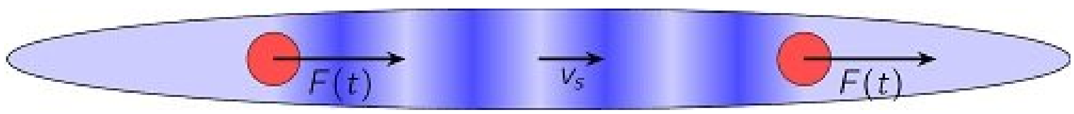
Surfing on waves in a one-dimensional quantum liquid

October 18 2019



Credit: University of Luxembourg

Physicists from the University of Luxembourg, together with international collaborators, have recently published an article in the internationally renowned journal *Physical Review Letters*. In this article, they demonstrate how quantum-mechanical interference effects could allow experimenters to better study the properties of particles trapped in quantum liquids via resonances in the absorption spectrum.

Surface waves in water

Throwing a stone into a quiet lake creates ripples on the water surface. Throwing two stones into the lake creates two such surface waves, which can form an interesting interference pattern. Creating these waves requires energy, which is transferred from the stones to the water, ultimately resulting in the stones experiencing a friction force. In classical physics this is a very old problem, but its quantum mechanical counterpart still holds surprises.

Bose-Einstein condensates

The quantum mechanical equivalent consists of two charged ions which are immersed in a "liquid" formed by lighter neutral atoms. Experimentally, such systems have already been realized a few years ago by combining an ion trap, which holds the charged ions in place, with a magneto-optical trap which allows one to bring the neutral atoms into a collective quantum state called a Bose-Einstein condensate (BEC). As the pair of ions is electrically charged, they can be manipulated using electric fields. In particular, the energy transfer from the ions into the BEC, and the resulting friction force, can be measured by studying the absorption of electromagnetic fields.

Resonances and antiresonances

Physicists from the group of Thomas Schmidt at the University of Luxembourg, together with researchers from the Institut Polytechnique de Paris and Iowa State University, discovered that a new phenomenon arises if the BEC is elongated and the quantum-mechanical nature of the two ions and the atoms are taken into account. In this case, the interference between the waves emitted by the ions and the externally applied electric field causes resonance and antiresonance features in the absorption spectrum. At the resonant frequency, the ions react very strongly to an applied electric field, whereas at the antiresonances, no energy at all can be absorbed from the applied field.

These resonances and antiresonances are a consequence of quantum interferences, the elongated nature of the BEC, and the strong Coulomb force acting between the ion and the atoms. Therefore, they can serve as a useful experimental tool for further characterizing the properties of BECs, such as their speed of sound or how they interact with embedded ions.

More information: Thomas L. Schmidt et al. Mechanical Resonances of Mobile Impurities in a One-Dimensional Quantum Fluid, *Physical Review Letters* (2019). DOI: 10.1103/PhysRevLett.123.075302

Provided by University of Luxembourg