High Resolution Tunnel Diode Oscillator Operation at Field-center in Pulsed Magnets

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Introduction

High frequency resonator techniques such as the Tunnel Diode Oscillator (TDO) and Proximity Detector Oscillator (PDO) are commonly used to measure various properties of conducting and/or magnetic samples in DC and pulsed magnetic fields. In most cases, the PDO setup is simpler and more robust, while the TDO may be tuned and optimized in many ways. We present optimizations to the TDO technique we discovered while working in the 65 T short pulse and 100 T magnets at the Los Alamos branch of the National High Magnetic Field Laboratory.

We are interested in studying the Fermi surface of metals at high pressure. The presence of a pressure cell hampers efforts to use low frequency de Haas-van Alphen techniques, and we turn to the TDO as a high resolution technique that works inside a pressure cell and does not put mechanical strain on the samples.

Experimental

In a parallel-resonant circuit where energy is passed between an inductor and capacitor through a length of transmission line, the line length drastically reduces the resonant frequency's dependence on the inductance (and therefore the sample properties). For highest resolution measurements, the coil, transmission line, capacitor, and oscillator should all be located within millimeters or centimeters of each other. Since tunnel diodes operate properly in low temperature environments, DC field experiments commonly place the TDO on the probe near maximum field. Due to the rapidly changing and large field, this practice is more difficult in pulsed magnets. In particular, placing the tunnel diode very close to the sample and exposed to the full field of the magnet provides the highest possible resolution but the greatest experimental challenge.

We make a few observations from our experiments at Los Alamos: 1) There are at least two mechanisms that stop oscillation of the circuit during the pulse. One is the well-known disruption of the bias point due to the rapidly changing field (B-dot effects). Another is due to the magnitude of the field. In some cases, oscillations stop as the field rises and restart at the same field on the way down without regard to the sweep rate. We have found that miniaturization of the TDO (2.5 mm x 5.5 mm) and increasing the IP rating of the diode (650 μA) is useful in this case. 2) In a case where B-dot voltage stopped oscillation mid-pulse, we tried using feedback from the field-sensing pickup coil to adjust the TDO bias voltage in real time during the pulse. While we were able to confirm the feedback circuit was working, it appeared to perturb the frequency of oscillation, while B-dot pickup from the sample coil altered primarily the amplitude. 3) It is common in pulsed field TDO experiments to attempt pulses with the DC bias near each end of the useful range to provide some headroom for B-dot voltages. By examining oscillation amplitudes, we found that under very high fields, the diode requires more power to oscillate. Particularly in the 100 T magnet, B-dot from the insert can be used to provide extra power to maintain oscillation up to higher fields.

Conclusions

Building on these observations, we achieved TDO oscillations up to 73 Tesla with the tunnel diode and sample colocated at field-center. To our knowledge, this experiment represents the highest magnetic field at which any active semiconductor (tunnel diode, transistor, FET, etc...) has been successfully operated.

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