

# Lecture 1: Superposition

# **This course: a Quantum of Quantum Computing**

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*Quantum mechanics* is about  
understanding a world that is  
hard to see.

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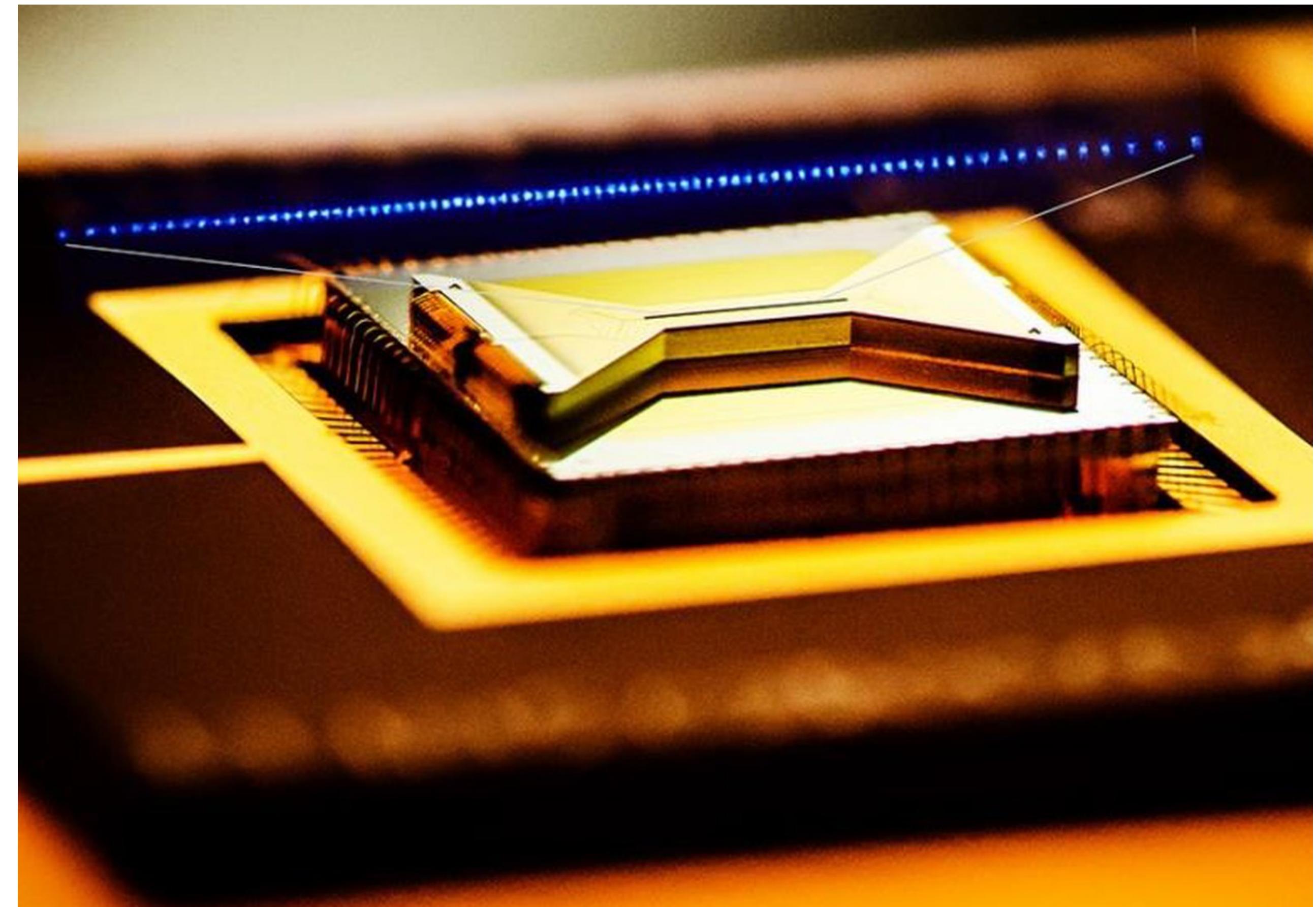
Quantum *mechanics* is about understanding a world that is hard to see.

Quantum *computing* is about harnessing that world for computation.

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The linear ion-trap on an IonQ chip. <https://ionq.com/technology>

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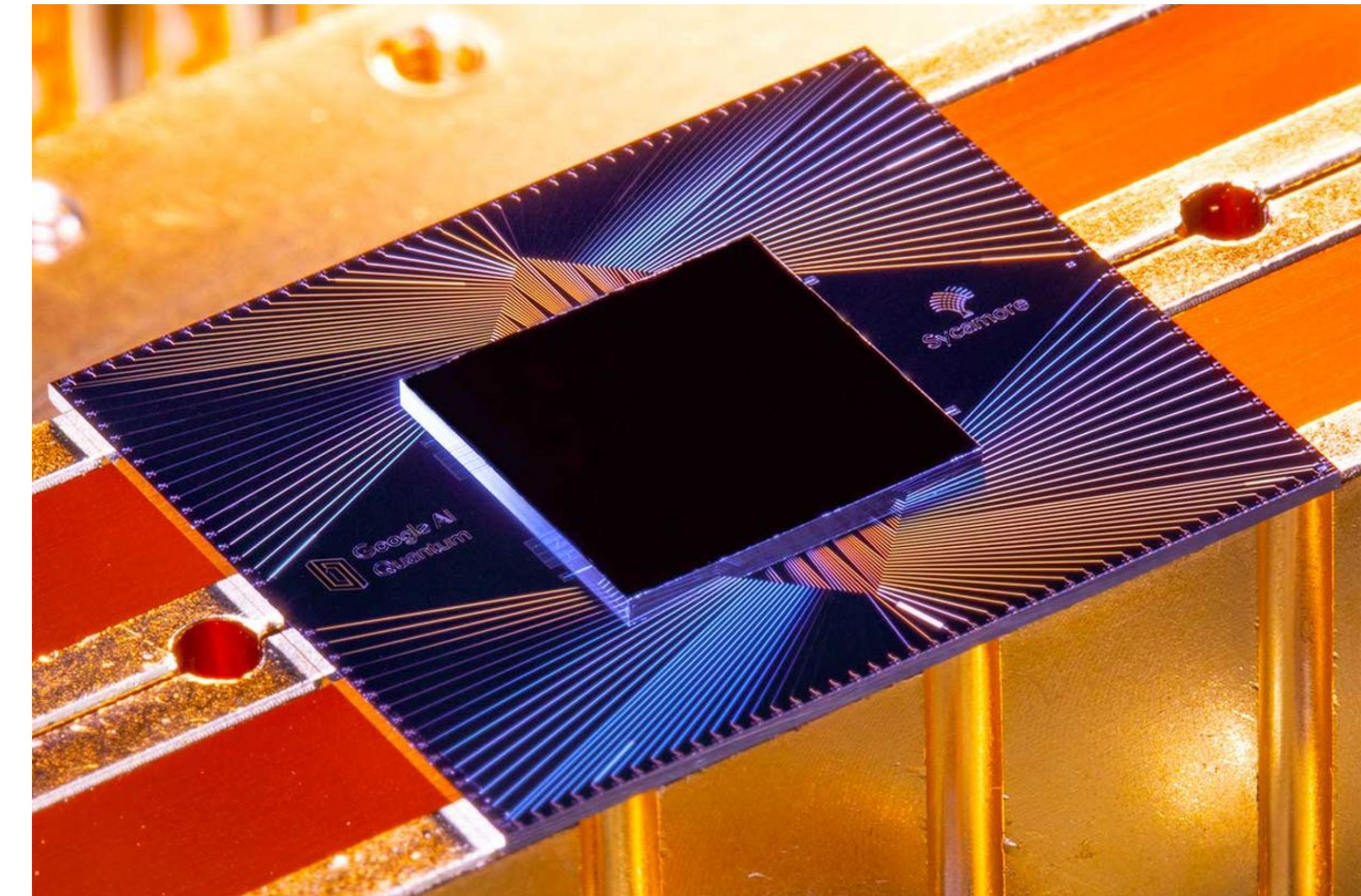
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The Google Sycamore superconducting processor. <https://spectrum.ieee.org/googles-quantum-computer-exponentially-suppress-errors>

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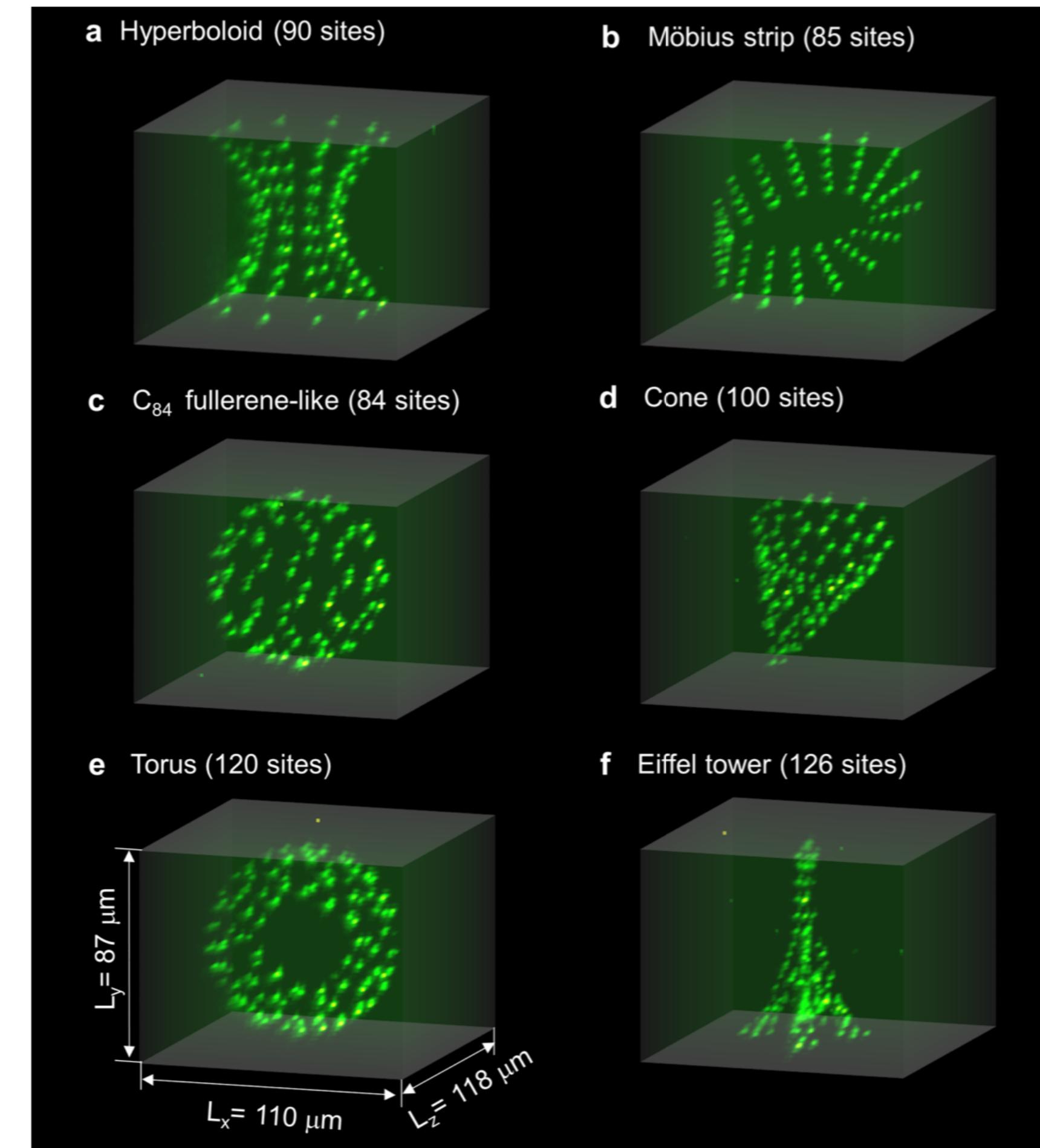
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<https://arxiv.org/abs/1712.02727>: “Single atom fluorescence in 3d arrays. (a-f) Maximum intensity projection reconstruction of the average fluorescence of single atoms stochastically loaded into exemplary arrays of traps. The x,y,z scan range of the fluorescence is indicated and is the same for all the 3d reconstructions.”

# Instructors

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**Cora Barrett (she/her)**  
PhD student, MIT Physics



**Om Joshi (he/him)**  
PhD student, MIT RLE



**Matthew Yeh (he/him)**  
PhD student, Harvard SEAS



**Ági Villányi (they/them)**  
PhD student, MIT CSAIL

# Schedule

# Schedule

Tues: Superposition

Lecture 10am - 12pm  
4-149

Lunch 12pm - 1pm

Problem Solving Session  
1pm - 3pm  
4-149

Wed: Interference

Lecture 10am - 12pm  
4-149

Lunch 12pm - 1pm

Problem Solving Session  
1pm - 3pm  
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Thurs: Entanglement

Lecture 10am - 12pm  
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Friday: Applications

Lecture 10am - 12pm  
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Lab Tours  
3pm - 4pm

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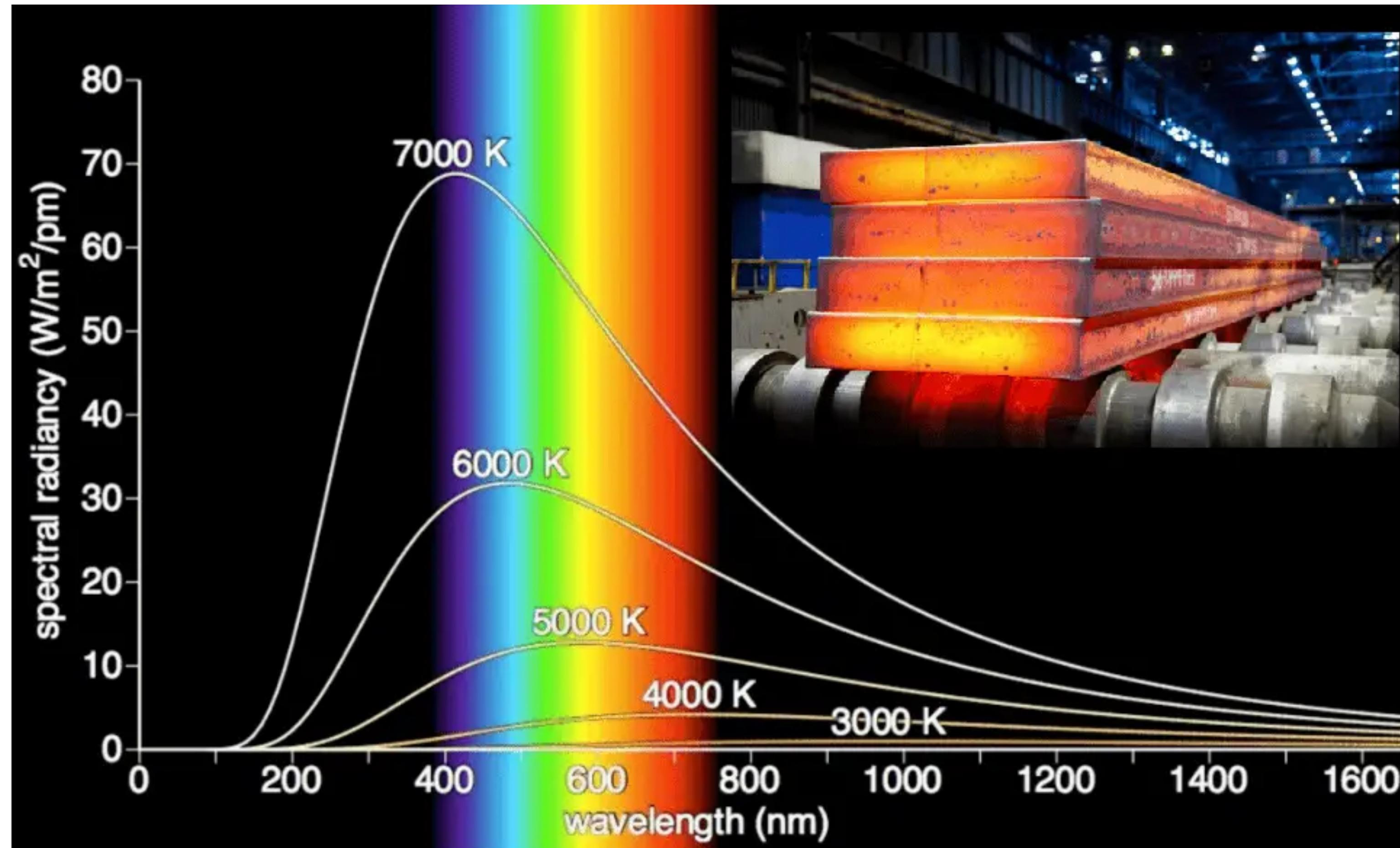
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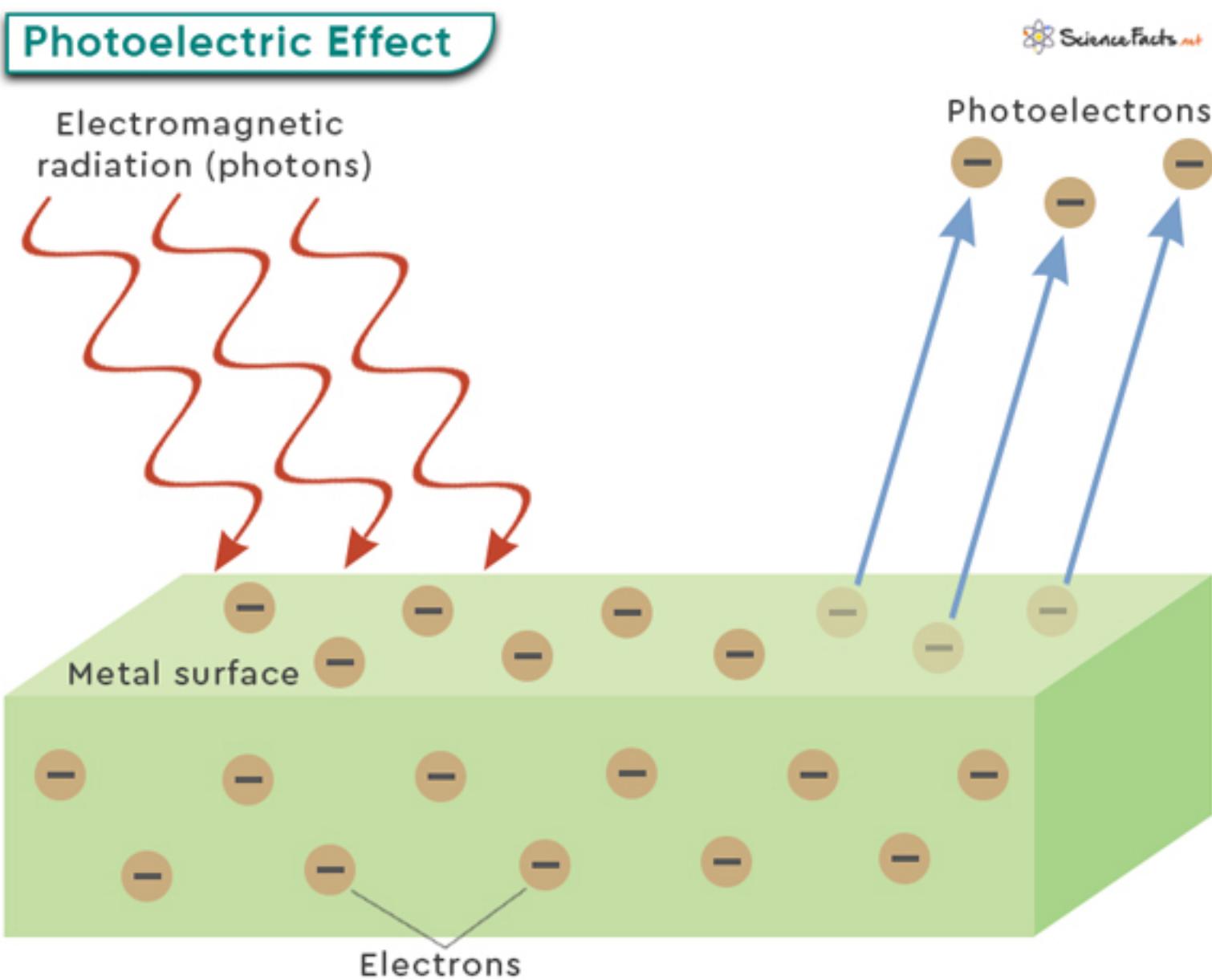
**1900: Planck and Blackbody Radiation**

**1905: Einstein and the Photoelectric Effect**

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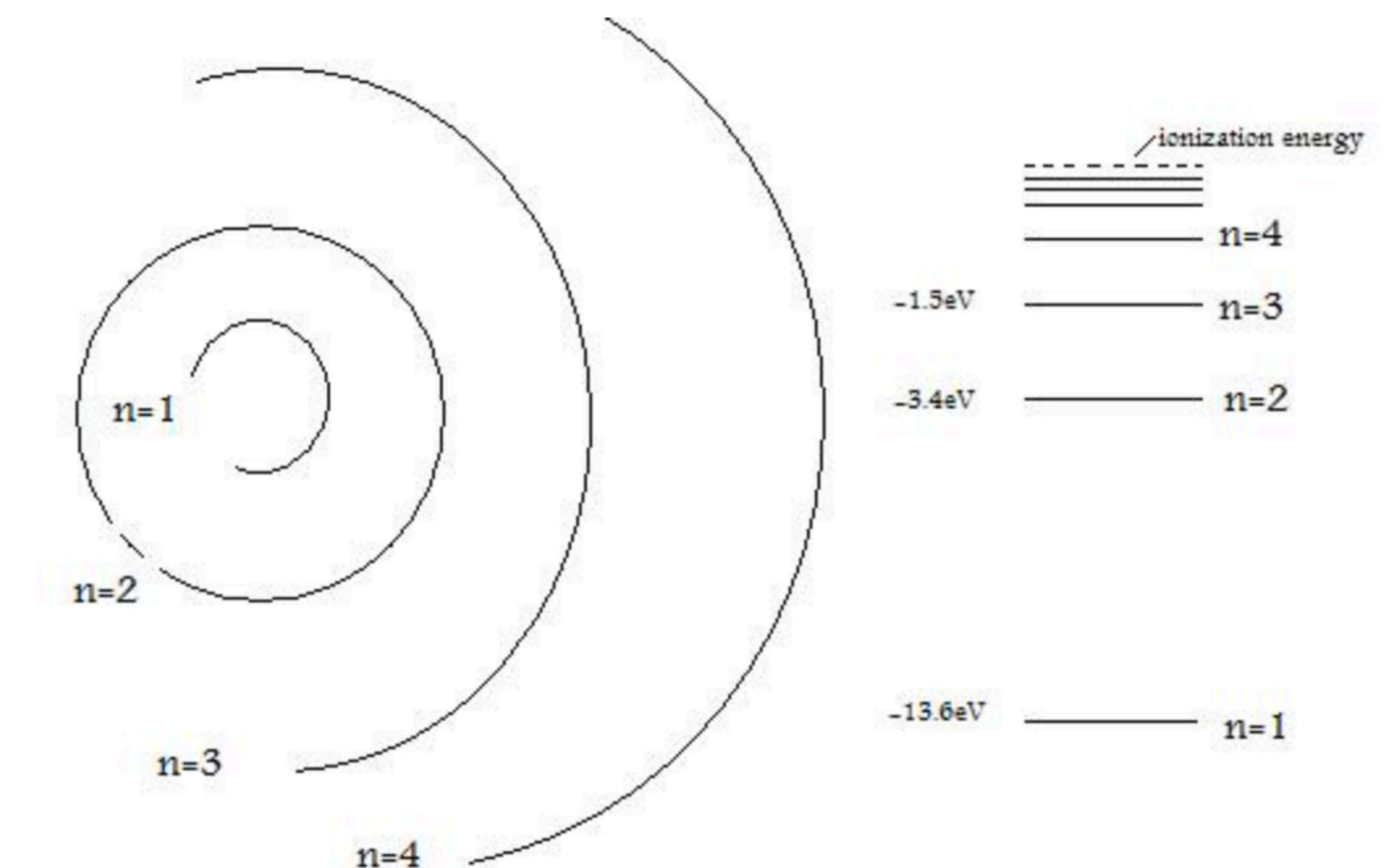
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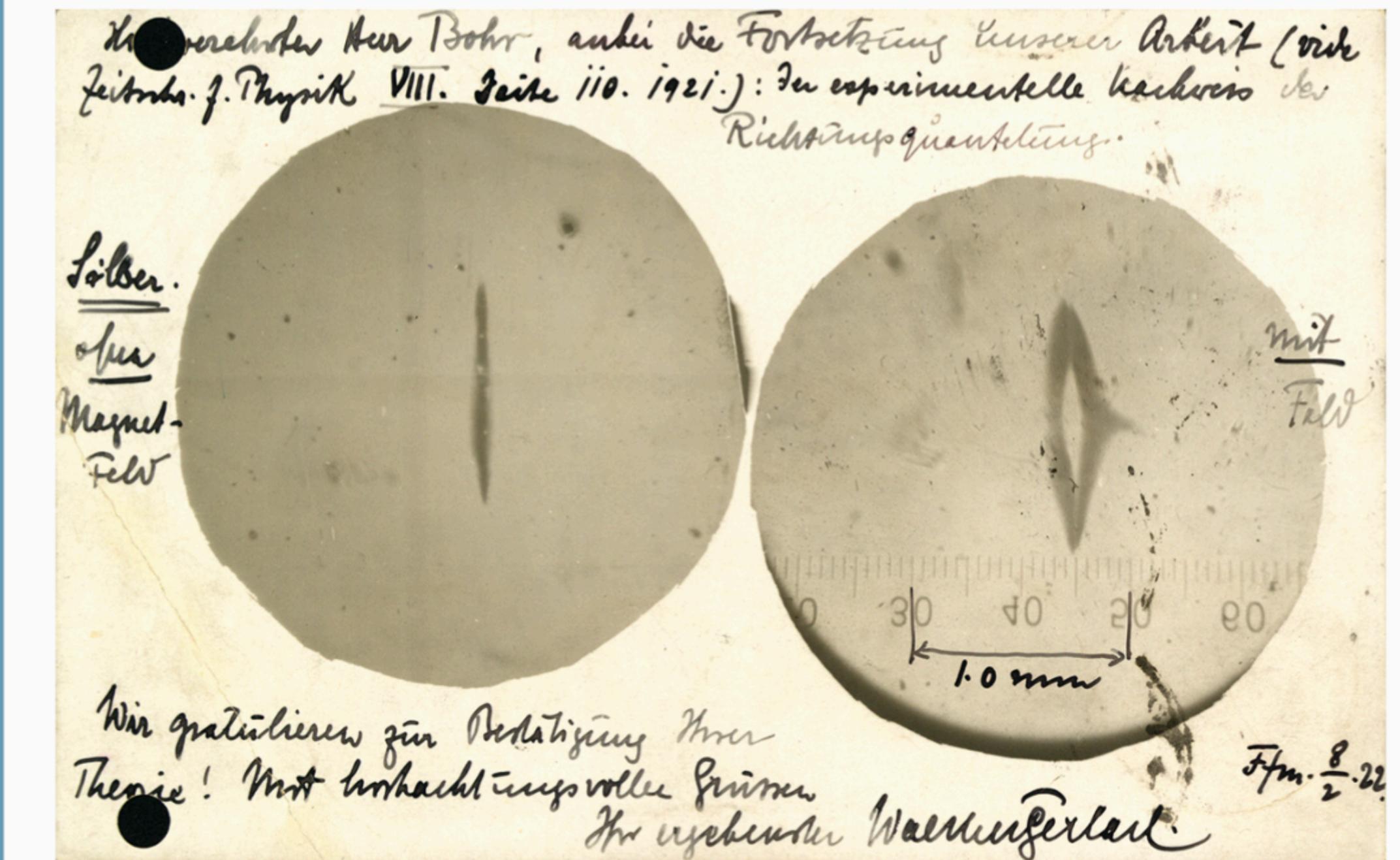
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## Stern-Gerlach Experiment



**Fig. 1.** Walther Gerlach sent this postcard to Niels Bohr, which says in German: "Attached is the experimental proof of spatial quantization (silver without and with field). We congratulate you on the confirmation of your theory."

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## Physics

- **Quantum simulation:** approximate quantum dynamics on a computational device.
  - Quantum chemistry
  - Engineering new materials
  - Fundamental many body physics discoveries
- **Quantum sensing:** using quantum bits (qubits) for precision measurement.

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## Computer Science

- **Computability:** The Extended-Church Turing Thesis claims that every reasonable computer that can be built physically can be simulated by a Turing machine. Is this true? Cryptography: more secure communication protocols (quantum cryptography), new challenges of developing quantum-safe protocols (post-quantum cryptography).
- **Algorithms:** new models of computation and new tools for both quantum and classical algorithms.

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**2. The ability to initialize a quantum state.**

**3. Long coherence times.**

**4. A universal set of quantum gates.**

**5. The ability to make measurements.**

At any given point in time, a *classical computation* with an  $n$ -bit memory can work with  $n$  bits of data, while a quantum computer with an  $n$ -qubit memory can work with  $2^n$  bits of data.

# The Qubit