Measurement of the spatial coherence of a trapped Bose gas at the phase transition

I. Bloch, M. Köhl, T. W. Hänsch and T. Esslinger

Sektion Physik, LMU München
Schellingstr. 4/III, 80799, Munich, Germany
Tel +49-89-2180-3704, Fax +49-89-285192
E-mail: imb@mpq.mpg.de, Website: http://www.mpq.mpg.de
and Max-Planck-Institut für Quantenoptik, Hans Kopfermann Str. 1,
85748, Garching, Germany

Bose-Einstein condensates and atom lasers show fascinating interference phenomena on a macroscopic scale. The formation of an interference pattern depends fundamentally on the phase coherence of the system, which can be quantified by the spatial correlation function. Phase coherence over a long range [1, 2, 3] is the essential factor underlying Bose-Einstein condensation and related macroscopic quantum phenomena, such as superconductivity and superfluidity.

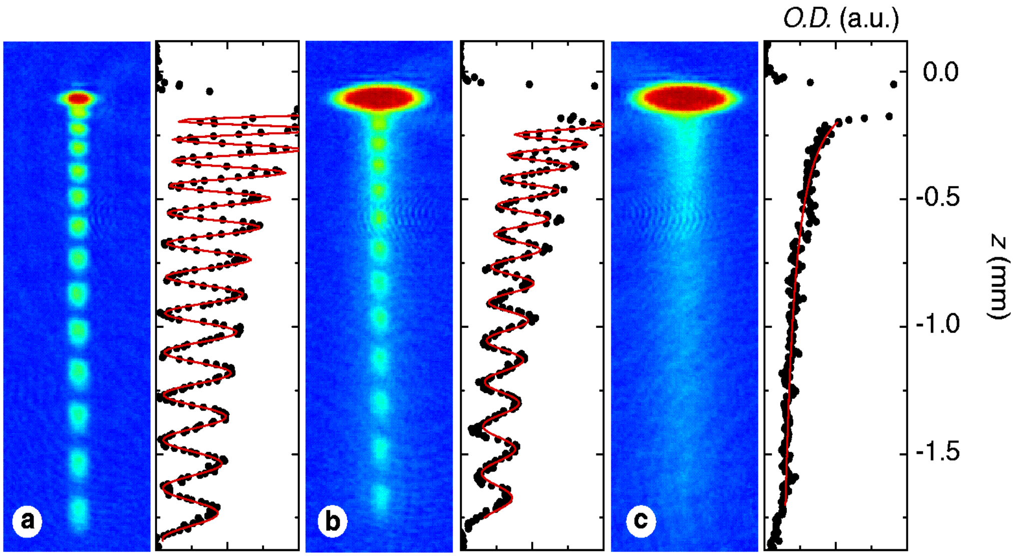

Figure 1: Interference pattern of matter-wave beams emitted from two spatially separated regions of a trapped Bose gas for different temperatures T of the trapped gas below and above the transition temperature T_c. **(a)** $T \ll T_c$, **(b)** $T < T_c$ and **(c)** $T > T_c$. The frequency difference between the two components of the radio-wave field was 1000 Hz which corresponds to a slit separation of 465 nm. The plots next to the images show 21 μm-wide vertical cuts through the centres of the absorption images.

Here we report a direct measurement of the first order spatial correlation function of a weakly interacting Bose gas [4]. Using a radio-wave field with two frequency components we effectively create a double slit for magnetically trapped atoms. The spatial correlation function of the system is determined by evaluating the visibility of the interference pattern of two matter waves originating from the spatially separated 'slit' regions of the trapped gas (Fig. 1). Above the critical temperature for Bose-Einstein condensation, the correlation function shows a rapid gaussian decay, as expected for a thermal gas. Below the critical temperature, the correlation function has a different shape; a slow decay towards a plateau is observed, indicating the long-range phase coherence of the condensate fraction. The observed interference pattern furthermore showed a reproducible phase for temperatures of almost pure condensates up to the transition temperature.

[1] O. Penrose, *Phil. Mag.* **42** 1374 (1951).
[2] O. Penrose and L. Onsager, *Phys. Rev.* **105** 576 (1956).
[3] C. N. Yang, *Rev. Mod. Phys.* **34** 694 (1962).
[4] I. Bloch, T. W. Hänsch and T. Esslinger, *Nature* **403** 166 (2000)).