
AWS
re:Invent
NOV. 28 – DEC. 2, 2022 | LAS VEGAS, NV

QTC401-R

Analog quantum computing with Amazon Braket

Eric Kessler, PhD (he/him)

Sr. Manager and Applied Scientist, Amazon Braket
AWS

Katharine Hyatt, PhD (she/her)

Scientist, Amazon Braket
AWS

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Talk agenda:

- Introduction to Amazon Braket
- Analog quantum computing
- Quantum computing with Rydberg atoms – from physics to optimization

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Introduction to Amazon Braket

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

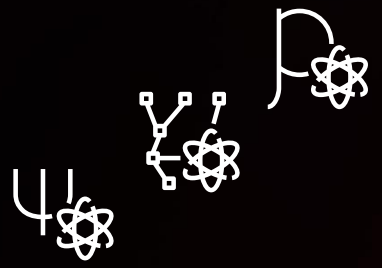
Amazon Braket – the AWS quantum computing service

A fully managed service that makes it easy for scientists and developers to explore quantum computing



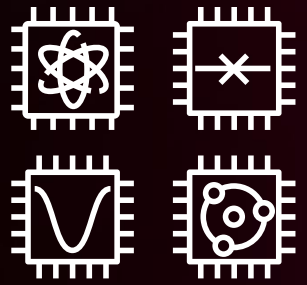
Build

- Amazon Braket Python SDK
- Jupyter notebooks
- Command Line Interface (CLI)



Test

- Local simulators for rapid testing
- High-performance simulators



Run

- Access multiple quantum computers
- Combine quantum and classical resources



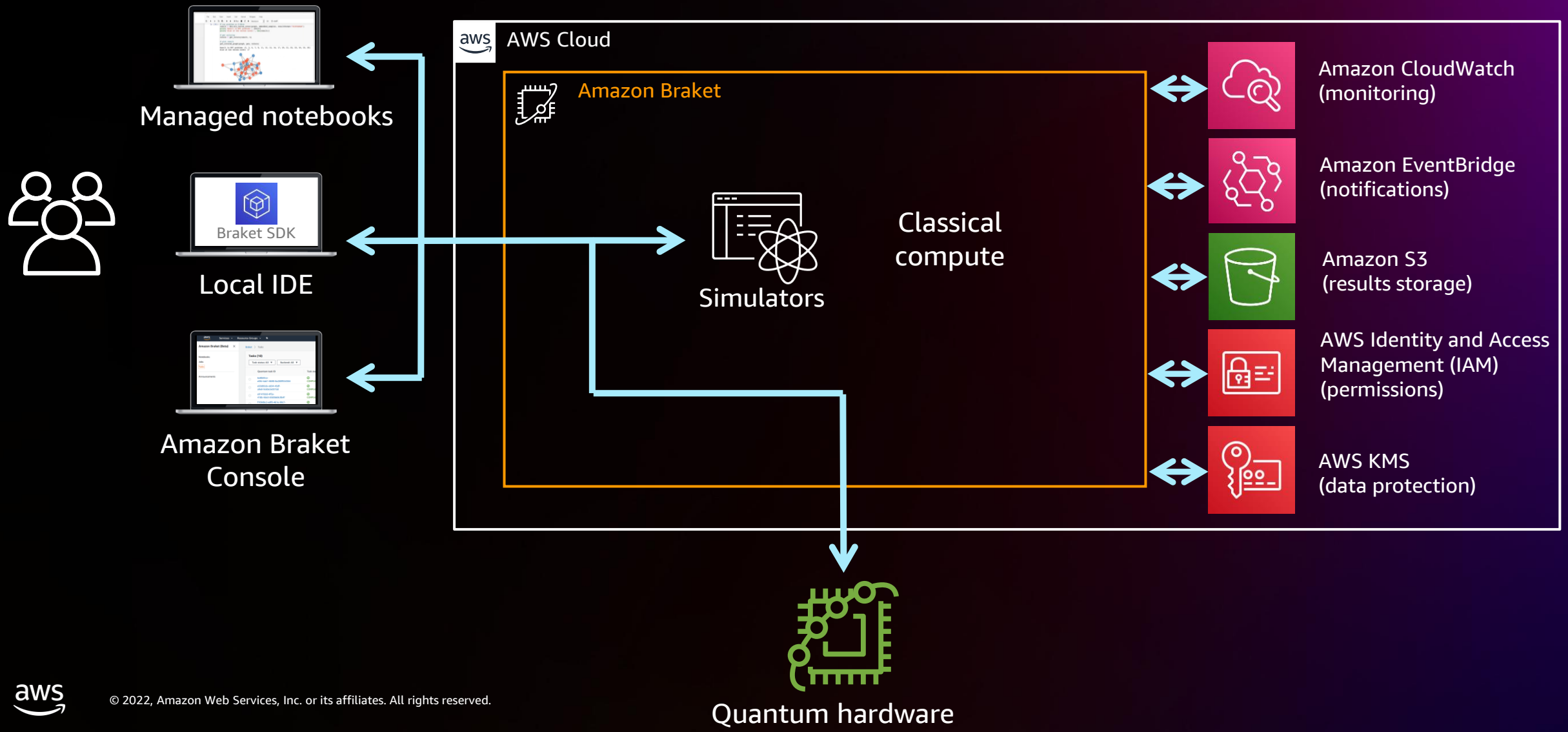
Analyze

- Monitor algorithms in almost real time
- Analyze algorithm results and performance

aws

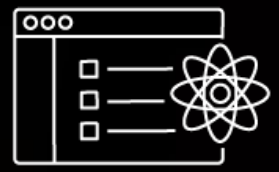
© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Amazon Braket architecture



© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Local and on-demand simulators

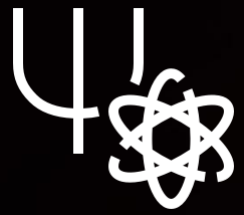


Local simulator

Part of Braket Python SDK

Fast and convenient prototyping

Number of qubits based on hardware

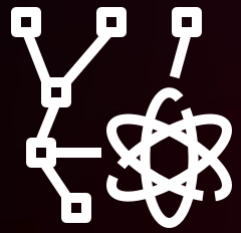


SV1: State vector simulator

Quantum circuit with up to 34 qubits

Stores the full wave function state

Concurrency: Default 35, max 100

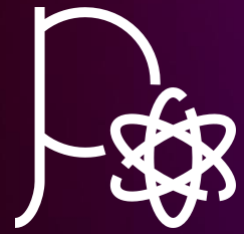


TN1: Tensor network simulator

Quantum circuit with up to 50 qubits

Encodes quantum circuits into a structured graph

Concurrency: Default 10, max 10



DM1: Density matrix simulator

Quantum circuit with up to 17 qubits

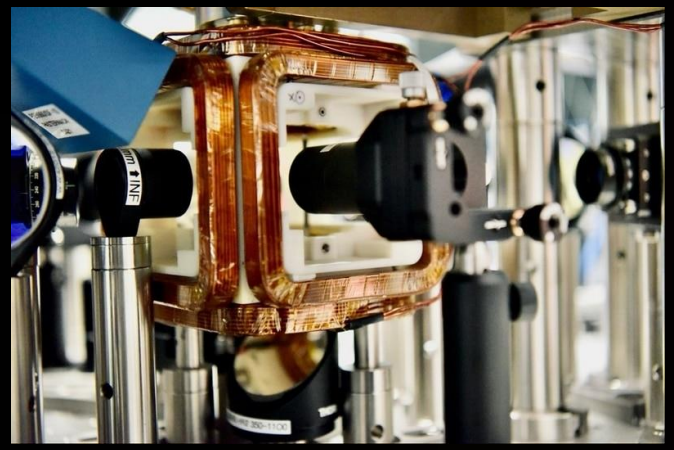
Run multiple circuits in parallel with noise simulation

Concurrency: Default 35, max 50

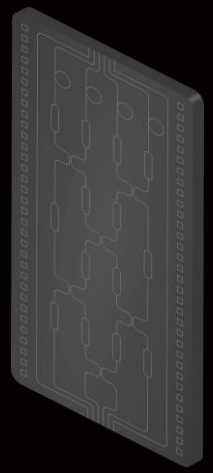
aws

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

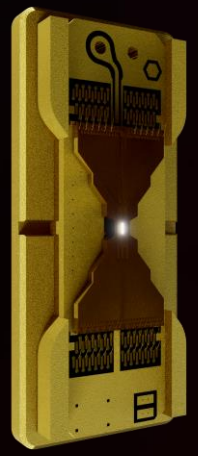
Available quantum computers



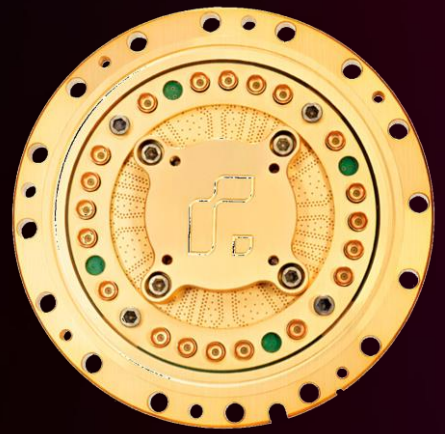
IQuEra COMPUTING INC.



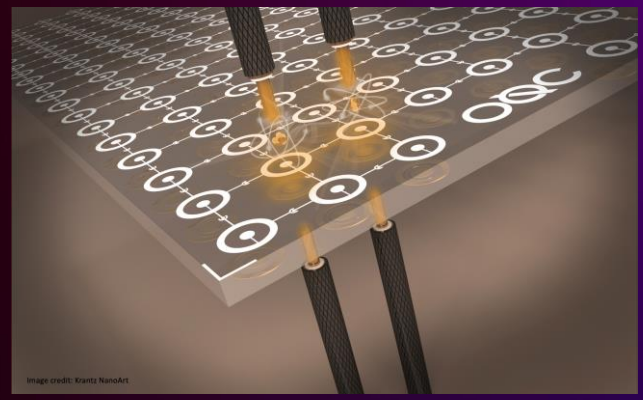
XANADU



IONQ



rigetti



OQC

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Analog quantum computing

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

The digital model of quantum computing

Circuit representation

```
T  : |0|1|2|3|4|

q0 : -H-C-------
        |
q1 : ---X-C-----
          |
q2 : -----X-C---
            |
q3 : -------X-C-
              |
q4 : ---------X-

T  : |0|1|2|3|4|
```



OpenQASM 3.0 IR

```
OPENQASM 3.0;
bit[5] b;
qubit[5] q;
h q[0];
cnot q[0], q[1];
cnot q[1], q[2];
cnot q[2], q[3];
cnot q[3], q[4];
b[0] = measure q[0];
b[1] = measure q[1];
b[2] = measure q[2];
b[3] = measure q[3];
b[4] = measure q[4];
```

Classical analogue: Compiling to LLVM IR

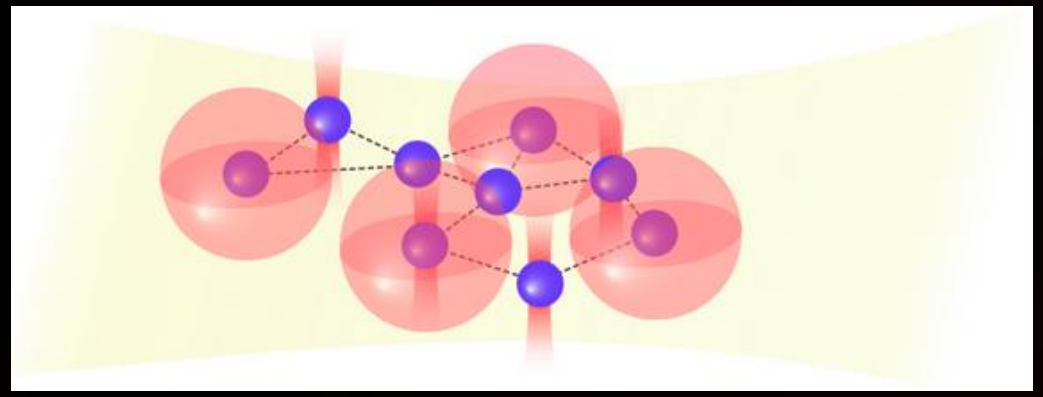
```
int add(int x, int y, int z) {
    return x + y + z;
}
```

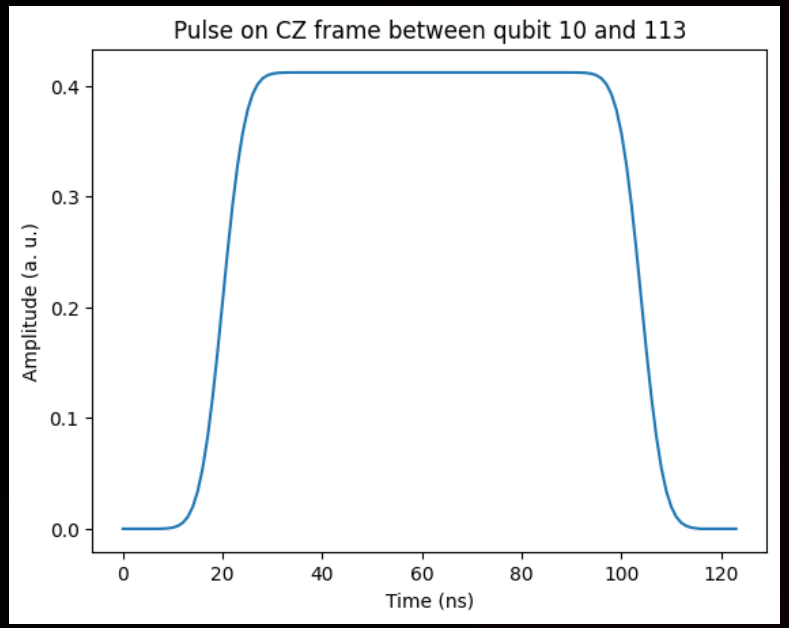


```
define i32 @add(i32 %x, i32 %y, i32 %z) {
entry:
    %tmp =add i32 %x, %y
    %tmp2 = add i32 %tmp, %z
    ret i32 %tmp2
}
```

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

But quantum computers are analog by nature

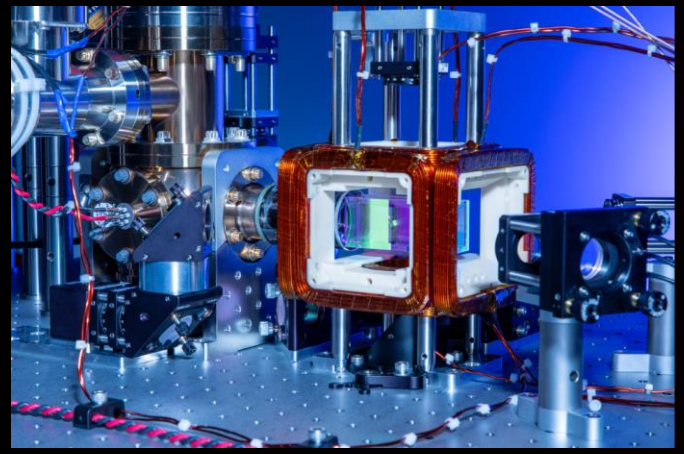


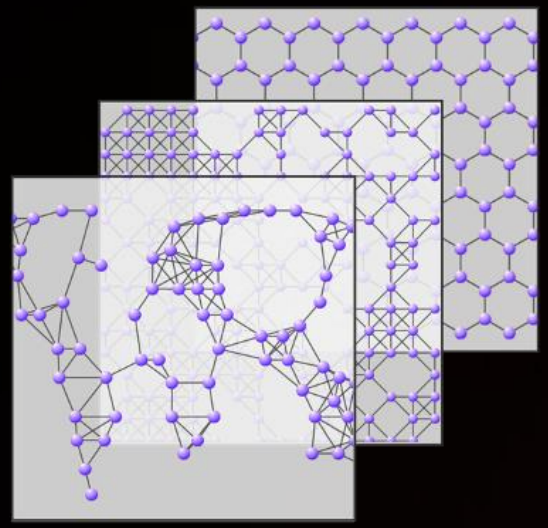




© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Aquila – Analog quantum computing by QuEra





AWS Quantum Technologies Blog

Realizing quantum spin liquid phase on an analog Hamiltonian Rydberg simulator

by Alexander Keesling, Eric Kessler, and Peter Komar | on 03 DEC 2021 | in Amazon Braket, Announcements, Quantum Technologies | Permalink | Share

This week at re:I
computing parad

AHS uses progra
to study quantu
quantum compu
paper published
Rydberg atom A
verification of th
matter].

AWS Quantum Technologies Blog

Optimization with a Rydberg atom-based quantum processor

by Pedro Lopes, Alexander Keesling, Mao Lin, and Peter Komar | on 10 NOV 2022 | in Amazon Braket, Quantum Technologies | Permalink | Share

Amazon Braket recently launched the Aquila quantum processing unit (QPU) based on Rydberg atoms by QuEra Computing. In a previous post, we explored how researchers can use Rydberg devices to study problems and quantum phenomena in fundamental physics, for instance the emergence of a spin liquid phase [Semeghini et al., 2021]. But QuEra's device also enables researchers to study quantum algorithms in new regimes. In this post, we review a recent publication, "Quantum optimization of maximum independent set using Rydberg atom arrays" [Ebadi et al., Science (2022)], in which the authors report the largest deployment of a variational algorithm to date, used to solve combinatorial optimization problems on a Rydberg device similar to the one launched on Nov 1 on Amazon Braket.

In the publication [Ebadi et al., Science (2022)], researchers from Harvard University, in collaboration with scientists from QuEra Computing, MIT, and the University of Innsbruck, reported on using Rydberg atom-based quantum processors to compute solutions for a particular graph coloring problem: finding the maximum independent set (MIS), which is relevant for optimal resource allocation, for example. By running a quantum-classical hybrid algorithm on the device, researchers were able to find the MIS for a class of graphs with a probability that scales favorably with the difficulty of the problem when compared to a classical simulated annealing approach. This work not only highlights the potential of Rydberg-atom devices for solving hard optimization problems, but also opens new research directions.

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Quantum computing with Rydberg atoms – from physics to optimization

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.

Thank you!



Please complete the session survey in the **mobile app**

© 2022, Amazon Web Services, Inc. or its affiliates. All rights reserved.