INSTRUMENTATION FOR THE SINGLE TURN MAGNET PROJECT PART 1: GHz-FREQUENCY MEASUREMENTS OF QUANTUM OSCILLATIONS

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The development of non-metallic microwave resonators for use in pulsed fields has been reported in previous years [1]. Here we demonstrated the sensitivity of these GHz-frequency conductivity techniques, with measurements of quantum oscillations in a 50 Tesla short pulse magnet. These GHz-frequency techniques are not only an exciting addition to the User Program's pulsed field capabilities, but also mark an import milestone in the development of instrumentation for the single-turn magnet facility currently under construction at the NHMFL in Los Alamos.

The extreme rate of change of magnetic flux during a magnet pulse limits the use of metallic microwave components. Thus, to perform these measurements we have used an all dielectric photonic-band-gap resonator [1,2] (see Figure 1). The Q-factor of the empty resonator is ≈ 1500. The perturbation from loading a sample, in this case the organic superconductor (BEDT-TTF)$_2$Cu(SCN)$_2$, reduces the Q-factor by a third to a half. As a result, temperature or magnetic field induced changes in the sample conductivity strongly influence the microwave transmission at resonance.

Figure 1a. Waveguide-coupled photonic-band-gap resonator. **b.** A κ-(BEDT-TTF)$_2$Cu(SCN)$_2$ sample loaded in the dielectric resonator.

Figure 2 shows the magneto-conductivity of κ-(BEDT-TTF)$_2$Cu(SCN)$_2$ measured a pulsed magnetic field with a rise time of 8 ms at a frequency of 64 GHz and a temperature of 2.1 Kelvin. Under these conditions the quantum oscillations corresponding to the alpha and beta-orbits, plus Stark quantum interference between the two are clearly visible (see the upper inset of Figure 3). It should be noted that the effective mass of the alpha orbit is ≈ 3.5m_e and that of the beta orbit ≈ 7.1m_e such that their observation at this temperature is only possible at these high fields. The dip in transmission at low field is a Josephson plasma resonance, which occurs close to the superconducting upper critical field.

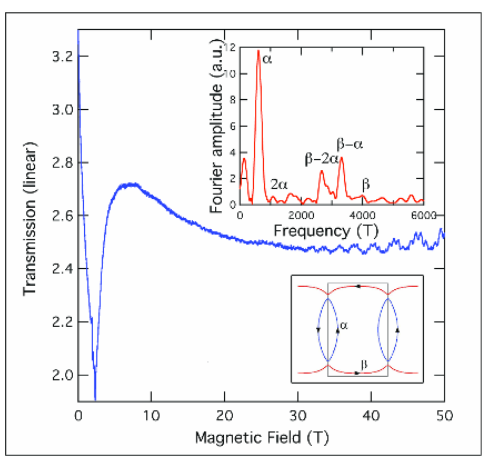

Figure 2. The GHz-frequency magneto-conductivity of κ-(BEDT-TTF)$_2$Cu(SCN)$_2$ measured at a temperature of 2.1 Kelvin and a frequency of 64 GHz. Note the Josephson plasma resonance at low field and the quantum oscillations at higher fields. The insets show the Fourier spectrum of the quantum oscillations and the associated Fermi-surface orbits.

References

[1] McDonald R.D., *et al*., NHMFL Annual Research Review, 122-124 (2003).
[2] McDonald, R.D., *et al*., NHMFL Reports, **11**, vol 5, 10-12 (2004).