Thermal entanglement in a two-qubit Ising chain subjected to Dzialoshinski-Moriya interaction

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The study of thermal entanglement, the entanglement in the thermal equilibrium state of a quantum system, particularly quantum spin chains in solid state systems, is known to provide a bridge between quantum information processing and condensed matter physics [1–12]. The usefulness of entangled spin chains in thermal equilibrium to the future realization of quantum computers [13] has necessitated this potentially rich area of study. In this context many authors have studied the entanglement properties in both the ground and thermal states of spin chains interacting through various Heisenberg interaction models such as XX, XY, XXZ and XYZ [2–8]. The study of thermal entanglement properties in solid state systems with Ising like interaction subjected to an external transverse magnetic field has also been carried out quite extensively [9–12].

Dzialoshinski-Moriya (DM) interaction [14, 15], an anisotropic and antisymmetric exchange interaction, arising due to spin orbit coupling is seen to enhance the thermal and ground state entanglement of Heisenberg spin chains [7, 8]. Thermal entanglement of a two-qutrit Ising system subjected to a magnetic field and DM interaction, both along the direction of Ising axis, is studied by C. Akyüz et. al. [12]. They have found that at given temperature, an appropriate choice of magnetic field and DM interaction will maximize thermal entanglement in the two-qutrit antiferromagnetic Ising chain [12]. In this article, we examine the combined effect of external magnetic field as well as DM interaction on the variation of thermal entanglement in a two-qubit Ising chain [16]. For an unambiguous determination of the thermal entanglement, we have adopted negativity of partial transpose [17–19] as the measure of entanglement.

We analyze the Ising model with longitudinal magnetic field, DM interaction and compare the results with a transverse Ising model with DM interaction being perpendicular to the Ising direction [16]. We show that a pure DM interaction (without magnetic field) along the Ising axis (longitudinal DM interaction) can give rise to a thermal entanglement and a larger value of the DM interaction parameter is shown to result in a larger range of temperature over which the entanglement persists [16]. We have also analyzed the situation in which the Ising chain is subjected to a magnetic field and DM interaction, both being perpendicular to the Ising direction. The thermal entanglement in the case of transerve DM interaction is seen to last for a smaller temperature range in comparison with that in the case of longitudinal DM interaction. The usefulness of longitudinal DM interaction over the one that is perpendicular to the Ising axis, in the manipulation and control of entanglement at a feasible temperature, is thus illustrated [16]. We conjecture that these results are applicable to the pariwise entanglement in an N-qubit Ising chain in the presence of DM interaction.

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