



Introduction to the PPMS

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What is a PPMS

Physical Property Measurement System

Standard superconducting magnet used for many types of measurements

Relatively cheap and easy to use

Option to design your own experiments

The PPMS dewar along with the controls. The magnet itself is near the bottom of the dewar.



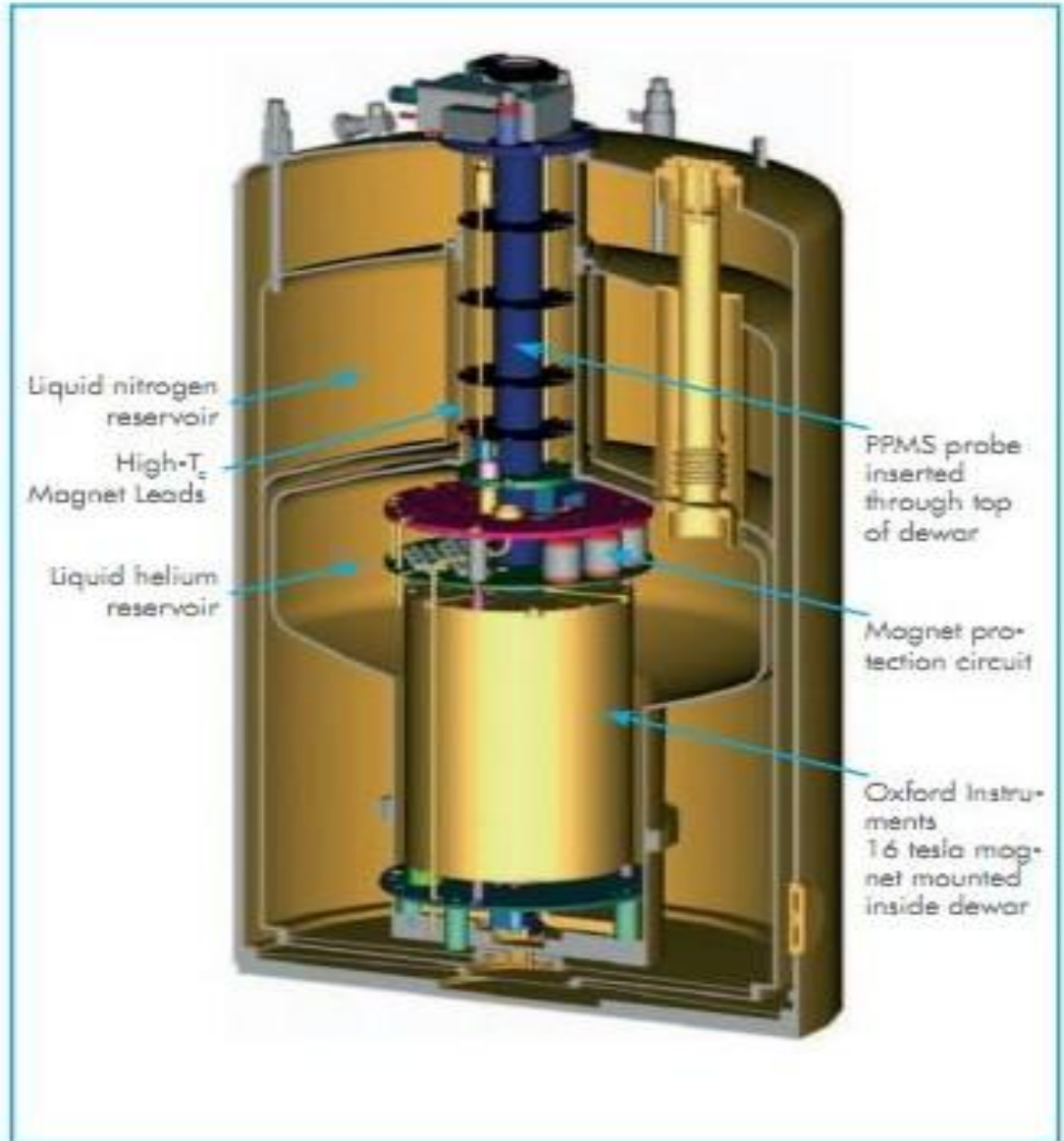
Model PPMS-16

16 Tesla PPMS (Features/Specifications)

Cutaway view showing the PPMS-16 magnet and probe inside its nitrogen jacketed dewar.

The nitrogen jacket helps to keep the liquid helium (expensive) cool

Sample chamber near bottom of magnet



Specifications



HIGH-CAPACITY LN2 -JACKETED DEWAR

Max. Hold Time: 3 weeks

LN2 Capacity: 74 liters

Static Boil-off w/Probe: < 2 liters/day

TEMPERATURE CONTROL

1.9–400 K

ACCURACY

±1% zero to full field (up to 14 tesla)

SLEW RATE

0.01–6 K/min.

CONTROL MODES

No Overshoot

Fast Settle

Temperature Sweep

Preliminary System Specifications

(Standard system specification apply except where noted):

Magnet	±16 Tesla Longitudinal Field
Magnet Type	NbTi/Nb3Sn hybrid
Field Homogeneity	0.1% over 1 cm DSV
Slew Rate	0.05–21 mT/sec. (typical)
Field Resolution	0.03 mT
Remanent Field	<150 Oe over the sample volume
Location of Magnet	Magnet is mounted in the special PPMS helium dewar.
Power Supply	New 120A, 10V power supply
Special Helium Dewar	Bottom-loading, High Capacity, Liquid Nitrogen jacketed
Helium Capacity	~60 liters with magnet and probe in dewar
Nitrogen Capacity	~74 liters
Static LHe Boil-off	~3.6 liters/day
LHe Boil-off	~6 liters/day (Under normal usage)
Power Requirements	200-240V/50 or 60 Hz, 20 A

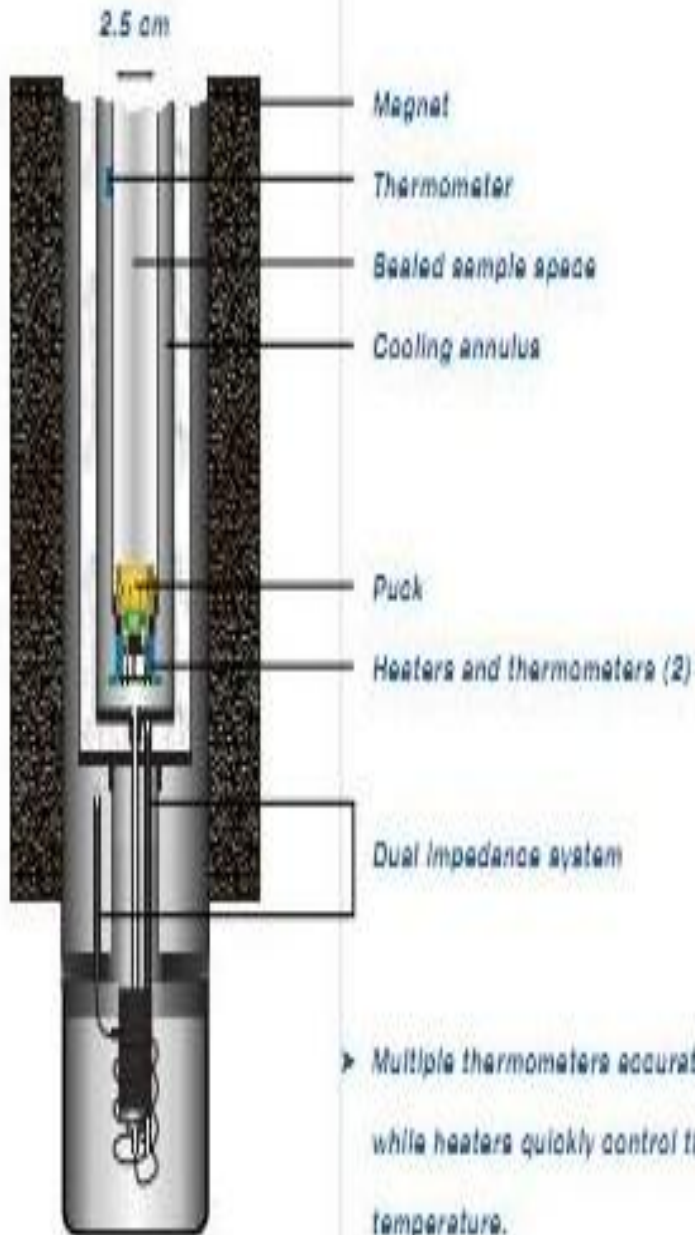
Probes and the Sample Chamber

Many different types of probes offered from Q.D., but you can create your own probe with desired properties

The probes have a 12-pin, keyed bottom connector that plugs in to the PPMS, which allows for data to be taken

Many different types of pucks for different experiments

PPMS Probe



➤ Multiple thermometers accurately monitor while heaters quickly control the system temperature.

The Puck

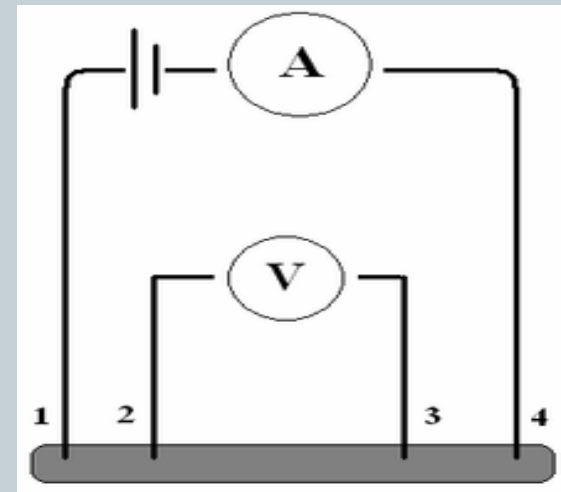


The puck is used to hold the sample.

Four Terminal Sensing

$$V = IR$$

Below: Current is supplied to the sample (grey) via contacts 1 and 4. The voltage drop over the center section of the sample can then be measured very accurately because there is almost no current in the circuit loop that is used to measure the voltage. Above is a picture of uranium with gold wires attached.



Types of Measurements



- Heat Capacity
- Torque Magnetometry
- Electro-Transport
- Hall Effect
- Residual-Resistance Ratio (RRR)

Magnetometry

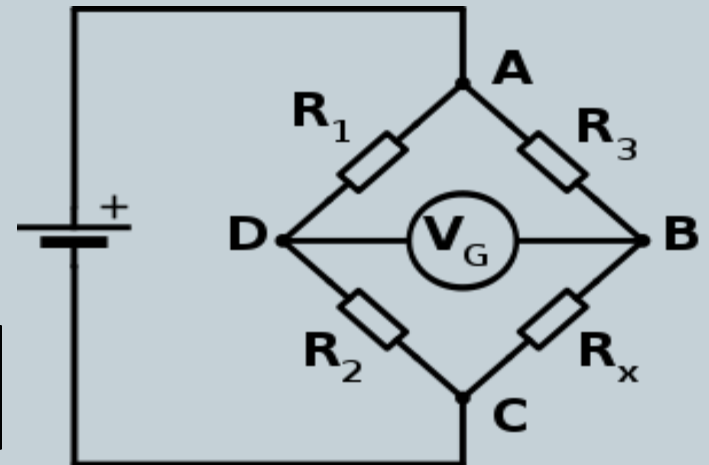
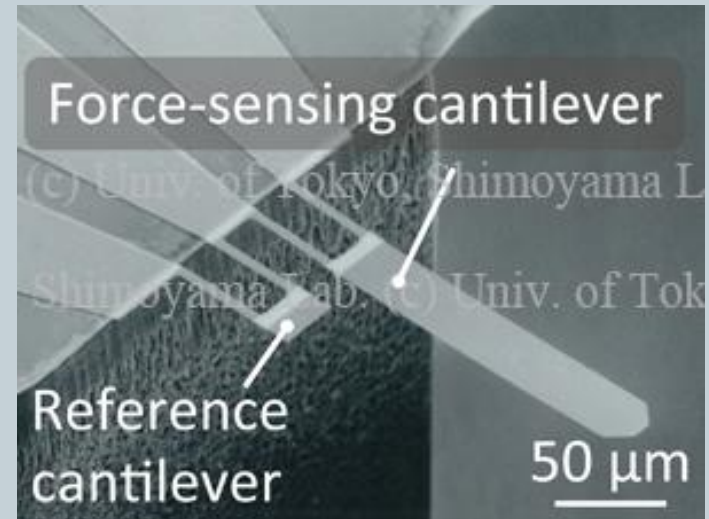
Place sample on piezo-resistive cantilever arm, turn B field up, sample oscillates

Up to 3 cantilever platforms per PPMS puck allows for 3 individual measurements

You can “see” these oscillations from measuring the oscillations in V_G

$$\tau = m \times B = \mu_0 m \times H,$$

Top: Force-sensing cantilever. Bottom: Wheatstone Bridge circuit diagram.



Fermi Surface

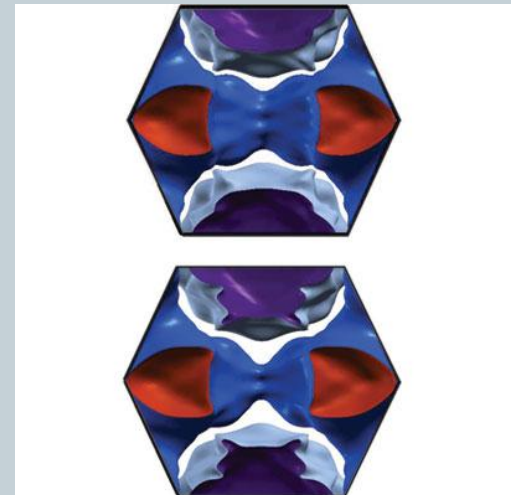
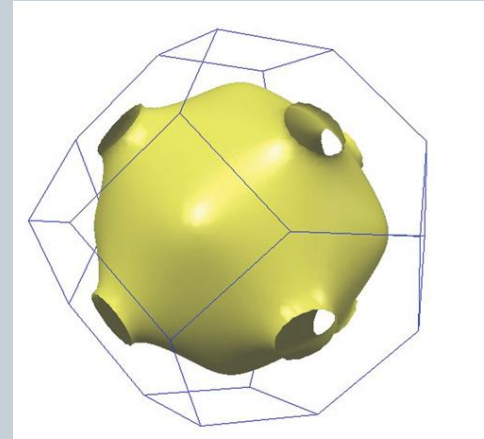


The Fermi Energy is the energy of the highest occupied state in a system of fermions at absolute zero temperature

Electrons fill up orbitals in order of lowest energy first, similar to people filling the best seats at the movie theatre first.

Electrons at the highest energy (worst movie theatre seats) are said to exist on the Fermi surface

The Fermi surface reveals how the energy varies with momentum for the highest energy electrons that have the Fermi energy. Top is the Fermi surface of copper. Below is a model of the Fermi surface of uranium at ambient pressure and 20 GPa (top and bottom, respectively).



Electro-transport

PPMS has options for resistivity, hall effect, I-V curves, and many other electro-transport measurements

Rotator platforms available for angular dependence measurements

Current Range: 5 nA to 5 mA
Sensitivity: 20 n



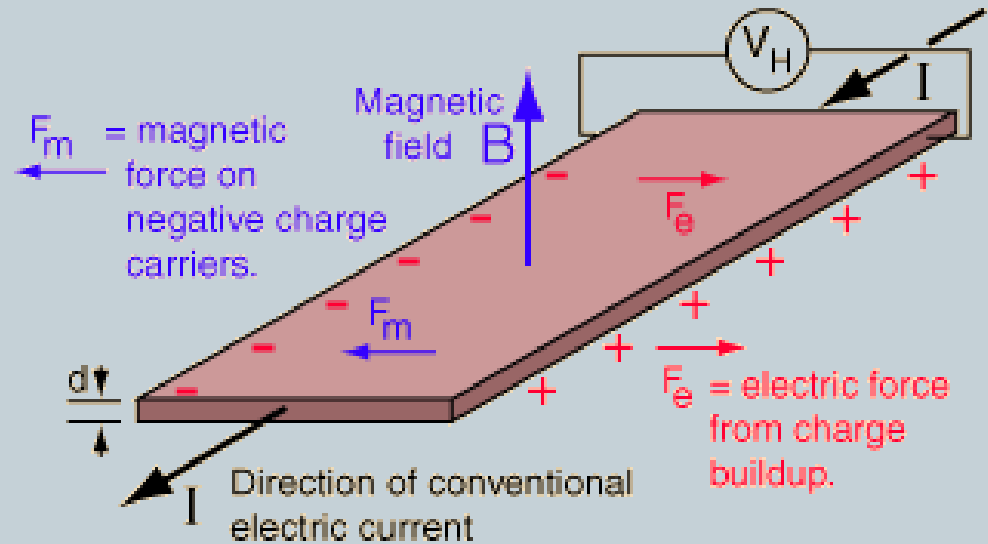
The rotator can be either rotated manually or automatically by turning a knob (outside of the PPMS) connected to the probe.

Hall Effect



If an electric current flows through a conductor in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor.

A buildup of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor.



$$V_H = \frac{IB}{ned}$$

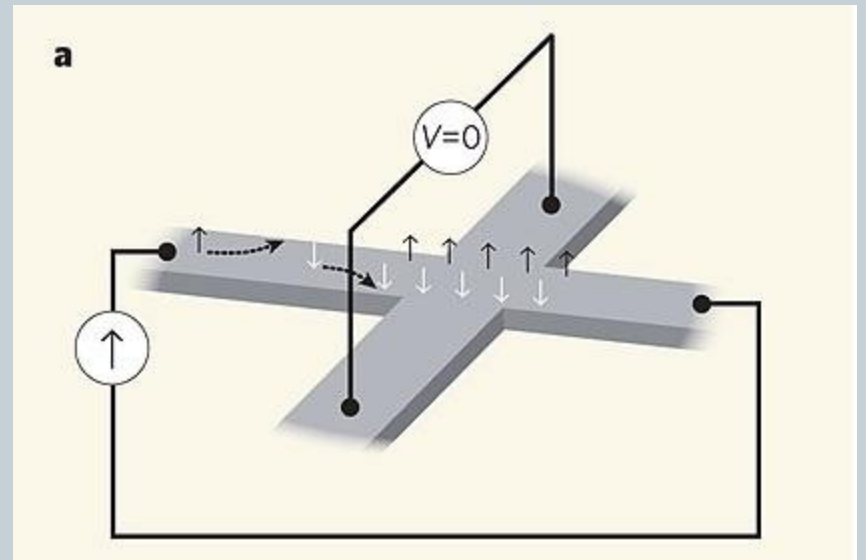
Hall Effect Measurement



The charge carrier sign can be measured using the PPMS.

The Hall Cross is engraved into the sample.

Used to study the details of conduction in semiconductors and other materials



Residual-resistance ratio (RRR)



- A RRR measurement is the ratio of the resistivity of a material at room temperature and at 0 K.
- Seems to diverge since $\rho_{(0K)} = 0$, but with defects in the material $\rho_{(0K)} \neq 0$
- For Superconductors, where ρ is always exactly 0 above 0K the RRR is calculated using the ρ is taken just above the superconducting transition temperature.
- The RRR of copper wire is generally $\sim 40-50$ when used for telephone lines, etc.

$$RRR = \frac{\rho_{300K}}{\rho_{0K}}$$

Heat Capacity Measurements

The sample sits on a platform, which is suspended by eight thin wires that serve as the electrical leads for an embedded heater and thermometer. The wires also provide a well-defined thermal connection between the sample platform and the puck.

The measurement of the heat capacity of solids can provide considerable information about the lattice, electronic, and even magnetic properties of materials.

He3 system available for low temperature heat capacity and electrotransport measurements

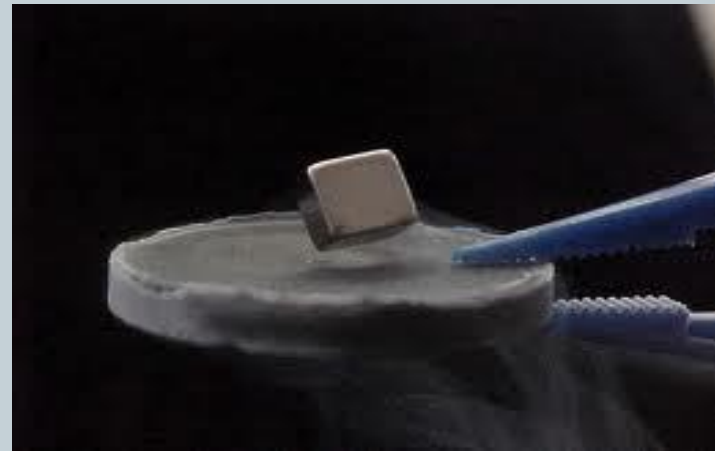
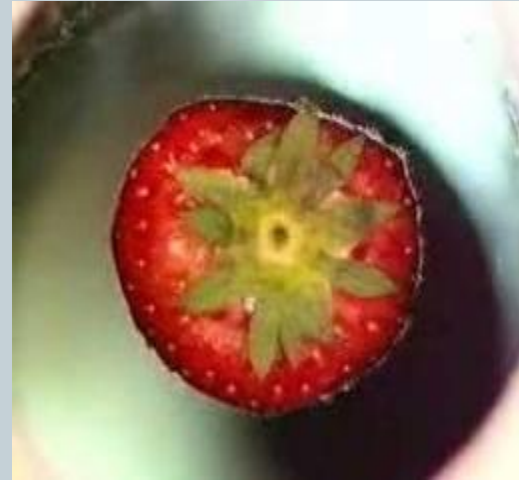
$$C_p = \left(\frac{dQ}{dT} \right)_p$$



Conclusion



•Go get a PPMS!!



Sources



- (1) "Quantum Design, Inc. - Products - Physical Property Measurement System PPMS®." *Quantum Design, Inc. - Home*. Web. 07 Dec. 2011. <<http://www.qdusa.com/products/ppms.html>>.
- (2) "PPMS - Physical Property Measurement - LOT-Oriel." - *LOT-Oriel*. Web. 07 Dec. 2011. <<http://www.lot-oriel.com/uk/en/home/ppms/>>.
- (3) "Kelvin (4-wire) Resistance Measurement : DC METERING CIRCUITS." *All About Circuits : Free Electric Circuits Textbooks*. Web. 07 Dec. 2011. <http://www.allaboutcircuits.com/vol_1/chpt_8/9.html>.