Active control of flux penetration in superconducting Nb films

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In type-II superconducting films subjected to external magnetic fields, the magnetic flux penetrates in form of vortices. Generally, this flux penetration occurs smoothly, with a high concentration of vortices at the edge of the sample that gradually decreases toward the sample center. However, under certain circumstances, small disturbances in the self-organized state of the vortices induce the occurrence of sudden bursts of flux invading the sample, known as thermomagnetic avalanches. In most cases, the flux avalanches have a dendritic appearance and the growth of their branches is random all over the sample. The dendritic avalanches pop up spontaneously when the magnetic field is varied, but can also be triggered by the injection of an electrical current.

In this work, we have designed a device called superconducting flux injector (SFI) that allows controlling in a predefined location along the samples edge the point in time when an avalanche will develop [1]. Using this approach, both dendritic avalanches as well as flux penetration in the smooth regime can be activated via a pulse of current. The samples were made from a 200 nm thick niobium film, and the, leads for current injection were transferred to the film through optical lithography. Each sample has a square shape with sides of 2.5 mm. The leads for current injection consist of two segments that join at the same point, as a V shape, in the middle of one of the square sample edges. The experiments were carried out using a magneto-optical imaging setup, which allows a real-time mapping of magnetic flux.

When the sample is cooled down in the presence of a sufficiently high in-plane magnetic field, the flux penetration becomes anisotropic [2]. This makes the magnetic field applied along the plane of the film a versatile external tool to control flux dynamics. We used the SFI to trigger the flux entrance and the in-plane magnetic field to guide subsequent flux penetration [3,4]. By combining the flux injector and the in-plane field we have actively triggered and manipulated the flux penetration in both the avalanching and the smooth penetration regimes.