EUROPEAN SYNCHROTRON RADIATION FACILITY
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	Experiment title: Polarization-resolved study of phonons in RIXS	**Experiment number**: HC4171
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Report:

We have performed a RIXS experiment with high resolution and polarization analysis to study the phonon dynamics in three cuprate perovskites. In particular, we studied three compounds: $YBa_2Cu_3O_6$, $CaCuO_2$, which have two-dimensional CuO_2 planes, and Ca_2CuO_3 which is composed by one-dimensional chains.
The phonon features in RIXS have been up to now regarded as a purely charge signal, i.e. involving $\Delta J = 0$ signal and therefore no change in photon polarizaiton. However, it is known that phonon could posses a non-zero angular momentum [1], and could also be coupled to magnetic degrees of freedom. Our goal in this experiment was to search for lattice excitations involving flipping of polarization.
The experiment was divided into two parts. In the first one, we acquired polarization-resolved spectra on the three samples with a resolution of ≈42 meV. The spectrometer angle was set at 149.5° to have the biggest momentum transferred to the samples, and we worked mostly in grazing-in (low incidence angle) configuration to maximize intensity. We used σ (vertical) incoming polarization since it maximises phonon signal [2]. It was still necessary to count for 6 hours per spectrum to acquire meaningful statistics, because of the intrinsic low efficiency (10%) of the polarimeter.
Thanks to the stability of the beam and of the beamline, we have obtained high-quality spectra which reveal that, at high momentum transfer, some spectral weight belongs to crossed-polarizion channel. This means that indeed some low-energy excitation transfer spin / angular momentum to the sample. We note that these are the first high-resolution exploiting polarization analysis ever performed.

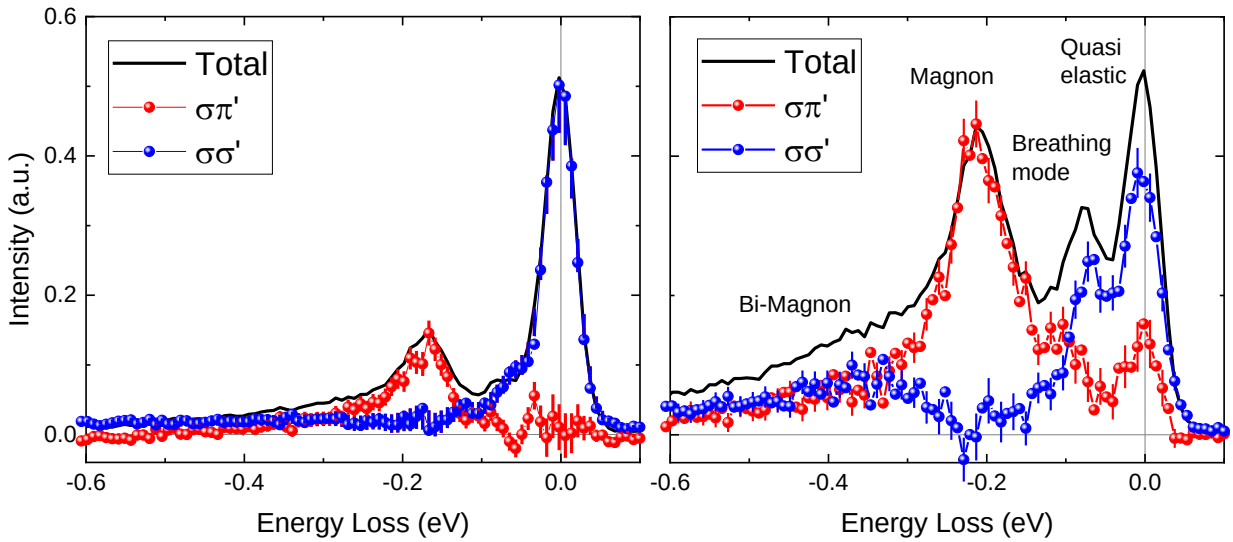

***Figure 1**: Polarimetric spectrum of $YBa_2Cu_3O_6$ at (-0.15,0) (left) and (-0.30,0.30) (right). Blue always denote the parallel channel and red the crossed one. As can be seen, at high-Q there is a non-zero crossed spectral weight in the quasi-elastic region.*

Fig.1 shows two of the spectra which we have collected on $YBa_2Cu_3O_6$. As can be seen, while at low-Q the quasi elastic part seems to be entirely belonging to non-crossed channel, at high-Q there is a non-zero σπ' crossed component. In particular, it seems to be present mostly close to the elastic line, at energies where the buckling mode is expected. This could be an indication of non-zero angular momentum of some particular phonon branch [1], or of some coupling between phonons and spins.

The second part of the experiment was devoted to acquire high-resolution RIXS spectra at the same momentum transfer used with the polarimeter, in order to better disentangle the different low-energy phonon features. The combined resolution was measured to be around 28 meV, and again we used σ incident plarization and low incidence angles to be in the same conditions as for the polarimeter measurements. The counting time was again around 6 hours per spectrum due to the low efficiency of high-resolution configuration.

Figure 2. shows an example of one of the spectra: we can resolve three features, the breathing and buckling branches, plus another one at lower energies. The goal of these measurements is to link to the crossed spectral weight observed in the polarized spectra, to check which phonon branch is responsible for the flipping of the polarization or whether it is an effect of the elastic scattering.

The experiment has been a success under the technical point of view. Analysis of the data is ongoing and requires special attention due to the long acquisition times, and we will then proceed to provide a theoretical intepretation of the effect. Since this is the first experiment of this type, future perspectives involve performing the same measurements on other cuprates, or even on different compounds in which spin-phonon couplings are expected to play an important role [4].

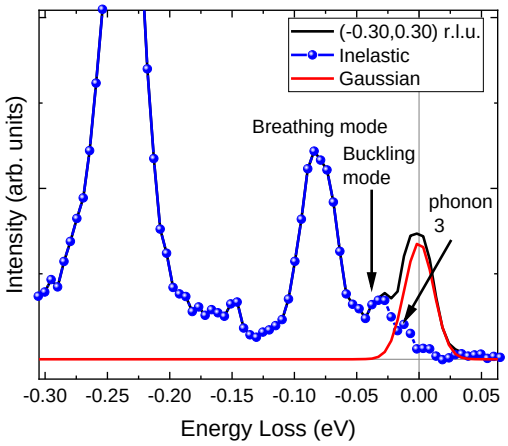

***Figure 2**: High-resolution spectrum of $CaCuO_2$ at (-0.30,0.30) collected with s polarization. Red line is a Gaussian with FWHM equal to the measured expeimental resolution.*

References:

[1] L. Zhang et al., 085503 (2014)
[2] Braicovich, Lucio, et al. Phys. Rev. Research 2 (2020): 023231.
[3] L. Pintschovius Phys. Stat. Sol. B 242, 30-50 (2005)
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