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Vortex Lattice Domain Formation in the Type-II/1 Superconductor Niobium

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Besides the well-known vortex lattice (VL), type-II/1 superconductors exhibit the intermediate mixed state (IMS), where VL domains and Meissner domains coexist, due to an attractive component of the VL interaction [1]. Despite some work in the 1970s, no detailed theoretical model for the IMS exists. Primary obstacles are the inapplicability of most standard models of superconductivity and the importance of demagnetization effects and vortex pinning.

We have readdressed the IMS in bulk niobium by combining several neutron based techniques [2],[3]. Using small angle scattering, we characterized the VL crystallography. For the larger IMS domains, we used ultra-small angle scattering to investigate the domain morphology. Additionally, neutron grating interferometry revealed information about the spatial distribution of IMS domains.

Following a field cooling protocol, we find that while the macroscopic magnetic properties remain homogeneous, vortices are gradually rearranged microscopically from a uniform VL to inhomogeneous domains. Surprisingly, this process takes place below the macroscopic freezing transition of the VL. The IMS domains form at a preferred length scale which remains nearly unchanged with temperature. These results shed new light on the detailed formation of the IMS in bulk superconductors.
[1] E. H. Brandt and M. P. Das, J. Supercond. Novel Magn. 24, 57 (2011)
[2] T. Reimann, et al, Nat. Com. 6, 8813 (2015)
[3] T. Reimann, et al, Phys. Rev. B 96(14), 144506 (2017)

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