Quantum Design Hackathon

Project Title: The Qubitarium of Trapped Ions

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Description

Inside the Qubitarium, three ions—red, blue, and yellow—emerge in a dark vacuum, each contained within their own layered electromagnetic field. As opposing sides of the room sustain C and G, these harmonies introduce control fields that rotate the ions between two possible quantum states. Audience members then shine their phone lights as photons, optically pumping and initializing the ions into stable ground states on their chairs. A coordinated light pulse triggers controlled rotation, and with the introduction of a fourth participant, the ions synchronize in shared motion to represent entanglement. Finally, a focused measurement beam resolves the system, and when a state is chosen—C or G—the qubit collapses into a definite outcome, demonstrating how isolation, control, and observation transform fragile quantum potential into measurable reality.

Supporting material

Presentation Link:
https://docs.google.com/presentation/d/1OrF3gyMUgq7G4pX8ksY8-o8FMnQFM1vCLhMj4iZvYIY/edit?usp=sharing

Abstraction

We used the analogy of a puppet show for describing the idea of a laser controlling the ion in a trapped ion system. The “stage” for the puppet show is the ground-zero of the ions, and the show the ions put on is controlled by the puppet strings, i.e., the photonic lasers.

Explanation of the Quantum Concept

Trapped-ion qubits use electrically charged atoms—ions—held in place by electromagnetic fields inside a vacuum chamber. These ions are confined using oscillating electric fields in devices called Paul traps, which suspend them in free space with extremely high stability. Quantum information is stored in the ions' internal electronic or hyperfine states, and lasers are used to cool the ions, prepare them in well-defined states, and perform quantum gates by driving transitions between these states or coupling them to shared vibrational motion for entanglement. Trapped-ion systems achieve very long coherence times and high-fidelity operations, though they face challenges such as slower gate speeds and the need for complex laser control.

Resources referenced

- Trapped-ion quantum computers: https://www.youtube.com/shorts/Ee57rQyVr4A
- Acoustic levitation: https://www.youtube.com/shorts/cWe3I8paA4Y
- Wikipedia: https://en.wikipedia.org/wiki/Trapped-ion_quantum_computer

Our Process

Brainstorming

We explored multiple ideas including:

- A puppet show where the strings on the puppets symbolize lasers. We considered shadow puppet theater and mimed human puppets
- A trapped atom tamagotchi where we'd create a game that would allow you to trap and entangle ions
- Ion "farmville" / "stardew valley", a single player version of farmville where you farm different types of ions (trapped, cat, etc)

Narrowing scope

We liked the idea of the puppet show and the possibility of audience interaction and looked at how we could build audience participation into our project

Opportunities

We had the opportunity to collaborate with a special guest hacker, a 9 year old participant. We tested our ideas of what might be fun with her and she contributed names to our trapped ions (Dot, Bob, and Sneaky).

Constraints

Our main constraint was time. We wanted to hit on a balance of fun, completeness, and we wanted to open a door to a room of ideas for how to educate, inspire, and communicate the complexities of trapped ions.

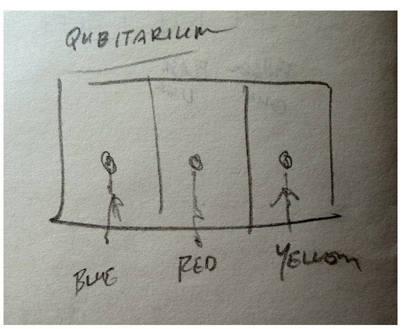
Our Goals

- **Keep it simple:** easy enough for a 9 year old to understand and feel included
- **Make it human:** pair humans and overhead visuals
- **Make it fun:** include audience participation (voice, movement, phone lights)
- **Make it "Team 5" collaborative**: bring all of the team's skills to bear (knowledge, programming, design, composition, storytelling, physics)
- **Make it repeatable:** make it simple enough to take to any event with an audience.

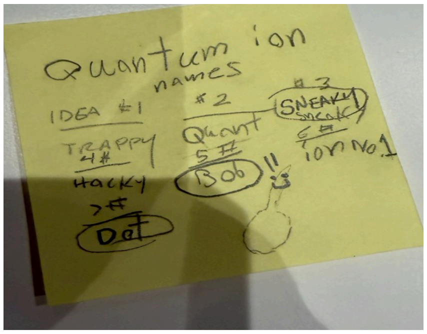
Our Breakthroughs

- **Simplifying with Simon:** first iterations of our Qubitorium biased to granular 1:1 mapping of each step of trapping an ion. Introducing the "Simon Says" narrator allowed us to simplify and condense the time needed to traverse multiple steps in our story.

Our Workflow



We sketched ideas on screen and on paper and rapidly prototyped high resolution graphic backdrops for our stage



Our special 9 year old collaborator contributed names for our Trapped Ions

Our audience met “Simon” (Mahnoor) and our trapped Ions

If we had more time

- We would explore gamifying the interaction and building out a way for the audience to accrue points through measurement or entanglements
- We would embed data visualization in the singing sections of our presentation so that the audience could ‘see’ their voices in either pitch match or wave form on the screen behind our actors

The Acts

ACT 1 — Vacuum & Emergence

- Simon welcomes the audience to the Qubitorium, a vacuum where three ions are in layers

- ~~Audience closes eyes.~~
- ~~In darkness,~~ three ions move into the stage, each standing inside their own circular "layer."
- The three positions of the ions indicate their location in layers in the Qubitarium.
- Audience sees:
    - Three distinct ions
    - Each suspended within their own invisible field
- No chaos. Just presence.
- Physics meaning: The vacuum chamber is established. Ions are confined but not yet initialized.

ACT 2 — Electromagnetic Rotation Introduced

- Simon says audience left side sings C
- Simon says audience right side sings G
- These are your two basis states.
- The sustained tones create a harmonic field.
- ~~The ions begin subtly rotating in place — shifting posture or orientation between two alignments.~~
- ~~They are not choosing.~~
- ~~They are resonating between two control fields.~~
- Physics meaning: Control pulses rotate the qubit state.

ACT 3 — Optical Pumping (Initialization)
- The ions are still moving slightly.
- Simon says Audience now turn on iPhone flashlights and points them at the ions.
- This represents photon interaction.
- Gradually:
    - The ions stop jumping.
    - They become still.
- They are now initialized into a known state.
- Important distinction:
    - They are stabilized but not yet entangled.

ACT 4 — Rotation Pulse
- Simon says imagine you are still singing C and G singing.
- ~~Table 5 (or a designated group) sharply raises their phone lights in unison — a visible "pulse."~~
- ~~One table points finger gun hand~~
- Simon says tilt your phones right
- Simon says tilt your phones left
- Two ions begin walking slowly toward eachother in a controlled circular motion
- Controlled circular motion.
- This is active state rotation.

- Physics meaning: A pulse drives coherent rotation on the Bloch sphere.

ACT 5 — Entanglement

- Two ions pair up and form small synchronized circles (ring around the rosy).
- Their movements mirror each other precisely.
- If one shifts, the other shifts.
- They are now coupled.
- Physics meaning: Entangled qubits sharing a joint state.

ACT 6 — Measurement

- An audience participant picks a state out of a hat (C or G)
- The audience member walks between the entangled ions and announces the state picked (C or G) and says it out loud
- The entangled ions release hands and make a C or G shape with their arms YMCA style
- This represents
  - Measurement
  - State resolved.
  - No more blending.
- Physics meaning: Measurement collapses the qubit into one eigenstate.