ESRF	**Experiment title:** Acoustic plasmons in cuprate superconductors	**Experiment number:** HE-2024
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Report:

The experiment to measure the low-energy acoustic plasmon excitations in a layered high-T_C superconductors was performed at beamline ID16 using the non-resonant inelastic x-ray scattering (IXS) method. Our purpose was to use the very-high resolution setup developed at ID16 to measure the response of electrons to high-energy x-rays in the energy transfer regime of 50–500 meV to find signatures of proposed acoustic plasmon braches which may, if existing, have important consequences in the electron-phonon coupling and superconductivity.

The incident photon energy was chosen to be 9.9 keV in order to achive an incident bandwidth of 15 meV utilising the backscattering Si(555) channel-cut monochromator originally developed for the Volume Photoemission (VOLPE) project. Before the channel-cut, the incident beam was monochromatised to a bandwidth of 1 eV by a Si(111) double-crystal monochromator, and finally focused on the sample in a spot size of about 50 μm (V) $\times$ 150μm (H). The spectrum of scattered radiation was analysed with a backscattering spectrometer utilising a diced Si(111) analyser crystal and the two-dimensional (2D) Medipix2 pixel detector [1]. Energy scans were performed by tuning the incident photon energy while keeping the scattered photon energy fixed. The final energy resolution was achieved to 30 meV. In this non-resonant IXS setup, from the single-crystal sample of YBCO we finally did not find any acoustic plasmon branch. We could only see the elastic line and higher-energy features, which were later much better resolved with the medium energy resolution ($\Delta E \approx 1$ eV) experiment on the same sample [2].

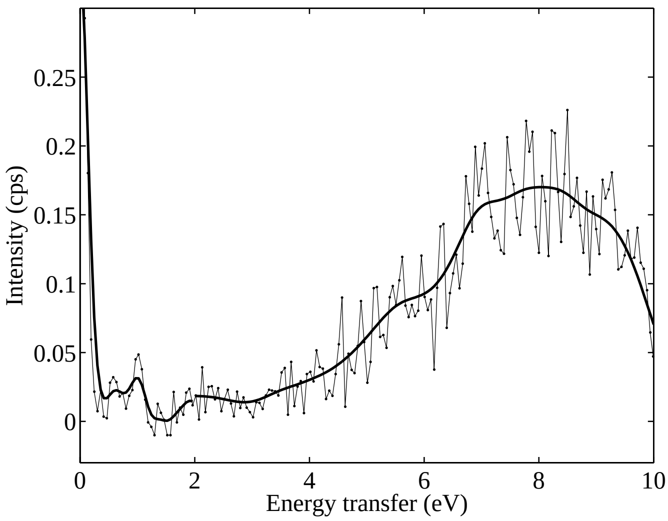

Figure 1. Energy-loss spectrum of an YBCO sample when the incident energy was tuned to the vicinity of the Cu K absorption edge. Despite of the statistical noise, a $d-d$ type excitation can be observed at 1 eV and a broad charge-transfer excitation at 8 eV.

Thus it seems that acoustic plasmons are either very weak, overdamped, or simply nonexisting in the YBCO sample we studied. Perhaps higher photon flux and improved signal-to-noise ratio will in future reveal the acoustic plasmon branches but this experiment was not successful finding them. To see if choosing resonant inelastic x-ray scattering (RIXS) conditions would improve the signal (at least revealing other low-energy features typically seen in RIXS experiments like $d-d$ excitations) we tried the very-high resolution method by utilising the 2D pixel detector in RIXS. In this setup, the analyser crystal was a diced Si(553) and the Bragg angle 77.5°. The reflection plane was chosen to be vertical to minimise the effect of the finite source size to the energy resolution. This setup was more experimental since we were not sure if the very-high resolution setup will work in a RIXS experiment, but the result of this test was very successful and has now been partly published in Ref. [3]. In this part of the experiment, we could enhance the signal at low energy transfer resonantly. The resulting signal was dominanted by the $d-d$ and charge transfer excitations well known from earlier RIXS studies. However, the result of this experiment was that a) for non-resonant IXS the acoustic plasmon branches can not be observed with the current photon flux available and b) the very-high resolution setup of Ref. [1] works well in RIXS conditions [3].

[1] S. Huotari et al. J. Synchrotron Rad. 12, 467 (2005)

[2] Experimental report HE-2143

[3] S. Huotari et al. Rev. Sci. Instrum. 77, 053102 (2006)