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Scalable, nanomechanical acoustic processor for high quality quantum computing

Stanford researchers at Prof. Safavi-Naeini's laboratory have developed a high quality, scalable processor architecture using small, phononic crystal resonators for read-out and long-lived storage in superconducting circuit quantum computing. This quantum acoustic system couples individual qubits to clusters of coherent mechanical resonators. Because each qubit controls multiple resonators, the hardware is extremely space-efficient for greater functionality with fewer elements, smaller size and less complicated controls. Furthermore, the patterning of the phononic crystals mitigates both acoustic and electromagnetic losses and its compact size (a few microns) facilitates scaling. Overall, this hybrid quantum information processing platform offers quantum volume 3-fold higher than an analogous system using traditional superconducting microwave circuits with electromagnetic resonators.

Stage of Research
Proof-of-concept - The inventors have demonstrated the proof-of-concept for coupling the phononic crystal resonator architecture to superconducting devices. The nanomechanical resonators offer both very long lifetime and small size with an estimated quantum volume of 220.

Prototype chip – The inventors continue to develop a prototype of entire chip with the single-qubit multiple mechanical mode system.

Applications

- **Quantum computing**, including:
    - NISQ (Noisy Intermediate Quantum Systems) machines

    - next generation quantum processors and quantum networks
    - memories for quantum communications, e.g. quantum repeaters

Advantages

- **Large quantum volume:**
    - estimated quantum volume ~220 (analogous system using on-chip microwave resonators would be smaller by about a factor of 3 due to lower quality factors)
    - phononic bandgap structures leads to robust high-Q mechanical resonances
    - low loss and high coherence
    - quality factors can exceed 10^{10}
- **Scalable, compact and efficient** - less hardware than traditional architecture
    - small mechanical/acoustic wave resonators (a few microns)
    - many resonators can be connected to a single qubit which is controlled externally
    - long-lived storage
- **Compatible** - could plug and play into other quantum processors currently being developed

Publications

- Pechal, M., Arrangoiz-Arriola, P., & Safavi-Naeini, A. H. (2018). Superconducting circuit quantum computing with nanomechanical resonators as storage. *Quantum Science and Technology*, 4(1), 015006.
- Hadhazy, Adam. New hardware created by Stanford team shows a way to develop delicate quantum technologies based on tiny mechanical devices *Stanford News News* (2022).

Patents

- Published Application: 20210281241
- Issued: 12,021,507 (USA)

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