Magnetization of superconducting tube computed in 3D geometry using A-formulation in Comsol Multiphysics.

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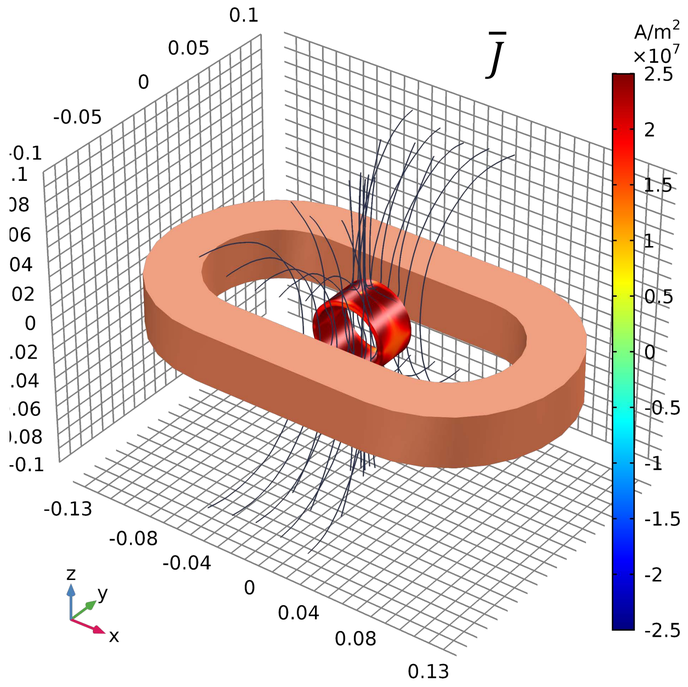
Theoretical background is the A-V formulation in 2D, which is commonly used [1]. Approximation of the critical state model controlling the distribution of current density in superconducting domains with respect to evolution of the magnetic vector potential is (1).

$$\vec{J}(x,y,z) = J_{c0}\left(\tanh\left(\frac{A_{px}-A_x}{A_n}\right)\hat{\imath} + \tanh\left(\frac{A_{py}-A_y}{A_n}\right)\hat{\jmath} + \tanh\left(\frac{A_{pz}-A_z}{A_n}\right)\hat{k}\right) \quad (1)$$

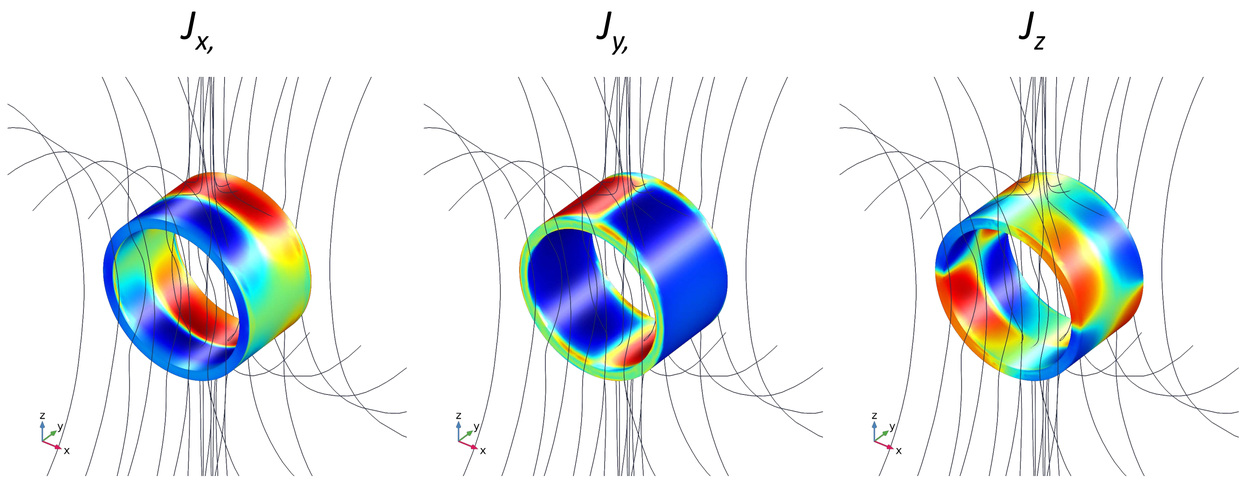
Such simple definition may locally produce current densities up to $\sqrt{3}$ times higher than J_{c0}. For the real geometry, overall error is not big and valid results can be obtained. However, for further simulation, current density definition will be corrected by (2).

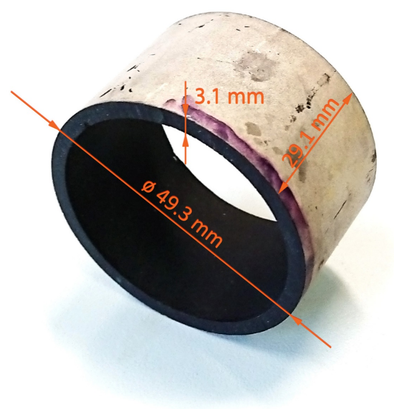
$$j_i = J_{c0}\left(\tanh\left(\frac{A_{pi}-A_i}{A_n}\right)\frac{|A_{pi}-A_i|}{\sqrt{(A_{px}-A_x)^2+(A_{py}-A_y)^2+(A_{pz}-A_z)^2}}\right) \quad (2)$$

Here, $\vec{A}_p$ and $\vec{A}$ represented previous and present values of the magnetic vector potential, respectively; J_{c0} is the critical current density of superconductor.



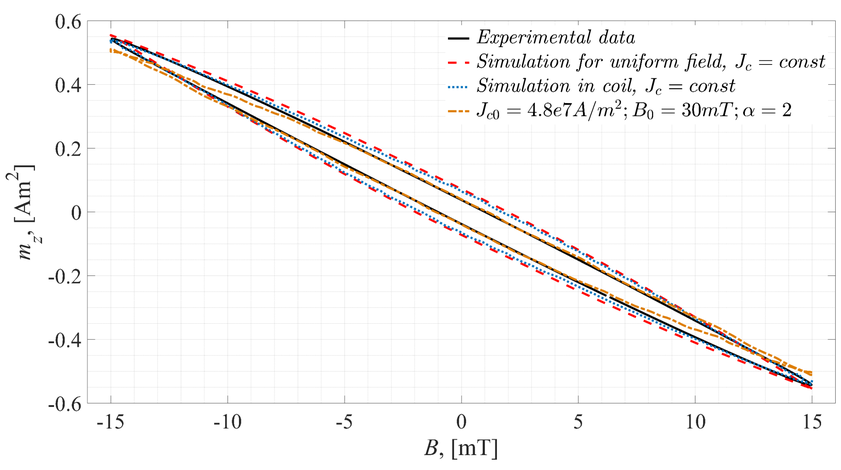
Cylinder from the melt-cast processed $Bi_2Sr_2CaCu_2O_{8+\delta}$, taken from Nexans production for BSCCO-2212 FCL program.

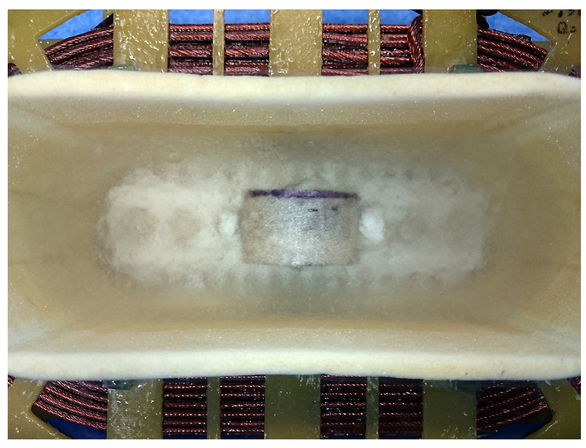


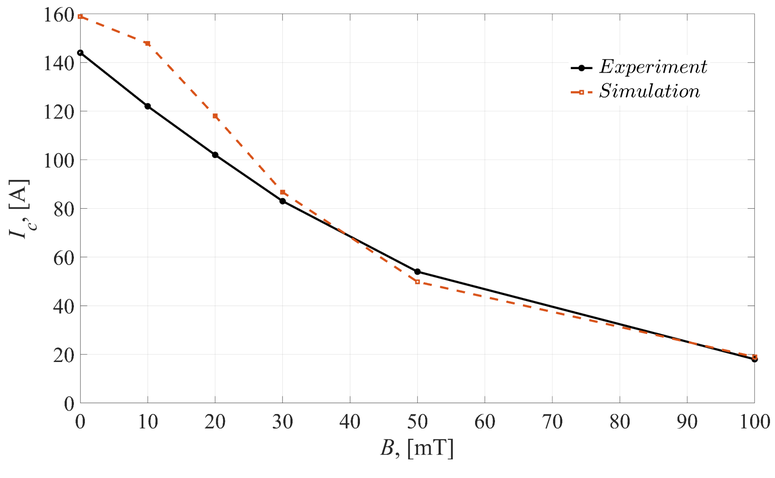


Numerical simulations were performed initially for the uniform applied magnetic field. Afterwards more realistic condition of the magnetic field generated by the racetrack coil was applied. Also the $J_c(B)$ dependence was introduced.

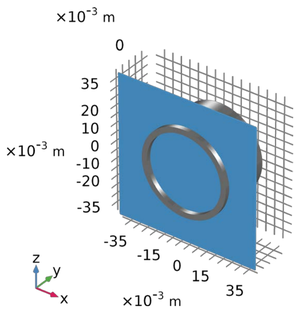
Experimental results were obtained in "Calibration-free" system at the frequency 72 Hz.



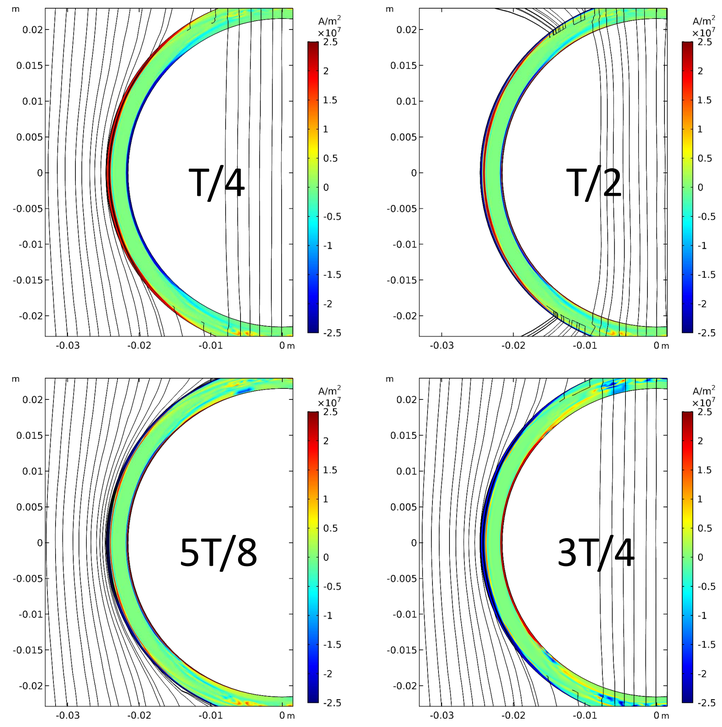




$I_c(B)$ dependence was measured on the small peace of BSCCO, cut from the tube along the main axis.



The penetration of opposite critical current density from the edges (*y*-component of current density in *zx* cross-section).



Helical ReBCO tapes forming the layer of magnetic cloak's superconducting insert.

Computation takes about 1 day and 20 hours for 851863 DOF and A_n value 2e-8 [Wb/m].

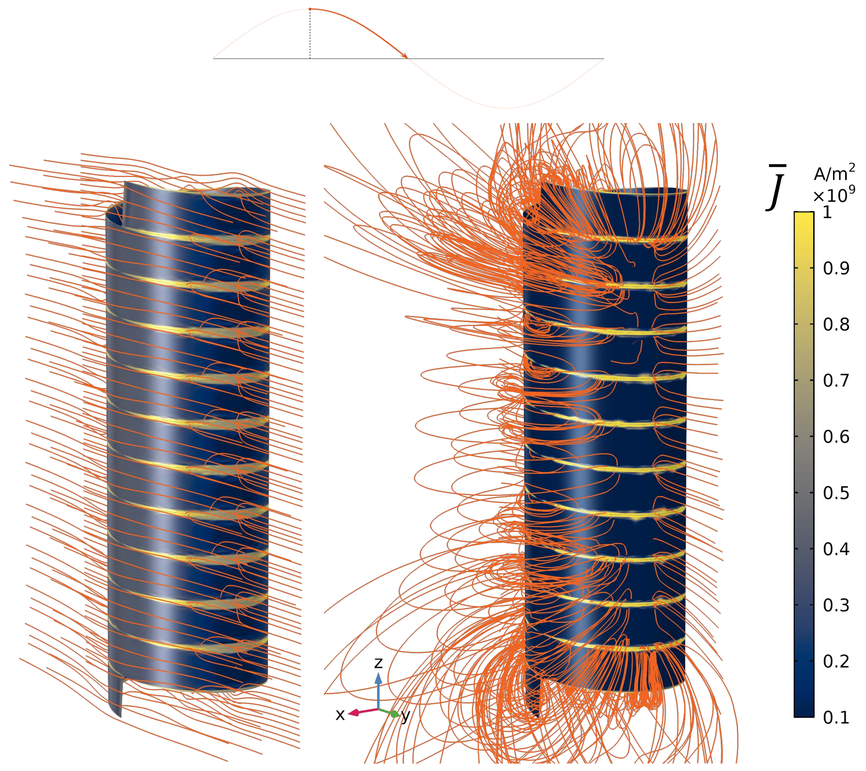
Swept mesh was used for superconductor and free tetrahedral for the rest space.

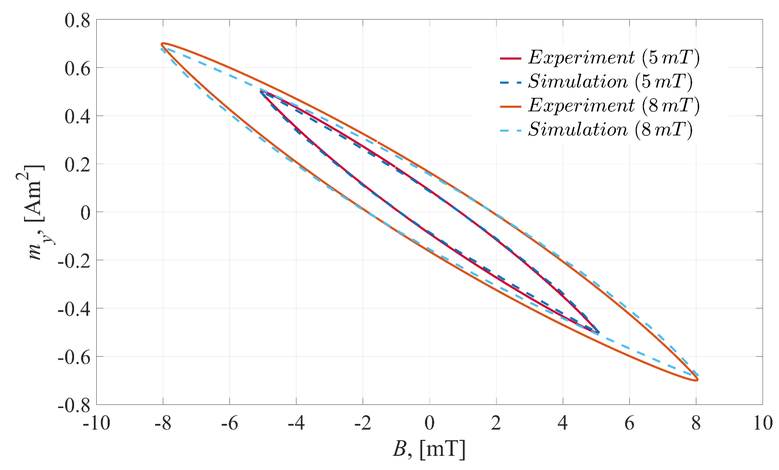
The discretization of magnetic vector potential was linear.

Computation assumes 50 μm thickness of the superconducting layer.

Agreement, shown on the plot was obtained for 50 μm gap between the turns and 400 A tape's critical current.

Measurements were performed on the SF12050-AP tape from Furukawa (SuperPower) company. Declared minimal I_c was 387 A.





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[1] GÖMÖRY F., VOJENČIAK M., PARDO E., ŠOUC J. Magnetic flux penetration and AC loss in a composite superconducting wire with ferromagnetic parts. In Superconductor Science and Technology, 2009, vol. 22, 034017. ISSN 0953-2048.