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Report:

Actinide materials often contain magnetic structures at low temperature that can be described by several Fourier components. Such magnetic structures have previously been realized by neutron diffraction measurements with an applied magnetic field. The highest symmetry case is the triple-**k** magnetic structure, which is described by the superposition of three orthogonal Fourier components of similar magnitude. Lower symmetry cases, for example the double-**k** structure, are multi-domain. We have been conducting a series of experiments on these types of materials in which we now examine the possibility of a novel scattering process that is unique to multi-domain magnetic materials.

The UAs-USe materials that we have been studying using the resonant x-ray magnetic scattering (RXMS) technique are known from neutron diffraction measurements to contain multi-**k** magnetic structures with a + + - - spin period. Such magnetic structures have a set of <0 0 k> reflections, and <k k k> type reflections are symmetry extinct. Surprisingly RXMS has also been observed from the <k k k> type reflections in the Se=20% material. The aim of this experiment was to characterize this new set of reflections and try to establish their origin.

Our measurements have shown that that the <k k k> reflections have an unusual azimuthal dependence, which is not consistent with a multi-scattering process. Importantly, the energy dependence of these reflections is that expected of the terms in the cross-section that are linear in the magnetic moment. By projecting these terms in the scattering cross-section along the [k k k] directions we have been able to model exactly (with no variable parameters) the azimuthal scattering of the <k k k> reflections. The results suggest that these reflections have the same cross-section as the standard <0 0 k> reflections but originate from a different crystal volume. Consequently we have created a model that could explain the origin of these unusual <k k k> reflections.

Since this material is multi-domain with dynamic fluctuations of the magnetic structures it could be that there is a superposition of the various magnetic structures at the boundaries of neighbouring domains. The effect of this would be to produce a new set of Fourier components the instant that the x-ray photons probe the material.

The temperature dependence of these reflections compared with those of the <0 0 k>, <k k 0> could indicate the physical origin of the <k k k> peaks. (The <k k 0> reflections arise from the second order terms in the RXMS cross-section and require the presence of two wave-vectors in a single domain, see Longfield et al., Phys. Rev. B 66 054417 (2002)). If the <k k k> reflections were linear in the magnetic moment, which we know from their energy dependence, their temperature dependence should be the same as the <0 0 k> reflections and thus arise from a single domain. However, if the <k k k> reflections have the same temperature dependence as the <k k 0> reflections, which require two or more wave vectors, then we conclude that the <k k k> reflections arise from the superposition of several different magnetic domains. Our measurements show clearly that the temperature dependence of the <k k k> reflections is identical to the <k k 0> reflections. We therefore conclude that these reflections result from the standard scattering cross-section and the <k k k> reflections are a snapshot of the domain boundaries of dynamic double-**k** structures. The <k k k> reflections develop on cooling below the ordering but at lower temperatures, below ~ 50 K, the <k k k> reflections disappear almost completely. We believe this indicates that for these temperatures the dynamic character no longer exists on the time scale of the measurement.