Feedback cooling and control of quantum superfluid

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Accurately modelling measurement and control of ultracold Bose gases has so far proved unfeasible due the prohibitively large size of the numeric simulations, and problems with under-sampling. We present a new field-theoretic technique based on existing phase-space methods, and use it model feedback cooling of a Bose gas subject to measurements via phase-contrast imaging.

We check the validity of our approach in a two-mode system, which permits an exact solution due to its low-dimensional nature, and observe exceptional agreement across various moments of pseudospin operators.

In addition, we benchmark our approach with existing techniques such as the Number-Phase Wigner particle filter, which has been the leading choice for existing simulations of controlled quantum systems.

Finally, we present preliminary results demonstrating successful cooling of a thermal state with low condensate fraction to condensate formation in both quasi-1D and 2D geometries, correctly accounting for measurement induced backaction and spontaneous emission effects. It is shown that the final achievable condensate fraction is dependent upon experimental parameters such as the measurement strength, rate, and detector resolution, and a simple model is constructed to derive optimal values for the parameters above.

References

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