An Interaction Quench Heat Engine Using a One-Dimensional Bose Gas

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Quantum thermodynamics is a highly active field thanks in part to its link with the development of future quantum technologies, but also to its connection with the advancement of theoretical and experimental physics. The quantum Otto cycle, shown in Figure 1, has been a particular focus due to its experimental realisability. In recent years there has been a growing focus on many-body quantum heat engines (QHE's) since it was shown in Ref. [1] that these machines are capable of outperforming an ensemble of single-particle heat engines operating under a quantum Otto cycle with the same resources, thus theoretically demonstrating a many-body quantum advantage. The Lieb-Liniger model of the one-dimensional (1D) Bose gas is ideal for the implementation of QHE's due to its rich phase diagram and experimental realisability. Recently, the concept of an interaction-driven many-particle QHE was introduced [2], where the control over inter-atomic interaction strength was utilized for the production of work in a uniform 1D Bose gas. Taking advantage of the many theoretical tools and exact results available for the Lieb-Liniger model at finite temperature, we investigate the performance, focusing on total work output and efficiency, of an interaction-driven many-body QHE, exploring the entire phase diagram for the experimentally relevant case of a harmonically trapped 1D Bose gas.

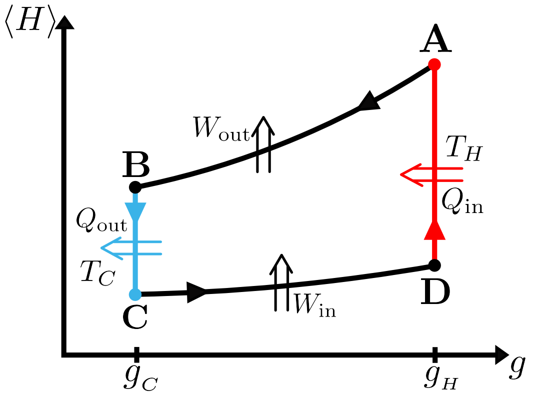

Figure 1: Interaction-driven quantum Otto cycle for a 1D Bose gas. This cycle consists of four strokes: $(A \to B)$ starting from equilibrium at temperature T_H, while not coupled to a reservoir, the interaction strength, g, of the system is reduced from g_H to g_C, producing a difference in the energy, $\langle H \rangle$, associated with work output $W_{\text{out}} < 0$. $(B \to C)$ the system is put in contact with a cold reservoir at temperature T_C, reaching equilibrium, the energy flow from the system to the reservoir denoted Q_{out}. $(C \to D)$ the system is decoupled from the cold reservoir, and the interaction strength is ramped down from g_C to g_H, transferring work $W_{\text{in}} > 0$ to the system. $(D \to A)$ the system is put in contact with a hot reservoir at temperature T_H, reaching equilibrium, the energy flow from reservoir to system denoted Q_{out}. Heat engine performance is characterized by the total work output $W = |W_{\text{out}}| - W_{\text{in}}$ and efficiency $\eta = W/Q_{\text{in}}$.

[1] J. Jaramillo, M. Beau and A. del Campo, *New Journal of Physics* **18**, 7 (2016).

[2] Y. Chen, G. Watanabe, Y. Yu, X. Guan and A. del Campo, *npj Quantum Information* **5**, 1 (2019).