An interferometer for large molecules

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We demonstrate a near-field Talbot-Lau interferometer (TLI) for C_{70} fullerene molecules with a wavelength of 3 - 5 pm at a velocity of 80-150 m/s. Such interferometers are particularly suitable for even larger masses. The setup makes use of the Talbot-Lau-Effect, which is a self-imaging phenomenon that occurs when a periodic structure is illuminated by a spatially incoherent beam. Images of this grating are then reconstructed at discrete multiples of the Talbot length $L_T = d^2/\lambda_{dB}$ where d is the grating constant and λ_{dB} the de Broglie wave length of the incident object.

In the present setup (cf. Fig. 1) we used three free-standing gold gratings of 1 μm period and a thermal beam of C_{70} molecules. We achieve an interference fringe visibility of $\sim$ 40 %. This high but velocity dependent contrast can only be explained quantum mechanically, a classical point particle model yields a velocity-independent fringe visibility of only 5 %.
The interference fringes are detected by transversal scanning of the third grating and integral detection using an ionizing laser beam.

Both the high visibility and its velocity dependence are in good agreement with a quantum simulation that takes into account the van der Waals interaction of the molecules with the gratings and are in striking contrast to a classical Moiré model.

The fact that the experimental visibility is not significantly lower than the theoretical expectation shows that decoherence by emission of black-body radiation does not play a significant role in this experiment. However, there is a chance to study decoherence in future experiments involving laser heating of the fullerene molecules and collisions between fullerenes and the residual gas.

With decreasing grating period the influence of the Van der Waals potential increases strongly and higher diffraction orders are populated. This results in more stringent requirements on the spectral purity of the incoming beam and significantly affects the scalability properties of a matter wave interferometer based on material gratings.

We are currently preparing experiments aiming at the demonstration of interference with small proteins, like insulin, in the mass range of 3.000-10.000 amu.

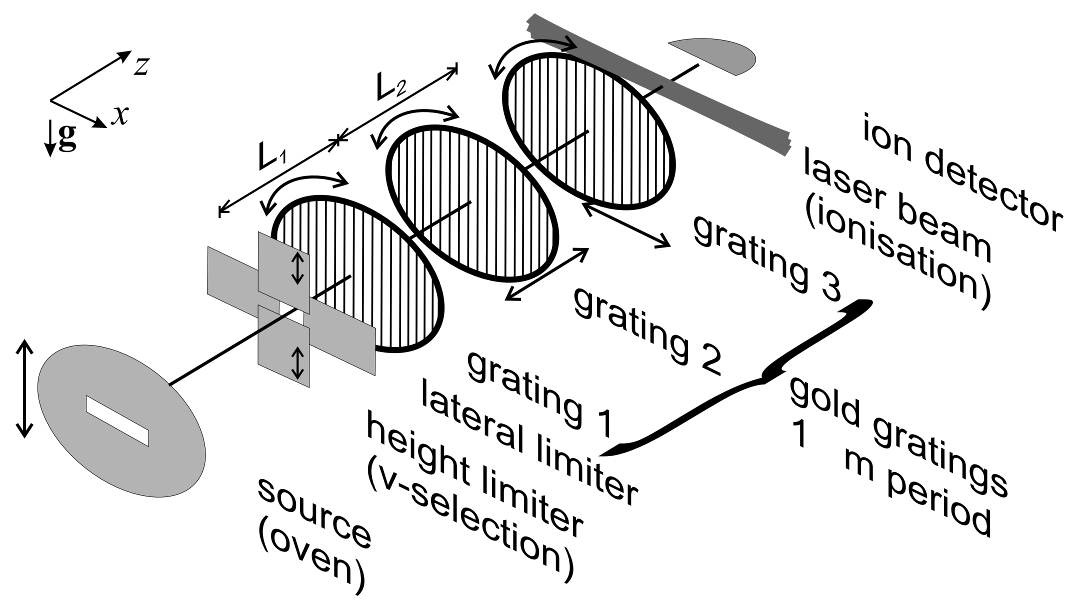

Figure 1: Setup of the Talbot-Lau interferometer inside the vacuum chamber.

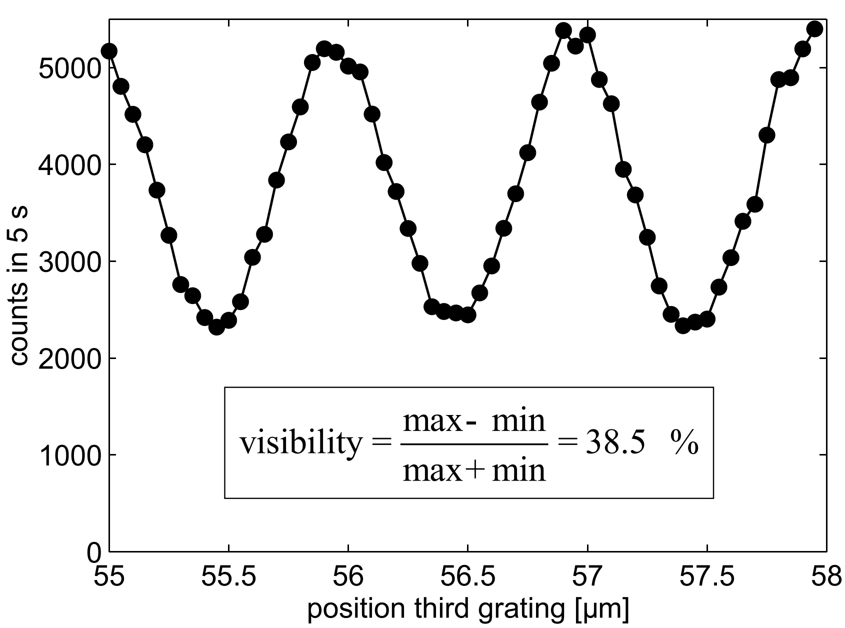

Figure 2: Interference fringes (raw data) resulting from a typical single scan of the third grating.