Solitons in the $F = 1$ Bose-Einstein Condensates

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Bose-Einstein condensate with internal degrees of freedom has attracted much attention of experimental and theoretical physicists. Internal degrees of freedom which are frozen under magnetic traps are liberated, and are expected to play a significant role with wide possibilities now under optical traps.

We study soliton solutions of a multi-component Gross-Pitaevskii equation for hyperfine spin $F = 1$ spinor Bose-Einstein condensates. The interactions are supposed to be inter-atomic repulsive (attractive) and antiferromagnetic (ferromagnetic) ones of equal magnitude [1,2]. The solutions are obtained from those of a new integrable 2×2 matrix nonlinear Schrödinger equation [3] with non-vanishing boundary conditions [4,5]. Note that the equation is different from the Manakov equation. By the inverse scattering method, both coupling cases are studied and the multiple-soliton solutions are explicitly obtained.

We investigate the one-soliton and two-soliton solutions in detail. One-soliton is classified into two kinds. The ferromagnetic state has waveforms of domain-wall shape and its total spin is nonzero. The polar state exhibits a hole (peak) soliton and its total spin is zero. These two states are selected by choosing the type of the boundary conditions. In two-soliton collisions, we discover a novel phenomenon, which we call the spin-mixing or spin transfer, for ferromagnetic and polar solitons. This indicates that, as magnetic carriers, solitons in the ferromagnetic state are operative for the spin-mixing while those in the polar state are passive.

References

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