Building Faster Computers Using Quantum Physics

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Overview of Our Research

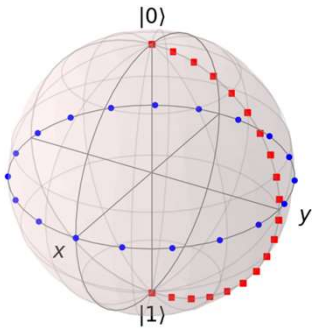
Quantum computing uses principles of quantum physics to exponentially speed up calculation times.

- Instead of using zeroes and ones (binary) like classical computer bits, quantum computers use a **combination of zeroes and ones** to store more information in a single quantum bit ("qubit").

Gyenis Quantum Lab: Superconducting qubits

- **Superconductors are unique metals that transport electrical current without energy loss** from things like heat.
- Superconductors make **Josephson junctions:** nanometer-sized circuit elements where electrons use "quantum tunneling" (transmission through a barrier that ordinarily couldn't be crossed) to store information.

Foundations of Quantum Computing

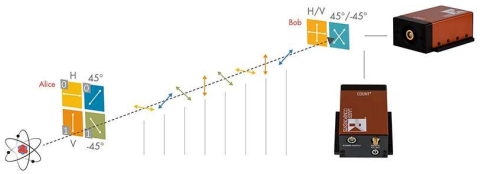


Graphical representation of the possible states of a qubit. Instead of being limited to either 0 or 1 (binary), qubit states can be anywhere in between – like a position on the surface of this sphere[4].

- **Binary vs Quantum:** Qubits are prepared as a superposition (combination) of 0 and 1. This solves problems exponentially faster than classical computers.
- **Transistors vs Josephson Junctions:** transistors are either on or off, while Josephson junctions use **quantum tunneling** to access both based on probabilities.

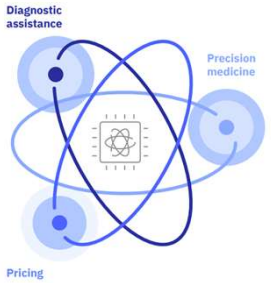
Broader Impacts of Quantum Computing

Quantum Cryptography[1]



Using quantum physics, data and information may be encoded using new algorithms that classical computers can never decrypt

Healthcare[2]



Combine quantum computing and classical modeling to improve diagnosis procedure, medicine development, and mitigate cost increases

Finance[3]

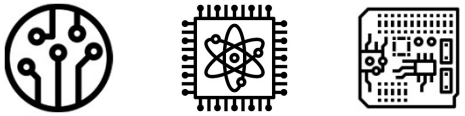
Apply quantum algorithms to financial problems involving uncertainty and constrained optimization

Experiment

- Unlike a laptop or PC, quantum computers have to be cold, colder than outer space!
- Superconductors can only **operate at milli-Kelvin temperatures.**
- We conduct experiments on our new designs for qubits in a **dilution refrigerator** (pictured to the right[5]), which can cool qubits down to temperatures needed for operation.

Conclusion

Quantum computing is an alternative to classical computing that offers new solutions and possibilities **for cryptography, healthcare development, financial modeling,** and more. By going **beyond 0s and 1s**, quantum computing can become an **exponentially faster platform for calculations** as a result of research like this.



Acknowledgements

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[1] Graphic from 2023 Laser Components Photonics News No 69
[2] Graphic from IBM Institute for Business Value publication on Quantum Computing in Financial Services
[3] Graphic from IBM Expert Insights publication on Quantum Computing in Healthcare
[4] Graphic from qutip: Quantum Toolbox in Python documentation
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