Experimental report

14/09/2018

Proposal: **5-23-695** **Council:** 10/2016

Title: Tuning multiferroicity in RBaCuFeO5 perovskites with chemical pressure

Research area: Physics

This proposal is a continuation of 5-31-2380

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Samples: PrBaCuFeO5
NdBaCuFeO5
LaBaCuFeO5
154SmBaCuFeO5
153EuBaCuFeO5
160GdBaCuFeO5
TbBaCuFeO5
DyBaCuFeO5
HoBaCuFeO5
TmBaFeCuO5
ErBaCuFeO5
YbBaCuFeO5
LuBaCuFeO5

Instrument	Requested days	Allocated days	From	To
D2B	3	2	09/12/2016	11/12/2016

Abstract:

We propose to investigate the impact of "chemical pressure" in the crystal structure of the high-temperature magnetoelectric multiferroic YBaCuFeO5 through the replacement of Y3+ by trivalent 4f lanthanide ions. The obtained information should provide insight about the link between the evolution of the multiferroic order temperature and the modification of the lattice due to the lanthanide contraction. This information may help to design other materials with improved multiferroic properties.

Scientific Report

The goal of this experiment was to investigate additional ways of tuning the spiral ordering temperature of the layered perovskite $YBaCuFeO_5$ [1], whose crystal structure is schematically shown in Fig. 1. The renewed interest on material, extensively investigated during the 80's [2,3] due to its parentage with the high-temperature superconductor $YBa_2Cu_3O_{6+x}$, is the recent observation of magnetism-driven ferroelectricity at an unexpectedly high temperatures. As reported in refs. [4,5], spontaneous electrical polarization develops in $YBaCuFeO_5$ below T_{N2} ~ 240K, coinciding with a spin-reorientation of the Fe^{3+} and Cu^{2+} magnetic moments [4,5]. This reorientation involves a change in the periodicity of the magnetic order, which is commensurate with the crystal unit cell above T_{N1} (k_c = ½ ½ ½) and becomes incommensurate below this temperature.

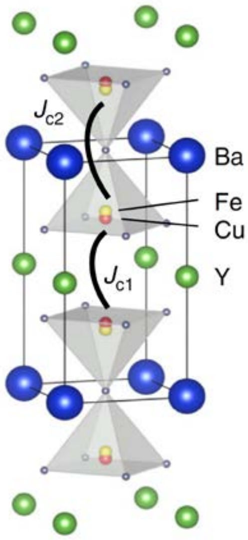


Fig. 1. Crystal structure of $YBaCuFeO_5$ (from ref. 7)

As part of Mickael Morin's PhD work, we recently succeeded to prepare $YBaCuFeO_5$ ceramic samples of unprecedented quality in our group at the PSI [6]. We also reported the first model for the low temperature incommensurate phase, which is of spiral type. Moreover, we managed to increase the spiral order temperature up to 310K using a novel route based in the targeted manipulation of the Cu/Fe chemical disorder in the structure [7]. As shown in Fig. 1, the spiral order temperature, signaled by the red arrow, is quite low for the sample with the smallest amount of disorder (154K, upper panel) , but it increases up to 310K for the most disordered sample (310K, lowest panel). At the same time, the paramagnetic-to-collinear transition temperature (indicated by a blue arrow) displays the opposite behavior. From Fig. 2, it is clear that both temperatures should merge for larger degrees of disorder.

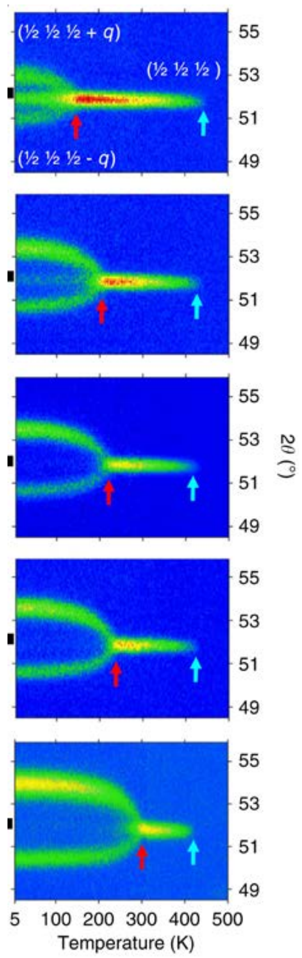
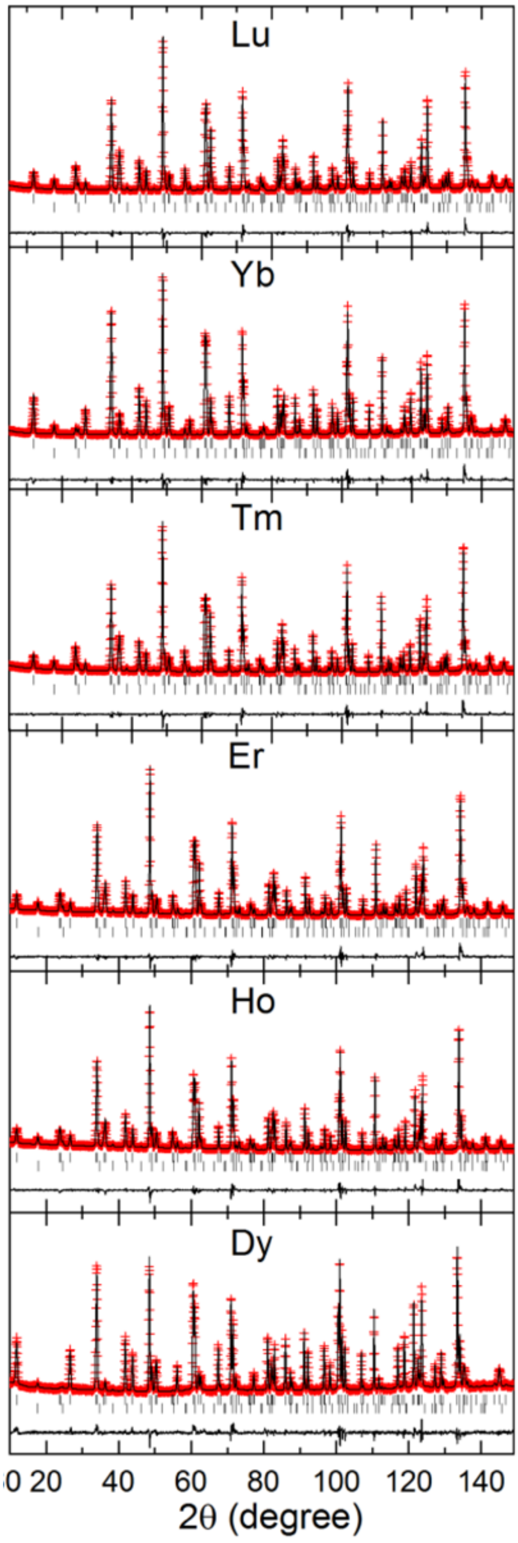


Fig. 2. Low angle part of the neutron powder diffraction patterns of 5 $YBaCuFeO_5$ samples with different degrees of disorder (from ref. 7)

Fig. 3. Neutron powder diffraction patterns of the $RBaCuFeO_5$ layered perovskites at RT measured at D1B using 1.59A.



In the present experiment we have tried to reach this limit by combining a maximal chemical disorder with a targeted manipulation of some magnetic exchange couplings. For this purpose we prepared the $RBaCuFeO_5$ series (R = Lu, Yb, Tm, Er, Ho, and Dy) aimed to change Jc1 (see Fig. 1). Unfortunately, the highest spiral transition temperature, which corresponds to R = Dy, was 312K, only slightly higher than in the case of quenched $YBaCuFeO_5$ (see Fig. 2). Nevertheless, the data recorded on D2B (Fig. 3) allowed to understand the reasons of this behavior. These results, combined with those extracted from data obtained at the Swiss neutron source SINQ for other layered perovskites, were recently accepted for publication in Science Advances

References

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