



	Experiment title: RIXS study of charge order in optimally doped $\text{Bi}_2(\text{Sr},\text{La})_2\text{CuO}_{6+\delta}$ superconductor	Experiment number: HC 2401
Beamline: ID32	Date of experiment: from: 30/03/2016 to: 03/04/2016	Date of report: 08/09/2016
Shifts: 12	Local contact(s): Kurt Kummer (email: kurt.kummer@esrf.fr)	<i>Received at ESRF:</i>
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Report:

In this experiment, we use Cu L_3 edge resonant inelastic x-ray scattering (RIXS) to study the charge order in underdoped and optimally doped high- T_c superconductor $\text{Bi}_2\text{Sr}_{2-x}\text{La}_x\text{CuO}_{6+\delta}$ (Bi2201). We have directly observed charge density modulation in optimally doped Bi2201 (OP33K) at momentum transfer $Q \sim 0.23$ r.l.u., with smaller intensity and correlation length comparing to underdoped sample. We explored also the nodal (diagonal) direction and found no charge order peak, confirming the charge order modulates only along the Cu-O bond directions. We also measured the out-of-plane dependence of charge order, finding no peaks at half integer in L -direction. This suggests there is no out-of-plane phase correlation in Bi2201. The manuscript of these results is under review in Phys. Rev. B [1]. In addition, we have also measured some paramagnon dispersions along the high-symmetry direction for OP33K and UD15K, which will be discussed in another manuscript in preparation. In this brief report, we will mainly present our charge order results including the doping dependence, momentum dependence, temperature dependence and L -dependence.

-----Doping dependence

By using the high resolution RIXS spectrometer in ID32, we have directly observed the charge order in underdoped 15K (UD15K) and optimally doped 33K (OP33K) Bi2201, as shown in Figure 1. The energy/momentum intensity maps of RIXS spectra were taken along $(0,0)-(0.5,0)$ symmetry direction, collected at $T = 20\text{K}$ with both π - and σ -polarized incident x-rays. In Fig. 1 (a), for UD15K it exhibits a charge order signal around quasi-elastic energy region at $Q_{\parallel} \sim 0.26$ rlu, in agreement with prior report by REXS [2]. In Fig. 1(b), we have first identified a bulk charge order at $Q_{\parallel} \sim 0.23$ rlu in OP33K, with both π - and σ -polarized incident x-rays. The charge order signal in OP33K looks much broader and weaker than that in UD15K, which might be the reason to hinder its

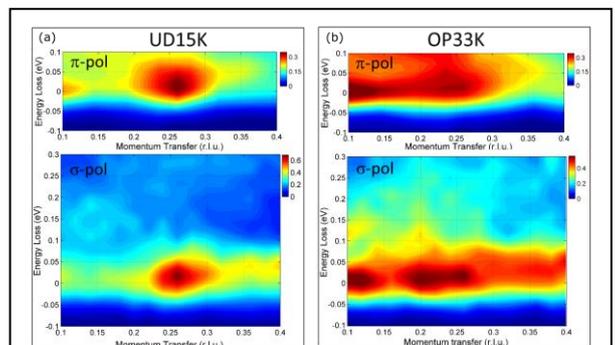


Figure 1. (a) Energy/momentum intensity maps of RIXS spectra along $(0,0)-(0.5,0)$ symmetry direction taken with π - or σ -polarized incident light at 20 K for UD15K. (b) Same as (a) but for OP33K.

discovery in previous study with lower resolution [3]. We notice a new feature ~ 100 meV appearing at small $Q_{\parallel} \sim 0.1$ rlu in OP33K, which requires further investigation.

----Momentum dependence

The energy/momentum intensity map of RIXS spectra along $(0.5, -0.5)$ direction in Figure 2 shows no charge order signal at $(0.26, -0.26)$ r.l.u. around the quasi-elastic energy region, while there are clear phonon signals present ~ 55 meV. This confirms the charge density modulates only along the Cu-O bond directions.

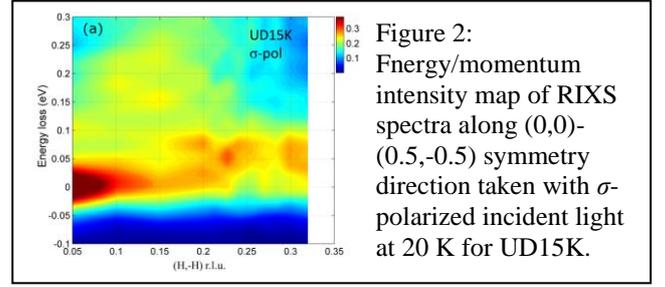


Figure 2: Energy/momentum intensity map of RIXS spectra along $(0,0)$ - $(0.5,-0.5)$ symmetry direction taken with σ -polarized incident light at 20 K for UD15K.

----Temperature dependence

We investigated the temperature dependence of the charge order across $T_c \sim 33$ K and $T^* \sim 160$ K for OP33K. As shown in Fig. 3: the charge order can be seen clearly at 20K and becomes sharper at $T_c \sim 33$ K; above T_c , fluctuations destroy the charge correlations and the intensity of charge order signal decreases. We can still observe a charge order remanent at 125K below $T^* \sim 160$ K, which disappears at 190K above T^* .

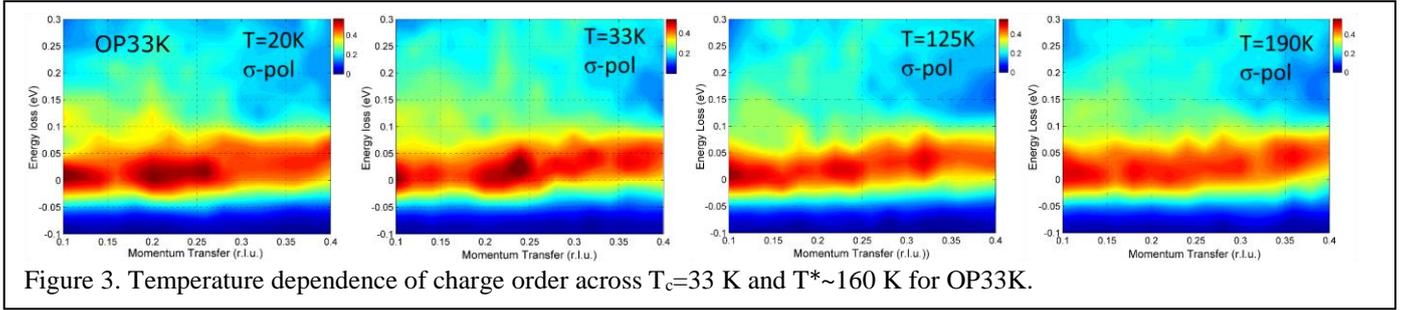


Figure 3. Temperature dependence of charge order across $T_c=33$ K and $T^* \sim 160$ K for OP33K.

----L dependence

By exploiting the unique possibility available at ID32 of changing continuously the scattering angle in RIXS, we investigated the L dependence of CDW in UD15K to see whether there is an intensity maximum at half integer or not in single-layer Bi2201. Figure 4 shows the L dependence of the RIXS spectra at Q_{CDW} and at $|Q_{\phi}| = |Q_{CDW}|$ with $\phi = 20^\circ$ in-plane rotation as defined in the inset. The L values are ranging from 2.1 to 3.0 rlu. The difference between two spectra at the same L is marked by the green area, indicating the charge order intensity. In Fig. 4(b) we display the integral quasi-elastic intensities at Q_{CDW} and at $Q_{\phi}=20^\circ$, neither of them display any maximum within error bar. In Fig. 4(c) we obtained the intensity difference between the two momenta and again it shows no maximum intensity at half integer.

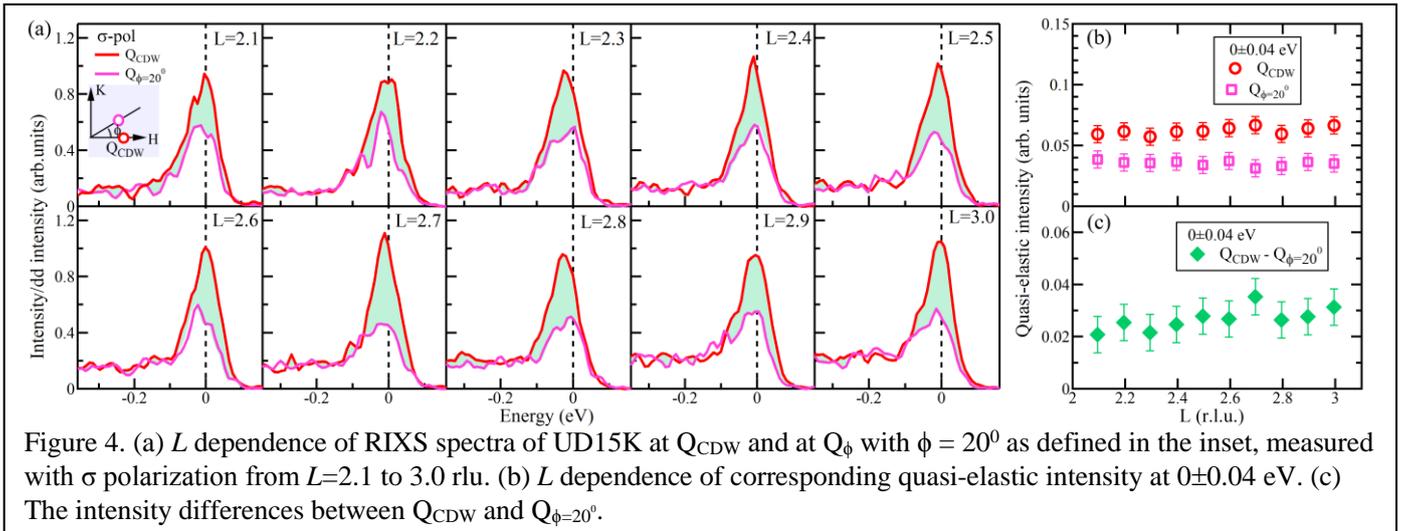


Figure 4. (a) L dependence of RIXS spectra of UD15K at Q_{CDW} and at Q_{ϕ} with $\phi = 20^\circ$ as defined in the inset, measured with σ polarization from $L=2.1$ to 3.0 rlu. (b) L dependence of corresponding quasi-elastic intensity at 0 ± 0.04 eV. (c) The intensity differences between Q_{CDW} and $Q_{\phi}=20^\circ$.

References:

- [1] Y. Y. Peng *et al.*, under review in Phys. Rev. B, arXiv:1610.01823 (2016).
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- [3] Y. Y. Peng *et al.*, Phys. Rev. B 92, 064517 (2015).