PHYSICAL MATH SEMINAR

Exploring Quantum Mechanical and Optical Analogies through Surface Gravity Water Waves

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ABSTRACT:

The investigation of analogies across various physical domains, including quantum mechanics, nonlinear optics, and classical physics, offers a rich tapestry for understanding the fundamental behaviors that govern the universe. Among these explorations, the study of surface gravity water waves stands out for its capacity to bridge the realms of quantum and classical physics, particularly through the lens of wave-particle duality. This concept, central to quantum physics, posits that entities like photons and electrons possess both wave-like and particle-like characteristics, a duality also resonant in classical physics.

Our research delves into the theoretical and experimental exploration of these quantum mechanical analogies within the context of hydrodynamics. Specifically, we focus on the propagation dynamics of surface gravity water waves as they mimic the behaviors predicted by the Schrödinger equation under certain conditions. Our initial foray into this domain involved studying the propagation of Gaussian and Airy wave packets, leading to the pioneering observation of the Kennard cubic phase [1]. Further exploration allowed us to examine solitons within a linear potential [2], highlighting their unique ability to maintain shape while accelerating.

Significantly, our work extends to the Talbot effect, where we not only confirmed its occurrence in both amplitude and phase but also ventured into its nonlinear aspects, marking the first observation of the fractional Talbot effect's absence due to nonlinear medium interference [3]. Our current efforts are aimed at deepening the understanding of quantum mechanics and surface wave analogies, focusing on phenomena such as wave packet scattering from inverted oscillator potentials, quantum decoherence, and the emulation of black holes in phase space.

Remarkably, our experimental framework has facilitated the measurement and analysis of Bohm trajectories and quantum potentials across various wave packet configurations, including multiple slit arrangements and Airy slits [4]. This has opened the door to potentially observing the Wigner distribution of wave functions and related quantum phenomena. Our recent discoveries also include the ability to simulate antireflection temporal coatings and the diffractive focusing and guiding of waves, positioning our research as a novel platform for elucidating complex optical system fundamentals and quantum phenomena.

[1] Rozenman, Georgi Gary, et al. "Amplitude and phase of wave packets in a linear potential." Physical Review Letters 122.12 (2019): 124302.
[2] Rozenman, Georgi Gary, Lev Shemer, and Ady Arie. "Observation of accelerating solitary wavepackets." Physical Review E 101.5 (2020): 050201.
[3] Rozenman, Georgi Gary, et al. "Periodic wave trains in nonlinear media: Talbot revivals, Akhmediev breathers, and asymmetry breaking." Physical Review Letters 128.21 (2022): 214101.
[4] Rozenman, Georgi Gary, et al. "Observation of Bohm trajectories and quantum potentials of classical waves." Physica Scripta 98.4 (2023): 044004.

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2:30 PM – 3:30 PM
Building 2, Room 449

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