Highlights

ACTIVITY F Electronic and thermal transport from the nanoscale to the macroscale 2020

Dissipative dynamics of an open quantum battery

M. Carrega[1], A. Crescente[1,2], D. Ferraro[1,2], M. Sassetti[1,2]

[1]CNR-SPIN Superconductors, Innovative Materials and other Devices Institute, Via Dodecaneso 33, 16146 Genoa, Italy
[2]Physics Department, University of Genoa, Via Dodecaneso 33, 16146 Genoa, Italy

NEW JOURNAL OF PHYSICS 22, 083085 (2020)

Recently, in the study of thermodynamic processes at the nanoscale, it has been realized that quantum systems can be exploited to efficiently store energy by relying on quantum coherences and correlations, hence coining the word quantum battery (QB). Most of the literature on QBs focused on the dynamics of closed systems where the energy is coherently transferred from a charger to the battery without losses. In view of realistic modeling, it is however an important task to understand how an external environment affects the charging performances of a quantum battery. Here we model the QB as a two-level system, with energy separation Δ, coupled to an external charger, and we take into account dissipation effect by introducing a microscopic model for a thermal reservoir. The latter is coupled to both longitudinal and transverse spin components of the quantum battery in order to include decoherence and pure dephasing mechanisms. Charging and discharging dynamics of the quantum battery, subjected to a static driving of amplitude A, are obtained analytically in the case of weak dissipation strength, by exploiting an exact mapping to the so-called spin-boson model. In this framework, the impact of decoherence and pure dephasing mechanisms on charging performance of a QB are discussed in detail (see Fig. 1). We have found that the former is a better choice of coupling, since there the QB can absorb energy both from the charger and the reservoir. In contrast, in the latter case the charger supplies energy both to the QB and to the reservoir, resulting in a more dissipative dynamics (see Fig. 2). This study represents an important step toward a realistic and microscopic description of QBs that can be realized on solid-state quantum technology, where unavoidable presence of external environments has to be properly considered and engineered.

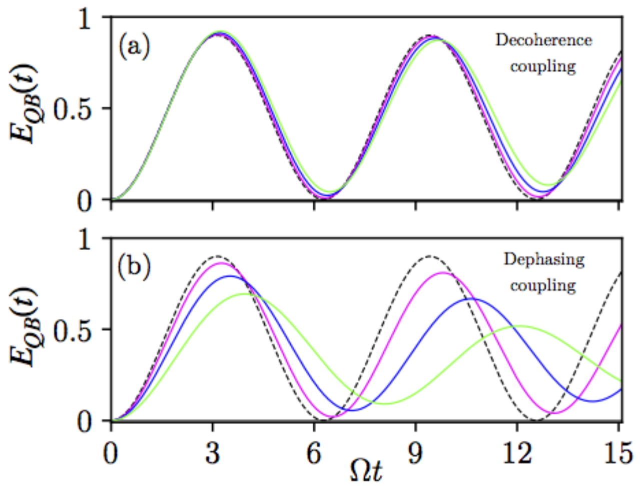

Fig. 1: Time evolution of the average energy stored in the quantum battery $E_{QB}(t)$ (in units of Δ) as function of Ωt [with $\Omega=(A^2+\Delta^2)^{1/2}$ the Rabi frequency] for increasing dissipation strengths (magenta, blue and green curves) compared to the non-dissipative case (dashed black curves). Panel (a) shows the results obtained in the decoherence case, while panel (b) represents the dephasing one.

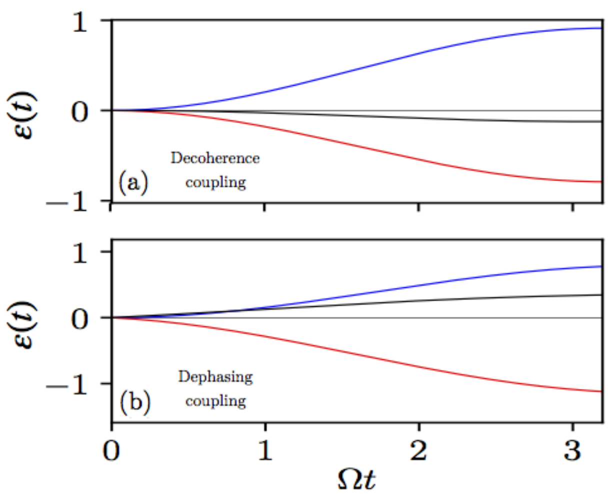

Fig. 2: Average energy flows ε(t)=E(t)-E(0) (in units of Δ) for the quantum battery (blue curve), the charger (red curve) and the reservoir (black curve). Panel (a) shows the results obtained in the decoherence case, while panel (b) represents the dephasing one.