General summary on

Theory and experimental verification of Kapitza-Dirac-Talbot-Lau interferometry

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1. Introduction and background

Matter wave interferometers can demonstrate the quantum nature of complex molecules by establishing coherent superposition states that are spatially separated up to thousand times the particle's geometric size. A three-grating Talbot-Lau arrangement has turned out to be particularly suitable for objects of high mass and short de Broglie wavelength. But when realized with nanofabricated gratings – as done in the past – such a device is extremely sensitive to the van der Waals forces between the grating walls and the molecules. This used to impose a strong practical limit to the molecular size and polarizability that could be tested in such quantum experiments.

2. The main results

This problem is solved when the central grating is replaced by an optical phase structure, produced by a standing laser light field. The present article provides an analytic theory of the resulting Kapitza-Dirac-Talbot-Lau interferometer (KDTLI), which incorporates all relevant experimental parameters, including the incoherent effect of photon absorption. Very good quantitative agreement is found when the theoretical predictions are compared to new experiments with fullerenes and fluorofullerenes. In particular the agreement for C60F36 and C60F48 significantly surpasses earlier experiments and models for material gratings.

3. Wider implications

Molecule interferometry has matured from a proof-of-principle experiment into an instrument that allows to obtain precise values of molecular properties such as optical polarizabilities and absorption cross sections. The use of a phase grating overcomes the van der Waals limit and opens the way to future quantum experiments in a new mass and complexity regime.

Figure:

A plot of the quantum interference contrast as a function of the diffracting laser power allows a clear distinction of different molecules. The high degree of agreement between theory and experiment allows in particular the derivation of optical polarizabilities with an accuracy of a few percent. This number is also an indicator for the molecular structure or conformation.