TT 26: Superconductivity: Vortex Dynamics, Vortex Phases, Pinning

Time: Wednesday 15:45–18:15 Location: H 3010

TT 26.1 Wed 15:45 H 3010

General critical state in type-II superconductors with longitudinal currents — •Ernst Helmut Brandt[1] and Grigorii Mikitik[1,2] — [1]Max-Planck-Institut für Metallforschung, Stuttgart — [2]B. Verkin Institute for Low Temperature Physics and Engineering, NUAS, Kharkov, Ukraine

The concept of the Bean critical state has been very successful in superconductors with vortex pinning. It states that the current density $|\mathbf{j}|$ is either zero or j_c, the critical current density, and it thus predicts sharp spatial jumps of $\mathbf{j}$. However, this usual critical state model applies only when $\mathbf{j}$ is perpendicular to the vortex lines everywhere. We generalize this model to the frequent situation when $\mathbf{j}(\mathbf{r})$ is at arbitrary angle with respect to the induction $\mathbf{B}(\mathbf{r})$, by postulating that only the perpendicular component $j_\perp$ (which causes the Lorentz force) is critical, $j_\perp \le j_c$. Surprisingly, even for the simple example of a slab in rotating magnetic field such that no flux cutting occurs, the resulting spatial profiles of $\mathbf{j}(x)$ and $\mathbf{B}(x)$ in the critical state are now smooth, diffusion like, and do not exhibit the expected sharp fronts.

[1] E. H. Brandt and G. P. Mikitik, Phys. Rev. B **76**, 64526 (2007).

TT 26.2 Wed 16:00 H 3010

Vortex Matter and Vortex Manipulation in Mesoscopic Superconducting Systems — •Roger Wördenweber[1], Eugen Hollmann[1], Jürgen Schubert[1], Rolf Kutzner[1], Konstantin Ilin[2], and Michael Siegel[2] — [1]Institute for Bio- and Nanosystems and cni - Center of Nanoelectronic Systems for Information Technology, Research Center Jülich — [2]Institute for Micro- and Nano-Electronic Systems, University of Karlsruhe

The understanding of the properties of Abrikosov vortices in mesoscopic superconducting systems that are exposed to low and high-frequencies electric fields is of interest for basic aspects of vortex matter and for potential application of superconductivity in fluxonic devices. We report on theoretical aspects and new experiments on vortex matter in patterned superconducting films. The impact of micropatterns on the vortex mobility and vortex manipulation is examined for frequencies ranging from dc to 20GHz. Conventional superconducting films (Nb and NbN) as well as HTS films (YBCO) are examined. The manipulation of the vortices in thin films is achieved either by patterning with various hole arrays (antidots of different size and geometry) or by adding nanodots. The mobility and the manipulation of the direction of vortex motion by the micro and nanostructures are analyzed as function of frequency. Vortex diodes are generated by asymmetric pinning or an additional vortex driving potential provided by a dc current. The diode effect is demonstrated for different frequency regimes.

TT 26.3 Wed 16:15 H 3010

Commensurability effects in Nb thin films with randomly diluted pinning arrays — •Daniel Bothner[1], Matthias Kemmler[1], Konstantin Ilin[2], Michael Siegel[2], Reinhold Kleiner[1], and Dieter Koelle[1] — [1]Physikalisches Institut - Experimentalphysik II and Center for Collective Quantum Phenomena, Universität Tübingen, Germany — [2]IMS, Universität Karlsruhe, Germany

We study experimentally the critical depinning current I_c versus applied magnetic field B in Nb thin films, which contain 2D arrays of circular antidots arranged in randomly diluted triangular lattices.

For measurements of electric transport close to the Nb transition temperature T_c, the sample temperature is controlled and stabilized via an optical, very low noise heating system.

We investigate samples with fixed lattice constant as well as such with fixed antidot-density and compare dilutions between 0% and 80%. Our results show some interesting features in the $I_c(B)$ patterns as commensurability effects at nonmatching fields and a significant suppression of vortex channeling for higher magnetic fields as predicted by Reichhardt *et al.* [1].

[1] C. Reichhardt and C.J. Olson Reichhardt, Phys. Rev. B **76**, 094512(2007)

TT 26.4 Wed 16:30 H 3010

Self-generated vortices in NbN ultra-thin film structures — •Konstantin Ilin[1], Michael Siegel[1], Andreas Engel[2], Holger Bartolf[2], Andreas Schilling[2], Alexei Semenov[3], and Heinz-Wilhelm Huebers[3] — [1]Institute of Micro- and Nano-Electronic Systems, University of Karlsruhe, Germany — [2]Physics Institute, University of Zurich, Switzerland — [3]DLR e.V. Institute of Planetary Research, Berlin, Germany

Detectors of electro-magnetic radiation made from NbN ultra-thin superconducting films find their application in different fields: astronomy, optical and THz spectroscopy, imaging and security. The detecting element of these devices is typically a micrometer or submicrometer wide superconducting strip operating at temperatures well below the critical temperature. The bias current required for proper operation of detectors is about the critical value. We present results on study of a current-generated critical state in 3-5 nm thick NbN structures with different width. The critical current of micrometer wide strips of ultra-thin NbN film is almost independent of temperature below 6 K. This is typically caused by de-pinning of self-generated magnetic vortices in current carrying superconductors. A reduction of the strip width leads to an increase of the critical current density approaching the value of de-pairing critical current for 300-400 nm wide stripes, which are much larger than the coherence length in NbN films. We describe the obtained results in term of the three-current model considering an enhancement of the Bean-Livingston edge barrier for vortex penetration with decreasing width of superconducting strip.

TT 26.5 Wed 16:45 H 3010

Vortex structures in ultra high purity niobium revealed by neutron scattering — •Sebastian Muehlbauer[1,2], C. Pfleiderer[1], P. Boeni[1], A. Wiedenmann[3], R. Kampmann[4], E. M. Forgan[5], and G. Behr[6] — [1]Physik-Department E21, Technische Universität München, D-85748 Garching — [2]Forschungsneutronenquelle Heinz Maier-Leibnitz, FRM II, D-85748 Garching — [3]Hahn-Meitner-Institut, D-14109 Berlin — [4]Geesthacht Neutron Facility, GKSS, D-21502 Geesthacht — [5]School of Physics and Astronomy, Birmingham UK — [6]IFW Dresden , D-01171 Dresden

Small angle neutron scattering (SANS) directly maps the vortex lattice (VL) of type II superconductors and gives valuable information on both the underlying Fermi surface and the mechanism of the superconducting pairing. But the symmetry of the VL is also mainly influenced by pinning and impurity effects. Recent studies of the VL in ultra pure samples of the classical superconductor Niobium with field applied along the four-fold (100) axis are showing frustration between the six-fold VL and four-fold crystal symmetry. Four-fold VL patterns additionally breaking the crystal symmetry have been identified in Niobium, which can be partially explained by non-local corrections in the Eilenberger model (1). The symmetry breaking transition is vanishing at a specific rotation angle of the magnetic field versus the (100) axis. As this angle also shows specific features in magnetoresistance, a direct link between the Fermi symmetry and VL symmetry maybe drawn. First experiments benefiting from time-of-flight SANS on VL will be presented. (1) M. Laver et al, Phys. Rev. Lett. 96, 167002 (2006)

15 min. break

TT 26.6 Wed 17:15 H 3010

Critical Currents in $YBa_2Cu_3O_{7-\delta}/La_{2/3}Ca_{1/3}MnO_3$ Hybrid Structures — •Märit Djupmyr[1], Soltan Soltan[2], Hanns-Ulrich Habermeier[2], and Joachim Albrecht[1] — [1]MPI für Metallforschung, Heisenbergstr. 3, D-70569 Stuttgart — [2]MPI für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart

The local critical current density in hybrid structures of high-temperature superconducting $YBa_2Cu_3O_{7-\delta}$ and ferromagnetic $La_{2/3}Ca_{1/3}MnO_3$, grown on vicinal cut substrates is measured with high accuracy using a spatially resolved magneto-optical method. A detailed study of the temperature dependence of the critical current in the film gives information about the flux pinning mechanisms. In YBCO thin films different pinning mechanisms has been found depending on temperature and microstructure of the film. We have studied what influence the ferromagnetic layer has on these pinning mechanisms and the critical current. Found were a substantial modification of the critical current that could be explained by a transfer of an inhomogeneous magnetic induction distribution from the ferromagnet to the superconductor

TT 26.7 Wed 17:30 H 3010

Signatures of the quantum zero-point motion of vortices in the cuprate superconductors — •Lorenz Bartosch[1] and Subir Sachdev[2] — [1]Institut für Theoretische Physik, Universität Frankfurt — [2]Department of Physics, Harvard University

We explore the experimental implications of a recent theory of the quantum dynamics of vortices in two-dimensional superfluids proximate to Mott insulators [L. Balents, L. Bartosch, A. Burkov, S. Sachdev, and K. Sengupta, Physical Review B **71**, 144508 (2005)]. The theory predicts modulations in the local density of states in the regions over which the vortices execute their quantum zero point motion. We use the spatial extent of such modulations in scanning tunneling microscopy measurements on the vortex lattice of BSCCO to estimate the inertial mass of a point vortex. We also discuss the influence of the quantum zero-point motion of a vortex on the electronic quasiparticle spectra and give a possible explanation for the origin of the 7 meV peaks which were observed in STM studies of the electronic structure of the vortex core in BSCCO.

TT 26.8 Wed 17:45 H 3010

Flux dynamics in superconductors with columnar array of artificial defects — •Carolina Romero-Salazar[1], Omar Augusto-Flores[2], and Christian Jooss[1] — [1]Institut fuer Materialphysik, Friedrich Hund Platz 1, 37077 Goettingen, Germany — [2]Instituto de Fisica, Universidad Autonoma de Puebla, Apdo. Post. J-48, Puebla, Mexico

In this work we extend the analysis of the dynamic properties in thin film superconductors to more complicate materials, with patterned holes or areas with locally enhanced pinning. Understanding how interactions of ensembles of vortices with artificial holes or inhomogeneous pinning take place have implications for possible technological applications, based on controlled-transport of vortices. Employing our electric field reconstruction method, we perform experimental and theoretical studies on BSSCO single crystals, where columnar defects (strong vortex attractors) are presented in cylindrical regions of 100μm diameter. The columnar defects were created by high-energy ion irradiation [1] A better understanding of vortex dynamics in presence of inhomogeneities is necessary to learn about local losses. We observe that in inhomogeneous superconductors, the vector velocity is not strictly parallel to the Lorentz force.

[1] S.S Banerjee *et al Phys. Rev. Lett.* **93** 097002 (2004).

TT 26.9 Wed 18:00 H 3010

Effect of planar defects on the stability of the Bragg glass phase of type-II superconductors — •Aleksandra Petković[1], Thorsten Emig[1,2], and Thomas Nattermann[1] — [1]Institut für Theoretische Physik der Universität zu Köln — [2]Laboratoire de Physique Théorique et Modèles Statistiques, CNRS UMR 8626, Bât. 100, Université Paris-Sud, 91405 Orsay cedex, France

It is shown that the Bragg glass phase can become unstable with respect to planar defects. A single defect plane that is oriented parallel to the magnetic field as well as to one of the main axis of the Abrikosov flux line lattice is always relevant, whereas we argue that a plane with higher Miller index is irrelevant. A finite density of parallel defects with random separations can be relevant even for larger Miller indices. Defects that are aligned with the applied field restore locally the flux density oscillations which decay algebraically with distance from the defect. We calculate the current voltage relation. The theory exhibits some similarities to the physics of Luttinger liquids with impurities.