Comment on “Phase Controlled Conductance of Mesoscopic Structures with Superconducting Mirrors”

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Recently, Petrashov *et al.* [1,2] reported conductance measurements on an Ag crossed wire as well as a ring geometry coupled to an Al superconducting loop. Apart from the large amplitude, a striking feature of the observed oscillations is the nonsinusoidal relation between the resistance R and the applied flux Φ_a through the loop. In addition, the data on the ring geometry show a lower and an upper envelope, which depend on the flux Φ_r through the ring, with periods of Φ_0 $(= h/2e)$ and $h/4e$, respectively.

In this Comment, we point out an important aspect which has not been addressed, and which in our opinion can account for a major part of the above features. A clarification of the data is required, since the effect we discuss hides the relevant physics.

For the observation of interference effects the spacing between the superconducting electrodes has to be comparable to the normal metal coherence length $\xi_n = \sqrt{\hbar D/kT}$. This implies that a supercurrent can flow between the electrodes with an associated critical current I_c. Because of the self-inductance L of the loop (measured to be about 0.3 nH), a maximum flux LI_c can be generated by the circulating supercurrent in the loop. The total flux Φ_t through the loop is then implicitly given by

$$\Phi_t = \Phi_a - LI_c \sin\left(\frac{2\pi\Phi_t}{\Phi_0}\right). \qquad (1)$$

The response of the loop depends on the parameter $\alpha = LI_c/\Phi_0$. As shown in [3], for $\alpha > 1/(2\pi)$ the phase ϕ $(= 2\pi\Phi_t/\Phi_0)$ across the superconductors does not change continuously, but jumps when a critical value ϕ_c is reached, so that only the range $-\phi_c < \phi < \phi_c$ (mod 2π) is scanned. When we assume that the actual relation between the resistance and the phase is given by $\Delta R = -R_0 \cos(\phi)$, the above argument can account for the parabolic shape of the oscillations in the crossed wire geometry [4,5]. Although some deviations from exact parabolicity are visible in the data, it is nevertheless difficult to determine α and R_0 separately in this geometry.

However, similar considerations can be used to explain the data on the ring geometry. Here two effects take place: First, the critical current will be modulated by the flux Φ_r through the ring. We assume a SQUID-like dependence: $I_c = I_{c0} \cos(\pi\Phi_r/\Phi_0)$. Second, for the calculation of ΔR_t we assume that we can add the contributions of both arms of the ring, taking into account their different phases: $\Delta R_t = -R_0 \cos(\phi + \pi\Phi_r/\Phi_0) - \gamma R_0 \cos(\phi - \pi\Phi_r/\Phi_0)$. Here we included the possibility for an asymmetry between both arms of the ring, when $\gamma \neq 1$. Figure 1 shows the calculated result for which a best fit was obtained, with $LI_{c0}/\Phi_0 = 0.22$, which implies $I_{c0} = 1.5$ μA, and $\gamma = 1.3$. A small asymmetry is required to obtain a finite amplitude at the nodes of the oscillations.

Given the assumptions made, the model reproduces the experimental features quite well. The description of the interference in the ring as the sum of the interferences in both arms may not be fully justified. Also we have ignored thermal activation which may result in the switching of the system between adjacent flux states [3].

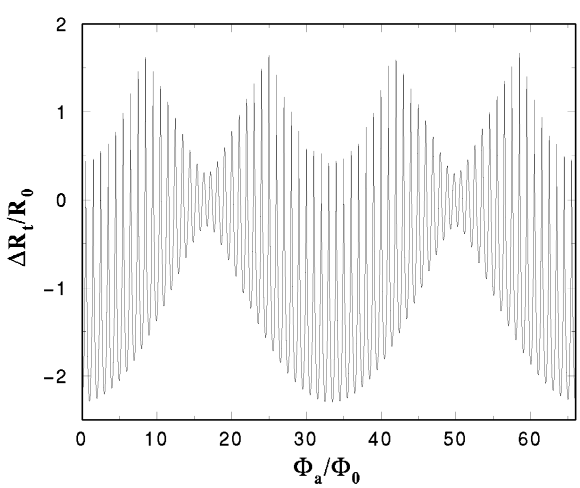

FIG. 1. Resistance as a function of applied field, calculated for $\Phi_r/\Phi_a = 0.03$.

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[2] V. T. Petrashov, V. N. Antonov, P. Delsing, and T. Claeson, Phys. Rev. Lett. **74**, 5268 (1995).
[3] A. Barone and G. Paterno, *Physics and Applications of the Josephson Effect* (Wiley, New York, 1981), p. 362.
[4] The Sb/Al structures show a purely sinusoidal behavior, which can be attributed to the absence of a supercurrent in these samples.
[5] S. G. den Hartog *et al.* (to be published) studied quasiparticle interference in a similar structure. Because of the smaller value of α, the oscillations remained sinusoidal, albeit with the addition of a small component with $h/4e$ periodicity.

