# Experimental report

17/11/2017

**Proposal:** **7-02-164** **Council:** 4/2016

**Title:** Temperature-dependent investigation of the mechanical anisotropy of $Bi_2Mn_4O_{10}$ in the multiferroic phase

**Research area:** Materials

**This proposal is a new proposal**

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**Samples:** $Bi_2Mn_4O_{10}$

| Instrument | Requested days | Allocated days | From | To |
|---|---|---|---|---|
| IN8 | 7 | 5 | 21/02/2017 | 27/02/2017 |

**Abstract:**

There are ongoing debates on the origin of multiferroicity in many materials and different microscopic mechanisms of the magneto-electric coupling are discussed. In the mullite-type $Bi_2Mn_4O_{10}$-compound, ferroelectricity is supposed to be induced by magnetostriction as consequence of the magnetic long-range order. Since lattice distortions play a vital role in this mechanism, it is essential to investigate the temperature-dependent mechanical properties of the relevant compounds near the magnetic phase transition. As a straight-forward continuation of our previous inelastic neutron scattering study at ambient conditions performed at the PUMA-spectrometer, we propose to determine the temperature dependence of selected acoustic phonons which reflect the dynamical anisotropy near the multiferroic transition at $T_N$=40 K.

## Temperature-dependent investigation of the mechanical anisotropy of $Bi_2Mn_4O_{10}$ in the multiferroic phase

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In a recent inelastic neutron scattering study [1], we determined the elastic constants of multiferroic $Bi_2Mn_4O_{10}$ at room temperature and found a distinct mechanical anisotropy along the ***a***-axis. Since the spins in the antiferromagnetic phase below $T_N$ = 40 K are pointing along the same direction, it is reasonable to assume that there is a connection between magnetic order and mechanical properties. This is furthermore supported by the fact that the ferroelectricity in $Bi_2Mn_4O_{10}$ is supposed to be induced by magnetostriction as consequence of the magnetic long-range order. Therefore, the aim of this experiment was the investigation of the mechanical behaviour at low temperatures close to the magnetic phase transition in order to determine the effect of the multiferroic coupling.

This experiment is divided into two parts. Additionally to the beam time at IN8, we also got the opportunity to perform measurements at PUMA@FRMII. The latter was scheduled earlier and we started determining all elastic constants accessible within the (010)-scattering plane. This left the remaining phonons of the (100)- and (001)-plane for the experiment at IN8 including three longitudinal phonons propagating along the directions [0 $\xi$ 0], [$\xi$ $\xi$ 0] and [0 $\xi$ $\xi$] as well as five transverse ones along [$\xi$ 0 0], [0 $\xi$ 0], [0 $\xi$ 0], [$\xi$ $\xi$ 0] and [0 $\xi$ $\xi$]. This collection allows the determination of the elastic constants $c_{22}$, $c_{44}$, $c_{66}$, and $c_{23}$. The determination of the remaining off-diagonal element $c_{12}$ at low temperatures was prevented by the fact that the required longitudinal phonon along [$\xi$ $\xi$ 0] was too weak and could not reliably be detected within a reasonable amount of time.

For the determination of the temperature-dependence near the magnetic phase transition, we selected a single phonon of each branch which was measured at various temperatures above and below the transition. However, no significant temperature effect could be observed for all phonons within the accuracy of the instrument. Sample spectra are shown in figure 1 for the transverse phonon propagating along [0 $\xi$ $\xi$].

At 30 K, well below the phase transition temperature, additional spectra were taken at different wavevectors in order to determine the initial slopes (sound velocities) of all accessible phonon branches. This allows the calculation of the respective elastic constants as explained in [1]. The differences to the room temperature results are below 10% which is the accuracy for this experimental setup. As an example, Figure 2 shows the dispersion curve of one transverse phonon at both temperatures.

These results obtained at IN8 are in agreement with the other part of the experiment using PUMA@FRMII. The elastic constants which could be calculated from the results of the (010)-scattering plane again turned out to agree with the room temperature data. In conclusion, there is no effect of the multiferroic phase transition on the elastic properties of $Bi_2Mn_4O_{10}$ within in the instrumental resolution. This is true directly at the phase transition and at temperatures well below.

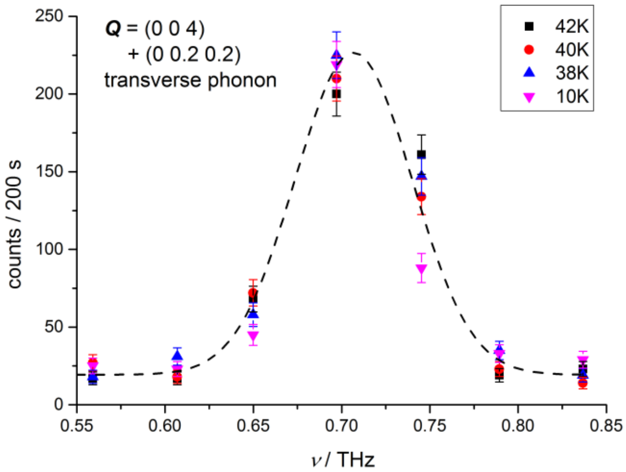


**Fig. 1**: Constant-***q*** scans of the TA[0 $\xi$ $\xi$]-phonon polarized within the (100)-plane at four different temperatures near the multiferroic transition ($T_N$ = 40 K). The dashed line is a guide to the eye.

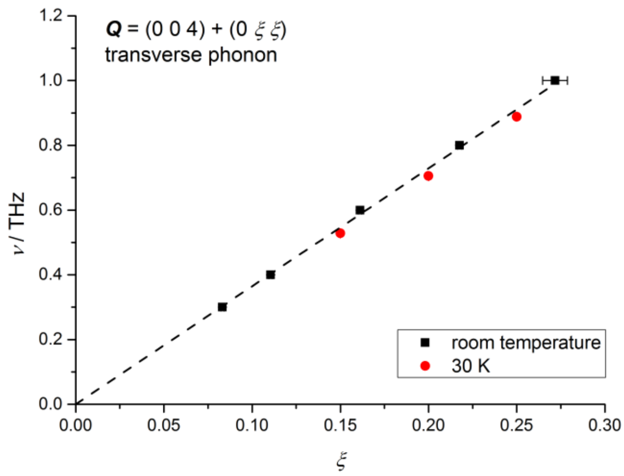


**Fig. 2**: Comparison of the dispersion curves of the TA[0 $\xi$ $\xi$]-phonon polarized within the (100)-plane at room temperature [1] and 30 K. The dashed line is a guide to the eye.

## References


[1] F. Ziegler *et al.*, Mechanical properties of multiferroic $Bi_2Mn_4O_{10}$: Full set of elastic constants determined by inelastic neutron scattering, *Phys. Status Solidi B* 253, No. 5, **2016**, 976–982.