Cirq Ion Trap Demo

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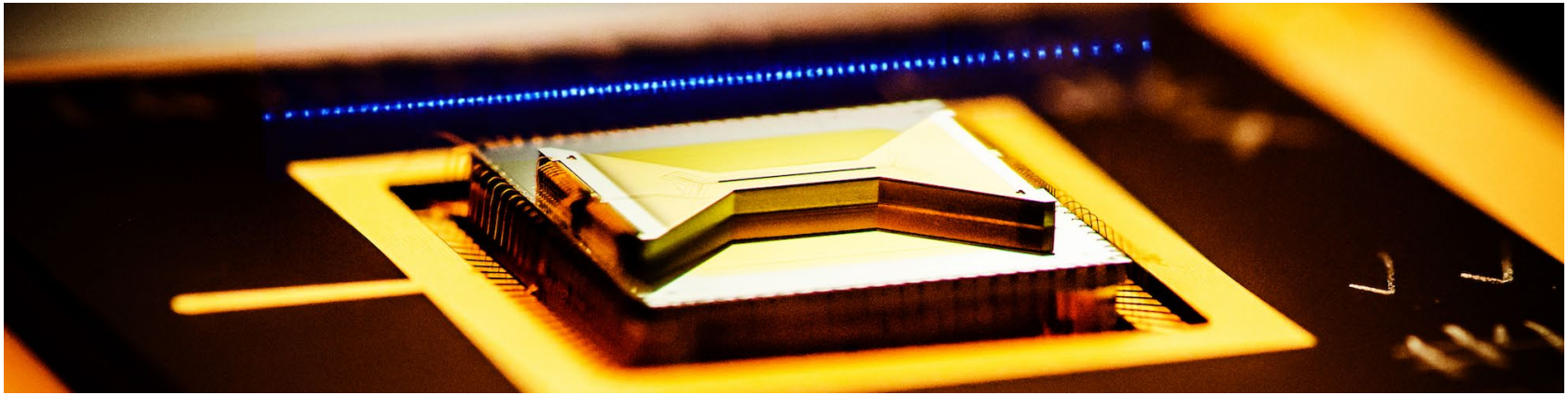
Ion Trap Architecture



Ion Trap Native Gate Set

$$RX(\theta) := \begin{pmatrix} \cos\frac{\theta}{2} & -\mathrm{i}\sin\frac{\theta}{2} \\ -\mathrm{i}\sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix}$$

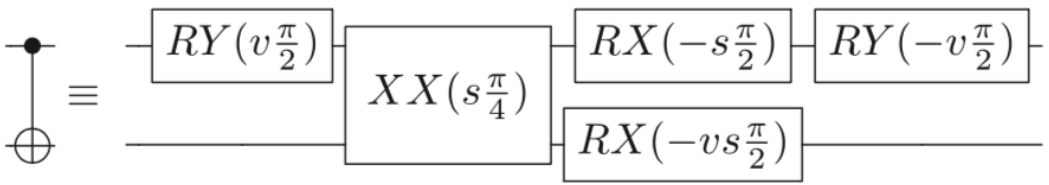
$$RY(\theta) := \begin{pmatrix} \cos\frac{\theta}{2} & -\sin\frac{\theta}{2} \\ \sin\frac{\theta}{2} & \cos\frac{\theta}{2} \end{pmatrix}$$

$$RZ(\theta) := \begin{pmatrix} \mathrm{e}^{-\mathrm{i}\theta/2} & 0 \\ 0 & \mathrm{e}^{\mathrm{i}\theta/2} \end{pmatrix}$$

$$XX(\chi) = \begin{pmatrix} \cos(\chi) & 0 & 0 & -\mathrm{i}\sin(\chi) \\ 0 & \cos(\chi) & -\mathrm{i}\sin(\chi) & 0 \\ 0 & -\mathrm{i}\sin(\chi) & \cos(\chi) & 0 \\ -\mathrm{i}\sin(\chi) & 0 & 0 & \cos(\chi) \end{pmatrix}$$

Single/Two -Qubit Gate Decomposition

$$H \equiv RY(-\pi/2).RX(\pi)$$
$$H \equiv RX(-\pi).RY(\pi/2)$$



[1]

Cartan Decomposition (KAK Decomposition) [2]

[1] D. Maslov, New J. Phys. 19, 023035 (2017).
[2] R. R. Tucci, arXiv: quant-ph/0507171

Ion Trap Device

```
us = 1000*cirq.Duration(nanos=1)
ion_device = ci.IonDevice(measurement_duration=100*us,
                          twoq_gates_duration=200*us,
                          oneq_gates_duration=10*us,
                          qubits=cirq.LineQubit.range(qubit_num))
```

1. Gate times.
2. Line qubit: qubits alined on a linear chain.
3. Convert given circuit into ion trap native gate set.
4. Verify if a given circuit conforms with ion trap requirements (gate set, overlapping operations)

Future Implementation

1. Shuttle/split/join of ion chains for intermediate measurements.
2. Circuit optimization for gate decomposition: eliminating unnecessary single qubit gates, optimize over degrees of freedom for implementing gates