Experimental report

14/02/2018

Proposal: **5-42-458**

Council: 10/2016

Title: Inside the magnetic polaron

Research area: Physics

This proposal is a new proposal

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Samples: Very lightly (iodine) doped (5 dopings) and undoped EuTe

Instrument	Requested days	Allocated days	From	To
D33	0	3	27/02/2017	02/03/2017
D22	5	0		

Abstract:

Polarons --- quasiparticles consisting of charge carriers 'dressed' with lattice distortions or magnetic spins --- have been ubiquitous in condensed matter physics. Yet polarons have resisted direct measurement and subsequent characterisation due to a lack of suitable experimental techniques. Here we propose to use SANS to probe, for the first time, the internal structure of individual magnetic polarons. Two methods will be used to induce polarons: charge doping of the semiconductor sample (EuTe) and incident light.

Search of Magnetic Polarons in EuTe

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In the EuTe, the antiferromagnetic (AFM) superexchange mediated by the Te anions dominates over the indirect FM exchange from overlapping Eu orbitals, resulting in AFM order at T_N = 9.9 K. This AFM ground state in EuTe, instead of FM in EuB6, makes it much easier to probe the magnetic polarons using SANS, as they will appear as superparamagnetic (SPM) regions[1] against an AFM (i.e. $\langle M \rangle = 0$) matrix. Their lifetimes 15 μs (from time-resolved Faraday rotation[1]) are essentially static on neutron scattering timescales. Three models have been studied: I. a FM core with M = 0 outside ('hard' polaron); then, using the results of Refs. [2] and [3] that describe the polaron with a Bohr hydrogenic wavefunction: II. a small FM core radius ~1.8 with M decaying slowly outside, obtained using a self-consistent approach[3]; III. a large FM core radius ~5.3 . with decaying M outside obtained using a variational method[3].

Small-angle neutron scattering (SANS) was employed to study the ferromagnetic spin clusters in EuTe, due to its sensitivity to the magnetization contrast in the mesoscopic range. The aim of these experiments was to determine the presence of these short-range ferromagnetic fluctuations, i.e., the proposed magnetic polarons in EuTe. Anomalies in the scattered intensity I(q) as a function of transferred momentum q are expected from well-defined spin clusters. Such an approach was earlier successfully used to study polarons in EuB_6 [5].

Measurements on D33 were carried out with a mosaic of co-aligned EuTe single crystals, which were polished to a thickness of less than 200 μm. The sample was cooled by a 7 T horizontal-field cryomagnet with $\mathbf{n}$ | | [1 0 0], where $\mathbf{n}$ is the direction of the neutron beam. The magnetic field direction $\mathbf{H}$ was aligned perpendicular to $\mathbf{n}$. Also a LED light was shed on the mosaic to induce the formation of polarons[2]. (See Figure 1)

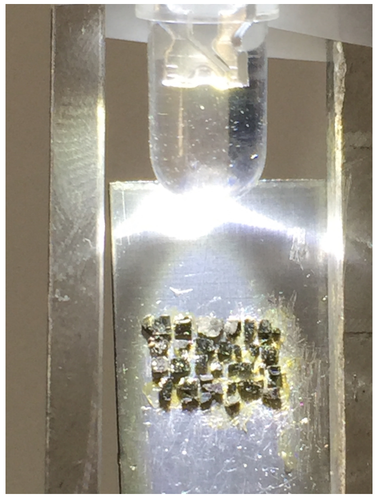

Figure 1: Mosaic of EuTe with mounted LED.

At first, the instrument was set up in a medium-q configuration with a neutron wave-length of λ = 3.35 Å, 5.3 m collimation and 6 m detector distance, taking data with light and no light on at base temperature. However, the large neutron absorption, primarily of europium, resulted in very long counting times for the different q-ranges [multiple datasets are needed for a complete I(q)]. We tried increasing the power of the LED since there was no apparent signal. After no success, we changed to low-q regime with 7.8 m collimation and 10 m detector distance. We also attempted a perpendicular geometry with a small field applied. The main reason for the lack of observable neutron intensity is the large thickness of the sample.

A promising route for future neutron experiments on EuTe may be to measure the SANS signal on film samples in a reflection/grazing incidence geometry. With that, the absorption will be greatly reduced without too much affecting the signal coming from the magnetic polarons.

[1]. Henriques et al. , PRB 93 , 201201 (2016).

[2]. Mauger & Mills, PRL 53 , 1594 (1984) and PRB 31 , 8024 (1985)

[3]. Henriques et al. , PRB 90 , 165202 (2014).

[4]. Henriques et al. , Appl. Phys. Lett. 99, 091906 (2011).

[5]. Beaudin et al. In preparation.