Exercises week 4

Overview

Week 4: The fluxonium qubit

Keywords: Artificial atom, heavy fluxonium, Josephson array.

[1] Vladimir E. Manucharyan, Jens Koch, Leonid I. Glazman, and Michel H. Devoret. Fluxonium: Single Cooper-Pair Circuit Free of Charge Offsets. *Science*, 326(5949):113–116, October 2009

[2, Chapters: II, IV, App. A-B] Long B. Nguyen, Gerwin Koolstra, Yosep Kim, Alexis Morvan, Trevor Chistolini, Shraddha Singh, Konstantin N. Nesterov, Christian Jünger, Larry Chen, Zahra Pedramrazi, Bradley K. Mitchell, John Mark Kreikebaum, Shruti Puri, David I. Santiago, and Irfan Siddiqi. Blueprint for a high-performance fluxonium quantum processor. *PRX Quantum*, 3:037001, Aug 2022

[3, Chapters: I-II, V-VI, App. G] Helin Zhang, Srivatsan Chakram, Tanay Roy, Nathan Earnest, Yao Lu, Ziwen Huang, D. K. Weiss, Jens Koch, and David I. Schuster. Universal fast-flux control of a coherent, low-frequency qubit. *Phys. Rev. X*, 11:011010, Jan 2021

E1

Exercises concerning Ref. [2].

(a) Plot the fluxonium potential in Eq. (1) with a slider controlling ϕ_{ext}, using for example the "Manipulate[...]"-function in Mathematica.

(b) Consider a coordinate transformation $\hat{\phi} \to \hat{\phi} - \phi_{ext}$ such that the potential becomes $-E_J \cos\hat{\phi} + \frac{1}{2}E_L(\hat{\phi} - \phi_{ext})^2$. The physics should be the same after this simple transmformation and it is, yet the potential is not 2π-periodic in ϕ_{ext} anymore. Plot the potential after the transformation along the potential from E1(a) and play with the slider controlling ϕ_{ext}. Argue, that the physics should stay the same despite the different appearances of the two potentials.

E2

Exercises concerning Ref. [2]. In this exercise, we want to make a numerical analysis of the fluxonium as in Ref. [2]. Since the phase coordinate is no longer periodic and the charge variable not discrete, it appears useful to write our code in the flux basis. Since the coordinate is not periodic, you should choose a flux cutoff such that your lowest waverfunctions are contained in the potential. You can begin with $\phi_{cutoff} = 4\pi$ but it depends on parameters.

(a) Define a function that returns the Hamiltonian in Eq. (1) from Ref. [2] as a sparse matrix in the flux basis.

(b) Reproduce panels (a) and (b) in Fig. 2 from Ref. [2].

(c) Write a function that computes the relaxation time T_1 due to dielectric loss, see for example App. A.

(d) Reproduce Fig. 2(d) using dielectric loss only (if you want, try also to include quasiparticle poisoning as in Eq. A1).

(e) Simulate a DRAG-pulse that achives an infidelity below $1 - \mathcal{F} < 10^{-4}$ and plot the infidelity (see Eq. 8) and $|\langle\psi_1|\psi(t)\rangle|^2$ as a function of time. You may find inspiration in App. B.

References

[1] Vladimir E. Manucharyan, Jens Koch, Leonid I. Glazman, and Michel H. Devoret. Fluxonium: Single Cooper-Pair Circuit Free of Charge Offsets. *Science*, 326(5949):113–116, October 2009.

[2] Long B. Nguyen, Gerwin Koolstra, Yosep Kim, Alexis Morvan, Trevor Chistolini, Shraddha Singh, Konstantin N. Nesterov, Christian Jünger, Larry Chen, Zahra Pedramrazi, Bradley K. Mitchell, John Mark Kreikebaum, Shruti Puri, David I. Santiago, and Irfan Siddiqi. Blueprint for a high-performance fluxonium quantum processor. *PRX Quantum*, 3:037001, Aug 2022.

[3] Helin Zhang, Srivatsan Chakram, Tanay Roy, Nathan Earnest, Yao Lu, Ziwen Huang, D. K. Weiss, Jens Koch, and David I. Schuster. Universal fast-flux control of a coherent, low-frequency qubit. *Phys. Rev. X*, 11:011010, Jan 2021.