Observation of self-organized coherence in dissipative spinor Bose-Einstein condensates

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1. Introduction

Dissipation is a ubiquitous phenomenon, and it is important to understand its role in non-equilibrium dynamics. In the quantum systems, dissipation often reduce the coherence of the quantum states. But sometimes, it induces completely different effects than the decoherence. For example, strong dissipation can be used to suppress the loss [1] and control the quantum state [2] and quantum phase transition [3].

Here, we have observed novel spinor dynamics caused by strong dissipation in quantum atomic gas. We have observed spontaneous magnetization with self-organized coherence in spin-2 Bose-Einstein condensates (BECs). It should be noted that spin-2 BEC of 87Rb favors the non-ferromagnetic nature due to spin-dependent elastic collision [4], and they are dissipative system due to large hyperfine exchange loss [5]. These properties seemingly contradict the spontaneous magnetization and formation of coherence. We have found that these nontrivial effects are mainly due to the hyperfine changing inelastic loss, which wants to leave the ferromagnetic spins.

2. Experimental procedure

We produce an 87Rb BEC containing 3×10^5 atoms in the hyperfine state $|F, m_F\rangle = |2, 0\rangle$ in a crossed far-off-resonant optical dipole trap with axial and radial frequencies of 64 Hz and 185 Hz (Ref. [6] for a more detailed description). The external magnetic field of 200.9 mG is aligned with the axis of the trap (z direction). After holding for a variable time, T_{hold}, we measure m_F populations along two axes. In the case where the m_F populations along the z axis are measured, the BEC is simply released from the trap. On the other hand, in the case of measurement along the orthogonal axis, we applied $\pi/2$ radiofrequency (rf) pulse just before release from the trap. For both cases, the atomic distribution of each m_F component is measured using absorption imaging with the Stern-Gerlach separation.

3. Result and discussion

In the measurements along z axis, all m_F components are occupied at $T_{\mathrm{hold}} \geq 50$ ms, as shown in Fig. 1. On the other hand, when we applied a $\pi/2$ rf pulse, different spin populations were observed for each measurement under the same experimental condition. For example, only $|2, 2\rangle$ or $|2, -2\rangle$ is occupied as shown in Fig. 2. These results can be interpreted that the unpolarized spin populated in $|2, 0\rangle$ state spontaneously evolves into a transversely polarized spin state, in which the phases between m_F components are synchronized. The different m_F populations observed in Fig. 2 would correspond to the different precession angles of a transversely polarized spin.

3. Conclusions

We have observed spontaneous magnetization and self-organized coherence in spin-2 BECs. We have found these nontrivial effects are mainly due to the dissipation. Our study will provide significant insight for quantum non-equilibrium dynamics.

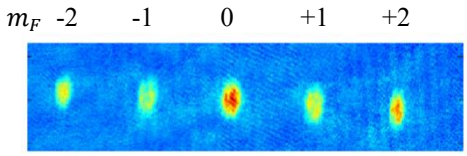

Fig.1: Absorption image without π/2 pulse (T_{hold} = 100 ms)

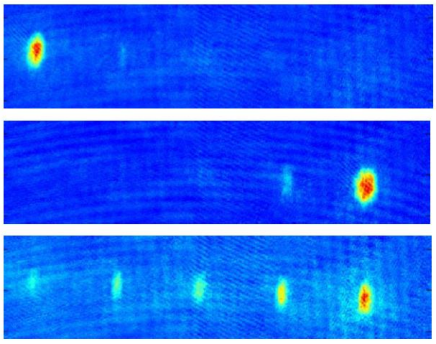

Fig.2: Absorption images with π/2 pulse (T_{hold} = 100 ms)

Acknowledgements

This work was supported by Grant-in-Aid for Scientific Research (C) (No. 17K05595, No. 17K05596, No. 16K05505, No. 15K05233), Grant-in-Aid for Scientific Research on Innovative Areas (No. 25103007, ``Fluctuation & Structure") from MEXT, Japan.

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