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Phase-contrast imaging of atomic superfluid state in degenerate gas of ^{6}Li atoms

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The recent experimental realizations of Bose–Einstein condensation in trapped ultracold atomic gases composed of bosonic alkali atoms has generated a broad interest in studying different properties of these degenerate atomic Bose systems. Although the degenerate atomic gas composed of fermionic atoms has not yet been demonstrated, theoretical study has predicted that the degenerate Fermi gas can experience BCS-like phase transition to an atomic superfluid state.[1]

In this paper, a technique based on coherent Fourier optical imaging is proposed to detect such an atomic superfluid state in a degenerate gas of ^{6}Li atoms. We show that the superfluid state is characterized by the formation of atomic Cooper pairs in the degenerate ^{6}Li gas. The key to observe such a superfluid state is to determine the quantum pair correlation due to the existence of atomic Cooper pairs. By use of the vector quantum-field theory,[2] we study the propagation of light field through the ^{6}Li gas in the superfluid state. The total intensity of the scattered light and the transmitted light by the gas is calculated. The results show that there is an interference term in the total intensity of light that is directly proportional to the quantum pair-correlation function due to the existence of atomic Cooper pairs. However, the interference signal cannot be directly detected because of a strong background signal associated with the normal part of the gas. To pick up the information of the atomic superfluid state, we propose the use of phase-contrast imaging in coherent Fourier optics to separate out the interference signal from the background signal. The existence of the interference signal in the imaging field gives the signature of the BCS-like phase transition to the atomic superfluid state in the degenerate gas of ^{6}Li atoms.

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