Measuring Phases of Quantum Mechanical Wavepackets Using Surface Gravity Water-Waves

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For decades, phases have played an extraordinary role in understanding quantum theory. As such, the quantum mechanical propagator of a massive particle in a linear gravitational potential was derived already in 1927 by Kennard [1,2] and contains a phase that scales with the third power of the time $T^3$ during which the particle experiences the corresponding force. However, in conventional interferometers both the signal and reference arms are usually exposed to the same acceleration. As a result, this $T^3$-phase cancels out and cannot be measured. Here we overcome this difficulty by using surface gravity water waves. The full waveform of this slow wave can be directly recorded, without the need to perform interferometric measurement.

Since the work of Dysthe on the 4th order modification of the nonlinear Schrödinger equation for water waves [3], it has been shown that wave propagation dynamics in surface gravity water-waves in many aspects is analogous to that of wave functions of quantum mechanical particles [4]. In this project, we take advantage of the analogy between quantum mechanics and surface gravity wave-packet theory to investigate the propagation of Gaussian and Airy wave packets under a linear potential in a wave tank for the first time. This linear potential is obtained by operating a water pump that creates a quadratic time-dependent flow. The two wave packets are generated at origin by a programmable wave maker, and the water wave itself is measured at different points along the 5-meter tank using wave gauges. This analogy allows us to measure the phase of the wave-function directly and extract the exact phases of these wave packets under linear potential for the first time.

The goal of this talk is to explain how surface gravity water-waves are analogous to quantum mechanics, to present our experimental set-up and experimental observations of the $T^3$-phase accumulated by a wave packet having initially a Gaussian or Airy function envelope.