Superconducting Nb films with tunable anisotropy

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Anisotropy in type-II superconductors often causes a preferred direction for motion of the vortices present in the material. Commonly, the anisotropic behavior is due to intrinsic and permanent characteristics of the sample. However, a different way to produce anisotropic flux dynamics is by applying crossing magnetic fields [1]. This extrinsic approach has the important features of being fully reversible and easily tunable. Anisotropic superconductors are today considered promising for development of active fluxonics devices such as diodes [2] and triodes [3] based on controlling the vortex matter dynamics.

In this work, magneto-optical imaging was used to investigate flux penetration in superconducting films, which in zero in-plane field behave fully isotropic. When freezing in in-plane magnetic fields the anisotropy grows dramatically. Another feature known from superconducting films is the occurrence of abrupt penetrations of large amounts of flux that visually look like dendritic structures. These dendritic patterns result from flux avalanches, which arise upon variation of the externally applied perpendicular field. The samples were niobium films with a thickness of 200 nm and shaped as squares with sides of 2.5 mm.

The frozen-in in-plane vortices strongly guide the penetration of perpendicular vortices, whereas their penetration across the array of in-plane vortices is essentially unchanged. This result provides the key to understanding why field-cooled square superconducting films show anisotropic nucleation of flux avalanches along the four edges [4]. The avalanching dendrites consistently bend towards the direction perpendicular to that of the in-plane field [5]. The experimental observations are explained based on a theoretical model for thermomagnetic avalanche nucleation in superconducting films, and by assuming that the frozen-in flux generates in-plane anisotropy in the film thermal conductance.