Fermi Surface and Magnetoresistance of High Purity Uranium Single Crystals

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Depleted uranium is of particular interest to the US Department of Energy and the National Nuclear Security Agency both for its role as a civilian power source and its destructive capabilities in rogue hands. We are interested in the fundamental crystal properties with a particular eye toward the ground state con_guration and the three volume collapses that occur below 50 K. These volume collapses transform the room temperature (_) con_guration into progressively more complicated phases (_1, _2, _3) with the ground state _3 phase having a k-space volume of 6000_A3.

While we have previously observed quantum oscillations by Shubnikov de Haas and de Haas von Alphen techniques in ambient pressure _-Uranium, it has been suggested[1] that the Fermi surface of the _, _1, or _2 phases should be more easily observable when the sample does not experience the _3 phase transition and its associated volume collapse. Accordingly, we loaded our samples in a large volume metal piston cylinder cell that we showed earlier in the year to be compatible with Los Alamos' 60T Long Pulse magnet. Compared to the short duration capacitor driven magnets, the entirely unique 60T Long Pulse magnet has very little vibration and extremely good repeatability. The slow rise and fall of the _eld also allows us to use our metal piston cylinder cell without undue eddy current heating of the sample during the pulse.

With this experimental con_guration, we succeeded in measuring the highest pressure quantum oscillations ever observed in uranium. At a pressure of 1.8 GPa, the 300T oscillation persisted to at least 50 K, and the e_ective mass was correspondingly quite low. We rotated the pressure cell 45 degrees in situ and obtained another low e_ective mass. After reducing the pressure to 1.0 GPa, we again observed the same 300T orbit but with somewhat increased mass. One of these data sets appears in Fig. 1.

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References

[1] J. E. Schirber, A. J. Arko. Phys. Rev. B 21 2175 (1980).

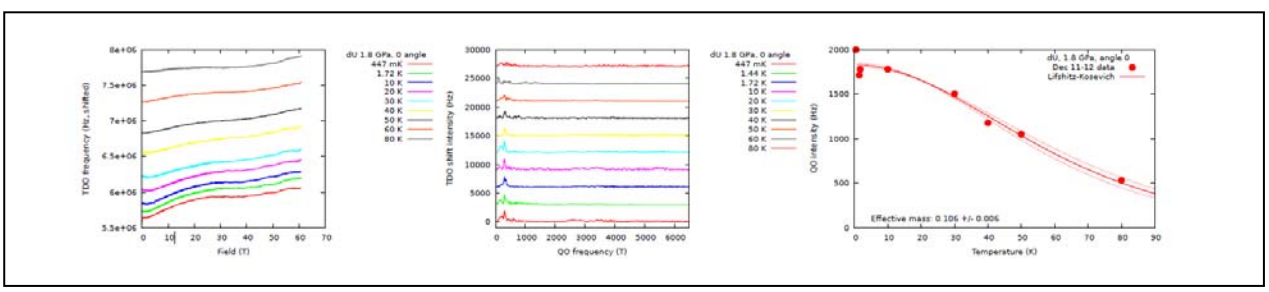

FIG. 1: Depleted uranium under 1.8 GPa with the field oriented along the edge of the crystal. Left: TDO frequency data shifted down from about 165 MHz. Shubnikov de Haas oscillations are immediately visible in the low temperature data. Middle: After transforming the x-axis to 1/Field and taking an FFT, we obtain a single peak at 300 T. Noise at higher frequencies is due to the switching noise of the power supplies but does not interfere with our low frequency measurement. Right: We fit the peak amplitude to the Lifshitz-Kosevich form and obtained an exceptionally light mass for a metal. Points at 20 and 60 K have been eliminated from the fit because we did not allow the sample sufficient time to thermally equilibrate with the thermometer and results were erroneous. The fitted value does not change significantly in their absence.