

Non-stationary longitudinal Josephson effect in bilayer systems with electron-hole pairing

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The non-stationary longitudinal Josephson effect in bilayer systems with pairing of spatially separated electrons and holes is investigated [1]. The tunneling current between two weakly coupled electron-hole condensates (right and left) is analyzed in the presence of an external voltage applied along the layers. Two limiting regimes are considered: the high-density regime, where pairing occurs in momentum space similarly to conventional superconductors, and the low-density regime corresponding to a Bose-Einstein condensate of spatially indirect excitons. Using the tunneling Hamiltonian approach, expressions for the quasiparticle, superconducting, and interference contributions to the tunneling current are derived. It is shown that in the high-density limit, the quasiparticle and interference currents vanish at zero temperature below a threshold voltage determined by the energy gap, so that only the supercurrent remains. In contrast, in the low-density regime, the gapless spectrum of collective excitations leads to finite dissipative contributions even at zero temperature, resulting in damping of Josephson oscillations. For spatially separated tunneling barriers with a distance exceeding the coherence length, phase jumps occur at each barrier, resulting in voltage oscillations across the electron and hole barriers and a nonsinusoidal current-phase relation governed by the critical currents of the two barriers. Observation of the characteristic features of the longitudinal Josephson effect would provide direct evidence of superfluidity in the bilayer exciton condensate [2].

[1] O. M. Konstantynov and S. I. Shevchenko, *Low Temp. Phys.* **52**, 1063 (2026). <https://doi.org/10.1063/10.0044481>

[2] F. Pascucci, A. R. Hamilton, M. V. Milošević, and D. Neilson, arXiv:2606.23303 (2026). <https://doi.org/10.48550/arXiv.2606.23303>

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