Utilization of surface gravity water waves for the observation of quantum mechanical and optical phenomena

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Since the early days of Newtonian mechanics, scientists were interested in the motion of bodies in different potentials. For instance, a massive point-like particle accelerating in a linear potential. In 1927, Kennard [1] has shown that within the quantum-mechanical description, the wave function corresponding to this particle accumulates a position-dependent phase, associated with the momentum change in the linear potential, as well as a position-independent phase that scales with the third power of time (t^3) during which the particle experienced the linear potential [1]. This cubic phase is also accumulated in other physical systems[2]. However, although being a fundamental property of quantum mechanics, so far, no observation of the Kennard phase has been reported, owing to the fact that any setup providing us only with the probability density is insensitive to any global position-independent phase.

The time evolution of a wave function in quantum mechanics is analogous, in many ways, to that of surface gravity water wave pulses. Thus, we utilize this analogy and study the propagation of surface gravity water waves in an effective linear potential, realized by means of a time-dependent homogeneous and well-controlled water flow. In our experiments, we have measured the Kennard cubic phase, for the first time for Gaussian and both normal and inverted Airy wave packets [3].

Motivated by these successful experiments, we have been already studying other analogies between quantum mechanics, optical physics and hydrodynamics, including (i) quantum carpets for periodic input wave packets (Talbot effect), (ii) propagation dynamics of solitary wave packets in an effective linear potential, as well as (iii) different time-dependent flows and black holes.

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