ESRF	**Experiment title:** Details of complex magnetic interactions in UP-US solid solutions	**Experiment number:** HE-1303
Beamline: BM28-XMaS	**Date of experiment:** from: 19/06/2002 to: 24/06/2002	**Date of report:** 19/08/2002
Shifts: 18	**Local contact(s):** D. Mannix	*Received at ESRF:*

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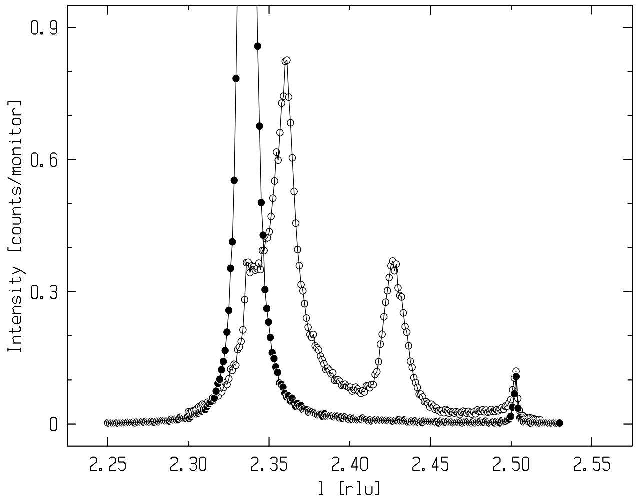
Report:
During the allocated 18 shifts a single-crystal sample with composition $x = 0.20$, corresponding to one of the most interesting regions of the phase diagram, was examined in detail. Most of the experiment was conducted on resonance at the U M_4 edge, a few shifts at the end of the experiment having been used for lattice studies at higher energy (7.5 keV).
In agreement with previous neutron work [1] the low-temperature magnetic phase was found to be type IA ($k =< 001/2 >$). This phase disappears abruptly at 42 K (1st order transition) being replaced by a $3+3-$ ($k =< 0\,0\,1/3 >$) magnetic structure. Depending on the thermal history of the sample a small amount of the $3+3-$ phase coexists with the type IA phase in the temperature range 32.5–42.0 K.
One of the aims of this experiment was to determine whether the $3+3-$ phase is a perfect square wave-modulation and our results indeed confirm this. The high resolution available shows that the wave vector is locked-in at 1/3 rlu and the third order harmonic has the correct intensity ratio for an undistorted square wave. The transition from the $3+3-$ structure to the incommensurate phase is highly hysteretic, the incommensurate peaks found depending upon the thermal history of the sample. In this study, the much higher resolution compared to the neutron work resolved many details previously unobserved. Upon warming, a transition occurs at 78 K from the $3+3-$ structure to a phase with $k \sim 0.43$ rlu. At 80 K a complex magnetic structure is observed with several wave vectors. Upon cooling, the incommensurate phase starts at $T_N = 88$ K and grows up to 75 K, disappearing abruptly at the onset of the $3+3-$ phase sets at 72 K. It is build up mainly from 2 broad components, with $k \sim 0.43$ and 0.36 rlu (Fig 1).
In the type-IA phase a set of intermodulation reflections of the type $k_i + k_j$, $i \neq j$, was found showing that this phase is multi- **k**. This is an import information determined from the experiment, as it was unknown whether any of the magnetic phases was multi- **k**. The intermodulation reflections appear in both $\sigma \to \pi$ and $\sigma \to \sigma$ channels. They are narrower in energy than the main magnetic reflections (6 vs 9 eV FWHM) and slightly displaced by 2.5 eV towards lower energies (Fig.2). This behaviour is similar to that observed in the UAs-Se system [2].



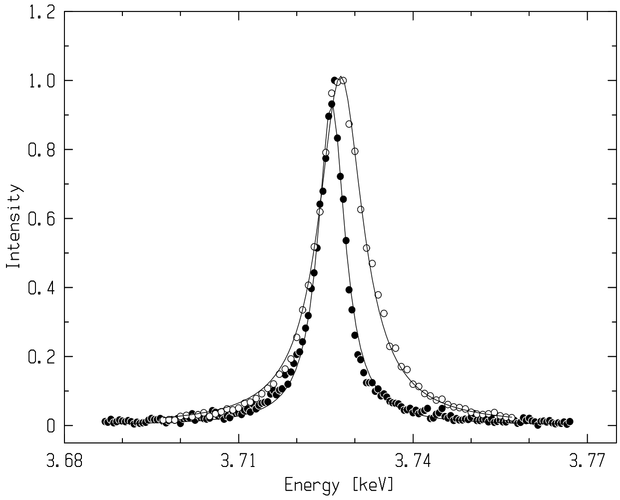
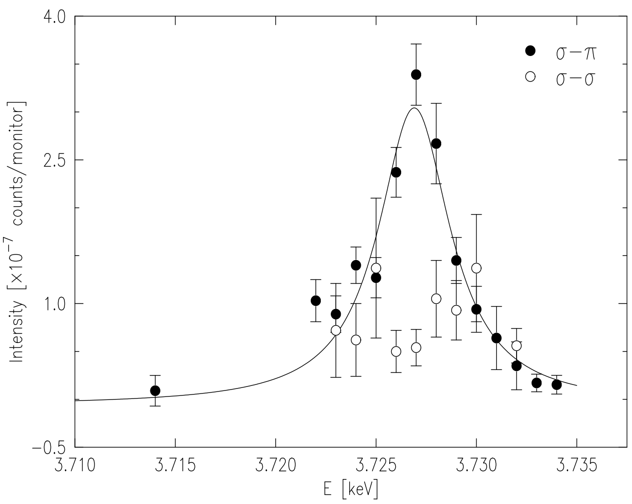


Fig. 1 (left) - Reciprocal lattice scans performed at 75 K on heating (solid points) and cooling (open points) cycles showing the hysteresis of the incommensurate phase. Fig. 2 (right) - Energy dependence of the intermodulation peak (1/2 0 5/2) (solid points) compared with that of a main magnetic satellite (open points) at 12 K.

The most interesting result of this experiment was the observation of a 2 **k** peak in the IA and $3+3-$ phases. These small peaks are resonant, narrow ($\sim$ 5 eV FWHM) but not significantly displaced in energy and appear only in the $\sigma \rightarrow \pi$ channel (Fig. 3). They do *not* arise simply from lattice displacements, although at these positions a small amount of charge scattering does occur that can be measured at high energies (see below). A similar peak was recently observed in NpP, and might be a signature of orbital ordering. Further studies of the azimuthal dependence would help to clarify the origin of these peaks. Unfortunately the 2θ angle of the (003) reflection on resonance was to high to perform azimuthal scans, and the (001) reflection too weak.

Finally, a detailed study of the lattice behaviour as a function of temperature was conducted with high energy photons. Fig. 4 shows the T-dependence of the (005) reflection which is due to an internal distortion of the fcc lattice. This charge peak sets in abruptly at 42 K but a small peak is also present in the higher temperature range where the $k = 1/2$ peak coexists with the incommensurate phase. The charge modulation induced by the $3+3-$ magnetic structure was also observed and followed as function of temperature. The lattice parameter and crystal mosaicity were accurately determined from the position and width of longitudinal and transverse scans of the (006) reflection. A discontinuity of the lattice parameter occurs at the 1st order transition at 42K.



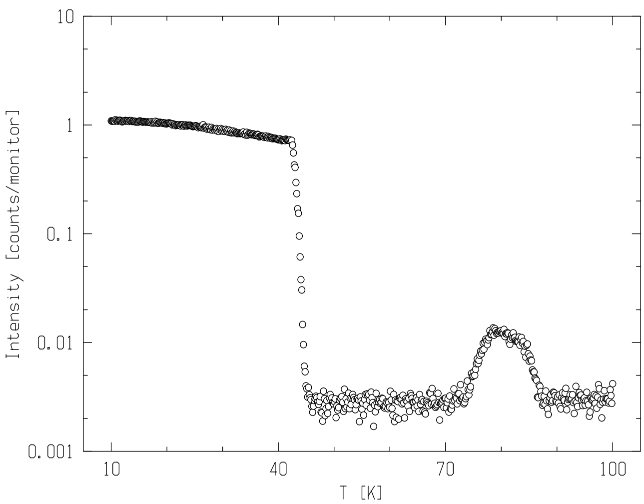


Fig. 3 (left) - Polarization analysis of the (003) reflection at 12 K (IA phase). Fig. 4 (right) - $T-$dependence of the (005) peak measured at high energy (7.456 keV).

References

1- M. Kuznietz et al., JMMM 63-64 (1987), 165. ibid, Phys. Rev. B 35 (1987), 7142. 2- M. Longfield et al., Phys. Rev. B 66 (2002), 54417.