Kopelevich and Esquinazi Reply: In their Comment, Miu, Jakob, and Adrian [1] have questioned a nonlocal origin of the in-plane voltage measured in $\mathrm{YBa_2Cu_3O_{7-x}}$ (Y123) high-T_c films with electrodes situated outside the electrical current path [2].

(1) The authors [1] claim that the nonlocal voltage $V_{56}(I,T)$ due to vortex-antivortex dynamics should be undetectable in the configuration used in [2]. In particular, a very short characteristic range for the vortex-antivortex interaction $\Lambda = 2\lambda_L(T)^2/l_c$ was calculated, i.e., $\Lambda(T \sim T_{\mathrm{ub}}) \sim 4\ \mu\mathrm{m}$ assuming the effective correlation length along the c axis l_c equal to the film thickness $t \simeq 400$ nm. T_{ub} is the vortex-antivortex unbinding temperature (88.97 K for sample 1 and 88.5 K for sample 2 [2]). However, in the vicinity of T_{ub} the threshold current $I_c(T)$, due to a *finite* Josephson interplane coupling, is negligibly small [2], suggesting that at $T \sim T_{\mathrm{ub}}$ the decoupling of the superconducting $\mathrm{CuO_2}$ layers takes place. Hence, the correlation length l_c at $T \sim T_{\mathrm{ub}}$ should be much smaller than the film thickness t. At large enough measuring currents and/or $T > T_{\mathrm{ub}}$ the correlation along the c axis disappears (see Ref. [12] in [2]), l_c reduces to the spacing between the superconducting layers $s \sim 1$ nm, and one gets $\Lambda > 1.5$ mm at $T > T_{\mathrm{ub}}$ for both samples 1 and 2, which is comparable to the length of the films. Therefore the nonlocal voltage $V_{56}(I,T)$ should be detectable at $T \sim T_{\mathrm{ub}}$, as was found [2]. We stress that the sample characteristics such as, e.g., O content, may influence the correlation length. Our measurements, performed on Y123 films having a finite $I_c(T)$ up to T_{c0} (sample 3 in [2]) and hence larger l_c, have revealed a much smaller nonlocal $V_{56}(I,T)$ signal indeed (see Fig. 5 in Ref. [2]).

(2) The authors [1] pointed out that the mixed state that is supposed to arise from the magnetic field generated by the applied current I_{14} may influence the measurements. Let us assume that at large enough currents the measured $V_{23}(I_{14})$ characteristics originate from the flow of the field-induced vortices. Then, we have, e.g., at $T = 91$ K, the linear "flux flow" resistivity $\rho_L = 96\ \mu\Omega\,\mathrm{cm}$ (see Fig. 4 in Ref. [2]). The local current $I_{14} = 100$ mA generates a self-field (in the region between contacts 1 and 4) $H = 2I_{14}/c\sqrt{wt/2} \simeq 11$ Oe [3], where w is the film's width. According to Bardeen-Stephen and Nozieres-Vinen models $\rho_{ff} = \rho_n(H/H_{c2})$, where the upper critical field near the superconducting transition temperature $H_{c2}(T) \simeq (dH_{c2}/dT)(T_{c0} - T)$, and ρ_n is the normal state resistivity. With $T_{c0} = 92$ K, the onset superconducting transition temperature [at $T < 92$ K, nonlinear I-V characteristics were measured at intermediate currents (Fig. 4 in Ref. [2]), indicating that the film is in the superconducting state], $\rho_n(T \sim T_{c0}) = 115\ \mu\Omega\,\mathrm{cm}$, and $dH_{c2}/dT = 2$ T/K [4,5], we calculate $\rho_{ff} \sim 6.3 \times 10^{-2}\ \mu\Omega\,\mathrm{cm}$ at $T = 91$ K, which is several orders of magnitude smaller than the measured resistivity $\rho_L = 96\ \mu\Omega\,\mathrm{cm}$. Therefore, we conclude that the resistive state is not due to the motion of field-induced vortices.

(3) The authors [1] further suggest that the nonlocal voltage $V_{56}(I,T)$ may result from a current I_{56} flowing outside the region restricted by the current leads (1–4) due to deviation from an ideal current distribution, in particular, because of a mixed state Hall effect. Let us consider ρ_L as the flux flow resistivity. The typical value for the Hall angle in the superconducting state is $\tan(\Theta_H) = \rho_{xy}/\rho_{xx} \sim 10^{-3}$ (ρ_{xy} and ρ_{xx} are the Hall and longitudinal flux flow resistivities, respectively). Assuming that the whole Hall current flows between contacts 5 and 6, the Hall electric field between contacts 5 and 6 is $E_H \simeq j_y\rho_{xy} \sim E_y\rho_{xy}/\rho_n$ [6], where $E_y \simeq j_x\rho_{xy}$ is the transverse electric field due to the vortex movement by the current density j_x between contacts 1 and 4. One estimates $V_{56} \sim 25$ nV, which is ~450 times smaller than the measured V_{56} at $T = 91$ K and $I_{14} = 100$ mA.

(4) We agree with the authors' comment, however, that in general the current distribution may not be ideal and can mask the nonlocal signal. This was observed in films with much higher resistivity, as those reported in [2], and/or with relatively high electrical contact resistance. Note also that the voltage and current patterns are expected to be sample dependent [7], influenced partially by the sample surface [8]. Therefore, a careful study of the nonlocal effects is necessary to distinguish between different contributions. Finally, we note the observation of the hysteretic jump in the I-V curves when the vortex motion is high enough (Fig. 4 in Ref. [2]). This is measured in both local and nonlocal voltages *at the same* I_{14}. This fact can hardly be understood within a local approach since $V_{23} \gg |V_{56}|$ which implies $|I_{56}| \ll I_{14}$.

Y. Kopelevich[1] and P. Esquinazi[2]
[1]Instituto de Fisica, Unicamp
13083-970 Campinas, Sao Paulo, Brazil
[2]Abteilung Supraleitung und Magnetismus
Universität Leipzig
Linnéstrasse 5, D-04103 Leipzig, Germany

Received 2 September 1998 [S0031-9007(98)08067-3]
PACS numbers: 74.76.Bz, 74.40.+k, 74.60.Ge

[1] L. Miu, G. Jakob, and H. Adrian, preceding Comment, Phys. Rev. Lett. **82**, 672 (1999).
[2] Y. Kopelevich *et al.*, Phys. Rev. Lett. **80**, 4048 (1998).
[3] E. Zeldov *et al.*, Phys. Rev. B **49**, 9802 (1994).
[4] U. Welp *et al.*, Phys. Rev. Lett. **67**, 3180 (1991).
[5] M. Kunchur *et al.*, Phys. Rev. Lett. **70**, 998 (1993).
[6] S. Artemenko *et al.*, Phys. Lett. A **138**, 428 (1989).
[7] D. Huse and S. Majumdar, Phys. Rev. Lett. **71**, 2473 (1993).
[8] S. Phillipson *et al.*, Phys. Rev. B **57**, 5512 (1998).