application note

QuantumDesign

VIBRATING SAMPLE MAGNETOMETER

IN ITS CONTINUING EFFORT TO OFFER ADVANCED MEASUREMENT CAPABILITIES FOR THE PHYSICAL PROPERTY MEASUREMENT SYSTEM (PPMS), QUANTUM DESIGN ANNOUNCES THE INTRODUCTION OF THE P525 PPMS VIBRATING SAMPLE MAGNETOMETER (VSM) APPLICATION. THE ADDITION OF THE VSM TO THE CURRENT LIST OF AUTOMATED PPMS MEASUREMENT APPLICATIONS MAKES THIS EXCEPTIONALLY VERSATILE MATERIAL CHARACTERIZATION SYSTEM EVEN MORE POWERFUL.

Long-Throw Linear Motor Sample Drive

Control Area Network (CAN) electronics tower

MODEL P525: PPMS VIBRATING SAMPLE MAGNETOMETER

The Model P525 Vibrating Sample Magnetometer (VSM) measurement system for the Physical Property Measurement System (PPMS) is a fast, sensitive and fully automated DC magnetometer.

Benefits of the VSM System Design:

The VSM linear motor transport uses a uniquely designed linear motor to vibrate the sample. Unlike other vibrating sample magnetometers that use a short-throw resonant voice-coil design, you will find that the PPMS VSM linear motor is designed to operate at 40 Hz, with rapid slewing possible over about 6.5 cm of travel. The large range of motion enables the PPMS VSM system to perform rapid, completely automated centering operations - you will not need to perform manual adjustments to center the sample.

The sensitivity of the VSM detection coils is not significantly affected by large magnetic fields, so the PPMS VSM can perform sensitive measurements up to the maximum field available from your PPMS magnet. The VSM detection coil is inserted into the PPMS sample chamber by using the standard PPMS sample interface design. This procedure will make it easy to reconfigure the VSM option with alternate pickup coil designs in the future. You will find that you can change the pickup coil configuration as easily as you can change a sample puck.

You will find it easy to activate and deactivate the VSM option on your PPMS, just like the other PPMS options. The modularity of the design enables you to perform successive types of measurement with little additional effort. For example, you could follow state-of-the-art VSM measurements with heat capacity measurements by inserting a different sample puck or probe.

The PPMS VSM is the first new measurement option from Quantum Design to use the next generation electronics architecture based on the CANopen networking protocol. The VSM option includes the Model 1000 modular control system, which is the heart of the new architecture. Plug-in modules, including the Model CM-A VSM motor module and the Model CM-B VSM detection module, provide option-specific functionality. This new modular architecture offers very high reliability as well as the ability to be expanded when you add options in the future.

vibrating sample m

The Measurement:

The basic measurement is accomplished by oscillating the sample near a detection (pickup) coil and synchronously detecting the voltage induced. By using a compact gradiometer pickup coil configuration, a relatively large oscillation amplitude (1-3 mm peak) and a frequency of 40 Hz, the system is able to resolve magnetization changes of less than 10^{-6} emu at a data rate of 1 Hz. The VSM option for the PPMS consists primarily of a VSM linear motor transport (head) for vibrating the sample, a coilset puck for detection, electronics for driving the linear motor transport and detecting the response from the pickup coils, and a copy of the MultiVu software application for automation and control.

The sample is attached to the end of a sample rod that is driven sinusoidally. The center of oscillation is positioned at the vertical center of a gradiometer pickup coil. The precise position and amplitude of oscillation is controlled from the VSM motor module using an optical linear encoder signal readback from the VSM linear motor transport. The voltage induced in the pickup coil is amplified and lock-in detected in the VSM detection module. The VSM detection module uses the position encoder signal as a reference for the synchronous detection. This encoder signal is obtained from the VSM motor module, which interprets the raw encoder signals from the VSM linear motor transport. The VSM detection module detects the in-phase and quadrature-phase signals from the encoder and from the amplified voltage from the pickup coil. These signals are averaged and sent over the CAN bus to the VSM application running on the PC.

The system is designed to be user-installable and compatible with existing PPMS systems. Upgrading your current system will therefore be a simple process. Like the other PPMS applications, the VSM is used only when required, leaving the PPMS to run other applications as needed. Since the VSM system is a completely self-contained measurement application, other than one of the PPMS Base Systems, there are no other PPMS applications or options required for its use.

System Requirements:

The P525 VSM requires a PPMS computer system running Microsoft Windows^{XP} software. If upgrading an installed PPMS, it may be necessary to upgrade the computer to Windows^{XP}.

PPMS systems with serial numbers below P-087 may need to replace their Kepco magnet power supply with the Quantum Design Model 250 50 Amp Bipolar Magnet Power Supply.

Systems with VSM require a minimum clearance height of 3m (10 ft) for sample exchange. Systems that have shielded dewars require a clearance height of 3.2m (10.5 ft).

System Specifications/Features:

PPMS system properties:

- Temperature range: 1.9 K - 400 K.
- Magnetic field: up to16 tesla.
- Magnetic field ramp rate: determined by magnet and power supply.
- Temperature and magnetic field may be ramped during the measurement.

Geometry:

- Longitudinal configuration: magnetic field, VSM vibration and moment detection all along vertical axis.
- Coil-set bore: 6.3 mm
- Sample holders provided:
  Brass half tube: inner diameter = 3.3 mm; outer diameter = 3.6 mm
  Fused quartz paddle: diameter = 4 mm
- Coilset baseline: 9 mm
- Sample Mass < 1 gram

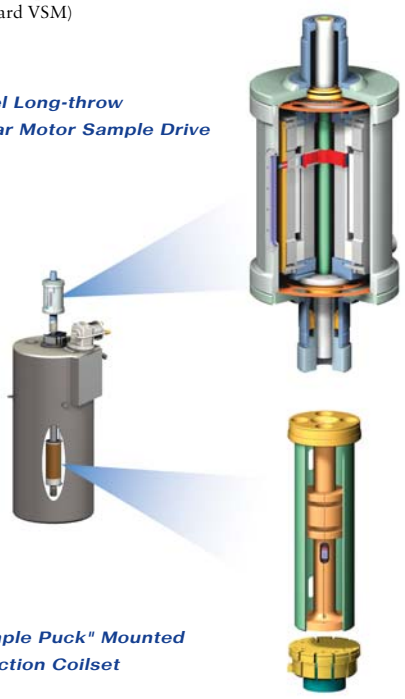
VSM measurement parameters:

- VSM oscillation frequency (calibrated): 40 Hz
- VSM oscillation amplitude (typical): 2 mm peak - Range of 0.1 mm - 5mm
- Data rate and averaging window (typical): 1 sec - Range of 0.5 to 750 sec

Sensitivity using the above typical parameters and longitudinal coilset:

- rms sensitivity: $<10^{-6}$ emu or 0.5 %
- Relative Noise, Standard VSM:
  Larger of (6×10^{-7} emu + 3×10^{-7} emu/tesla)/√Hz or 0.5%/√Hz
- Relative Noise, EverCool VSM, with coldhead ON:
  Larger of (6×10^{-7} emu + 1×10^{-6} emu/tesla)/√Hz or 0.5%/√Hz
- Accuracy:
  0.5 %, using 2.8mm diameter x 4mm high cylinder (shape of Pd standard)
  or
  Better than (6×10^{-6} emu + 5×10^{-6} emu/tesla) or 2%, whichever is greater
- Largest measurable moment: M_{max} [emu] = 40/(Peak Amplitude [mm])

(Note that when EverCool coldhead is OFF, the specification is the same as standard VSM)



➤ *Novel Long-throw Linear Motor Sample Drive*

➤ *"Sample Puck" Mounted Detection Coilset*

magnetometer

MODEL P120B: LARGE BORE COILSET

Geometry:

- Longitudinal configuration: magnetic field, VSM vibration and moment detection all along vertical axis.
- Coilset bore: 12.0 mm
- Sample holders provided:
  Brass half tube: inner diameter = 4.8 mm; outer diameter = 5.1 mm
  Fused quartz paddle: diameter = 4.0 mm
- Coilset baseline: 12.2 mm
- Sample Mass < 2 grams

VSM measurement parameters:

- VSM oscillation frequency (calibrated): 40 Hz
- VSM oscillation amplitude (typical): 2 mm peak - Range of 0.1 mm - 5mm
- Data rate and averaging window (typical): 1 sec - Range of 0.5 to 750 sec

Sensitivity using the above typical parameters:

- rms sensitivity: < 1.5×10^{-6} emu/√Hz
- Relative Noise, Standard VSM:
  Larger of (1.5×10^{-6} emu + 3×10^{-7} emu/tesla)/√Hz or 0.5%/√Hz
- Relative Noise, EverCool VSM, with coldhead ON:
  (TBD)
- Accuracy:
  0.5 %, using 2.8mm diameter x 4mm high cylinder (shape of Pd standard)
  or
  Better than (6×10^{-6} emu + 9×10^{-6} emu/tesla) or 2%, whichever is greater
- Largest measurable moment: M_{max} [emu] = 75/(Peak Amplitude [mm])

MODEL P527: VIBRATING SAMPLE MAGNETOMETER OVEN

To increase the utility of the P525 PPMS Vibrating Sample Magnetometer (VSM), Quantum Design has developed an oven option that will give users the capability to make magnetic measurements from room temperature up to 1000 K.

This oven uses a heater and thermocouple integrated into the vibrating sample rod. A standard VSM detection coilset is used, while the PPMS sample chamber is maintained at 300 K in a high vacuum state (<10^{-4} torr required) during oven operation. A modular design allows the heater /thermometer sample holder to be easily removed from the sample rod for sample changing. The special sample rod has wire feedthroughs for the heater, thermocouple and a thermistor. The latter is used for correction of the thermocouple cold joint temperature. The heated region, including the sample, is wrapped in low emissivity copper foil to minimize heat leak from the hot region to the surrounding coilset.

Features/Benefits:

- Stable temperature control from 300 to 1000 K
- Durable construction of the sample rod (carbon fiber) and sample holder (zirconia)
- Convenient, easy and strong sample mounting
- Minimized radiation heat leaks

System Requirements:

- P525 Vibrating Sample Magnetometer (VSM) System
- P640 High Vacuum System required for thermal isolation

Specifications:

- Range of Temperature: 300 - 1000 K
- RMS Sensitivity: < 10^{-5} emu or 0.5%
- Noise Floor: < 10^{-5} emu rms (H = 0)
- Accuracy: < 1×10^{-5} emu/tesla
- Temperature Precision: 0.5 K
- Temperature Accuracy: 2%

Specifications subject to change without notice.

MODEL P701: VSM ULTRA LOW FIELD

The VSM Ultra Low Field (ULF) option for the PPMS, actively cancels residual magnetic flux in the PPMS superconducting magnets so samples can be cooled in a very low field. The VSM ULF is similar is similar to the standard ULF option with the main difference being that the VSM sample transport (instead of the ACMS sample transport) is used to move the fluxgate field sensor during the field-nulling procedure.

The VSM ULF option uses an additional superconducting coil wound directly on the specially designed coil form that fits between the magnet and the PPMS outer vacuum jacket. The field in the sample space is measured using a custom-designed fluxgate magnetometer. An automated routine measures the remanent field in the sample chamber and uses the superconducting nulling coil to cancel the remanent field. It then performs a controlled quench of the primary superconducting magnet to trap thia zero flux state so that the power to the nulling coil can be turned off. The process is iterated to achieve extremely low remanent field. You may null the field at any axial location with the sample chamber. The fluxgate also allows low field profiling of the magnetic field in the sample chamber, up to fields of 4 Oe.

System Requirements:

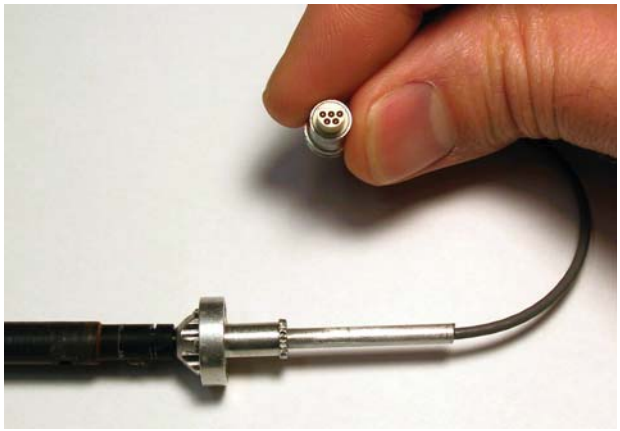
Since the field profiling requires the VSM sample transport, the P525 option is required for proper operation of this option.

Specifications:

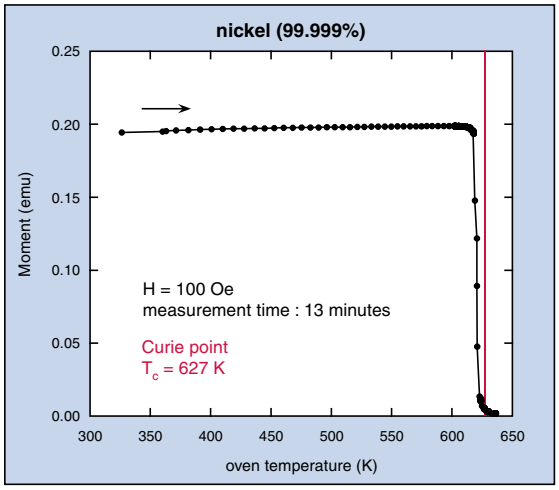
- Residual Field: < 0.1 Gauss at a point.
- Residual Field Uniformity: ±0.1 Gauss along 1 cm vertical length, typically centered at the VSM coilset (4.1 cm above the puck).

Not available for the 7-T transverse, 14-T, or 16-T systems.

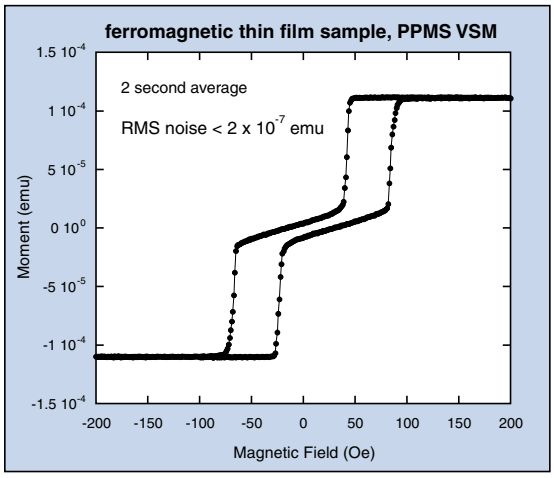
➤ *Bottom of Oven sample rod: zirconia sample holder (lower image), which plugs into the aluminum lower washer coupling.*



➤ *Top of Oven sample rod: wires feed out of aluminum magnetic lock and end in a 5-pin connector, which plugs into a special sample transport cap at the top of the motor sample transport.*



➤ *The temperature range of a prototype oven is demonstrated using a Ni standard. The Curie temperature of pure Ni is 627 K.*



➤ *The sensitivity of the VSM is demonstrated on a thin film ferromagnetic sample provided by professor Y.U. Idzerda of Montana State University.*

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