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Time-dependent quantum harmonic oscillator: a continuous route from adiabatic to sudden changes

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In this work, we give a quantitative answer to the question: how sudden or how adiabatic is a frequency change in a quantum harmonic oscillator (HO)? We do that by studying the time evolution of a HO which is initially in its fundamental state and whose time-dependent frequency is controlled by a parameter (denoted by ϵ) that can continuously tune from a totally slow process to a completely abrupt one. We extend a solution based on algebraic methods introduced recently in the literature that is very suited for numerical implementations, from the basis that diagonalizes the initial hamiltonian to the one that diagonalizes the instantaneous hamiltonian. Our results are in agreement with the adiabatic theorem and the comparison of the descriptions using the different bases together with the proper interpretation of this theorem allows us to clarify a common inaccuracy present in the literature. More importantly, we obtain a simple expression that relates squeezing to the transition rate and the initial and final frequencies, from which we calculate the adiabatic limit of the transition. Analysis of these results reveals a significant difference in squeezing production between enhancing or diminishing the frequency of a HO in a non-sudden way.

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