A high energy X-ray diffraction study probing symmetry breaking states in the high temperature superconductor YBa$_2$Cu$_3$O$_{6.67}$ is presented. A charge density wave is found to emerge in the normal state above the transition temperature of the superconducting phase and persists in the superconducting state. Application of an external magnetic field enhances the intensity of the charge ordering reflection and suppresses superconductivity. These results provide a mechanism for the Fermi surface reconstruction probed by quantum oscillation experiments in high magnetic fields. The experiment was performed at the high-energy X-ray beamline BW5 at DORIS using 100 keV X-rays. The YBa$_2$Cu$_3$O$_{6.67}$ sample with a doping concentration of $p = 1/8$ and a size of 1.5 x 1.5 x 0.8 mm$^3$ was studied in transmission geometry, thus probing bulk properties. High field studies were performed with a 17 Tesla superconducting magnet, which was newly developed by University of Birmingham for beamline use.

Signatures of a charge density wave order are observed by the appearance of diffuse scattering reflections at ordering wave vectors (0.3, 0, 0.5) and (0, 0.3, 0.5) as shown in figure 1a. The intensity of this charge density wave reflection grows below 135 K and reaches a maximum at $T_c = 67$ K, the transition temperature into the superconducting phase. The competition of superconductivity and CDW order is well observed by the sharp drop in intensity of the CDW reflection below $T_c$. Furthermore, the drop is converted into a strong intensity increase by the application of a magnetic field that suppresses superconductivity. At the same time the correlation length increases reaching a maximum of 95 Å at 17 T.

An interesting question is whether the CDW observed in YBCO and the stripe order in the single layer compounds are of common origin. Like the CDW wave in YBCO, the charge stripes are competing with superconductivity and are enhanced by a magnetic field applied parallel to the c-axis [1]. Translational symmetry is broken along c in a similar way by both kinds of orders. However, the in-plane ordering wave vectors of (0.31, 0) and (0, 0.32) could suggest that Fermi surface nesting gives rise to the CDW in YBCO and no magnetic order is involved, as found in the...
NMR and resonant scattering studies [2,3]. In contrast, stripe order exhibits a very intimate relation between charge and magnetic order and it is the separation of spin and charge that leads to this particular order [4].

This study shows that charge density wave order is competing with superconductivity. Thus, one route to push T_c towards higher temperatures might be to artificially suppress CDW order. Such a route might be promising as demonstrated in a recent study on non-superconducting La_{1.675}Eu_{0.2}Sr_{0.125}CuO_4 where stripe order was destroyed by an intense laser pulse and a transient superconducting state obtained on timescales of ps [5].

![Figure 1: Charge density wave reflections at (1.695, 0, 0.5) and (0, 1.682, 0.5). Scans along (h, 0, 0.5) and T = 2 K show a clear difference between H = 17 T and 0 T (a), above T_c = 66 K no field dependence is found (b) and the intensity is of the order 2 x 10^{-6} weaker than the (2, 0, 0) reflection. CDW order disappears above 135 K (c). The field induced intensity is shown in (d) with peaks at l = ±0.5. Scan directions in reciprocal space (e) and scan along (0, k, 0.5) (d).](image)

References