Experimental Report

11/03/2014

Proposal: **4-01-1327** **Council:** 10/2012

Title: Low energy spin fluctuation in superoxygenated La(2)CuO(4+y)

This proposal is resubmission of: 4-01-893

Research Area: Physics

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Samples: La(2)CuO(4+y)

Instrument	Req. Days	All. Days	From	To
IN12	7	5	14/05/2013	17/05/2013
			01/07/2013	03/07/2013

Abstract:

In La(2)CuO(4+y) (LCO+O) the existence and size of a spin fluctuation gap has not yet been established, although both an elastic magnetic signal and spin fluctuations in the 2-4 meV range have been observed in crystals with varying oxygen content and Tc in the range 30-42K [11]. We intend to establish whether there is a gap in a highly oxygenated (superoxygenated) and good quality LCO+O single crystal and measure the details of the spin fluctuation spectrum. This is an important task in order to understand the fundamental influence of superoxygenation on the magnetic phase both in LCO+O itself but also as a basis for understanding the Sr/O co-doped system and its electronic phase separation.

We aim to perform the first low-energy experiments on LCO+O, and clarify the magnetic response of the system. From this we will conclude about similarities to stripe-like 1/8 doped systems, as well as examine the role of the annealed oxygen dopants vs. the more studied quenched Sr doped systems La(2-x)Sr(x)CuO(4).

Incommensurate AFM peaks in superoxygenated La_2CuO_{4+y}

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1 Introduction

This is a summary of the experiment (ILL proposal number 4-01-1327) performed on a large single crystal La_2CuO_{4+y} sample at the instrument IN12 at the Institute Laue Langevin, in May 2013. A continuation of the experiment was performed in July 2013.

In the bulk measurements during this experiment, we did not use any collimation other than that naturally from the instrument, and did not use the second monitor. The slits were relatively tight. The final setup for the bulk measurements were as follows (the plexi was only put in when we looked at elastic peaks):

MVH - Open - (Plexi) - Mon1 - D - S - D - Mon2 - Open - AVH - SingleTubeDetector

The sample consists of four ∼3.5 g cylindrical pieces of La_2CuO_{4+y} single crystals, all from the same crystal rod. The large initial rod broke into two pieces (A and B) during the oxygenation process, and these two pieces were checked for quality back in July 2012 [1]. The two pieces were later each cut up into three smaller pieces (and some smaller pieces that broke off) with a round diamond blade. Four of the large pieces – two from A and two from B – were then used for this experiment. The total mass of the used sample was 15.788 g.

The sample was held in an orange cryostat [2] for the duration of the IN12 experiment, and was initially cooled down to 2 K with a ramping rate of 1 K/min, to allow for the oxygen to order. Later, the sample was heated to 45 K, cooled back down to 2 K, heated to 45 K again, and finally heated all the way to room temperature. The cooling rates were always kept to 1 K/min, while the heating was allowed to go quickly.

Several different sets of scans were performed during the experiment, mainly:

Energy scans The energy resolution of the instrument was investigated by both scanning the energy over a Bragg peak and an incoherent signal – giving the Bragg and Vanadium resolutions, respectively.

Inelastic scans This was the bulk of the experiment. The (0.875,±0.125,0) incommensurate positions at an energy transfer $\hbar\omega$ of different values between 0.3 meV and 7.0 meV were scanned for k_f values of 1.2 Å^{-1} and 1.5 Å^{-1}, at both 2 K and 45 K temperatures.

Inelastic temperature scans Three-point scans of the (0.875,−0.125,0) incommensurate positions at $\hbar\omega = 0.3$ meV and 1.5 meV were performed over heating and cooling of the sample between 2 K and 45 K.

Phonon scans Scans of the (2,0,0) phonon for $\hbar\omega = 3$ meV and 2 meV at $k_f = 1.5$ Å^{-1} were performed in the end of the experiment.

Grid scans Mapping of peaks.

Temperature scan Of (1 0 0) peak while heating from 45 K to room temperature

An example of the data is shown in figure 1.1, where changes in outgoing wave vector k_f, energy transfer $\hbar\omega$, and temperature T are shown. A fit to a double-peaked function named "Sato-Maki" is performed. The Sato-Maki fit shown on the raw data was first introduced by H. Sato and K.

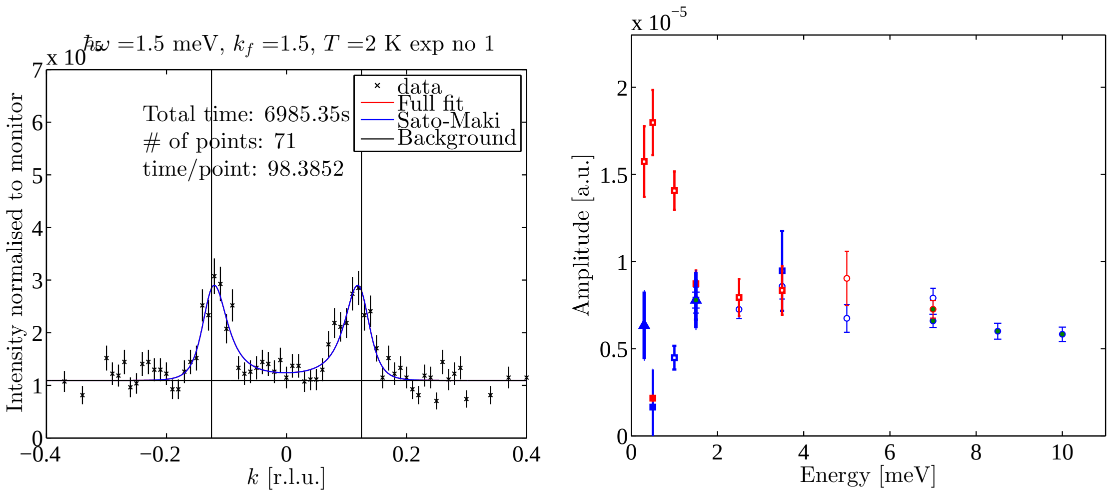

Figure 1.1: Left: Raw data with Sato-Maki fit with no bound parameters of the (0.875,k,0) incommensurate positions. Right: The amplitude of the peaks as function of energy. Red points are above the SC transition at 45 K, blue points at 2 K.

Maki. We have followed the procedure by Aeppli et. al in Ref. [3].

The main result of the experiment is the amplitude of the peaks as function of energy, as shown in the right part of figure 1.1.

In the first experiment we were plagued by spurions. Inserting a filter in the second experiment improved this a lot.

2 Conclusion

We have measured the behavior of the incommensurate antiferromagnetic signal at (0.875,±0.125,0) for a large La_2CuO_{4+y} single crystal, both for changing energy transfer and temperature. We have found that the signal falls for lower energy transfers, but seems to rise again at the lowest energy transfer for 2 K data, as opposed to the 45 K data.

Apart from this change at the lowest energy transfer, these results correspond well to other measured similar systems.

References

[1] Pia Jensen and Martin Böhm. Crystal quality determination – experiment at OrientExpress (ILL, France). Beam time report, July 2012.

[2] IN12 Orange Cryostat 72ILHV49, May 2013. URL `http://www.ill.eu/instruments-support/sample-environment/equipment/low-temperatures/cryostats/72ilhv49/`.

[3] G. Aeppli, T. E. Mason, S. M. Hayden, H. A. Mook, and J. Kulda. Nearly Singular Magnetic Fluctuations in the Normal State of a High-T_C Cuprate Superconductor. *Science*, 278:1432–1435, 1997.