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Universal and measurable entanglement in the spin-boson model

ANGELA KOPP, Center for Materials Theory, Rutgers University, KARYN LE HUR, Department of Physics, Yale University; Departement de Physique, Universite de Sherbrooke — We study the entanglement between a qubit and its environment by calculating the von Neumann entropy of the spin in the delocalized phase of the spin-boson model. Using a well-known mapping between the spin-boson model with Ohmic dissipation and the anisotropic Kondo model, we obtain exact results for the entanglement entropy E at arbitrary dissipation strength α and level asymmetry h. We show that the Kondo energy scale T_K controls the entanglement between the qubit and the bosonic environment. For $h \ll T_K$, we find that $E = E(h=0) - \frac{2e^{b/(2-2\alpha)}\Gamma[1+1/(2-2\alpha)]}{\pi \ln 2\Gamma[1+\alpha/(2-2\alpha)]}(\frac{h}{T_K})^2$, where $b = \alpha \ln \alpha + (1-\alpha)\ln(1-\alpha)$. The universal $(h/T_K)^2$ scaling reflects the Fermi liquid nature of the Kondo ground state. In the limit $h \gg T_K$, E vanishes as $(T_K/h)^{2-2\alpha}$, up to a logarithmic correction. We thoroughly explore the phase space (α, h); for a given h, the maximal entanglement occurs in the crossover regime $h \sim T_K$. We also emphasize the possibility of measuring this entanglement using charge qubits subject to electromagnetic noise.

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