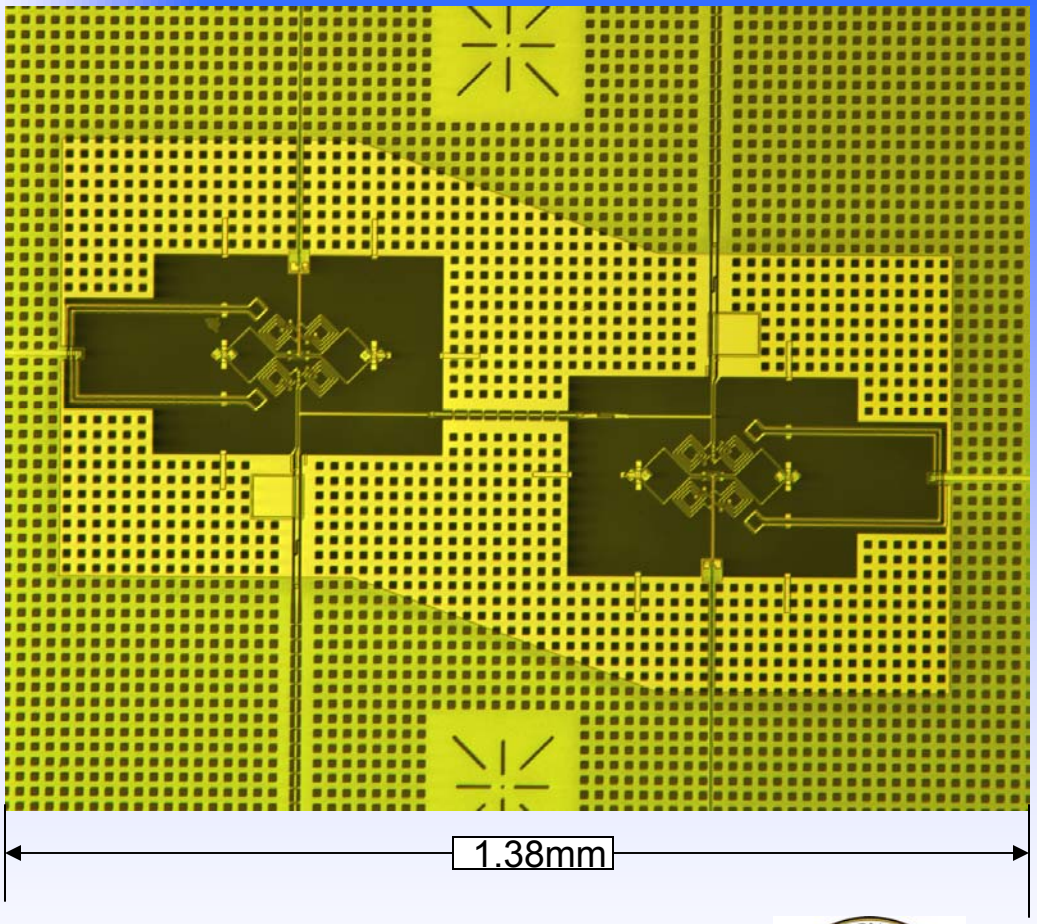
Superconducting Qubits



Ryan Martin

8/2/06

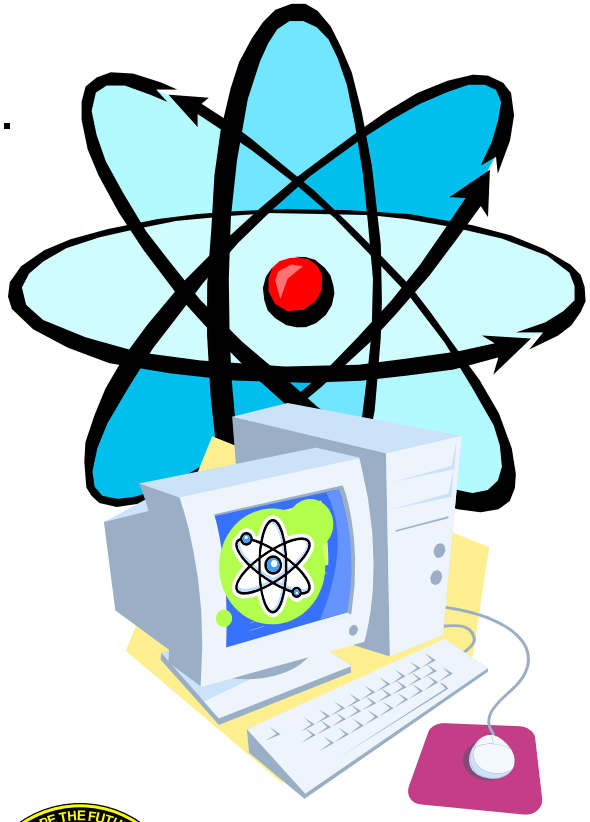
SBCC

Major: Electrical Engineering

Mentor: Nadav Katz

Group: John Martinis'

Superconducting Qubits are very scalable! so…..



We could use them to build a:

Quantum Computer

With a quantum computer, you can:

- Run much faster simulations
- Crack tough codes in real time
- Impress people at parties

Quantum Computation is known to be an exponential speed increase over classical computation!

Qubit?!?

Qubit (kyü-bit)

Qubit = Quantum bit

- A classical computer bit has two states:

  on or off

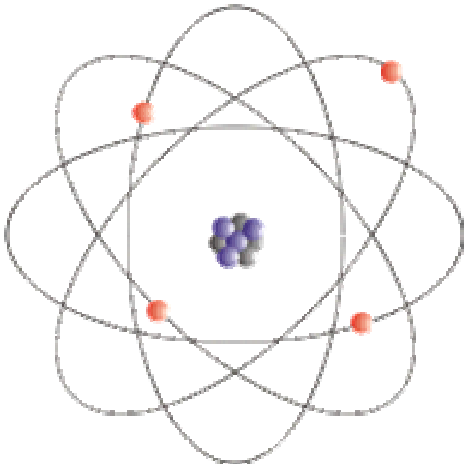
- A qubit is governed by

  Quantum Mechanics

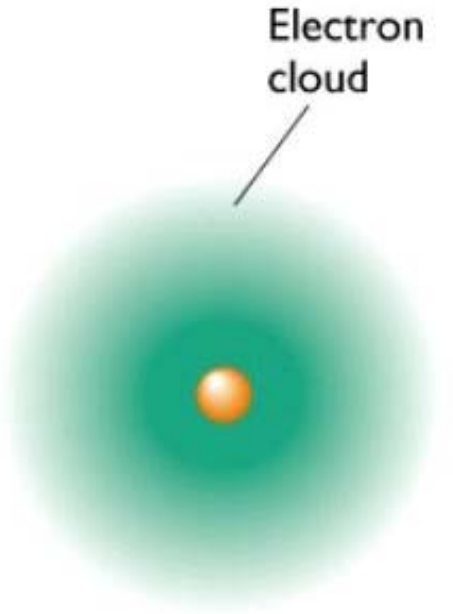
  – A qubit can be in a **superposition** of two states

The Quantum World

- Superposition means many places at once…. and then we measure it…



www.ktf-split.hr



http://www.gly.fsu.edu/~salters/GLY1000/6_Minerals/Slide9.jpg

What Superposition Can Do For You!

$$A\left|0\right\rangle + B\left|1\right\rangle = \left|\psi\right\rangle$$

…Where $\left|\psi\right\rangle$ is the state you're in

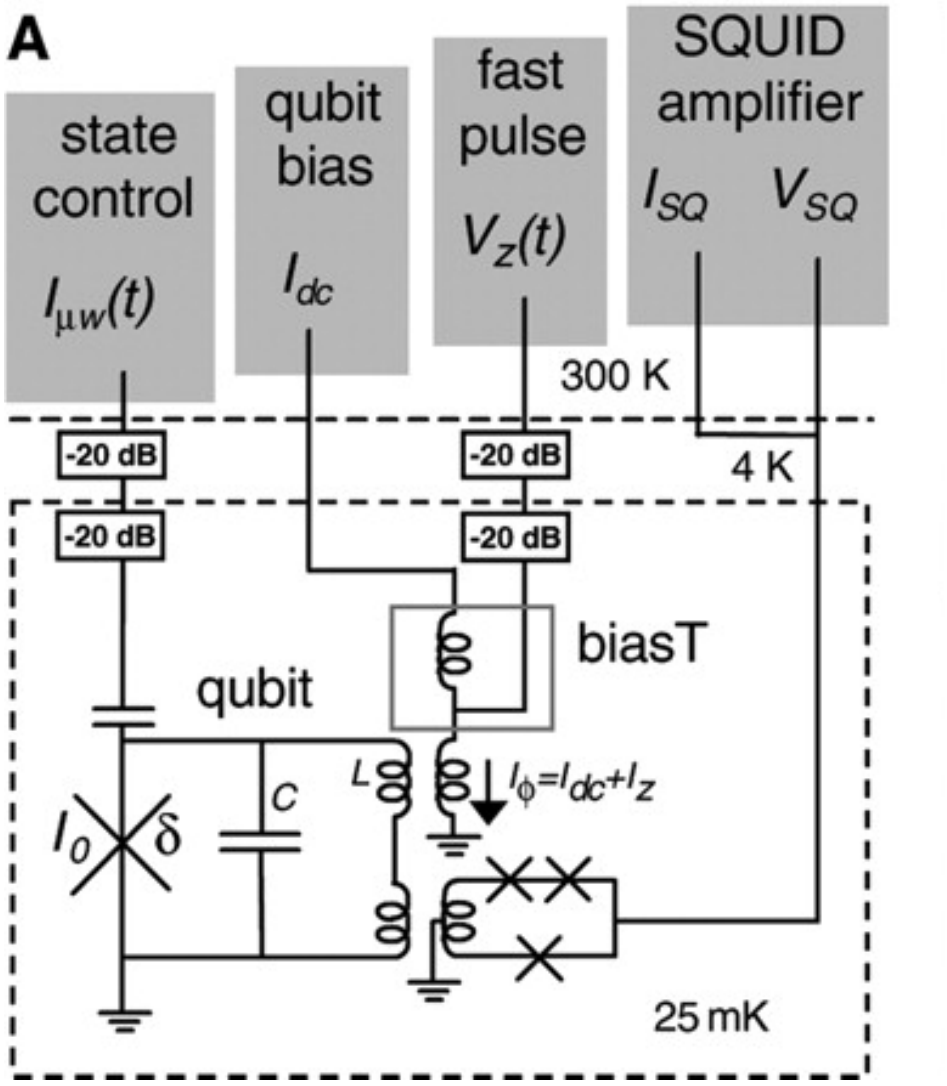
- In a Classical bit, A and B can only be 0 or 1
- In a Quantum Bit, The only governing rule is:

$$\left|A\right|^2 + \left|B\right|^2 = 1$$

Where $\left|A\right|^2$ is the probability of your bit measuring in the $\left|0\right\rangle$ state

And $\left|B\right|^2$ is the probability of measuring your bit in the $\left|1\right\rangle$ state

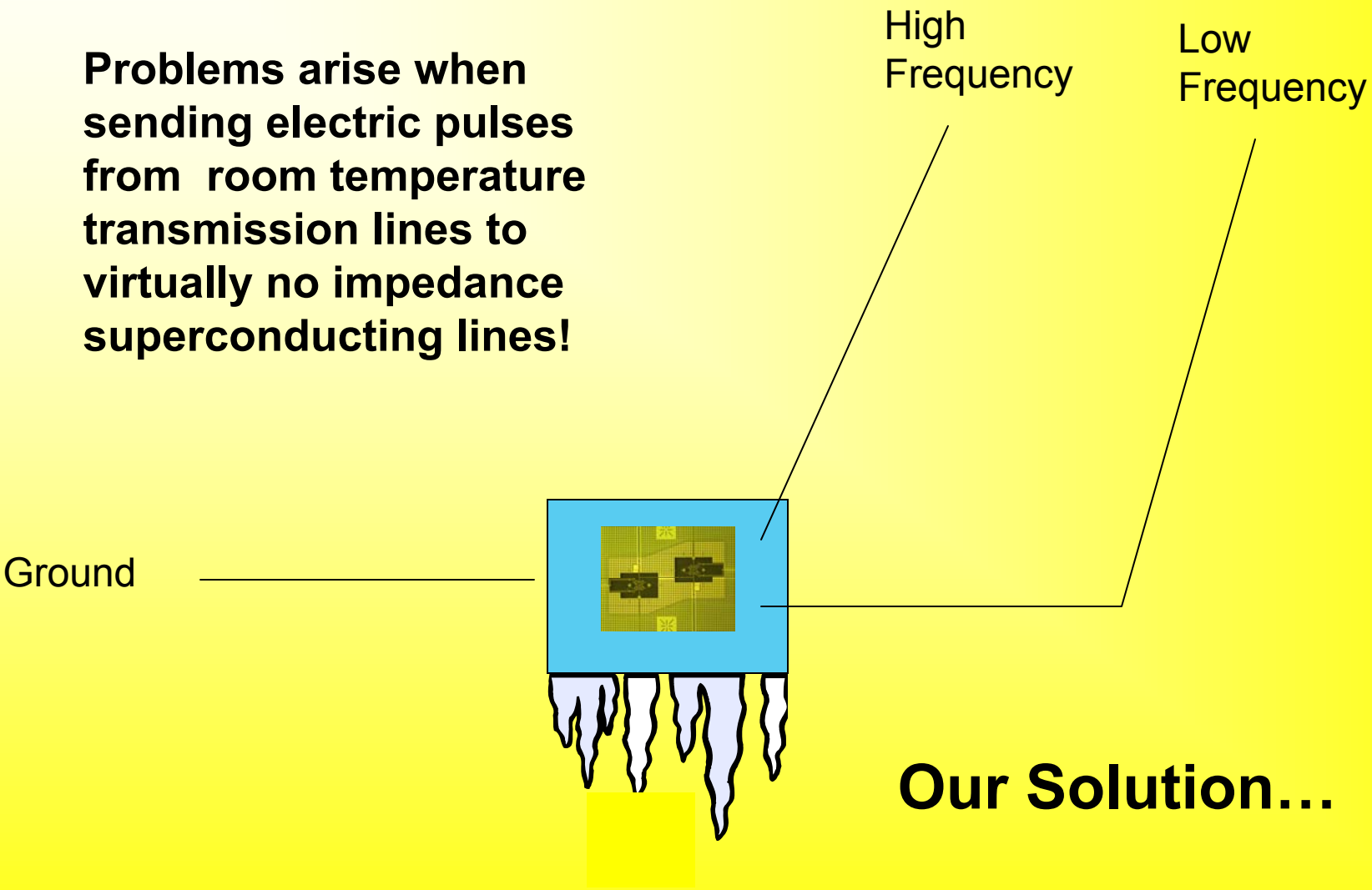
The Quantum World with Electric Circuits



N. Katz,1 M. Ansmann,1 Radoslaw C. Bialczak,1 Erik Lucero,1 R. McDermott,1 Matthew Neeley,1 Matthias Steffen,1 E. M. Weig,1 A. N. Cleland,1 John M. Martinis,1* A. N. Korotkov2 . **Coherent State Evolution in a Superconducting Qubit from Partial-Collapse Measurement**. *Science. 9 June, 2006.* http://www.sciencemag.org/cgi/content/full/312/5779/1498?ijkey=IRLKuFaYL68Q.&keytype=ref&siteid=sci.

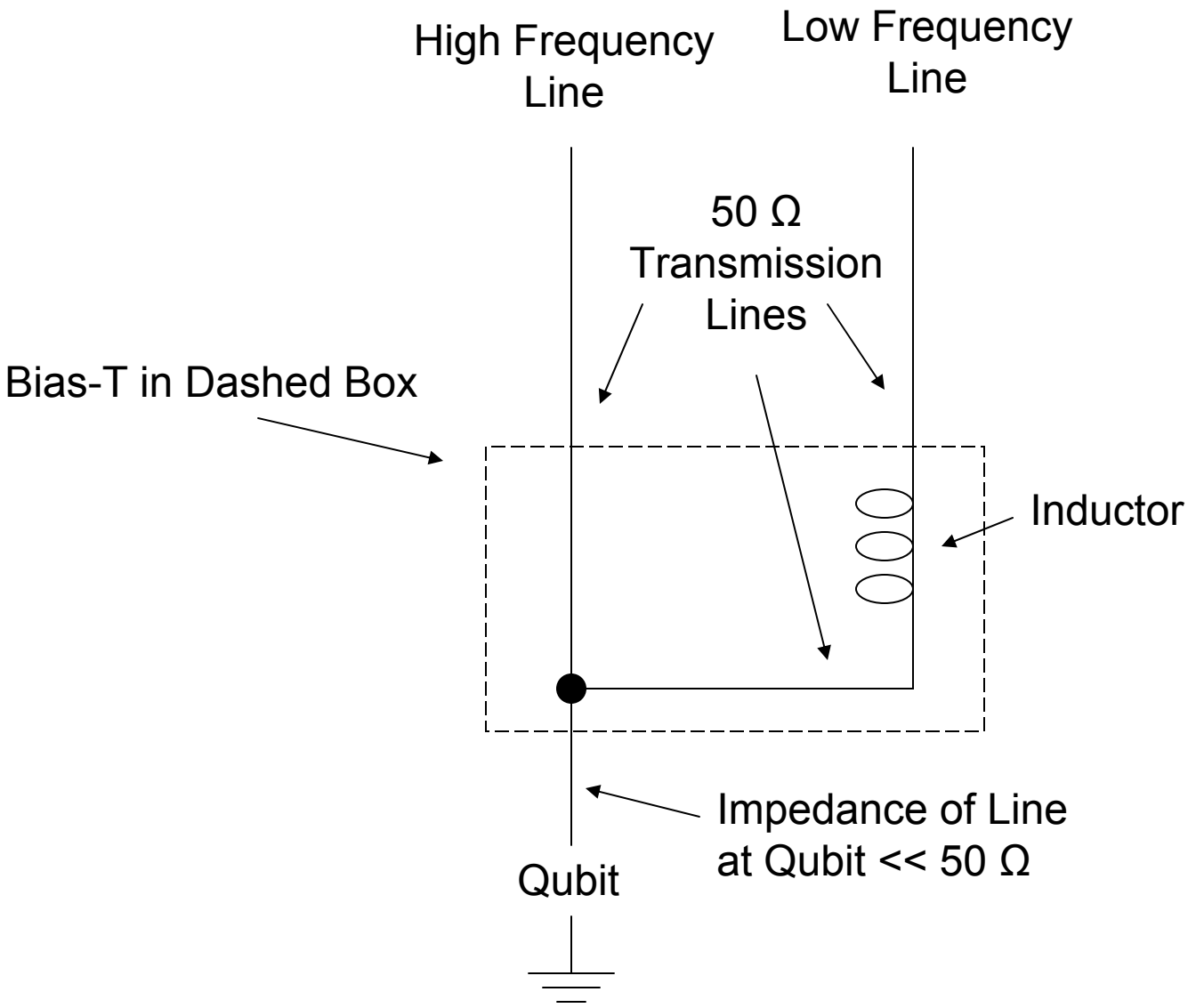
Controlling Our Qubit!

Problems arise when sending electric pulses from room temperature transmission lines to virtually no impedance superconducting lines!



Our Solution…

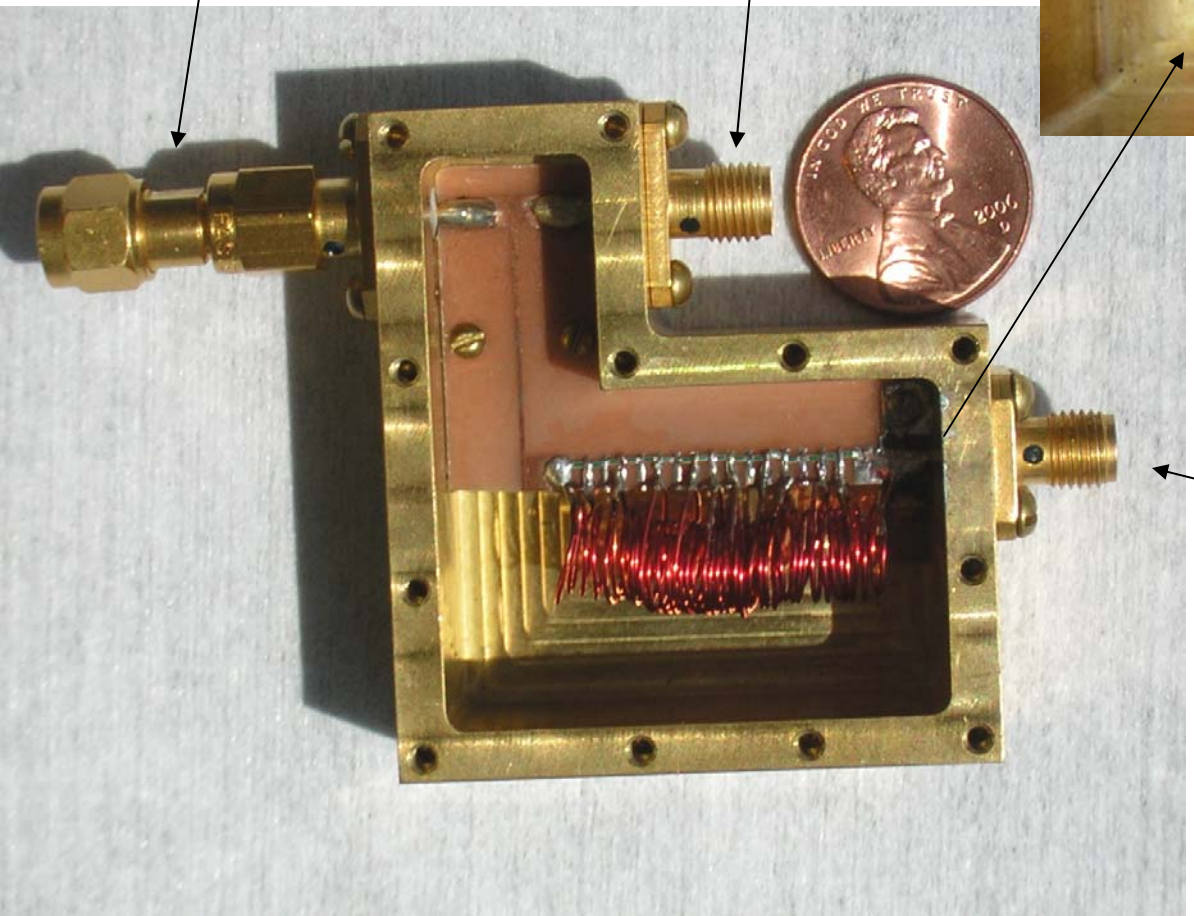
Schematic

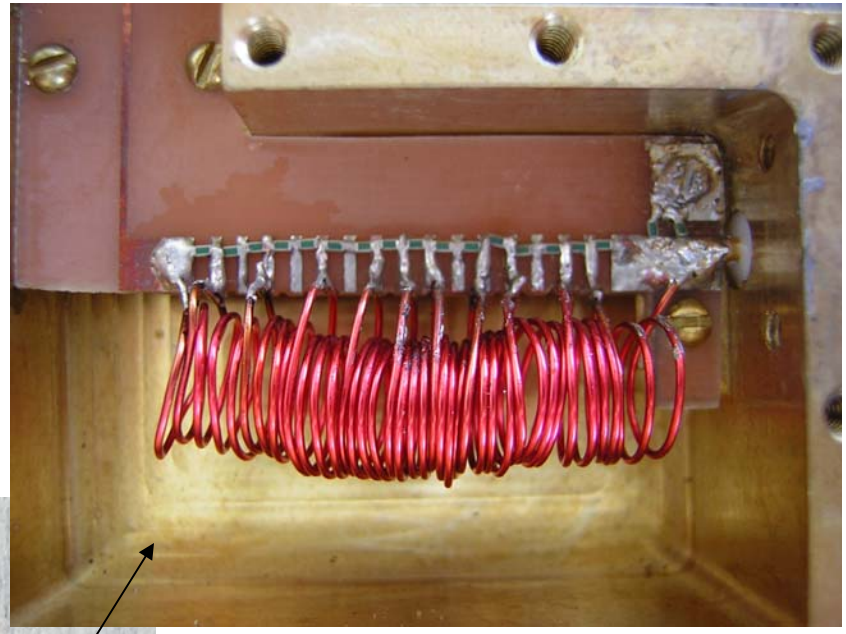

High Frequency Line
Low Frequency Line
50 Ω Transmission Lines
Bias-T in Dashed Box
Inductor
Impedance of Line at Qubit << 50 Ω
Qubit

Our “Bias-T”

Connection to Qubit

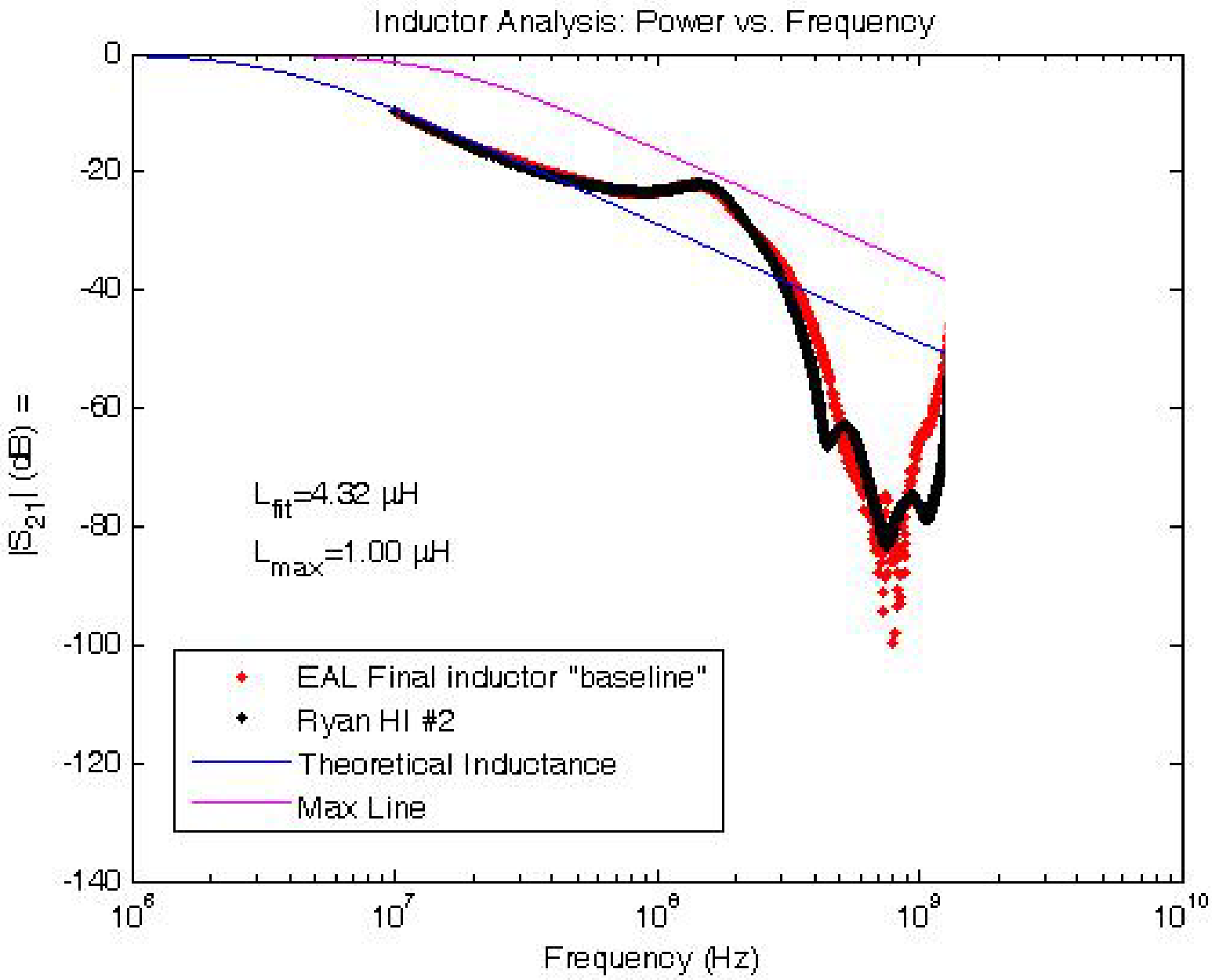
High Frequency Line Connection



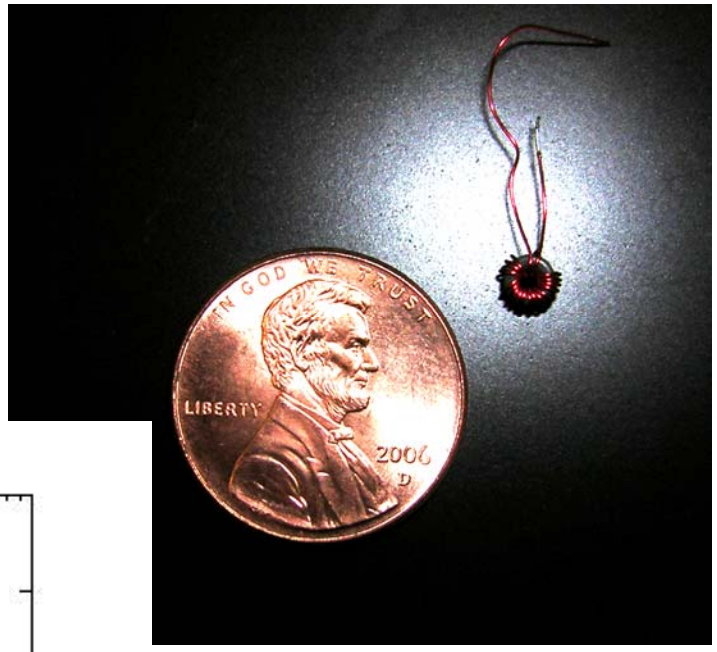


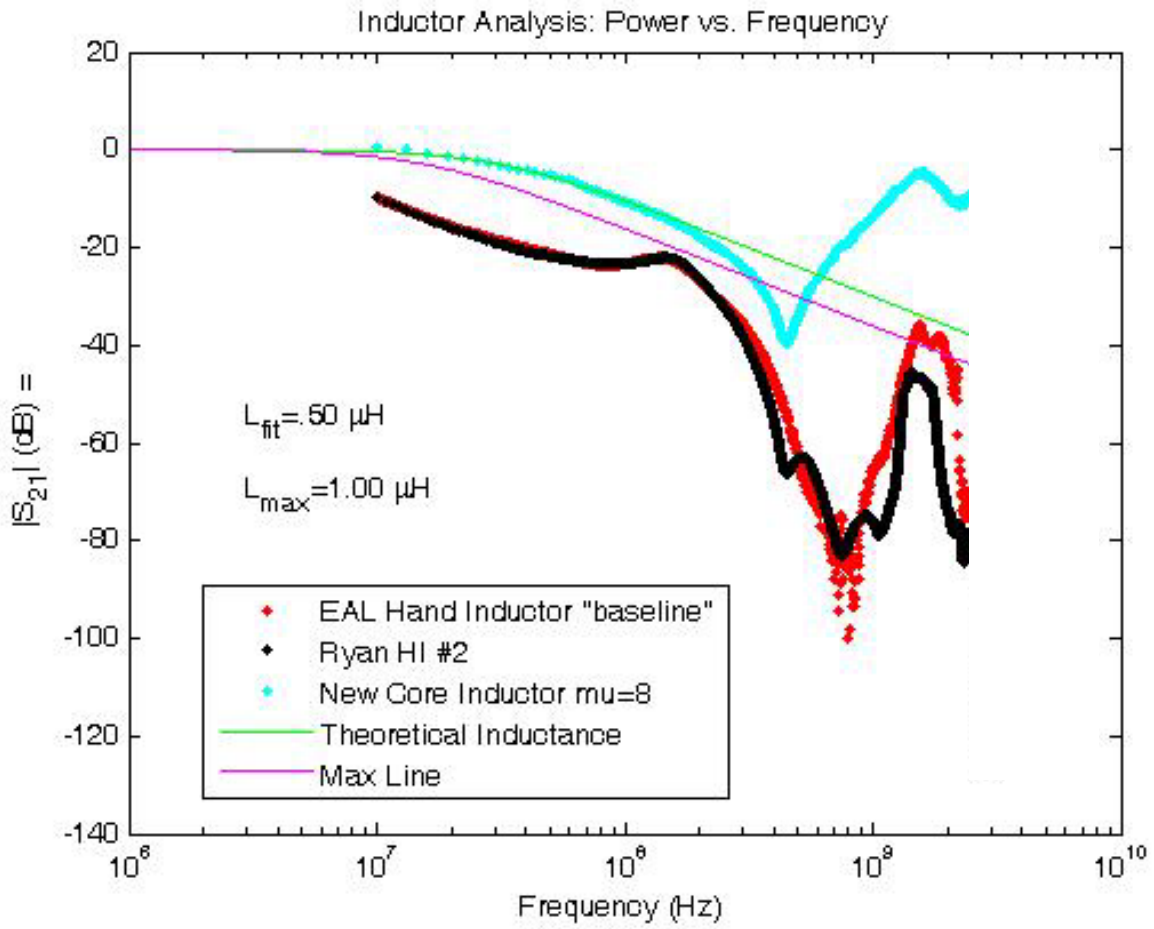
Zoom of Inductor coils and resistors

Low Frequency Line


Inductor Analysis: Power vs. Frequency
0
-20
-40
-60
-80
-100
-120
-140
|S21| (dB) =
L_fit=4.32 µH
L_max=1.00 µH
EAL Final inductor "baseline"
Ryan HI #2
Theoretical Inductance
Max Line
10^6
10^7
10^8
10^9
10^10
Frequency (Hz)

New Possibilities





Acknowledgements

INSET

CNSI

John Martinis Group:

- **Professor: John Martinis**
- **Mentor: Nadav Katz**
- **Markus Ansmann**
- **Robert McDermot**
- **Radek Bialzcak**
- **Eric Lucero**
- **Matthew Neeley**
- **Sam Rosenthal**

National Science Foundation

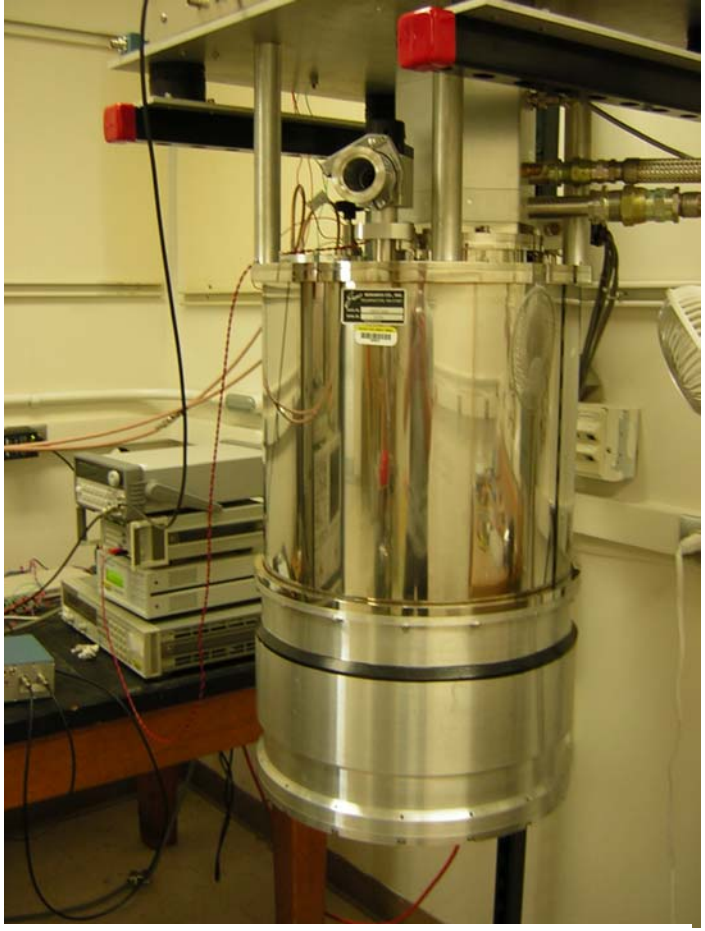
Army Research Office

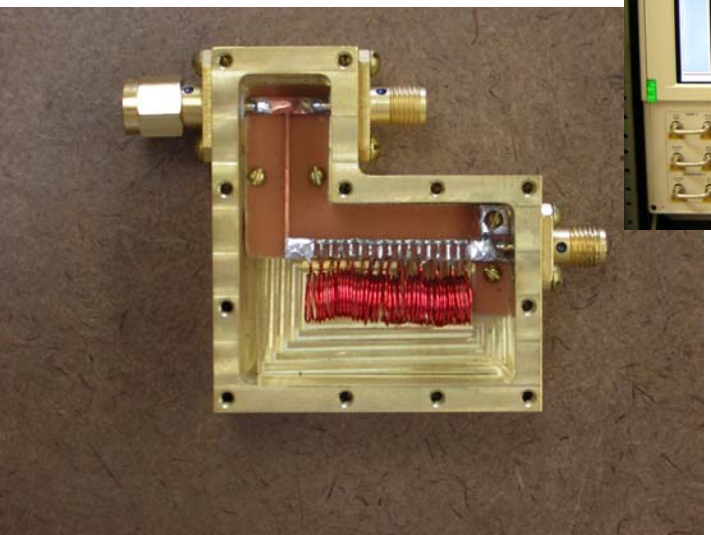
National Security Agency

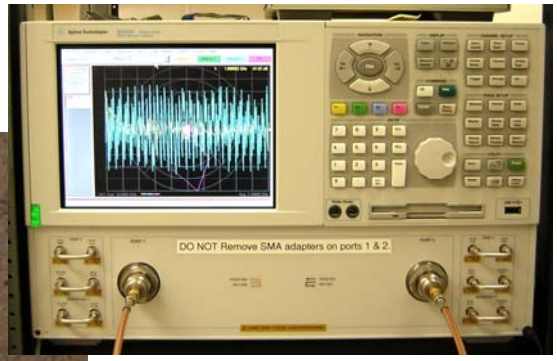
Disruptive Technology Office

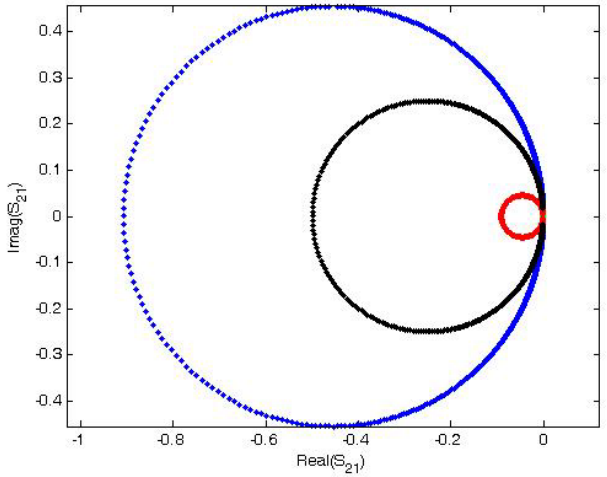
My Role:

- Fabrication and Analysis of microwave components
- Experimental setup and analysis using Adiabatic Demagnetization Refrigerator (ADR)
- Understanding and Application of Theory

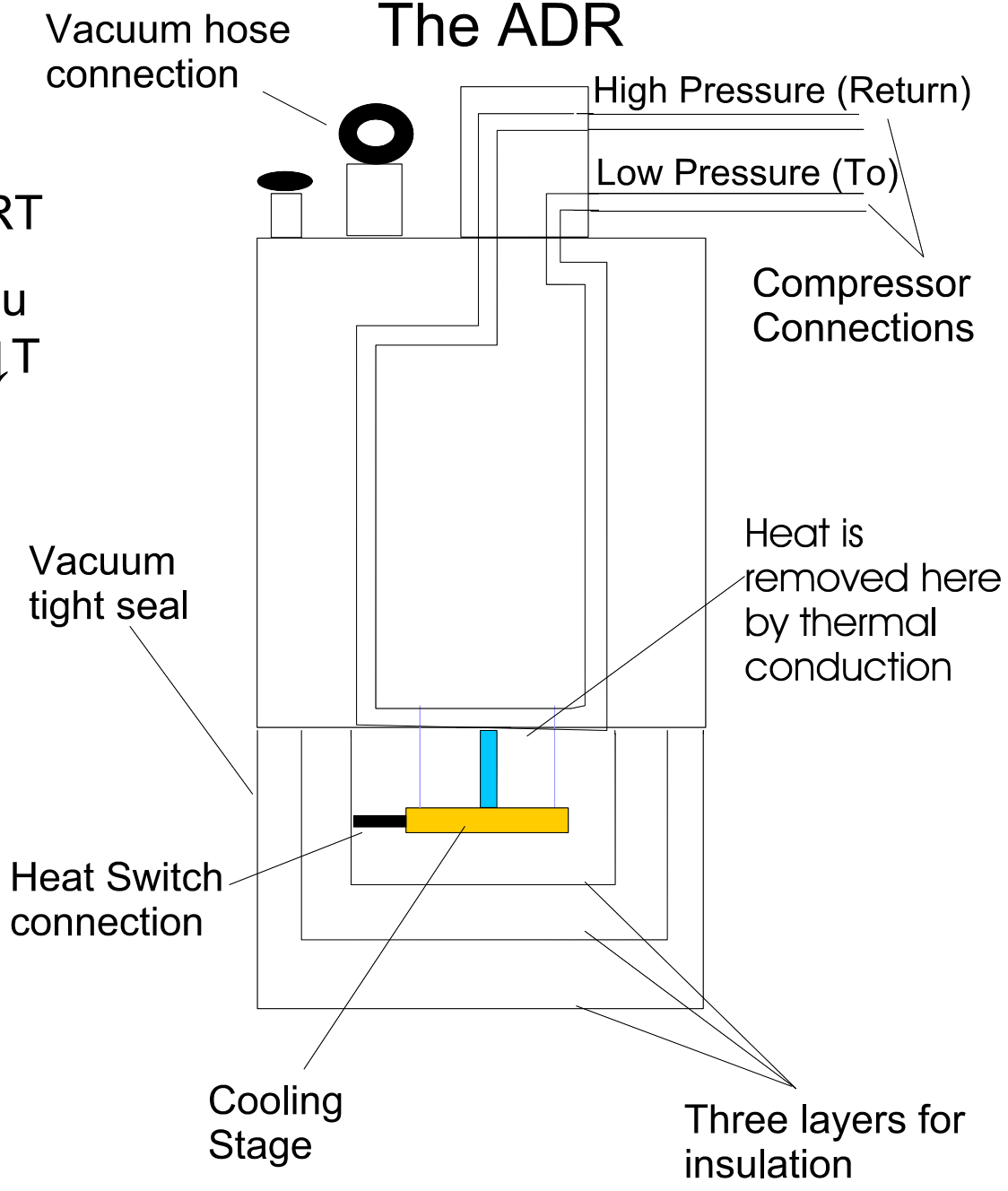




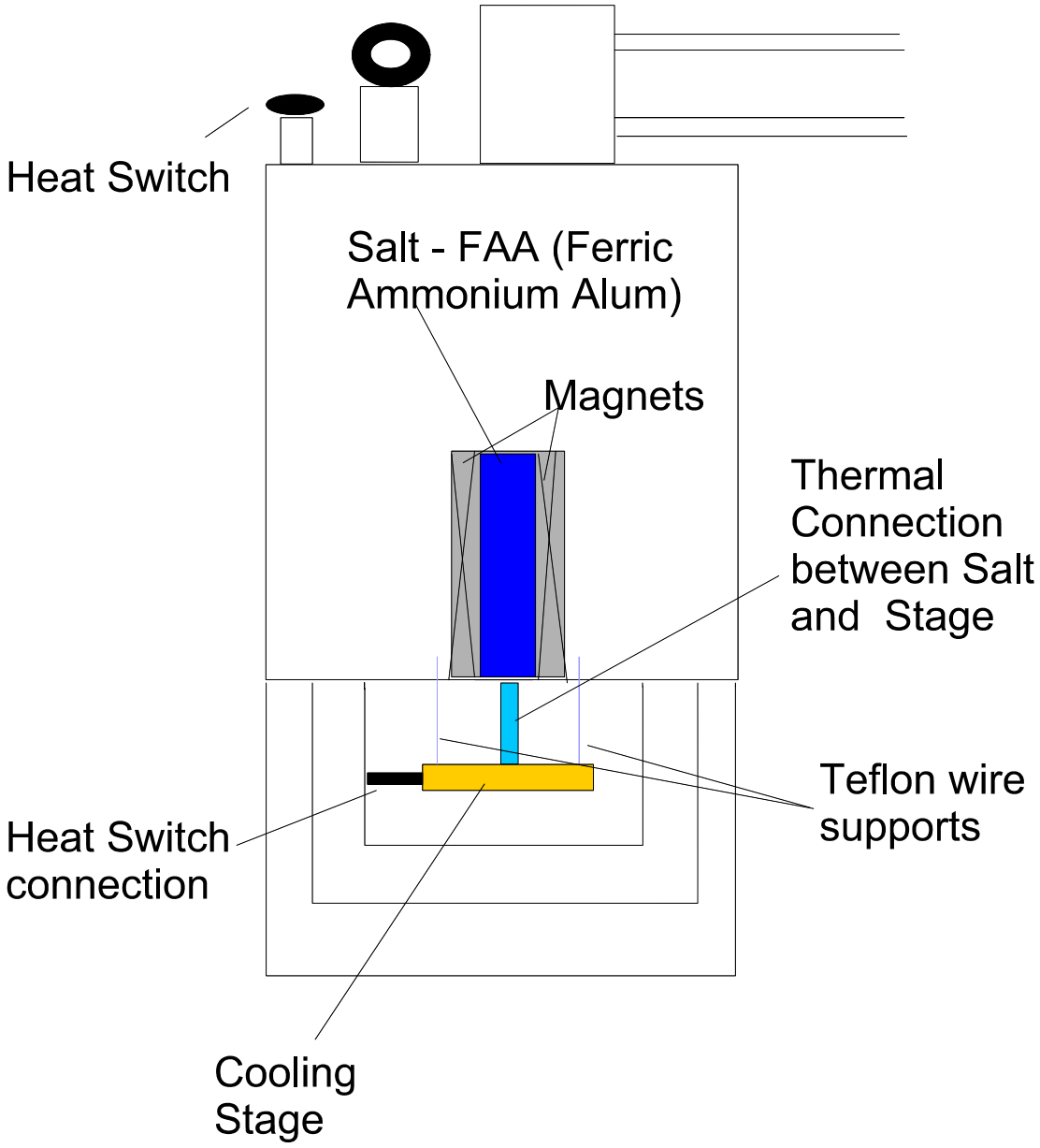




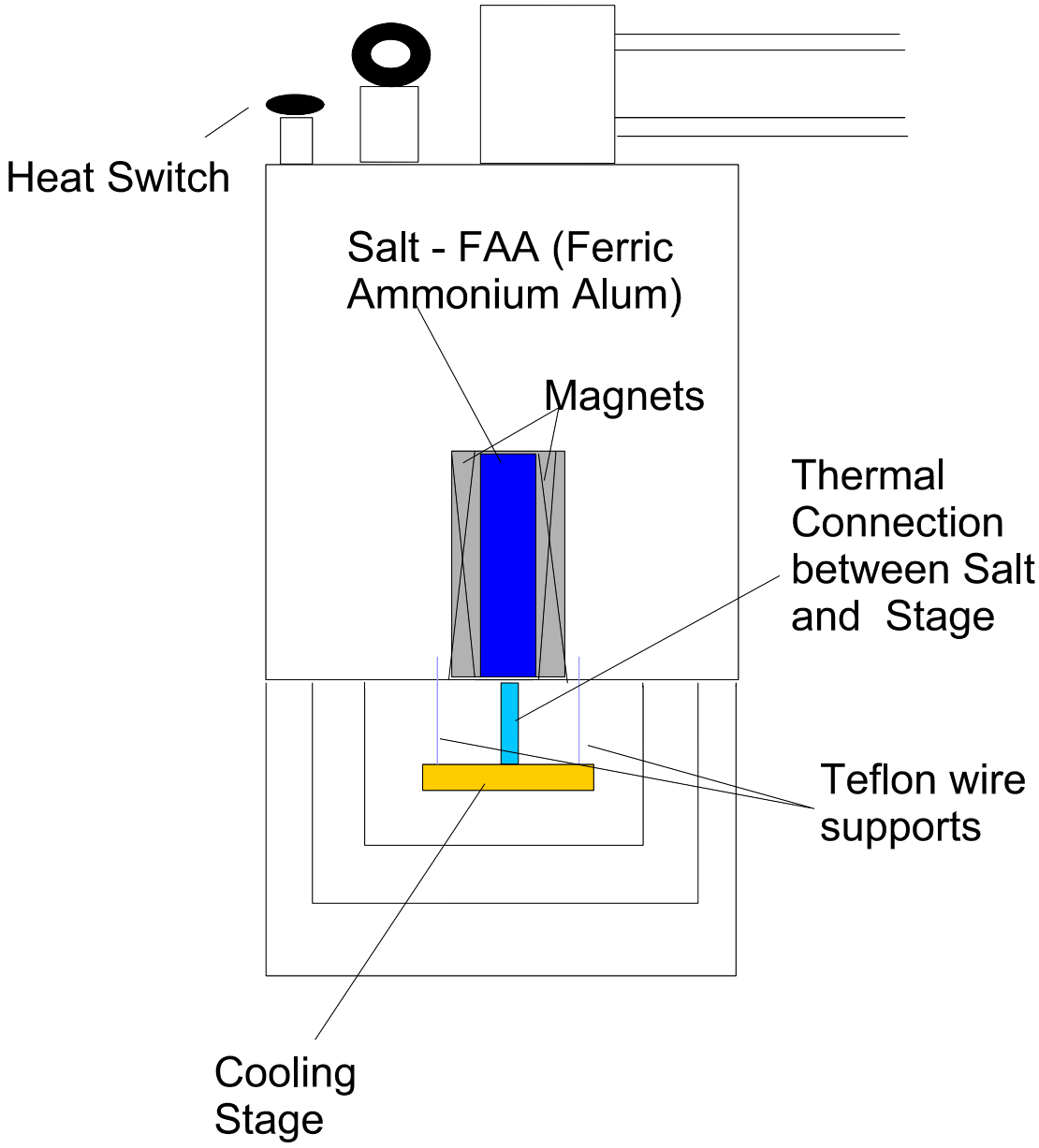
The ADR


Vacuum hose connection
High Pressure (Return)
Low Pressure (To)
Compressor Connections
PV = nRT
so if you
↑V = ↓T
Vacuum tight seal
Heat is removed here by thermal conduction
Heat Switch connection
Cooling Stage
Three layers for insulation

The ADR


Heat Switch
Salt - FAA (Ferric Ammonium Alum)
Magnets
Thermal Connection between Salt and Stage
Teflon wire supports
Heat Switch connection
Cooling Stage

The ADR


Heat Switch
Salt - FAA (Ferric Ammonium Alum)
Magnets
Thermal Connection between Salt and Stage
Teflon wire supports
Cooling Stage

Josephson Junction

Two superconductors separated by a thin dielectric