QUENCH MECHANISMS STUDY IN SUPERCONDUCTORS FOR SAFE ENERGY AND ENERGY SAVING: THE QUESTIONS PROJECT

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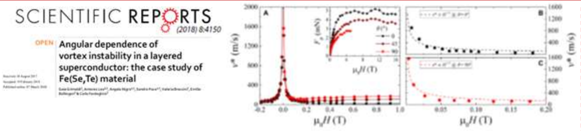
Intro

QUESTIONs project aims to investigate pinning mechanisms preventing vortex motion and the features of this motion through the analysis of the critical parameters as a function of temperature, magnetic field, and field orientation. In fact, the vortex motion cannot be easily visualized, and it is therefore necessary to deduce its features through indirect measurements. By the same token, careful modelling is essential to interpret the experiments. In QUESTIONs key measurements in different extreme conditions of the critical voltage at which vortex motion becomes unstable and leads to a process known as *quench*, in the jargon of superconducting applications, are the project core.

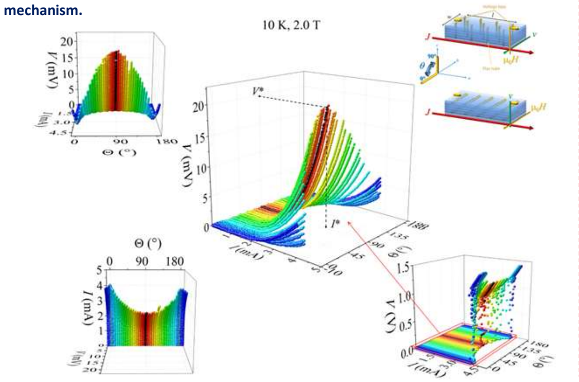
Quench measurements will allow to estimate microscopic parameters as the quasiparticle energy relaxation time, and to grasp the microscopic scattering mechanisms of quasiparticles inside and outside the moving vortex core to discriminate between electronic non-equilibrium effects and pure thermal overheating origin of dissipation. Materials choice is a central issue also for superconducting power applications. The project will therefore check several materials, either belonging to the class of High-Tc Superconductors, or to the intermediate material, MgB_2, highly promising for applications.

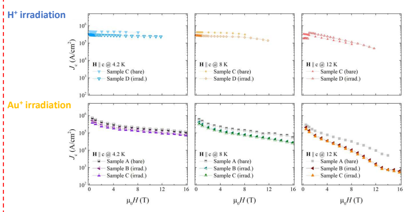
Here, we present an overall picture of manipulating geometry and pinning to control vortex motion velocity in thin films of different materials, including Low-Tc Superconductors, ReBCO and Fe(Se,Te). The aim is dual: attaining higher vortex velocities pushing towards the operating limits in any superconducting device and gaining a deeper understanding of vortex and quasi-particle dynamics in extreme out-of-equilibrium conditions. We also show that a deep knowledge of the material anisotropy can boost high-speed limits of vortex dynamics, thus resulting in robust quenching currents against external fields.

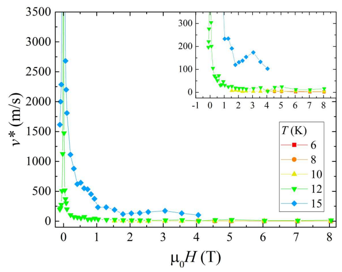
The Iron age



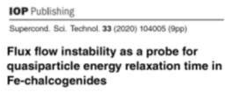
The layered Fe(Se,Te) has some similarities with BSCCO, this is another case in which the instability voltage $V^*(\theta,H,T)$ and current $I^*(\theta,H,T)$ are influenced by pinning mechanism.



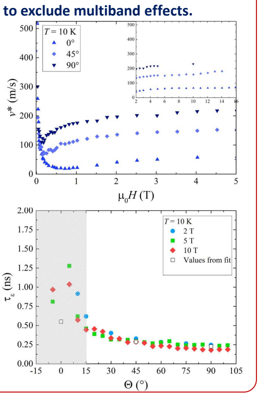




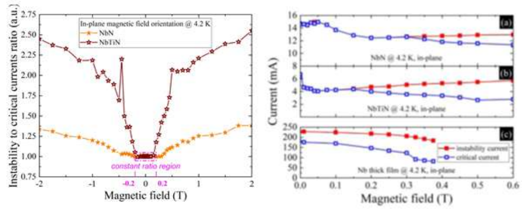
Fe(Se,Te) is well known to be a material resilient to irradiation



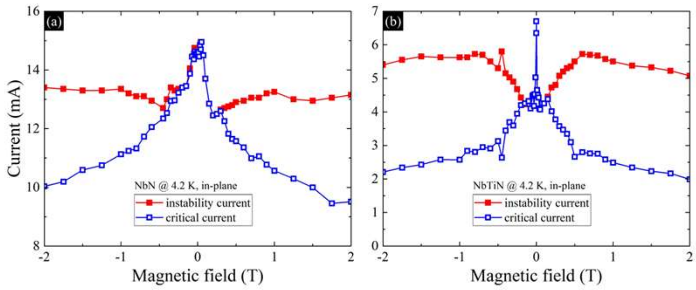
Fe(Se,Te) qp relaxation time shows features similar to *s*-wave superconductors, but it is not trivial to exclude multiband effects.



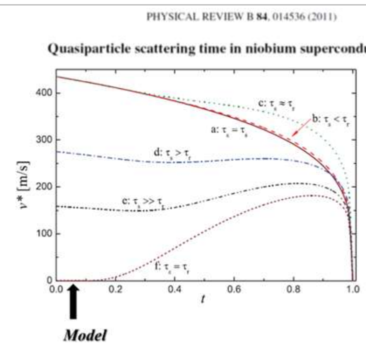
The nano-world



FLYING BIRDS EFFECT



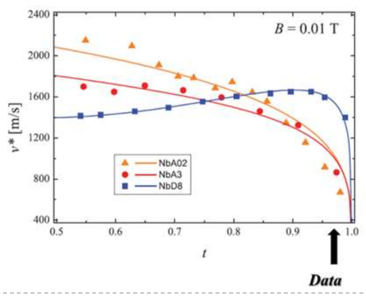
Models vs. Data

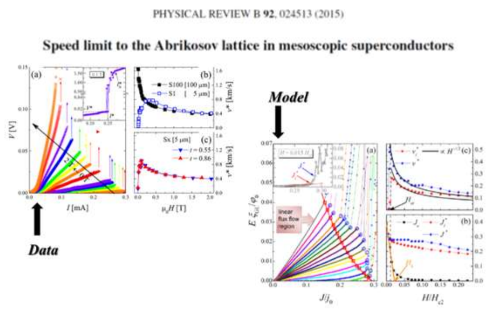


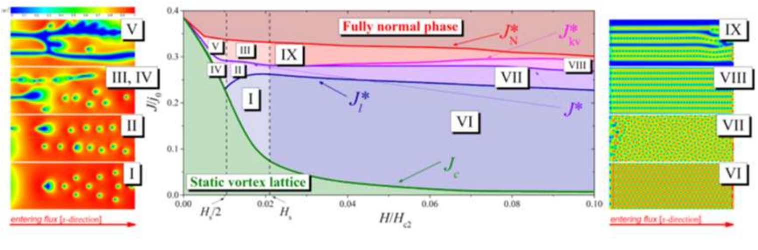
Set of $v^*(t)$ curves obtained by inverting Eq. (1), with D fixed to the value 1.5×10^{-4} m^2/s, assuming that the relaxation of the quasiparticle is due (curve a) only to the electron-phonon scattering, (curve f) only to the recombination, or (curves b, c, d, e) to both processes [here τ_s is compared with the value of $\tau_r(T)$ for $T=T_c$].

$$v^*=\left[\frac{(1-t)^{1/2}D[14\zeta(3)]^{1/2}}{\pi\tau_\epsilon}\right]^{\frac{1}{2}}\left(1+\frac{a_0}{\sqrt{D\tau_\epsilon}}\right)$$

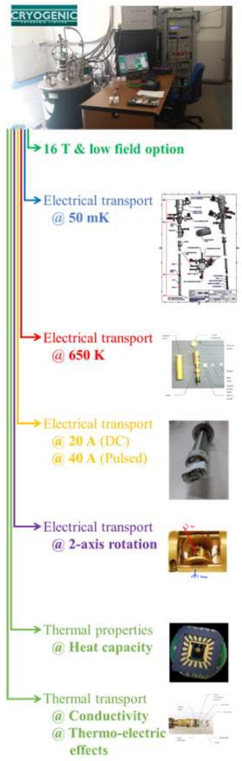
$$\frac{1}{\tau_\epsilon}=\frac{1}{\tau_s}+\frac{1}{\tau_{el}}\exp\left[-1.76m\frac{\sqrt{1-t}}{t}\right]$$







Setup & Samples



Nb films were provided by C. Attanasio's group from Salerno University.

NbN and NbTiN ultra-thin films were fabricated by N. Martucciello from CNR-SPIN in collaboration with J.C. Villégier from CEA Grenoble.

MoGe films were provided by A. Silhanek from Liège Belgium.

NbN thick film were provided by R. Cristiano's group from CNR Naples.

Al nanostructured samples were provided by V. Moshchalkov's group Leuven Belgium.

Fe(Se,Te) thin films were grown at CNR SPIN Genoa.

TDGL simulations were realized in collaboration with G. Carapella UNISA.

TDGL numerical results were provided by M. Milosevic from Antwerpen Belgium.

Modelling of scattering mechanisms was implemented in collaboration with R. Citro and C. Guarcello from Salerno University and G. Filatrella and P. Romano from Sannio University.

MUR-PRIN project "QUESTIONs"

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