Macroscopic quantum self-trapping of ultracold Bose-Fermi mixtures

E. A. Ostrovskaya, S. F. Caballero-Benitez, and Yu. S. Kivshar
Research School of Physics and Engineering, ACQAO, ANU

Self-trapping phenomena are among the most dramatic effects of atomic interactions in the systems of quantum degenerate gases. The so-called *macroscopic quantum self-trapping* (MQST) effect manifests itself as localization of most of the particles in the system in a particular region in space. The MQST and related effects in purely bosonic systems have been extensively analyzed in different physical contexts, from the Josephson effect in superconductors and the study of superfluid ^{4}He to the alkali Bose-Einstein condensates. The MQST effect in a so-called Bose-Josephson junction, i.e. a Bose-Einstein condensate loaded into a double-well potential, has been extensively studied theoretically [1] and observed experimentally [2]. Its appearance is linked to the formation of new stationary states that are characterized by a population imbalance between the wells of the trapping potential, which becomes more pronounced with growing nonlinearity. Moreover, it turns out that the MQST effect plays an important role in the dynamics of condensates in periodic potentials, leading to the formation of self-trapped or truncated gap states [3].

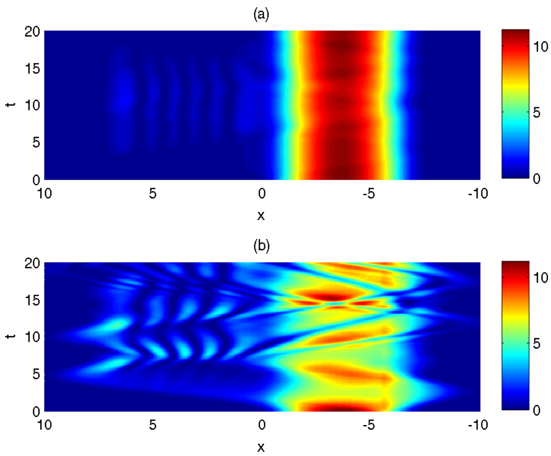

Fig. 1: Dynamical suppression of MQST regime in the case of repulsive inter-species interactions. Shown are the densities of the bosonic component at (a) zero and (b) non-zero concentration of fermions.

In the context of ultracold Bose-Fermi gases, we have analysed theoretically the effect of degenerate fermions on the self-trapping behavior of ultracold bosons in a quasi-one dimensional symmetric double-well potential [4]. In order to analyze the static properties of the system, we used a self-consistent numerical approach, as well as a quasi-analytical treatment, based on a mean-field density approximation for the fermionic component and a coupled-mode theory for the bosonic component. We considered both attractive and repulsive interactions between bosons and fermions, and found that, depending on the type of the inter-species interactions, a significant enhancement or suppression of the MQST regime can occur in the system (see Fig. 1). Both the enhancement and the suppression of self-trapping in the BEC cloud mixed with degenerate fermions may signal the existence of the new regimes of the dynamics and switching of BECs in atomic waveguides and nonlinear interferometers with mixed atomic species.

They are also expected to have profound consequence for the formation and dynamics of the self-trapped gap states in the Bose-Fermi mixtures loaded into periodic potentials. Beyond the mean field, these effects may have an implication for the onset of the superfluid to Mott insulator (MI) transition in a lattice potential, leading to the inhomogeneous suppression of the MI regime in the case of repulsive interaction and phase separation.

References

[1] E. A. Ostrovskaya, Yu. S. Kivshar, M. Lisak, B. Hall, F. Cattani, and D. Anderson, Phys. Rev. A **61** 031601(R) (2000).

[2] M. Albiez, R. Gati, J. Folling, S. Hunsmann, M. Cristiani, and M. K. Oberthaler, Phys. Rev. Lett.**95** 010402 (2005).

[3] T. J. Alexander, E. A. Ostrovskaya, and Yu. S. Kivshar, Phys. Rev. Lett. **96** 040401 (2006).

[4] S. F. Caballero-Benitez, E. A. Ostrovskaya, M. Gulacsi, and Yu. S. Kivshar J. Phys. B **42** 215308 (2009).