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Wave mechanics observed with a lens

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The recent realization of atomic Bose-Einstein condensates opens up the way to directly observe fundamental quantum mechanical effects on a macroscopic scale. Fortunately the physical implemantation leads to a relaization which is far from an ideal gas: The interactions between particles play a crucial role and lead to new phenomena [1].

As an example of a paradigm quantum effect we will discuss the expansion of a wave packet in a periodic potential. The concept of effective mass, borrowed from condensed matter physics, allows a quantitative comparison between theory and experiment only as long as the interaction between the atoms can be neglected. With interaction, non-spreading wave packets - bright solitons - can be formed, which for repulsive atom-atom interaction require negative mass.

The physical situation can be further simplified by looking at the dynamics of a degenerate Bose gas in a double-well potential. The physics is now closely related to the Josephson junction known from weakly coupled superconductors. In contrast to the condensed matter experiments we can directly measure the population difference as well as the phase difference. The atom-atom interaction leads to new dynamical modes such as macroscopic self-trapping. Finally some light will be shed on the fact that the experiments are never performed at zero temperature.

[1] Nobel laureate Eric Cornell pointed out: "The overall picture [of BEC theory of an ideal gas] is sufficiently easy to understand that, if the system truly were an ideal gas, there would be little left to study at this point."

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