Quantum Oscillations in the High Pressure Metallised Mott Insulator NiS_2

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Introduction

The cubic system NiS_2 can be tuned through a Mott metal-insulator transition at applied pressures of about 3 GPa [1]. This enables electronic structure studies in the metallic state at moderate pressures, at which technical challenges such as inhomogeneity due to the pressure medium are reduced. We have grown single crystals of NiS_2, which display residual resistivities of less than 1 $\mu\Omega$cm in the metallic state above 3GPa. In order to optimize signal to noise performance in anvil cell high pressure measurements, we have combined a microcoil in the sample space with a tank circuit oscillator circuit. Using this setup, Shubnikov-de Haas oscillations can be observed indirectly by tracking the tank circuit resonance frequency. The value of this technique has been proven in numerous high field studies at ambient pressure, including quantum oscillation measurements in pulsed magnetic fields. With this technique, we have now been able to observe quantum oscillations in high pressure NiS_2 on a 31 T magnet system at Tallahassee.

Experimental

The microcoil with a diameter of 0.3 mm is located in the gasket hole of a miniature Moissanite anvil pressure cell, which has an outer diameter of 18 mm. A tunnel diode oscillator, was mounted on the low temperature stage of a helium-3 insert. Wiring the microcoil as the tank circuit inductance, we have obtained stable oscillations near 60 MHz in preliminary measurements in Cambridge, and near 250 MHz at NHFML Tallahassee. Measurements were performed in a top loading ^{3}He cryostat in the 31T magnet of cell 9.

Results and Discussion

The August 2014 data (Fig. 1) show quantum oscillations above 25 T with a frequency of 6 kT, consistent with a large orbit expected from DFT calculations. The mass study suggests an effective mass of about 6 m_e for this orbit.

Conclusions

Our findings open the way for a detailed study of electronic structure and mass enhancement on the threshold of the Mott insulating state in a clean system. More data at intermediate temperatures will be needed to determine the mass for this orbit accurately, and to conduct effective mass studies at other pressures.

Acknowledgements

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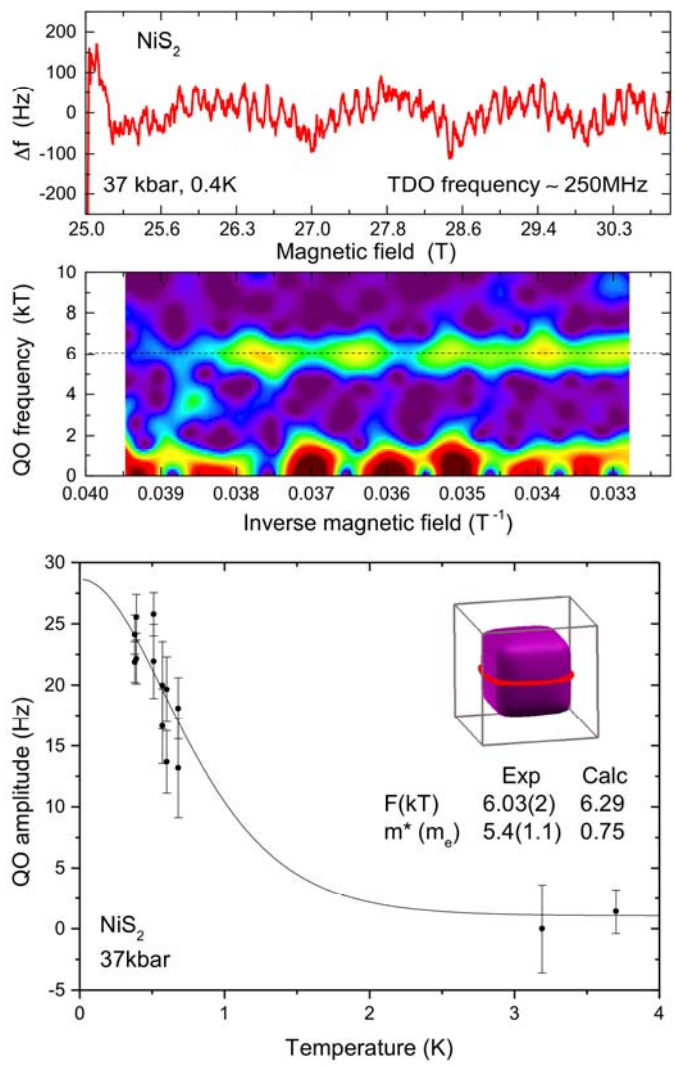

Figure 1: High pressure quantum oscillations in NiS2. Tank circuit oscillator measurements in a moissanite anvil cell show field dependent skin depth oscillations of frequency 6 kT consistent with a large Fermi surface orbit.

References

[1] see, e.g., N. Takeshita et al., arXiv 0704.0591v1 (2007)