Shapiro steps in a strongly-interacting atomic Josephson junction under AC drive

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Abstract: We report on the observation of Shapiro steps in the current-chemical potential characteristic of an atomic Josephson junction under AC drive, unveiling the microscopic mechanism behind the phenomenon.

The Josephson effect is one of the most striking manifestations of a macroscopic system phase coherence. Besides representing a powerful probe of phase coherence, Josephson junctions (JJ) are also fundamental building blocks for atomtronics circuits, thanks to their well defined current-chemical potential and current-phase characteristics.

Here, I report on our recent research on the response of an atomic JJ with Fermi superfluids of lithium-6 under an AC driving [1]. To inject in the junction an alternate current, we modulate the position of the tunneling barrier at a given frequency [2] and probe the chemical potential imbalance developed across the junction after a few modulation periods. The AC drive introduces in the current-chemical potential characteristic a number of Shapiro steps at a chemical potential value that is an integer multiple of the driving frequency, similarly to superconducting JJ with an external radiofrequency drive. We connect the presence of the steps to the synchronization of the relative phase at the junction with the external drive, which leads to n phase slips events in the n-th Shapiro steps, which we could directly access by counting the number of emitted vortices. Besides providing the first experimental observation of Shapiro steps in a fermionic atomic JJ, our work highlights the microscopic mechanism behind such a phenomenon, providing important insights on the role of synchronisation in AC driven junctions. Moreover, our system successfully realizes the first AC driven atomtronic circuit, opening for more complex architectures.

References

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[2] V. P. Singh, J. Polo, L.Mathey and L. Amico, "Shapiro steps in driven atomic Josephson junctions." *Phys. Rev. Lett.*, *133*(9), p.093401 (2024.)