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Truly adiabatic quantum annealing in novel NMR systems which do not leave their ground state

Previous implementations of adiabatic quantum computing algorithms using spin systems were not absolutely adiabatic, since they relied on control pulses which could spuriously cause the system to exit the ground state, and further control pulses to return the system back. We have experimentally demonstrated a complete adiabatic quantum computation where we managed to keep the system in the ground state all the way from the beginning to the end of a fully adiabatic passage. This was possible because we used the natural Hamiltonian of our sample to realize the problem Hamiltonian, and extrinsic Hamiltonians induced by electromagnetic pulses to drive the system along the adiabatic passage. As a showcase example, we prime factorized 291311 experimentally at room temperature, and we used tomography to measure the populations in the computational basis at 11 different stages of the adiabatic passage to demonstrate that the system remained in the ground state the entire time. The fluctuation in our fidelity was ~ 0.0005, compared to what we get with the previous method for NMR annealing, which is ~ 0.02. In contrast to superconducting flux-based annealing, NMR annealing has already succeeded with 3-local terms [PRL (2009) 102, 104501], 2-local non-stoquastic terms XX, YY in addition to ZZ [PRA (2016) 93, 052116], and 4-local, non-stoquastic terms XYXY + YXYX [PRL (2014) 113, 080404]. We will therefore discuss prospects for scaling universal NMR annealers to numbers of qubits competing with non-universal superconducting annealers.

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