Superfluidity and thermodynamics of low-dimensional Bose gases

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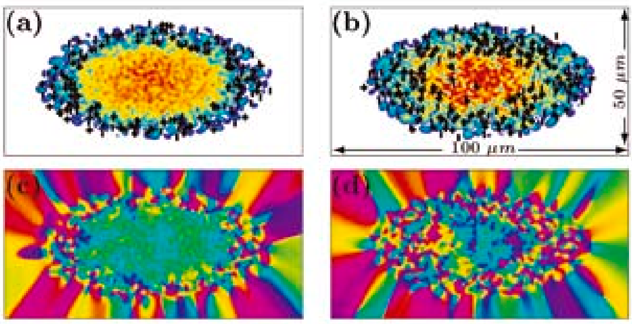
Degenerate Bose gas systems in one and two dimensions have many differences to standard Bose-Einstein condensates in three dimensions, and are now beginning to be realised in the laboratory [1]. It is important to be able to apply our theoretical techniques to make predictions for realistic experimental systems, or to analyze existing experimental data and interpret these results from a theoretical viewpoint.

1. Recent analytic work has suggested that quantum fluctuations in 3D BECs in an infinite system can cause a non-zero drag force on an object in a flow at all velocities [2], in contradiction with our conventional understanding of superfluidity. We are near completing a similar calculation for a one-dimensional system, which has the advantage that much of it can be done analytically. It is also feasible to numerically simulate this system, and we have begun calculations aimed at conclusively demonstrating this force in a finite system.

2. A recent experiment has made a measurement of the first-order correlation function of a 2D Bose gas that provides evidence for a superfluid Berezinskii-Kosterlitz-Thouless (BKT) phase [1]. We have been studying a size-matched homogeneous system using classical field methods in order to study the behaviour of vortex pairs, and to develop an understanding of the relationship between BEC and BKT phases in a finite-size system. We have also studied the penetration of vortices into the centre of a trapped 2D condensate (as shown in the figure below), and considered the measurement of scissor mode properties as a method to establish the existence of superfluidity [3]. Finally, we have been analyzing unpublished experimental data from NIST Gaithersburg in order to enhance the understanding of their 2D system.



(a,b) Density and (c,d) phase of a 2D trapped Bose gas at a temperature of (a,c) 114 nK and (b,d) 151 nK. The critical temperature was determined to be 155 nK. The plus and minus signs indicate vortices of positive and negative circulation, respectively. (b,d) is an example where a vortex has penetrated to the core of the gas.

3. We have established a collaboration with the van Druten group in Amsterdam who have been studying the thermodynamics of the 1D Bose gas. They have made measurements of the density profiles of their system over a range of temperatures, and we have fit these using the Yang-Yang thermodynamic solution for the 1D Bose gas in the local density approximation [4]. Their results also provide a method for accessing the momentum distribution, which cannot be computed using the Yang-Yang solution. Recently we have begun using classical field methods to try to make a connection with these results.

References

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