NUCLEAR MAGNETIC RESONANCE USING A TUNNEL DIODE OSCILLATOR

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Introduction

Self-resonating tunnel diode oscillator (TDO) circuits are employed to study surface conductivity in a variety of materials. The sample is placed inside the resonating coil that produces the rf field, while external parameters such as temperature, dc magnetic field, or pressure are changed. The resulting changes in sample properties, e.g. phase transitions, are recorded as shifts in the TDO resonance frequency.

Experimental

In order to achieve maximum stability at millikelvin (mK) temperatures and magnetic fields up to 45 tesla (T) with signal-to-noise ratio in the ppm range, we used nickel-chromium resistors and dielectric NPO capacitors as electronic components for the TDO operation. Tunnel diodes with peak currents below 100 µA were used to avoid excess heating. For the current experiment we used a 4-turn 50 AWG copper wire coil with inner diameter of 600 µm resonating at 180 MHz. To test the sensitivity and versatility of our TDO setup, we measured the nuclear magnetic resonance (NMR) signal of a piece of aluminum foil placed inside the coil in the top-loading 18/20 T dilution refrigerator system at the NHMFL in Tallahassee.

Results and Discussion

Fig. 1(a) shows the shift in TDO resonance frequency for a field sweep to 18 tesla at 70 mK. The raw 180 MHz signal passes several stages of filtering, amplification, and mixing before being recorded by a frequency counter. The initial steep increase is a circuit artifact and is seen for any sample. Upon closer examination, six NMR lines can be found. These correspond to hydrogen (H) at 4.199 T, fluorine (F) at 4.465 T, helium-3 (He) at 5.519 T, copper-65 (Cu) at 14.779 T, copper-63 at 15.830 T, and aluminum (Al) at 16.113 T. Fig. 1(b) shows the Al NMR line taken at a ramp rate of 0.1 T/min after subtracting the background. The NMR signal is about 500 Hz or 3 ppm of the TDO carrier signal, while the noise is on the order of 0.5 ppm. We identified the NMR lines by taking ratios and comparing to literature values (http://bic.beckman.uiuc.edu/mritab1/MRItable.html). The experimental Al-to-H ratio, for instance, yields 3.8373 and is in excellent agreement with the literature value 3.8377. The two Cu lines originate from the Cu wire coil, while H and F stem from the varnish that was used to attach coil and sample to its platform. He-3 is part of the liquid He-3/He-4 mixture of the dilution refrigerator, showing that millikelvin narrow band NMR in solution with a standard 18/20 tesla superconducting magnet is achievable.

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