NMR using SQUIDs

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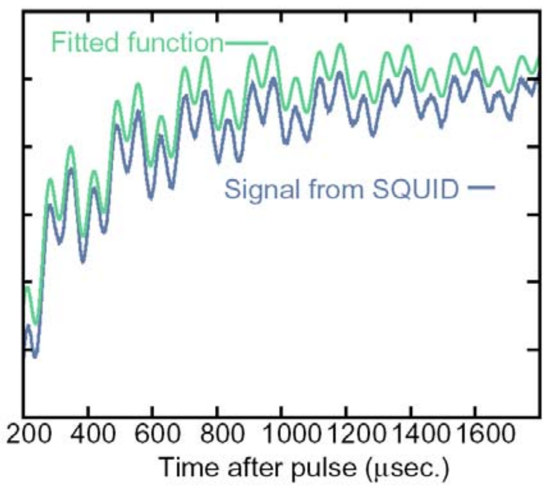
New ultralow temperature measurements require high performance SQUIDS for NMR.

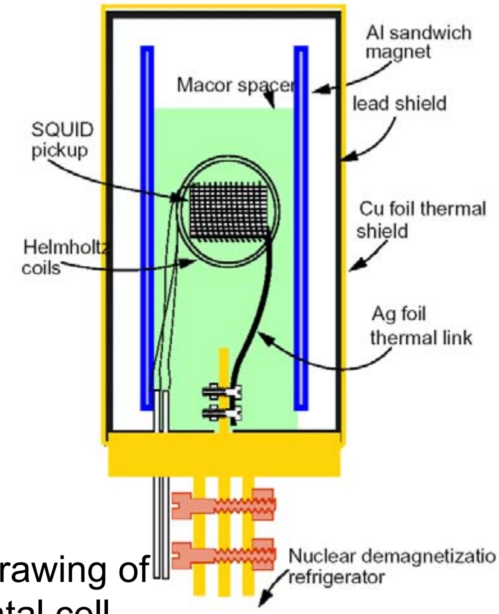
- Surface Magnetism
- Superfluid ^{3}He Order Parameter
- Disordered Materials

Why SQUIDs?

- Low noise
- High bandwidth allowing simultaneous observation of multiple resonances.
- More sensitive than conventional amplifiers at low frequencies.



Demonstration of NMR signal from ^{3}He and ^{13}C compared with its fit (slightly displaced).

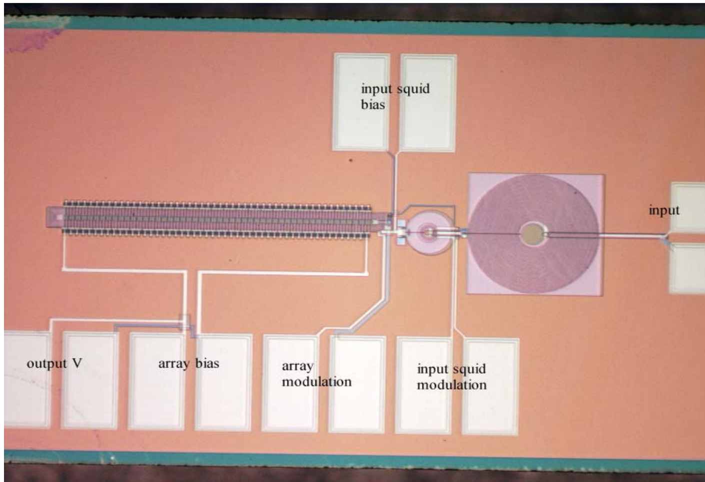


Schematic drawing of experimental cell

Technical program at USC

- Better understanding of noise sources
- 2 – stage high performance SQUIDS
- Model of noise in hysteretic SQUIDs

2-stage DC Squid



The ultralow temperature group at USC has focused on measurements that use SQUIDs (Superconducting Quantum Interference Devices) for observing NMR (Nuclear Magnetic Resonance). The low temperature experiments are on very thin two-dimensional films of ^{3}He (an excellent model system for magnetism) and the ^{3}He in aerogel (a quantum fluid system whose physics is closely related to high temperature superconductors). While the physics of these experiments has its own intrinsic interest, the use of state-of-the-art SQUID detectors poses a technical challenge that also has many other applications.

The main advantages of using SQUIDs come from their high sensitivity while being able to observe signals at vastly different frequencies. We show a sample cell at the top right. The figure in the middle is an example of observing simultaneous resonance from two nuclear species with resonance frequencies separated by a factor of three. The figure on the lower right is an example of a two-stage SQUID chip of the type we are now using.

Applications of High Performance SQUIDs in NMR

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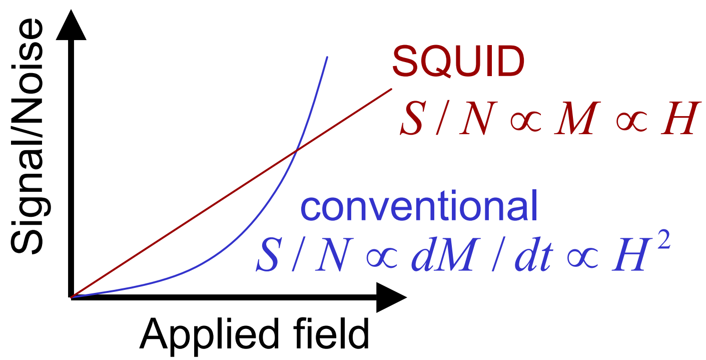
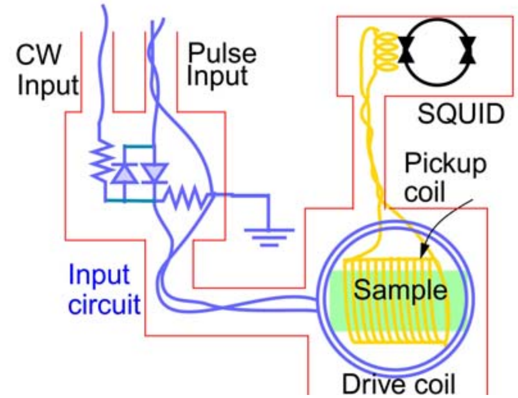
Advantages of SQUID NMR

• SQUID NMR is always better than conventional NMR at low fields.



• Broadband detection of several nuclear species simultaneously. Examples include ^{3}He with ^{13}C (USC) and ^{1}H with ^{31}P (Berkeley) with gyromagnetic ratios 3.0:1 and 2.5:1 respectively.



Pulse & CW NMR drive circuit and pick-up circuit. Red outlines are shields.

Applications of SQUID NMR

• Enables MRI of biological systems without large (and expensive) high field magnet systems.

•Analysis of biomolecules: Scalar couplings in heteronuclear systems are observed at low fields where NMR lines are extremely narrow. [Robert McDermott, *et al*. *Science* **295**, 2247 (2002).]

Education:

Graduate students: Jinshan Zhang, Yuliang Du, Lei Guo, Justin Schneiderman
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