
NINGPING CAO, National Research Council Canada

Quantum Error-Corrected Non-Markovian Metrology

Quantum metrology aims to maximize measurement precision on quantum systems, with a wide range of applications in quantum sensing. Achieving the Heisenberg limit (HL)—the fundamental precision bound set by quantum mechanics—is often hindered by noise-induced decoherence, which typically reduces achievable precision to the standard quantum limit (SQL). While quantum error correction (QEC) can recover the HL under Markovian noise, its applicability to non-Markovian noise remains less explored. In this work, we analyze a hidden Markov model (HMM) in which a quantum probe, coupled to an inaccessible environment, undergoes joint evolution described by Lindbladian dynamics, with the inaccessible degrees of freedom serving as a memory. We derive generalized Knill-Laflamme conditions for the HMM and establish three types of sufficient conditions for achieving the HL under non-Markovian noise using QEC. Additionally, we demonstrate the attainability of the SQL when these sufficient conditions are violated, by analytical solutions for special cases and numerical methods for general scenarios. Our results not only extend prior QEC frameworks for metrology but also provide new insights into precision limits under realistic noise conditions.