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Talbot-Lau Schemes and Bragg Diffraction: Theory and Applications in High-Mass Matter-Wave Interferometry

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Abstract:

This thesis describes theoretical work carried out in connection with the high-mass matter-wave interference experiments at the University of Vienna. Its scope ranges from the simulation and analysis of experimental data to the proposal of a trapped interference scheme applicable to a variety of matter-wave platforms.

The first main result of the thesis is the phase-space description of a near-field interferometer with any number of gratings. This theory is used to analyse a four-grating Talbot-Lau interferometer, in which passive compensation of low-frequency vibrations and of the Coriolis force are expected. The compensation is numerically confirmed and its effectiveness is compared to existing techniques.

The second main result is the demonstration of Bragg diffraction of complex molecules on optical gratings, to which the author contributed the basic experimental design, simulations, and the interpretation of the data. This demonstration is a first step towards applying large momentum transfer coherent manipulation techniques to the interference of heavy molecules and clusters.

The third main result is a new interference scheme for matter waves in toroidal confinement. The beam splitting and recombination in this scheme rely on the free evolution in the waveguide and require no interaction with the matter waves. The scheme is within reach of state-of-the-art experiments with Bose-Einstein condensates, where it could be used to measure weak atom-atom interactions or magnetic field gradients.