Non-degenerate noise-resilient superconducting qubit

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Abstract

We propose a superconducting qubit based on engineering the first and second harmonics of the Josephson energy and phase relation $E_{J1}\cos\varphi$ and $E_{J2}\cos\varphi$. By constructing a circuit such that E_{J2} is negative and $|E_{J1}| \ll |E_{J2}|$, we create a periodic potential with two non-degenerate minima. The qubit, which we dub "harmonium", is formed from the lowest-energy states of each minimum. Bit-flip protection of the qubit arises due to the localization of each qubit state to their respective minima, while phase-flip protection can be understood by considering the circuit within the Born-Oppenheimer approximation. We demonstrate with time-domain simulations that single- and two-qubit gates can be performed in approximately one hundred nanoseconds. Finally, we compute the qubit coherence times using numerical diagonalization of the complete circuit in conjunction with state-of-the-art noise models. We estimate out-of-manifold heating times on the order of milliseconds, which can be treated as erasure errors using conventional dispersive readout. We estimate pure-dephasing times on the order of tens of milliseconds, and bit-flip times on the order of seconds.

References

[1] Manucharyan et al., Science, 326 (2009) 113.
[2] Smith et al., npj Quant. Inf, 6 (2020) 8.

Figures

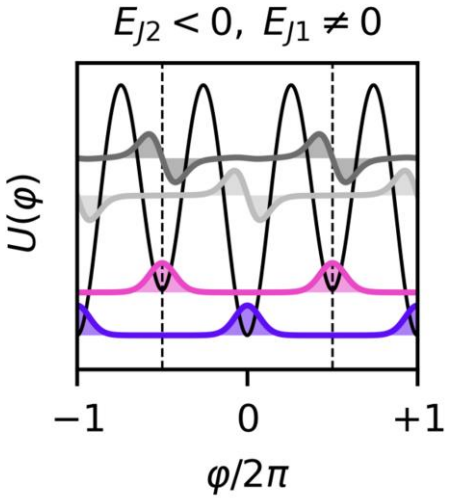

Figure 1: The qubit states (purple/pink wavefunctions) are localized to two non-degenerate wells of the potential.

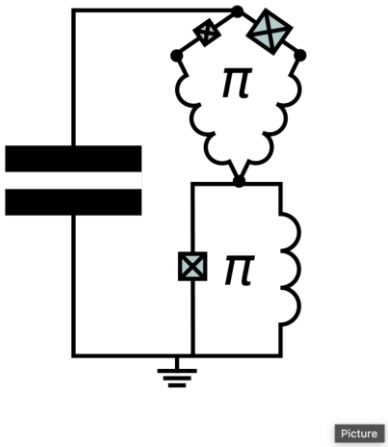

Figure 2: The desired potential can be realized by a series combination of a fluxonium [1] and a kite [2].