Vortex Matter in Type-1.5 Superconductors

Victor V. Moshchalkov, A. V. Silhanek, T. Nishio, Q. H. Chen, M. Menghini, L.J. Li, J. Gutierrez, B. Raes, A. Gebremedhin, V.H. Dao, L.F. Chibotaru, N.D. Zhigadlo, and J. Karpinski

INPAC-Institute for Nanoscale Physics and Chemistry, University of Leuven, Celestijnenlaan 200 D, B-3001 Leuven, Belgium

The existence of the novel superconducting state has been demonstrated in two-component high quality MgB_2 single crystalline superconductors where a unique combination of both type-1 and type-2 conditions is realized in a single material: $\lambda_1/\xi_1<1/\sqrt{2}$for the first component of the order parameter and$\lambda_2/\xi_2>1/\sqrt{2}$ for the second one. Such materials are, in fact, neither type-1 nor type-2 superconductors (PRB 72, 180502 (2005)) and can be introduced as $''type-1.5 superconductors''$(PRL 102, 117001 (2009); PRB 81, 020506(R) (2010)), since they combine simultaneously characteristic features of both type-1 and type-2 regimes. This leads to a drastic change in the vortex-vortex interaction, which results in the appearance of stable *vortex stripes*, *clusters and gossamer-sllike slvortex patterns*. We have directly visualized these novel patterns by using scanning Hall probe microscopy, Bitter decoration and scanning SQUID microscopy. The observed patterns are in a good agreement with the molecular dynamics simulations based on the vortex-vortex interaction corresponding to the type-1.5 superconductivity. These data are also compared with the exotic vortex-vortex interactions in the so called "intermediate/mixed state" observed earlier in single gap superconductors in the vicinity of the special point $\lambda/\xi=1/\sqrt{2}$.