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.
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

<table>
<thead>
<tr>
<th>Preliminary System Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Standard system specification apply except where noted):</td>
</tr>
<tr>
<td><strong>Magnet</strong></td>
</tr>
<tr>
<td><strong>Magnet Type</strong></td>
</tr>
<tr>
<td><strong>Field Homogeneity</strong></td>
</tr>
<tr>
<td><strong>Slew Rate</strong></td>
</tr>
<tr>
<td><strong>Field Resolution</strong></td>
</tr>
<tr>
<td><strong>Remanent Field</strong></td>
</tr>
<tr>
<td><strong>Location of Magnet</strong></td>
</tr>
<tr>
<td><strong>Power Supply</strong></td>
</tr>
<tr>
<td><strong>Special Helium Dewar</strong></td>
</tr>
<tr>
<td><strong>Helium Capacity</strong></td>
</tr>
<tr>
<td><strong>Nitrogen Capacity</strong></td>
</tr>
<tr>
<td><strong>Static LHe Boil-off</strong></td>
</tr>
<tr>
<td><strong>LHe Boil-off</strong></td>
</tr>
<tr>
<td><strong>Power Requirements</strong></td>
</tr>
</tbody>
</table>
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 into the PPMS, which allows for data to be taken.

Many different types of pucks for different experiments.
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 $V_G$.

\[ \tau = m \times B = \mu_0 m \times H \]

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 $\rho(0\,\text{K}) = 0$, but with defects in the material $\rho(0\,\text{K}) \neq 0$

- For Superconductors, where $\rho$ is always exactly 0 above 0K the RRR is calculated using the $\rho$ is taken just above the superconducting transition temperature.

- The RRR of copper wire is generally $\sim 40–50$ when used for telephone lines, etc.
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.
Conclusion

• Go get a PPMS!!
Sources

