

Vibrating Sample Magnetometry

Theoretical principle

Faraday's law of induction

$$V(t) = -\frac{d\phi_B}{dt} \quad (1)$$

$$\phi_B = \iint_S \vec{B}(\vec{r}, t) \cdot d\vec{A} = BS \quad (2)$$

$$\Rightarrow V(z, t) = -NS \frac{dB}{dz} \frac{dz}{dt} \quad (3)$$

Magnetization

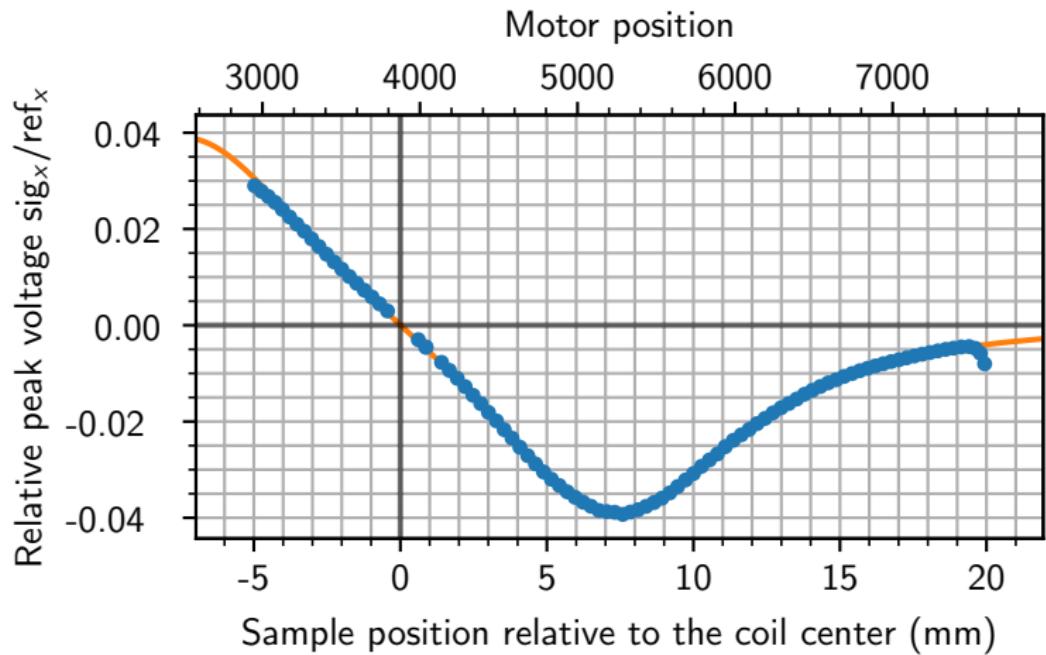
- **Paramagnetism:** Magnetic moment of unpaired electrons
- **Diamagnetism:** Lorentz force on electrons in orbitals

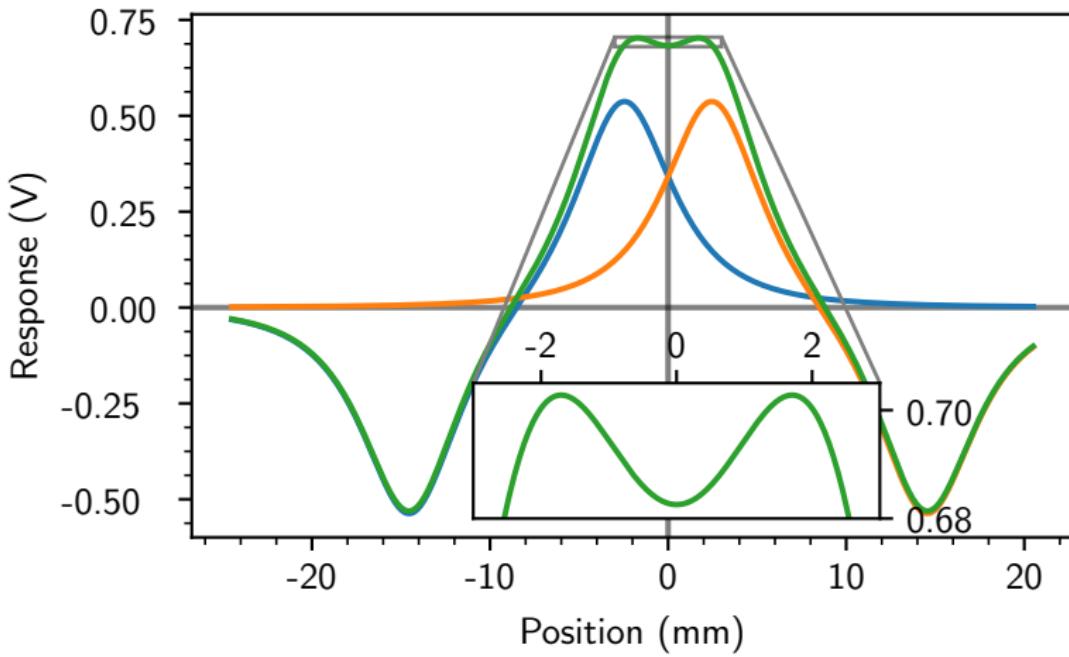
Theoretical principle

Induction on one pickup coil

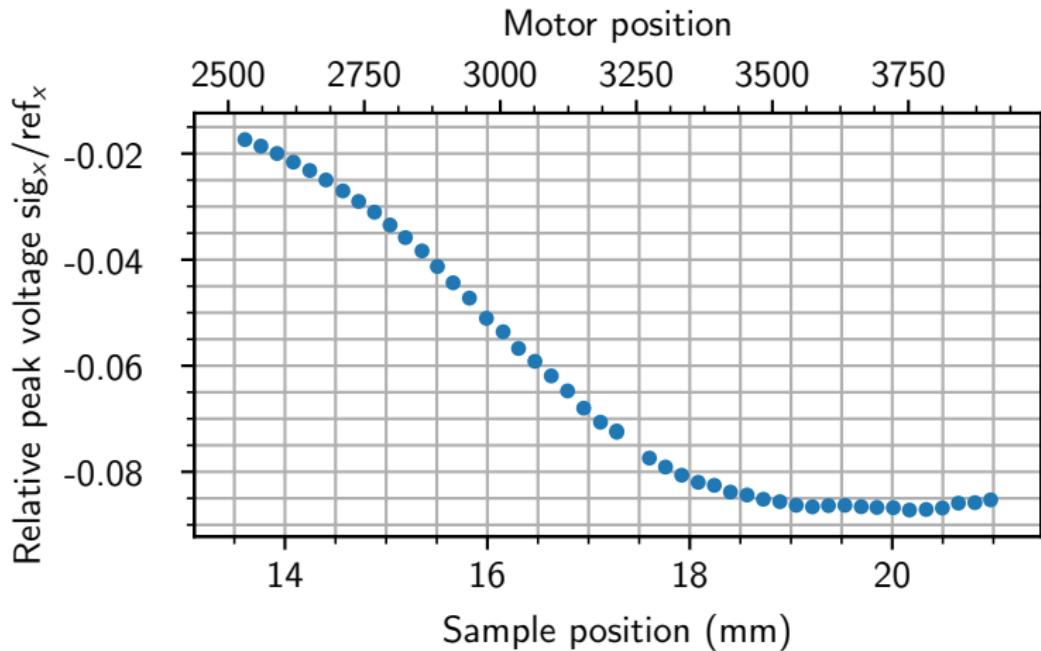
$$\begin{aligned} V(z) = & -N A S I \mu_0 \frac{f \pi}{\sqrt{2}} \left[\ln \left(r_2 + \sqrt{r_2^2 + (z-L)^2} \right) - \ln \left(r_1 + \sqrt{r_1^2 + (z-L)^2} \right) + \right. \\ & (z-L)^2 \left(\frac{1}{r_2 \sqrt{r_2^2 + (z-L)^2} + r_2^2 + (z-L)^2} - \frac{1}{r_1 \sqrt{r_1^2 + (z-L)^2} + r_1^2 + (z-L)^2} \right) + \\ & \ln \left(r_1 + \sqrt{r_1^2 + z^2} \right) - \ln \left(r_2 + \sqrt{r_2^2 + z^2} \right) + \\ & \left. z^2 \left(\frac{1}{r_1 \sqrt{r_1^2 + z^2} + r_1^2 + z^2} - \frac{1}{r_2 \sqrt{r_2^2 + z^2} + r_2^2 + z^2} \right) \right] \end{aligned} \quad (4)$$

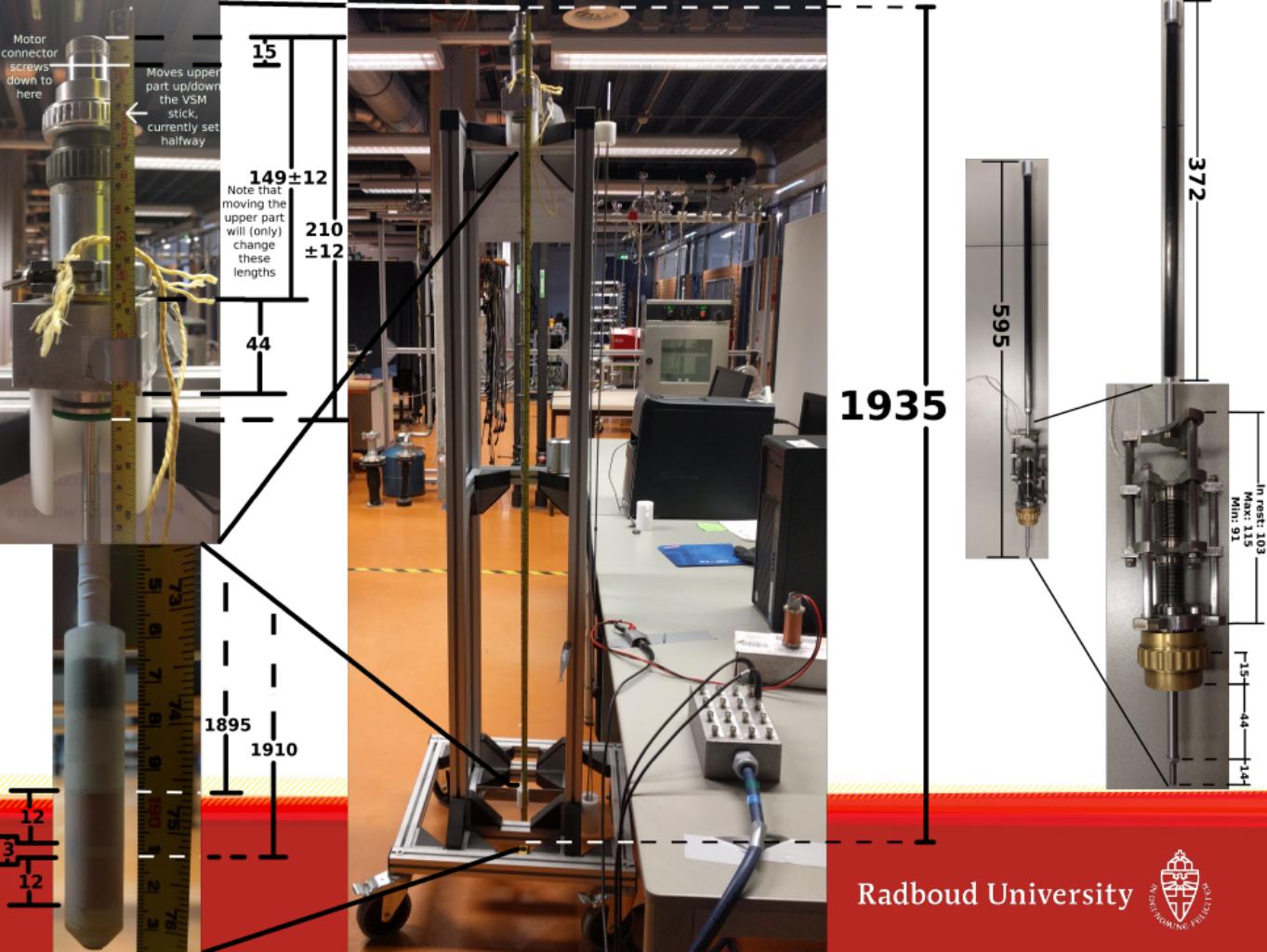
One pickup coil, permanent magnet: 30.9 mg

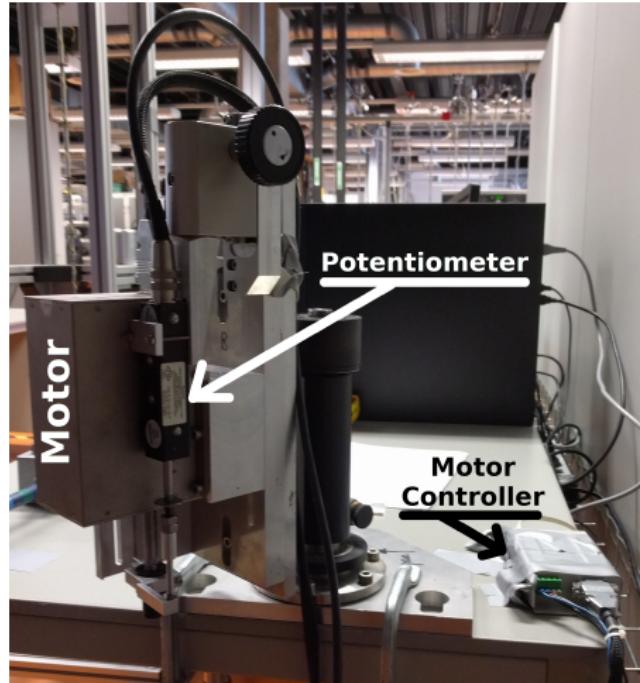
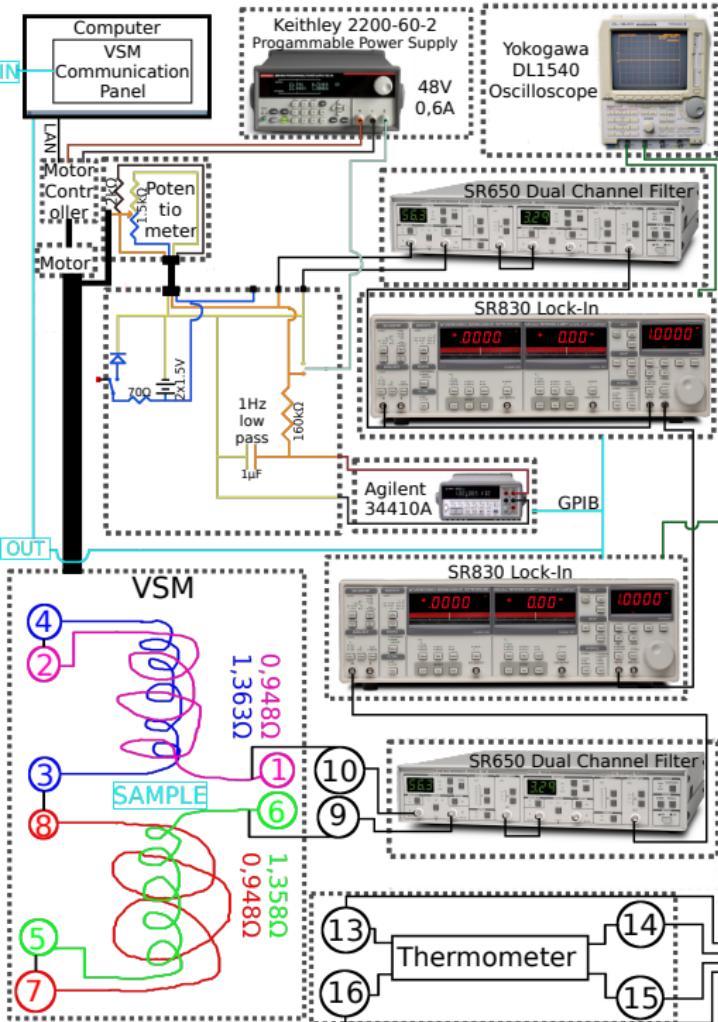




All 4 pickup coils, Nickel: 42.5 mg at 2 T (Room Temperature)



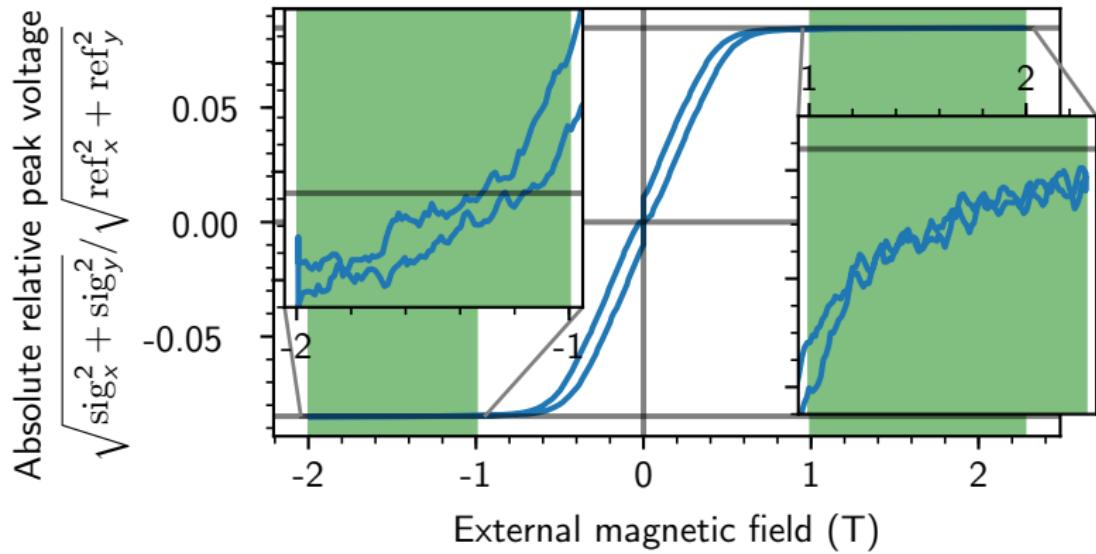




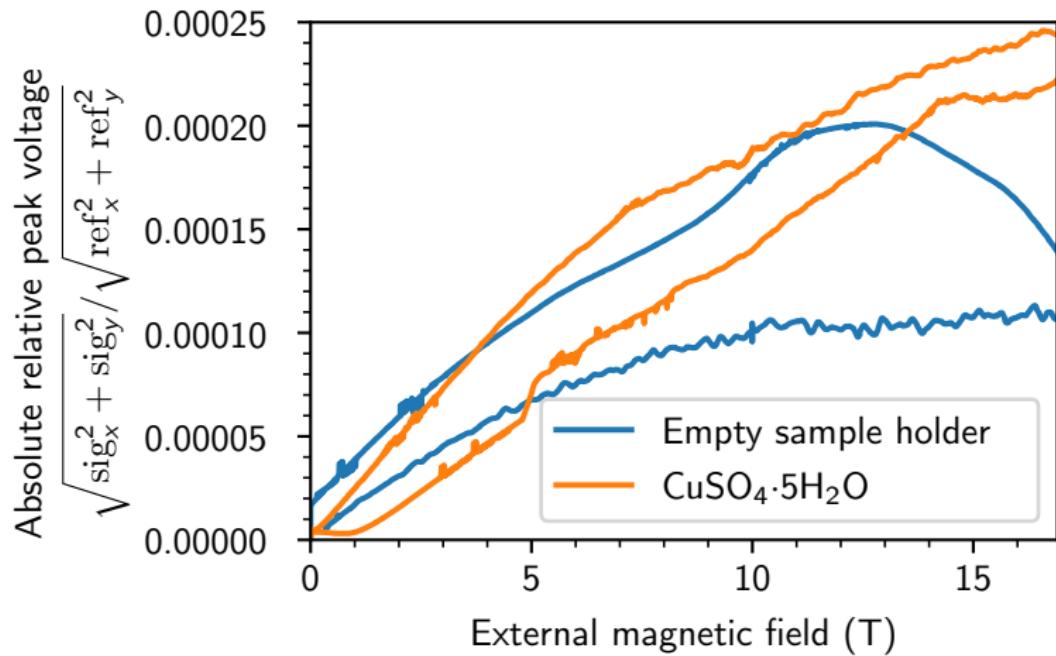
Nickel: 42.5 mg (**Room Temperature**)

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

Average of absolute value in
shaded area: 0.084839 ± 0.000153



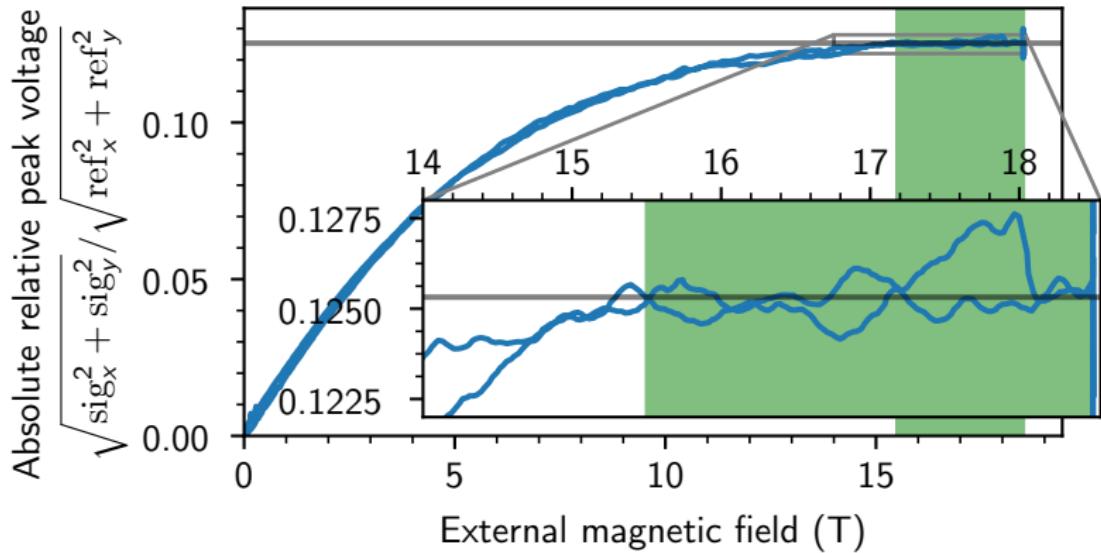
$\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$: 143 mg (Room Temperature)



$\text{CuSO}_4 \cdot 5 \text{H}_2\text{O}$: 143 mg (4 K)

$$c = (29.34 \pm 0.06) \text{ emu} \implies (3.67 \pm 0.04) \text{ emu} \implies (25.7 \pm 0.3) \text{ emu/g}$$

Average of absolute value in
shaded area: 0.125318 ± 0.001352



Sanity Check

- Paramagnetic Cu²⁺ ions: Spin 1/2
- $2\sqrt{s(s+1)} = \sqrt{3} \mu_B$
- CuSO₄·5H₂O: 249.684 u
- $\Rightarrow 39 \text{ emu/g}$
- Diamagnetic contributions of H₂O and SO₄²⁻

More info:

github.com/AndrewAmmerlaan/HFML-VSM_CoilProfilePlotter

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