TOF-SCD and polarized neutrons – first scientific results

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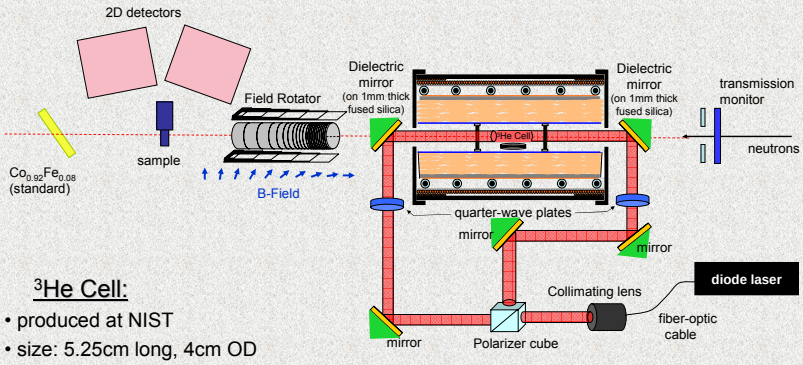
Polarized neutron diffraction provides the spatial distributions of magnetization as well as the direction of the magnetization vector on an atomic scale in a wide range of materials of fundamental and technological importance. Recent advances in the development of ^{3}He spin filters have made it possible to polarize neutrons efficiently at neutron spallation sources.

We report the results of a test experiment carried out using a polarized ^{3}He filter installed at the Single-Crystal Diffractometer (SCD) instrument at the Intense Pulsed Neutron Source (IPNS). The goal of the experiment was to determine the distribution of the spin density in the $MnSb_4$ tetrahedra of the Zintl semiconductor $Yb_{14}MnSb_{11}$.

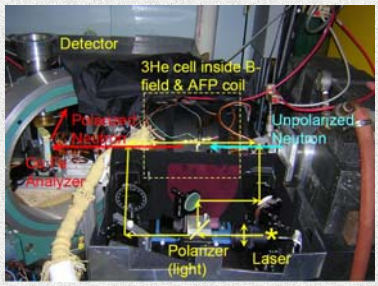
Experimental Details

- compact system to continuously polarize a ^{3}He spin filter by spin-exchange optical pumping
- ^{3}He Spin Filter polarizes broad energy range of neutrons with minimal effect on beam divergence
- NMR coils are used to quickly flip the ^{3}He polarization with 0.01% loss



^{3}He Cell:

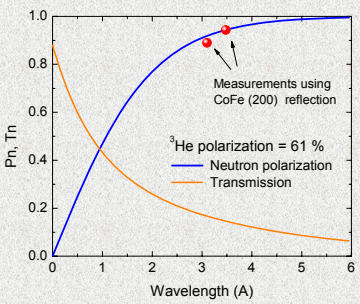
- produced at NIST
- size: 5.25cm long, 4cm OD
- $n\sigma l$ = 4.19 at 0.496nm
- 2.2 bar of ^{3}He, 60 mbar of N_2, drop of Rb



Parameters:

- size: length ~ 31 cm, O.D. ~ 28 cm
- beam size = 9mm
- T_e = approx. 88%
  - 2 double paned fused silica windows ~ 4mm total
  - 2 dielectric mirrors on fused silica ~ 2mm total
  - Cell windows ~ 3mm total

P_n and T_n, vs. wavelength (P_{He} ~ 61%)



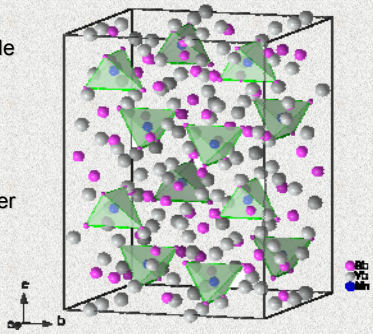
$$T_0(\lambda) = T_e e^{-n\sigma_0 \lambda l}$$

$$T_n = T_0 \cosh(P_{He} n \sigma_0 \lambda l)$$

$$P_n = \tanh(P_{He} n \sigma_0 \lambda l) = \sqrt{1 - \frac{T_0^2}{T_n^2}}$$

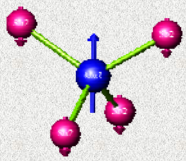
T_n = transmission
P_n = neutron polarization
P_{He} = ^{3}He polarization
l = cell length
λ = neutron wavelength
n = number density of ^{3}He

- The achieved 61% ^{3}He polarization corresponds to P_n = 94% at λ= 3.47 Å, confirmed by measuring the ratio between spin-flips of the (200) reflection of the CoFe crystal standard.



$Yb_{14}MnSb_{11}$

- Tetragonal with space group $I4_1/acd$
  1 Mn atom
  4 inequivalent Sb atoms
  Sb (2) involved in Mn-Sb tetrahedra
- Ferromagnet regarded as a rare example of an underscreened Kondo lattice. (T_C = 53 K)



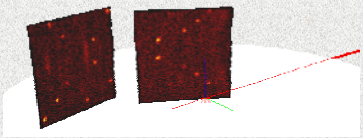
- It is proposed a Mn^{2+} (d^5) configuration with the moment compensated by the anti-alligned spin of an Sb 5p hole.

- neutron scattering on $Yb_{14}MnSb_{11}$ single crystals grown by Sn flux technique
- custom made permanent magnet arrangement to apply a magnetic field of approximately 0.4 T at low temperatures of 6 K at the sample position

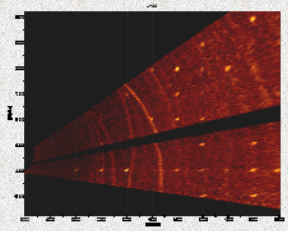
Neutron diffraction results

ISAW program: data visualization and integrating peaks

- Neutron diffraction measurements at T = 70 K, above the transition temperature, confirmed the nuclear structure of $Yb_{14}MnSb_{11}$



(hk0) slice view



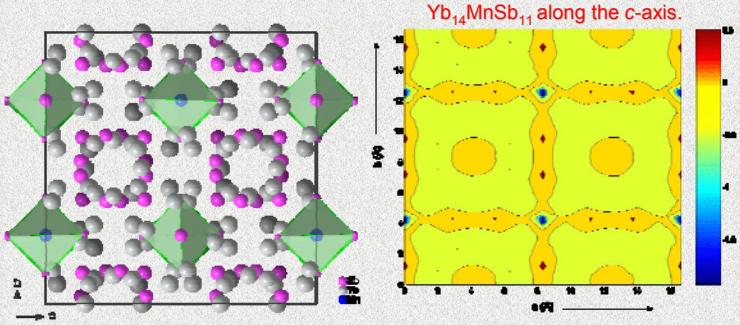
selection rules :
Mn (8a): 2h + l = 4n
Sb (32g): h + k + l = 2n

Selected reflections:

h	k	l	I+	I-	λ(Å)	Q(Å^{-1})	I+/I-	(2h+l)/4	
6	0	0	293.3	222.6	5.18	2.26	1.317	3	Mn & Sb
8	0	0	1315.8	920.7	2.43	3.02	1.429	4	Mn & Sb
6	1	-1	223.8	306.8	4.67	2.31	0.729	2.75	Sb

Polarized neutron diffraction data (47 reflections)
→ MaxEnt reconstructions of spin density distribution

Projection of the spin density in $Yb_{14}MnSb_{11}$ along the *c*-axis.



→ maximum entropy magnetization density reconstruction reveals the presence of a magnetic moment on the Sb site with opposite sign with respect to the Mn moment