Vibrating Sample Magnetometry

Radboud University

Theoretical principle

Faraday's law of induction

$$V(t) = -\frac{\mathrm{d}\phi_B}{\mathrm{d}t} \tag{1}$$

$$\phi_B = \iint\limits_S \vec{B}\,(\vec{r}, t) \cdot \mathrm{d}\vec{A} = BS \tag{2}$$

$$\implies V(z,t) = -NS\frac{\mathrm{d}B}{\mathrm{d}z}\frac{\mathrm{d}z}{\mathrm{d}t} \tag{3}$$

Magnetization

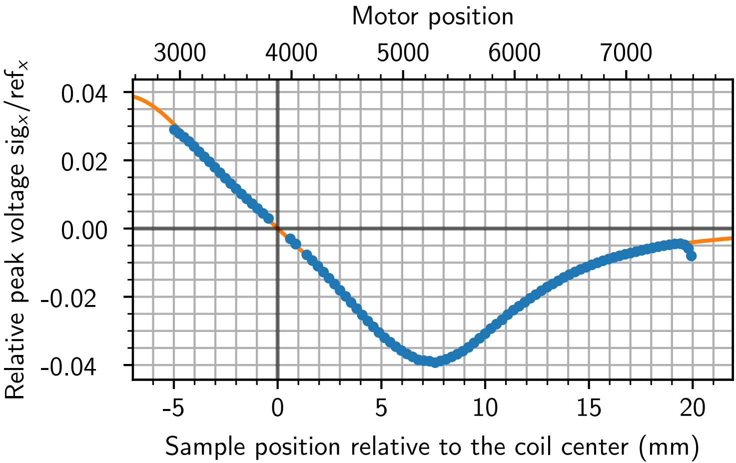
- **Paramagnetism:** Magnetic moment of unpaired electrons
- **Diamagnetism:** Lorentz force on electrons in orbitals

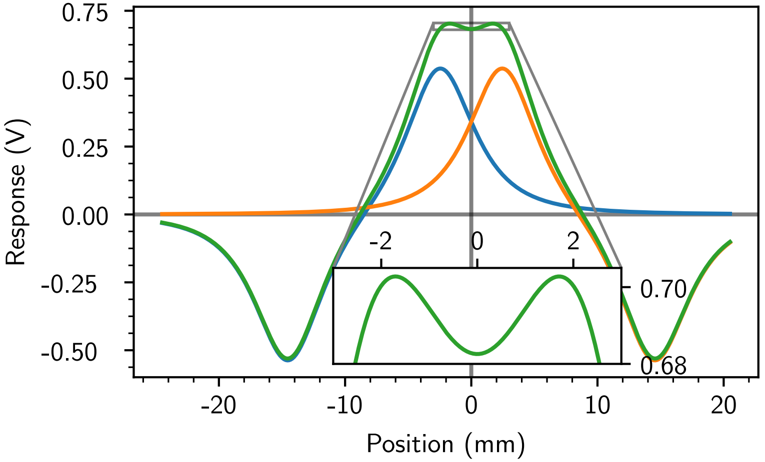
Theoretical principle

Induction on one pickup coil

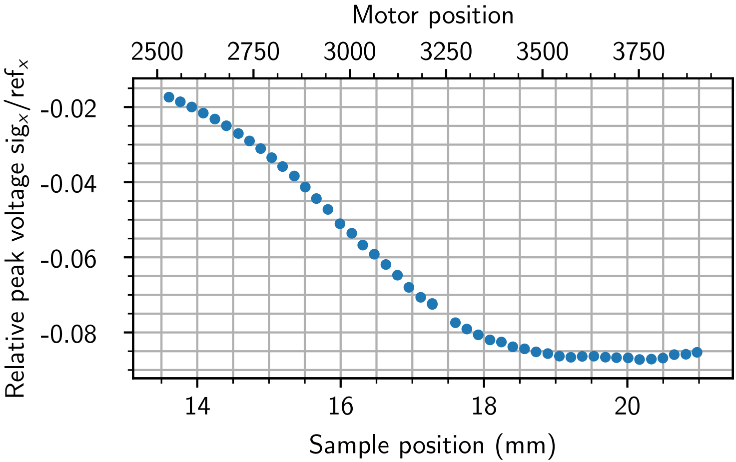
$$V(z) = -NASI\mu_0 \frac{f\pi}{\sqrt{2}} \left[\ln\left(r_2 + \sqrt{r_2^2 + (z-L)^2} \right) - \ln\left(r_1 + \sqrt{r_1^2 + (z-L)^2} \right) + \right.$$
$$(z-L)^2 \left(\frac{1}{r_2\sqrt{r_2^2+(z-L)^2} + r_2^2 + (z-L)^2} - \frac{1}{r_1\sqrt{r_1^2+(z-L)^2} + r_1^2 + (z-L)^2} \right) +$$
$$\ln\left(r_1 + \sqrt{r_1^2 + z^2} \right) - \ln\left(r_2 + \sqrt{r_2^2 + z^2} \right) +$$
$$\left. z^2 \left(\frac{1}{r_1\sqrt{r_1^2+z^2} + r_1^2 + z^2} - \frac{1}{r_2\sqrt{r_2^2+z^2} + r_2^2 + z^2} \right) \right] \tag{4}$$

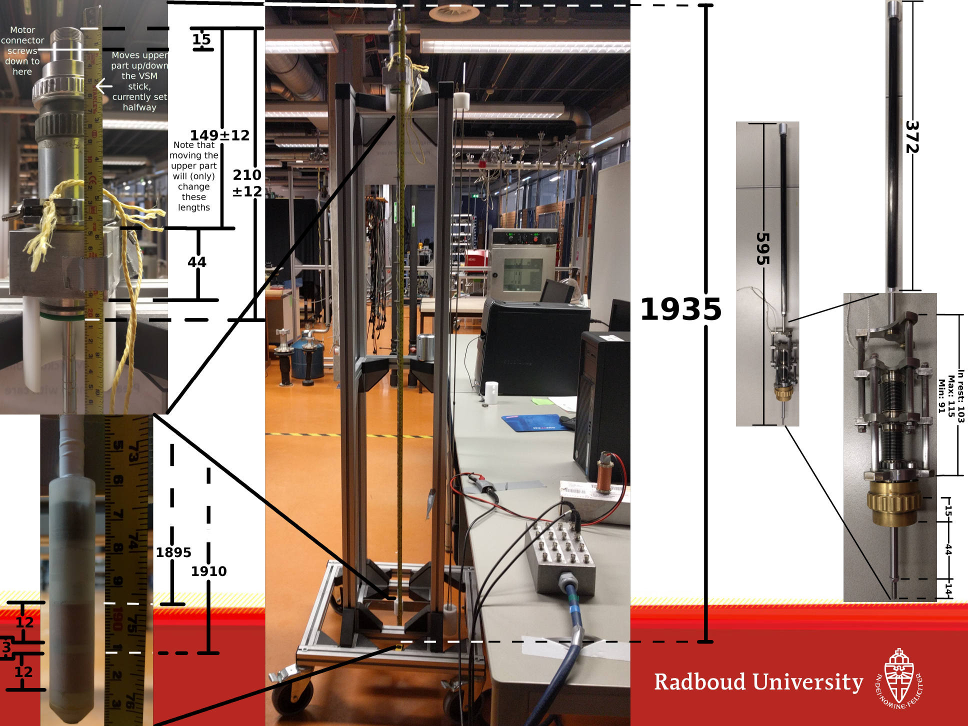
One pickup coil, permanent magnet: 30.9 mg

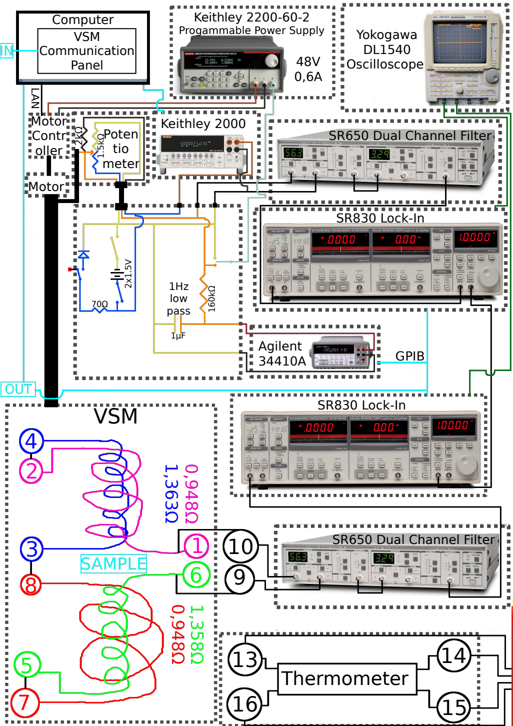


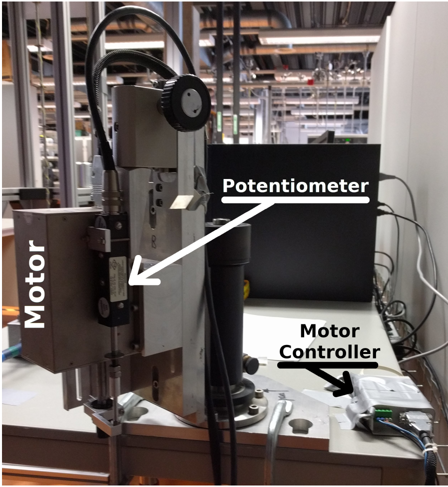

0.75
0.50
0.25
0.00
-0.25
-0.50
Response (V)
-20
-10
0
10
20
Position (mm)
-2
0
2
0.70
0.68

All 4 pickup coils, Nickel: 42.5 mg **at** 2 T **(Room Temperature)**



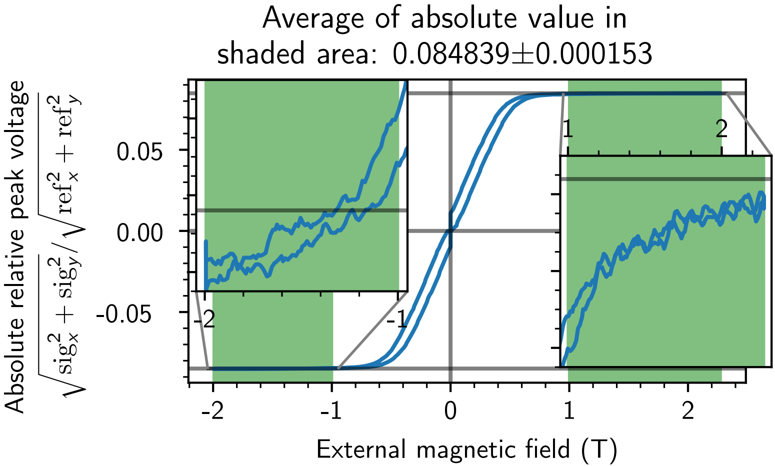

Motor connector screws down to here
Moves upper part up/down the VSM stick, currently set halfway
15
149±12
Note that moving the upper part will (only) change these lengths
210 ±12
44
1895
1910
12
3
12
1935
595
372
In rest: 103
Max: 115
Min: 91
15
44
14


Computer
VSM Communication Panel
IN
LAN
Keithley 2200-60-2
Progammable Power Supply
48V
0,6A
Yokogawa
DL1540
Oscilloscope
Motor Controller
2kΩ
1.5kΩ
Potentiometer
Keithley 2000
SR650 Dual Channel Filter
Motor
SR830 Lock-In
2x1.5V
70Ω
1Hz
low
pass
160kΩ
1µF
Agilent
34410A
GPIB
OUT
VSM
SR830 Lock-In
4
2
1,363Ω
0,948Ω
3
SAMPLE
1
10
6
9
SR650 Dual Channel Filter
8
1,358Ω
0,948Ω
5
7
13
Thermometer
14
16
15

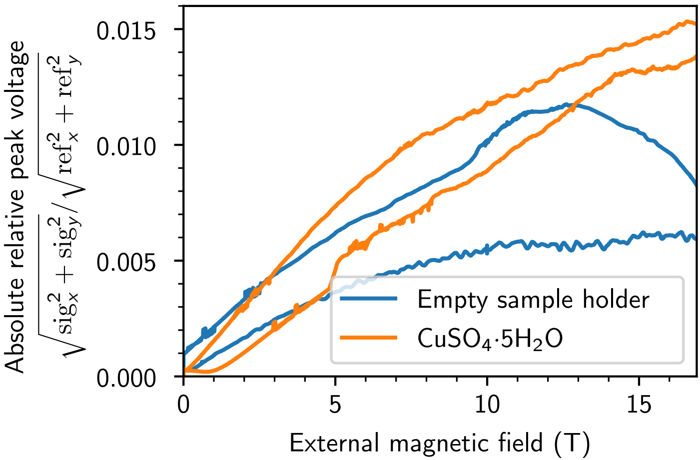

Potentiometer
Motor
Motor
Controller

Nickel: 42.5 mg **(Room Temperature)**

$(58.57 \pm 0.03)\,\mathrm{emu/g} \implies (2.489 \pm 0.002)\,\mathrm{emu} \implies c{=}(29.34 \pm 0.06)\,\mathrm{emu}$

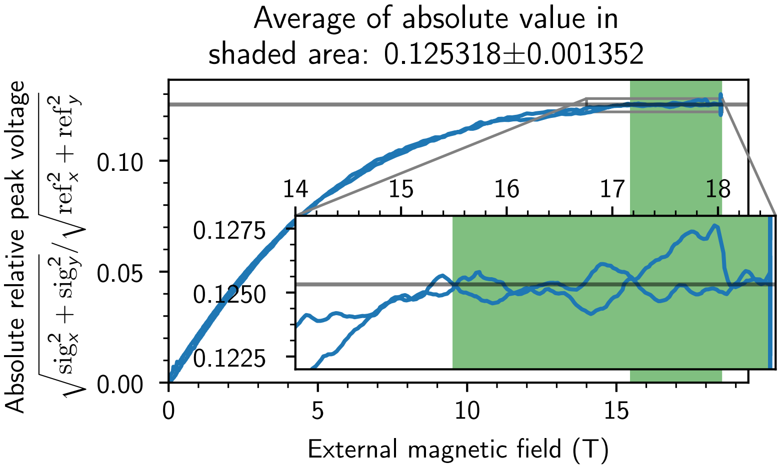


$CuSO_4 \cdot 5\,H_2O$: 143 mg (Room Temperature)



$CuSO_4 \cdot 5\,H_2O$: 143 mg **(**4 K**)**

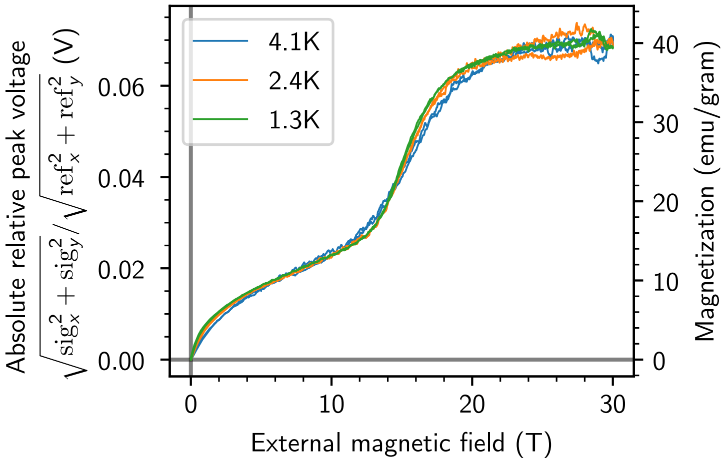
c=(29.34 ± 0.06) emu $\Longrightarrow$ (3.67 ± 0.04) emu $\Longrightarrow$ (25.7 ± 0.3) emu/g



Sanity Check

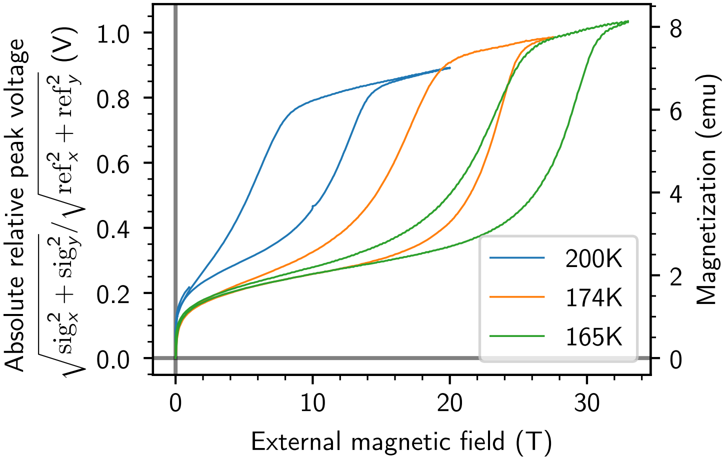
- Paramagnetic Cu^{2+} ions: Spin 1/2
- $2\sqrt{s\,(s+1)} = \sqrt{3}\ \mu_\mathrm{B}$
- $CuSO_4 \cdot 5\,H_2O$: 249.684 u
- $\Longrightarrow$ 39 emu/g
- Diamagnetic contributions of H_2O and SO_4^{2-}

$KEr(MoO_4)_2$: 6.2 mg



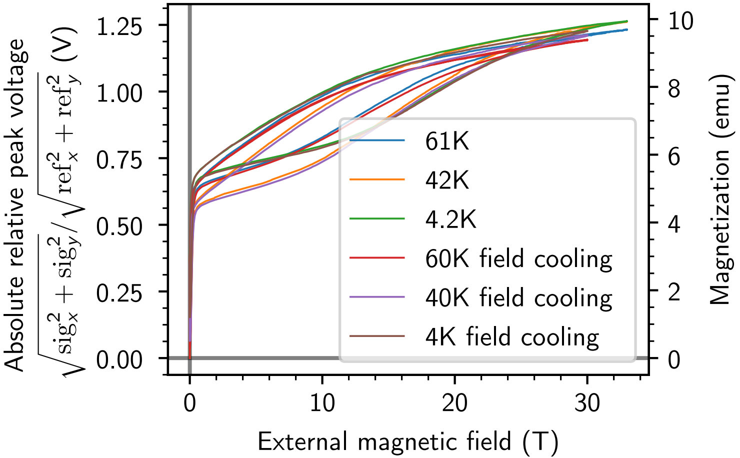
$Ni_{38}Mn_{49}Sn_9Fe_4$

Martensite (strained body-centered tetragonal), Austenite (face-centered cubic) phase transition.



$Ni_{37}Mn_{49}Sn_9Fe_5$

Martensite (strained body-centered tetragonal), Austenite (face-centered cubic) phase transition.



More info:
github.com/AndrewAmmerlaan/HFML-VSM_CoilProfilePlotter

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