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Technical Specifications for Physical Property Measurement System (PPMS)

1. Broad System Requirements and Usage

Description: We intend to procure a fully automated computer-controlled cryogen-free SQUID based PPMS operational in the temperature range $\leq$ 1.8 K to $\geq$ 1000 K and magnetic fields up to $\pm$ 9 Tesla or higher. The instrument should have a strong track record for the specified measurement options including but not limited to the measurements of bulk, thin-film, single crystal, and nano-particle based organic, inorganic samples. Therefore, the following technical criteria are to be met by any PPMS being quoted:

a) The PPMS equipment being quoted should be multi-user friendly with an easy-to-use software interface, modular hardware design that allows for rapid user training and should also be easy to change from one measurement mode to another with relative ease. For example, the change from a magnetic property measurement mode to an electrical transport measurement option should be relatively easy so that our student scan set-up measurements and collect reliable and reproducible experimental data.
b) Our faculty members work in diverse areas of research at the intersection of fundamental chemistry, physics and new materials synthesis and characterization. Therefore, the PPMS being quoted should be an advanced PPMS system that can go far beyond the basic physical property measurements. For example, the PPMS should, in addition to the basic magnetic property measurements, electrical property measurements and thermal property measurements, be capable of measuring magnetization in samples with low magnetic moment (<0.1 micro emu) using torque Magnetometry; should be customizable for Ferromagnetic Resonance (FMR)Measurements on thin magnetic films, and be able to perform optical and Raman measurements with suitable accessories.
c) In addition, the system being quoted should have a modular design providing the flexibility to add any of the above capabilities or other physical property measurement techniques either at the time of procurement or at a later date.

2. PPMS Base System Requirements

a) The system being quoted should be a closed-loop cryo-cooling system without the need for liquid helium and/or nitrogen. Neither liquid helium nor liquid nitrogen should be needed at any time. The system must accomplish the initial cool-down directly from Helium gas as quickly as possible. Provide supporting data and log files with the offer. A demonstration will be asked during technical evaluation. We are looking for a **turn-key solution** wherein vendor/OEM should install all the additional accessories including but not limited to He gas cylinders and connectors etc.
b) Cryo-cooling should be based on a pulse tube cryocooler so that noise associated with mechanical vibrations can be minimized. A two-stage pulse tube cryocooler is preferred for efficient and faster cooling. Mechanical vibrations should be low enough to attain all of the mentioned specifications in later sections.
c) The system should not use recirculation of any remotely located source of liquid helium as a refrigerant.
d) Any capillaries, needle valve system or other similar systems used for refrigerant injection into the sample space for cooling, should be serviceable on the field if ever they get clogged with moisture. Such a service should be possible by trained users. If service personnel is required, the total time required for such a service before the machine can be used should be mentioned. Since this is a machine for a general user facility, service times of less than two days are required. Supporting documentation for such service must be provided. A sample space with a bore diameter of at least 25-30 mm is required.
e) Compatible sample transferring system and sample holders (or pucks) with necessary electrical connections must be included. Such sample holders should be designed to have a good thermal uniformity across the sample over the measurement temperature range of 1.8 K to 1000 K.
f) The sample chamber should be sealed to retain either vacuum or an inert gas environment during measurements.
g) Necessary vacuum and gas purging systems should be integral to the base system, and their operations should have been fully automated, such that minimum user intervention is required. A high vacuum system, with for example a cryo/turbo pumping option, should be included. The high vacuum system (10^{-5}Torr) should be able to achieve as quickly as possible.
h) All vacuum pumps or any other pumps used for the purpose in point 2g should be "dry" that is they should not use any oil-based pumping systems.
i) All communications on the system must either use a Universal Serial Bus (USB),Controller Area Network (CAN) or similar high speed and high-fidelity communications protocols.
j) Necessary software for performing all measurements (the measurements requested in this tender and measurements to be acquired through possible future upgrades)should be included. The software should also enable sample loading, unloading, and provide system status – magnet temperature, sample temperature, system status such as measurement in progress or idle.
k) All system operations, including temperature changes and magnetic field changes, should be completely remotely controllable using the software provided.

l) A provision for having different software access levels such as a user-level, engineer, or expert level is preferable.

m) The software should allow for fully automated measurements and should minimize user intervention. This is essential since the instrument will be housed in a general user facility.

n) Furthermore, communications to and data acquisition from the instrument should be possible with user-customizable programs such as Labview. Supporting software modules in Labview must also be provided for any customized measurements that the user wishes to setup. Such programs should enable both magnetic field and temperature control and full data acquisition capabilities of the software provided with the system.

o) A superconducting magnet, with the following specifications, should be included in the base system:

- A longitudinal magnetic field (along the axis of the sample bore) of ± 9 Tesla or greater with a magnet charge time of fewer than 10 minutes for 0 to 9 Teslais required.
- Magnetic field stability of better than 5 ppm/hour (*please provide data*).
- Field homogeneity of better than 100 ppm over an on-axis distance of at least an inch is required (*please provide data*).
- Magnet electronics and power supply should be fully interlocked so that the magnet is fully protected in case of a failure of other supporting systems such as the cryo-cooler.
- There should be a suitable built-in magnetic shield so that the stray fields should be less than 5 Gauss at a distance of 30 cm from the surface of the system when the magnet is fully charged to 9 Tesla. This is important both from a safety standpoint and from ensuring that the stray magnetic fields do not interfere with other measurements in the proximity of the system. *(pleaseprovide data).*
- The magnet charging or control modes should be completely software integrated. At the least, there should be linear, oscillating, and no overshoot mode. Please specify the field overshoot in the ‘no overshoot’ mode for field strengths of 1, 3, 9 and 14 Tesla.
- Magnet control should be fully software-integrated.
- Magnet's health and status monitoring and protection from accidental quenches should all be handled through internal electronics or software. Thisis absolutely essential as the system is intended for a general user facility.
- The cooling of the magnet should be efficient. After a service warm up, the magnet should cool down to its operating temperature in less than 20hours.This is essential to ensure that the downtime of the system is minimized. Please provide the time needed for a full system cool down. Further, provide the approximate helium gas usage for such a full cool down. This data is important to determine the resources (time and money) required for bringing the system back up after a service warm-up.

- A fully automated variable temperature option should be integral to the base system. The variable temperature option should meet the following specifications:
  - The cryostat assembly should enable fast, efficient and continuous cool down from 400 K to 1.8 K or warm-up from a temperature of from 1.8 K to 400 K.Please provide approximate helium gas usage for sample cool down from400 K to 1.8 K. The time required for a cool down from 400 K to 1.8 K or a warm up from 1.8 K to 400 K should both be less than 80 minutes. Please provide supporting data.
  - Temperature changes to the sample – either cool down or warm up should be fully automated with the system software.
  - The system should enable cooling or heating of the sample at any magnetic field; the system should be able to hold the measurement temperature to within 0.1% in the temperature range of 1.8 K to 20 K under magnetic fields of up to 9 T or more and to within 0.05% at temperatures of 20 K to 400 K. Please provide temperature stability data at 1.8 K at a magnetic field of 9 Tesla. The data should have been collected as prescribed below: a) Set the sample temperature to 1.8 K at 0 tesla magnetic field (nominally zero field); b)stabilize the sample temperature at 1.8 K for 10 min; c) continuously ramp the magnetic field to 9 Tesla while recording the temperature. Please provide the recorded data in a temperature versus time format, clearly indicating the three steps above.
  - A high fidelity PID-Temperature control should be fully integrated with the base system and associated software.
  - Necessary thermometers and heaters for temperature control should be provided with the base system.

3. Magnetic Property Measurement

a) A vibrating sample magnetometer accessory that can perform both and AC and DC magnetic property measurements.
b) The system should be capable of measuring over the temperature range of 1.8 K to400 K or more in magnetic fields ranging from – 9 to +9 Tesla or above. Please provide data of DC magnetization versus temperature (during both warm-up and cool down) at magnetic fields of 1, 3, and 9 Tesla on a sample with a total magnetization of 10 micro emu or less. The data should have been collected at 1 second or smaller averaging time. Shorter averaging times are required to speed up data acquisition which is essential for a general user facility such as this.
c) The system should provide for temperature stability during a DC magnetization (M)versus magnetic field (H) measurement. Please provide data of M-H curves collected at 1.8 K, 10 K, 300 K and 400 K on a sample with a total magnetization of 10 microemu or less.
d) The RMS sensitivity in zero field should be at least 0.5 micro emu and at any magnetic field other than zero should be at least 5 micro emu.
e) Besides the standard sample holders, brass and quartz sample holders for sample mounting should be included. The sample holders must be suitable for powders, pellets and thin films.

f) Sample preparation/alignment box with a mirror should be included.
g) VSM coil set bore size should be 6 mm or larger.
h) The VSM oscillation frequency should be tunable from 10 Hz to 50 Hz over the entire temperature range.
i) VSM measurements should be fully integrated with the software such that sample auto-centering and complete measurements should be possible through the software interface.
j) NIST standard samples must be provided for calibration of magnetic moment at low and high magnetic fields/temperatures.
k) In addition to VSM measurement, the software should be able to integrate with First Order Reversal Curve (FORC) measurements and FORC distributions must be calculated and displayed in real-time during the measurement.
l) FORC measurement must be able to provide a qualitative/quantitative fingerprint of the magnetic reversal mechanisms, Separating reversible and irreversible switching mechanisms, calculate reversal mechanism phase fractions and calculate coercivity and interaction field distributions. Supporting datasheet/brochure with measurements is essential to support the claims
m) In addition, the following should be possible with the AC magnetic property measurement accessory:
    - ❖ In addition to DC measurements, AC magnetization measurements without any change in the hardware, sample or sample mount.
    - ❖ Temperature range 1.8 K to 400 K.
    - ❖ AC drive amplitude range of 0.05 Oe to 15 Oe or greater should be possible.(*please provide data*)
    - ❖ AC drive frequency of 10 Hz to 10 kHz or above should be possible. (*please provide data*)
    - ❖ A phase resolution of less than or equal to 0.5 degrees should be possible.
    - ❖ The system and integrated software must allow for accurately separating the real and imaginary components of AC response. Magnetization resolution should be less than or equal to 2×10^{-7}emu for AC measurements
    - ❖ AC magnetic susceptibility option must be capable of performing real-time auto-calibration at each measurement point while performing measurements rather than relying on a calibration table or data that was collected at a previous time. This is important for highly accurate measurements.
    - ❖ A thermometer for measuring temperature should be mounted directly on the AC coil to reduce errors from thermal lags.
    - ❖ Options for measuring higher harmonics should also be quoted.

4. Electrical Property Measurement

a) 4-wire and 2-wire resistivity options with simultaneous Hall Effect measurements and magneto-transport measurements should be possible with in-built electronics. It should be possible to measure resistances ranging from 10^{-6} Ω to 10^{+5} Ω over the temperature range of 1.8 K to 400 K.
b) Standard electrical probes, sample chucks, power supplies and measurement meters for measuring up to nA current levels should be provided with the system.

c) Additional probes that are compatible with other high-precision DC source meters and digital multimeters, to enable current measurements from nA to pA, along with the appropriate adaptors and cables should be provided. Such probes should have inbuilt thermometric readers and be compatible and integrable with the main system.
d) Must have two built-in independent sources and meters so that two measurement channels are truly independent (upton A current levels)
e) Such measurements should be possible over the temperature range of 1.8 K to 400 Kin magnetic fields ranging from – 9 to +9 Tesla or above.
f) A horizontal sample rotator should be offered for angular dependence measurements of resistivity, Hall effect, I-V Characteristics etc in an axis perpendicular to the vertical magnetic field.
g) The rotator should have an easily mountable/ dismountable PCB sample loading platform with gold pads for electrical connections. It should be capable of mounting 2 samples and should have a thermometer to closely monitor sample temperature.
h) The rotator accessory must include a high-resolution computer-controlled stepper motor with an angle of rotation between zero to 360° to change the orientation of the applied magnetic field relative to the sample.
i) The angular range should provide for a full 0- to 360-degree rotation.
j) Position control: with inbuilt sensor
k) Angular Accuracy: 0.1 deg.
l) Manually operated Hot Press capable of reaching upto 12 tons of clamping force, equipped with top and bottom programmable heating platens capable of reaching temperatures of 350 deg C with digital control (+/- 5 deg C) and display of temperatures (set temp and current temp during operation) and equipped with analog/digital pressure/clamping force gauges'

5. Thermal Transport

a) Temperature range ≤1.9 K to 400K or wider. The vendor should provide data for the supported temperature range.
b) The option should simultaneously measure a sample's thermal conductivity, Seebeck coefficient, and electrical resistivity with a single sequence command.
c) Provide the data for the standard reference sample for conductivity, Seebeck coefficient, resistivity along with the calculated thermoelectric figure of merit.
d) The user should be able to measure the Nernst Ettingshausen effect with this option. Please provide supporting data/publication for reference.
e) Thermal conductance measurement accuracy: ± 5 % or better and the dynamic range should be 10 μW/K - 1 mW/K for 1.9K measurements. The system should be able to measure thermal conductivity ranging from 0.1 to 250 W/mK @ 300 K.
f) Typical accuracy of the Seebeck coefficient: ± 5% or better in the range of 1μV/K to 1 V/K.
g) Typical accuracy for Thermoelectric Figure of Merit: ± 10 %
h) Seebeck coefficient measurement range: 1 μV/K to 1 V/K or wider with an accuracy of ± 5 %

6. Heat Capacity:

(a) Temperature Range: 1.8 K – 400 K or above. Provide supporting information to validate the complete temperature range.
(b) Using relaxation technique, two-tau model fit analyses, corrections of backgrounds from sample platform, adhesives through sophisticated software routines that are fully integrated to the main system software (claim need to be supported by references of the papers published and patents).
(c) Sample quantity should be as minimal as possible without compromising the quality and precise measurements (1 mg or more).
(d) Measurement Accuracy: 5 % or better over 2K – 300K.
(e) Heat Capacity resolution: less than 10 nJ/mole.K at 2 K temperature (to be specified by the company and the claim needs to be supported by references of the papers published and patents).
(f) Thermometers on the platform.

7. Torque Magnetometry Measurement:

a) Should measure magnetic torque $mB\sin\theta$ for $\leq$1.9 K to $\geq$ 400 K temperature range.
b) Moment sensitivity of 3×10^{-7} emu at 9T or better
c) Must include sample rotation along horizontal rotation axis with rotation range of -10 degrees to 370 degrees
d) Angular step rotation must be 0.005 degrees/step or better
e) The vendor must provide data of Torque Curves of 100 nm thick magnetic film as a function of the angle of the applied field (with respect to the film normal). Data must show the anisotropy of the sample at 1.5T, 2.5T, 5T, and 9T magnetic fields.
f) There should be Four independent channels for performing DC resistivity

8. UPS and Chillers

- The vendor should offer suitable UPS (with 30% more output than the maximum power utilization expected by the instrument, with a minimum battery backup of 60 min or more) and a compatible Chiller with the offer. It should be compatible with Indian voltage (220 V/50 Hz)

9. Future upgrades

The system should be amenable for future upgrades with the following capabilities

- An optical probe for high sensitivity photo-magnetic measurements
- Raman and other related optical spectroscopy techniques.
- Adding a He3 dilution refrigerator to attain temperatures of ~ 50 mK.

10. Terms and Conditions

a) The vendor is responsible for the installation of the system at the institute.
b) The price quotation should include the cost of installation and training of potential users.

c) The system should be provided with five years of comprehensive warranty, on all parts and labor, from the date of installation. Additionally, the main component of the equipment, as well as all spare parts, should be available for the next ten years. Hence vendor should quote the top-of-the-line model and not the model which is likely to be obsolete soon.
d) The vendor should have a track record of having previously supplied at least five advanced PPMS systems in India with identical available options (as in sections 1-7). Details of such systems should be provided along with a copy of purchase orders/prices.
e) The vendor should have qualified technical service personnel for the equipment based in India and should assure a response time of <48 hours.
f) The lead-time for the delivery of the equipment should not be more than 6 months from the date of receipt of our purchase order.
g) Wherever requested data must be supplied along with technical compliance documents. Technical bids without supporting data will be deemed as technically non-compliant.
h) All guaranteed specifications may have to be demonstrated at the time of installation. Any necessary standard samples for that purpose should be brought by the service engineers.
i) Printed literature and published papers in support of all compliance to the prescribed specifications may be provided.
j) The vendor must provide a compliance statement in a tabular form with respect to each technical specification in the tender document duly supported by the manufacturer's literature and published papers. Any other claim will not be accepted and may lead to the rejection of the bid.
k) Technical evaluation by the institute may include a demonstration to verify the functionalities and capabilities of the system quoted. The institute reserves the right to provide samples after opening the technical bids for verification of promised specifications. Any discrepancy between the promised specifications and measurements will be deemed as technical non-compliance.
l) The quote should also include additional spares sufficient for two years of system usage, assuming an average usage of 120 hours of operation per week. In addition, 8sample holders that are compatible with the system should be provided for physical property measurements.

11. Other Details

a) The offer must be supported with the measurement data and literature.
b) Pre-installation on-site to the quoted accuracy in the given technical specifications for the demonstration of the performance of the equipment.
c) Standard samples are to be provided by the company for testing the instruments at the time of installation on-site to the quoted accuracy in the given technical specifications for the demonstration of the performance of the equipment.
d) Guaranteed specifications to be demonstrated at the time of installation. Any necessary standard samples for that purpose should be brought by the service engineers.

e) Printed literature and published papers in support of all compliance to the prescribed specifications should be provided.
f) The vendor must provide a compliance statement **IN TABULAR FORM** with respect to each technical specification in the tender document duly supported by the manufacturer's literature and published papers. Any other claim will not be accepted and may lead to the rejection of the bid.
g) Technical evaluation by the institute may include a demonstration to verify functionalities and capabilities of the system quoted.