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Quantum Coherence Sets the Quantum Speed Limit for Mixed States

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Abstract : Quantum coherence is a key resource like entanglement and discord in quantum information theory. Wigner-Yanase skew information, which was shown to be the quantum part of the uncertainty, has recently been projected as an observable measure of quantum coherence. On the other hand, the quantum speed limit has been established as an important notion for developing the ultra-speed quantum computer and communication channel. Here, we show that both of these quantities are related. Thus, cast coherence as a resource to control the speed of quantum communication. In this work, we address three basic and fundamental questions. There have been rigorous attempts to achieve more and tighter evolution time bounds and to generalize them for mixed states. However, we are yet to know (i) what is the ultimate limit of quantum speed? (ii) Can we measure this speed of quantum evolution in the interferometry by measuring a physically realizable quantity? Most of the bounds in the literature are either not measurable in the interference experiments or not tight enough. As a result, cannot be effectively used in the experiments on quantum metrology, quantum thermodynamics, and quantum communication and especially in Unruh effect detection et cetera, where a small fluctuation in a parameter is needed to be detected. Therefore, a search for the tightest yet experimentally realisable bound is a need of the hour. It will be much more interesting if one can relate various properties of the states or operations, such as coherence, asymmetry, dimension, quantum correlations et cetera and QSL. Although, these understandings may help us to control and manipulate the speed of communication, apart from the particular cases like the Josephson junction and multipartite scenario, there has been a little advancement in this direction. Therefore, the third question we ask: (iii) Can we relate such quantities with QSL? In this paper, we address these fundamental questions and show that quantum coherence or asymmetry plays an important role in setting the QSL. An important question in the study of quantum speed limit may be how it behaves under classical mixing and partial elimination of states. This is because this may help us to choose properly a state or evolution operator to control the speed limit. In this paper, we try to address this question and show that the product of the time bound of the evolution and the quantum part of the uncertainty in energy or quantum coherence or asymmetry of the state with respect to the evolution operator decreases under classical mixing and partial elimination of states.

Keywords : completely positive trace preserving maps, quantum coherence, quantum speed limit, Wigner-Yanase Skew information
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