Phonons and Electrons in $YBa_2Cu_3O_{7-\delta}$ via *non-resonant* inelastic x-ray scattering

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Electron phonon coupling (epc) and the electronic structure (Fermi-surface) of the high-T_c cuprates have been the subject of a huge number of investigations, but remain poorly understood. On the one hand, while some phonons are broad, which can be a sign of strong epc, the materials are complex, usually doped and disordered, so the source of the broadening is not clear. On the other hand, the electronic structure, as probed by ARPES, shows, naively surprising non-closed Fermi-arcs in under-doped materials that develop into more reasonable closed structures near optimal doping. However, discerning the Fermi-surface in ARPES, especially for under-doped materials, is not so simple. Meanwhile, recent quantum oscillation (QO) experiments show surprising *electron* "Fermi-pockets" and while some reconciliation may be possible by considering intermediate range structure, as has been seen also in scanning tunneling work, additional clear results are highly desirable.

We apply meV-resolved IXS to investigate phonons in optimally doped $YBa_2Cu_3O_{7-\delta}$ (YBCO). By focusing on the temperature induced phonon changes, we avoid effects from modifying doping or disorder, and also can infer a direct relations to superconductivity. We find, on cooling below T_c, the line-width of the Cu-O bond-stretching phonon increase from 7 to nearly 20 meV at a momentum transfer of $(0,\delta)$ rlu ($\delta\sim0.27$) [1]. These experiments were made possible using RIKEN's new beamline for non-resonant IXS, BL43LXU, now commissioning [2]. The broadening is strong evidence of electron-phonon interaction, that couples to the superconductivity. In the context of recent investigations of CDWs in cuprates, one might interpret this as dynamical version of the CDW, but coupling positively, not competing, with the superconductivity. We were not able to understand this via simple models of the Fermi-surface, so continued with further investigations of the electronic structure.

We apply Compton scattering to investigate the electronic structure [3]. In under-doped material we find evidence of an electron Fermi-pocket (more precisely, a peak in electron occupation number, $n(\mathbf{k})$), at the nodal point, in surprising agreement with QO experiments. However, in the optimally doped materials, the occupation number density, $n(\mathbf{k})$, changes very gradually, with only a weak hint of a Fermi-surface. This highlights the fragility of the concept of a Fermi surface in these materials, at least as regard to its impact on electron momentum density. We also find structure consistent with a new nesting vector at $\sim(0,0.3)$ as may help explain the phonon linewidth change described above.

References

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