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Sensitivity beyond standard quantum limit in molecular dynamics

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Quantum parameter estimation with high precision is a challenging field which has drawn enormous physicists' attention in recent times. Quantum metrology is the field which exactly deals with the sensitivity of quantum parameters beyond standard quantum limit. It was first pointed out by Zurek that the smallest quantum interference structures (sub-Planck scale structures) play a promising role in Heisenberg limited measurement. In diatomic molecular system, we have introduced the origin of sub-Planck scale structures in phase space quantum interference region and their relevance in quantum sensitivity. We have also showed that these structures, having negative region in the Wigner phase-space distribution, are particularly very sensitive to environmental decoherence or any infinitesimal external perturbation. We have further showed that there exists the scope for enhancing the measurement sensitivity limit by utilizing coherent control method for an experimentally realized molecular phase-locked wave packet. For a rotating-Morse potential, we investigate the emergence of a new kind of compass state, which reveals the maximum sensitivity limit for the molecular system. Here, we propose a novel method for molecular isotope separation by utilizing sub-Planck scale structures. In a recent experiment, isotope separation from a mixture of 79Br2 and 81Br2 molecules is carried out by Averbukh, et al. We combine two existing experimental techniques to improve the efficiency by minimizing the time scale of isotope separation. A thorough analysis of the Wigner quasi-probability distribution is carried out, which distinguishes the two states when they become quasi-orthogonal as a result of introducing a time delay in the wave packet evolution. Separating the isotopes at much smaller time will be more useful in experiments as every mesoscopic object in quantum physics is prone to environment decoherence.

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