Interferometry and precision measurements with Bose-condensed atoms

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Declaration

To the best of my knowledge and except where acknowledged in the customary manner, the material presented in this thesis is original and has not been submitted in whole or part for a degree in any university.

Daniel Döring, April 2011
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Abstract

Bose-Einstein condensates are coherent matter waves, produced by cooling gaseous atomic clouds to ultra-low temperatures. For applications in atom interferometry and precision measurements, Bose-condensed sources present an intriguing alternative to thermal atoms. Although the current sensitivity achievable with interferometers using coherent atoms is not comparable to thermal beam machines (mainly due to the lower flux), there are promising ways to utilise the potential of Bose-condensed sources for atom interferometry. Among those is the low momentum width of Bose-Einstein condensates, which can generally be well controlled and is advantageous for increased interferometric sensitivities by implementing large momentum transfer beam splitters. As part of this thesis, experimental and theoretical investigations are presented to investigate the potential of Bose-Einstein condensates for such applications. We shall present the quantum projection noise limited performance of a Ramsey interferometer operating on the atomic clock transition of a freely expanding cloud of Bose-condensed rubidium 87 atoms. The results include Ramsey fringes of high visibility, not measurably affected by atomic interaction-induced dephasing effects. The achievement and detection of the quantum projection noise limit rely critically on the precision and accuracy of both the imaging setup and the coupling scheme in the interferometric beam splitters. The stabilisation of the beam splitters via an optical Sagnac interferometer is the basis for the quantum projection noise limited performance of the interferometer presented. For an increase of bandwidth and flux in atom interferometric measurements, it is advantageous to use a continuous atomic beam. A truly continuous coherent atom source has not been realised to date, and we present results on a pumping mechanism in this thesis, as a decisive step towards a continuous atom laser. By the investigation of different momentum resonances, we find that the pumping scheme relies on a Raman superradiance-like process. Finally, the thesis demonstrates two interaction measurements in rubidium. The strong mean field interactions due to the high densities in Bose-Einstein condensates are used to probe the potential of a rubidium 87 condensate with an atom laser. The measurement allows a determination of the scattering length between the two atomic states involved. In addition to this two-body scattering scheme, we present a measurement of three-body loss coefficients, extracted from loss curves in rubidium 85 Bose-Einstein condensates. The measurement provides new upper bounds on the three-body loss coefficients at the scattering lengths considered.
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