Ultra-Sensitive Calorimetry for Microwave Cyclotron Resonance In a Two-Dimensional Electron Gas

Jie Zhang,[1] Hongyu Xiong[1], Junichiro Kono,[1,2]Rui-Rui Du,[1]Loren Pfeiffer[3], and Ken West[3]

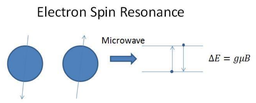
[1]*Department of Physics and Astronomy, Rice University, Houston, Texas, U.S.A.*

[2]*Department of Electrical and Computer Engineering, Rice University, Houston, Texas, U.S.A.*

[3]*Department of Electrical Engineering, Princeton University, Princeton, New Jersey, USA*

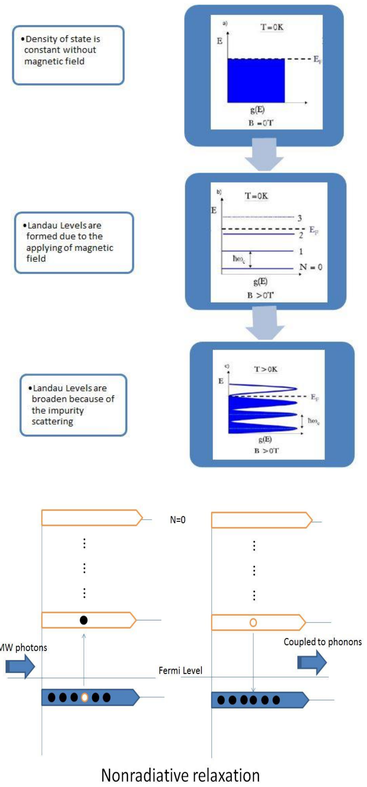
GOAL

In order to detect the **electron spin resonance (ESR) of a single nano-object**, high sensitive tool is required. So far, the best commercial ESR detector can detect around 1000 spins.



We develop an ultra-sensitive calorimeter which is aimed at resolving the ESR of one nano-object. As a pretest, we show that cyclotron resonance (CR) can be measured at 300 mK with a precision of tens of micro-Kelvins, thereby increasing the sensitivity to several nano-watts. This method opens up the possibility to detect ESR which is the prerequisite for building spintronics.

BACKGROUND



- electrons coupled to phonons
- heat absorbed by lattice
- lattice temperature increased
- temperature detected by thermometer

CONSTRUCTION & METHODS

- Coaxial cable probe and a He3 cryostat refrigerator (300mK)
- Vacuum can which avoid heat from carried away

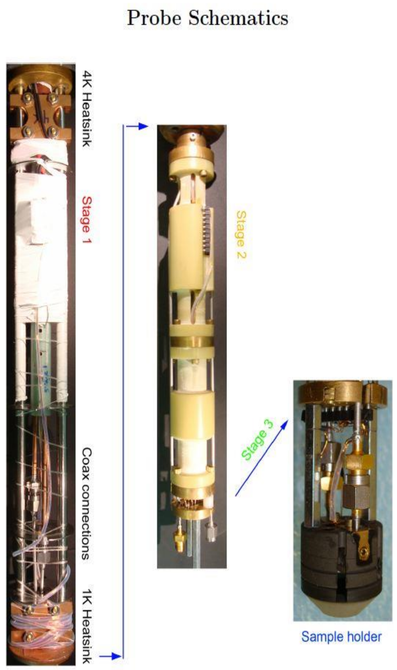
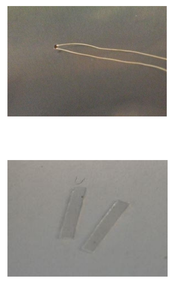
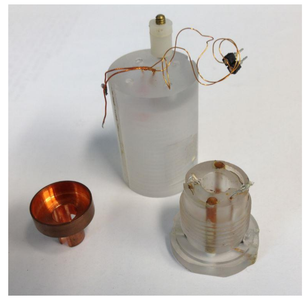
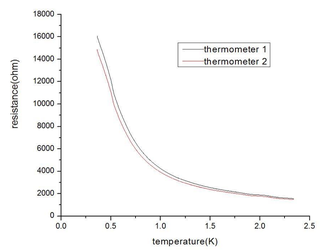


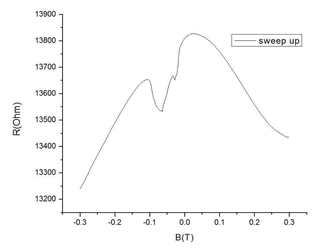
Figure D.1: Pictures of the probe stages: 4K, 1K, and the sample holder.





- Properties of the thermometer R(T), R(B)



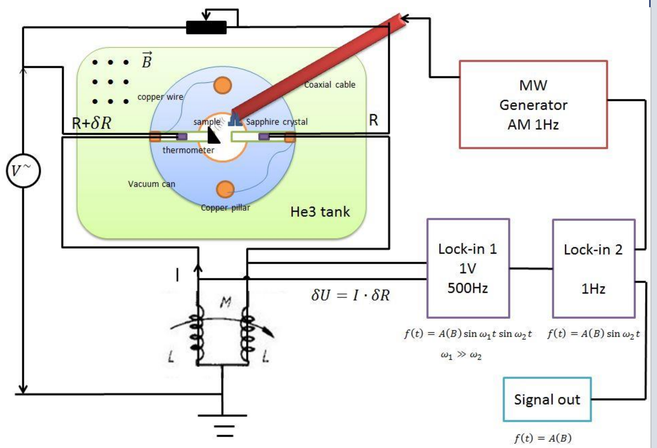


- Differential method ----filters the background noise

Two identical geometries are constructed.
Heat generation and absorption are tuned.

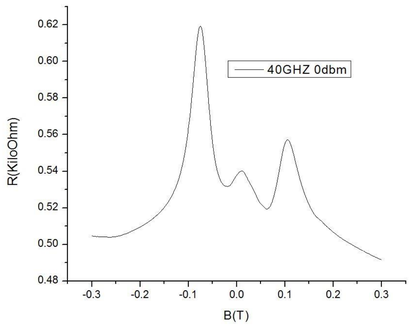
- Amplitude modulation ----quenches the asymmetry left in the differential geometry

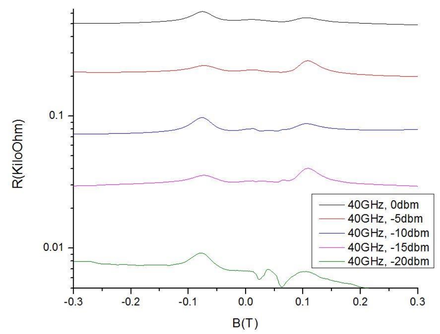
Integral time constant need to be set much larger than $\frac{1}{\omega}$.
The signal is dependent on the modulation depth.



RESULT

- Differential method ---------- ten times
- Amplitude modulation ---------- thirty times
- Lowest microwave power ---------- -20dbm (0.01mW)





CONCLUSIONS

An ultra-sensitive calorimeter is built to detect CR on 2DEG with microwave power as low as 0.01mW. With such great sensitivity, this method could resolve ESR without requiring electrical contacts. It is also promising for measuring microscopic samples like a single carbon nanotube and monolayer graphene.

REFERENCES

[1] Kristjan Jakob Stone, PhD thesis, *Millimeter Wave Transmission Spectroscopy of 2D Electron and Hole Systems.*

[2] S. J. Allen, Jr., H. L. Stormer, and J. C. M. Hwang *Dimensional resonance of the two-dimensional electron gas in selectively doped GaAs/A1GaAs heterostructures* Phys. Rev. B, 28,4875(1983).