	Experiment title: Competition of CDW with superconductivity in HgBa2CuO4+y single crystals revealed by magnetic field effect on lattice fluctuations below Tc=96K by Cu K-edge XANES-EXAFS	**Experiment number**: HC-2051
Beamline:	**Date of experiment**: from: 03 Feb 2016 to 09 Feb 2016	**Date of report**: March 1, 2016
Shifts: 18	**Local contact(s)**: ID12 Francois Guillou	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Boby Joseph[1], Alessandro Puri[2], Valentin Ivanov[3], Alexey Menushenkov[3], Purans Juris[4], Andrei Rogalev[5], Francois Guillou[5], Antonio Bianconi[6,3]

[1]*Elettra Sincrotrone Trieste, Strada Statale 14-km 163,5, AREA Science Park, 34149 Basovizza, Trieste, Italy*

[2]*CNR-IOM-OGG c/o ESRF LISA CRG Grenoble, 71 Avenue des Martyrs,38000 Grenoble, France*

[3]*Physics of Solid State and Nanosystems Department, National Research Nuclear University "MEPhI" (Moscow Engineering Physics Institute), Moscow, Russia*

[4]*Laboratory Universita di Trento Dipartimento di Fisica Via Sommarive 14 Povo IT - 38050 Trento*

[5]*ESRF - The European Synchrotron Radiation Facility, 71 Avenue des Martyrs CS40220, F-38043 Grenoble Cedex 09, France*

[6]*Institute of Crystallography, CNR, via Salaria Km 29.300, Monterotondo Roma, I-00015, Italy*

Report:

Competition between superconductivity and charge density wave (CDW) is a hot topic in the search for the high temperature superconductivity (HTS) mechanism in cuprates [1] and related superconducting oxide superconductors [2].

First evidence for short range charge density wave order and its associated short range periodic lattice distortion was obtained in cuprates [3-8] using X-ray Absorption Near Edge Structure (XANES) [9-11] and EXAFS analysis of x-ray absorption spectra [12]. The wide HTS community has accepted the compelling evidence for the competition between CDW and superconductivity in cuprate perovskites only when it was shown experimentally that the diffuse CDW satellite in the x-ray diffraction (XRD) pattern increases its intensity by the application of an external magnetic field below the superconducting critical temperature [13]. For this purpose a 17 T horizontal cryomagnet designed for beamline use was installed on the triple-axis diffractometer at a synchrotron radiation beamline. The research activity following this discovery has shown that the effect of the magnetic field on CDW is ubiquitous in cuprates [14-17] showing that the short range CDW puddles form the so called superstripes scenario [18,19].

We have carried a temperature dependent Cu K-edge XANES experiment to confirm the presence of a direct involvement of the Cu-O bond length fluctuations in CDW using polarized synchrotron radiation.

We have used the ID12 beamline dedicated for polarization dependent X-ray. We used circularly polarized x-rays generated by the HELIOS-II undulator. The second harmonic of low intensity is used so that the heating of the sample by x-rays could be safely neglected. The sample is mounted on a cold finger of a constant flow He cryostat allowing the temperature on the sample to be controlled in the range 50- 150 K. The cryostat was inserted in a bore of 17 Tesla superconducting solenoid. The surface area of the samples are larger than the typical size of x-ray beam on the sample, about 300 by 300 microns. All spectra were recorded using total fluorescence yield detection mode using Si photodiode mounted inside the solenoid. Having the c axis parallel to the x-ray wavevector, absorption spectrum measured with circularly polarized x-rays give E//ab spectrum. Advantage for us is that higher order harmonics emission of undulator were absent.

We have measure the Cu K-edge XANES of a Bi2212 single crystals and of a YBa2Cu3O7-y powder sample in the temperature range between 150 K and 50 K around the critical temperature and below the onset of charge density wave Tcdw. We have confirmed the previously observed change of XANES spectra at T(cdw) and at Tc [20] interpreted using multiple scattering theory [4,5]. The HgBa2CuO4+y sample was smaller than the x-ray beam size so it was not measured in this run.
The onset of CDW order in cuprates has been observed by temperature dependent XANES which is a method of choice since it probes directly the amplitude of fluctuations of the Cu-O bond distance because it is a fast (10^-15 seconds) probe of the short range structure.
The competition between the polaronic charge density wave (CDW) and the superconducting condensate has been studied by measuring the effect of a large magnetic field of 17 Tesla on the temperature dependence of the Cu K-edge XANES spectra. The results show the variation of Cu K-edge XANES in the superconducting phase by increasing the magnetic field from H=0 T to H= 16 T. The results support the proposal [1-12] that polaronic lattice distortions are key features in cuprate superconductors.

References

1. K. A. Müller, *The unique properties of superconductivity in cuprates* Journal of Superconductivity and Novel Magnetism, 27, 2163 (2014)
2. A. Y. Ignatov, A.P. Menushenkov, et al. Physica C: Superconductivity 271, 32 (1996)
3. S. Della Longa, A. Di Cicco, S. Stizza, M. De Santis, K. Garg, and A. Bianconi, Physica B: Condensed Matter **158**, 469 (1989)
4. A. Bianconi, C. Li, F. Campanella, S. D. Longa, I. Pettiti, M. Pompa, S. Turtù, and D. Udron, Physical Review B **44**, 4560 (1991)
5. Bianconi, M. Missori, H. Oyanagi, H. Yamaguchi, Y. Nishiara, and S. Della Longa, Europhysics Letters (EPL) **31**, 411 (1995)
6. A. Bianconi, et al.., Physical Review Letters 76, 3412 (1996)
7. A. Lanzara, et al. Journal of Superconductivity and Novel Magnetism 1**0**, 319 (1997)
8. A. Lanzara, et al.. Physical Review B 55, 9120 (1997)
9. A. Bianconi, S. Doniach, and D. Lublin, Chemical Physics Letters **59**, 121 (1978), URL http://dx.doi.org/10.1016/0009-2614(78)85629-2.
10. J. Garcia, A. Bianconi, M. Benfatto, and C. R. Natoli, Le Journal de Physique Colloques **47**, C8 (1986)
11. S. Della Longa, A. Soldatov, Pompa, and A. Bianconi, Computational Materials Science **4**, 199 (1995)
12. A. Bianconi, in *X-Ray Absorption: Principles, Applications, Techniques of EXAFS, SEXAFS and XANES*, edited by D. C. Koningsberger and R. Prins (Wiley-Interscience., New York, 1988), Chemical Analysis: A Series of Monographs on Analytical Chemistry and Its Applications (Book 134), pp. 573-662,.
13. J. Chang, et al. Nature Physics **8**, 871–876 (2012)
14. G. Ghiringhelli, et al. Science **337**, 821-825 (2012)
15. A. J. Achkar, et al. Phys. Rev. Lett. **109**, 167001 (2012)
16. N. Poccia, et al., Proceedings of the National Academy of Sciences **109**, 15685 (2012)
17. G. Campi et al., Nature **525**, 359 (2015).
18. A. Bianconi, ed., *SUPERSTRIPES 2015*, vol. 6 of *Science Series* (SUPERSTRIPES PRESS, Rome, Italy, 2015), ISBN 9788866830382.
19. A. Bianconi, International Journal of Modern Physics B **14**, 3289 (2000), URL http://dx.doi.org/10.1142/S0217979200003769.
20. A. Lanzara, G.-m. Zhao, N. L. Saini, A. Bianconi, K. Conder, H. Keller, and K. A. Müller, Journal of Physics: Condensed Matter **11**, L541 (1999) URL http://dx.doi.org/10.1088/0953-8984/11/48/103.