Annexure 1

Physical Properties Measurement System (PPMS):
A Cryogen-free Physical Properties Measurement system that operates over a wider range of temperature and magnetic fields: fully automated/computer controlled and user friendly. The instrument should be a proven one for multi-functional and capable of performing a broad range of measurements, including electric, magneto-electric transport, thermal transport and heat capacity, on bulk, thin-film, single crystal

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Detailed specifications:

(1) **Basic unit**

1) System should be **cryogen-free**, i.e. no requirement of liquid Helium and/or Liquid Nitrogen at any point of time. Both superconducting magnet and cryostat assembly should be cooled by 2-stage pulse tube cryocooler to cool both superconducting magnet and the temperature control system, and providing a low vibration environment for measurements. Small amount of helium gas for its fully automated start-up and operation.
2) Option of remote access to the system via internet must be enabled.
3) Any Liquid Helium and/or cold Helium gas flow into sample chamber or to any other parts within the system, and all low temperature operations must be handled in fully automated way through electronic and computer controls.
4) A dedicated window for monitoring cryostat status. Cryocooler should not be mounted in vacuum and not coupled to any cryostat components via solid links. Cryocooler resides in helium gas in cryogenic tank.
5) The system should be equipped with sufficient number of thermometers at different stages / locations and on cryocooler and magnet to monitor their temperatures through the main operating software.
6) The system must have a large temperature controlled region, or sample chamber, that can either be under vacuum or use various exchange gases. Material samples can be measured either with, or without, measurement probes giving users more flexibility in research design and scope.

(2) Superconducting magnet with longitudinal field in the range of ± 9T

a) ± 9Tesla field strength (longitudinal field)
b) Sweep rate: Up to 20mT/sec.
c) Field Homogeneity: ± 0.01 % over 3 cm on axis or better
d) Field Stability: 1-2 ppm/hr
e) Magnet has to be cooled by solid conduction without any liquid helium.
f) Magnet ramping should not affect the temperature stability
g) Thermometer directly on the magnet. Automatic discharge of the magnet if the cryo-cooler system fails (For example, due to water chiller failure.).
h) Magnet control software monitors the temperature of the magnet and cryostat at various locations to ensure proper operation of the magnet system from quenches.
i) Bi-polar power supply with over voltage protection and indication.

j) Various operating modes: Linear, Oscillating, No Overshoot must be given in details. There should be no overshoot in the field or the tolerable overshoot in "No Overshoot" mode should be specified for various field strengths.

k) Magnet should be protected from quenches.

(3) Temperature control:

a) Cryostat assembly which will include sample chamber and radiation shields and other assembly must be cooled by counter flow heat exchange mechanism for efficient cooling and efficient use of cooling resources. All the operations must be fully automated without user intervention.

b) The system should enable cooling of samples from highest temperature to the lowest at the highest specified cooling rate at any given magnetic field of up to ±9 T without affecting the system performance including the heating of magnet. The same procedures should be hold for heating of the samples as well.

c) System should have sophisticated temperature control and provide seamless transition between high temperature (400 K) to low temperature.

d) The sample chamber has to be sealed for controllable sample environment (static He gas, vacuum).

e) Temperature range of 1.8 to 400 K with milli-Kelvin stability and accuracy.

f) Temperature stability should be at least ±0.5 % for $T < 10$ K and ±0.05 % for $T > 10$ K irrespective of the magnitude of applied magnetic field.

g) Temperature of 1.9 K for the samples must be achieved from room temperature with a fast cooling not more than 45 minutes. Sweeps through 4.2 K are smooth and monotonic on cooling and warming sequences.

h) Accuracy: ± 1% and sweeping rate 0.01 to 30 K/min irrespective of the magnitude of applied magnetic field.

i) Temperature control should be fully automated.

j) Dual Helium impedance design (no mechanical cryogenic needle-valve) for continuous, fully automated, low temperature operation. Measurements at $T < 4.2$ K are possible for a continuous long time.

k) Various modes of Fast settle, No overshoot, and sweep mode must be given in details.

l) Required thermometers and heaters to manage temperature gradients and to ensure smooth temperature control throughout the accessible temperature range.

(4) **Vacuum pumps and fittings:**

a) Vacuum pumps and fittings along with vacuum gauges, meter, standard vacuum coupling essential for the uninterrupted functioning of the instrument and its various measurements options must be included.

b) All pumps must be dry pumps.

(5) **Data acquisition and analysis:**

a) Licensed windows based operating software and State-of-the-art computer control system compatible with the measurement options. Data acquisition system must be the latest version based on modular architecture (company must specify their data acquisition system). The software should be able to run the various measurement options automatically and in different modes. There must be a scope to control the external instruments by using different programs for the experiments designed by users.

b) Fully automated measurements (except changing samples). Temperature, field control and sample measurement shall be fully automated. The software shall control all aspects of the instrument's electronics, hardware, gas handling, data acquisition and data analysis. The software shall include a comprehensive sequence editor for setting up unattended measurement runs.

c) Remote user access to the system via Internet.

d) The software must allow the users to remotely control and monitor experiments over any internet connection.

e) System should have capability to control temperature and magnetic field from external programs like lab view or any other third party software.

(6) Other accessories: Essential accessories/spares for the smooth operation of equipment for a period of 5 years should be quoted separately as an optional item.

Measurements:

1. AC and DC transport:

(a) 4-wire & 2-wire resistivity and simultaneous Hall effect measurement, I-V characteristics and differential resistance measurement (dV/dI vs. I or dV/dI vs V)

(b) Should have two built-in independent sources and meters so that two measurement channels are truly independent.

(c) In addition to standard mode (4-wire resistance up 10MΩ), there should be high impedance mode - 2-wire resistance measurement up to 5GΩ.

(d) Current Source: DC & AC, **10nA** (or less) to 100 mA (or more) or better continuous (1 Hz to 200hz or better for ac)

(e) Sensitivity: 20 nV or better

2. Thermal Transport:

(a) Temperature range 2K to 400K

(b) Capability to measure thermal conductivity, Seebeck coefficient, electrical resistivity, thermoelectric figure if merit

(c) 2 and 4 probe measurement capability

(d) Continuous measurements while slewing in temperature provide high density of data

(e) Required thermometers and heaters to should be provided

(f) Easy to use fully automated measurement

(g) Calibrated sample should be provided preferably Nickel

(h) Thermal conductance measurement accuracy: ± 5 % or better
(i) Typical accuracy of the Seebeck coefficient: ± 5 % or better
(j) Seebeck coefficient measurement range: 1 V/K to 1 V/K or wider

3. Heat Capacity:

(a) Temperature Range: 2 K – 400 K, with a ± 0.1% between 2 K to 10 K.(Range need to be specified by the company)
(b) Magnetic Field: ±9 Tesla
(c) Relaxation technique, two-tau model fit analyses, corrections of back grounds from sample platform.
(d) Sample Mass: typically few milligrams
(e) Measurement Accuracy: 5% (or better) over 2K – 300K
(f) Heat Capacity resolution: less than 10 nJ/mole.K at 2 K temperature (to be specified by the company and the claim need to be supported by references of the papers published and patents)
(g) Thermometers on the platform

4. Multi-functional probe with sample stage and calibrated thermometer

a. for low and high frequency dielectric constant measurements and electric polarization measurements in both with and without magnetic field configurations.
b. with external electric leads to customize the equipment. This probe should be compatible with basic unit sample space electrical connections and should be able to utilize the electro-transport accessories

5. UPS: 40KVA Online UPS, 3 Phase input & 3 Phase output.
6. Chiller: Suitable water chiller should be provided

Future Upgrades:

The system should be field upgradable to add options to Dilution Refrigerator, He3, FMR, Dilatometer, Optical probe etc.

Other details.

1. **Warranty** 3 years from the date of installation and extended warranty for another 2 years
2. **Other accessories** Separate sample holders should be included in the basic unit.
3. Standard samples to be provided by the company for testing the instruments at the time of installation on site to the quoted accuracy in the given Tech-specs for the demonstration of the performance of equipment.
4. Please provide the segmented quotation for each optional measurement capability.
5. The bid should contain information about the requirement of helium gas replenishment.
6. The tender document should also indicate what kind of service/maintenance is required for the system. Whether this service has to be carried out by a company engineer or it can be carried by trained service personnel within India.

7. Bid should include all essential ancillary equipment and spares for its operation on turn-key basis on delivery (please provide list with details). □
8. Power requirement: 230 V, 50 Hz. □
9. Pre-installation site preparation requirements to be indicated and specified along with the bid. □
10. Warranty period to be clearly mentioned and should begin from the date of installation. Annual □Maintenance Contract should be clearly mentioned after warranty period. □
11. Guaranteed specifications to be demonstrated at the time of installation. Any necessary standard □samples for that purpose should be brought by the Service Engineers.
12. Installation and on – site training of our staff in operation and maintenance is essential by factory trained personal free of cost.
13. Bid should include CIP Chennai prices. □
14. Service manuals with complete circuit diagram and PCB layout for all equipment to be provided with □the instrument. □
15. Give Bankers name and address. □
16. The vendor should have supplied and installed at least 5 similar instruments in the past 5 years in institutes like IIT/IISER/NIT's etc. List of similar systems installed during the last five years in India with contact person name, address, □phone, fax and email Ids. □
17. The vendor to provide compliance statement with respect to each technical specification in the □tender document duly supported by the manufacturer's literature along with the technical bid. Any other claim will not be □accepted and may lead to rejection of the bid.
18. Printed literature in support of compliance to the prescribed specifications is to be submitted. □
19. In case during shipment period newer versions of software/hardware is available with vendor in lieu □of the existing one for which Letter of Credit was opened, then improved version should be made □available without any extra cost. □□
20. Technical evaluation by the Institute may include demonstration to verify functionalities and □capabilities of the system quoted. □

Services: Vendor must submit Factory Acceptance Test procedure supported with relevant printed literature and certificates.