Unprecedented Fermi Surface Spectral Resolution in the Underdoped High T_c Superconductor $YBa_2Cu_3O_{6+x}$ Obtained Using 100 Tesla Magnetic Fields

N. Harrison, C. H. Mielke (LANL), S. E. Sebastian, G. G. Lonzarich (Cavendish Lab., Cambridge Univ., UK), R.-X. Liang, D. A. Bonn, W. N. Hardy (Univ. British Columbia, Canada)

In signal processing, an increase in the time interval over which a signal is sampled leads to an increase in the amount of information that can be extracted within a given frequency bandwidth. The same principle also applies to the measurement of magnetic quantum oscillations in metals as a function of the reciprocal magnetic field. An increase in the range in reciprocal magnetic field over which quantum oscillations are measured (obtained by extending measurements to both lower and higher magnetic fields) leads to an increase in spectral information that can be extracted regarding the Fermi surface geometry.

The recent achievement of magnetic fields exceeding 100 tesla in the 100 tesla multishot magnet in Los Alamos provided the ideal opportunity to increase the resolution and precision to which the Fermi surface of the underdoped high T_c superconductor $YBa_2Cu_3O_{6+x}$ can be measured, enabling us to achieve substantial progress in our understanding of the origin of the small Fermi surface pockets [1].

A key distinguishing feature of the quantum oscillation waveform in underdoped $YBa_2Cu_3O_{6+x}$ is the beat pattern giving rise to nodes (at which the amplitude is suppressed) at $1/B$ = 0.033 and 0.022 T^{-1}. A Fourier transform of the oscillations reveals the beat pattern in the dominant amplitude quantum oscillation frequency (of 534 T) to be caused by the presence of two smaller amplitude frequencies that are separated from the main frequency peak by +/- 90 T. The values of the frequencies obtained in the Fourier transform are further confirmed by performing sinusoidal fits to the quantum oscillation data.

Rather than corresponding to three individual sections of Fermi surface, the observed distribution of frequencies in which a central peak is equally flanked by two adjacent peaks of similar amplitude can be shown to be the simple consequence of quasiparticles tunneling between two concentric Fermi surface orbits that differ slightly in size [2]. Such an observation is expected for a bilayer Fermi surface that is split into separate bonding and antibonding cross-sections by the presences of a direct coupling between the layers. A simple model that includes the effect of the tunneling is shown to provide an explanation for both the frequency distribution and the magnetic field-dependent quantum oscillation amplitude and beat pattern.

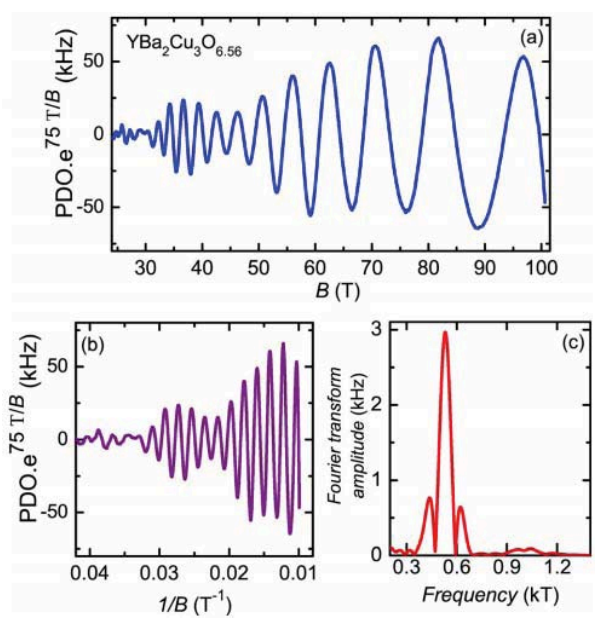

Figure 1. Quantum oscillations in $YBa_2Cu_3O_{6+x}$ obtained using the contactless conductivity technique shown versus magnetic field (a) and reciprocal magnetic field (b). (c) shows a Fourier transform in which a Blackman window has been applied to the data.

Acknowledgements

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References

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[2] Yernoso, A.A., *et al*., Phys. Rev. B, **78**, 115312 (2008).