論文の内容の要旨

Towards the creation of an ideal Bose gas in a Bose-Fermi mixture

(ボース・フェルミ混合系における理想ボース気体の生成に向けて)

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The ideal Bose gas is the most common model in quantum statistics. It predicts a pure statistical Bose-Einstein condensate (BEC). However, real systems are interactive. Many properties of the BEC are known to be altered by the interaction. Interestingly, the model for interacting BEC is not explicitly connected to the ideal one. One distinctive difference between an interacting BEC and an ideal BEC is that they are in different universality classes. Thus, possess different critical exponents.

Previous investigations on the critical phenomena of interacting BECs all show good agreement with the 3D-XY model, which is predicted to be the universality class for an interacting BEC. But a BEC phase transition matches the description of the ideal gas model has never been observed.

In this thesis, ^{7}Li bosons are cooled using ^{6}Li fermionic coolant. In addition, the interaction between the bosons is controllable via the Feshbach resonance by changing an external magnetic field applied to the system. This potentially allow us to eliminate the interaction between the bosons to create an equilibrium ideal Bose gas in canonical ensemble under proper condition.

The condition for the Bosons to become non-interacting is experimentally decided in this research. We further consider the possible effects of the Bose-Fermi mixture on the Bosons and find that the Fermions can be treated as simple coolant for our experiment conditions. We also present the method we use to extract precise local information via the inverse Abel transform. We then use this method to examine the equivalence of ensembles, where it is shown that the equilibrium state of the gas is the same with or without the coolant. These results imply that the non-interacting Bose gas created in our system is a close analogue to the ideal Bose gas. Finally, we use both the non-interacting gas and a repulsively interacting gas to measure the isothermal compressibility near the critical point of the BEC phase transition. We find that the scaling behavior is similar in both cases and deviates from the ideal gas model. The deviation matches the interacting 3D-XY model so that we conclude the interacting model offers a better description for the phenomenon. Our results also imply the possible absence of a “textbook” ideal matter wave BEC inside an ultracold atomic gas with tunable interaction.