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Optimal spectrum estimation of density operators with alkaline-earth atoms

ALEXEY GORSHKOV, Joint Quantum Institute

The eigenspectrum $\vec{p} \equiv (p_1, p_2, ..p_d)$ of the density operator $\hat{\rho}$ describing the state of a quantum system can be used to characterize the entanglement of this system with its environment. In the seminal paper [Phys. Rev. A 64, 052311 (2001)], Keyl and Werner present the optimal measurement scheme for inferring $\vec{p}$ given n copies of an unknown state $\hat{\rho}$. Since this measurement uses a highly entangled basis over the full joint state $\hat{\rho}^{\otimes n}$ of all copies, it should naively be extremely difficult to implement in practice. In this talk, we give a simple experimental protocol to carry out the Keyl-Werner measurement for $\hat{\rho}$ on the nuclear spin degrees of freedom of n alkaline-earth atoms using standard Ramsey spectroscopy techniques.