Critical Velocity and Dissipation of an Ultracold Bose-Fermi Counterflow

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Superfluidity is amongst the most impressive macroscopic manifestations of quantum behavior. Frictionless flow has been observed in several low-temperature quantum systems, such as liquid helium [1,2], or more recently ultracold gases [3-5]. Several hallmarks of superfluidity such as critical velocity, quantized vortices, and second sound have been observed [6-11], in both liquid helium and ultracold gases, and in both Bose and Fermi systems.

However, despite intensive experimental efforts in the liquid helium community, no double Bose-Fermi superfluid had been reported before the recent realization in our group. Indeed, strong interactions between liquid ^{3}He and ^{4}He lead to a demixion at low temperature that prevents the double superfluid to appear [12]. Here, we use the high level of tunability offered by ultracold gases to control their interactions and obtain a double Bose-Fermi superfluid of fermionic ^{6}Li and bosonic ^{7}Li. We have typically $N_f = 3.5 \cdot 10^5$ fermionic atoms and $N_b = 4 \cdot 10^4$ bosonic atoms at a temperature of about 100 nK, which is below the critical temperature for superfluidity for both the Bose and the Fermi cloud [13].

To probe the superfluidity of the mixture, we induce a relative oscillating motion between the two gases and study the dynamics of the counterflow. First, for low-amplitude oscillations, we observe long-lived oscillations during up to 5 s, which confirms the superfluidity of the mixture. Second, by raising the relative oscillation velocity and with a fine tuning of the interaction strength, we measure the critical velocity v_c of the system in the BEC- BCS crossover and compare it to a recent prediction [14]. We find that it is close to the sound velocity for the Fermi gas near unitarity [15]. Third, raising the temperature of the mixture slightly above the superfluid transitions reveals an unexpected phase locking of the oscillations of the clouds induced by dissipation. This can be interpreted with a Zeno-like model induced by dissipation [15].

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