Cooling through engineered dissipation on a programmable quantum annealer

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Finding low energy states is a key challenge for quantum computers not only for preparing states for quantum simulations [1], but also for solving optimization problems [2]. These can be mapped onto spin models where the ground state corresponds to the optimal solution [3]. Recently, a low-energy state preparation protocol using ancillary qubits has been demonstrated in [4]. We present an implementation of a cooling protocol based on the theoretical proposal [5] on a D-Wave quantum annealer. The process is analogous to magnetic refrigeration, where a material in contact with a heat bath in a strong external magnetic field is first decoupled from the bath before removing the field which cools the material below the original temperature. Similarly, the protocol consists of coupling qubits representing the system spins, to ancillary qubits that serve as a spin bath. Starting in the fully polarized state, these bath qubits are subjected to an external field, which is ramped down during a cycle of the protocol. Each cycle ends with a measurement of the system and bath qubits and only the system state is kept for the next cycle, removing the energy that the bath extracted from the system, thereby cooling the system. The protocol is realized by adjusting control parameters on the quantum annealer to realize different values of fields in the system and in the bath qubits. Results of the implementation are presented for a spin glass Ising model system implemented on the D-Wave device and compared to the standard quantum annealing state preparation. Additionally, we present numerical simulations exploring a variation of the protocol implementation that utilizes Pauli basis measurements to improve the solution quality for the transverse Ising model ground state preparation.

References

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