RESIDUAL DISSIPATION OF A STRONGLY INTERACTING SUPERFLUID FLOWING THROUGH A DIGITALLY CONTROLLED MESOSCOPIC CHANNEL

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Strongly interacting fermionic superfluids at unitarity provide a powerful platform to study transport in regimes that are difficult to access theoretically. Here, we investigate the flow of a unitary two-component Fermi gas through a long channel connecting two large reservoirs. Using a digital micromirror device, we precisely control the width of the channel and tune the transport region from one dimension (1D) to two dimensions (2D), enabling a systematic study of dissipation across the dimensional crossover. The central observable is the oscillatory motion of the superfluid between the two reservoirs. While the oscillation frequency is well described by the interplay between the reservoirs' compressibility and the channel's kinetic inductance, the decay of the oscillations reveals the dissipation mechanisms of the superfluid flow. We observe a non-monotonic dependence of the dissipation on channel width when crossing over from a 1D to a 2D transport regime. In low-dimensional superconductors and superfluids, the residual resistance arises from topological fluctuations of the order parameter. In the deep 1D regime, dissipation is governed by phase-slips. Our measurements are consistent with the Langer–Ambegaokar–McCumber–Halperin (LAMH) theory and experimentally confirm the predicted exponential dependence of the activation factor on channel width over more than ten orders of magnitude. In the 2D regime, by contrast, the observations are consistent with dissipation mediated by the nucleation of vortex–antivortex pairs and their subsequent motion across the channel. Between these two limits, we identify a crossover region in which both phase-slips and vortices are simultaneously suppressed. Our measurements suggest a route to minimize dissipation in superconducting devices and provide a benchmark for theoretical efforts aimed at describing the dimensional crossover.

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