Vortex jets in superconducting films

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The recent great interest in superconductor thin strips with the critical current I_c approaching the depairing current I_d is caused by the required close-to-I_d bias regime of superconducting microstrip single-photon detectors (SMSPDs) [1], ultrafast vortex motion at large transport currents I_{tr} [2], and the phenomena of generation of sound [3] and spin waves [4] at a few km/s vortex velocities. In this context, the issue of high I_c is related to blocking of the penetration of vortices via the strip edges, its control via material and edge-barrier engineering, and knowledge of the effects of various edge defects on the penetration and patterns of Abrikosov vortices.

In my talk, I will review our recent results on the ultra-fast vortex motion in superconductors [5]. Namely, high structural uniformity [6], fast relaxation of heated electrons [7] and perfect edges [8] are required for the realization of ultra-fast vortex motion at velocities exceeding 10 km/s.

I will further discuss vortex patterns upon penetration of vortices from single edge defects and consider the evolution of patterns from vortex chains over vortex jets to vortex rivers with increase of the transport current [9]. Next, an attempt will be made to deduce the maximal vortex velocity v^* from the current-voltage (*I*-*V*) curves at zero magnetic field (SMSPD operation condition). This attempt will be hindered by the unknown number of vortices, n_v, and the fact that a small number of fast-moving vortices can induce the same voltage as a large number of slow-moving ones.

To resolve the above issue, in our recent work [10] we have introduced an approach for the quantitative determination of n_v and v^*. The idea is based on the Aslamazov and Larkin prediction [11] of kinks in the *I*-*V* curves of wide and short superconducting constrictions when the number of fluxons crossing the constriction is increased by one. We realize such conditions in wide MoSi thin strips with slits milled by a focused ion beam and reveal quantum effects in a macroscopic system. By observing kinks in the I-V curves with increase of the transport current, we evidence a crossover from a single- to multi-fluxon dynamics and deduce $v^* \simeq 12$km/s. Our experimental observations are augmented with numerical modeling results which reveal a transition from a vortex chain over a vortex jet to a vortex river with increase of n_v and v^*. In all, our findings are essential for the development of 1D and 2D few-fluxon devices and provide a demanded approach for the deduction of maximal vortex velocities at the SMSPD operation conditions.

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