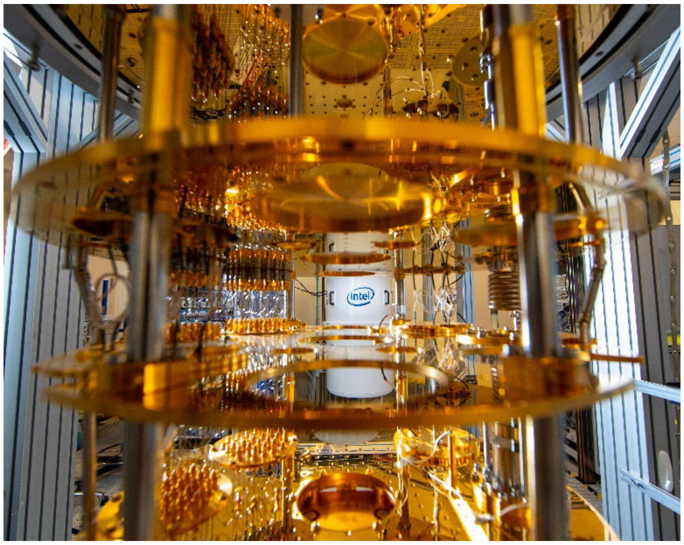
Intel Labs Quantum Computing Backgrounder

Quantum Computing Today



Quantum computing presents a new computing paradigm that harnesses the power of quantum physics to solve complex problems exponentially faster than conventional compute. It promises to revolutionize industries and solve critical problems involving climate change, chemical engineering, drug design and discovery, finance, and aerospace design. While there have been many developments, there are major challenges that must be solved to realize its full potential.

Quantum computing employs the properties of quantum physics like superposition and entanglement to deliver the ultimate in parallel computing. Traditional transistors use binary encoding of data represented electrically as “on” or “off” states. Quantum bits or “qubits” can simultaneously operate in multiple states. However, qubits are tremendously fragile. Any radio frequency noise or unintended observation can cause data loss. To eliminate noise, most qubits must operate at approximately 20 millikelvin – or 250 times colder than deep space.

While quantum computers promise greater efficiency and performance to handle certain problems, it will take a massive amount of computing power to design, model and operate these systems. These systems won’t replace conventional computing, they will *augment* supercomputers and high-performance computing (HPC). A large-scale supercomputer will run applications alongside a quantum system, resulting in a “hybrid” quantum/classical model.

Currently, quantum systems only include tens or hundreds of qubits, and more complex quantum systems include entangled qubits, in which two members of a pair of qubits exist in a single quantum state. To achieve commercial relevance, quantum systems need to scale to over a million qubits and overcome daunting challenges, like qubit fragility and software programmability. While there have been many recent developments, Intel believes the industry is still about 10-15 years from large-scale implementation that delivers commercial value to users.

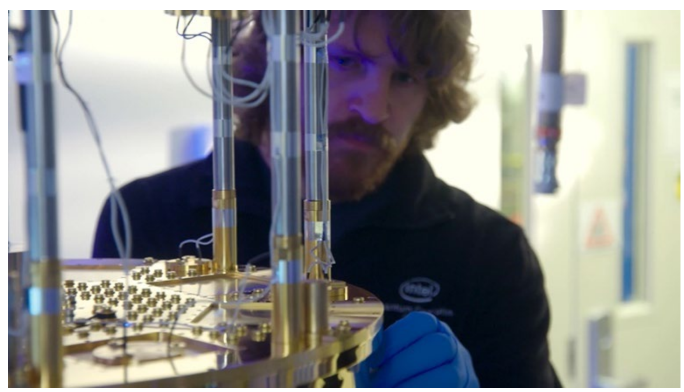
Intel's Vision for Quantum Computing

Intel has invested heavily in quantum computing research over the past decade and is taking a full-systems architecture approach that spans the complete compute stack. Each piece is carefully considered, from qubit architecture and algorithms research to control electronics, interconnects, quantum software toolchains and compilers.

Intel is focused on silicon spin qubits that resemble single electron transistors and leverage the company's 50+ years of semiconductor manufacturing expertise. The quantum research team uses Intel's most advanced transistor fabrication capabilities including extreme ultraviolet lithography (EUV) and materials processing techniques such as standard complementary metal oxide semiconductor (CMOS) logic processing. To control these advanced devices, Intel has developed the [Horse Ridge II cryogenic control chip](). The customized control chip is based on Intel 16 technology, which operates at 4 Kelvin to control qubits.

In June 2023, Intel announced Tunnel Falls, a 12-qubit quantum research chip built on its leading-edge transistor technology. Tunnel Falls represents a step toward accelerating quantum research as it will enable the research community to expand testing, qubit capabilities, and data sharing.

At the software level, Intel recently released an open source Intel Quantum Software Development Kit (SDK). Available on the Intel DevCloud, the SDK enables developers to begin programming quantum applications and explore future technology uses on Intel hardware so they are ready when Intel's quantum hardware becomes available.



Intel is also committed to developing the entire quantum industry ecosystem. To help build the future quantum workforce and democratize spin qubit research, Intel is making its Tunnel Falls chip available to universities and other laboratories to conduct novel silicon qubit research.

In addition, Intel has several academic collaborators and serves on the White House Office of Science and Technology Policy (OSTP) board and the U.S. Department of Energy's (DOE) National Quantum Initiative.

What's Next?

Intel's quantum computing vision focuses on bringing quantum out of the lab and into commercial reality. Intel's researchers are truly excited about the possibilities ahead. They remain steadfast in Intel's journey to help break down the technological barriers and apply expertise to make a large-scale quantum compute system, and ultimately realize quantum's full potential.

About Intel

Intel (Nasdaq: INTC) is an industry leader, creating world-changing technology that enables global progress and enriches lives. Inspired by Moore's Law, we continuously work to advance the design and manufacturing of semiconductors to help address our customers' greatest challenges. By embedding intelligence in the cloud, network, edge and every kind of computing device, we unleash the potential of data to transform business and society for the better. To learn more about Intel's innovations, go to newsroom.intel.com and intel.com.