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Interpolating Entanglement Detection and State Tomography via Quantum 2-Design

We here show an interpolation of entanglement detection and quantum state tomography in the practical sense that positive-operator-valued-measure elements of quantum measurement is devised consistently such that when they are tomographically incomplete they apply to distinguishing entangled states from separable ones, but once they are tomographically complete, the measurement performs state tomography. We show that the interpolation is possible with quantum 2-design such as mutually unbiased bases and symmetric, informationally complete states, and establish a natural framework of relating quantum 2-design to entanglement detection. Compared to entanglement witnesses having the zero-valued lower bound for all separable states, our scheme of detecting entangled states is twice efficient, accompanying both upper and lower bounds for separable states. The scheme can be readily converted to a form that is valid in a measurement-device-independent scenario. Our results present a systematic way of economizing measurement from learning entanglement to identifying quantum states.