C5 spectrometer demonstration

Polarized neutron scattering and magnetic properties of MnF_2

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Neutron is a spin-1/2 nuclear particle. A neutron beam where majority of neutrons have their spin pointing in one direction rather than at random , is called polarized neutron beam. Experiments with polarized neutron allow an unambiguous separation of nuclear and magnetic scattering and a determination of the directional components of the magnetization.

MnF_2 is one of the best-studied antiferromagnets in condensed matter physics. It has a tetragonal bcc-like structure with magnetic Mn^{2+} ions at the corner and body-centered tetragonal positions, see Figure 1. Below the antiferromagnetic Néel temperature of 68 K the magnetic moments of the two Mn^{2+} ions in the body-centered tetragonal lattice are opposite to each other and aligned along the tetragonal axis of the rutile structure as shown in Figure 1.

In this demonstration we will:

1. Introduce you to the triple axis spectroscopy (Figure 2). This will include main components of a triple-axis set-up such as monochromator, analyzer, detector, filters, and collimations.
2. Show you how to set up and run a polarized neutron triple axis spectrometer. This will include components such as neutron spin polarizer/analyzer, spin-flippers and guide fields.
3. Show you how neutron scattering can be used to determine not only whether a material is magnetically ordered or not but also what the nature of ordering is i.e. ferromagnetic or antiferromagnetic. We will discuss how the build up of spatial correlations between the magnetic ions results in the appearance of magnetic scattering in form of Bragg peaks in the elastic channel and spin waves in inelastic channel. We will also show how the orientation of magnetic moments can be determined.

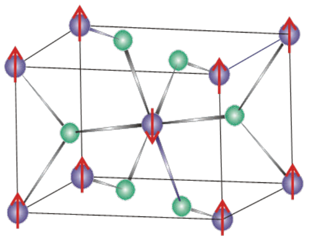

Figure 1: Magnetic structure of MnF_2.

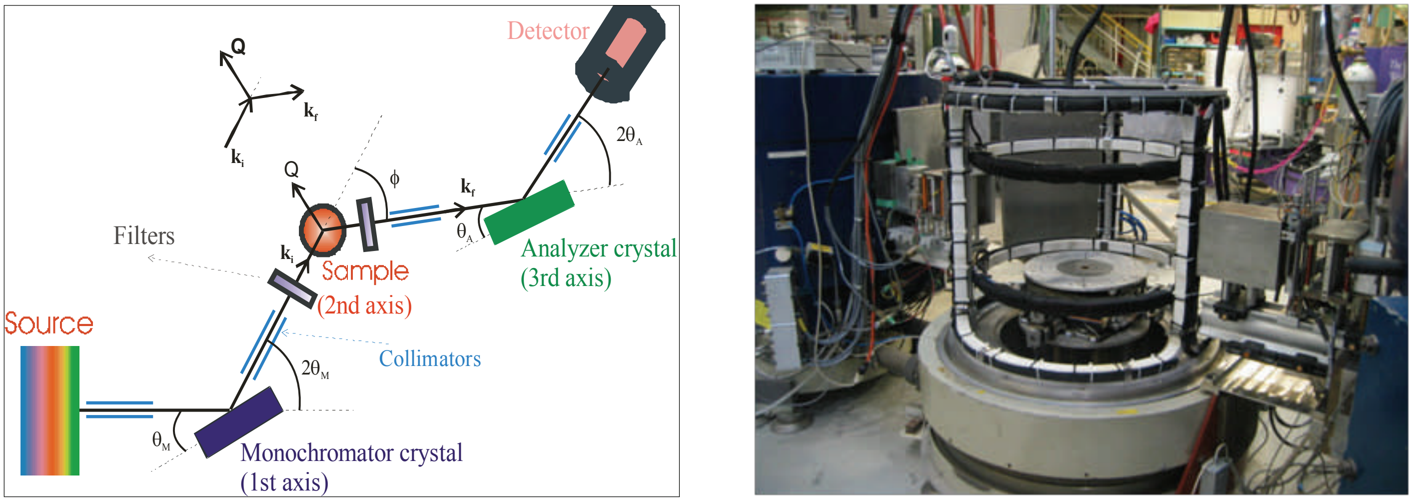

Figure 2: (Left) A schematic layout of a TAS is shown. A white beam is extracted from the reactor. A single-crystal monochromator (1st axis) selects neutrons with a specific wavelength from this white beam. The monochromated beam proceeds towards the sample (2nd axis) where it interacts with the sample via both nuclear and magnetic interactions. The neutrons scattered by the sample are Bragg reflected from yet another single-crystal analyzer (3rd axis) to determine their final energy. Finally, neutrons reflected by the analyzer are detected by the neutron detector. The angular divergence of the beam is controlled by the collimators placed at different locations in the neutron path (and also indirectly by the mosaic of monochromator, analyzer, and sample). Different types of filters are used to cut the fast neutron background and higher harmonics. (Right) A photograph of C5 triple axis spectrometer setup for polarized neutron scattering measurements. Components such as guide fields and spin flippers can be seen. Helmholtz coil assembly at the sample position is used to orient the neutron spin in vertical or horizontal directions.