Focused Neutron Depolarization a new probe for High Pressure Magnetic Phases

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Neutron depolarization imaging (NDI) provides a spatially-resolved distribution of long range ferromagnetic (FM) order in a bulk sample [1, 2, 3]. When a neutron non-adiabatically enters a magnetic field, its magnetic moment undergoes Larmor precession. Neutron depolarization can thus also probe magnetic islands in spin glasses [4], or the Meissner field outside a superconductor [5]. Neutrons easily penetrate cryogenic equipment, pressure cells and bulk metal samples, making NDI a great technique to investigate these different phenomenon under extreme conditions. Unfortunately, NDI suffers from poor spatial resolution (circa 1 mm) and limited counting statistics, which in combination with the small sample size available in high pressure vessels, strongly limits the possibilities of this technique.

In order to overcome these difficulties, we have enhanced neutron depolarization imaging by using focusing neutron supermirror guides. These guides increase the neutron flux by 40 times in a small beam section of less than 1 mm diameter. Figure 1 shows the compared neutron depolarization profile obtained with standard NDI and with focused neutron depolarization on a 100 µm thick FM sample. The standard deviation around the mean value is decreased from 2% to 0.2% while decreasing the counting time.

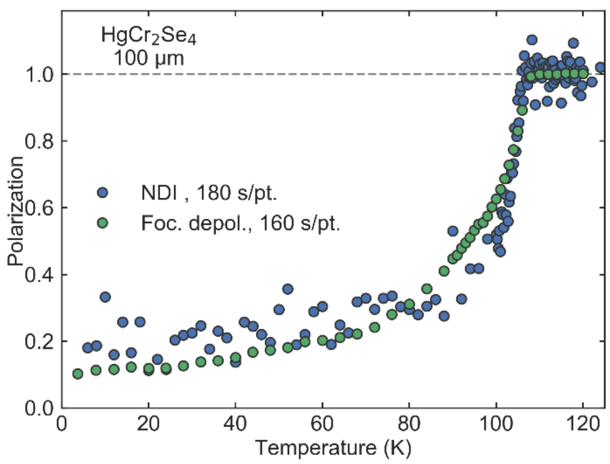

Figure 1. Neutron depolarization of a 100 µm thick $HgCr_2Se_4$ sample versus temperature for two different measurement methods, standard NDI (blue), and focused neutron depolarization (green).

By placing the sample space of our custom built diamond and moissanite anvil cell at the focal spot of the neutron optics, we are able to measure neutron depolarization at unprecedented pressures. The low counting times needed also allows us to span a larger area in temperature, and magnetic field.

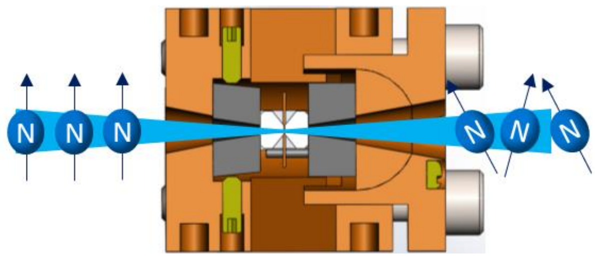

Figure 2. Section cut of a CuBe moissanite anvil cell used in the experiments, illustrating how the polarized neutron beam easily accesses the sample space through the optical aperture.

We showcase this technique by presenting the high pressure phase diagram of the semiconductor FM spinel $HgCr_2Se_4$. Due to the competition between the direct antiferromagnetic (AFM) exchange, and direct FM superexchange, the Curie-Weiss temperature scales with the lattice parameter in the whole chromium spinel family [6]. Hydrostatic pressure allows us to tune the relative strength of the competing interactions while maintaining the exchange interaction scheme.

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