Quantum Control Experiment Help Sheet

CSUEB Advanced Lab

Flippin' Spins for that Echo

This document guides experimentalists in the setup, collection of data, and analysis of spin flip "echos" - quantum effects due to the user's intervention. It is a helpful guide to this exciting and topical lab created by fellow students.

Following the experimental setup isn't particularly challenging, and you should be seeing spin echoes in no time. The real challenges, and learnings, come in tying the actual physics to what you are seeing!

This experiment is a great primer on the fundamentals of quantum computing. Quantum computing and information is an exploding industry, so understanding its basic tools are essential if you are interested in this field (a field that can use *all* of our help btw!).

In addition, this lab provides excellent practice in using an oscilloscope. A lot of the measurements taken for the lab require an understanding of timing scales and ranges, as well as how triggers work. We recommend first running through the experimental setup on a regular oscilloscope for practice, and then, if available, take advantage of the Moku:Go for automated oscilloscope control and data collection for seamless analysis with advanced computational tools.

To support this, a Jupyter notebook is provided to help you get started using the Moku device, allowing for in-browser data collection and analysis. This is a great way to learn how to interface with equipment using python and other languages through your laptop, and if desired get practiced with advanced AI/ML techniques.

Getting Started

The introduction - Chapter 0 in the binder - is a good overview of the experiment. However the first chapter, the theoretical background (Chapter 1), can be a bit challenging and downright a struggle if one has not had quantum mechanics. We recommend focusing on the text of this theory chapter and focus on what is happening rather than getting lost in the math. The process of experimentation and data analysis

should actually provide helpful context for understanding the theory, so definitely go back to this chapter after completing the rest to review and truly understand the experimental underpinnings and further applications. Overall, these two chapters can be reviewed before the first lab meeting.

At the first lab meeting, gather and check the equipment: device (coil), controller box, oscilloscope, BNC cables (3-4), BNC T-connector, and a flat head screwdriver. Also, have a cup of water (can be from tap) and syringe available for water chamber filling - these should be with the equipment.

Using the steps in the book, along with the video guide, perform the following steps:

1. Remove and fill the chamber with water.
2. Make initial connections and understand all current and data flows.
3. Enter initial settings and find the max amplification frequency.
4. Preparation and Intervention Pulse Optimization.
5. Getting and reading a spin echo.

This process is covered in Chapter 2, and most groups can get through it in the first two lab meetings. Definitely note that the labels are slightly different than given in the book, but clarified in the video.

After the spin echo is discovered on an Oscilloscope, it is recommended to use the Moku to collect data. And when using the Moku, it is important to use the 'Envelope' output on the control box, as opposed to the normal output. If not the Moku will show no reading as it cannot capture the full signal due to bandwidth limitations.

The code used to interact with the Moku API to control it and pull data off it is found in the spin_echo.ipynb Jupyter notebook. The notebook is written in tutorial format, but it is completely functional and ready for immediate data collection. Please make a copy of the notebook on your own device. We recommend spending one class learning the Moku by utilizing the desktop application, and then using the second class meeting that week to learn and use the API.

Additional experimental weeks can be used for both data collection on the machine.

Good luck, enjoy, and do not be afraid of the documentation!