Electron Spin Resonance Measurements Using On-chip Structures at Low Temperature

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Introduction

We study the coupling between electronic spins of a magnetic material and resonant photons inside a cavity. When the number of photons is much smaller than the number of spins, it is possible to attain the so-called strong coupling regime. For that, the photon lifetime inside the cavity and the spin phase coherence time must be longer than the inverse of the spin-photon coupling strength. This condition ensures that there is enough time for the spins and the cavity to coherently exchange photons before either the photons escape the resonant cavity or the spin dephasing sets in [1,2]. The technique was first studied in the field of atomic physics and dealt with atoms passing through a cavity (cavity Quantum ElectroDynamics).

Experimental

We use a microstrip resonator (MR) which operates in the transverse electromagnetic (TEM) mode where only the longitudinal dimension sets the resonant frequency. In particular, our MR utilizes an omega shape which has been shown to nicely center the magnetic field inside the loop of the omega at resonance. The preliminary results have been obtained at room temperature, using a spin ½ system (DPPH).

Results and Discussion

The spin system is placed in the middle of a microstrip resonator, in a specially designed constriction resembling the Greek letter omega. An advantage of our setup is that it allows scanning either the field or the frequency, whereas traditional ESR setup can scan only the field. **Figure 1** shows example at frequency scans at fixed fields listed in the figure. The dips in the signal are due to the spins which are absorbing the resonant excitation and therefore the signal at detection is less intense. One observes an overall base line signal which is due to smallness of the quality factor of the cavity. This allows scanning the frequency over a relatively large frequency range (~200 MHz). The detection can be done in three ways. First, by means of a high speed digital acquisition card, the microwave pulse is recorded directly (after a down-shifting to 70 MHz). In this mode, one can study pulse-dependent spin dynamics as well as perform spectroscopy studies. To improve the signal resolution for the spectroscopy data, we can insert a lock-in amplifier and amplitude modulate the microwave excitation, at the modulation accepted by the lock-in. In addition, we insert (in a 3rd scenario) a bridge able to balance entirely the signal out of resonance. Therefore, at resonance, the bridge becomes unbalanced and a non-zero signal can be read by the lock-in.

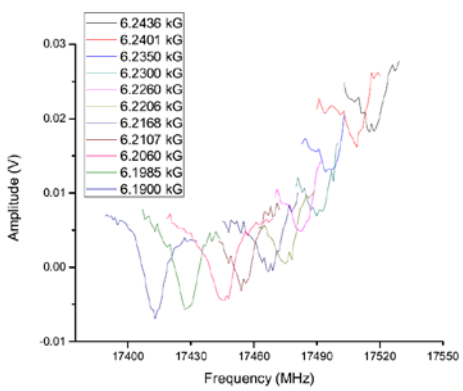

Figure 1. Frequency scans at fixed fields. Data acquisition was done through use of the high speed digital acquisition card. A reference curve was taken at zero field and subtracted out.

Conclusions

We realized a setup able to perform magnetic resonance studies on-chip, using a microstrip resonator at room temperature. The setup will be inserted in a dilution refrigerator for testing at low temperatures.

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References

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[2] Chiorescu, I., PRB **82,** 024413 (2010).