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# Experiment Report Form

**The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF**.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

*http://193.49.43.2:8080/smis/servlet/UserUtils?start*

***Reports supporting requests for additional beam time***

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

***Reports on experiments relating to long term projects***

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***Published papers***

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

## Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

## Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

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|---|---|---|
| ESRF | **Experiment title:**<br>**Analysis of charge density waves in $La_{1-x}Sr_{1+x}MnO_4$ layered manganites far from the half-doping by RXS** | **Experiment number**:<br>HE-2909 |
| **Beamline**: | **Date of experiment**:<br>from: 10/12/2008 to: 15/12/2008 | **Date of report**:<br>01/09/2009 |
| **Shifts:** | **Local contact(s)**:<br>C. Mazzoli | *Received at ESRF:* |

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## Report:

The emergence of superlattice periodicities at metal to insulator transitions in hole doped perovskite oxides responds to a rearrangement of the local atomic structure, and electron and spin density distribution. Originally, the ionic model based on a checkerboard- type atomic distribution served to describe the low temperature charge and orbital ordered (COO) phases arising in half- doped manganites.

However, in the last years, the exploitation of resonant x- ray scattering (RXS) capabilities has shown the need to revisit these concepts and improve the picture. Yet, we have realised that COO is a more common phenomenon than expected that can be observed in a wide range of doping levels.

In this experiment we have recorded RXS experimental data on $La_{1-x}Sr_{1+x}MnO_4$ for x=0.5 and x=0.6. The half-doped compound was first studied by Murakami [1] with this technique. His interpretation of the checkerboard phase in terms of a mixture of $Mn^{3+}$ and $Mn^{4+}$ ions has been later challenged but the basis of the tensorial formalism applied to analyze the observed superlattice reflections has remained more or less unaltered. We have reproduced the experimental results obtained on $La_{0.5}Sr_{1.5}MnO_4$ and also recorded other COO- related reflections, in addition to a complete polarization and azimuthal dependence study. We plan to write soon a paper solely dedicated to the analysis of these experimental data.

The comparison to the x=0.6 case is crucial since for $0.5<x<0.67$ an incommensurate COO-kind insulator phase has been also described at low T (~220-230 K) [2]. We have observed OO and CO related superlattice reflections at $\mathbf{Q}_{OO}\sim(h\pm\varepsilon, h\pm\varepsilon, 0)$ and $\mathbf{Q}_{CO}\sim(h\pm2\varepsilon, h\pm2\varepsilon, 0)$, $2\varepsilon=1-x$, for h=1,2. Our results permit to extract several conclusions. First, energy and azimuthal dependent spectra are nearly identical in both x=0.5 and 0.6 cases, apart from a significantly reduced intensity in the latter. This induces to think of the prevalence of the checkerboard model in the COO incommensurate phase. Nevertheless, any temptation to propose a simple $Mn^{3+}/Mn^{4+}$ ionic distribution to account for the formal average $Mn^{+3.6}$ for x=0.6 sample is difficult to compatibilize with the T dependent measurements. They confirm that superlattice reflections in this compound are incommensurate and reflections Miller indexes vary with T [3]. The combination of these

results leads us to suggest the existence of an incommensurate charge density wave, where charge modulation is not only supported by Mn atoms but also La (Sr) and O.

In our opinion, structural distortions in the low T phase with respect to the high T tetragonal phase are an important ingredient that needs to be integrated in the COO model to better evaluate the charge disproportionation between inequivalent Mn sites. This might be very small, as previous works on related materiales have shown [4].

A structural study on this series is currently underway at ID31 beamline and we hope to combine these and RXS results got in ID20 to be able to propose a consistent structural and electronic model in the COO phase.


[1] Murakami Y et al 1998 Phys. Rev. Lett. **80** 1932
[2] Larochelle S et al 2001 Phys. Rev. Lett. **87** 095502
[3] Herrero-Martin J et al 2009 J. Phys.: Conf. Series (in press)
[4] Herrero-Martin J et al 2004 Phys. Rev. B **70** 024408