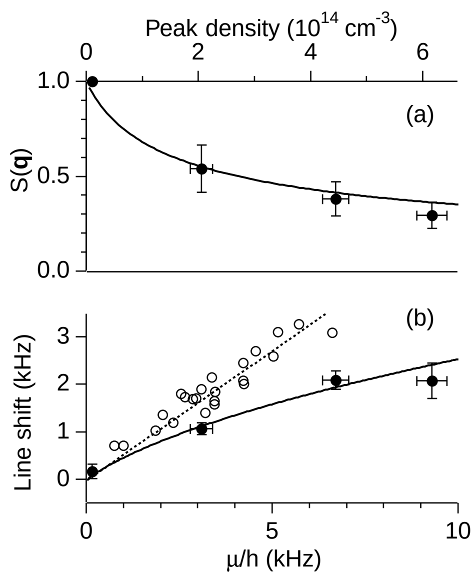
Excitation of phonons in a Bose-Einstein condensate by light scattering

Light scattering imparts momentum to the condensate and creates an excitation (which can be a phonon or a free particle). A detailed study of the scattered light should therefore reveal a detailed picture of the Bose condensate similar to the case of superfluid helium where neutron scattering was used to obtain the spectrum of elementary excitations.

In previous work [1] we showed how a condensate responds to a large momentum transfer which lead to particle-like excitations. Light scattering at small angles does not impart enough momentum to the condensate to create a recoiling atom. Instead, it creates a sound wave by "optically imprinting" phonons into the gas. A sound wave is a collective excitation of all the atoms in the system and therefore requires that the atoms don't act as individual atoms, but show correlated motion. It has been predicted that this correlated motion results in much weaker light scattering than for free atoms. We found a significant decrease of the rate of light scattering in the phonon regime, providing dramatic evidence for the presence of correlated momentum excitations in the many-body condensate wavefunction [2]. For high-density condensates, even large-angle scattering is in the phonon regime. Therefore, this effect should turn a "pitch-black" condensate transparent since the collective nature of the condensate suppresses its ability to scatter light.



(a) Static structure factor S(q) and (b) shift of the line center from the free particle resonance. S(q) characterizes the strength of the scattering process during which momentum q is transferred to the condensate. As the density and the chemical potential μ increase, the structure factor is reduced, and the Bragg resonance is shifted upward in frequency. Solid lines are predictions of a local-density approximation. Dotted line indicates a mean-field shift of 4μ/7 h as measured in the free-particle regime (shown in open symbols).

1. J. Stenger, S. Inouye, A.P. Chikkatur, D.M. Stamper-Kurn, D.E. Pritchard, and W. Ketterle, Phys. Rev. Lett. **82**, 4569 (1999).
2. D.M. Stamper-Kurn, A.P. Chikkatur, A. Görlitz, S. Inouye, S. Gupta, D.E. Pritchard, and W. Ketterle, Phys. Rev. Lett. **83**, 2876 (1999).