Hysteresis of matter waves.

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Ultracold gases confined in optical and microwave traps are promising elements for quantum computing architectures [1, 2]. We study the properties of macroscopic wavefunction of neutral atoms trapped by specially arranged optical and magnetic fields. The configuration of optical dipole trap with strongly inhomogeneous magnetic field is proposed(fig.1). Two elongated sigar-shaped 3D-wells are separated by potential barrier. The smaller well is located in the external magnetic field whose strength $\tilde{\mathbf{B}}$ is set to be close enough to Feshbach resonance of trapped BEC. The nonlinearity induced by Feshbach resonance is sufficient to change a phase of BEC wavefunction Ψ_B for several π radians. The Gross-Pitaevsky equation[1]:

$$i\hbar\,\frac{\partial\Psi(\vec{r},t)}{\partial t} = -\frac{\hbar^2}{2m}\Delta\Psi(\vec{r},t) + V_{ext}(\vec{r},t)\Psi(\vec{r},t) \quad + \\ + \frac{4\pi\hbar^{\,2}\,\boldsymbol{a(\vec{B}(\vec{r}))}}{m}\Psi(\vec{r},t)|\Psi(\vec{r},t)|^{\,2}, \qquad (1)$$

is solved for such asymmetrical elongated double-well trapping potential under following assumptions:

- The scattering length $\boldsymbol{a(\vec{B}(\vec{r}))}$ is a function of spatially inhomogeneous static magnetic field.
- Trapping potential $\boldsymbol{V_{ext}(\vec{r},t)}$ has a form of two elongated wells of nonequal length.
- The barrier between wells is partially transparent to atoms.
- Nonlinear phase shift of wavefunction in right well Ψ_B is of the order of several π radians.

In equilibrium situation the wavefunction in the right well Ψ_B and wavefunction in left well Ψ_0 are connected by nonmonotonous multivalued curve(fig.1). The curve has sections with negative slope which separate the sections of stable amplitudes of Ψ_B [3]. The several stable amplitudes of Ψ_B correspond to single value of Ψ_0 . The switching between stable amplitudes of Ψ_B exhibits hysteresis. It means that "up" switching to higher amplitudes of Ψ_B occurs at larger amplitudes of Ψ_0 than "down" switching. The experimental conditions for observation of hysteresis of macroscopic wavefunction are analysed.

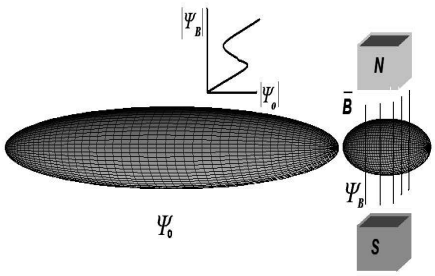

Figure 1: Asymmetric two-well trap for neutral atoms with placed in inhomogeneous magnetic field $\tilde{\mathbf{B}}$. Gray elliptical clouds are the isosurfaces of wavefunctions in left trap (Ψ_0) and right trap (Ψ_B) correspondingly. Upper box N and bottom box S are the poles of a magnetized micron - size needle .

References

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