Tighter and Stronger Quantum Speed Limits for General Quantum States

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The quantum speed limit provides a fundamental bound on how fast a quantum system can evolve between the initial and the final states under any physical operation. The celebrated Mandelstam-Tamm (MT) bound has been widely studied for various quantum systems undergoing unitary time evolution. Not only of fundamental importance, but motivated by the immense potential for it to be useful in quantum metrology and practical quantum technology, we find out newer quantum speed limit bounds from time energy uncertainty relations. Specifically, here we derive a tighter uncertainty relation for general mixed quantum states and then derive a new quantum speed limit for general quantum states from it such that it reduces to that of the pure quantum states derived from tighter uncertainty relations. We show that the MT bound is a special case of the tighter quantum speed limit derived here. We also show that this bound can be improved when optimized over many different sets of basis vectors. We illustrate the tighter speed limit for pure states with examples using random Hamiltonians and show that the new quantum speed limit outperforms the MT bound. Thereafter, we derive a quantum speed limit for mixed quantum states using the stronger uncertainty relation for mixed quantum states and unitary evolution. We also show that this bound can be optimized over different choices of operators for obtaining a better bound. We illustrate this bound with some examples and show its better performance with respect to some important earlier and recent bounds. Our work will thus be useful in various areas of quantum metrology and quantum control.

Everyone is invited to attend