C-field simulations of thermal Bose-Einstein condensates

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The aim of this project is to develop and apply methods for describing the dynamics of Bose-Einstein condensates (BECs) at finite temperature. The techniques being utilised are approximate; however they provide for non-equilibrium simulations of realistic experimental systems [1].

1. We have developed a 1D model of a continuously pumped atom laser using a stochastic Gross-Pitaevskii equation. In this model the condensate is continuously replenished from a thermal atomic reservoir using a realistic growth model, and the atom laser beam is generated by Raman outcoupling from the centre of the trap. We have identified that atoms leaving the condensate sufficiently slowly can be jostled in a random fashion by thermal fluctuations of the trapped condensate. We have identified this as the cause of significant broadening of the linewidth of the atom laser below a critical outcoupling momentum.

2. An experimental team at the Institut d'Optique has been working on creating a guided atom laser by outcoupling magnetically trapped atoms into a wave-guide formed by a red detuned optical laser. They have been measuring the transmission coefficient as a function of the height of a barrier in the waveguide at finite temperatures in order to make a measurement of the linewidth. We have modeled their system in order to relate their results to the thermal linewidth and to help them refine their experiment.

3. C-field methods for Bose gases have been described as being non-perturbative as they incorporate many-body effects to all orders in the interaction, going beyond the usual factorisation of operator moments in mean-field theories. Using the projected GPE we have quantified the anomalous and non-Gaussian character of the fluctuations of the Bose-field at finite temperature, and demonstrated that the c-field method is consistent with (and goes beyond) symmetry-breaking treatments of BEC at finite temperature [3].

4. We have studied the phases of vortex matter in rapidly rotating two-dimensional Bose-Einstein condensates as a function of temperature. At zero temperature the vortices in the condensate are arranged in a hexagonal lattice, and the temperature is increased, dislocations and disclinations in the lattice start forming in pairs. It is predicted there is a transition from a solid to a hexatic phase when the dislocations unbind, and then to a liquid phase when the disclinations unbind. We have found evidence for this in our numerical simulations.

5. Ongoing work on the microscopic characteristics of vortices in the two-dimensional homogeneous Bose gases was published [4]. This was followed with a study of the temporal statistics of the vortices in this system and a comparison with analytical predictions.

6. Work with University of Queensland BEC group on the formation of condensates by combining a 1D laser sheet with a cigar-shaped BEC was completed and accepted for publication [5].

References

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