ESRF	**Experiment title:** The Role of the Doping on the Lattice Dynamics of LSCO High Temperature Superconductors	**Experiment number:** HS-2440
Beamline: ID28	**Date of experiment:** from: 3 March 2004 to: 9 March 2004	**Date of report:** 15 June 2004
Shifts: 18	**Local contact(s):** Alexei BOSSAK	*Received at ESRF:*

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Report:

In the present experiment we have studied the phonon dispersion in $La_{2-x}Sr_xCuO_{4+\delta}$ along $a*$, with a particular focus on the high energy longitudinal optic phonons corresponding to *in-plane* oxygen vibration. From previous neutron scattering investigations [1, 2, 3, 4], these modes are known to become anomalous with doping in transition metal oxides, and it has been suggested that the sharp 'kink' observed in the photoemission spectra of the electrons in cuprate have the same origin [5]. However, only the optimal Tc doping has been investigated so far (and recently the overdoped regime by IXS [6]), and it is not clear how the anomaly appear with doping, an information particularly important in order to find an adequate model. In the present experiment we have studied the x=0.08 doping, halfway from optimal doping (0.16) and metallic non-superconductor underdoped (0.04). A second motivation for our investigation was the possibility to measure the same dispersion of [2, 3] with a different resolution function, in order to distinguish the two proposed interpretation of the observed anomaly: a softening [3], or an additional damped second "impurity" mode [2]. As can be see in Fig. 1, we have observed an anomaly quite similar to the one observed in optimally doped $La_{2-x}Sr_xCuO_{4+\delta}$,

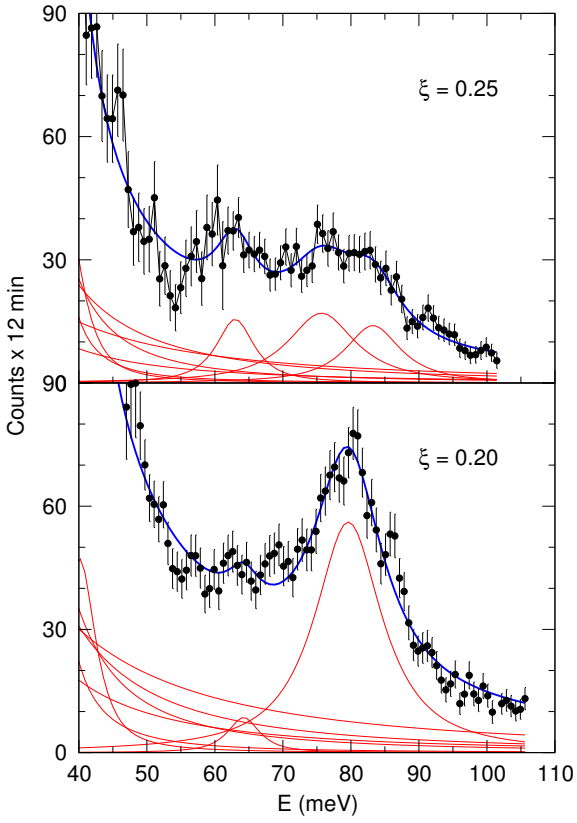

Fig. 1: High energy longitudinal optic phonon group in $La_{2-x}Sr_xCuO_{4+\delta}$ *with* $x \approx 0.08$ *at* $Q = (3 + \xi, 0, 0)$*, measured by IXS on ID28 (HS2440).*

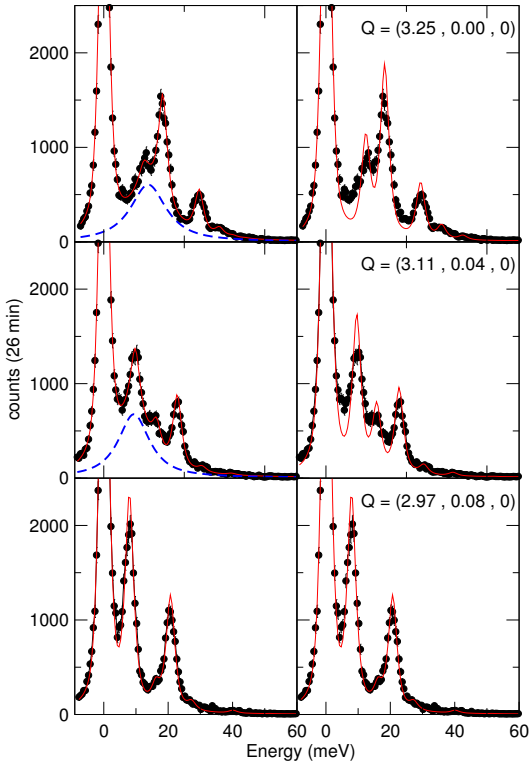

Fig. 2: Low energy phonon group at high resolution Si(999) measured by IXS on ID28 (HS2440). Top: scan in longitudinal configuration at Q = (3.25,0,0); middle: almost longitudinal at Q=(3.11, 0.04,0); bottom: almost transverse at Q=(2.97, 0.08,0). Left: total fit (red) with an additional broad low energy resonance (blue dashed).

as can be expected in an hypothesis where the phenomena is much stronger of the superconductivity itself and essentially linked to local charge inhomogeneities, as suggested in [4].
Moreover, we note that a sudden drop of the intensity by one half with a $\Delta\xi$ change as small as 0.05 cannot be understood with a simple dispersion and broadening. As a matter of fact our data are better fitted with two modes at q=(0.25,0,0), in agreement to the interpretation suggested in [2, 4]. This is particularly important because the observed phenomena seems to be the only dynamical signature of a depinned stripes ground state [7].

An additional, unexpected and intriguing result has come from the analysis of a limited series of high resolution data, obtained with the monochromator Si(999) reflection, with approximately 3.0 meV resolution. In the case of scans made in longitudinal configuration, we observe a broad bell shaped background, with a width of the same order of its energy (see Fig. 2, left). The broad inelastic signal does not appear in almost transverse configuration, which in the present measurements has a very close geometry to the longitudinal ones (see Fig. 2, bottom panel). This observation gives evidence that it is an intrinsic phenomenon and not an artifact or a double scattering contribution. However, the very limited set of data does not allow to rule out any hypothesis. If confirmed, this additional dynamical resonance does not have, at the moment, any explanation, as it does not correspond to any previously observed energy scale. A more complete investigation, with different doping, and wider Q and temperature range is necessary in order to confirm this observation, and allow some knowledge of its physics.

References

[1] L. Pintschovius and W. Reichardt, in *Neutron Scattering in Layered Copper-Oxide Superconductors*, ed. A. Furrer, Physics and Chemistry of Materials with Low-Dimensional Structures Vol. 20 (Kluwer Academic Publishers, Dordrecht, 1998) p. 165; M. Braden *et al., Europhys. Lett.* **34**, 531 (1996).

[2] R.McQueeney *et al., Phys. Rev. Lett.* **82**, 628 (1999).

[3] L. Pintschovius and M. Braden, *Phys. Rev. B* **60**, R15039 (1999).

[4] J.M. Tranquada *et al.*, *Phys. Rev. Lett.* **88**, 075505 (2002).

[5] A. Lanzara *et al.*, *Nature* **412**, 510 (2001).

[6] T. Fukuda *et al.*, cond-mat/0306190 (2003).

[7] S. A. Kivelson *et al.*, *Rev. Mod. Phys.* **75**, 1210 (2003).