LAB 2023: Superconducting qubits

MCC180 Open quantum systems

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Location: Laboratory room F4204 (F building, 4th floor; meet up by glass doors near Café Canyon in MC2)

Schedule: Week 15 - Introductory Course, Thursday, April 13, 10:00 - 10:45
Lab Tour, Thursday, April 13, 10:50 - 11:20
Week 16 - Group 1 & 2, Monday, April 17, 13:15 - 17:00
Group 3 & 4, Wednesday, April 19, 13:15 - 17:00
Group 5 & 6, Thursday, April 20, 08:00 - 12:00
Group 7 & 8, Friday, April 21, 13:15 - 17:00

I. INTRODUCTION

In this lab you will manipulate and read out the quantum state of a superconducting transmon qubit coupled to a microwave transmission line resonator. There will be an introductory course followed by a lab tour before the lab session to equip you with the necessary fundamental and technical knowledge. You will use our research equipment and microchips made by graduate students in our group.

The aim of the lab is for you to gain some practical insights on the central concepts from the course, which you have so far encountered only in an abstract, mathematical form:

- Rabi Model: semi-classical description of the atom–field interaction
- Jaynes-Cummings Hamiltonian: atom-photon interaction at the quantum level, "circuit-QED"
- Bloch Equations: dynamics and decoherence of a two-state system
- Randomized Benchmarking: rapidly infer error rate of single- and two-qubit gates

You will learn some experimental skills relevant for a quantum mechanical engineer, and get an opportunity to improve your skills in communicating and reporting on a scientific/technical topic.

II. LEARNING OBJECTIVES

By the end of the lab session, you will hopefully acquire a good grasp of the following concepts and skills

- Understand the operating principles of the resonator and qubit spectroscopy
- Set up the Rabi experiment to calibrate the drive amplitude for a π-pulse
- Set up Ramsey experiments to fine-tune qubit drive frequency
- Understand the fundamental ideas of randomized benchmarking and gate fidelity

III. LAB REPORT INSTRUCTIONS

You will do the experimental lab assignments in teams of two, with two teams per lab session. The teams attending the same session will get different reporting tasks, if possible (e.g. focus on Rabi and Ramsey measurement or randomized benchmarking).

Each team writes a lab report, maximum 5 pages including everything. While writing your reports, think of your intended reader as another student of the course who hasn't done the lab. Report-writing instructions based on Chalmers' writing guidelines are given on the next page, and the assessment criteria and rubrics are in a separate file.

In the report, you should include the experimental setup, measurement schematic and proper references when you use such expressions, theory, etc. Explain what the different variables and parameters mean. You don't need to derive any expressions that you can find in books or lecture notes.

Please send your report as a pdf file to liangyuc@chalmers.se, within one week after your respective lab session and please name your file using the authors' last names on this format: LabReport_Name1_Name2.pdf.

If possible, use the format of the American Physical Society available as an Overleaf template.

IV. ASSESSMENT

You will receive some collective feedback on your reports. Then we will work with peer feedback and revision, with instructions to follow after you have submitted your first version reports. The second version of your report will be marked according to the rubrics and criteria, and account for 15% of the grade on the course. The quality of your feedback to your peers, your response to received feedback, and your timeliness in submission will also be taken into account.