Asymmetric edge supercurrents in $MoTe_2$ Josephson junctions: Supporting Information

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Extraction of the supercurrent distribution with the Dynes-Fulton method

For a Josephson junction exposed to a perpendicular magnetic field B, the magnitude of the critical current $I_c(B)$ is strongly correlated with the supercurrent distribution $J_c(x)$. To understand this relationship, we first consider the complex Fourier transform of $J_c(x)$, which yields a complex critical current function,

$$I_c(B) = |\mathcal{I}_c(B)| = \left| \int_{-\infty}^{+\infty} J_c(x) exp(\frac{i2\pi L_{eff}Bx}{\Phi_0}) dx \right| \quad (1)$$

where x represents the dimension along the width of the junction, and $L_{eff} = L + 2\lambda$ stands for the effective length of the junction. Additionally, Φ_0 is the magnetic flux quantum with a value of $\frac{h}{2e}$. In the following, we will derive $J_c(x)$ from the observed $I_c(B)$ pattern using the method proposed by Dynes and Fulton [1].

When the current distribution is symmetric, *i.e.*, the odd part of $exp(\frac{i2\pi L_{eff}Bx}{\Phi_0})$ vanishes in the integral, Eq. (1) becomes $I_E(B) = \int_{-\infty}^{+\infty} J_E(x) cos\left(\frac{2\pi L_{eff}Bx}{\Phi_0}\right) dx$. However, if the current distribution has a small odd component, we also need to consider the Fourier transform of this odd component, $I_O(B) = \int_{-\infty}^{+\infty} J_O(x) sin\left(\frac{2\pi L_{eff}Bx}{\Phi_0}\right) dx$. Thus, the overall complex critical current is

$$\mathcal{I}_c(B) = I_E(B) + iI_O(B) \quad (2)$$

The observed critical current $I_c(B)$ is given by $I_c(B) = \sqrt{I_E^2(B) + I_O^2(B)}$. Through appropriate mathematical manipulation, we can recover $J_c(x)$ from the observed $I_c(B)$. The even component, $I_E(B)$, is obtained by flipping the sign of alternate lobes in the $I_c(B)$ pattern, as shown in Supplementary Fig. 1 (b). The odd component, $I_O(B)$, is derived by interpolating between the minima of $I_c(B)$ and flipping sign between lobes, as shown in Supplementary Fig. 1 (c). Finally, by performing an inverse Fourier transform of $\mathcal{I}_c(B)$, we can obtain the supercurrent density profile,

$$J_c(x) = \frac{1}{\Delta BW} \left| \int_{B_{min}}^{B_{max}} \mathcal{I}_c(B) exp(\frac{-i2\pi L_{eff}Bx}{\Phi_0}) dB \right|. \quad (3)$$

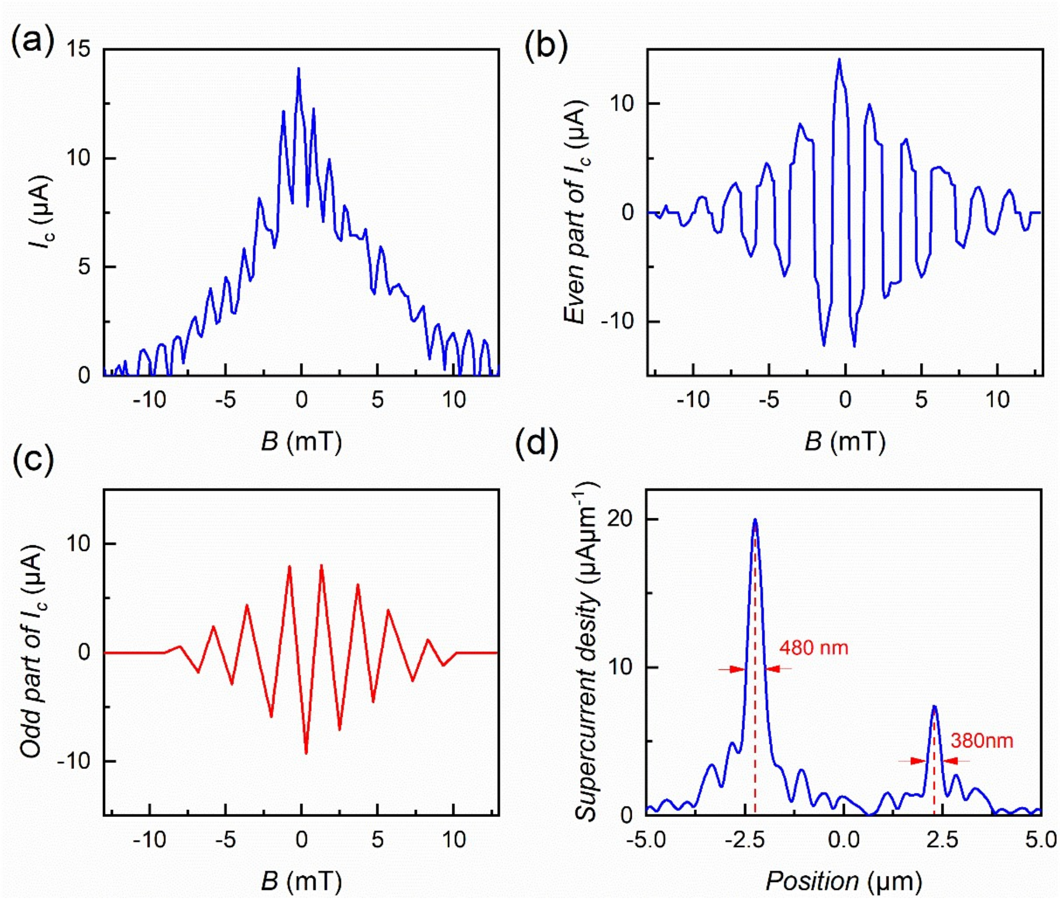

Figure S1. (a) Field dependence of the critical current $I_c(B)$. (b) The critical current $I_E(B)$ corresponding to the even component of the current distribution $J_E(x)$. (c) The critical current $I_O(B)$ corresponding to the odd component of the current distribution $J_O(x)$. (d) The derived current density distribution $J_c(x)$.

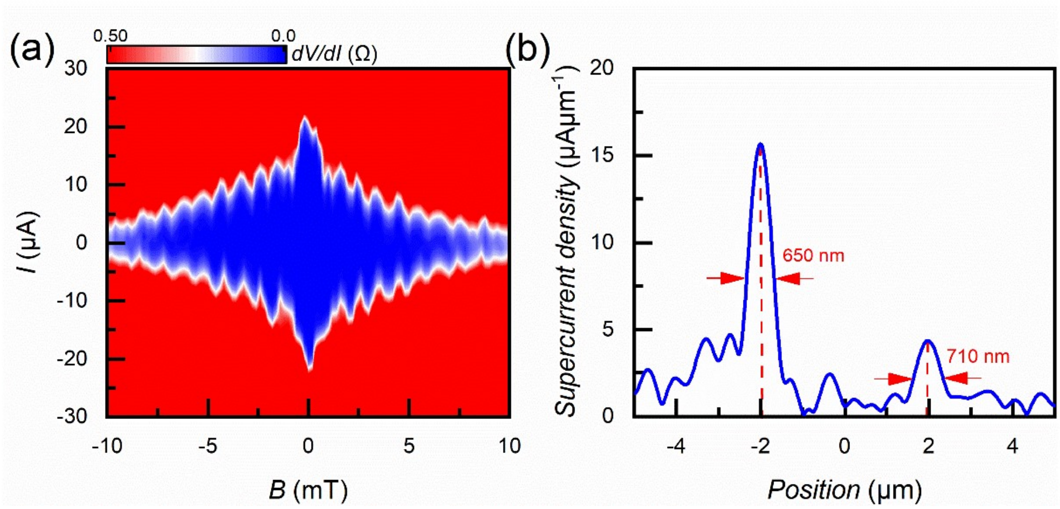

Figure S2. Asymmetric edge supercurrents were also observed in another Nb/$MoTe_2$/Nb Josephson junction with L=400 nm, W=3.94 μm, and t=50 nm. (a) Color map of the differential resistance versus the current bias and magnetic field at T=0.9 K. (b) The supercurrent density distribution derived with the Dynes-Fulton method, clearly showing the presence of edge states with characteristic widths of 650 nm and 710 nm, respectively.

Supporting reference

[1] R. C. Dynes and T. A. Fulton, *Phys. Rev. B*, 1971, **3**, 3015-3023.