Feedback control of an interacting Bose-Einstein condensate

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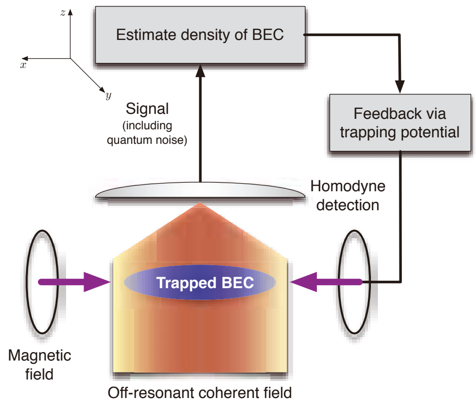

Figure 1: Control setup used to reduce multimode density fluctuations in a BEC

Recently there has been interest in utilising Bose-Einstein condensates (BEC) and atom lasers for precision metrology [1, 2]. However, research has demonstrated that the transverse and longitudinal spatial modes of a BEC exhibit complicated multimode behaviour [3], thereby reducing the precision of atom interferometric measurements. In [4] we theoretically showed that the feedback control scheme shown in Fig. 1 could be used to generate a stable spatial mode for a BEC possessing negligible interatomic interactions. However, many BEC experiments work with condensates that have strong interatomic interactions. Furthermore, it is likely that nonlinear interactions are necessary for the stability of continuously pumped atom lasers [5]. Recently in [6] we further developed the theory presented in [4] to show that feedback control can be used to generate a stable spatial mode for a BEC with a large nonlinearity.

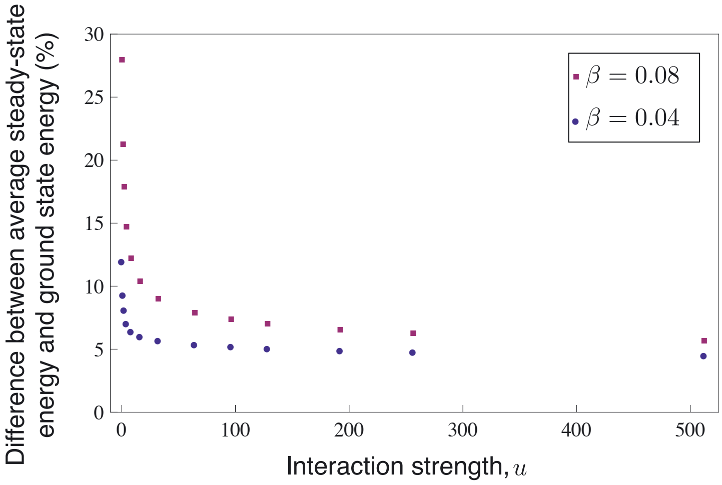

Figure 2: Plot showing how the average steady-state energy compares to the ground state energy as a function of the interaction strength u for (blue dot) $\beta = 0.04$ and (maroon square) $\beta = 0.08$. β is the physical parameter that is related to the strength of the measurement. It is proportional to the intensity of the laser and inversely proportional to the square of the detuning.

In particular, our model solves the problem of inadequacy of the mean-field (coherent state) approximation by utilising a fixed number state approximation. Numerical analysis shows that for optimal values of the feedback control, the average steady-state energy (relative to the ground-state energy) decreases with increasing atomic interaction strength (see Fig. 2). Thus the control scheme is *more* effective for a strongly interacting BEC, which is the case in most BEC laboratories.

References

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