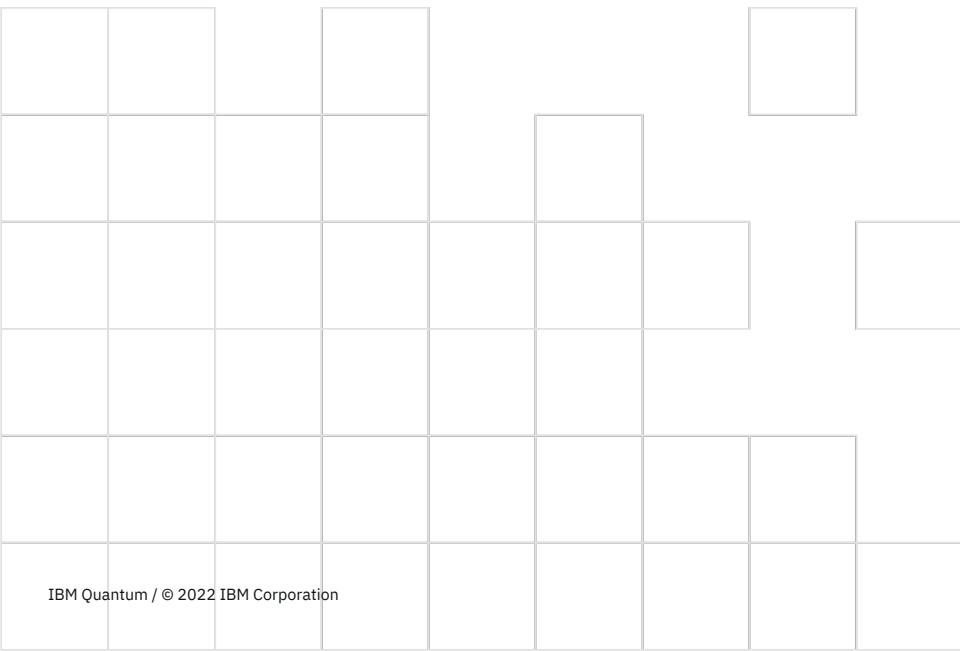


Qiskit Quantum Software Stack

Junye Huang

Quantum Developer Advocate



What is Qiskit?

What can you use Qiskit for?

Qiskit SDK Architecture

High level applications

Qiskit Nature

For applications relating to simulating quantum mechanical systems and natural phenomena.

Qiskit Finance

For applications relating to financial modeling.

Low level applications

Qiskit Metal

For designing quantum hardware and processors.

Qiskit Optimization

For applications relating to optimization problems.

Qiskit Machine Learning

For applications relating to machine learning.

Qiskit Dynamics

For building, transforming, and solving time-dependent models of quantum systems.

Qiskit Experiments

For running quantum experiments with a library of characterization, calibration, and verification experiments.



Core Capabilities

Qiskit Terra

For building and transforming quantum circuits and operators at the level of gates or pulses.

Simulator

Qiskit Aer

For simulating quantum circuits on classical hardware.

Hardware providers

IBM

IBM Quantum systems

AQT

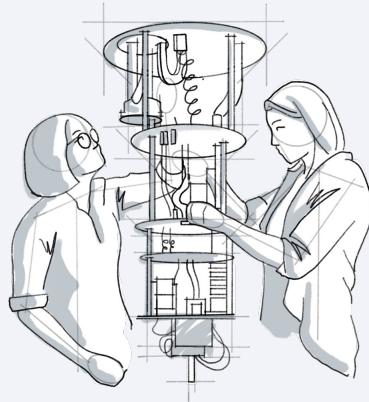
AQT systems

IonQ

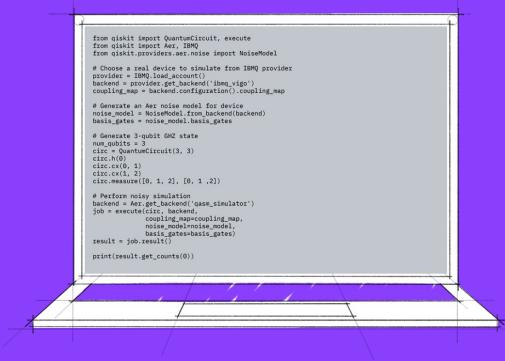
IonQ systems

Qiskit can connect to many other systems

Qiskit for



Research

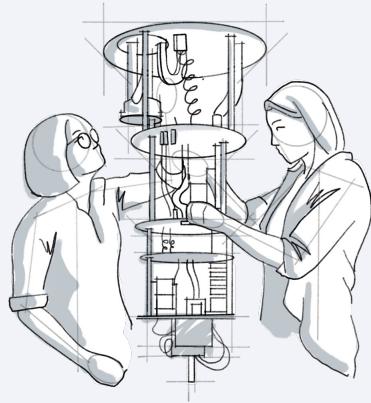


Development



Learning

Qiskit for



Research

```
from qiskit import QuantumCircuit, execute
from qiskit import Aer
from qiskit.providers.aer.noise import NoiseModel
# Choose a real device to simulate from IBMQ provider
provider = IBMQ.load_account()
backend = provider.get_backend('ibmq_vigo')
coupling_map = backend.configuration().coupling_map
# Generate an Aer noise model for device
noise_model = NoiseModel.from_backend(backend)
basis_gates = noise_model.basis_gates
# Generate 3-qubit GHZ state
circuit = QuantumCircuit(3)
circuit.h(0)
circuit.cx(0, 1)
circuit.cx(1, 2)
circuit.measure([0, 1, 2], [0, 1, 2])
# Perform noisy simulation
backend = Aer.get_backend('qasm_simulator')
job = execute(circuit, backend,
              coupling_map=coupling_map,
              noise_model=noise_model,
              basis_gates=basis_gates)
result = job.result()
print(result.get_counts(0))
```

Development



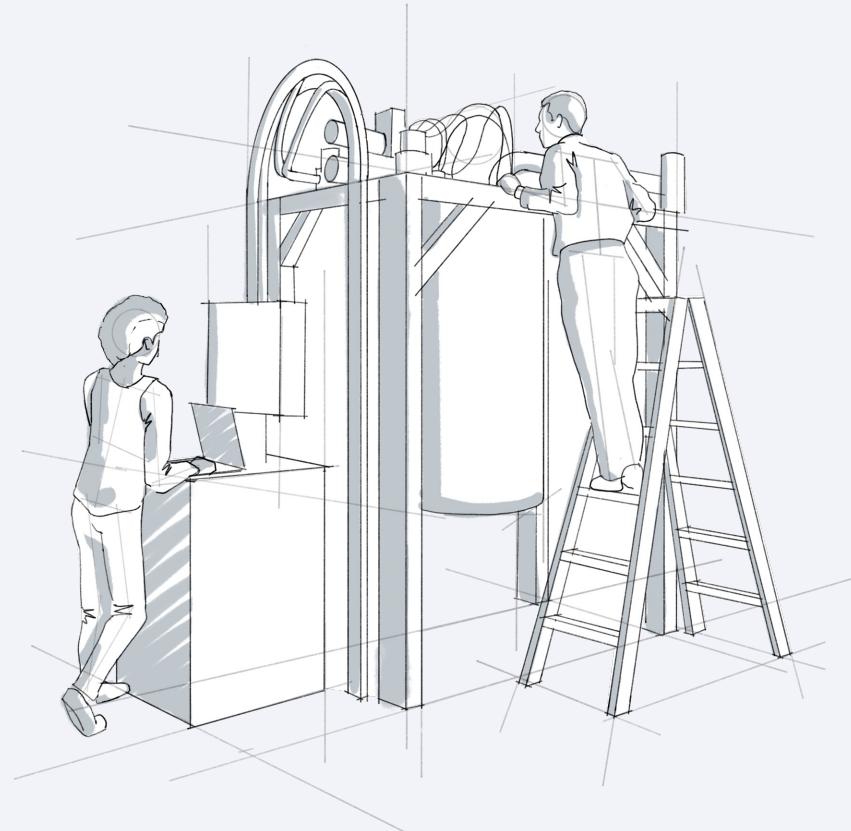
Learning

Since launching in Mar 2017



Qiskit has enabled

1400+
research
papers*



*based on the usage of IBM Quantum systems

Access to a wide range of quantum systems

IBM Quantum Services

View the availability and details of IBM Quantum programs, systems, and simulators.

Systems

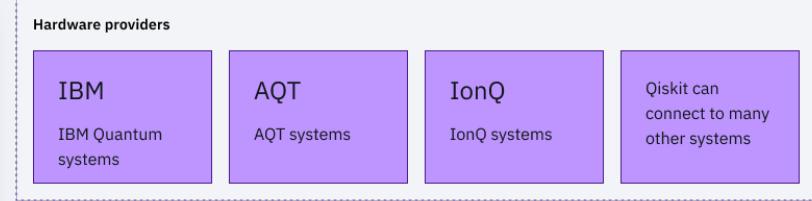
IBM Quantum systems combine world-leading quantum processors with cryogenic components, control electronics, and classical computing technology. [Learn more →](#)

Search by system name

All systems (22) | Card | Table

System	Status	Processor type	Qubits	QV	CLOPS
ibmq_washington	Online	Eagle r1	127	64	850
ibmq_brooklyn	Online	Hummingbird r2	65	32	1.5K
ibmq_kolkata	Online	Falcon r5.11	27	64	2K
ibmq_montreal	Online	Falcon r4	27	128	2K
ibmq_mumbai	Online	Falcon r5.1	27	128	1.8K
ibmq_cairo	Online - Queue paused maintenance	Falcon r5.11	27	64	2.4K
ibmq_auckland	Online	Falcon r5.11	27	64	2.4K
ibmq_hanoi	Online	Falcon r5.11	27	64	2.3K
ibmq_toronto	Online	Falcon r4	27	32	1.8K
ibmq_peekskill	Online	Falcon r8	27		
ibmq_guadalupe	Online - Queue paused maintenance	Falcon r4P	16	32	2.4K
ibmq_perth	Online	Falcon r5.11H	7	32	2.9K
ibmq_lagos	Online	Falcon r5.11H	7	32	2.7K
ibmq_nairobi	Online	Falcon r5.11H	7	32	2.6K
ibmq_jakarta	Online	Falcon r5.11H	7	16	2.4K
ibmq_manila	Online	Falcon r5.11L	5	32	2.8K
ibmq_bogota	Online	Falcon r4L	5	32	2.3K
ibmq_santiago	Online	Falcon r4L	5	32	
ibmq_quito	Online	Falcon r4T	5	16	2.5K
ibmq_belem	Online	Falcon r4T	5	16	2.5K
ibmq_ilma	Online	Falcon r4T	5	8	2.7K
ibmq_armonk	Online	Canary r1.2	1	1	

IBM Quantum / © 2022 IBM Corporation



Cross-platform support

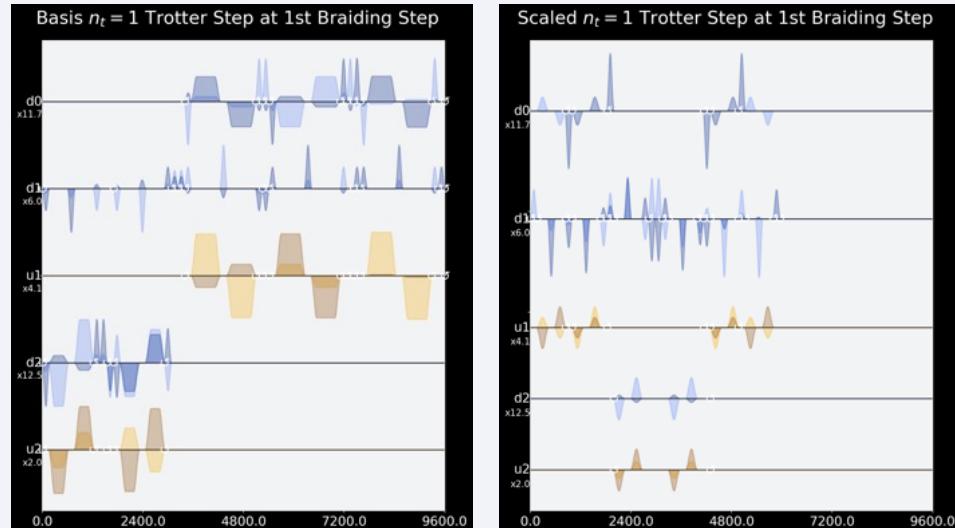
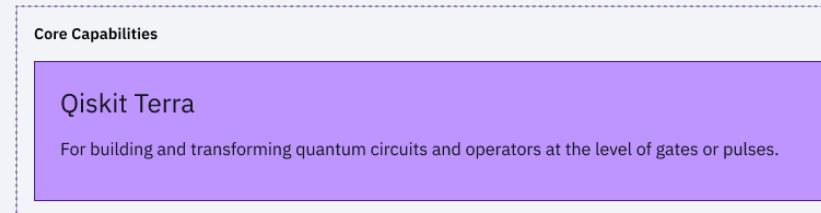
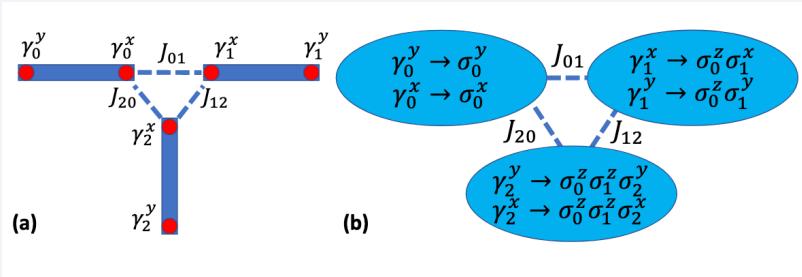
- Superconducting:** IBM Quantum, Rigetti
- Trapped ions:** AQT, IonQ, Quantinuum
- Spin qubits:** Quantum Inspire
- Cold atoms:** Qiskit Cold Atom provider
- Platform:** Azure Quantum, AWS Braket
- Simulator:** cuQuantum (NVIDIA)

Qiskit Pulse for pulse-level control

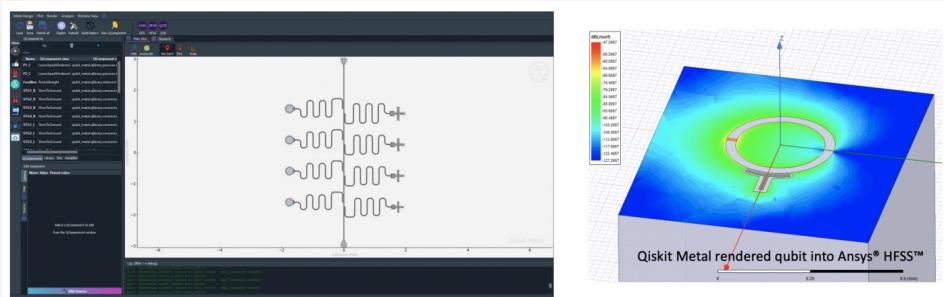
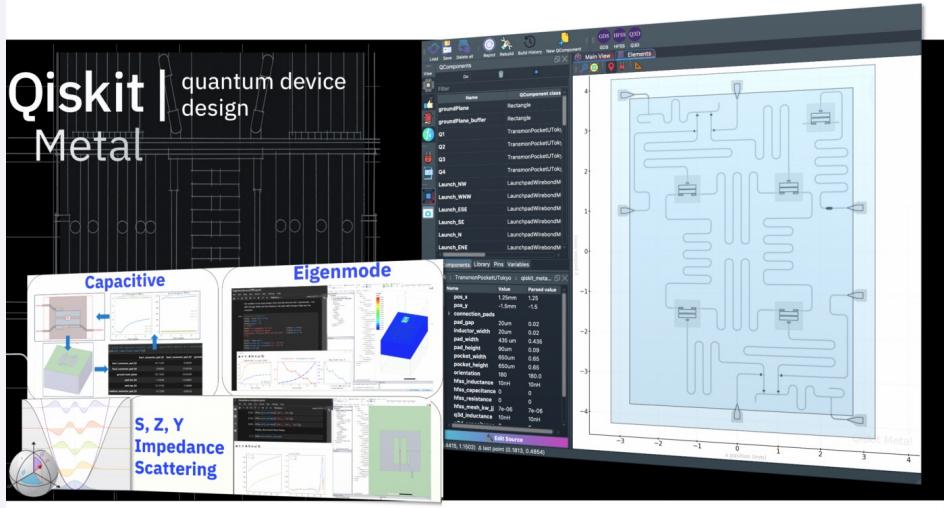
With pulses, you can dig deep into the heart of a quantum device and study the system as if you were physically present in the lab.

Highlight

- Simulating the dynamics of braiding of Majorana zero modes using an IBM Quantum computer with Qiskit Pulse [arXiv:2012.11660](https://arxiv.org/abs/2012.11660)
- Qiskit Pulse allowed the authors to overcome the device's noise with specially-crafted controlled gates.



Qiskit Metal for designing quantum processors



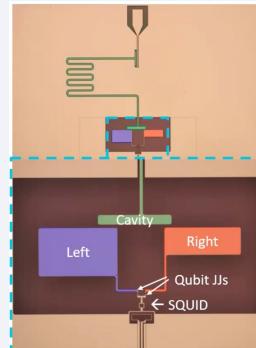
IBM Quantum / © 2022 IBM Corporation

An 8-qubit chip designed by C. Warren, Amr Osman, and team (Chalmers) with Qiskit Metal.

Qiskit Metal is the first EDA tool specifically for quantum computers used for designing, modelling and analyzing performance of quantum processors.

Community driven and experimentally tested by IBM Quantum and the community

Promote more knowledge sharing in the quantum hardware community

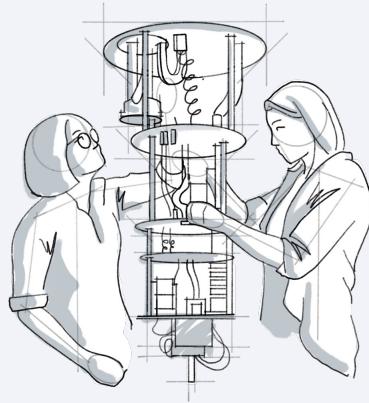


Two transmon qubits with a SQUID coupler designed by Zachary Parrott (UCB & NIST) with Qiskit Metal.

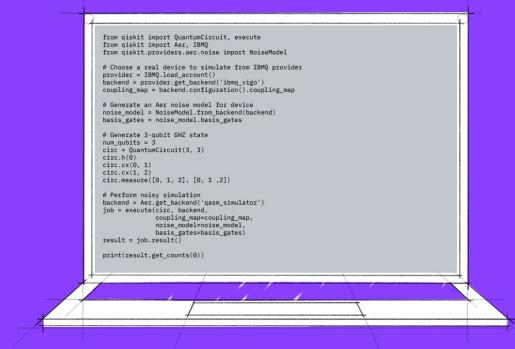
Qiskit Metal

For designing quantum hardware and processors.

Qiskit for



Research



Development



Learning

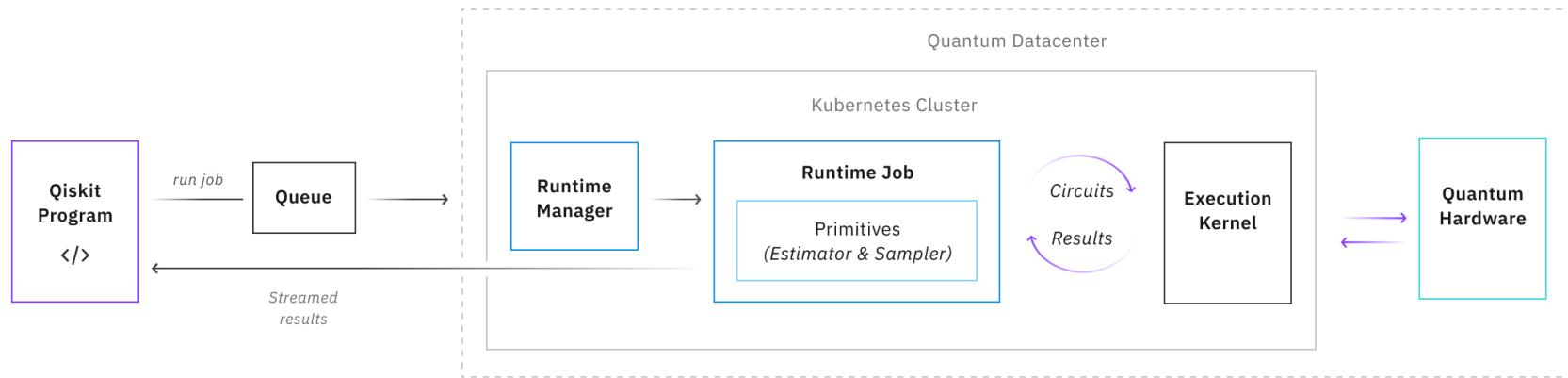
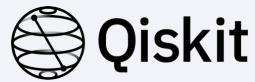
Development Roadmap

Executed by IBM ✓
On target ✅

IBM Quantum

2019 ✓	2020 ✓	2021 ✓	2022	2023	2024	2025	Beyond 2026	
Run quantum circuits on the IBM cloud	Demonstrate and prototype quantum algorithms and applications	Run quantum programs 100x faster with Qiskit Runtime	Bring dynamic circuits to Qiskit Runtime to unlock more computations	Enhancing applications with elastic computing and parallelization of Qiskit Runtime	Improve accuracy of Qiskit Runtime with scalable error mitigation	Scale quantum applications with circuit knitting toolbox controlling Qiskit Runtime	Increase accuracy and speed of quantum workflows with integration of error correction into Qiskit Runtime	
Model Developers				Prototype quantum software applications →	Quantum software applications			
Algorithm Developers	Quantum algorithm and application modules Machine learning Natural science Optimization			Quantum Serverless	Intelligent orchestration	Circuit Knitting Toolbox	Circuit libraries	
Kernel Developers	Circuits ✓	Qiskit Runtime ✓	Dynamic circuits ✅	Threaded primitives	Error suppression and mitigation		Error correction	
System Modularity	Falcon 27 qubits 	Hummingbird 65 qubits 	Eagle 127 qubits 	Osprey 433 qubits 	Condor 1,121 qubits 	Flamingo 1,386+ qubits 	Kookaburra 4,158+ qubits 	Scaling to 10K-100K qubits with classical and quantum communication
				Heron 133 qubits x p 	Crossbill 408 qubits 			

Qiskit Runtime



Qiskit Runtime is a quantum computing service and programming model that allows users to optimize workloads and efficiently execute them on quantum systems at scale. The programming model extends the existing interface in Qiskit with a set of new primitive programs.

Qiskit application modules

Qiskit Nature

For applications relating to simulating quantum mechanical systems and natural phenomena.

Qiskit Finance

For applications relating to financial modeling.

Qiskit Optimization

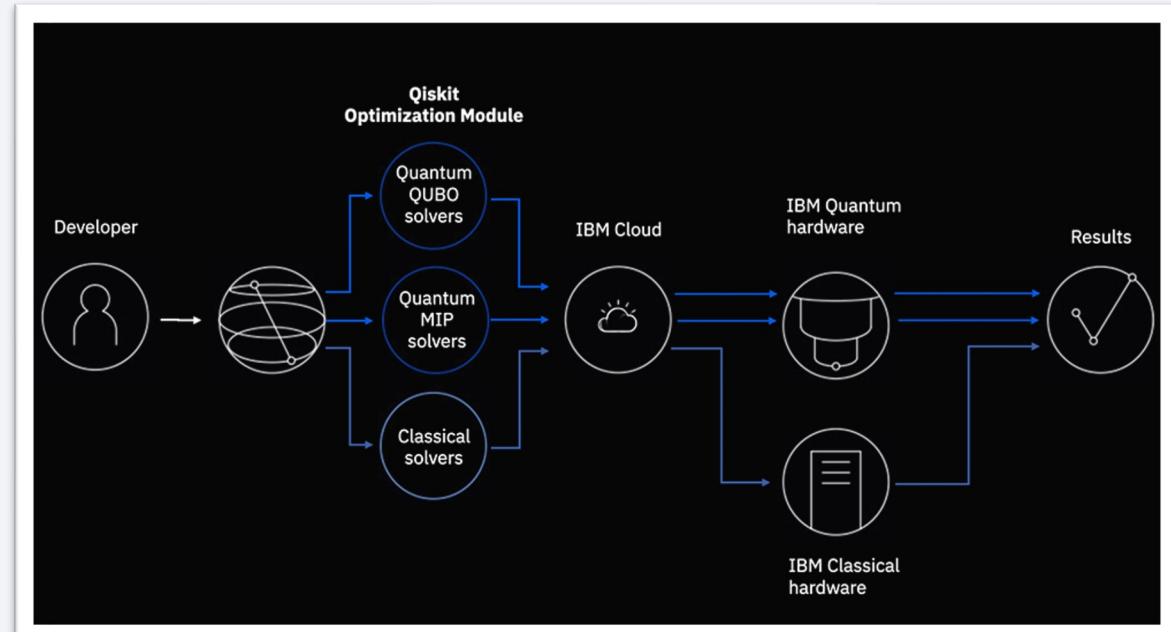
For applications relating to optimization problems.

Qiskit Machine Learning

For applications relating to machine learning.

Frictionless development vision:

a programming environment where the intricacies of the underlying technology are no longer a concern to users



Qiskit Ecosystem

Qiskit

- is open source
- has a culture of openness
- has a vibrant community

Qiskit Ecosystem (qiskit.org/ecosystem)

The Ecosystem consists of projects, tools, utilities, libraries and tutorials from a broad community of developers and researchers.

The goal of the Ecosystem is to celebrate, support and accelerate development of quantum technologies using Qiskit.

Explore community

from Qiskit and the Qiskit community

Ecosystem Resources

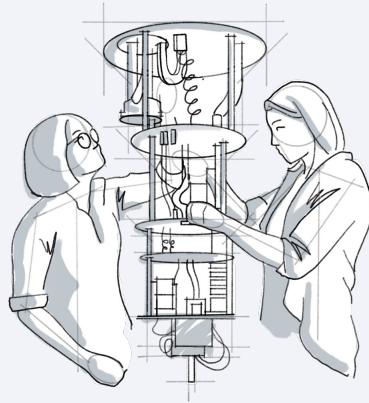
The Ecosystem consists of projects, tools, utilities, libraries and tutorials from a broad community of developers and researchers. The goal of the Ecosystem is to celebrate, support and accelerate development of quantum technologies using Qiskit.

[Join the ecosystem](#)

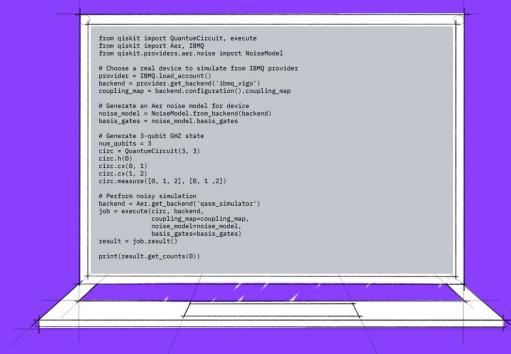
The screenshot shows a grid of nine project cards, each representing a different component of the Qiskit Ecosystem. The projects are:

- c3**: Apache-2.0 License. A plugin for SuperstaQ. Description: "The C3 package is intended to close the loop between open-loop control optimization, control pulse calibration, and model-matching based on calibration data." Includes a "Go to repo" link and a "Test Results" section from 06/12/2021 at 16:20:05.
- qiskit-superstaq**: Apache-2.0 License. A plugin for SuperstaQ. Description: "This package is used to access SuperstaQ via a Web API through Qiskit. Qiskit programmers can take advantage of the applications, pulse level optimizations, and write-once-target-all features of SuperstaQ with this package." Includes a "Go to repo" link and a "Test Results" section from 11/01/2022 at 22:09:52.
- mitiq**: Apache 2.0. A library for error mitigation. Description: "Mitiq is a Python toolkit for implementing error mitigation techniques on quantum computers." Includes a "Go to repo" link and a "Test Results" section from 11/01/2022 at 22:09:52.
- kaleidoscope**: Apache-2.0 License. A plugin for SuperstaQ. Description: "Kaleidoscope" (likely a misspelling of SuperstaQ). Includes a "Go to repo" link and a "Test Results" section from 11/01/2022 at 22:09:52.
- quantuminspire**: Apache 2.0. An algorithms library. Description: "platform allows to execute quantum algorithms using the cQASM language." Includes a "Go to repo" link and a "Test Results" section from 11/01/2022 at 22:09:52.
- qtcodes**: Apache-2.0 License. A plugin for SuperstaQ. Description: "Qiskit Topological Codes" (likely a misspelling of SuperstaQ). Includes a "Go to repo" link and a "Test Results" section from 11/01/2022 at 22:09:52.
- quantumcat**: Apache 2.0. A library for quantum computing. Description: "quantumcat is a platform-independent, open-source, high-level quantum computing library, which allows the quantum community to focus on developing platform-independent quantum applications without much effort." Includes a "Go to repo" link.
- pyEPR**: BSD 3-Clause New or Revised license. A plugin for SuperstaQ. Description: "Qiskit Metal E&M analysis with Ansys and the energy-participation-ratio method is based on pyEPR." Includes a "Go to repo" link.

Qiskit for



Research



Development



Learning

Qiskit textbook

The Qiskit textbook (qiskit.org/textbook-beta) is an open-source, university-level quantum algorithms / computation course with Qiskit code implementations and interactive features

Top source of QC knowledge on the web
(2nd only to Wikipedia)

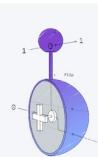
The screenshot shows the Qiskit Textbook (beta) website. At the top, there's a purple header with the Qiskit logo, navigation links for Overview, Learn, Community, and Documentation, and a note about the old version. Below the header is a large blue banner with the text "Qiskit Textbook (beta)" and a "Start learning" button. The main content area has a purple background with a white globe icon. It features sections for "Start learning in the way best for you" with "Courses", "Summer schools", "University supplements", and "Labs". Each section includes a brief description and a "Go to this resource" button.

This screenshot shows the "Introduction course" page of the Qiskit Textbook (beta). The top navigation bar includes the Qiskit logo and links for Overview, Learn, Community, and Documentation. A note about the old version is present. The main content area has a blue background with a white globe icon. It features a "Start learning" button and a "Browse all content" dropdown menu. Below the globe, there's a section titled "Start learning in the way best for you" with four categories: "Introduction course", "Summer schools", "University supplements", and "Labs". Each category has a brief description and a "Go to this resource" button.

Start learning in the way best for you

Courses

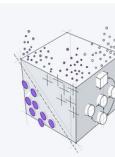
Quantum computing is a big topic and working out where to start can be difficult. In this interactive textbook, the content is organised into courses with clear prerequisites and end goals. If you're looking for something specific, you can browse all content, and if you can't find what you're looking for you can ask the community on Slack.



Introduction course

Not sure where to start? This path is for you. This introduction is aimed at audiences who are new to quantum computing. Whether you're keen to start your journey into quantum computing, or just curious as to what it's all about, this course will take you from zero to one, without the hand waving.

[Go to this course](#) →



Quantum machine learning

Want to learn about this exciting, developing field? If you're familiar with quantum computing basics, this course will give you a primer on machine learning, walk you through key concepts, and bring you up to speed with recent developments.

[Go to this course](#) →

Summer schools

The Qiskit Global Summer Schools are one-of-a-kind sequences that takes students from beginner level to solving advanced quantum problems on a quantum computer. These two-week courses are designed to empower the next generation of quantum developers with the knowledge to explore quantum applications on their own.

Quantum Computing & Quantum Machine Learning (2021)

Designed to empower the next generation of quantum researchers and developers with the skills and know-how to explore quantum applications on their own. Starting with an introductory "crash course" on quantum computing, the materials continue to dive into and explore one key area: quantum machine learning.

[Go to this resource](#) →

Introduction to Quantum Computing and Quantum Hardware (2020)

This introduction to the world of quantum computing explores key quantum algorithms, as well as the quantum hardware designed to run these algorithms. These lectures were first released as part of a two-week intensive summer school in July 2020.

[Go to this resource](#) →

University supplements

Are you teaching a course on quantum computing? Qiskit provides freely available materials to enhance your course.

Labs

This set of labs provides 7 different exercises you (or your students) can use to investigate the behaviour of current quantum computers and practice your Qiskit coding skills.

[View resource](#) ↗

IBM Quantum Challenges

One-week long online quantum programming challenges (1000+ participants each time)

Featuring Qiskit advanced capabilities and dedicated quantum systems

- Sep 2019: Fall Challenge 2019
- May 2020: Spring Challenge 2020
- Sep 2020: Qiskit Challenge India
- Nov 2020: Fall Challenge 2020
- Feb 2021: ICPC Challenge
- May 2021: Spring Challenge 2021
- Sep 2021: Africa Challenge
- Oct 2021: Fall Challenge 2021
- May 2022: Spring Challenge 2022

IBM Quantum Challenge generates better solutions than challenge creators thought possible

From May 20 to 26, 1,431 people from 76 countries participated in the IBM Quantum Challenge 2021, a celebration for 5-year anniversary of IBM Quantum and 40 years of quantum computing. Not only was the event a blast, but participants devised a more-efficient solution to one quantum computing problem than the problem's authors even thought possible.

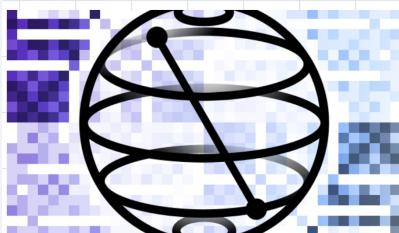
Qiskit Global Summer Schools

2-week intensive summer school (equivalent to one-semester course)

Largest quantum summer school (4000+ students for both 2020 and 2021)

QGSS 2022 will focus on quantum simulations. Early bird ran out in just a few hours! Registration will open again on June 2, 6pm ET. (Follow Qiskit Twitter for the latest announcement).

About the event:



Qiskit Global Summer School 2021: Quantum Machine Learning

The Qiskit Global Summer School returns as a two-week intensive course focused on Quantum Machine Learning and more!

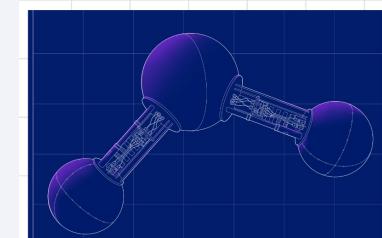
 Online
 July 12 - 23, 2021

[Learn more](#) 

The Future of Quantum Machine Learning



About the event:



Qiskit Global Summer School 2022: Quantum Simulations

The Qiskit Global Summer School returns as a two-week intensive course focused on Quantum Simulations and more!

 Online
 July 18 - 29, 2022

[Learn more](#) 

Qiskit advocate program

The Qiskit advocate program (qiskit.org/advocates) is a global program that provides support to the individuals who actively contribute to the Qiskit Community.

Benefits:

Mentorship

Network with experts
and enthusiasts

Access to Qiskit core
members and
projects

Invitation to events

2022 application opens on June 1!

Meet the Advocates

Qiskit advocates are some of the most prolific in quantum computing all over the world. If you are interested in getting involved with the quantum computing community, reach out to an advocate local to your area.

Sign up for the Qiskit Slack workspace to reach the advocates and join the conversation.

Locations

- North America
- South America
- Australia
- Africa
- Europe
- Asia



Abby Mitchell

North America



Abhay Kambal

Asia



Abhijit Mitra

North America



Abhishek Jayachandran

Asia



Aboulkhair Foda

Asia



Adity Girdharan

Asia



Ahmad, Syed Farhan

North America



Alan Leung Shek Lun

Asia



Alejandro Montañez

South America



Almudena Carrera Vazquez

Europe



Amadeep Singh Bhatia

Asia

Amaury de Miguel

Europe

Amir Ebrahimi

North America

321 advocates

38 countries

Other learning tools and resources

Learning resources

The below are designed and created by the Qiskit team. However, we recommend a familiarity with [linear algebra](#) and [Python](#) from these trusted resources.

All resources Beginner Advanced

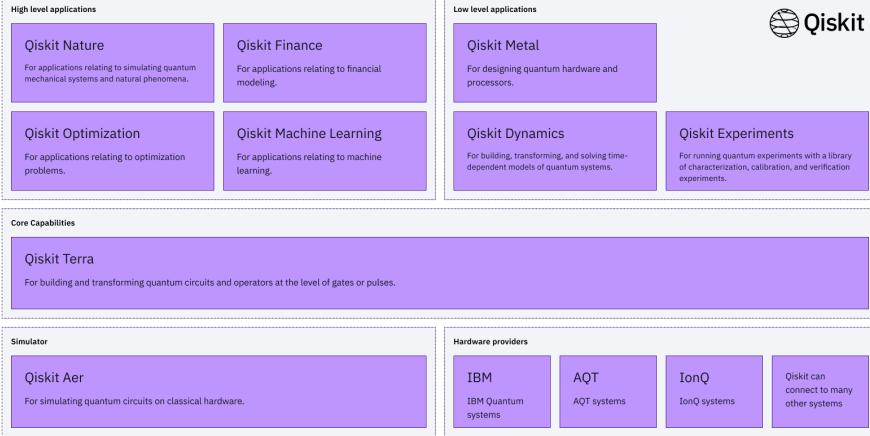
Time to spend learning	Icon	Name	Description	Action
<input checked="" type="radio"/> any		Qiskit Textbook	The Qiskit Textbook is a free digital open source textbook that will teach the concepts of quantum computing while you learn to use Qiskit.	Read the textbook →
<input type="radio"/> 1 minute		Coding with Qiskit	This video series starts at learning how to install Qiskit locally, understanding what gates to do quantum states and explores quantum algorithms and the latest research topics.	Watch the series →
<input type="radio"/> 1 day		Introduction Course	This introduction course is around 3 hours long and will take individuals from all backgrounds through a linear path of content that begins at the atoms of computation and ends at Grover's algorithm.	Take the course →
<input type="radio"/> 1 week		Qiskit Medium	This blog provides a nice overview of Qiskit and its direction as we explore what applications can be done on today's quantum devices.	Read the blog →
<input type="radio"/> 1 month		Qiskit Tutorial	Try out this hands on Qiskit tutorial that will provide an overview of working with Qiskit, building circuits, visualizing results and exploring more advanced features in the SDK.	Go to tutorials →
<input type="radio"/> 1 year		Introduction to Quantum Computing and Quantum Hardware	An introduction to the world of quantum computing, with an exploration of some of the key quantum algorithms and their implementations, as well as the quantum hardware that is designed to run these algorithms.	Join the lecture →

Qiskit Learn (qiskit.org/learn)

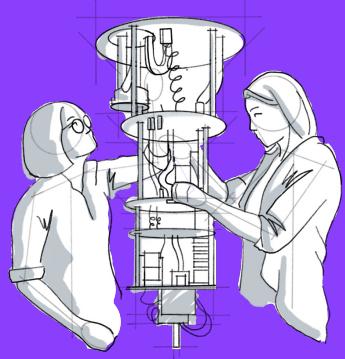
- [Qiskit Textbook](#)
- [Qiskit Tutorials](#)
- [Qiskit YouTube](#)
- [Qiskit Medium](#)
- [QGSS recordings and materials](#)

Summary

What is Qiskit?



Research



Development



Learning



Thank you

Slides are available on

<https://github.com/HuangJunye/presentations>

Follow @Qiskit



[Twitter](#)



[YouTube](#)



[Slack](#)



[Medium](#)

