Vibrating Sample Magnetometer

SWT Physics Department

SAFETY FIRST

- Turn on the equipment ONLY in the order specified.
- Failure to cool the vibration exciter during operation will lead to a system meltdown!

VSM PRINCIPLES

A vibrating sample magnetometer (VSM) operates on Faraday's Law of Induction, which tells us that a changing magnetic field will produce an electric field. This electric field can be measured and can tell us information about the changing magnetic field. A VSM is used to measure the magnetic behavior of magnetic materials.

For more information on magnetic properties and **hysteresis curves**, go to the Kerr Magnetometer page.

A VSM operates by first placing the sample to be studied in a constant magnetic field. If the sample is magnetic, this constant magnetic field will magnetize the sample by aligning the magnetic domains, or the individual magnetic spins, with the field. The stronger the constant field, the larger the magnetization will be. The magnetic dipole moment of the sample will create a magnetic field around the sample, sometimes called the **magnetic stray field**. As the sample is moved up and down, this magnetic stray field is changing as a function of time and can be sensed by a set of pick-up coils.

The alternating magnetic field will cause an electric field in the pick-up coils according to Faraday's Law of Induction. This current will be proportional to the magnetization of the sample. The greater the magnetization, the greater the induced current.

The induction current is amplified by a transimpedance amplifier and lock-in amplifier. The various components are hooked up to a computer interface. Using controlling and monitoring software, the system can tell you how much the sample is magnetized and how its magnetization depends on the strength of the constant magnetic field. A typical measurement of a sample is taken in the following manner:

- the strength of the constant magnetic field is set.

- the sample begins to vibrate
- the signal received from the probe is translated into a value for the magnetic moment of the sample
- the strength of the constant magnetic field changes to a new value. no data is taken during this transition
- the strength of the constant magnetic field reaches its new value
- the signal from the probe again gets translated into a value for the magnetization of the sample
- the constant magnetic field varies over a given range, and a plot of magnetization (M) versus magnetic field strength (H) is generated.

PARTS OF THE VSM

The VSM consists of ten parts:

- water cooled electromagnet and power supply
- vibration exciter and sample holder (with angle indicator)
- sensor coils
- Hall probe

- amplifier
- control chassis
- lock in amplifier
- meter
- computer interface

Water cooled electromagnet and power supply

The water cooled electromagnet, along with the power supply, generate the constant magnetic field used to magnetize the sample.

Vibration exciter and sample holder (with angle indicator)

The sample holder rod is attached to the vibration exciter, and the end of it hangs down in between the pole pieces. The exciter moves the sample up and down at a set frequency, typically **85Hz**. The sample rod can be rotated to achieve the desired orientation of the sample to the constant magnetic field. There are also three knobs for controlling the x,y, and z positions of the sample.

Sensor coils

The sample produces an alternating current in these coils at the same frequency as the vibration of the sample. The signal generated contains the information about the magnetization of the sample.

Amplifier

The amplifier does just that - amplifies the signal created by the sensor coils.

Control chassis

This controls the 85Hz oscillation of the exciter.

Lock in amplifier

This amplifier is tuned to pick up only signals at the vibrating frequency. This eliminates noise from the environment, such as from the overhead lights or hovering spacecraft nearby (unless the noise happens to be an 85Hz signal).

Meter

This is used to measure something important.

Computer Interface

The software makes data collection easier by automating the control of the various components during data collection. The data can be graphed and plotted on the printer.

VSM OPERATION PROCEDURES

- Mounting the sample
  - Place a small amount of rubber cement on the back of the sample
  - Attach the sample to one of the rods, depending on how the measurement is to be taken
  - Stand the rod upright in the metal can on the counter and allow the cement to dry for about 10 minutes
- Turning on the system
  - Turn on the DI (deionized) **water supply**. It is located at the back of the room on the floor. Turn the red handle and let the water run through the system and into the sink. WAIT FOR THE WATER TO FLOW INTO THE SINK BEFORE DOING ANYTHING ELSE.
  - Turn on the **power supply** to the electromagnets. It is the large blue box behind the electromagnetic coils.

- Turn on the **SS250 amplifier**. This is the one at the bottom of the rack on the computer desk.
- Turn on the **control chassis** (in the middle of the rack)
- Turn on the **lock in amplifier**
- Turn on the **Beckman Voltmeter**. Place it in the 20V DC range
- Turn on the **computer**, then the **plotter**.

- Running the computer software
  - Enter the password
  - Type "Win" at the prompt
  - At the "READY TO ROLL" window, click OK. The measurement software should load automatically.
  - Double click on the "Manual setup" icon at the left hand bottom corner of the screen.
  - In the "Commands" section of the pop-up window, click on "Setup"
  - In the "9600 Environment Setup" window, make the following changes:
    - Curve type = Hysteresis
    - MASS Sample Mass = 6.48E-02 g
    - DEN Sample Density = 5.00E0 g/cc
    - *HRG Field Range = 1.00E04 Oe
    - AVERAGE = Disabled
    - SYNTHESIZE = Disabled
    - TEST SPEED = Quick
    - *BRG Induction Range = 1.00E01 Oe
    - *VIB Vibration Toggle = Off
    - *TC Time Constant = 0.1s
    - Peak Field = 5000 Oe
  - Click OK

- Calibration
  - Carefully attach the Ni rod to the VSM
  - Under "Setup", make the following changes:
    - Test Speed = Quick
    - Induction Range = 10 emu
    - Peak Field = 5,000 Oe
    - Field Range = 10,000 Oe
    - Time Constant = 0.1 sec
  - Under "Set", make the following changes:
    - Field = 5,000 Oe
    - Vibration = On
- Optimization
  - Use the top most knob on the right side of the VSM to adjust the left-right orientation of the sample with respect to the Hall probe. Find the maximum attainable value for M.

    - Use the small knob on the front of the machine to adjust the front-back orientation of the sample with respect to the Hall probe. Find the maximum attainable value for M.
    - Use the large knob to adjst the vertical position of the sample with respect to the Hall probe. Find the maximum value attainable for M.
- Calibrating the Lock-In amplifier
    - After optimization, m should be 3.55-3.56 for the Ni sample. If not, then:
        - Use the small calibration screw driver to adjust the small calibration pot (potentiometer) on the Lock-In amplifier.
        - Verify the calibration by rotating the Quadrant knob through each position:
            - Quadrant I: M=3.55
            - Quadrant II: M=0
            - Quadrant III: M= -3.55
            - Quadrant IV: M=0
        - If any of the values are different than listed, use the small Phase Knob to set them to the prescribed values
    - Run a quick measurement to verify the calibration by clicking on "Sample" then "Curve"
    - The system is now calibrated.
- Taking a measurement
    - Replace the Ni calibration rod with the sample to be measured.
    - Use the large cylinder on the top of the VSM to rotate the sample such that the magnetic field passes through the desired axis
        - If the sample touches either pole face, adjust the sample's right-left orientation to provide clearance as it rotates.
        - Center the sample between the pole pieces
    - Optimize again with a field of 5,000 Oe (see Optimization)
    - Under "Setup", make the following change:
        - Induction Range = 0.1emu. Leave all other settings the same.
    - Under "Set", make the following changes:
        - Field=5,000 Oe
        - Vibration=ON
    - To begin the measurement, click on "Sample", then "Curve".