Experimental report

03/07/2018

Proposal: **4-01-1576** **Council:** 4/2017

Title: Magnon diffusion in the spin Seebeck material magnetite

Research area: Physics

This proposal is a new proposal

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Samples: Fe_3O_4

Instrument	Requested days	Allocated days	From	To
IN8	7	7	14/03/2018	21/03/2018
IN3	0	1	13/03/2018	14/03/2018

Abstract:

Utilising waste heat from industrial processes has the potential to increase efficiency and decrease greenhouse emissions. Thermoelectric generators (TEG) are a reliable form of waste heat recovery. For good device efficiency the thermal and electrical conductivities of a TEG needs to minimised and maximised respectively. But, these parameters are intrinsically linked for a given material and thus provide an ultimate efficiency limit. The spin Seebeck effect (SSE) is a recently discovered spintronic phenomenon and may provide a way of sidestepping this limit. SSE devices, however, saturate above a critical thickness limiting their performance. It has been theorised that this saturation length corresponds to the magnon diffusion length. We wish to use inelastic neutron scattering to measure the magnon lifetimes in Fe_3O_4 and thus deduce the magnon diffusion length. Our results will provide a key test of theory in this rapidly developing field and inform future device design.

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The aim of this experiment was to measure the magnon mean free path in Fe_3O_4 across a range of temperatures and compare them the saturation thickness of spincaloritronic devices. This would enable us to test the hypothesis that device thickness is limited by magnon diffusion.

A 5g single crystal of Fe_3O_4 was aligned in the *hhl* scattering plane on IN3 prior to transfer to IN8. IN8 was initially configured with the Cu double focussing monochromator and analyser. Initial measurements were made around the (004) and (222) reflections which demonstrated that the dispersion was rather steeper at 150 K than the literature suggested and although the energy resolution was excellent, the q-resolution with double focussing meant that the widths were many tens of meV wide.

As such we switched to the Pg-Pg mono-analyser with 20 minutes of collimation. Unfortunately, even with this degree of collimation the steeper than expected dispersion resulted in rather broad modes and as such we restricted the experiment to q-scans where it was easier to disentangle the magnetic excitation from the Al phonon density of states. Measurements were made around the (222) reflection along the *hhh* direction at 150, 300 and 500 K. Between 150 and 300 K the only detectable change was a subtle evolution in the gradient of the dispersion (see figure). While realigning at 500 K the vertical focussing motor on the monochromator became stuck. This has prevented us from directly comparing the 500 K data to the previous datasets however there appears to be a significant softening on heating, although no obvious broadening.

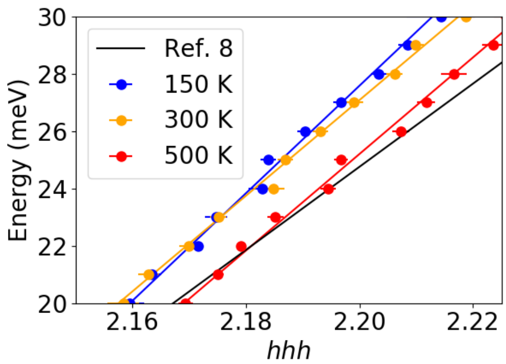

Figure 1: The dispersions obtained on IN8 at 150, 300 and 500 K compared to those in the literature. Both at 300 and 150 K the dispersion is significantly harder than previously reported. It softens considerably at 500 K however the instrumental issues described in the text may be the cause.

The difference between our data and the published values has complicated the analysis somewhat, as has its temperature evolution. While our results appear inconsistent with the proposed model of magnon diffusion limiting the devices (we should have detected a change in widths) working out the correct resolution function is not possible without a good underlying model of the dispersion. As such we have applied for time on MAPS@ISIS to properly measure the dispersion and will use this as input for fitting our IN8 data.