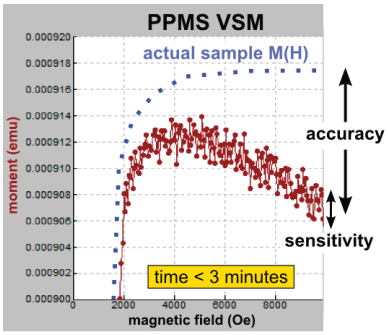
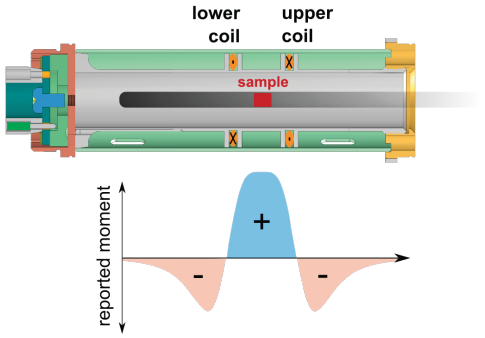
Quantum Design

Applications Newsletter
Fall 2014

How to Get the Most Out of Your Quantum Design VSM

The Vibrating Sample Magnetometry (VSM) technique is quite impressive: it is fast and sensitive, and uses a simple measurement scheme to determine the DC magnetic moment of a sample. The main challenge in VSM measurements is to achieve absolute accuracy, and this newsletter will show you how to improve accuracy in your measurements. The graph on the left side below reminds us of the difference between sensitivity and accuracy: it shows example PPMS VSM data of a ferromagnetic thin film which saturates near 6000 Oe but the diamagnetic substrate leads to a downturn at high fields. We see peak-to-peak sensitivity better than 2 micro-emu but accuracy at high fields is 10 micro-emu. Sensitivity (also called precision) is easy to determine with large data sets like those obtained with VSM, and furthermore can be improved by more data averaging. Achieving accuracy, however, requires careful work to know the actual sample magnetic dipole moment as distinguished from a background signal by, for example, separately measuring a sample holder, measuring samples of different geometries, etc. The diagram on the right shows a rotated view of a sample (red) positioned in the VSM gradiometer where we have shown the Large Bore (12mm) Coil Set in this example. The graph below that shows the coil response function: the reported magnetic moment of a sample as a function of its location in the coils.





The Six Golden Rules for VSM Measurements

1. *Don't disturb detection coils!* In an ideal VSM, the only thing moving is the sample itself; however, the accelerations that move the sample also cause the detection coil set to move a tiny amount and this causes a signal when the coils are sitting in a magnetic field. To minimize this:
    - avoid ice on the blue plastic parts at low temperature by doing an Extended Purge at the end of the VSM Sample Install wizard
    - don't contact the coils during measurement: keep the sample diameter <4mm for standard (6mm) coils and <10mm for Large Bore (12mm) coils
    - ensure the adhesive black felt strip on the VSM guide tube is intact; contact your local service rep to order a new QD part **4096-272**
    - inspect the integrity of the blue bearing surfaces of the sample rod, and of the glue joints on the sample rod and sample holder
    - in rare cases, 40 Hz is not an optimal VSM vibration frequency and you can investigate this by following this Service Note 1096-304
    - check your work: look at the column "M.Quad Signal (emu)" in the VSM data file as an indicator of remaining vibrational signals that will also be present in the "Moment (emu)" column
2. *Make the sample holder "invisible":* follow guidelines in VSM Sample Mounting App Note 1096-306
    - minimize magnetic impurities (Fe,Co,Ni) that come from dust, handling with steel tweezers, etc.
    - sample holder material should be uniform along the length and sample placed near 35mm from end; this way the VSM gradiometer coils don't see a signal as the sample holder moves
    - check your work: measure an empty sample holder, or holder + blank substrate (if using thin films) under identical conditions as your sample measurement.

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How to Get the Most Out of Your Quantum Design VSM (Cont.)

3. *Affix sample securely:* again follow App Note 1096-306
   - remember accelerations are typically > 100 m/sec2 so a strong adhesive or hard clamping of sample is needed; if sample is loose, intermittent jumps or noise will result, see App Note 1096-303
   - NEW: to mount samples in drinking straws – which works in Large Bore Coil Set ONLY! – order new straw adapter **4084-814** from your QD representative
4. *Correct for sample geometry:* see tables in Chap. 3 of VSM User Manual to understand typical corrections to the reported moment for various sample shapes; for samples with high susceptibility χ=dM/dH, the demagnetization factor for a given sample shape leads to a correction of the magnetic field
5. *Ensure accuracy of magnetic field:* for low field work, remanence in the magnet causes an inaccurate reported magnetic field; the magnitude is dependent on a particular magnet but is typically ~20 gauss in a 9 T magnet and ~100 gauss in 14 T; see App Note 1070-207
6. *Ensure accuracy of sample location:* For any measurements away from room temperature, keep the sample vertically centered using touchdowns; see App Note 1096-305

Dealing with Common Issues in VSM Data

1. *"Stair-steps" or gaps in data*
   - ¤ CAUSE: Touchdown sample centering was performed (see Centering or Advanced tab of VSM measurements)
     - "Transport Action"=2 in VSM data file, ~20 sec gap
   - ¤ SOLUTIONS:
     - in "Moment vs. Temp" VSM sequence command, select "Stabilize at each Temperature" to avoid gaps
     - for "Moment vs. Field", see example VSM sequences in Pharos that show how to coordinate touchdowns with measurements
   - ¤ CAUSE: VSM lock-in gain changed due to autoranging (see Advanced tab of VSM measurements)
     - see "Range(mV)" change by 10x in VSM data file, ~1 sec gap in data
   - ¤ SOLUTION:
     - use Fixed Range based on largest signal anticipated
2. *M(H) loop does not close*
   - ¤ CAUSE: sample center is still drifting after temperature stabilizes
   - ¤ SOLUTION: do touchdowns (see 1096-305)
   - ¤ CAUSE: background signal is changing
   - ¤ SOLUTION: see Golden Rule #1 above, test with an empty sample holder
3. *Peak in moment vs. Temp in 40-50 K range*
   - ¤ CAUSE: oxygen on sample (see app note 1014-210): an o-ring is leaking air into the sample chamber, or sample is porous and holds onto oxygen (Teflon tape is known to do this!)
4. *Noisy data*
   - ¤ CAUSE: coil vibration; SOLUTION: see Golden Rule #1
   - ¤ CAUSE: loose sample; SOLUTION: see Golden Rule #3
5. *Large noise ~10-3 emu, "VSM status" in VSM data file sometimes =1*
   - ¤ CAUSE: detection coil set wiring (pins 11-12) is open; SOLUTION: work with QD rep to replace the puck

In conclusion, the VSM offers a very fast and sensitive magnetometry option on the PPMS as well as on the cryogen-free DynaCool and VersaLab platforms. By following the guidelines in this newsletter, you can produce highly accurate and precise results for a tremendous range of samples.