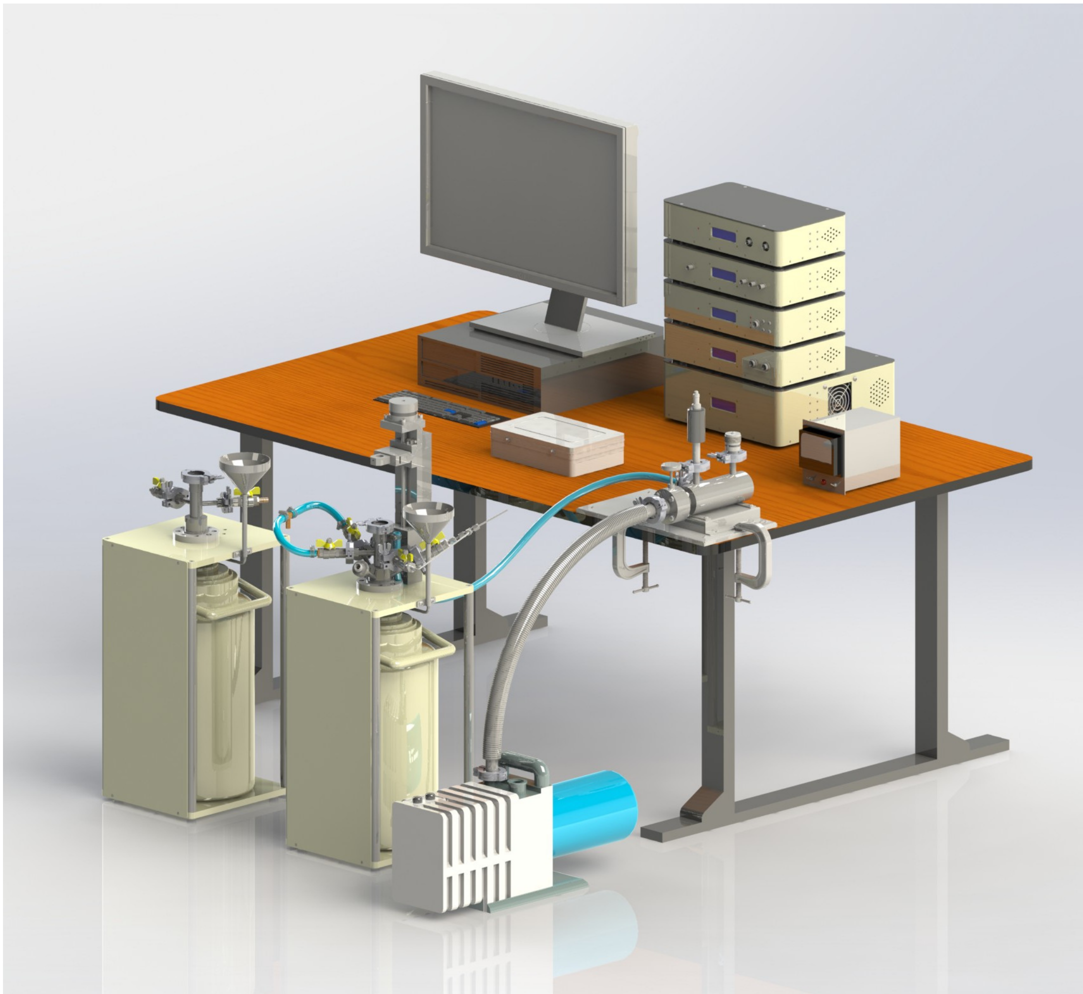
XPLORE 1.2
Physical Quantities Measurement System (PQMS)
Technical specifications

Precision-Quazar Tech Pvt. Ltd.



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1 Cryostat and temperature controller

Parameter		Value
Sample chamber		
Dimension		21 mm (dia) × 100 mm (length), top loading
Construction		Non-magnetic SS 316, double walled
Temperature range		
Temperature range		80 K – 450 K
Cryogen		Liquid N_2
Exchange gas		Helium
Temperature measurement and control		
Sensors		Pt100
Temperature resolution		0.01 K
Temperature stability		Better than ±0.1 K in isothermal mode
Temperature ramp-rate		0.1 K/min – 10 K/min in steps of 0.1 K/min
Control algorithm		PID
PID parameters		User configurable
Heater		
Heater power		40 Watt
Winding type		Non-magnetic nichrome
Flushing system		
Connection		Four independent on/off valves for heater and sample chambers
Vacuum system	Zone	Heater and/or sample chamber
	Pressure	10^{-3} Torr
	Mechanism	Double stage rotary pump
	Sense	Pirani gauge with readout unit
Exchange gas system	Zone	Heater and/or sample chamber
	Gas	Helium
	Cylinder volume	10 liters
	Purity	99.99%
	Accessories	Pressure regulator and piping
Others		
Computer connectivity		USB
Software development kit (SDK)		Python library for user programming
Liquid N_2 container		4 liters (BA-3 from IndianOil Corp. Ltd.)
Input Power		200 VAC to 240 VAC

2 Electrical transport property measurement

2.1 Overview

This module has been designed to measure I-V characteristics and resistance as a function of sample temperature using 2- and 4-probe connection topology in the temperature range of 80 K to 450 K.

For common application involving samples in the range of 1 mΩ to 1 GΩ, a 2/4-probe variable temperature insert along with a source-meter unit, as described respectively in Section 2.2 and 2.3, are provided.

For high-conductivity samples, the 4-probe resistance measurement performance can be improved to 10 $\mu\Omega$, using a nano-voltmeter unit as described in Section 2.4, as an add-on to the aforesaid module.

For insulating samples in the range of 1 MΩ to 100 TΩ, specially designed low-leakage 2-probe variable temperature insert is provided along with a low-current high-voltage source-meter unit. Their specification is provided respectively in Section 2.5 and 2.6.

2.2 4-probe variable temperature insert

Parameter	**Value**
Mounting area	25 mm × 15 mm
Mounting glue	GE varnish (supplied)
Contact glue	Silver ink (supplied)
Connection topology	2-probe or 4-probe
Base insulator	Kapton tape (supplied)
Temperature range	80 K to 450 K

2.3 I-V source and measurement unit

Parameter	**Value**
Source mode	Current or voltage
Current source specification	
Current source range(s)	± 100 μA, ± 1 mA, ± 10 mA
Current set-point resolution	Better than 0.05 % of full-scale
Voltage compliance	± 10V

I-V Source and Measurement unit specification continued on next page ...

... I-V Source and Measurement unit specification continued from previous page	
Parameter	**Value**
Voltage source specification	
Voltage source range(s)	$\pm$ 10 V
Voltage set-point resolution	Better than 0.05 % of full-scale
Current compliance	$\pm$ 10 mA
Ammeter specification	
Current measurement range(s)	$\pm$ 100 μA, $\pm$ 1 mA, $\pm$ 10 mA
Current measurement resolution	6½ digit
Voltmeter specification	
Voltage measurement range(s)	$\pm$ 100 mV, $\pm$ 1 V, $\pm$ 10 V
Voltage measurement resolution	6½ digit
Input impedance	$> 10^{12}\,\Omega$
Ohmmeter specification	
Resistance measurement range	0.01Ω to $10^8\Omega$ with $< 1\%$ error
Resistance measurement error	See Fig. 1

2.4 Nano-Voltmeter unit

Parameter	**Value**
Voltmeter specification	
Voltage measurement range(s)	$\pm$ 10 mV, $\pm$ 100 mV, $\pm$ 1 V, $\pm$ 10 V, $\pm$ 100 V
Voltage measurement resolution	7½ digit
Input impedance	$> 10^{12}\,\Omega$
Voltage protection	250V

2.5 2-probe high resistance variable temperature insert

Parameter	Value
Mounting area	10 mm × 18 mm
Mounting glue	GE varnish (supplied)
Contact glue	Silver ink (supplied)
Connection topology	2-probe
Mounting surface	Teflon
Temperature range	80 K to 450 K

2.6 High resistance measurement unit

Parameter	Value
Source mode	Voltage
Voltage source specification	
Voltage source range(s)	± 10 V, ± 100 V
Voltage set-point resolution	Better than 0.005 % of full-scale
Ammeter specification	
Current measurement range(s)	± 10 nA, ± 1 μA
Current measurement resolution	6½ digit
Voltmeter specification	
Voltage measurement range(s)	100 V
Voltage measurement resolution	6½ digit
Ohmmeter specification	
Resistance measurement range	$10^5\Omega$ to $10^{13}\Omega$ with $< 1\%$ error
Resistance measurement error	See Fig. 1
Others	
Computer connectivity	USB
Software development kit (SDK)	Python library for user programming
Input Power	200 VAC to 240 VAC

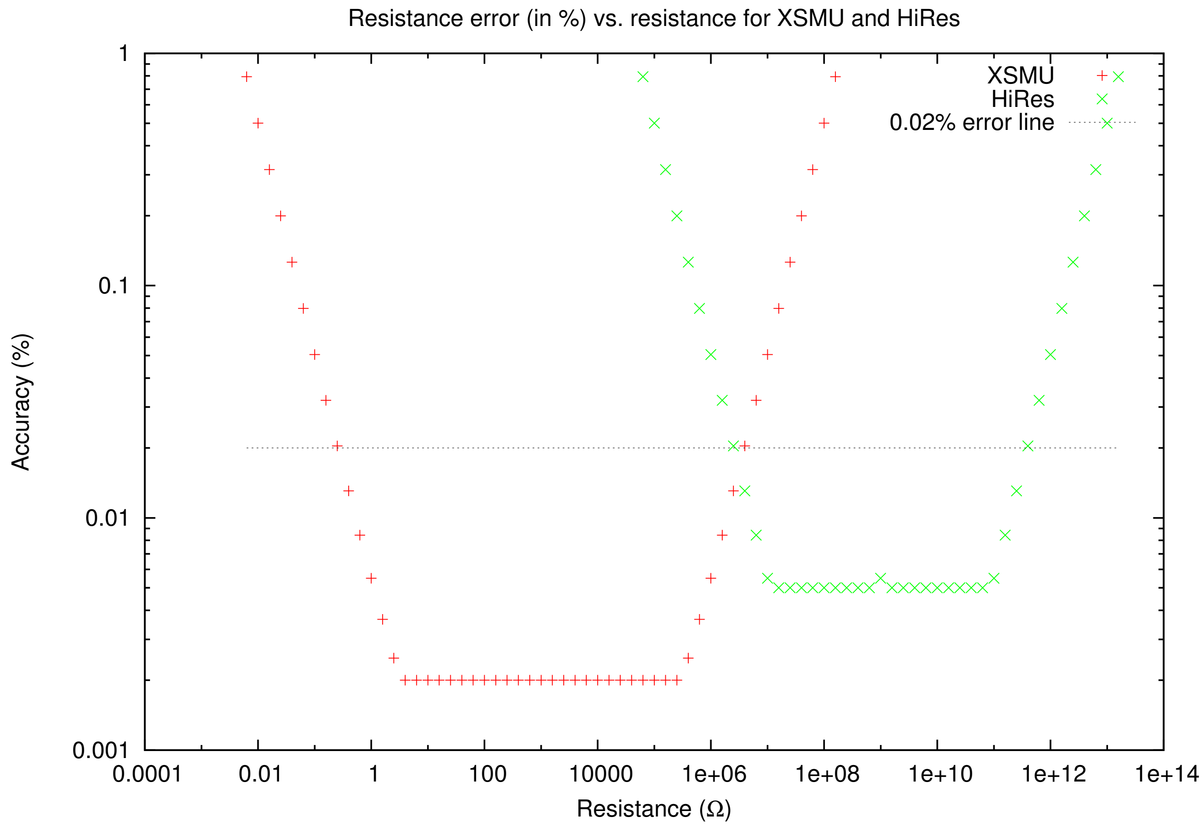

Figure 1: Error in resistance when measured using XSMU and XHiRes boxes.

3 Magnetic AC-susceptibility measurement

3.1 Overview

This module is designed to measure magnetic AC-susceptibility of a sample in the temperature range of 80 K to 450 K using a variable temperature insert, a lock-in amplifier, and an automatic sample positioner.

The sample is placed inside an air core solenoid and excited with a sinusoidal magnetic field. The resulting time varying magnetization is sensed using a pair of coaxial and symmetrical pick-up coils. A lock-in amplifier with an in-built reference generator is used to energies the excitation coil. The sensed signal from the pick-up coil is fed back to the lock-in amplifier for demodulation. Both amplitude and phase of the sensed signal are recorded to produce in-phase (χ') and quadrature-phase (χ'') measurements.

A major challenge in measuring magnetic AC-susceptibility as a function of temperature is a drift in the susceptometer output caused by the mechanical deformation of the coil assembly due to change in temperature. This drawback has been overcome using a novel technique where the sample is repeatedly moved up-n-down between two pick-up coils using an automated sample positioner, while subtracting successive readings to nullify offset on-the-fly.

The detailed specification of the variable temperature susceptometer insert, lock-in amplifier, and sample positioner is provided respectively in Section 3.2, 3.3, and 3.4.

3.2 Variable temperature insert

Parameter	**Value**
Maximum sample dimensions	5 mm (dia) × 10 mm (length)
Sample form	Powder or solid in paper capsule
Sample holder	Non-magnetic glass fibre sleeve
Temperature range	80 K to 450 K
Primary Coil Specification	
Length	57 mm
Number of turns	1000
Average diameter	8.3 mm
H-field	≈10 Oe pk-pk at 50 mA pk-pk current
Secondary Coils (2 Nos.) Specification	
Length	10 mm each
Number of turns	3000 each
Average diameter	14 mm each

3.3 Lock-in amplifier

Parameter	Value
Primary driver	
Frequency range(s)	10 Hz – 100 KHz
Reference output	Constant voltage: 2 V peak-to-peak
	Constant current: 50 mA peak-to-peak
Reference generation	Direct digital synthesis
Lock-in detection	
Integration time	1 sec
Pre-amp gain(s)	1, 10, 100
Post-amp gain(s)	1, 10, 100
Input ranges	1 mV, 10 mV, 100 mV, 1 V, 10 V
Measurement	
Measured quantities	Both amplitude and phase
Measurement resolution	Amplitude 6½ digit, phase 3½ digit
Others	
Computer connectivity	USB
Software development kit (SDK)	Python library for user programming
Input Power	200 VAC to 240 VAC

3.4 Automatic sample positioner

Parameter	Value
Stoke length	60 mm
Positioning accuracy	Better than 100 micron
Speed	0.5 mm/sec
Limit switch	In-built optical sensor
Stall detection	In-built optical sensor
Computer connectivity	USB

3.5 Susceptometer software

The susceptometer software is responsible for complete automation of temperature controller, lock-in amplifier, and sample positioner. Before starting a temperature sweep, it automatically searches for the best position of sample inside the susceptometer coil assembly to maximize pick-up response. Since, the pick-up voltage is directly proportional to the primary excitation current and frequency, the recorded voltage is normalized with respect to these parameters. The log file stores the following quantities – time, reference frequency, excitation current amplitude and phase, signal amplitude and phase, χ' and χ'', sample temperature, heater temperature, and probe position.

4 Magneto-resistance and Hall coefficient measurement

4.1 Electromagnet insert

Parameter	**Value**
Electromagnet Specification	
Electromagnet wire	Enameled copper wire
Electromagnet wire gauge	SWG-22 (0.711 mm dia)
Electromagnet bobbin material	Brass
Magnetic field to current ratio	$\sim$195 Gauss per Ampere
Magnetic field direction	Axial to cryostat
Temperature range	80 K to 450 K
Maximum magnetic field	1000 Gauss @ 5.2 A
Note: Liquid Nitrogen is needed as coolant to achieve above specifications.	
Cryostat Specification	
Core material	Quartz
Top assembly material	Stainless steel

4.2 Magneto-resistance insert

Parameter	**Value**
Mounting area	Circular, 19 mm dia
Magnetic field direction	Perpendicular to mounting area
Mounting glue	GE varnish (supplied)
Contact glue	Silver ink (supplied)
Connection topology	2-probe or 4-probe
Base insulator	Teflon
Temperature range	80 K to 450 K

4.3 Magnet Power Supply (MGPS)

Parameter	Value
Source mode	Magnetic field or current
Magnetic field source specification	
Magnetic field source range(s)	$\pm$ 100 mT (1000 Gauss)
Magnetic field set-point resolution	Better than 0.05 % of full-scale
Voltage compliance	$\pm$ 15V
Current source specification	
Current source range(s)	$\pm$ 6 A
Current set-point resolution	Better than 0.05 % of full-scale
Voltage compliance	$\pm$ 15V
Gauss meter specification	
Magnetic field measurement range(s)	$\pm$ 100 mT ($\pm$ 1000 Gauss)
Current measurement resolution	6½ digit
Ammeter specification	
Current measurement range(s)	$\pm$ 6 A
Current measurement resolution	6½ digit
Voltmeter specification	
Voltage measurement range(s)	$\pm$ 20 V
Voltage measurement resolution	6½ digit
Input impedance	$> 10^{12}\,\Omega$
Others	
Computer connectivity	USB
Software development kit (SDK)	Python library for user programming
Input Power (supplied)	200 VAC to 240 VAC

5 Data acquisition and control software: Qrius 2.0

Computer automation of R-T and χ-T measurements using above mentioned modules have been provided by Qrius 2.0 software. It allows easy control of all experimental parameters and real time recording and plot of physical quantities. The software runs on Ubuntu 14.04, and Fedora 20 or later.

New Qrius 2.0 features:

- Improved user interface.
- SmartSwitch™ technology for automatic switching between constant current and constant voltage sources for easy I-V characterization of non-linear devices, like P-N junction diodes.
- Maximize susceptometer signal through software controlled automatic sample positioning utility.
- Offset nullified susceptometer signal acquisition through alternate sample positioning between two susceptometer secondary coils.

6 Other accessories supplied with the system

The following is a list of items that are supplied for proper operation of XPLORE 1.2 system.

- BA-3 four liter liquid nitrogen dewar from IndianOil Corp. *Liquid nitrogen has to be provided by the user.*
- 250 LPM rotary pump for flushing and vacuum system.
- 10 liter Helium cylinder with regulator.
- 10 point power extension board.
- Controller PC.
- Toolkit containing Kapton tape reel, Teflon tape reel, screw driver set, GE varnish, brush, wire cutter, silver paste, scissor, AC susceptometer sample holding sleeves, tweezers, soldering iron, soldering wire, solenoid flux, soldering iron stand, toothpick, 44 SWG wire reel.

7 Installation requirement

- The system needs around 7 ft $\times$ 5 ft floor area to install all its modules.
- A 5 ft $\times$ 3 ft table is needed to place the computer and electronics boxes.
- One 220 VAC, 15 Amp, 50 Hz grounded power socket is needed.
- In case of frequent power failure, one 2 kVA online sine-wave UPS is necessary.
- An exhaust duct or window should be present within 10 meter of the installation site to safely dispense off vacuum pump exhaust.
- For successful demonstration of low temperature measurement capability of the system, 10 liter liquid nitrogen is needed.