sdMay23-24 Quantum Computing
Aug 2022 - May 2023
Early / Mid April Report

Team: Quantum Computing

Goal: Create a kilo-qubit scale (KQB) **design** for a quantum computer

Team Members:

- Nicholas Greenwood
- Jacob Frieden
- Emile Albert Kum Chi
- Colin Gorgen
- Arvid Gusatfson
- Sam Degnan

Advisors:

- Gavin Nop (PhD student) (not present)
- Dr. Jonathan Smith
- Dr. Durga Paudyal (late, communicated ahead of time)

Agenda: Virtual Meeting

- Software Side Updates **(Minor)**
    - Jacob
    - Arvid
    - Sam
- Hardware Side Updates **(Major)**
    - Nick
    - Emilie
    - Colin
- Discuss mid-semester Presentation if time allows and interest is there

Summary

- Weekly meeting summary, **including accomplishments, pending issues, and individual contributions**
    - Software Team
        - Jacob asked about the Fibonacci number cycle storage to Dr. Smith, a big proponent of this new technology
            - They discussed technicalities of the paper that proposed this idea and how the storage actually works (15 mins)
            - The specifics of this conversation were very technical and not useful o be noted here in the report
            - Results of the conversation can be viewed in the next section

        - During the software team’s Monday meeting, they worked on the technology to pay homage to the Fibonnaci number cycle storage using quasi crystals
        - The team also worked on code to get values out of the qubits at a given time (ie read the qubits)
        - The following email outlines work done during the following week:
            - Def of Job: A sequence of quantum instructions (operations and operands) that represent the steps in executing some quantum algorithm. Analogous to assembly instruction set.
                - We have our Cycle class: contains operations that can be done concurrently at a given point in a job’s execution, attempting to put an operation in a cycle that uses a qubit that’s already “occupied” for the cycle by a different operation generates an error.
                - Our NodeLiteral class: is the physical representation of the node during a job. It takes a list of cycles and executes them (sending things to qiskit-not 100% sure if this is necessary, but we are doing it, “moving” qubits to different places, etc.).
                - Last (new this week), our Node class: can take jobs and works to create a valid serialization of cycles by 1. picking which qubits in the node participate in the operations such that the operands specified in the job are respected 2. simply pipeline-able operations are able to be 3. choices of qubit-operand mappings minimize distance traveled per qubit.
                - Currently, the serialization isn’t complete in Node. It also does not try to optimize (e.g. minimize 2 bit ops, or maximize coherence time via any of the means proposed for doing so, or control movement), but eventually, that will more-or-less be its concern as well. We have thoughts on the optimization front, but mostly they’re rather complex, and some of the issues that we suspect will matter fall deep enough into the realm of quantum CS that we don’t expect to implement them in the remaining time frame. Our goals for the short-term are to finish the serialization. One big hurdle here is the quasi-memory idea.
    - Hardware Team
        - Emile, who is working on the circuitry, dropped a bombshell: The approximate drawings in the PPT that were used to base the global design off of were so inaccurate that they actually conflicted each other
            - The triangle part at the ends of the ion traps, which houses the wire bonds and much of the “circuitry” for a given ion trap, had

    - dimensions that significantly differed from how we were graphically representing them
    - The difference was so large that **this caused a spatial conflict in the triangle parts of different traps, a problem we thought we had alleviated over 1 month ago**
    - Colin also came to the same conclusion this week. He was working on the Solidworks design in tandem with Emile doing his work.
    - A majority of the meeting was spent adjusting the physical model (the PPT model not the Solidworks model) to see roughly how large these expanded traps would need to be
    - Exact decisions and ramifications are discussed in the section below
  - Meanwhile, Nick was working on the ancillary hardware, particularly the lasers. These were not discussed at length due to time constraints but were discussed in the next meeting
- Mid-Semester Presentation Review
  - For the purposes of constructive criticism, we ended the meeting with a viewing of the mid-semester presentation that we submitted prior to Spring Break
  - This video was 12.5 minutes long and covered our progress this semester from Week 1 to 8 (right before Spring Break)
  - This presentation did not include a background slide(s), which was a critique of Dr. Smith's. We said that for the purpose of this presentation, we did not need one nor did time allow us one.
    - In our final presentation, a large majority of our presentation will be focused on background. This is what we spent nearly all of 1st semester on.

Name	**Contributions**	**Weekly Hours**	**Total Hours**
Nick	Looked into actual examples of ancillary hardware, further organized input lasers	8	78
Emile	Worked on reconciling measurements from graphical representation	7	79
Colin	Worked on Solidworks design	6	74
Sam	Worked at software team meeting on Monday	7	77
Jacob	Worked at software team meeting on Monday	7	78

Arvid	Worked at software team meeting on Monday	6	79

- Please note: We have not been keeping track of weekly or cumulative hours before Early/Mid March. It seems very micro-manag-y and is not how we like to work. The only reason we have this table in here is to appease course requirements. All numbers are estimates.

- List of any decisions made
    - We are not going to dive into the technical side of the quasi-crystal memory notion. It is a little out of our wheelhouse and as such we will be diving into the ramifications and potential usage of this component within a quantum computer, without actually replicating how it works exactly
    - With the Solidworks design of Colin and rationale of Emile, we have decided that we needed to scale up the size of the isthmus of the ion trap. While we had already discussed that the HOA trap (the basis of our ion trap design) wouldn't perform the operations we'd want it to, we wanted to use it as an exact proxy for a trap that would. There doesn't seem to be any space limitation holding the HOA back.
    - We can decided to increase the size of the isthmus to 7.5mm vs the original 4.617mm. We plan on doing this by scaling up the size of the electrodes used in the quantum computing region. This means that the circuitry would not be any larger, and would alleviate the runaway ancillary hardware size problem
        - No longer use off the shelf hardware bc of this and HOA traps already wouldn't work
    - Due to the larger size of the traps, we will need to scale the chip size up to ~26mm square over 20mm. This is not significant in the chip world and shouldn't pose much of an issue. We are leaving some space leftover for internal wiring on the chip to connect to the wire bonds at the end of each trap.
- Next steps for the project / Plans for the coming week(s)
    - Nick has to go back and adjust measurements of the ion trap (as few as possible)
    - Colin and Emilie must be provided with these new measurement to adjust Solidworks and confirm interoperability with existing circuit design
    - Software team will continue to work on the Digital Twin and further work on the implementation of the quasi-crystal memory