Vortex dynamics and irreversibility line in FeSe$_{0.25}$Te$_{0.75}$. 

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Outline

- Short introduction on flux pinning in superconductors, and AC magnetic susceptibility
- Experimental setup and samples studied
- Results and discussion
- Conclusions
Superconductors in magnetic field
Superconductors in magnetic field

Under the action of an external current vortices experience a Lorenz force, which tend to move them

*flux flow:* vortices move in a rather steady motion, *flow resistivity* $\rho_f$

*Pinning* force ‘pins’ the vortices to some definite locations in the material. Current can flow without resistivity, until a critical value $J_c$. 
Superconductors in magnetic field

- Mixed phase
- Normal state
- Vortex liquid
- Vortex glass
- Meissner phase
- Irreversibility line

Simplified Phase Diagram

Temperature

Magnetic Field

$H_{c1}$

$H_{c2}$
**AC multi-Harmonic susceptibility**

The magnetic response of the sample induced by a time-varying excitation field $H_{ac}$ can be expressed in Fourier series:

$$M(t) = H_0 \sum_n [\chi'_n \cos(n\omega t) + \chi''_n \sin(n\omega t)]$$

\[\chi_n = \chi'_n + i\chi''_n\] is the non-linear complex susceptibility
Harmonic susceptibility applied to superconductors

\[ \chi'_n = \frac{1}{\pi H_0} \int_0^{2\pi} M(t) \cos(n \omega t) \, d(\omega t) \]

\[ \chi''_n = \frac{1}{\pi H_0} \int_0^{2\pi} M(t) \sin(n \omega t) \, d(\omega t) \]

\(\chi''_1\) is the first harmonic imaginary component associated with dissipative processes in the sample, is a measure of losses.

\(\chi'_1\) is the first harmonic real component associated with the magnetic response of the sample, and is a measure of screening.

The first harmonic \(\chi_1\) response measures the extent to which the magnetic field has penetrated into the sample. The onset is used to determine the \(H_{c2}(T)\):

High harmonics \(\chi_n\): Nonlinear, irreversible behaviour. The onset is used to determine the IL.
**FeSe$_{1-x}$Te$_x$ (11)**

Very simple crystal structure:

**Only iron-chalcogen (S, Se, Te) active layers stacked together**

Easy to synthesize, can be handled safely because does not contain arsenic

$T_c (0 \, \text{T}) \sim 14 \, \text{K}$
T sweep vs field
Phase diagram 507 Hz

\[ \frac{dH_{c2}}{dT} = -6.4 \pm 0.2 \, \text{T/K} \]

\[ H_{c2}(0 \, \text{K}) \approx 62 \, \text{T} \]

\[ H \propto \left(1 - \frac{T}{T_c}\right)^{1.47} \]

\[ H_{c2}(0 \, \text{K}) = 0.693T_c \left| \frac{dH_{c2}}{dT} \right|_{T\sim T_c} \]
IL frequency analysis

\[ T_{\text{trr}}(H, f) = T_{g}(H) + A(H) \times f^{1/\nu(z+2-D)} \]

\[ \nu = 1.2 \]

\[ z \approx 4.6 \]

\[ D = 3 \]
IL line vs frequency

\[ H \propto \left(1 - \frac{T}{T_c}\right)^\beta \quad ; \quad 0.4 < \beta < 0.5 \]
Conclusions

Harmonic AC susceptibility measurements vs allowed us to map a wide $T$-$f$-$H$ region of the FeSe$_{0.25}$Te$_{0.75}$ phase diagram.

The IL experimental behavior can be reasonably well described in the framework of a 3D vortex-glass model in high magnetic field.

The observed 3D flux-pinning response in a wide range of the magnetic field points out that this system is suitable for carrying quite high critical currents.

From WHH theory we have estimated $H_{c2} \sim 62$ T at 0 K
High Field Magnet Laboratory (HFML)

Radboud University Nijmegen, The Netherlands

Thank you for your attention!

Requests for Magnet Time:
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AC Magnetometry

In AC magnetic measurements, a small AC drive magnetic field is superimposed on the DC bias field, causing a time-dependent moment in the sample.

\[ \chi = \frac{dM}{dH_{AC}} \]

Since it probes the slope of \( M(H) \), this measurement is very sensitive to small changes in magnetization.

Contrary to dc measurement, the magnetic moment of the sample is now changing with time, thus the dynamics of the magnetic system can be studied.

This method also offers the opportunity to determine the frequency dependence of the complex susceptibility which leads to information about relaxation processes and the relaxation times of the magnetic systems studied.
Primary coil

- 2000 turns
- \( R = 190 \text{ Ohm @RT} \)
- \( L = 10.4 \text{ mH} \)
Pick up coils

4000 turns each coil

R = 950 Ohm @RT

L = 90 mH