Resistively Detected NMR in InSb

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InSb is a promising semiconductor for nuclear spin polarization due to the large electron g-factor. Dynamic nuclear polarization (DNP) in bulk n-type InSb is achieved through an applied current for multiple hours. Once achieved, this research is working on the detection of nuclear polarization using resistively detected nuclear magnetic resonance (RDNMR) at temperatures of 4 K and higher. Multiple variables of the applied current and radiofrequency field are also being studied. Spin manipulation in bulk InSb using RDNMR is an initial step towards its incorporation into a room temperature nanoscale spin control device.

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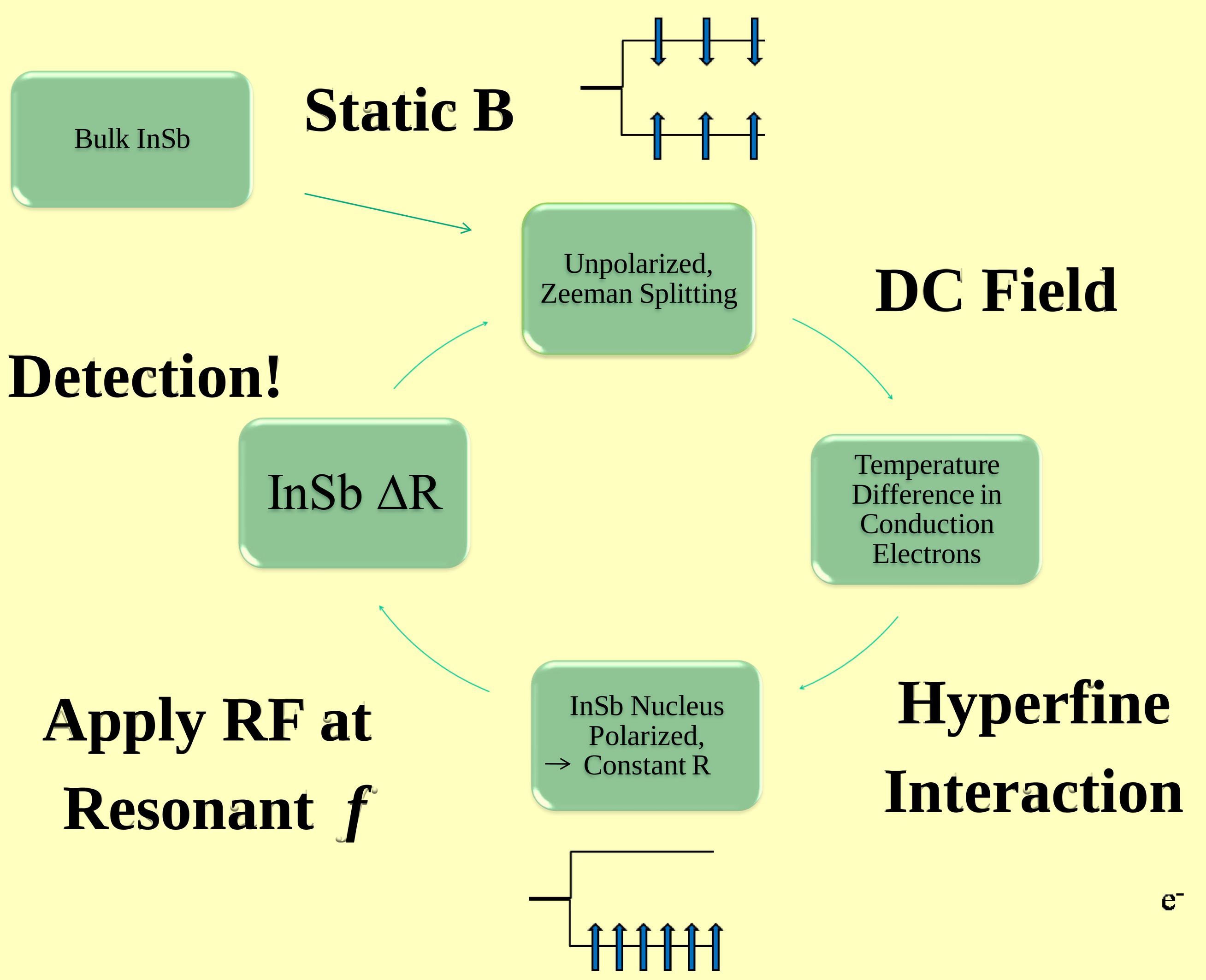
Background

Nuclear spin polarization is the process of separating quantum spin states in a material. Spin manipulation has promising applications in quantum computing and novel magnetic control devices. Resistively detecting spin polarization in InSb at room temperature will allow incorporation into an all electrical spin manipulation device, which is much simpler than other approaches.



An applied DC field in a static magnetic field will polarize nuclei. Detection is achieved by measuring the transverse resistance (Rxy) across InSb while applying the appropriate resonant frequency (RDNMR), which brings the spin states back to a mixed distribution.

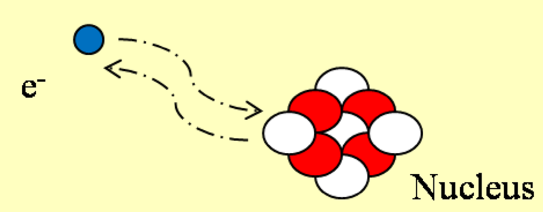


Figure 1

InSb Sample Properties

Semiconducting

Bulk n-type

Large electron g-factor (-50)

Size: ~ 4.20 X 3.30 X 1.00 mm^3

Contacts connected via Indium metal

Mobility: ~4 x 10^5 cm^2/Vs

Isotope:	Indium 115	Antimony 121	Antimony 123
Resonant *f* (MHz•T)	9.3295 B_o	10.189 B_o	5.5175 B_o
Spin Number	9/2	5/2	7/2
Abundance	95.7 %	57.3%	42.7 %

Exotic NMR!

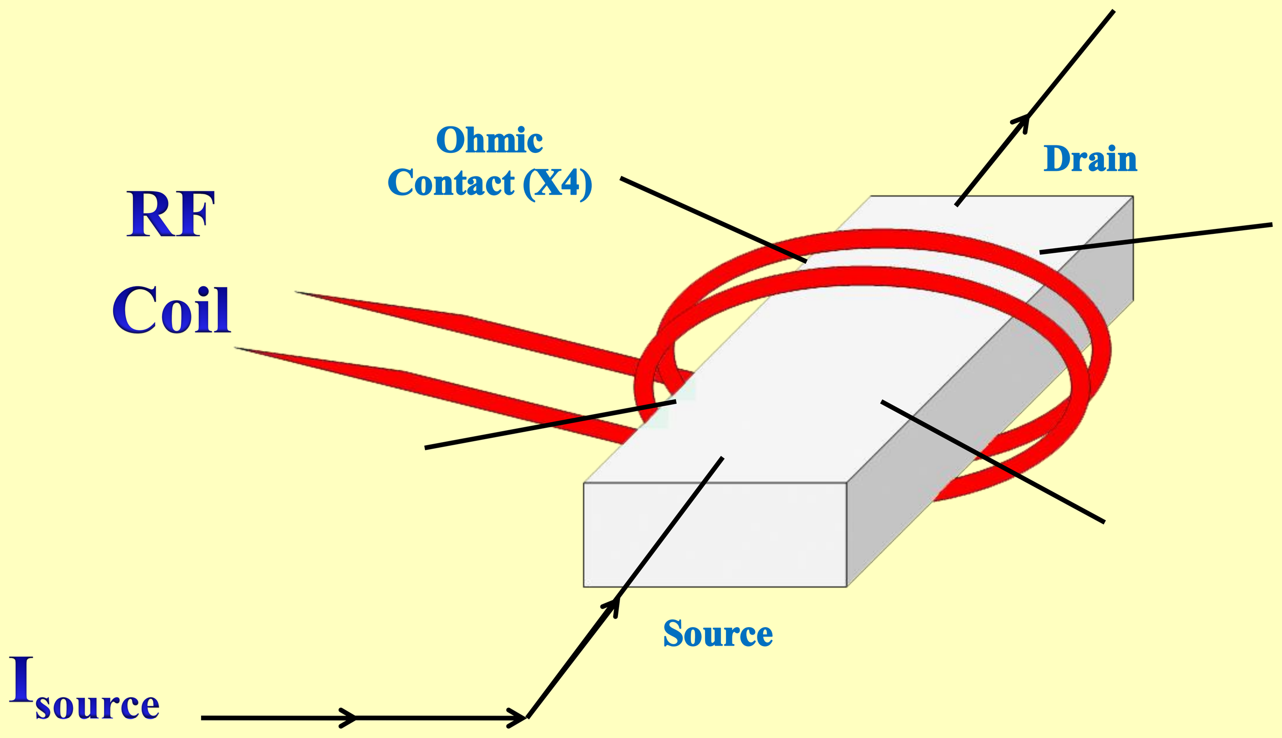
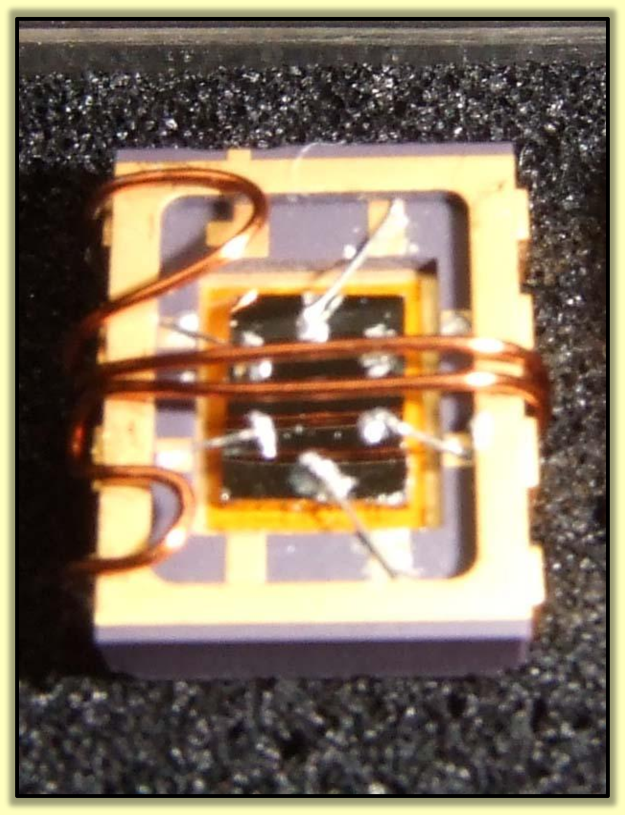


Figure 2



InSb Sample

Experiment Setup

Temperatures: **4.2 K** (Liquid Helium Cryostat)
77 K (Liquid Nitrogen)

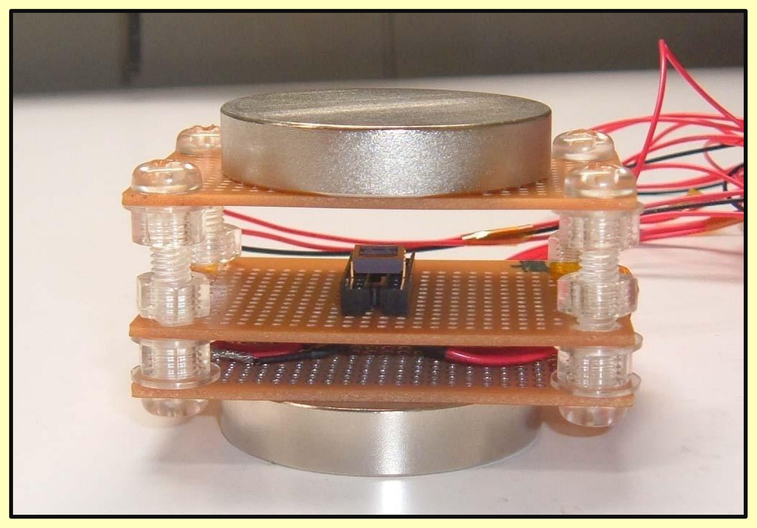
Orientation: (100) plane

4 Terminal Measurement:
Source/Drain Current & Ohmic Voltage

Static magnetic field: **1 - 1.3 T**

Apply a constant Source/Drain Voltage: **5 V**

RF Scan Rate :
50 Hz steps for 10 minutes/ step
15 dBm power exposure



77 K Apparatus

Results and Analysis, 4.2 K

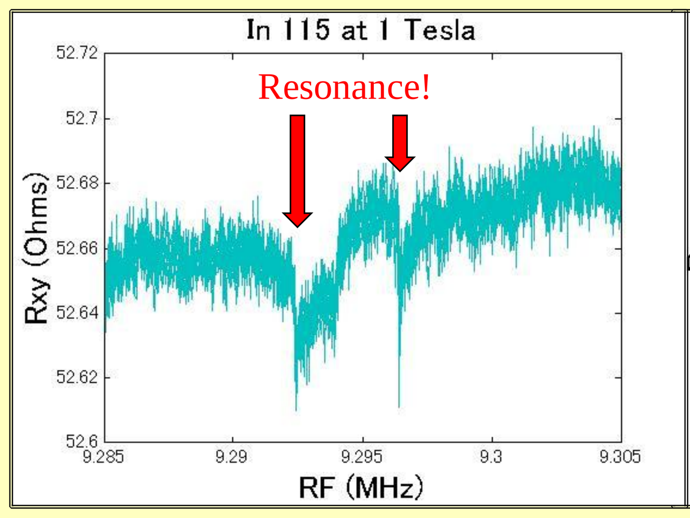


Figure 3

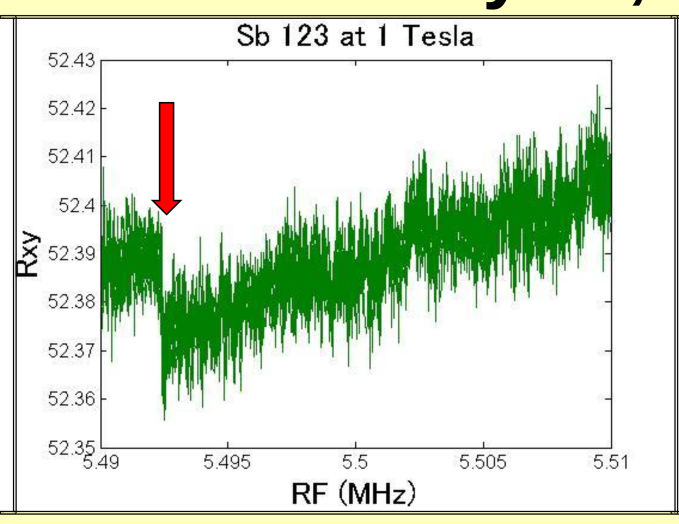


Figure 4

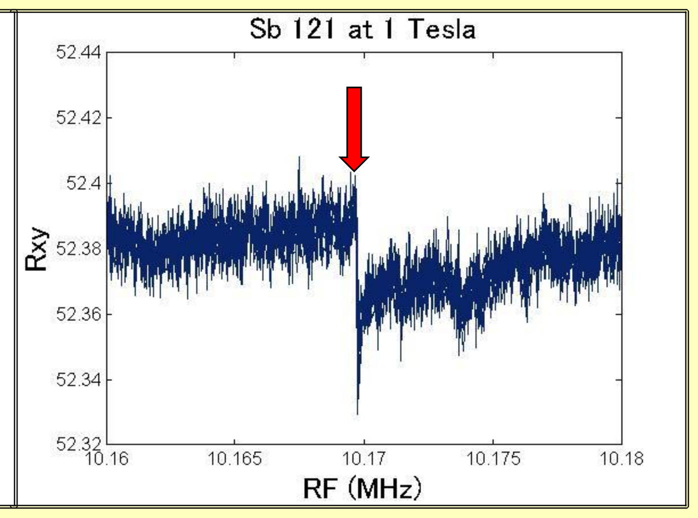


Figure 5

- These plots show a clear shift in the resistance at the resonant frequency. The resonant frequency is slightly offset from the accepted values due to placement in the magnetic field (~1 T).
- Resistance shifts may show some extra contributions of the electrons' spins to the magnetic field.
- Additionally, with the increase of the magnetic field, the resonant frequency rises linearly, showing that we have indeed detected resonance in InSb (Fig. 5 -8).
- An interesting observation about our system is that the RF scans require 10 seconds of exposure per tested frequency, perhaps due to the power exposure. At this rate, we have seen some frequency shifts of ~5 kHz in the resistance change and perhaps resonant frequency (Fig 3).

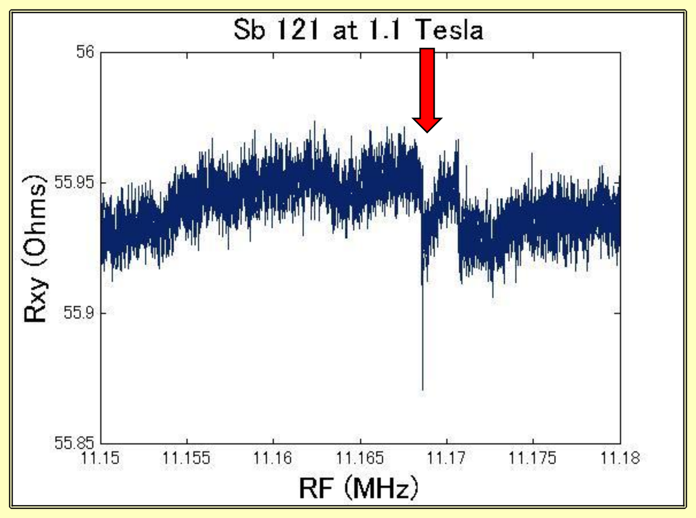


Figure 6

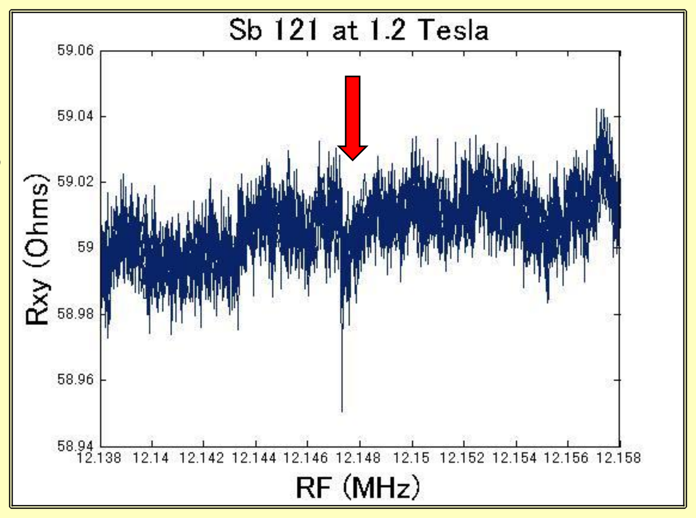


Figure 7

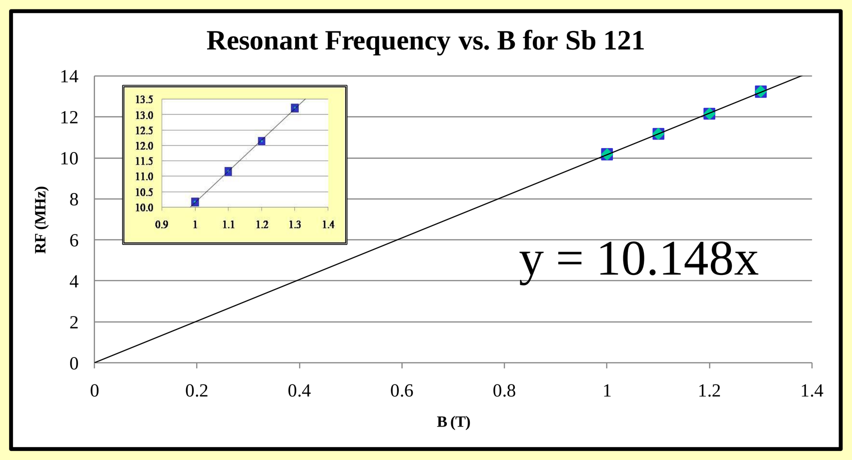


Figure 8

Future Work

Initial detection at 4.2 K is promising for moving up to 77 K and 300 K

Reduce the amount of noise in measurements

Investigate frequency shifts in ΔR

Begin incorporation into a nanoscale RDNMR device

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