Shapiro Resonance in a Spinor Bose-Einstein Condensate

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Ultracold atomic gases give a promising platform for exploring quantum dynamics driven by external fields. Among them, a spinor Bose-Einstein condensate (BEC) exhibits a unique resonance between internal states. Recent works [1–3] have experimentally and theoretically investigated spinor BECs driven by an oscillating quadratic Zeeman coupling and have found the resonance phenomenon – Shapiro resonance – which is similar to the Shapiro effect known in a Josephson junction of superconductors. However, the analyzes in the previous works are based on a single-mode approximation, and the spatial patterns induced by the resonance have not been discussed so far.

In this work, we have theoretically studied the resonant dynamics beyond the single-mode approximation by using the spinor Gross-Pitaevskii equation. Starting from the polar state, our numerical and analytical calculations reveal that the Shapiro resonance can generate spin waves with a finite wavenumber. Furthermore, we analytically derive the resonant frequency and width, together with the Lyapunov exponent (or growing rate) by using Floquet's theorem [4]. We also numerically find that the Shapiro resonance can occur starting from a one-dimensional system with domain walls, where the spin waves are localized in domain walls.

References

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