Non-Biological SQUID applications

Neutrons- neutron electric dipole measurement

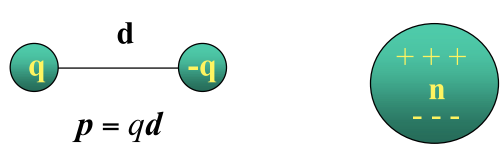
Welds, cracks, other stuff that breaks….

Neutron Electric Dipole Moment

Theoretical models describe how the fundamental particles are organized and how they interact via fundamental forces (*e.g..* The Standard Model).

These theories make predictions- neutron electric dipole moment (EDM).

Theories predict the EDM of a neutron (or any fundamental particle) to be very small. To date nobody has seen one!



Neutron Electric Dipole Moment

Experiment proposed at LANSCE
P-25 & P-23
Measure the neutron EDM to 10^{-28} *e*•cm

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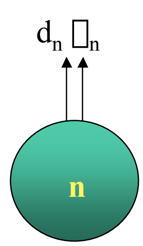
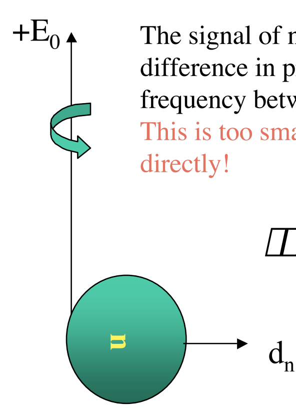
Neutron Electric Dipole Moment





The signal of nEDM is a difference in precession frequency between $+E_0$ and $-E_0$.
This is too small to measure directly!

$$\Delta\omega_n = \pm 2\frac{d_n E_0}{\hbar}$$

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Neutron EDM Measurement with SQUIDs

Use SQUIDs

Polarized ultracold neutrons & ^{3}He in a superfluid ^{4}He bath. Small B and big E.

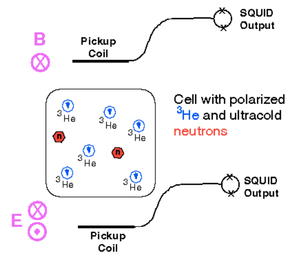
^{3}He Larmor frequency direct measure of B

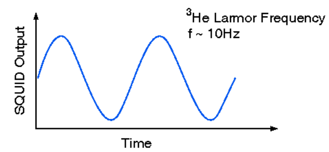
^{3}He, n precess at different ω

^{3}He + n ➔ ^{3}He + $h\nu$ when spins antiparallel
Scintillation rate is:

$$\frac{\partial \Gamma}{\partial t} = 1 - p_3 p_n \cos[(\omega_3 - \omega_n)t + \phi]$$

p_3 and p_n are the polarization vectors, ω_3 and ω_n are the precession frequencies.





Any difference of $d\Gamma/dt$ for $E_{parallel}$ or $E_{antiparallel}$ immediately leads to an EDM!

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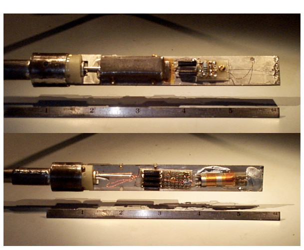
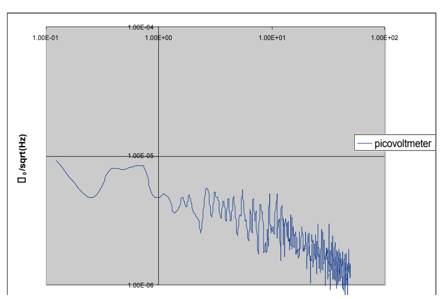
Neutron Electric Dipole Moment

Espy & Matlachov

The EDM experimental cell will be roughly 20 cm in diameter and 10 cm high. Signal expected at the 100 cm^2 pick-up is S=0.1 Φ_0. Striving for at least $3\mu\Phi_0$/Hz$^{1/2}$ SQUID noise.

$$SNR = \frac{S}{\sqrt{d\Phi_p^2 + d\Phi_e^2}} = 24\sqrt{Hz}$$





SQUID noise as a function of frequency. The data were taken with the picovoltmeter inside a superconducting shield and a small-area pick-up coil with the same inductive load as the large-area coil. At the frequency of interest, 10 Hz, the noise was 3 $\mu\Phi_0$/Hz$^{1/2}$

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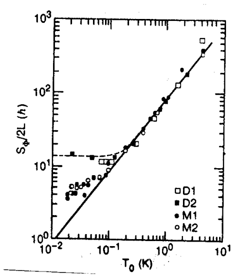
Neutron Electric Dipole Moment

Our initial work was at 4 K. The nEDM will be at 0.3 K.

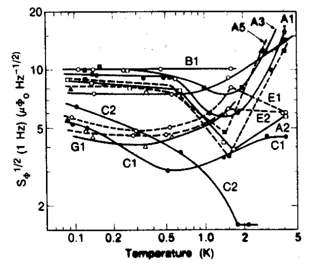
Wellstood, Urbina, Clarke

Appl. Phys. Lett., V**54** (25) 19 June 1989

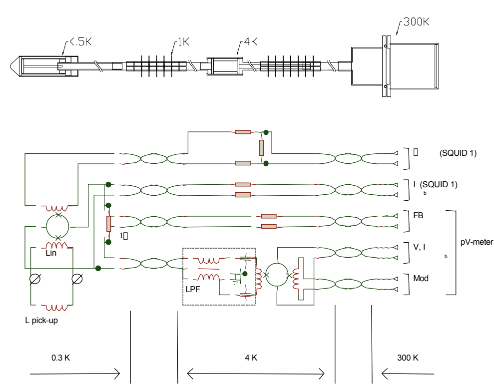


Wellstood, Urbina, Clarke

Appl. Phys. Lett., V**50** (12) 23 March 1987



Neutron Electric Dipole Moment



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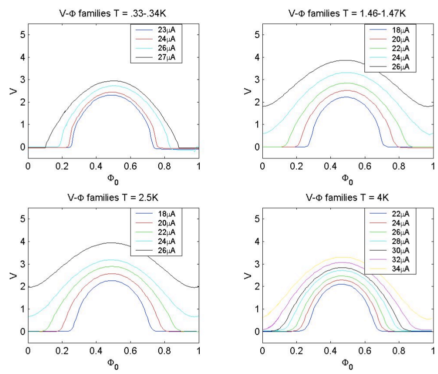
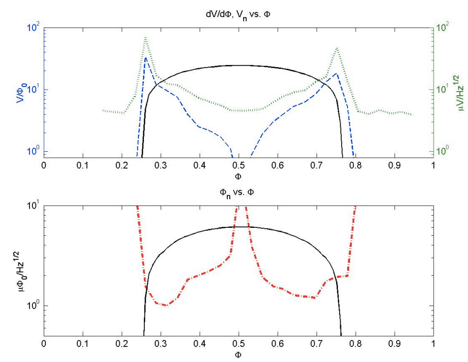
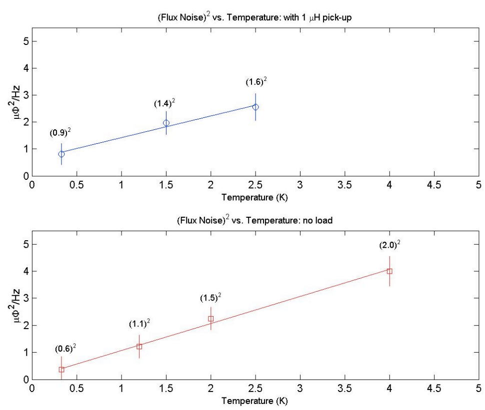


Families of V-Φ curves at different bias currents for the test SQUID with a 1 μH pick-up coil



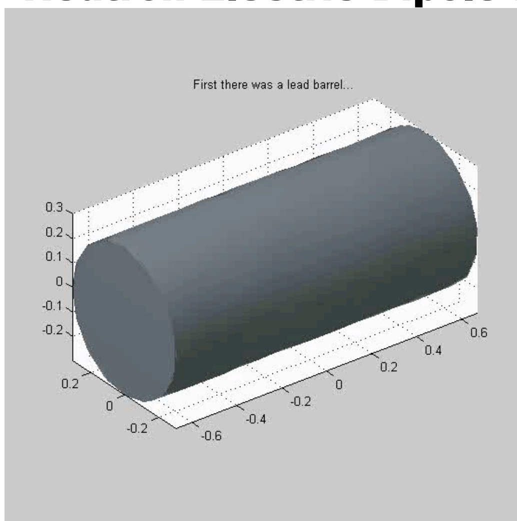
Upper: dV\dΦ (dashed line) and V_n (dotted line) vs. flux. Lower: Flux noise, Φn, (dashed line) vs. flux. The scaled V-Φ curve (solid line) is also plotted.

Neutron Electric Dipole Moment



Φ_n^2 vs. temperature. Data are the best values at each temperature. Solid lines are a fit to $\Phi_n^2 = a \cdot T + b$. Upper: SQUID with a 1 μH pickup coil. Lower: SQUID with no load.

Neutron Electric Dipole Moment



FEM method

Volegov/Maharajh UNM

Neutron Electric Dipole Moment

Latest Developments

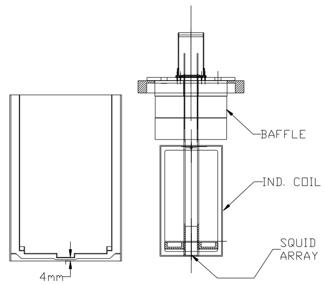
- **Magnetometers tested at NHMFL (Nov. 2001)**
- **First LANL production of UCN in ^{4}He (Dec. 2001)**
- **More tests at NHMFL (Feb. 11th 2002)**

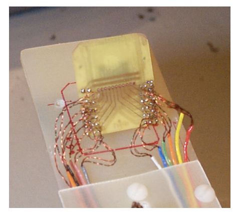
Future Work

- **Integrate SQUIDs into cryostat**
- **Preliminary tests with high voltage**
- **EDM collaboration**

SQUID Array Microscope

Espy, Kraus, Matlachov, Armijo, Newman, Clark, Peters





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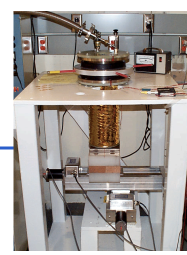
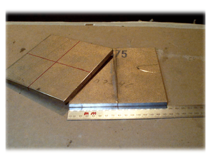
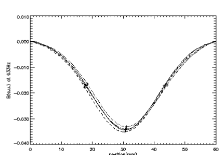
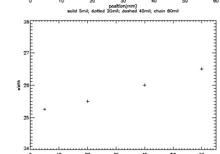
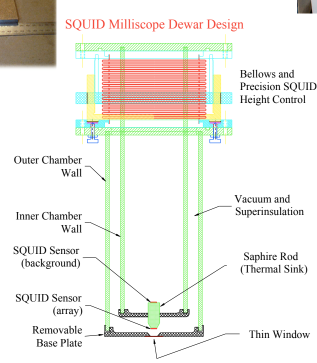
SQUID Array Microscope











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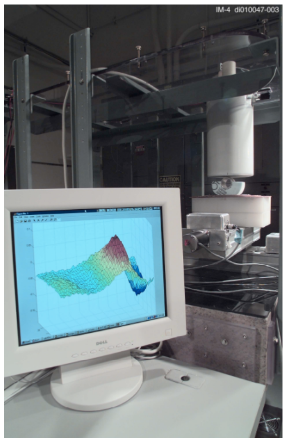
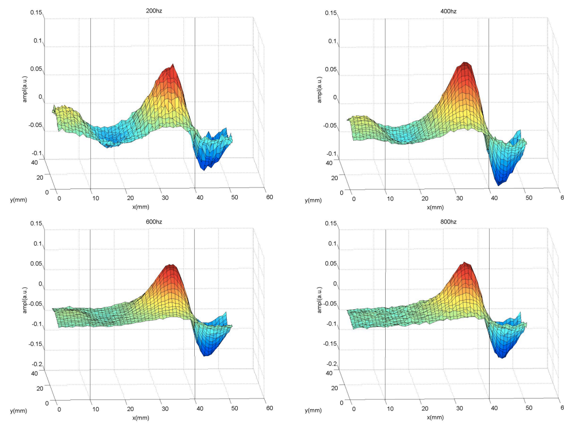
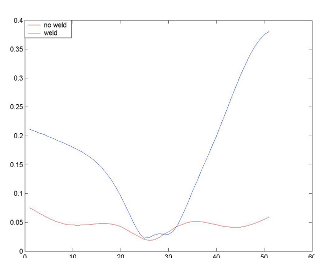
SQUID Array Microscope





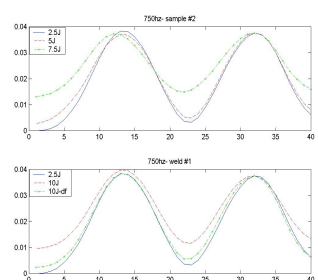
SQUID Array Microscope

Photograph of two samples, one welded and one solid The two are visually identical.

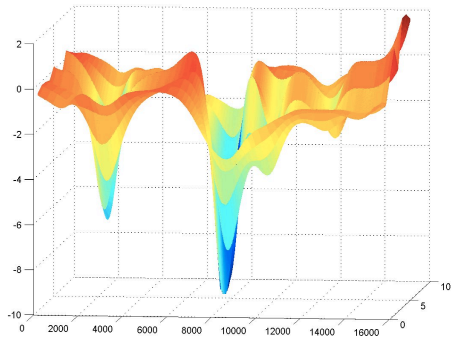


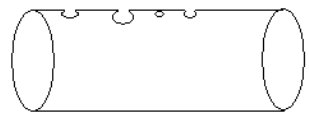
SAMi scans of the solid (red) and welded (blue) upset forge weld samples.

Upper panel: scans of three welds on the same sample. Lower panel: scans of welds in the same position for different samples.



SQUID Array Microscope





Steel pipe with holes in earth's magnetic field

SQUID Array Microscope

Latest Developments
- Collaboration with KCP to use our system for weld inspection (FY '02)
- First 360^0 scans complete (Dec. 2001)

Future Work
- 360^0 scans of welds followed by destructive testing
- New motion control system
- Tests with real parts
- Design system for KCP ?
- Steel pipes and higher order gradiometer configurations (summer '02 with Catholic University, Rio de Janeiro)