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Freiburg, Feb. 17, 2006

Abstract:

Since classical physics is described in phase space and quantum mechanics in Hilbert space a unified picture is desired. This is provided, for instance, by the so-called Wigner function (WF), which has remarkable properties: It transforms the wave function of a quantum mechanical particle (or the density operator of an ensemble of particles) into a function living in a position-momentum space similar to the classical phase space. The WF is a real valued function and in this respect compares with the classical probability density in phase space. However, it is not always positive.

Describing the dynamics of quantum mechanical transport processes by coined or continuous-time quantum walks has been very successful over the last few years. Especially quantum information theory has employed many ideas of quantum walks as potential algorithms for quantum compuation. However, the applicability of quantum walks reaches far beyond quantum computation; for instance in quantum optics also the (discrete) Talbot effect can be described by continuous-time quantum walks.

We formulate continuous-time quantum walks (CTQW), the quantum mechanical analog of continuous-time random walks (CTRW), in a discrete quantum mechanical phase space (with position x, and wave vector κ) [1]. We define and analytically calculate the time dependend Wigner function of a CTQW on cycles of arbitrary length N. Unlike previous studies of the discrete WF, our result holds for even and odd N.
The marginal distributions of these WF, i.e., integrals of the WF along lines in phase space, are shown to recover known results [1,2]. The time dependend WF of the transport process governed by the CTQW shows characteristic features at different times t in phase space (an example is shown in the figure below). Classically, in this case CTRW show (normal) diffusion in phase space.