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Grating interferometry experiments performed with university partners

In the following a brief overview of the user experiments performed within the last reporting period is given:

i) Demonstration of directional dark-field imaging with neutrons (MLZ & Physik Department E21/TUM)

The dark-field contrast modality of the grating interferometer is influenced by neutron scattering off the samples microstructure. However, the setup is only sensitive to the scattering component perpendicular to the grating lines. Hence, a single nGI scan cannot distinguish between an isotropic or an anisotropic microstructure. To overcome this limitation, the setup at ANTARES was constructed with a possibility to rotate all gratings simultaneously around the neutron beam. Hence, by an evaluation of the dark-field contrast variation as a function of the rotation angle of the gratings, it is possible to detect anisotropy directions within the microstructure of a sample. We have successfully demonstrated this capability of the new instrument at ANTARES.

ii) Quantitative dark-field evaluation (MLZ & Paul-Scherrer-Institut)

Besides mere marking of inhomogeneities on the micrometer scale, the dark-field contrast value is distinctly linked to the size, composition and shape of the microstructure. By a wavelength dependent nGI investigation, it is possible to extract quantitative structural information. In cooperation with Paul-Scherrer-Institut we have demonstrated this quantitative dark-field imaging approach for the simplest case of diluted microspheres. These data show the potential of nGI for the bulk sensitive investigation of even more complex microstructures which cannot be resolved by classical neutron imaging.

iii) Investigation of the intermediate mixed state domain structure in Nb by quantitative dark-field imaging (MLZ & Paul-Scherrer-Institut)

The intermediate mixed state in superconducting Niobium is characterized by the appearance of a magnetic domain structure. As the size of the domains lies in the range of a few µm, nGI is perfectly suited for its investigation [T. Reimann et al., Nat. Commun. 6:8813 (2015)]. In cooperation with Paul-Scherrer-Institut we used the quantitative dark-field imaging approach discussed above to study the domain structure in Nb. The aim of this experiment was to determine if the domain structure is homogeneous or if there are local variations in the domain morphology. This problem can only be addressed by nGI, as it is the sole bulk sensitive and magnetic imaging method that probes the µm range. The data evaluation is still ongoing.

iv) Investigation of the intermediate state in BiPd (MLZ & University of Birmingham)

BiPd is a superconductor which exhibits some indications of an intermediate mixed state domain structure at very low temperatures of approx. 1.5 K. In cooperation with the University of Birmingham it was planned to check the material for µm domains by means of nGI. However, the experiment had to be postponed as the cryogenic ^{3}He insert which is required to reach such low temperatures was malfunctioning caused by a cooling water problem.

Used resources: Tommy Reimann contributed to the project as PhD student until January 2016

Publications:

[1] T. Reimann, S. Mühlbauer, M. Schulz, B. Betz, A. Kaestner, V. Pipich, P. Böni and C. Grünzweig, Visualizing the morphology of vortex lattice domains in a bulk type-II superconductor, *Nat. Commun.* **6**:8813 (2015), doi: 10.1038/ncomms9813

[2] T. Reimann, M. Schulz, C. Grünzweig, A. Kaestner, A. Bauer, P. Böni and S. Mühlbauer , Neutron Dark-Field Imaging of the Domain Distribution in the Intermediate State of Lead, J. Low Temp. Phys. **182**: 107-116 (2016), doi: 10.1007/s10909-015-1399-2

[3] T. Reimann, S. Mühlbauer, M. Horisberger, C. Grünzweig, B. Betz, P. Böni and M. Schulz, The new neutron grating interferometer at the ANTARES beamline - Design, Principle, and Applications - , in preparation (2016)

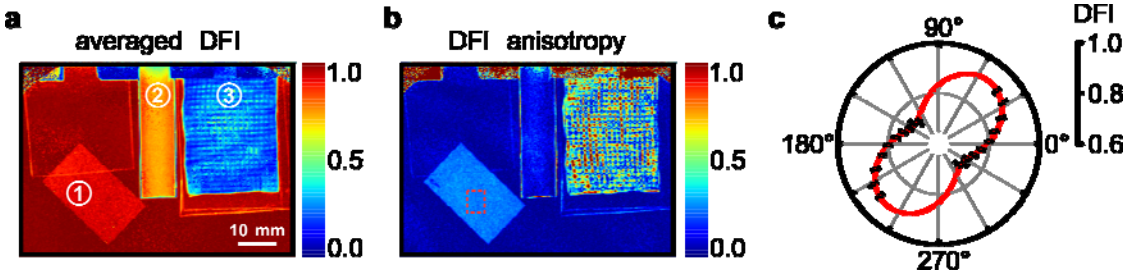

Figure 1: Directional dark-field imaging on a test object (1 - Gd µm-grating , 2 - copper rod, 3 - fiberglass mat). a: Directionally averaged DFI. b: Anisotropy of the DFI. c: DFI vs. grating rotation for the area marked in b. The angles of maximum and minimum DFI correspond to an orientation of the Gd test grating parallel or perpendicular to the setup gratings. Hence, a determination of the anisotropy direction within the object is possible by directional DFI .