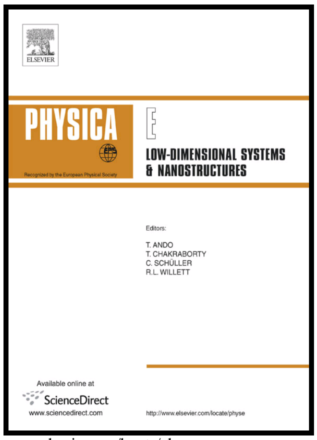
Author's Accepted Manuscript



www.elsevier.com/locate/physe

Quantum Measurements in Spin-Boson Model under non-Markovian Environment

K. Berrada, O. Aldaghri

PII: S1386-9477(16)31562-4
DOI: http://dx.doi.org/10.1016/j.physe.2017.04.021
Reference: PHYSE12794

To appear in: *Physica E: Low-dimensional Systems and Nanostructures*

Received date: 25 December 2016
Revised date: 7 April 2017
Accepted date: 21 April 2017

Cite this article as: K. Berrada and O. Aldaghri, Quantum Measurements in Spin Boson Model under non-Markovian Environment, *Physica E: Low-dimensiona Systems and Nanostructures,* http://dx.doi.org/10.1016/j.physe.2017.04.021

Quantum Measurements in Spin-Boson Model under non-Markovian Environment

K. Berrada
Al Imam Mohammad Ibn Saud Islamic University (IMISU), College of Science, Physics Department, P.O. Box 90950, Riyadh 11623, Saudi Arabia and The Abdus Salam International Centre for Theoretical Physics, Strada Costiera 11, Miramare-Trieste, Italy.

O. Aldaghri
Al Imam Mohammad Ibn Saud Islamic University (IMISU), College of Science, Physics Department, P.O. Box 90950, Riyadh 11623, Saudi Arabia. and School of Electronic and Electrical Engineering, University of Leeds, Leeds LS2 9JT, UK.

We propose a control approach of the parameter estimation for a two-level quantum system interacting with a bosonic reservoir considering non-Markovian open, dissipative quantum system. We show that the precision of the estimation significantly affected and behaves differently within the framework of the markovian and non-Markovian regimes. The influence of memory effects for an Ohmic reservoir with Lorentz-Drude regularization on the estimation-parameter precision are numerically demonstrated under the following three conditions: $\omega_0 \ll \omega_c$, $\omega_0 \approx \omega_c$ or $\omega_0 \gg \omega_c$, where ω_0 is the characteristic frequency of the two-level system, and ω_c is the cut-off frequency of Ohmic reservoir. We investigate the precision rate in high temperature, intermediate temperature, and low temperature reservoirs for various values of the ratio $r = \omega_c/\omega_0$ considering manifold external fields. We reveal that the enhancement and preservation of the measurement precision, highly depend on the combination of the external control field, reservoir parameters, and non-Markovian effects.

PACS numbers: 03.65.Ta,03.65,Yz,03.67.Mn,37.21.La,03.67.Bg

I. INTRODUCTION

Quantum mechanics is used to perform quantum information tasks in ways exceeding the capabilities of classical mechanics. Recently, the quantum metrology is considered as a fast developing field for current research in both theoretical and experimental physics [1]. It explores the capabilities of quantum systems that, when employed as probes sensing physical parameters, allow one to attain resolutions that are beyond the ability of classical protocols [2]. One of the important quantities for both quantum information processing and quantum estimation theory is quantum Fisher information (QFI), which is a useful tool for testing the precision of the parameter estimation and evaluating the accuracy limits of quantum measurements. Furthermore, QFI provides various important applications in quantum metrology such as quantum frequency standards [3], measurement of gravity accelerations [4] and clock synchronization [5], etc. In the field of quantum estimation, the main task is to determine the value of an unknown parameter labeling a quantum system, and the primary goal is to enhance the precision of measurements. There is a great deal of work on parameter estimation addressing the practical problems of state generation, loss, and decoherence [6–16]. Fisher information lies at the heart of a parameter estimation theory that was originally introduced by Fisher [17]. It provides in particular a bound to distinguish the members of a family of probability distributions. The quantum version of the Cramér-Rao inequality has been established and the lower bound is imposed by QFI [18]. Therefore, the QFI becomes the key problem to be solved. It presents an abstract quantity that measures the maximum information about an unknown parameter that can be extracted from a given measurement procedure.

Realistic quantum systems are not closed, which causes the rapid destruction of crucial quantum properties. Therefore, it is important to study the change rate of the estimation-parameter precision when the system loses its coherence due to interactions with the environment. Even a very low noise level can completely destroy the superiority of quantum metrological protocols of that system. The feasibility of preservation is greatly dependent on the intrinsic properties of the environment coupled to the system. According to the scale of correlation times, environments can be divided into Markovian or non-Markovian types. The Markovian approximation assumed that the correlation time between the system and its environment is infinitely short. However, in some cases, such as Brownian motion a system interacting with a reservoir with Lorentzian spectral density, an exact description of the open quantum system dynamics is needed [19]. In this case, the non-Markovian environments which are characterized by long correlation times or structured spectral features would be more general in many physical situations. So, it is necessary to extensively study the estimation-parameter precision considering the non-Markovian master equation. To the best of our knowledge, few detailed investigations of the effect of the physical parameters on the control of the parameter estimation under environmental noises are available at present. In order to shed light on this issue, we numerically evaluate the precision rate of the estimation in a two-level system coupled to its surrounding environment modeled by a spin degree of freedom in a magnetic field coupled lin-