Lissajous fields in spinor Bose−Einstein Condensates

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Abstract: We create atom-optic analogs of polarization patterned optical fields in spinor Bose−Einstein condensates (BECs) using Raman imprinting techniques. Addressing separate coherent spin-1/2 subsystems of a higher spin manifold in a spinor BEC, we explore spin Lissajous fields that are the atomic analog of the optical Lissajous fields found in coherent polychromatic optical vector fields. The spin Lissajous figures in this case may possess a higher order symmetry than the spin ellipses of the monochromatic case, allowing the study of interesting topological phenomena in these fields.

1. Introduction

Spinor Bose–Einstein condensates (BECs) are of interest in quantum simulation and in creating analogs of other physical systems. Recognizing that states of circular optical polarization map onto the atomic spin (Zeeman) states —eigenstates of spin angular momentum—we explore the connections between optical polarization and atomic spin degrees of freedom. A coherent Raman optical imprinting technique transfers the relative amplitudes and phases of optical fields onto the relative populations and phases of atomic spin states. Gaussian and Laguerre−Gaussian (LG) Raman beams allow us to create spatially varying spin textures across the cloud. For a pseudo-spin-1/2 system, these map directly onto monochromatic vector and vector vortex beams. Atomic Stokes polarimetry techniques allow us to analyze spin textures in the BEC in the language of optics, creating spin ellipse maps that are analogous to polarization ellipse maps in optics [1, 2, 3].

We extend our technique to study analogs of the polarization states of polychromatic optical vector fields. The electric field vector of these fields dynamically traces out generalized Lissajous figures [4]. Two separate but coherent pseudo-spin-1/2 subsystems of the F=2 ground state manifold of our BEC furnish the atomic analog of a bichromatic optical field, allowing us to create spin Lissajous maps of our cloud (Figure 1). The wavefunction of the atomic cloud may be sculpted so as to create spin Lissajous figures with higher order symmetries than the monochromatic (spin-½) spin ellipses possess. Using the phase dependence of LG beams to pattern our BEC creates an azimuthal rotation of the spin Lissajous figures around the LG vortex line, allowing a knotted topology to appear in the system [5].

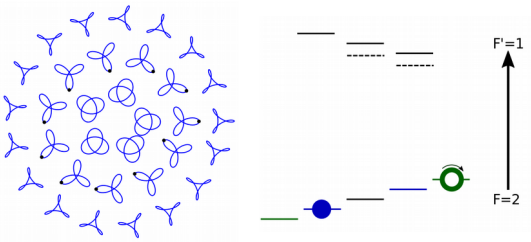

Figure 1. Spin Lissajous map of a spinor Bose−Einstein condensate with a vortex in state ⏐2,2〉 and a non-rotating core in state ⏐2, -1〉

2. References

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