Quantum solitons and their scattering on a barrier

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Abstract:

A quantum soliton of matter waves in a 1D wave guide is a fascinating bound state of matter, already realized with cold atoms using a Feshbach control of the interaction strength [1,2]. In these experiments, a soliton contains a thousand of lithium atoms, it is ten times more massive than a C_{70} fullerene. Interferometric experiments have already been realized with fullerenes [3]. Performing them with quantum solitons would be even more intriguing: much larger de Broglie and coherence lengths would be obtained, and a new regime where the center of mass kinetic energy becomes as large as the binding energy of the interferometric object would be at hand.

Along this line, we shall present in our talk a proposal to produce and observe a Schrödinger cat state in real space by scattering a quantum soliton on a barrier [4]. The intuitive idea is to send the soliton with a center of mass kinetic energy (i) smaller than the soliton single particle binding energy (so as to avoid fragmentation of the soliton), and (ii) very close to the barrier height, so that the soliton is transmitted and reflected with roughly equal probability amplitudes $\approx 1/\sqrt{2}$.

This idea raises non-trivial questions. How to prove experimentally that a cat is formed ? What are the constraints on the state preparation and on decoherence ? Is the transmission process through the barrier a macroscopic quantum tunneling, hopelessly sensitive to barrier fluctuations ? How to calculate the soliton transmission and reflection amplitudes t and r, knowing that the barrier breaks the integrability of the many-body problem ? These questions will be answered, in particular thanks to a rigorous result “bracketing” t and r in the complex plane.

References:

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