Dissipation in Bose-Einstein Condensates

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I will present two experiments with atomic Bose-Einstein condensates, where dissipation plays a central role.

The first is the observation of a dissipative phase transition. We realize an atomic superfluid, which is subject to drive and dissipation at the same time. The steady-states of the system depend on the competition between the two processes. Therefore, upon parameter change, the system can undergo a dissipative phase transition between different types of steady-states. One of the paradigmatic examples for a first order dissipative phase transition is the driven nonlinear single-mode optical resonator. I will report on the corresponding realization within an ultracold bosonic gas, which generalizes the single-mode system to many modes and stronger interactions [1]. We measure the effective Liouvillian gap of the system and find evidence for a first order dissipative phase transition. Due to the multi-mode nature of the system, the microscopic dynamics allows us to identify a non-equilibrium condensation process.

#In the second experiment we have realized Shapiro steps in a Bose-Einstein condensate. Shapiro steps occur in the reverse AC Josephson effect, which is one of the three fundamental effects in superconducting Josephson junctions. When a DC and an AC current are applied simultaneously to a Josephson junction, finite voltage steps are generated across the junction. The voltage is linked to the applied frequency via V= h/e x f, where f is the frequency of the alternating current. The series connection of several such junctions in one device corresponds to the current voltage standard. Following the protocol proposed by Singh et al [2], we move a narrow barrier through the superfluid at a constant velocity, which corresponds to a DC particle current through the barrier. At the same time, we perform a sinusoidal modulation of the barrier velocity with frequency f, which corresponds to an additional AC current through the barrier. When the instantaneous velocity of the barrier exceeds the critical velocity of the superfluid, a finite particle imbalance occurs between the two sides of the barrier. We find that the corresponding chemical potential difference takes on discrete values corresponding to Shapiro steps. We characterize the Shapiro steps and the parameter range in which they can be observed in our experiment.
Our experiment continues a long story of research with atomic Josephson physics, which had is origin in Heidelberg almost two decades ago.

[1] J. Benary et al., New J. Phys. 24, 103034 (2022)
[2] V. P. Singh, J. Polo, L. Mathey, and L. Amico. arXiv:2307.08743 (2023)
[3] M. Albiez et al. Phys. Rev. Lett. **95**, 010402 (2005)