Classical field simulations of thermal Bose-Einstein condensates

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The aim of this project is to continue to develop and apply methods for describing the dynamics of Bose-Einstein condensates at finite temperature. The techniques being utilised are approximate; however they are aimed at performing non-perturbative calculations for realistic experimental systems. The project is directly relevant to the atom-laser project at ANU, and potentially useful for the He^* and atom-chip BEC projects within ACQAO. It is mainly based at UQ with collaborators at the University of Otago.

The computational techniqued has become known as the classical field approximation, where the Gross-Pitaevskii equation (GPE) is used as a model of highly occupied interacting atomic modes [1]. In 2006 Blakie, Bradley, Davis and Gardiner were invited to submit a paper on this topic to the condensed matter review journal Advances in Physics, and this should be complete in early 2007.

The first application of the method to an experimental system has been to investigate the shift in the critical temperature T_c of condensation for the experiment of Gerbier *et al.* [2]. We find that critical fluctuations result in a significant increase of T_c as compared to a full Hartree-Fock-Bogoliubov (HFB) treatment, however both calculations lie within the experimental error bars [3].

Two-dimensional systems have been a major focus for 2006. Classical field methods are particularly useful for low-dimensional systems that have a more slowly increasing density of states. Recently, phase defects in quasi-2D condensates have been reported [4], and this was followed with a measurement of the first-order correlation function that provides evidence for a superfluid Berezinskii-Kosterlitz-Thouless (BKT) phase [5]. We have been studying the penetration of vortices into the centre of a trapped 2D condensate, analysing the experimental technique of determing the behaviour of the first-order coherence function, and considering the measurement of scissor mode properties for establishing the presence and nature of superfluidity in the system.

We have continued work on the formation of a vortex lattice during rotating Bose-Einstein condensation using a stochastic Gross-Pitaevskii equation for the highly-occupied modes coupled to a quenched rotating thermal cloud. This work is nearing submission for publication.

We have recently begun work on a 1D model of a continuously pumped atom laser using classical field methods, where the condensate is continuously replenished from a thermal atomic reservoir using a realistic growth scenario. The project focuses on the properties of the output beam and will provide realistic estimates of the linewidth and coherence limitations of a cw atom laser.

Using kinetic theory rather than classical field theory we have modelled the formation of a elongated condensate in a temperature quench as realised by the Orsay group [6]. We intend to carry out more appropriate classical field calculations that should provide improved agreement with experiment.

References

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