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Longitudinal Josephson effect in bilayer systems with electron-hole pairing

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The study investigates non-dissipative longitudinal current states in bilayer systems with pairing of spatially separated electrons and holes in the presence of a potential barrier that divides the system into two macroscopic regions. The longitudinal current flowing across this barrier is identified as the longitudinal Josephson effect, while the current between the electron and hole layers across the insulating interlayer is termed the transverse Josephson current. In practical experimental setups, the transverse current can be made negligible, and is therefore neglected in this study.

The analysis reveals that the longitudinal current's dependence on the tunneling matrix elements is strongly influenced by the system's density. In high-density systems, where the size of the electron-hole pairs greatly exceeds the average inter-pair distance, the current is proportional to the product of the tunneling matrix elements in the electron and hole layers. This means then for the longitudinal Josephson effect to occur in a high-density electron-hole bilayer system, the presence of weak coupling in both layers is required. In contrast, in low-density systems, the current is inversely proportional to the sum of the heights of the potential barriers. This result implies that in a low-density limit even in the absence of a barrier in one of the layers, the longitudinal Josephson effect will still occur due to the strong coupling of the pair components.

The obtained results demonstrate that non-dissipative electric currents can flow through a potential barrier in bilayer systems with pairing of spatially separated electrons and holes.

Primary authors: Dr KONSTANTYNOV, Oleksandr (B.Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine); Prof. SHEVCHENKO, Sergiy (B. Verkin ILTPE of NASU)

Presenter: Dr KONSTANTYNOV, Oleksandr (B.Verkin Institute for Low Temperature Physics and Engineering of the National Academy of Sciences of Ukraine)

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