Quantum Computing and the Forest SDK

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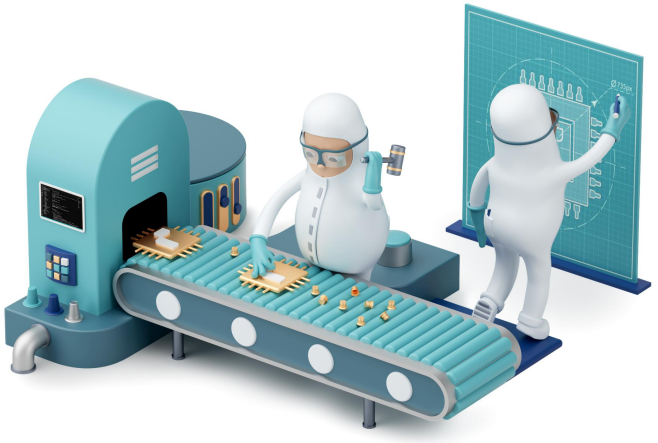
rigetti

a quick poll

Rigetti Computing, in a nutshell

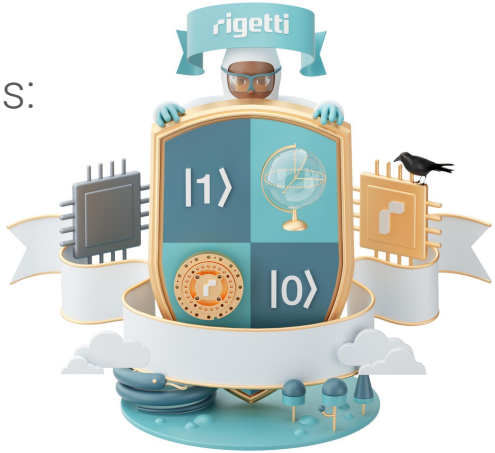


- Build **universal, gate-based hybrid classical/quantum computers**
  - Quantum computers are not more powerful than classical ones, yet
  - … but they can do real, interesting computations
- **Full-stack** company
  - all in-house: *design* → *manufacturing* → … → *applications development*
- Wide range of papers published
- Flagship product: **Quantum Cloud Services**

Quantum Cloud Services

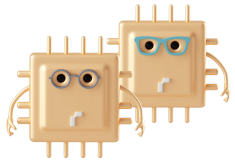
- **Fastest** quantum programming environment available to the public
- SW+HW+Infra innovations give **30x** speed-up over HTTP services
  - 2 hours of computation becomes 4 minutes
- Personal Quantum Machine Image (QMI) with SSH access, preloaded with a full suite of advanced tools:
  - Compiler
  - Simulator
  - Python API
  - Optional libraries

Forest SDK



Open source @ Rigetti

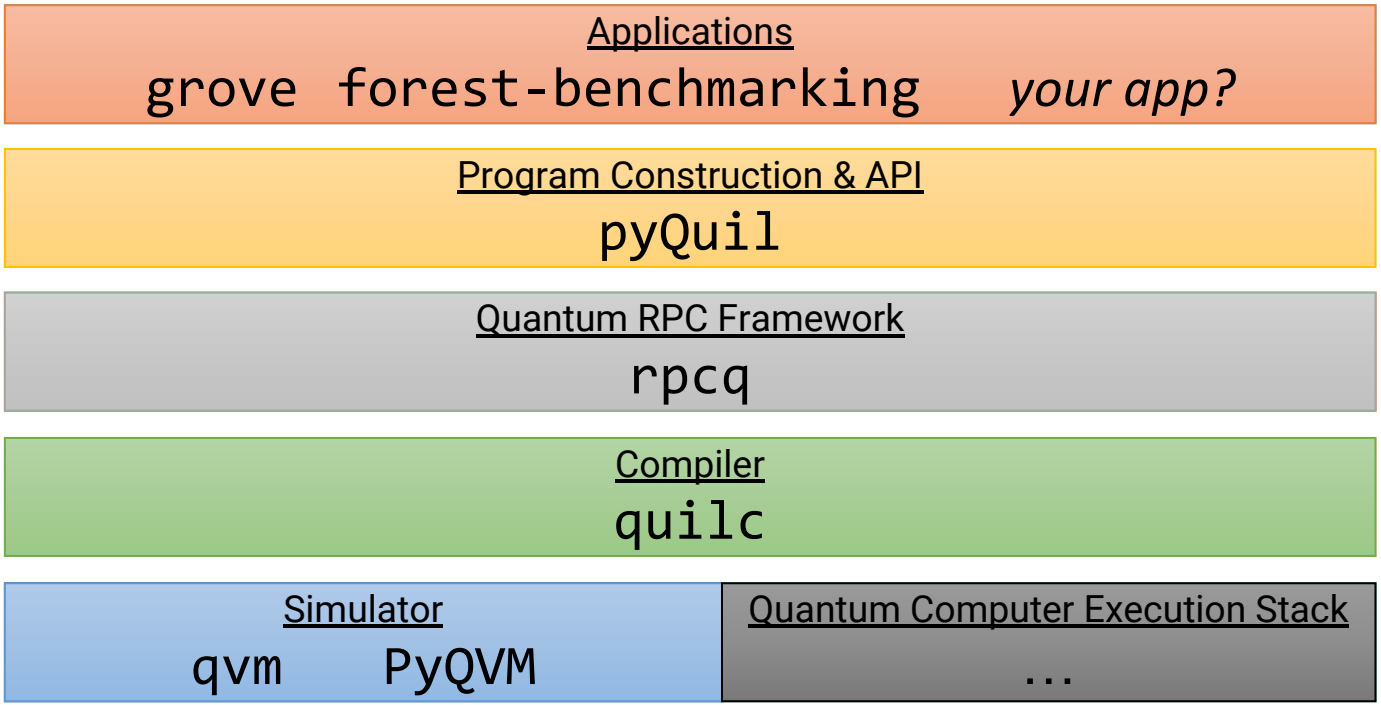
- 3 years ago, released an open standard for **Quil**
  - A portable **qu**antum **i**nstruction **l**anguage for hybrid computation
  - Language-independent: Python, OCaml, Lisp, JavaScript, …
- Since then, Rigetti has released a handful of OSS



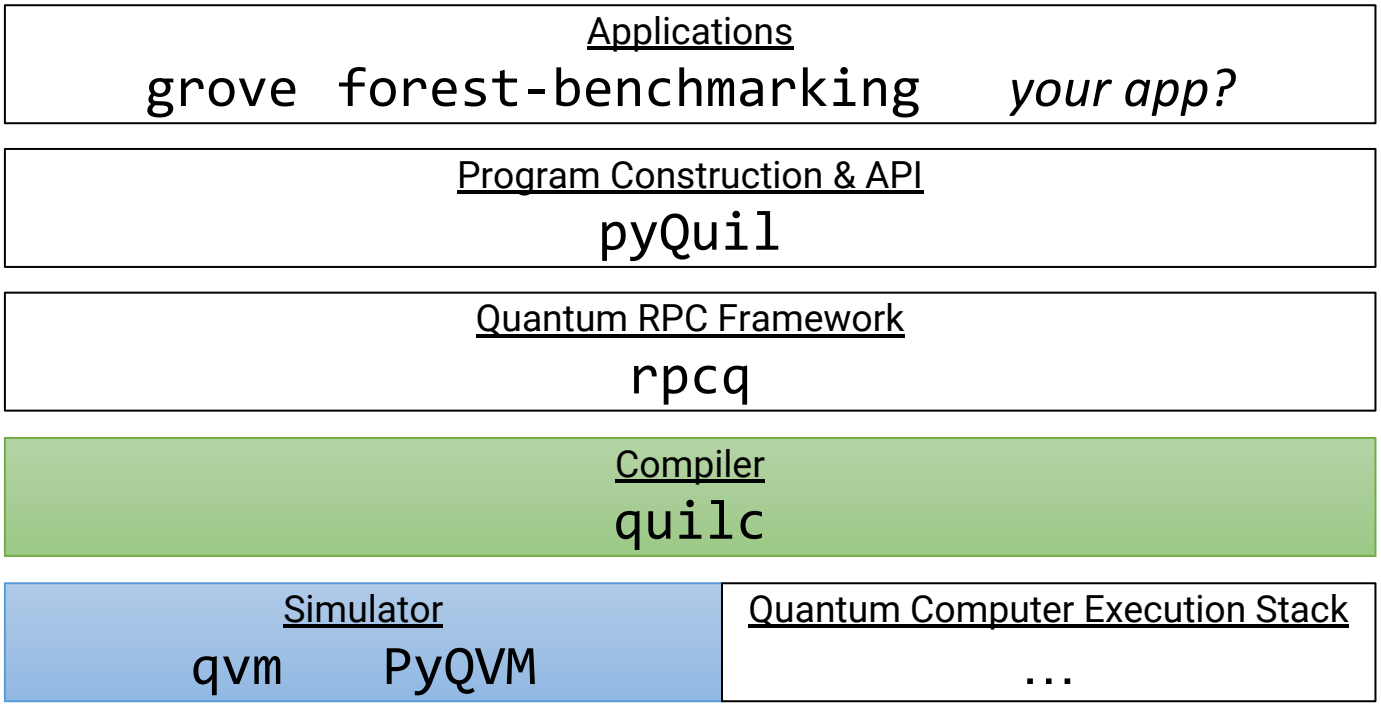
pyQuil	MAGICL	rpcq
forest-benchmarking	oqaml	grove
ALEXA	cmu-infix	*& more*

Many contributions back to OSS projects: CAD tools, testing libs, etc.

The Forest SDK



The Forest SDK: today's talk



The Rigetti Quantum Virtual Machine: `qvm`

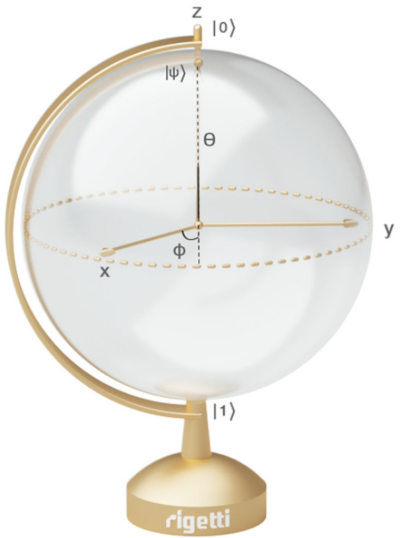
- Extremely **high-performance**: Eats all available CPU cores and RAM if you let it
- Can execute the entire Quil language
- Supports lots of execution modes
  - Standard & stochastic pure-state evolution (latter with Kraus operators)
  - Full density matrix evolution
  - Path integral formulation: calculate 1 amplitude with linear memory
- Simulates perfect and imperfect quantum computers
- Includes a compiler to **translate Quil into machine code**
  - Screaming fast execution, outperforms many simulators by 2x

demo

```
./qvm --verbose --benchmark
./qvm --verbose --benchmark --compile
```

The Rigetti optimizing Quil compiler: `quilc`

- The only general purpose, fully automatic, optimizing quantum compiler
- Built with **portability** in mind
  - Can compile to **user-specified** quantum architectures
- Can compile any unitary gate
  (2q, 3q, 4q, ... doesn't matter)
- Has lots of special knowledge to do quantum equivalents of:
  - register allocation
  - peephole optimization
  - flow analysis and optimization
  - optimal compilation

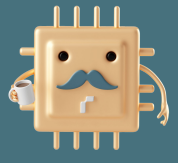


One of the most amazing pieces of software I've worked on in my career.

demo

```
./quilc
cat bernstein-vazirani.quil | ./quilc -Pd
```

Fully automatic compilation is good!



- As if it were the 1950s, some software firms suggest we should be:
  - hand compiling quantum programs
  - have our programs always be aware of the target architecture
    - which changes every 6 months
  - writing un-portable code
  - … because otherwise it “won’t be appropriate” for NISQ machines
- Computers are fast; what problems they can solve may surprise you
- If people can write C for microcontrollers, then they can write portable Quil for quantum computers

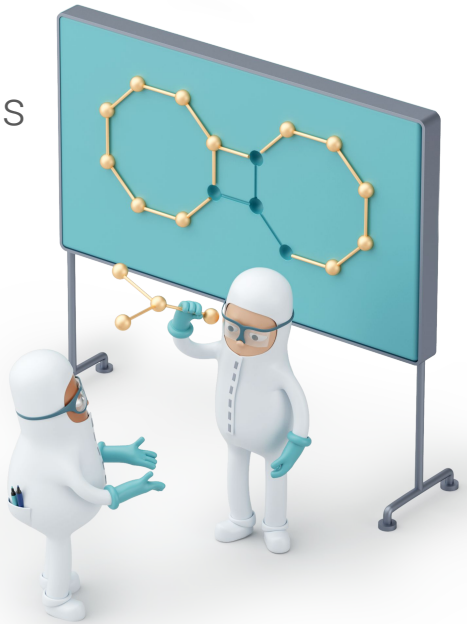
`quilc` is a good & improving demonstration of that

demo

```
cat bernstein-vazirani.quil | ./quilc -Pd --verbose
```

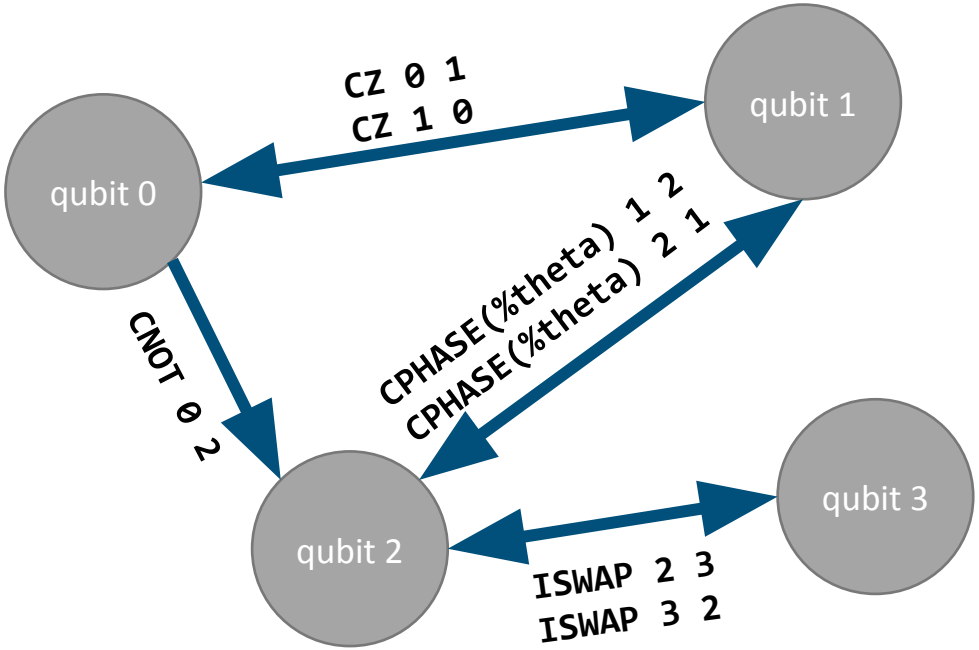
What does a compiler target look like?

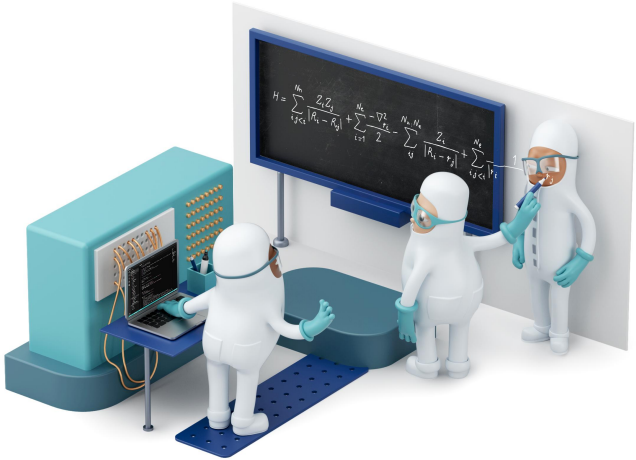
- Generally a graph of qubits
- Each qubit supports a collection of single-qubit gates
  - Could be static or parametric
  - e.g., `RX(pi/2)`, `RZ(%theta)`
- Each qubit-pair supports a collection of two-qubit gates
  - e.g., `CZ`, `CNOT`, `CPHASE(%theta)`
- Each qubit-{triplet, quadruplet, …} supports {3, 4, …}-qubit gates
  - The ion trap folks go nuts with these, e.g., **Mølmer-Sørensen gate**



Different qubits may be tuned for different operations!

`quilc` can compile for this architecture





Try hand-compiling a GHZ state on a quantum computer with this architecture!

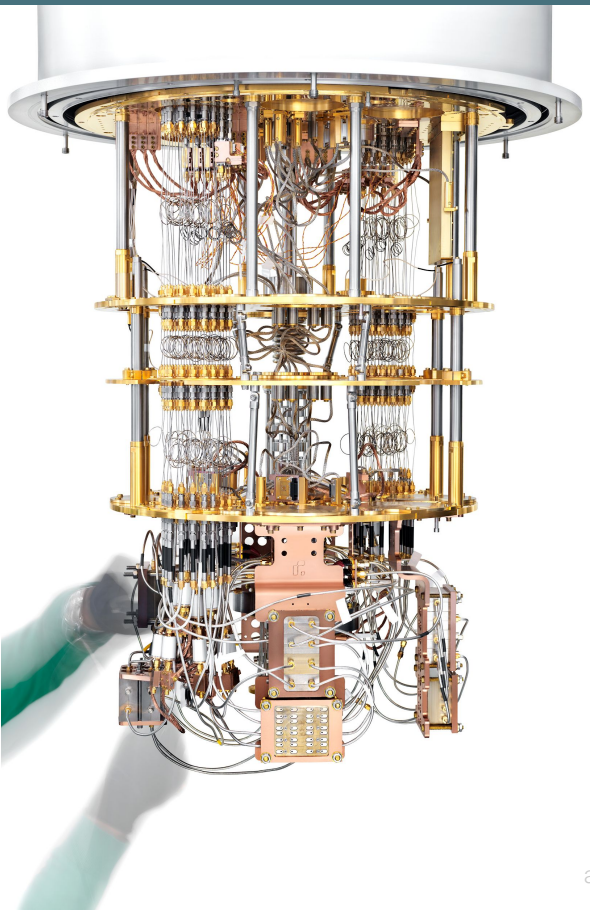
For FOSDEM, we ported `quilc`...

- ... to **Google's Bristlecone** architecture (72 qubits)
- ... to **IBM's ibmqx5** architecture (16 qubits)
- Any program written in Quil in whatever gate set will compile to Rigetti's, Google's, and IBM's architectures portably
  - And **`quilc` optimizes** for them
- Can work on the full chip or any subgraph of it
- The only compiler that can do so?

demo

```
cat molmer.quil | ./quilc -Pd --isa 8Q
cat molmer.quil | ./quilc -Pd --isa bristlecone
cat molmer.quil | ./quilc -Pd --isa ibmqx5
cat molmer.quil | ./quilc -Pd --isa bristlecone --enable-state-prep-reductions
```

`qvm` & `quilc` are free to download



- Free downloadable installers for Linux, macOS, and Windows$^{\beta}$
  - Comes with a EULA
- Open-source alternative to **`qvm`**: PyQVM
  - Just released; part of pyQuil
  - FOSS license: Apache 2.0
  - Much slower for lots of qubits, doesn't come with all the bells and whistles
- No real alternative to **`quilc`**
  - Follow folk advice and hand-compile?

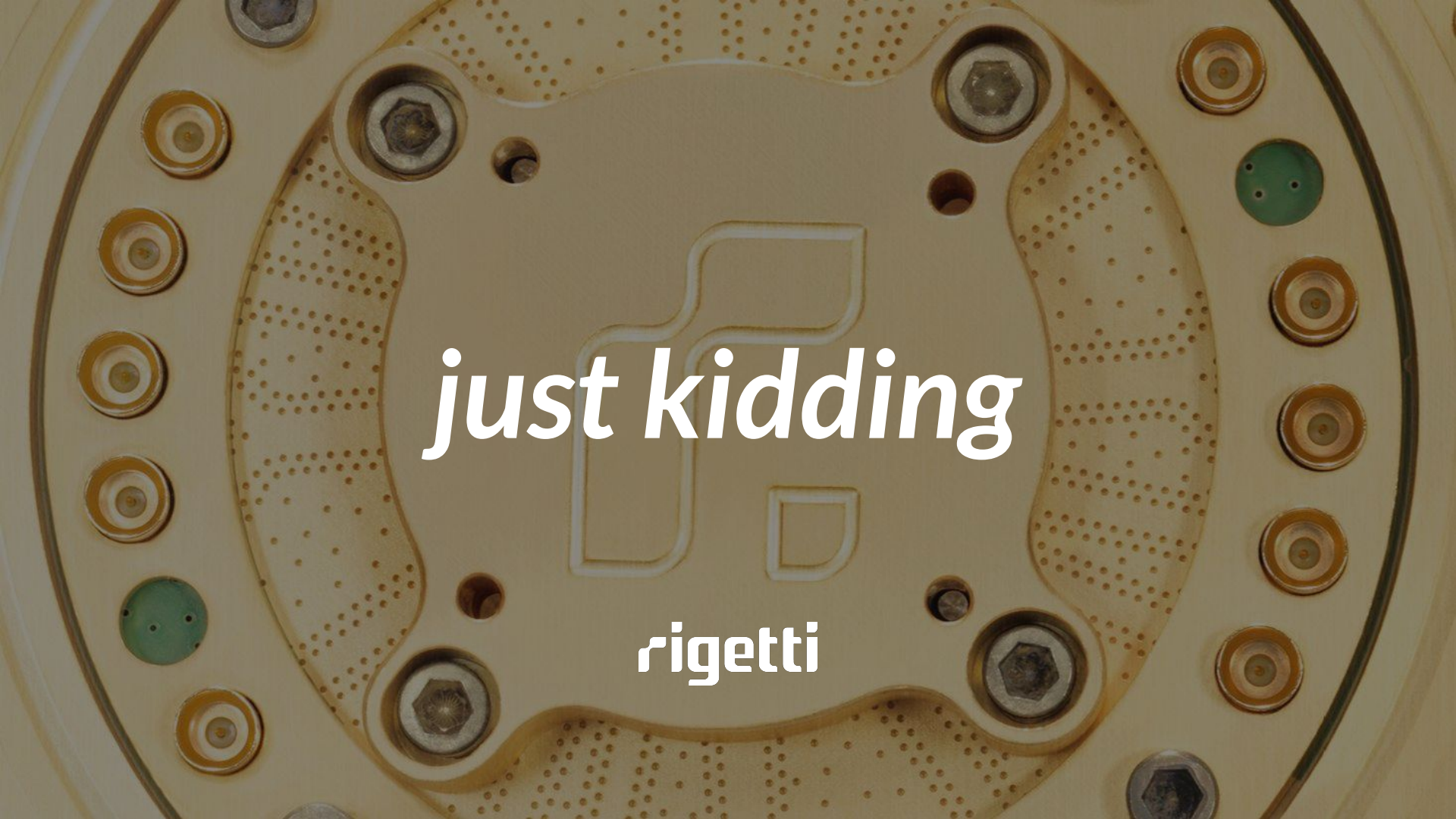
Split open/closed source = Good for startups

Pros of Open Source

- Open source allows us to reap the rewards of sharing the parts that users mostly use so that the customer experience can be improved
- Using RPC and creating good APIs allows anybody to slot in their own open source variants
- Languages (like Quil) and APIs are best fostered as a part of an open source community

Pros of Closed Source

- Closed source programmer tools allow us to innovate, sell, make money, license, and write EULAs
- Can't afford to "give everything for free" unlike the multi-billion dollar giants with tens or hundreds of thousands of employees
- Relying on the community for the most important tools is a haphazard bet. Otherwise Linux would be the #1 desktop OS

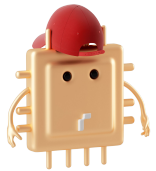

just kidding
rigetti

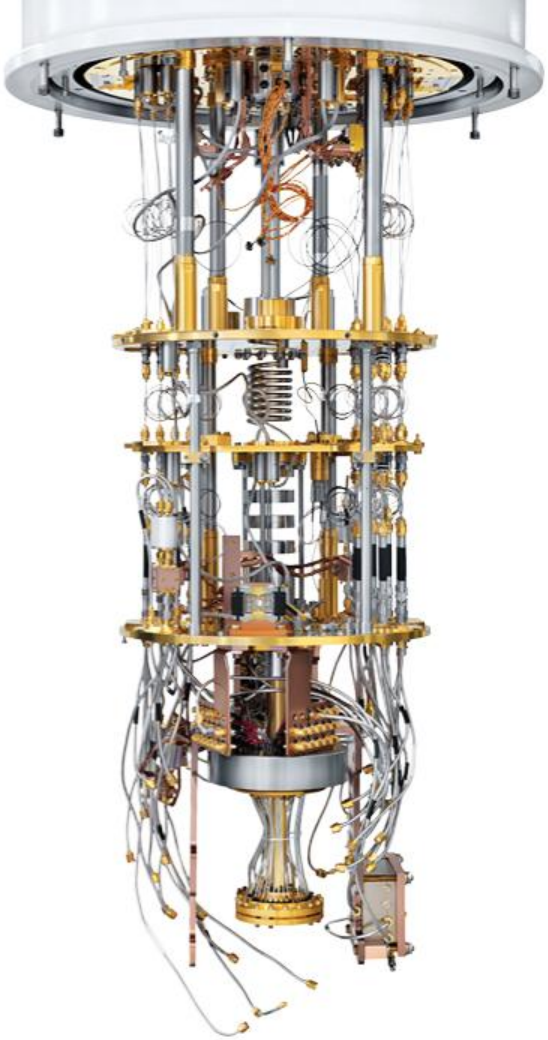
github.com/rigetti/**qvm**
github.com/rigetti/**quilc**

Apache 2.0 · AGPL

`qvm` & `quilc` are written in Common Lisp

- Many innovations couldn't have happened without it
  - Time & money budget aren't infinite at a startup
  - Developing in Lisp is snappy
- Nobody has figured out expressive syntax for quantum computing
  - Lisp is great—even optimized—for metasyntactic experiments
- Debugging a compiler in Lisp with Emacs+SLIME is much nicer than in Python or C++
  - Optimizing compilers are very difficult to debug
- Our team primarily consists of first-time Lisp programmers
  - New employees are always productive in just a few days

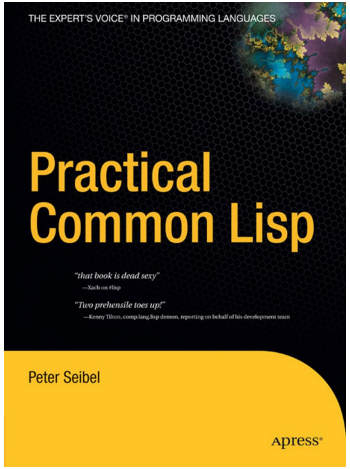




A book about Lisp for programmers

[Practical Common Lisp]

free ebook online



$|\mathbf{Beer}\rangle + |\mathbf{You}\rangle / \sqrt{2}$ Challenge

The first 3 people to…

solve an issue · fix a bug · make a contribution

…will get a beer on me.

Email: **robert@rigetti.com**
Code: **github.com/rigetti/qvm**
Code: **github.com/rigetti/quilc**
Slack: **rigetti.com/community**