Comment on "Nonlocal In-Plane Resistance due to Vortex-Antivortex Dynamics in High-T_c Superconducting Films"

In a recent Letter [1], Kopelevich *et al.* report the finding of sign-changing in-plane nonlocal resistance in high-temperature superconductors close to the vortex-antivortex (V-A) unbinding transition. In contrast to conventional resistance measurements, where the voltage contacts are within the electrical current path, the new idea is to use potential leads placed outside the region in which the current imposed by the external source is expected to flow. Typically, six gold electrodes (1 to 6) were patterned on top of a $YBa_2Cu_3O_{7-\delta}$ film, having the width $w = 1.6$ mm, the thickness $t = 400$ nm, and a length of 2.2 mm (Fig. 1 in Ref. [1]). The identical 0.2-mm-wide electrodes, separated by 0.2 mm, lie across the whole sample width. In zero external magnetic field, with the current flowing through the contacts 1 and 4, the authors detected a "secondary" voltage between the leads 5 and 6, V_{56} (much smaller than the local voltage V_{23}), changing the sign close to the mean-field transition temperature $T_{c0} \approx 91.5$ K. This was interpreted through the occurrence of in-plane nonlocal resistance due to V-A unbinding [2,3]. The authors proposed such measurements as a tool for the study of vortex dynamics in superconductors. Here we show that the peculiar voltage V_{56} observed in Ref. [1] may have a different origin.

In principle, a nonlocal voltage can result from the motion of a vortex-pair component dragged by its partner located in the applied current region [2]. However, for the electrode configuration used in [1], the V-A pairs which can contribute to V_{56} through nonlocal effects must have a separation $r > 0.4$ mm. The existence of (bound) V-A pairs of such large separations is questionable. In the case of a finite coupling between the superconducting Cu-O layers, the thermally excited vortex structures with large r are vortex string–antivortex string (VS-AS) pairs [4], but the (binding) logarithmic electromagnetic interaction is cut off on the scale $\Lambda = 2\lambda_L^2/t$ (Ref. [11] in [1]), where λ_L is the usual London penetration depth. With appropriate $\lambda_L(0)$ and T_{c0} values, one obtains for the sample 1 in Ref. [1] $\Lambda(89\text{ K}) \sim 5\ \mu\text{m} \ll 0.4$ mm. If one tacitly assumes the excitation of (bound) V-A pairs (VS-AS, quasi-2D, and/or 2D V-A pairs) with $r > 0.4$ mm, it can be shown that the voltage generated by these pairs is undetectable in [1] even as a local voltage. As known (Ref. [6] in [1]), the V-A pairs giving rise to V_{23} are those with r larger than the probing length $r_m = 2(a - 1)wtk_BT/[s\Phi_0(I - I_c)]$, depending on the transport current I. Here, a is the I-V exponent, I_c is the critical current given by the finite interlayer Josephson coupling (which is zero for VS-AS and 2D V-A pairs), and s is the interlayer spacing. At $T = 88.9$ K, for example (Fig. 2b in Ref. [1]), with $I - I_c \approx I = 8 \times 10^{-2}$ A and $a \approx 3$, one obtains $r_m \approx 10\ \mu$m. A probing length $r_m \geq 0.4$ mm corresponds to $I \leq 2 \times 10^{-3}$ A, where V_{23} ($\ll V_{56}$) is well below the sensitivity level.

The analysis of the contribution of thermoelectric and heating effects indicates that these cannot mimic the sign-reversing V_{56} (Ref. [5] in [1]). However, a local origin for this voltage should not be excluded. Taking into account the relatively high transport current values used in [1], the zero-field approach is no longer correct. Since the lower critical field (already small close to T_{c0}) is drastically reduced in the case of thin films, the samples investigated in [1] were, at least partially, in the mixed state. Further, one can argue that the transport current has a finite component j flowing in the region between leads 5 and 6. This is mainly because the current contacts do not represent equipotential lines if the film resistivity is comparable to, or smaller than, that of gold. The huge resistivity drop at the superconducting transition will change the ratio between the gold contact resistivity and that of the film by orders of magnitude. This leads to the redistribution of the transport current, with stream lines between contacts 5 and 6, as well. The current stream lines along the edge of the sample can easily create a negative voltage V_{56}. Another reason for the deviation from the ideal current distribution (assumed in [1]) may be given by the (transversal) Hall effect in the region between contacts 1 and 4. In any case, a (local) resistance signal will appear in the region between leads 5 and 6 from the moving vortices driven by the j component along the film length. At the same time, the vortex motion due to the j component parallel to contacts 5 and 6 could generate an anomalous mixed-state Hall signal just below T_{c0} (see, for example, Ref. [5]).

In conclusion, in our opinion, the sign-changing voltage $V_{56}(T)$ illustrated in Fig. 5 in Ref. [1] results from the superposition of local signals in a particular electrode configuration.

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