Comment on "Conductance fluctuations in mesoscopic normal-metal/superconductor samples"

Recently, Hecker et al. [1] experimentally studied magnetoconductance fluctuations in a mesoscopic Au wire connected to a superconducting Nb contact. They compared the rms magnitude of these conductance fluctuations in the superconducting state (rms($G_{NS}$)) to that in the normal state (rms($G_N$)) by increasing the magnetic field above the critical field of 2.5 T. It was reported that rms($G_{NS}$) was about 2.8±0.4 times larger than rms($G_N$), which should confirm the theoretical predicted enhancement factor of $2\sqrt{2} \approx 2.8$.

In this Comment, we show that their claim is not justified. Although not explicitly mentioned in Ref. [1], we have to assume that the rms($G$) was calculated according to: $\text{rms}(G) = \text{rms}(R)/R^2$, where $\text{rms}(R)$ denotes the rms magnitude of the measured resistance fluctuations and $R$ the total measured resistance. The point we want to make is that the authors did not take into account the presence of an incoherent series resistance $R_{\text{series}}$ from the contacts, which is different when the Nb is in the superconducting or normal state. Since the measured $\text{rms}(R)$ only originates from the phase-coherent part of the disordered conductor, with resistance $R_c$, the correct procedure is to calculate $\text{rms}(G)$ according to: $\text{rms}(G) = \text{rms}(R)/R_c^2 = \text{rms}(R)/(R - R_{\text{series}})^2$. As shown below, when we correct for the presence of this series resistance, we find that rms($G_{NS}$) is not significantly larger than rms($G_N$).

Their device consists of a narrow Au wire (Au$^w$, length $L = 1.0\mu$m, width $W = 0.13\mu$m) connected at its ends to a macroscopic Nb and Au contact (Nb$^c$ or Au$^c$) via a rectangular shaped contact (Nb$^c$ or Au$^c$, $L = 0.8\mu$m, $W = 1.6\mu$m). The total resistance is the sum of these five contributions: $R = R_{\text{Nb}} + R_{\text{Au}} + R_{\text{Au}}^c + R_{\text{Au}}^c + R_{\text{Au}}^w$. As shown below, when we correct for the presence of this series resistance, we find that rms($G_{NS}$) is not significantly larger than rms($G_N$).

TABLE I. The measured resistance $R_{NS}$ and uncorrected conductance fluctuations rms($G_{NS}$) in the superconducting state at $T=50$ mK and $B=1$ T, and the measured resistance $R_N$ and the corrected conductance fluctuations rms($G_N$) in the normal state at $T=50$ mK and $B=4$ T.

|            | sample 1 | sample 2 |
|------------|----------|----------|
| $R_{NS}$ (Ω) | 11.60    | 9.72     |
| $R_N$ (Ω)   | 15.87    | 14.34    |
| rms($G_{NS}$) (e²/h) | 0.16 ±0.02 | 0.14 ±0.02 |
| rms($G_N$) (e²/h)    | 0.109 ±0.006 | 0.109 ±0.009 |
| rms($G_{NS}$)/rms($G_N$) | 1.5 ±0.2   | 1.3 ±0.2  |

Since the series resistances of the Au contact ($R_{\text{Au}}^c + R_{\text{Au}}^w \approx 1.2 R_{\text{Au}}^c \approx 1.1$ Ω) are small compared to phase-coherent resistance of the Au wire (10.5Ω), we will only correct for the series resistances of the Nb contact ($R_{\text{Nb}} + R_{\text{Nb}}^c \approx 1.2 R_{\text{Nb}}^c \approx 4.8$ Ω). This series resistance is only present in the normal state and is exactly equal to the increase in resistance when the magnetic field exceeds $B_c$ (see Fig. 1a). We note that not only the macroscopic Nb contact is regarded to be incoherent, but the rectangular shaped Nb contact as well. Namely, the phase-breaking length $L_\phi \equiv \sqrt{D_{\text{Au}}/D_{\text{Nb}}}$ for Nb is expected to be reduced compared to $L_\phi \approx 0.6\mu$m for Au by $\sqrt{D_{\text{Au}}/D_{\text{Nb}}}$, which implies that the resistance fluctuations from this Nb rectangle are strongly suppressed due to ensemble-averaging as well.

In Table I we have reproduced the measured (average) resistance of the two studied samples in the normal state and in the superconducting state. We did not correct rms($G_{NS}$) [2]. The rms($G_N$) has been corrected as described above. As a result, the rms($G_N$) are a factor of $(R_N/R_{NS})^2 \approx 2$ larger than reported in Ref. [1] and consequently the ratio rms($G_{NS}$)/rms($G_N$) becomes about 1.4±0.2. We doubt, however, that the remaining difference from 1 is significant, since the statistical error could well be larger than 0.2 due to the fact that only a few large fluctuations determine rms($G_{NS}$) (see Fig. 1b) and Fig. 2).

In conclusion, we have argued that the measured rms($G_{NS}$) is not significantly enhanced compared to rms($G_N$), and it remains an experimental challenge to observe the predicted enhancement factor of $2\sqrt{2}$.

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[1] K. Hecker, H. Hegger, A. Altland, and K. Fiegle, Phys. Rev. Lett. 79, 1547 (1997).
[2] The reported values for rms($G_{NS}$) are considerably smaller than the rms magnitude of the sample-specific conductance fluctuations of about $\text{rms}(G_{NS}) \approx 1.0e^2/h$ observed in both a cross-shaped and a T-shaped 2-dimensional electron gas coupled to superconductors: S.G. den Hartog et al., Phys. Rev. Lett. 77, 4954 (1996); S.G. den Hartog et al., ibid. 76, 4592 (1996). A comparison with the normal state values was not made in these experiments.