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Driving transitions between quantized flow states in an atomtronic circuit

STEPHEN ECKEL, Joint Quantum Institute (NIST/UMD)

Superfluidity, or flow without resistance, is a macroscopic quantum effect that is present in a multitude of systems, including liquid helium, superconductors, and ultra-cold atomic gases. In superconductors, flow without resistance has led to the development of a number of useful devices. Here, I will present our work studying a superfluid analog to the rf-superconducting interference device (SQUID). Our atomtronic analog is formed in a ring-shaped Bose-Einstein condensate (BEC) of sodium atoms. Ring condensates are unique in that they can support persistent currents that are quantized. We drive transitions between persistent current states using a rotating perturbation, or weak link. Here, rotation acts as the analog to magnetic field in superconductors. In our system, a current (as viewed in the frame co-rotating with the perturbation) develops to oppose any change in rotation. If the rotation rate is sufficiently large, the critical current of the superfluid is exceeded in the weak link region, causing a transition to a state of larger persistent current. The strength of the perturbation tunes the critical rotation rates. Like the rf-SQUID, the transitions show hysteresis rotation rates that increase the quantized current are different from those that decrease the current. The size of the hysteresis loop allows us to explore the microscopic mechanisms responsible for the transitions. In a more recent experiment, we have observed the time it takes for the first persistent current state to decay in the presence of a stationary perturbation. The measured timescales depend strongly on temperature, but in a way that suggests that other physical effects, like quantum coherence, could also play a role in the transitions between current states.