Controlling phase separation of a two-component Bose-Einstein condensate by confinement

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Abstract:

We point out that the widely accepted condition $g_{11}g_{22} < g_{12}^2$ for phase separation of a two-component Bose-Einstein condensate is insufficient if kinetic energy is taken into account, which competes against the inter-component interaction and favors phase mixing. Here g_{11}, g_{22}, and g_{12} are the intra- and inter- component interaction strengths, respectively. Taking a d-dimensional infinitely deep square well potential of width L as an example, a simple scaling analysis shows that if $d = 1$ ($d = 3$), phase separation will be suppressed as $L \to 0$ ($L \to \infty$) whether the condition $g_{11}g_{22} < g_{12}^2$ is satisfied or not. In the intermediate case of $d = 2$, the width L is irrelevant but again phase separation can be partially, or even completely suppressed even if $g_{11}g_{22} < g_{12}^2$. Moreover, the miscibility-immiscibility transition is turned from a first-order one into a second-order one by the kinetic energy. All these results carry over to d-dimensional harmonic potentials, where the harmonic oscillator length ξ_{ho} plays the role of L. Our finding provides a scenario of controlling the miscibility-immiscibility transition of a two-component condensate by changing the confinement, instead of the conventional approach of changing the values of the g's.