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HFML
Science in High Magnetic Fields

Vortex dynamics and irreversibility line in $FeSe_{0.25}Te_{0.75}$.

A. Puri, D. Di Gioacchino, A. Marcelli, N. Poccia, A. Ricci, U. Zeitler*

**a.puri@science.ru.nl*

FOM

EMFL
European Magnetic Field Laboratory

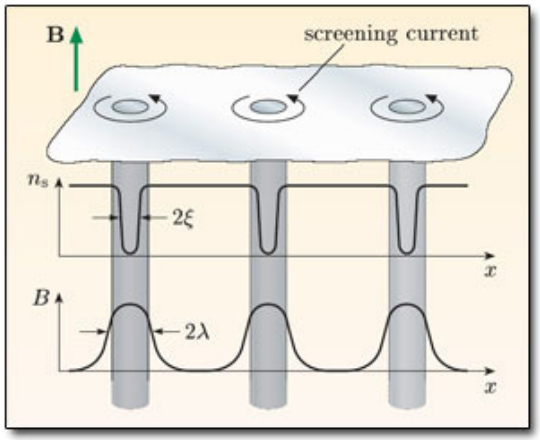
INFN
Istituto Nazionale di Fisica Nucleare

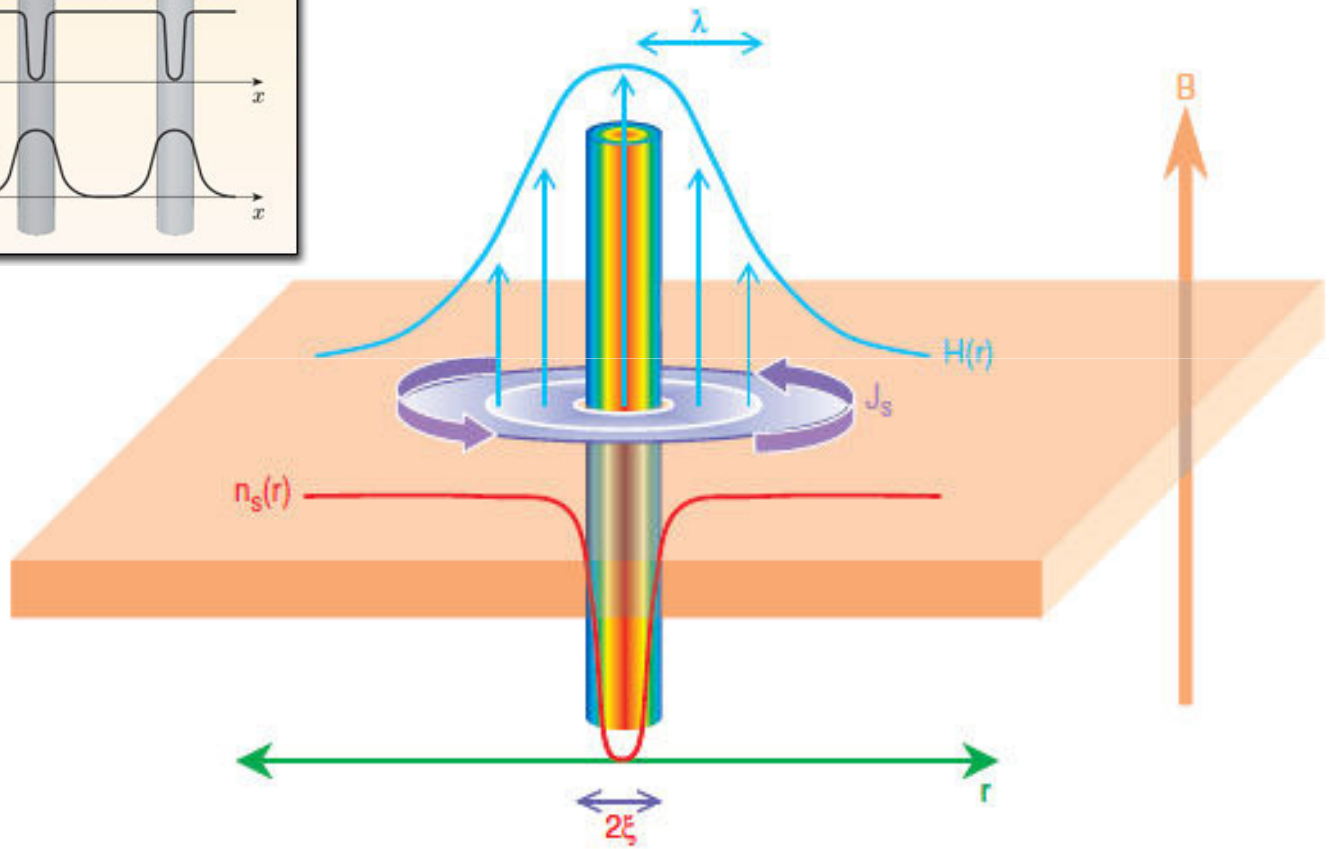
Radboud Universiteit Nijmegen

Outline

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

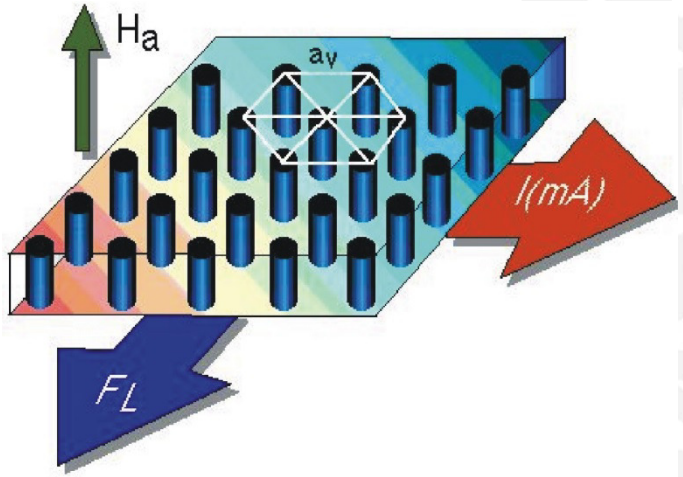
Superconductors in magnetic field





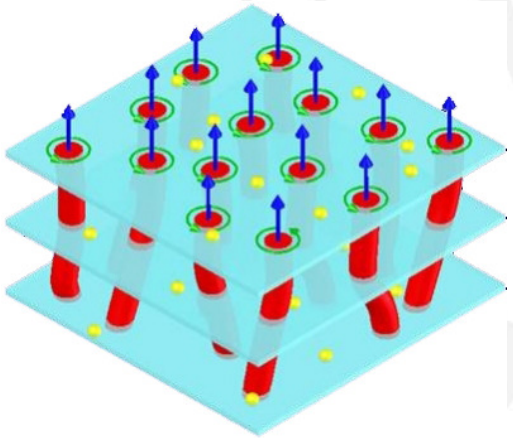
Superconductors in magnetic field

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

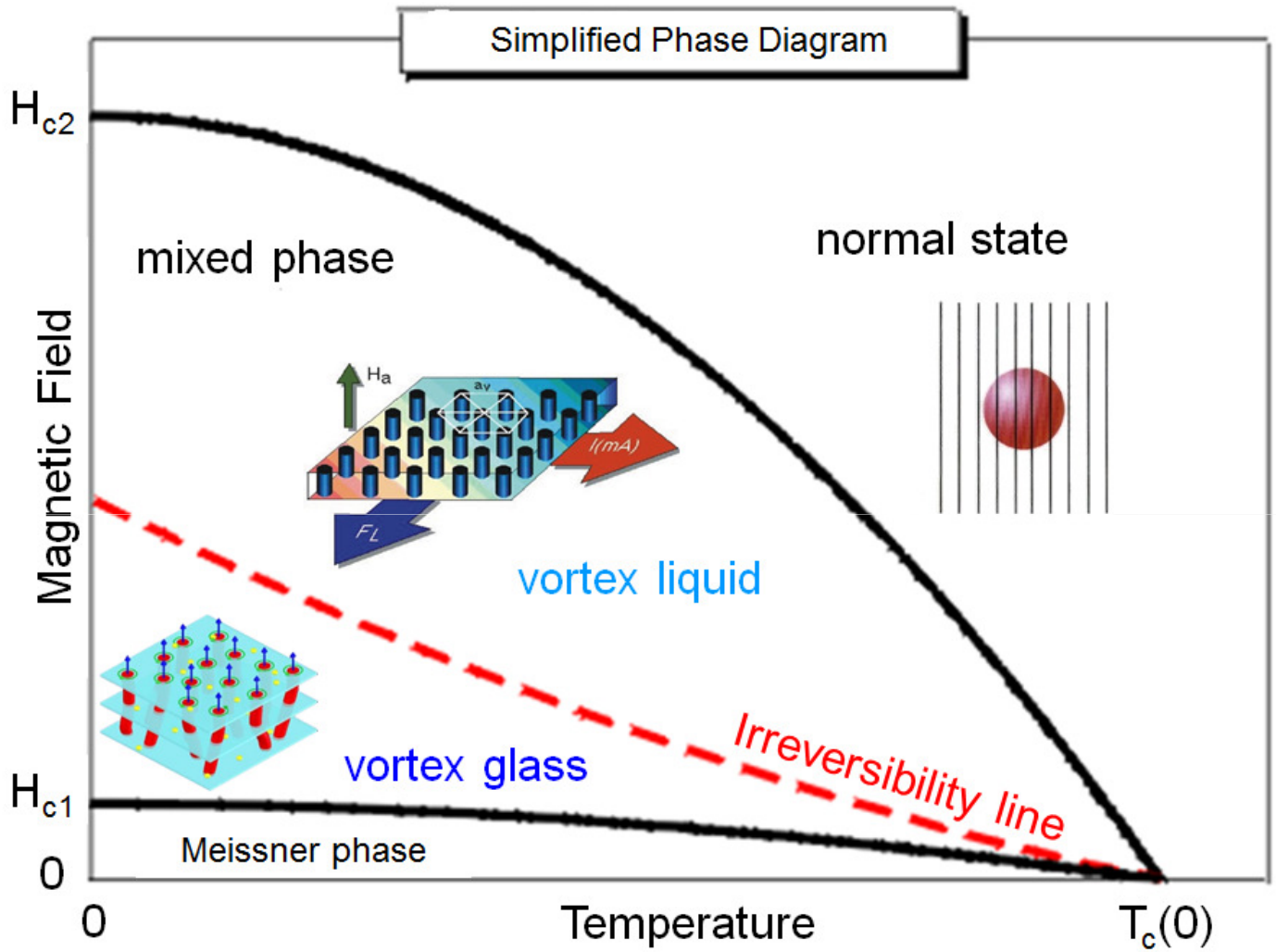


***flux flow:* vortices move in a rather steady motion, *flow resistivity* ρ_f**

***Pinning* force 'pins' the vortices to some definite locations in the material.** Current can flow without resistivity, until a critical value J_c.

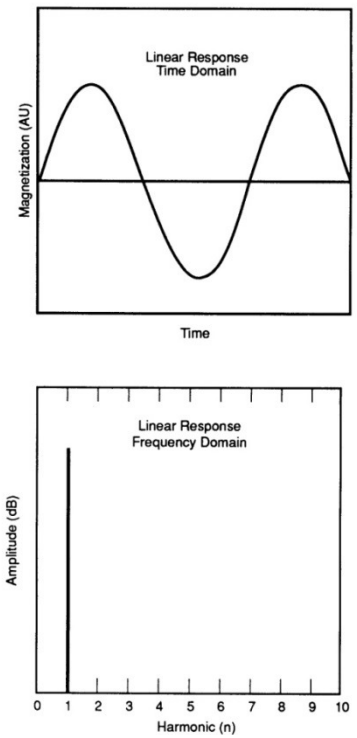


Superconductors in magnetic field

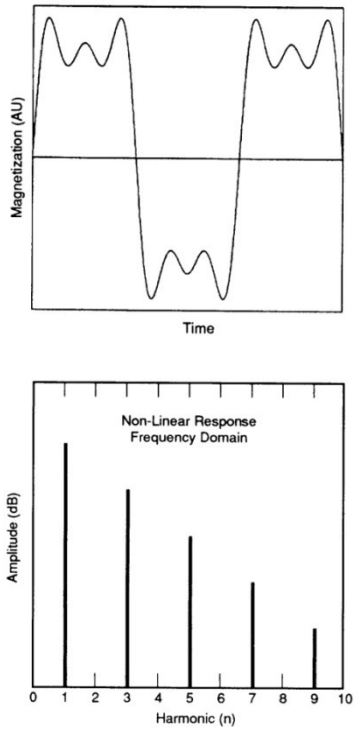


AC multi-Harmonic susceptibility

Reversible



Irreversible



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

$$M(t) = H_0 \sum_n [\chi_n^{'} \cos(n\omega t) + \chi_n^{''} \sin(n\omega t)]$$

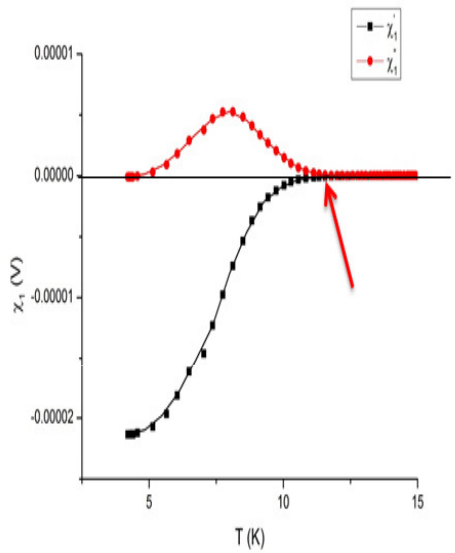
$\chi_n = \chi'_n + i\chi''_n$ is the non - linear complex susceptibility

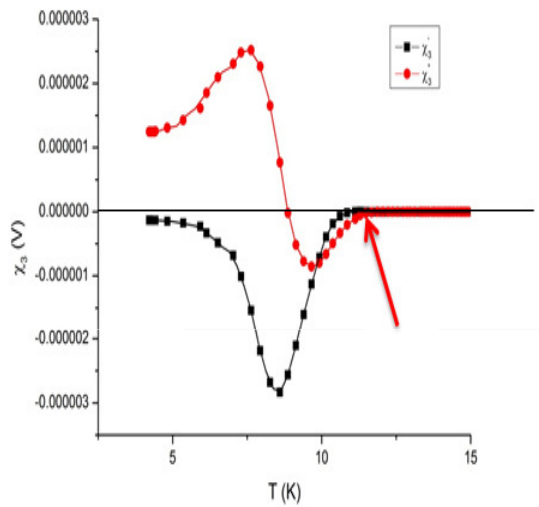
Harmonic susceptibility applied to superconductors

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

χ''_1 is the first harmonic *imaginary* component associated with dissipative processes in the sample, is a measure of losses

χ'_1 is the first harmonic *real* component associated with the magnetic response of the sample, and is a measure of screening

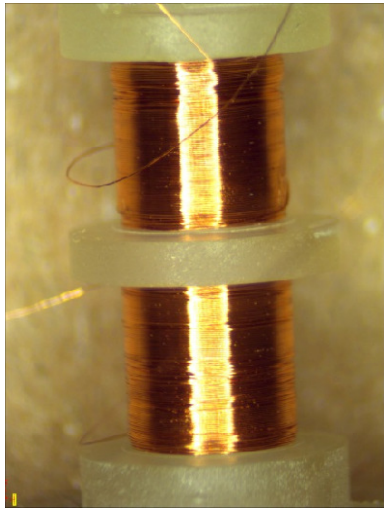


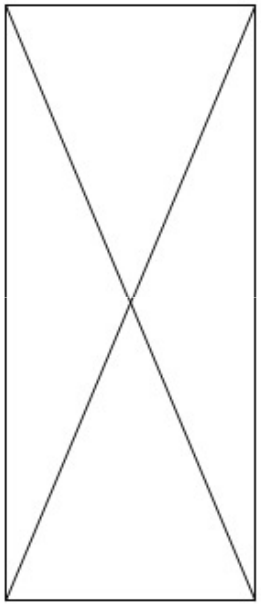


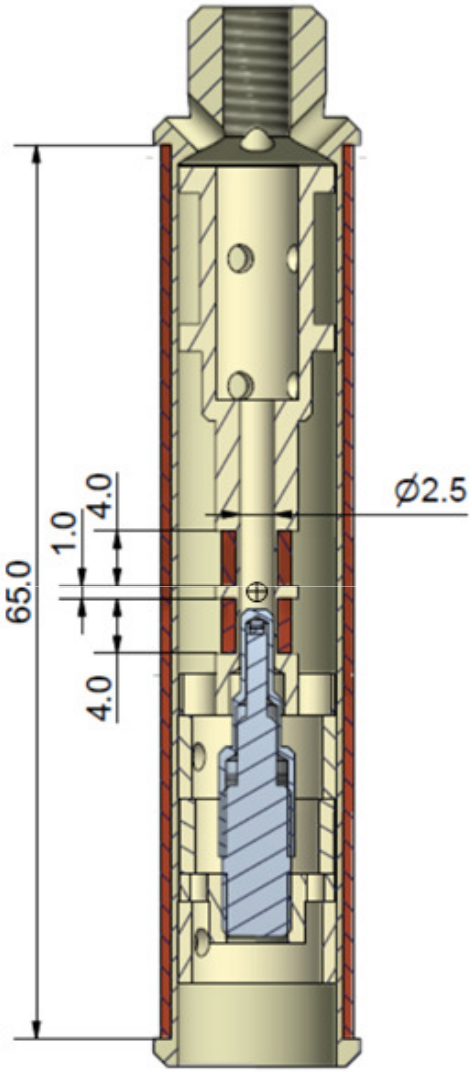
The first harmonic χ_1 response measures the extent to which the magnetic field has penetrated into the sample the onset is used to determine the $H_{c2}(T)$:

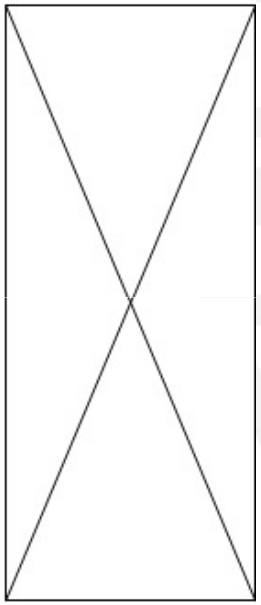
High harmonics χ_n : Non linear, irreversible behaviour. The onset is used to determine the IL

Coil assembly

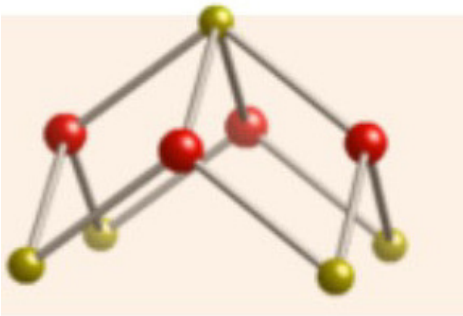






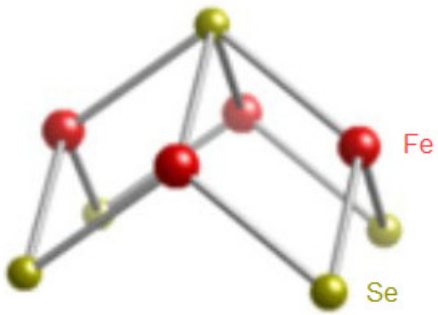


$FeSe_{1-x}Te_x$ (11)



Very simple crystal structure:

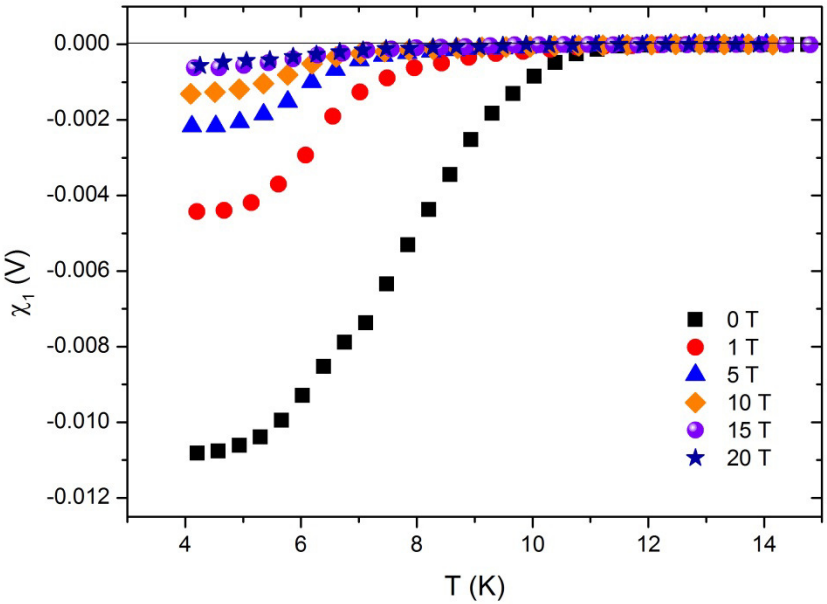
Only iron-chalcogen (S, Se, Te) active layers stacked together

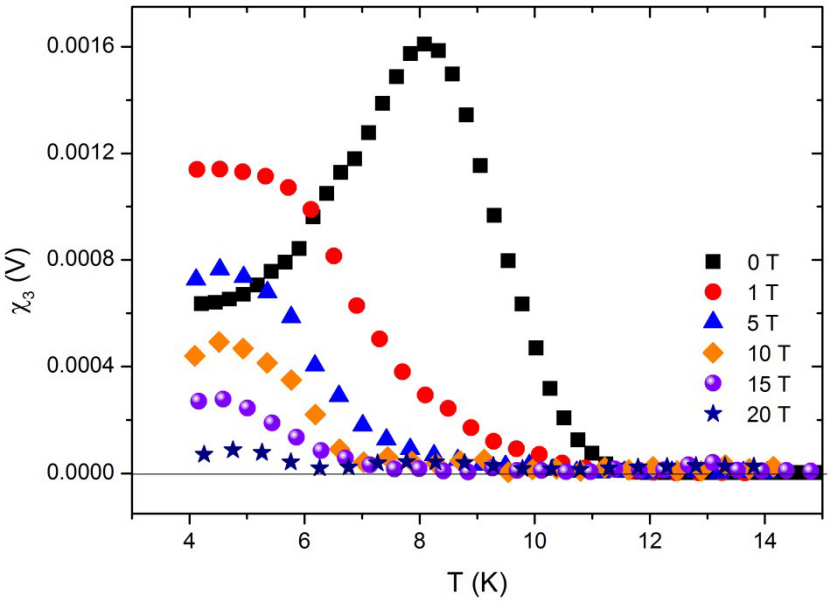


Easy to synthesize, can be handled safely because does not contain arsenic

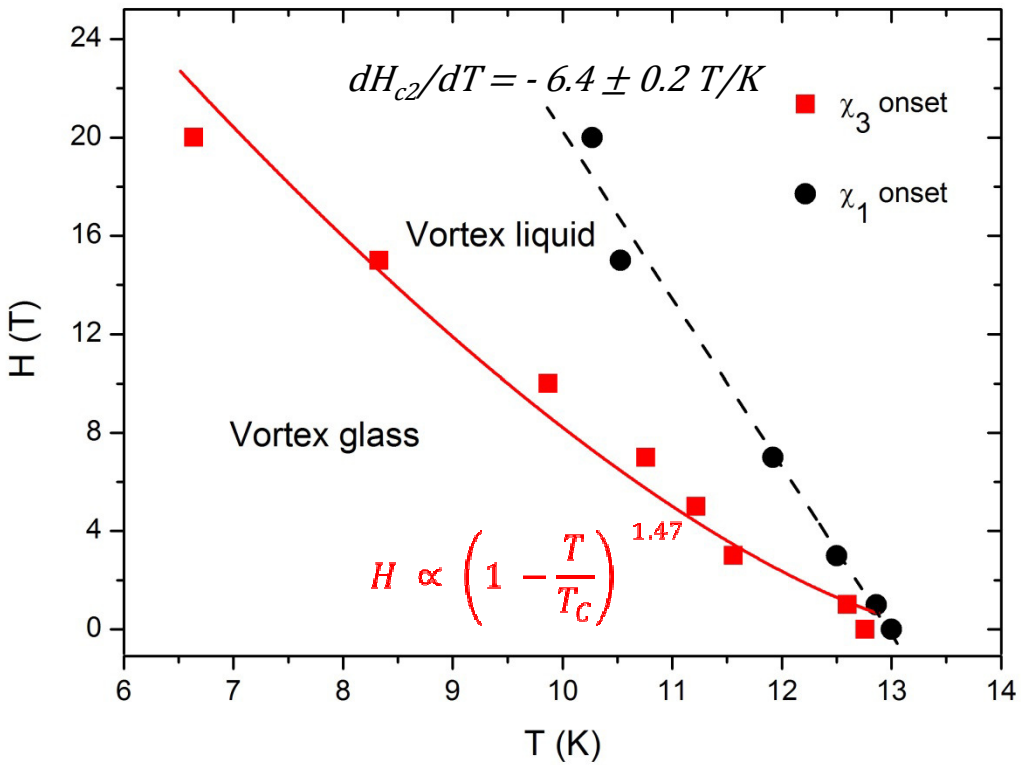
T_c (0 T) ~ 14 K

T sweep vs field





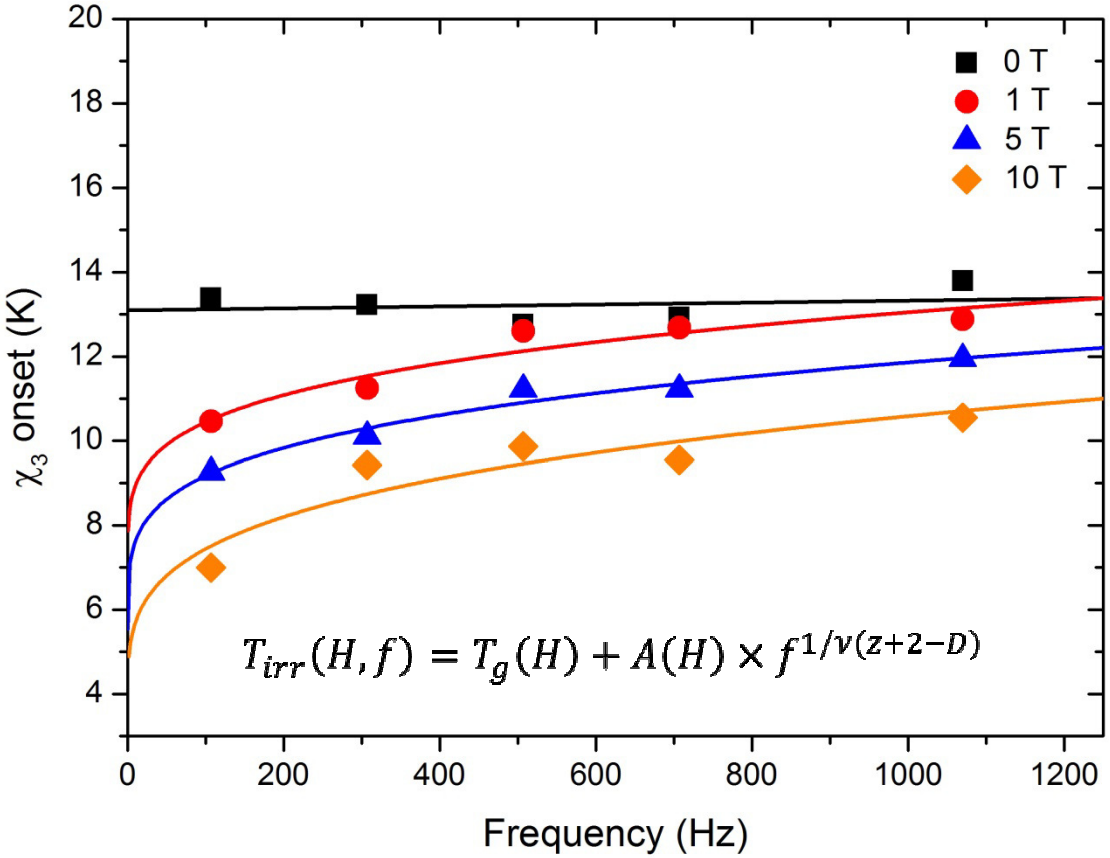
Phase diagram 507 Hz



$$H_{c2}(0\ K) = 0.693 T_c \left| \frac{dH_{c2}}{dT} \right|_{T \sim T_c}$$

H_{c2} (0 K) ~ 62 T

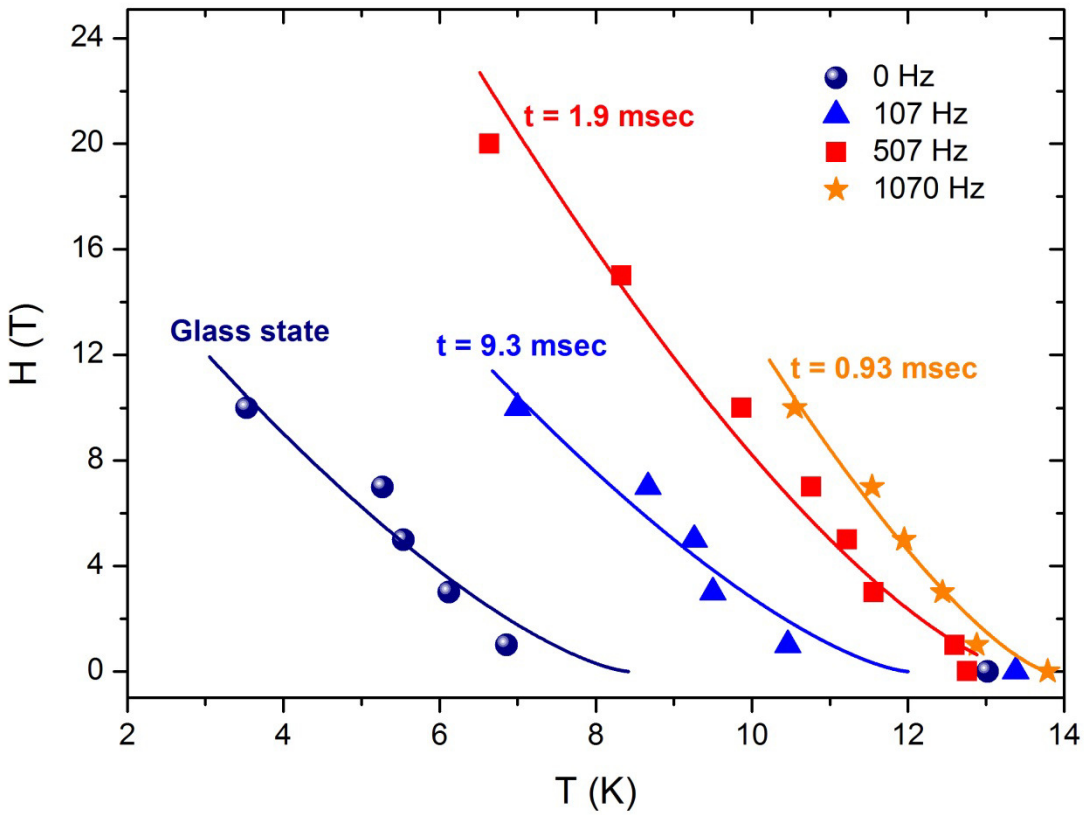
IL frequency analysis



$\nu = 1.2$
$z \sim 4.6$
$D = 3$

IL line vs frequency

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



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} ~ 62 T at 0 K

HFML
University of Nijmegen

High Field Magnet Laboratory (HFML)

Radboud University Nijmegen, The Netherlands

Thank you for your attention!

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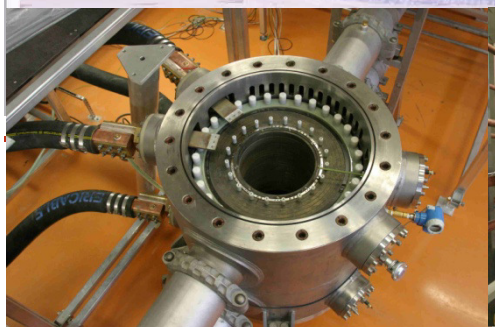
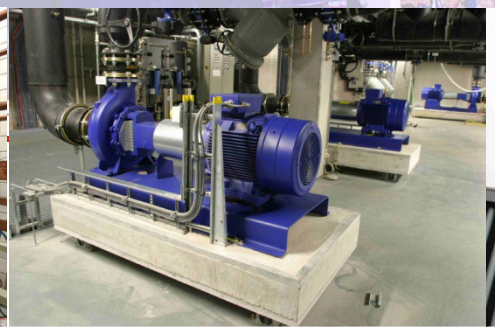





AC Magnetometry

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.

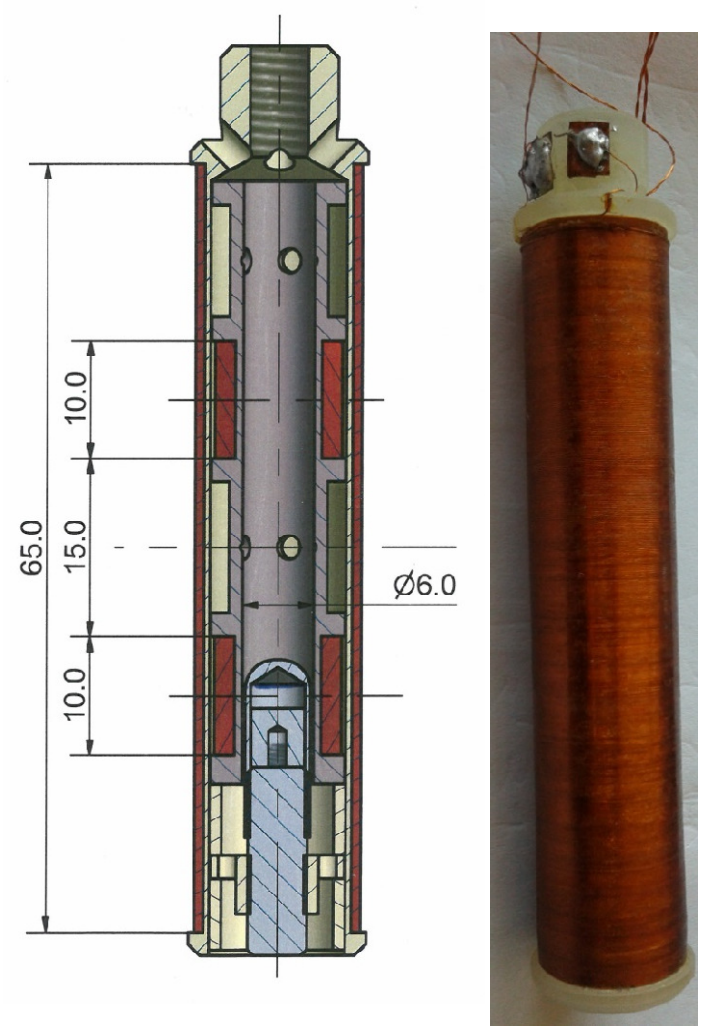
$$\chi = \frac{dM}{dH_{AC}}$$

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

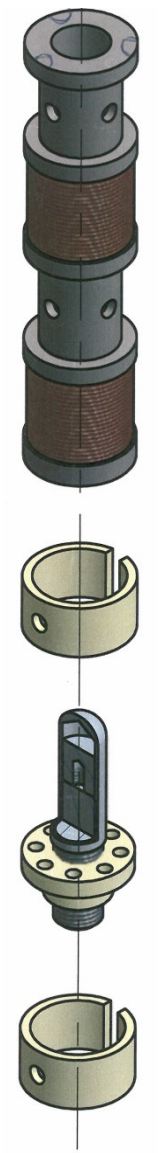


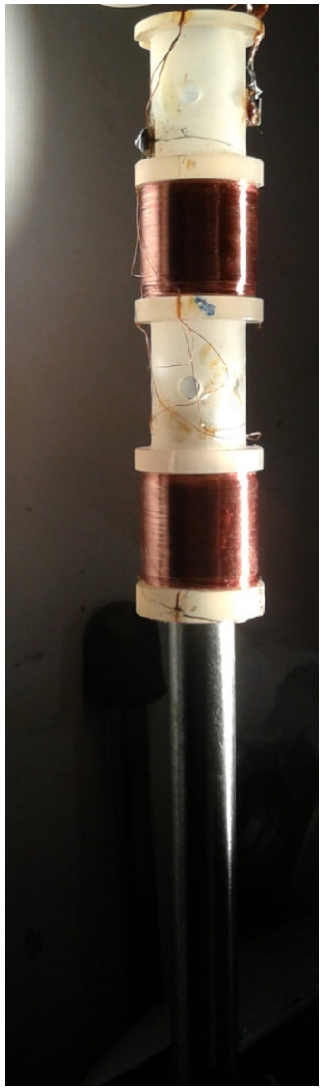
2000 turns

R = 190 Ohm @RT

L= 10,4 mH

Pick up coils





4000 turns each coil

R = 950 Ohm @RT

L= 90 mH