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Quantum computation using always-on coupling in superconducting circuits

We present recent theoretical and experimental results on a novel quantum computing scheme requiring only fixed couplings and single-qubit gates [1, 2, 3]. The control strategy removes the need for two-qubit gate calibration by using the free evolution of the native Hamiltonian, inspired by dynamical decoupling and refocusing techniques developed in the Nuclear Magnetic Resonance (NMR).

In the first part of the talk, we introduce the theoretical background of our method. We present algorithms for designing pulse sequences that can leverage static Ising Hamiltonians with arbitrary coupling strengths to perform quantum algorithms, with favourable total time duration and pulse count scaling [2, 3]. We then show how the pulse sequence generated by this method can be applied to hardware-efficient Noisy Intermediate-Scale Quantum (NISQ) algorithms and quantum error mitigation [4].

In the second half, we study the practicality of such an NMR-based quantum computing strategy on superconducting circuits. We implemented a proof-of-principle experiment on a two transmon qubit system, using the always-on residual ZZ coupling as a computing resource to perform a Variational Quantum Eigensolver algorithm. We will discuss practical challenges in controlling and measuring a device with always-on couplings and outline future improvements in circuit design to circumvent these issues.

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