordered state at a temperature of about 10 K, which is the blocking temperature of the particles. Fig. 2 shows the time-integral delayed intensity as a function of temperature, obtained during a period of 30 min while the sample was cooled down. The blocking temperature is marked by a strong drop in the countrate over two orders of magnitude with decreasing temperature.
In conclusion, the experiment has shown that NRS is a very sensitive probe of magnetic relaxation phenomena, especially in the thermal-scan mode. This is an important advantage over conventional Mössbauer spectroscopy, where comparable information from such dilute systems can be obtained only over a period of several days. Thus, NRS has the potential to investigate the magnetic relaxation behaviour as a function of external parameters. This is very important for the investigation of nanoparticles with respect to applications, e.g., in the field of magnetic data storage.

[1] T. Ezawa et al., Physica B 161 (1989) 281; W. Keune et al., Physica B 161 (1989) 269

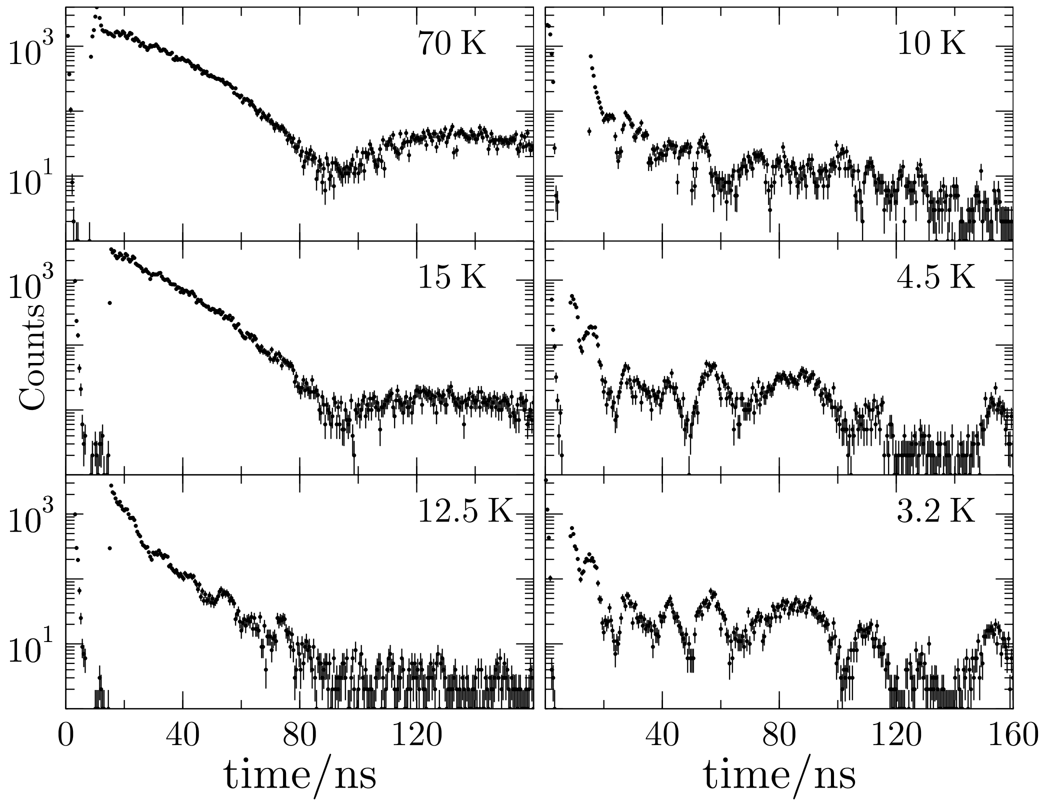

Figure 1: Time spectra of nuclear resonant forward scattering from γ - Fe_2O_3 precipitates in Cu.

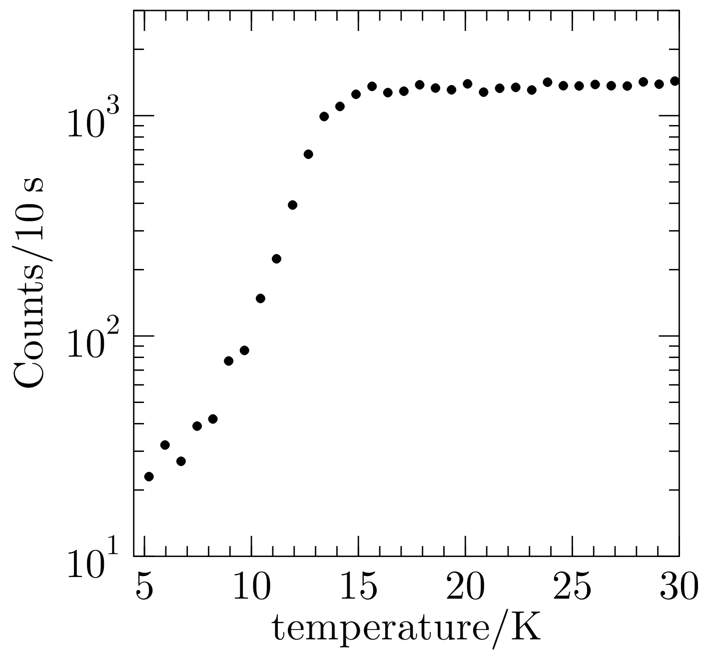

Figure 2: Time integrated delayed signal as function of temperature