Experimental report

24/01/2024

Proposal: 4-05-876 **Council:** 4/2023

Title: Magnetic character of chiral phonons

Research area: Physics

This proposal is a new proposal

Main proposer: Urs STAUB

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Samples: alpha SiO2 (quartz)

Instrument	Requested days	Allocated days	From	To
IN20 He3 Spin Filter	14	7	30/10/2023	06/11/2023
ORIENTEXPRESS	1	1	27/10/2023	28/10/2023

Abstract:

Chirality is one of the most fundamental symmetry properties in nature. In condensed matter systems, the connection of chirality and electronic and magnetic properties has gained renewed interest. Here we propose to directly test the underlying concept of orbital angular moment transfer required for an excitation of a chiral phonon in chiral ¿-quartz. Considering a 100% chiral phonon mode has to conserve orbital angular momentum, it will require the neutron to flip its spin when exciting the mode. As certain modes at a specific point in reciprocal space in quartz are highly chiraly polarized, one would expect a significant spin-flip signal, similar to the significant observed dichroic signal in our recent RIXS experiment. Besides the basic concepts, nothing is known to our knowledge on any attempt to confirm this process directly and quantify the magnetic character of a chiral phonon experimentally.

Experimental report 4-05-876 **Magnetic character of chiral phonons**

Experimental team: Hiroki Ueda (PSI), Carl Ramao (ETH), Mechthild Enderle (ILL), Ursula Bengaard-Hansen(ILL) and Urs Staub(PSI)

The goal of the experiment was to directly observe the magnetization carried by a chiral phonon due to the chiral motion of charged atoms in chiral non-magnetic quartz. The importance of magnetization in chiral phonons is currently hotly discussed but it misses a direct observation, which might be directly accessed by polarized neutron scattering. The experiment at IN20 could unfortunately not use the PASTIS and Flat cone setup due to problems with the flatness of the floor and a technical problem of a motor. Therefore, the experiments were performed with the Helmholtz coil setup. We have mainly concentrated on two points in (Q,E) with low Q, as the spin flip signal is magnetic and therefore decays with increasing Q. The first point has been chosen where calculations give a significant contribution, and the phonon cross section itself is not small, making the unflipped channel significant (see green markers Fig 1). The spin flip channels get some signals, which have a slightly different background (fig 1, right) and show the good flipping ratio of the instrument, but do not provide evidence for a magnetic signal due to their similar peak intensity.

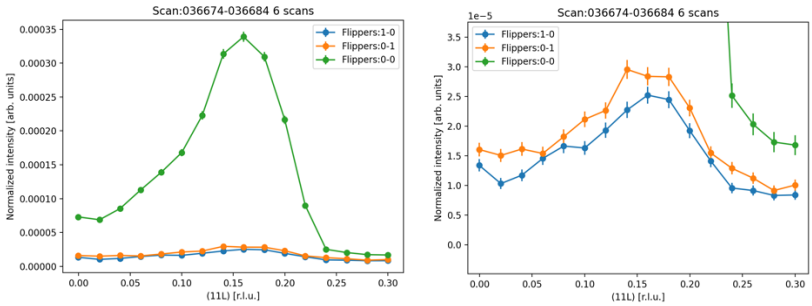

Fig. 1 q-scan along [11l] at fixed energy transfer of 5 meV for a 1 cm^3 quartz crystal.

In the second attempt, we concentrated on a point in reciprocal space with a predicted magnetic signal while the nuclear scattering is very weak. Interestingly, a very weak but clear difference has been observed between the two opposite spin flip signals as shown in figure 2. However, when exchanging the sample to the opposite enantiomer, the difference signal remains in the same channels. However, it should transfer to the other spin flip channel, as the chirality of the mode, and therefore the magnetization carried by it, should reverse. The origin of this difference is still under investigation, including a cross check of the chirality of the two commercially bought crystals from a company that previously correctly specified the handedness of two quartz crystals.
It is clear that magnetic signals will be weak, but a further experiment with the PASTIS setup, being able to look at the interference terms, will have a much better chance of detecting the calculated magnetic contribution of a chiral phonon. A further experiment will allow to benchmark the theoretical calculations and provide direct evidence of the magnetization carried by a chiral phonon.

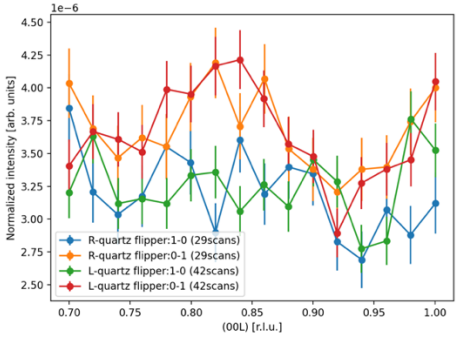

Fig. 2 q-scan along [00l] at fixed energy transfer of 5 meV for both handedness quartz crystals. (approx. 1h/point/polarization channel)