Abstract

Tensor networks for quantum metrology

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Identification of the optimal quantum metrological protocols in realistic many particle quantum models is in general a challenge that cannot be efficiently addressed by the state-of-the-art numerical and analytical methods. Here we provide a comprehensive framework exploiting tensor networks for quantum metrological problems. Tensor networks are natural language for describing problems with local correlations/entanglement. Thanks to this fact we were able to propose an efficient description of metrological models with short-range spatial and temporal noise correlations using tensor networks in form of a matrix product states. Using them we were able to calculate the maximal achievable estimation precision in such models, as well as identified the optimal probe states. Moreover, the application of infinite matrix product states techniques allows for a direct and efficient determination of the asymptotic precision of optimal protocols in the limit of infinite particle numbers. We illustrate the potential of our framework in terms of an atomic clock stabilization (temporal noise correlation) example as well as for magnetic field sensing (spatial noise correlations). As a byproduct, the developed methods for calculating the quantum Fisher information via tensor networks may be used to calculate the fidelity susceptibility – a parameter widely used in many-body physics to study quantum phase transitions.