Phase separation of Rabi-coupled spin states in an ^{87}Rb F = 1 BEC

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1. Introduction

A Bose-Einstein condensate (BEC) in cold atoms allows us to explore the nature of quantum phenomena in a controlled way. One of the most common tools for the control of a BEC system is an electromagnetic field. Particularly, the Rabi oscillations induced by light or RF pulses are often used for manipulation of the magnetic sublevels in atoms. The electromagnetic field can also change the interatomic interaction via the state mixing.

The state mixing via the electromagnetic field can rapidly and drastically change the miscibility of the system. The modification of (im)miscibility of a binary BEC via control of the interatomic interaction by the Rabi coupling has been demonstrated [1]. With a sudden quench induced by switching the coupling, scaling in time evolution of the pattern formation and spin-spin correlations in a binary BEC before equilibration was studied [2]. In addition, the spin healing length is short due to the equality of the interaction strengths in the dressed states, which may lead to multiple domain formation and be suitable for a test of the Kibble-Zurek mechanism (KZM) [3,4].

We couple the magnetic sublevels |F = 1, m = -1> and |F = 1, m = 0> in ^{87}Rb BEC where F and m denote the total angular momentum and the spin respectively, while the previous experiments [1, 2] coupled the |2, -1> and |1, +1> states, the interaction between which can be controlled via the magnetic Feshbach resonance [5,6]. The use of F = 1 hyperfine with less inelastic collisional loss would lead to a long lifetime. The long lifetime may enable us to perform a test for KZM via observing domain formation in the dressed state, which is expected to be slow [4].

2. Experimental procedure

We produced an ^{87}Rb BEC in the |1, -1> state in a crossed optical trap. We applied an RF field resonant to the transition between the |1, -1> and |1, 0> states. A magnetic field of over 10 Gauss was applied to induce the quadratic Zeeman shift prohibiting the coupling to the |1, +1> state. The atoms were held in the optical trap under the radiation of the RF field for a variable holding time. The population of each state after the holding was measured via the absorption imaging with the Stern-Gerlach separation.

3. Result and discussion

We successfully coupled |1, -1> and |1, 0> states (see Fig. 1). We also observed the change in the density distribution under the RF field application. The |1, -1> and |1, 0> states are immiscible for no coupling and the structure reflecting the immiscibility was observed in the atom density distribution when no RF field was applied. For a stronger coupling, we observed the loss of the structure, indicating the system turned to be miscible. The long time-scale evolution of the structure with intermediate coupling strength showed discrepancy from the theoretical expectation. The reason for the discrepancy has not been clarified. Subtle inhomogeneity of the coupling strength may be responsible, although further check is needed.

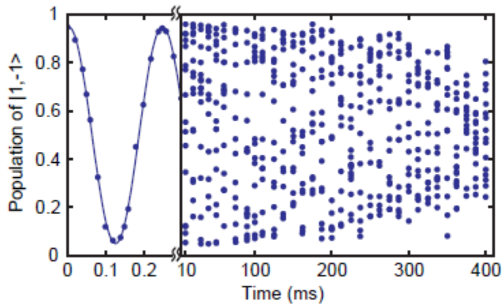

Fig. 1: The evolution of the population of the |F= 1, m = -1> state under the coupling with the Rabi frequency of 4000 Hz.

4. Conclusion

We have realized the modulation of the miscibility of a binary ^{87}Rb BEC in the F = 1 state via the RF coupling. Our work may open the possibility for revealing the long-time dynamics of the dressed states which has yet to be observed.

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