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# Application quantum renormalization group to optimal dense coding in transverse Ising model

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We have merged the object of renormalization group(RG) with quantum dense coding for one-dimensional Ising model in a transverse field. At first, we have shown how the dynamic quantum discord(QD) evolves in present intrinsic decoherence when the size of the system becomes large, i.e., the finite size scaling is obtained. By considering that the generation of highly entangeled quantum states is a fundamental requirment for qauantum information, the main purpose of this work is to answer the following question: how the valid optimal dense coding can be determined by RG in many body systems? We find that the optimal dense coding capacity depends on the normalization group. It has been found that valid dense coding can exist with the increasing of RG steps. Moreovere, the results show that by increasing of RG steps, valid dense coding capacity suddenly occurs near the critical point of the quantum phase transition in present intrinsic decoherence. Using this approach, identifying a critical point of the transverse Ising model in dense coding capacity quality can be very effective.

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## I. INTRODUCTION

In quantum information processing, entanglement can be exploited as a resource for super dense coding, as introduced by Bennett and Wiesner[1]. Quantum entanglement began as an attempt to find two particles which can be correlated even being far away from each other [1-3]. It plays an essential role in quantum information and quantum computation such as quantum key distribution [4], quantum teleportation [5], dense coding [6]and so on. Over recent dacades, theoretical studies and experimental investigations on entanglement and nonclassical correlation have been main topics for groups of researchers. In the process of so called superdense coding, two classical bits of information are transferred by sending only one quantum bit, qubit. The original optimal dense coding process with a pair of entangled two-level particles is shared between Alice, as sender, and Bob, as receiver [7]. Up to now, various systems have been studied in the field of optimal dense coding [8–11]. In a realistic scenario, however, noise is unavoidably present. At recent years, attention has been donated to various scenarios of super dense coding over noiseless channels and in the presence of noise[12]. Furthermore, multipartite entangled states is also regarded as a significant resource for super dense coding [13].

Usually, it has been difficult to obtain an eigenvector correspond to the energy of the groundstate for physicists who are interested in solving quantum many-body system by the use of analytical approaches. Even if the system is consisted of $N$ particles each with $S = 1/2$. In the past few years, the RG approach has been successfully used to study the quantum correlation properties in spin systems especially as the quantum phase transition (QPT) occurs at zero temperature in many-body systems. The property of many-body system is strongly influenced by the non-analytical changes of ground state close to the quantum critical regions. The RG method provides new insights into how the block entanglement changes as the size of the system becomes large [14–17]. To analyze the various spin models, RG method has been generalized. The nonanalytic behavior of entanglement and its scaling behaviors are also naturally revealed by this method. Over recent decades, researchers have gained some important insights to the relationship between quantum phase transition and entanglement [18]. Especially, how to detect $QPT$ has become a widely investigated topic. $QPT$ is determined by quantum fluctuations at absolute zero temperature at which they are induced by the change of an external parameter or coupling constant. During recent studies for the two-spin in the XY-spin model, the entanglement displays a sharp peak at the critical point. Besides the entanglement, other quantum correlations such as quantum discord (QD) [19–21], geometric measure of quantum discord (GQD)[22], fidelity [23] and entanglement entropy are also considered to describe the QPT in quantum system [24].

Recently, the relation between QPT and quantum information has attracted much attention, and has been one of the most interesting topics in the area of condensed-matter systems [25]. Quantum dense coding in many body systems that have been studeid with RG is rarely investigated. Motivated by these, in this paper we focus on quantum dense coding in a spin chain by using RG. The central theme of this paper is the question: how does RG in the transmission channel affect the super dense coding capacity in present intrinsic decoherence? What is the role of RG in amount of dense coding capacity. To check this topic, we consider the transverse Ising model. At first, we explore whether the onset of $QPT$ can also takes place in the transverse Ising model with $QD$ in present intrinsic decoherence. We find that the dynamic

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