Parametric Resonance in Bose-Einstein Condensates

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We conduct a stability analysis for Bose-Einstein condensates (BECs) in a harmonic trap under parametric excitation by periodic modulation of the s-wave scattering length. In analogy to the classical system of a parametrically driven pendulum, we aim to stabilize an originally unstable equilibrium (see case 1 below) and destabilize a stable equilibrium (see case 2 below) by parametric excitation. To this end, we obtain equations of motion for the radial and axial widths of the condensate using a Gaussian variational ansatz for the Gross-Pitaevskii condensate wave function. Linearizing about the equilibrium positions, we obtain a system of coupled Mathieu equations, the stability of which has already been studied extensively in the literature. We carry out an analytic stability analysis for the Mathieu equations, and compare with numerical results for the nonlinear equations of motion. We find qualitative agreement between the Mathieu analytics and nonlinear numerics, and conclude that the stability characteristics of two equilibrium radii of a BEC might be inverted by parametric excitation.

The linear stability diagram shows stable (blue) and unstable (white) regions for a BEC with attractive interaction in an isotropic harmonic trap with a periodic modulation of the s-wave scattering length.

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