Characterization and optimization of thin films using local magnetometer.

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Nanometric (d<Å), superconducting multilayers have been proposed to increase the maximum accelerating field of Nb RF cavities because of their high $H_{c1} > H_{c1}^{Nb}$ [1]. Measuring $H_{c1}$ on samples is not straightforward. One tool able to measure directly $H_{c1}$ is a local magnetometer as being developed at CEA, Saclay. The sample to be measured should be larger than the coil, thus the sample acts as an infinite plane for the coil allowing to neglect the edge and demagnetizing effect. The transition is measured via 3rd harmonic analysis using a Lock-In amplifier.

Why the need of local magnetometer

- Conventional Magnetometer (SQUID) give ambiguous results for very thin samples because of demagnetization effects (field on the back and sides, alignment issues).
- With Squid measurement, the samples exhibit a strong transverse moment, due to misalignment, which is insufficient to let vortices enter the material.
- Exact field configuration not known (applied uniform field + remnant perpendicular moment).

Local magnetometer principle

- Based on infinite slab approx. ($B \approx 0$ @ 5-6 mm away from the center of the sample).
- 3rd harmonic measurement of $H_{c1}$ developed by INFN Napoli at low field and $T > 4.5$ K [2,3].
- Design adapted at Saclay to approach accelerating cavities operating conditions ($T=2-4$ K, $B \geq 200$ mT).
- Coils able to provide 150 mT (upgrade ~ 400 mT).
- Experiment under vacuum (thermal insulation).
- Minimal contact b/w coil & sample (glass beads).
- A coil provides excitation field and detection of transition signal.
- If $f_{sample} > 4 f_{coil}$ : Sample is infinite plate => no edge effect and demagnetization effect.
- Sample is zero field cooled @ $T<T_c$.
- In Meissner state, sample = perfect magnetic mirror => no perturbation in the coil => only fundamental signal.

Measurement techniques

1) Initial method
- Fixed $L \cos(\omega t)$ applied in the coil ($B = b \cos(\omega t)$)
- Temperature ramp ($T \rightarrow 0$)
- Third harmonic signal ($3 \omega$) appears @ $T_{iso}$ when $b \rightarrow B_{iso}(T_{iso})$
- Series of $b \rightarrow$ series of transition $T \rightarrow$ reconstruction of $B_{c1}(T)$

Issue : thermal stabilization at high field (high current in the coil => heating + thermal inertia of cooling system)

2) New method
- Fixed temperature
- $L \cos(\omega t)$ applied in the coil ($B = b \cos(\omega t)$)
- $I (B)$ is increased slowly in the coil
- Third harmonic signal ($3 \omega$) appears @ $T_{iso}$ when $B \rightarrow B_{iso}(T_{iso})$
- Series of experiment at different $T \rightarrow$ reconstruction of $B_{c1}(T)$

References: