Como Programar um Computador Quântico

Evandro Chagas Ribeiro da Rosa

30 de Novembro 2024

Agenda

1. O Potencial da Computação Quântica
2. Características da Computação Quântica
3. Programação Quântica com Python

Impacto da QC na Indústria

Deep dive next | Economic value: + Low | ++ Medium | +++ High

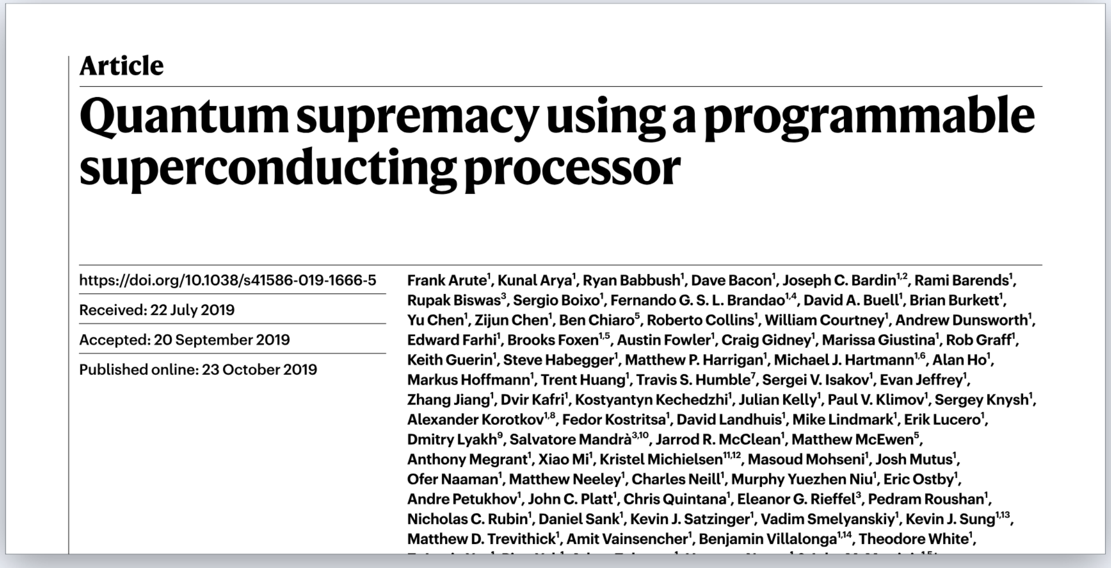
Industry	Key segment for QC	Economic value[1] ~2025–2030	Economic value[1] ~2030–2035	2035 market size, $ trillion	Value at stake with incremental impact of QC by 2035, $ billion
Financial industry[1]	Financial services	++	+++	14.1	400–600
Global energy & materials	Oil and gas	+	++		
	Sustainable energy[2]	+	+++		
	Chemicals	++	+++	6.1	200–500
Travel, transport, & logistics	Travel, transport, and logistics	+	+++	14.1	200–500
Pharmaceuticals & medical products	Pharmaceuticals	++	+++	3.1	70–400
Advanced industries	Automotive	+	++	8.3	50–100
	Aerospace and defense	+	++		
	Advanced electronics	+	++		
	Semiconductors	+	++		
Insurance	Insurance	+	++		
Telecommunications, media, & technology	Telecommunications	+	++		
	Media	+	+		
				Total	900–2,000

[1]Quantum computing technologies and industry is immature and has high uncertainty for viability and value of use cases. Business-value estimates are preliminary and intended to guide research toward high-value-potential areas, not as definitive projections for business value. Insurance is not included.

[2]Sustainable energy market is expected to grow rapidly from 2022–2035; however, the 2035 market size is influenced by numerous factors and challenging to predict.

Fonte: McKinsey

Demonstração de Vantagem Quântica



Article

Quantum supremacy using a programmable superconducting processor

https://doi.org/10.1038/s41586-019-1666-5

Received: 22 July 2019

Accepted: 20 September 2019

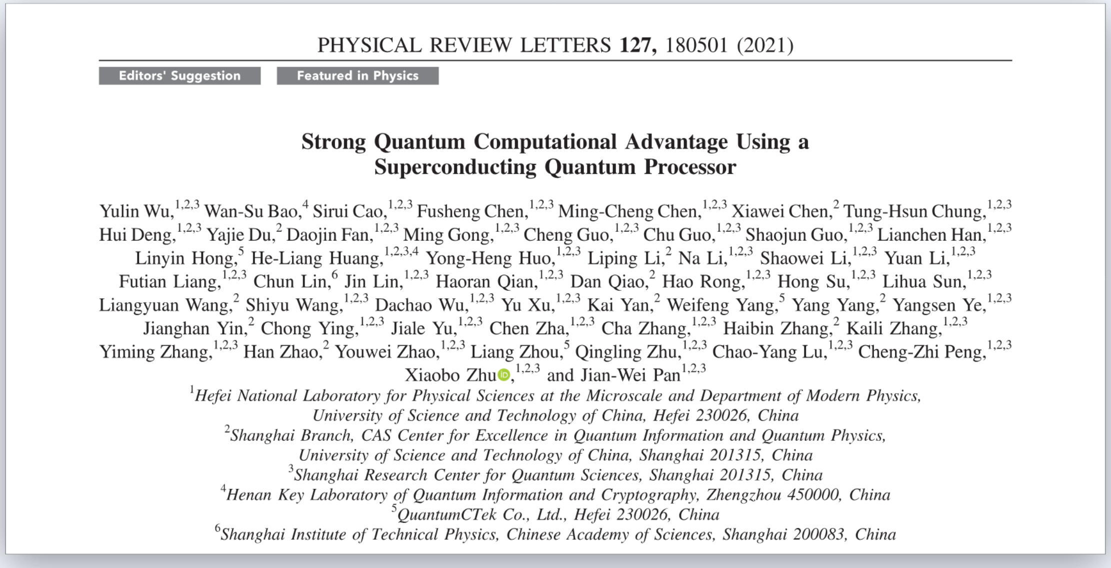
Published online: 23 October 2019

Frank Arute[1], Kunal Arya[1], Ryan Babbush[1], Dave Bacon[1], Joseph C. Bardin[1,2], Rami Barends[1], Rupak Biswas[3], Sergio Boixo[1], Fernando G. S. L. Brandao[1,4], David A. Buell[1], Brian Burkett[1], Yu Chen[1], Zijun Chen[1], Ben Chiaro[5], Roberto Collins[1], William Courtney[1], Andrew Dunsworth[1], Edward Farhi[1], Brooks Foxen[1,5], Austin Fowler[1], Craig Gidney[1], Marissa Giustina[1], Rob Graff[1], Keith Guerin[1], Steve Habegger[1], Matthew P. Harrigan[1], Michael J. Hartmann[1,6], Alan Ho[1], Markus Hoffmann[1], Trent Huang[1], Travis S. Humble[7], Sergei V. Isakov[1], Evan Jeffrey[1], Zhang Jiang[1], Dvir Kafri[1], Kostyantyn Kechedzhi[1], Julian Kelly[1], Paul V. Klimov[1], Sergey Knysh[1], Alexander Korotkov[1,8], Fedor Kostritsa[1], David Landhuis[1], Mike Lindmark[1], Erik Lucero[1], Dmitry Lyakh[9], Salvatore Mandrà[3,10], Jarrod R. McClean[1], Matthew McEwen[5], Anthony Megrant[1], Xiao Mi[1], Kristel Michielsen[11,12], Masoud Mohseni[1], Josh Mutus[1], Ofer Naaman[1], Matthew Neeley[1], Charles Neill[1], Murphy Yuezhen Niu[1], Eric Ostby[1], Andre Petukhov[1], John C. Platt[1], Chris Quintana[1], Eleanor G. Rieffel[3], Pedram Roushan[1], Nicholas C. Rubin[1], Daniel Sank[1], Kevin J. Satzinger[1], Vadim Smelyanskiy[1], Kevin J. Sung[1,13], Matthew D. Trevithick[1], Amit Vainsencher[1], Benjamin Villalonga[1,14], Theodore White[1],

2019 – Google

Sycamore 53-Qubits

200s Summit 60h



PHYSICAL REVIEW LETTERS 127, 180501 (2021)

Editors' Suggestion Featured in Physics

Strong Quantum Computational Advantage Using a Superconducting Quantum Processor

Yulin Wu,[1,2,3] Wan-Su Bao,[4] Sirui Cao,[1,2,3] Fusheng Chen,[1,2,3] Ming-Cheng Chen,[1,2,3] Xiawei Chen,[2] Tung-Hsun Chung,[1,2,3] Hui Deng,[1,2,3] Yajie Du,[2] Daojin Fan,[1,2,3] Ming Gong,[1,2,3] Cheng Guo,[1,2,3] Chu Guo,[1,2,3] Shaojun Guo,[1,2,3] Lianchen Han,[1,2,3] Linyin Hong,[5] He-Liang Huang,[1,2,3,4] Yong-Heng Huo,[1,2,3] Liping Li,[2] Na Li,[1,2,3] Shaowei Li,[1,2,3] Yuan Li,[1,2,3] Futian Liang,[1,2,3] Chun Lin,[6] Jin Lin,[1,2,3] Haoran Qian,[1,2,3] Dan Qiao,[2] Hao Rong,[1,2,3] Hong Su,[1,2,3] Lihua Sun,[1,2,3] Liangyuan Wang,[2] Shiyu Wang,[1,2,3] Dachao Wu,[1,2,3] Yu Xu,[1,2,3] Kai Yan,[2] Weifeng Yang,[5] Yang Yang,[2] Yangsen Ye,[1,2,3] Jianghan Yin,[2] Chong Ying,[1,2,3] Jiale Yu,[1,2,3] Chen Zha,[1,2,3] Cha Zhang,[1,2,3] Haibin Zhang,[2] Kaili Zhang,[1,2,3] Yiming Zhang,[1,2,3] Han Zhao,[2] Youwei Zhao,[1,2,3] Liang Zhou,[5] Qingling Zhu,[1,2,3] Chao-Yang Lu,[1,2,3] Cheng-Zhi Peng,[1,2,3] Xiaobo Zhu,[1,2,3] and Jian-Wei Pan[1,2,3]

[1]*Hefei National Laboratory for Physical Sciences at the Microscale and Department of Modern Physics, University of Science and Technology of China, Hefei 230026, China*

[2]*Shanghai Branch, CAS Center for Excellence in Quantum Information and Quantum Physics, University of Science and Technology of China, Shanghai 201315, China*

[3]*Shanghai Research Center for Quantum Sciences, Shanghai 201315, China*

[4]*Henan Key Laboratory of Quantum Information and Cryptography, Zhengzhou 450000, China*

[5]*QuantumCTek Co., Ltd., Hefei 230026, China*

[6]*Shanghai Institute of Technical Physics, Chinese Academy of Sciences, Shanghai 200083, China*

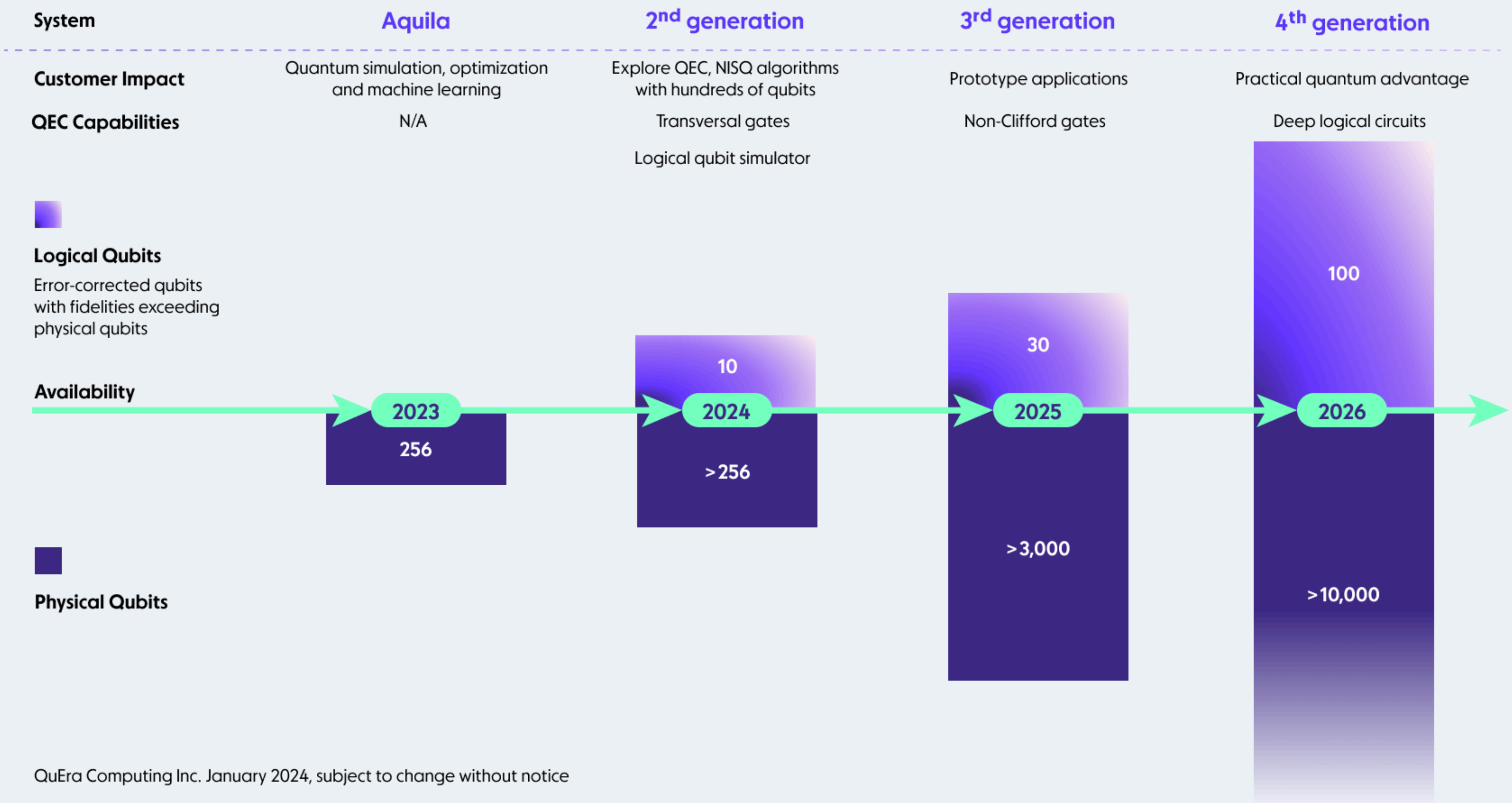
2021 – USTC

Zuchongzhi 66-Qubits

72min Summit 8 anos

QuEra Computing Inc.

Error-Corrected Quantum Computing Roadmap

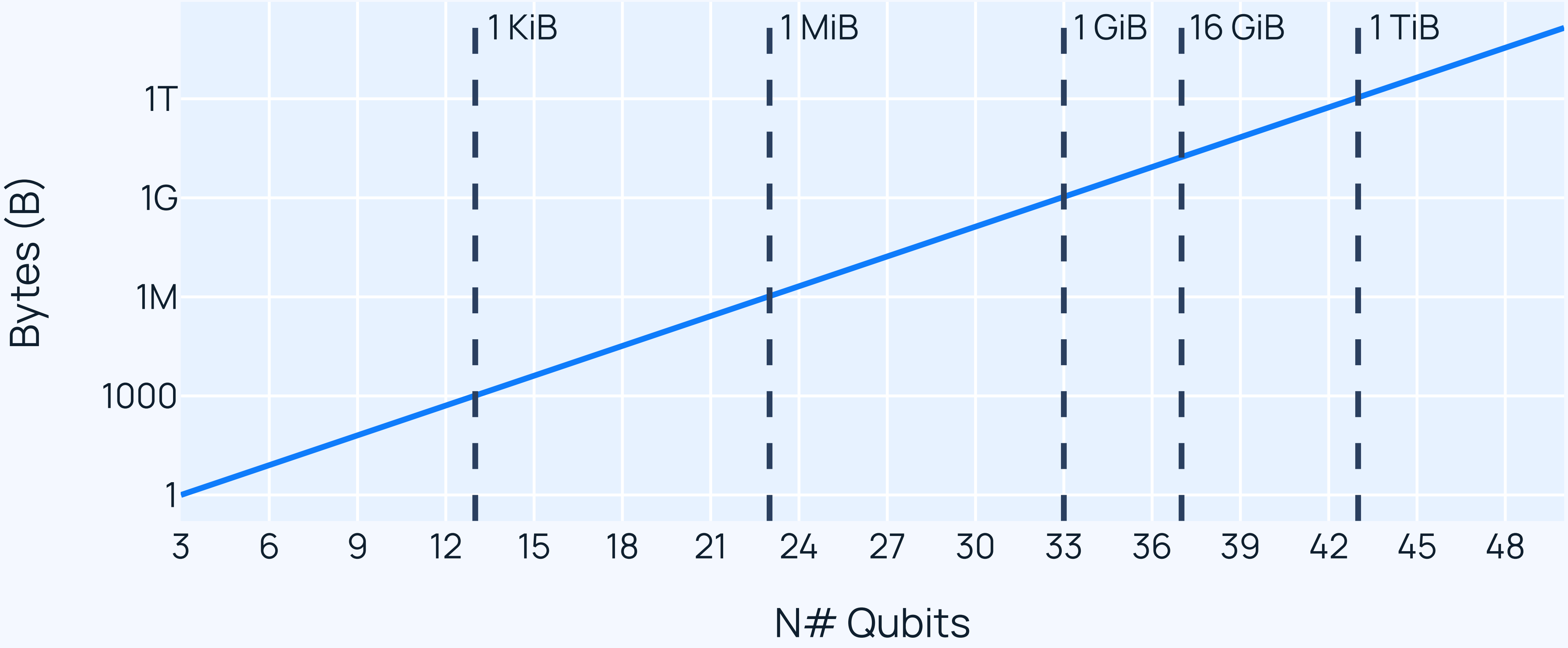


QuEra Computing Inc. January 2024, subject to change without notice

Características da Computação Quântica

|🐈⟩ + |💀⟩

Superposição



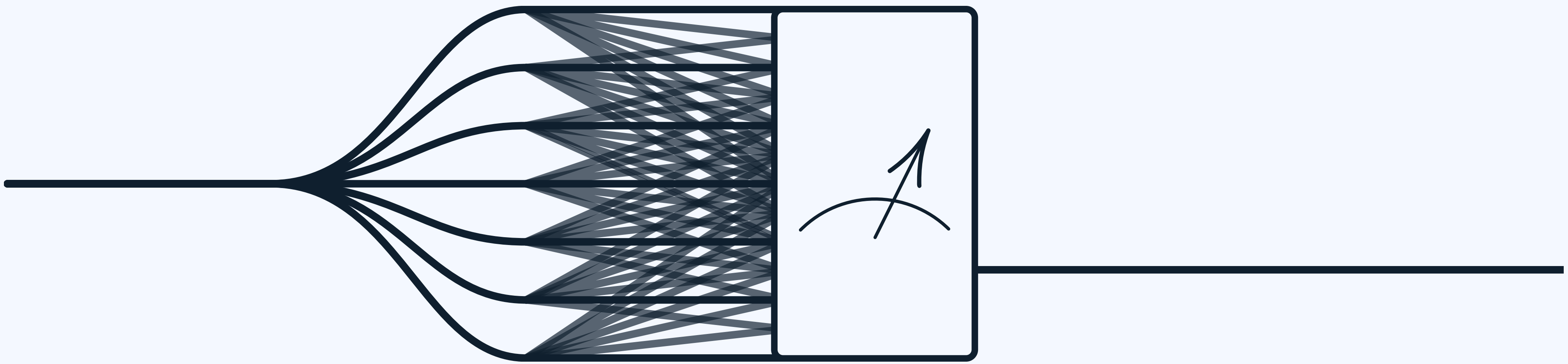
Capacidade exponencial de memória.

Entrelaçamento

Paralelismo Quântico

Medida

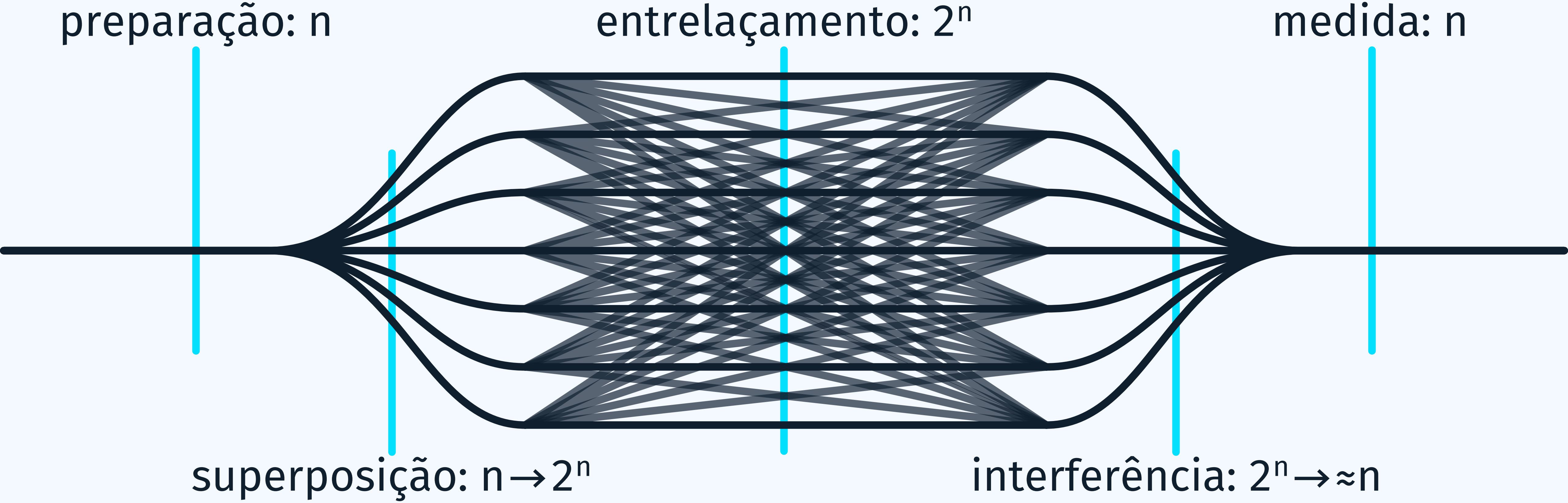
Colapso da Superposição



Capacidade exponencial de processamento paralelo.

Apenas parte da informação é retornada com a medida.

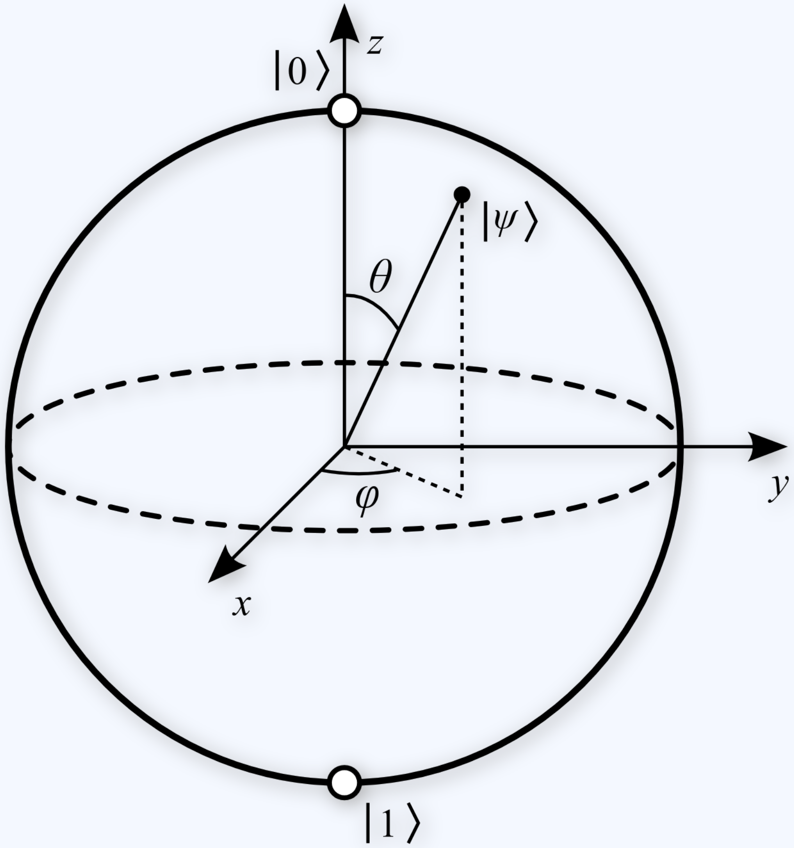
Algoritmo Quântico



O Bit Quantifico

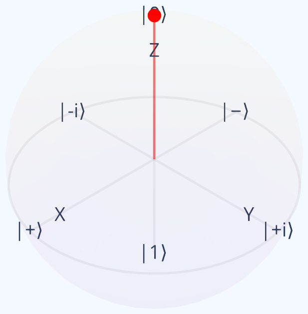
Bit	Qubit
0	$\|0\rangle$
1	$\|1\rangle$
NA	$\alpha\|0\rangle + \beta\|1\rangle$

Esfera de Bloch

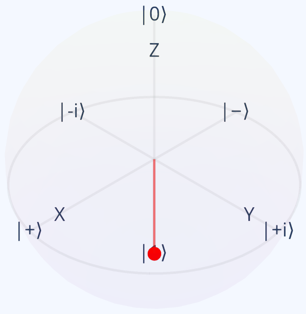


$$|\psi\rangle = \cos(\tfrac{\theta}{2}) + e^{i\varphi}\sin(\tfrac{\theta}{2})$$

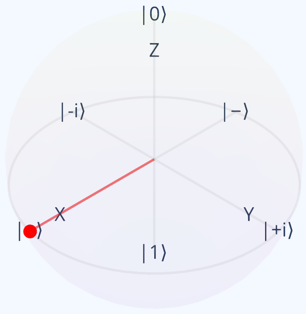
Estado Quântico



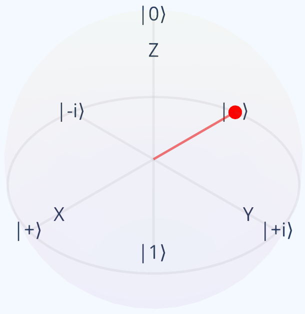
$$|0\rangle$$



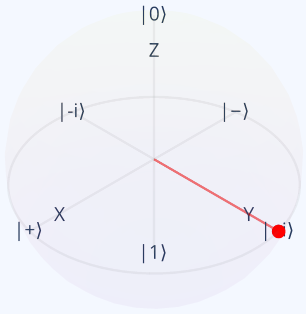
$$|1\rangle$$



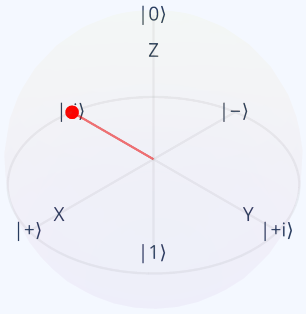
$$\frac{|0\rangle+|1\rangle}{\sqrt{2}}$$



$$\frac{|0\rangle-|1\rangle}{\sqrt{2}}$$



$$\frac{|0\rangle+i|1\rangle}{\sqrt{2}}$$



$$\frac{|0\rangle-i|1\rangle}{\sqrt{2}}$$

Portas Lógicas Quânticas

Hadamard

$$H|0\rangle = \frac{|0\rangle + |1\rangle}{\sqrt{2}}$$

$$H|1\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}}$$

CNOT

$\|\psi\rangle$	$\|\phi\rangle$	$\text{CNOT}\|\psi\phi\rangle$
$\|0\rangle$	$\|0\rangle$	$= \|00\rangle$
$\|0\rangle$	$\|1\rangle$	$= \|01\rangle$
$\|1\rangle$	$\|0\rangle$	$= \|11\rangle$
$\|1\rangle$	$\|1\rangle$	$= \|10\rangle$

Programação Quântica

python |ket⟩

ket

Python Quantum
Programming API

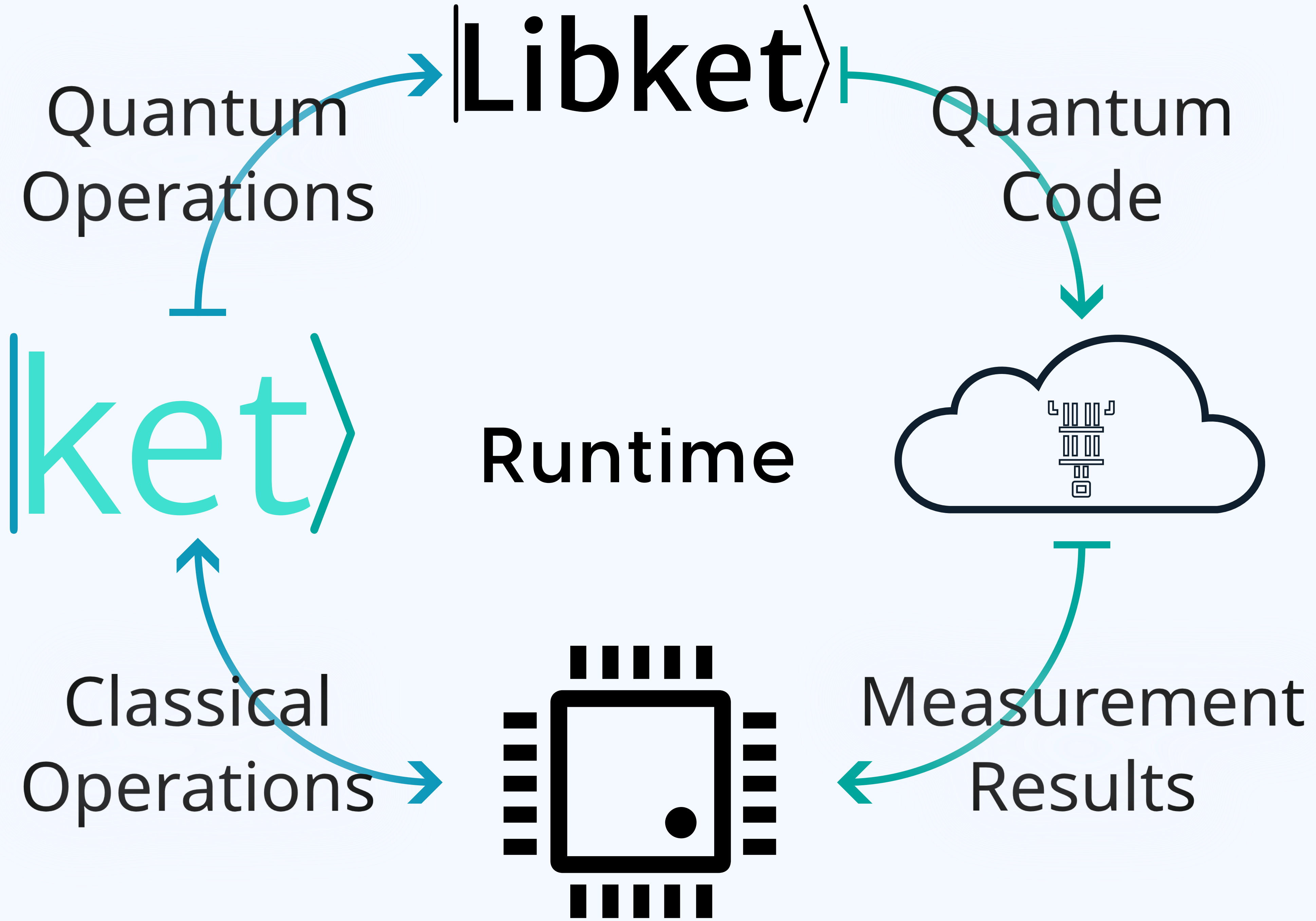
Libket

Rust Quantum
Runtime Library

Rust Quantum
CPU Simulator

Ket traz a **familiaridade** da programão em Python com a **performance** do Rust para a Computação Quântica.

```
pip install ket-lang==0.8
```


|Libket⟩
Quantum Operations
Quantum Code
|ket⟩
Runtime
Classical Operations
Measurement Results

Estado de Bell

```python
from ket import (
    Process, control,
    H, X, measure,
)

process = Process()
a, b = process.alloc(2)

H(a)  # Gera superposição

with control(a):  # Entrelaça
    X(b)          # os qubits

m_a = measure(a)
m_b = measure(b)

assert m_a.get() == m_b.get()
```

$$\rightarrow |00\rangle$$

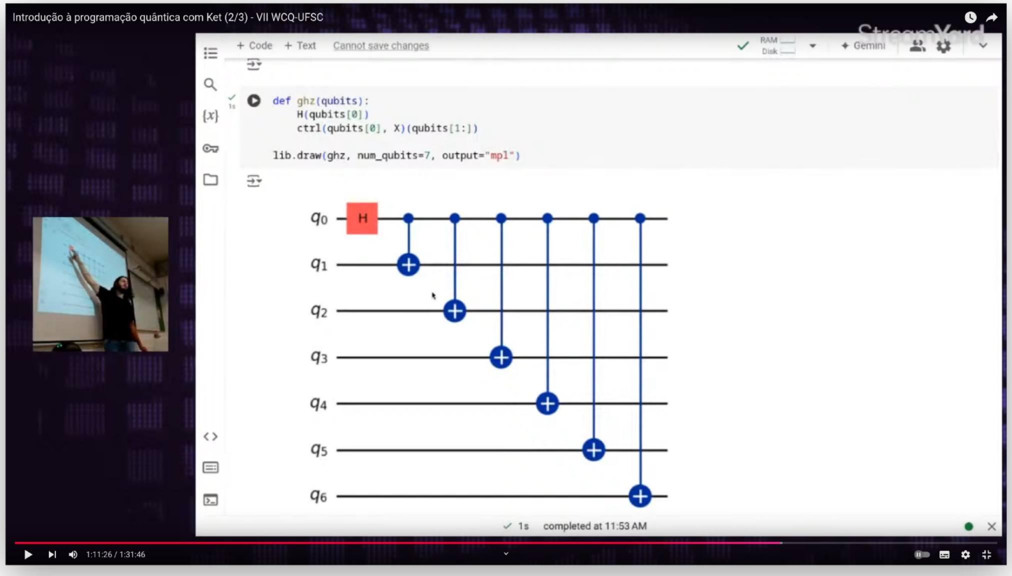
$$H|0\rangle \otimes |0\rangle = \left(\frac{|0\rangle + |1\rangle}{\sqrt{2}}\right) \otimes |0\rangle$$

$$= \frac{|00\rangle + |10\rangle}{\sqrt{2}}$$

$$\text{CNOT}\left(\frac{|00\rangle + |10\rangle}{\sqrt{2}}\right) = \frac{|00\rangle + |11\rangle}{\sqrt{2}}$$

VII Workshop de Computação Quântica - UFSC

Introdução à programação quântica com Ket



workshop-cq.ufsc.br

youtube.com/gcqufsc

Como Programar um Computador Quântico

Evandro Chagas Ribeiro da Rosa

30 de Novembro 2024