MODULE 8:
FUTURE CHALLENGES & CAREERS

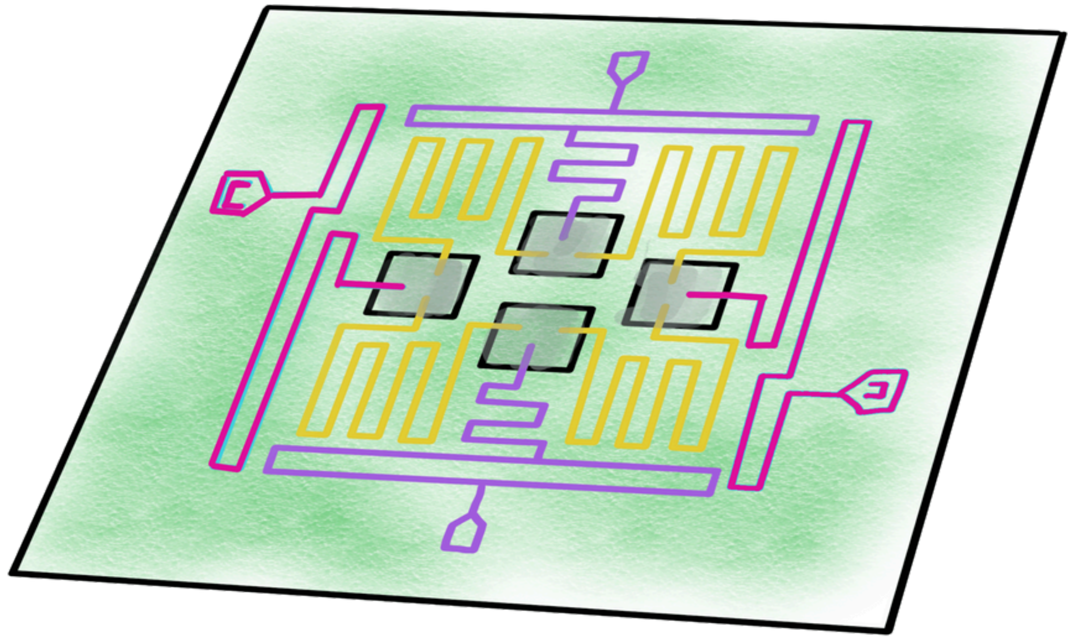
Contents

8.1 Quantum Hardware landscape:

The quantum hardware landscape is rapidly evolving, with multiple companies, universities, and research institutions building quantum computers using various qubit technologies, each with its strengths and challenges.

Superconducting Qubits:

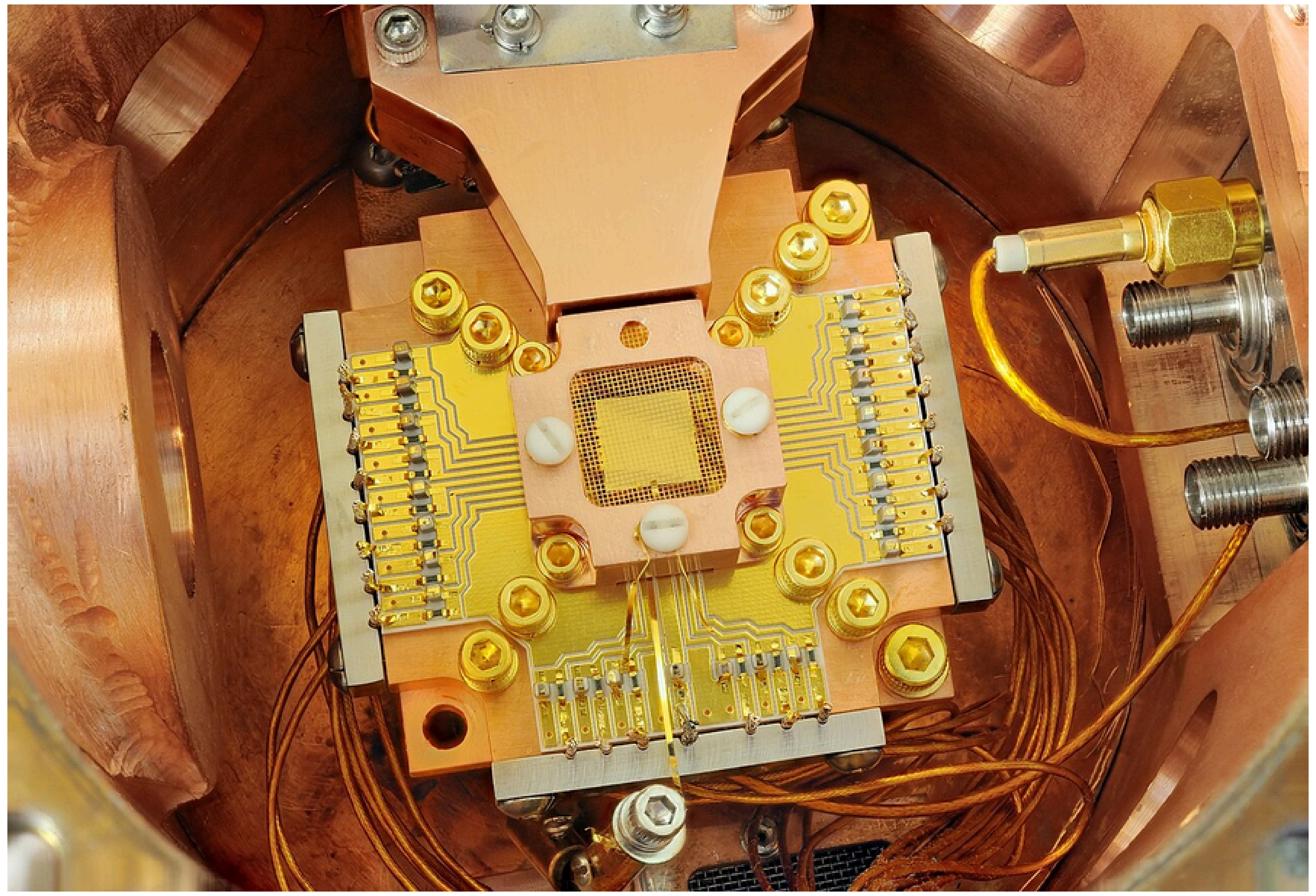
Used by companies like IBM, Google, and Rigetti, these qubits rely on superconducting circuits operating at cryogenic temperatures. IBM's Quantum roadmap includes systems like Condor (1,121 qubits) and aims for error-corrected systems by 2029. Google's Willow chip (2024) demonstrated advancements in quantum error correction.



Superconducting chip with 4 qubits

Trapped Ions:

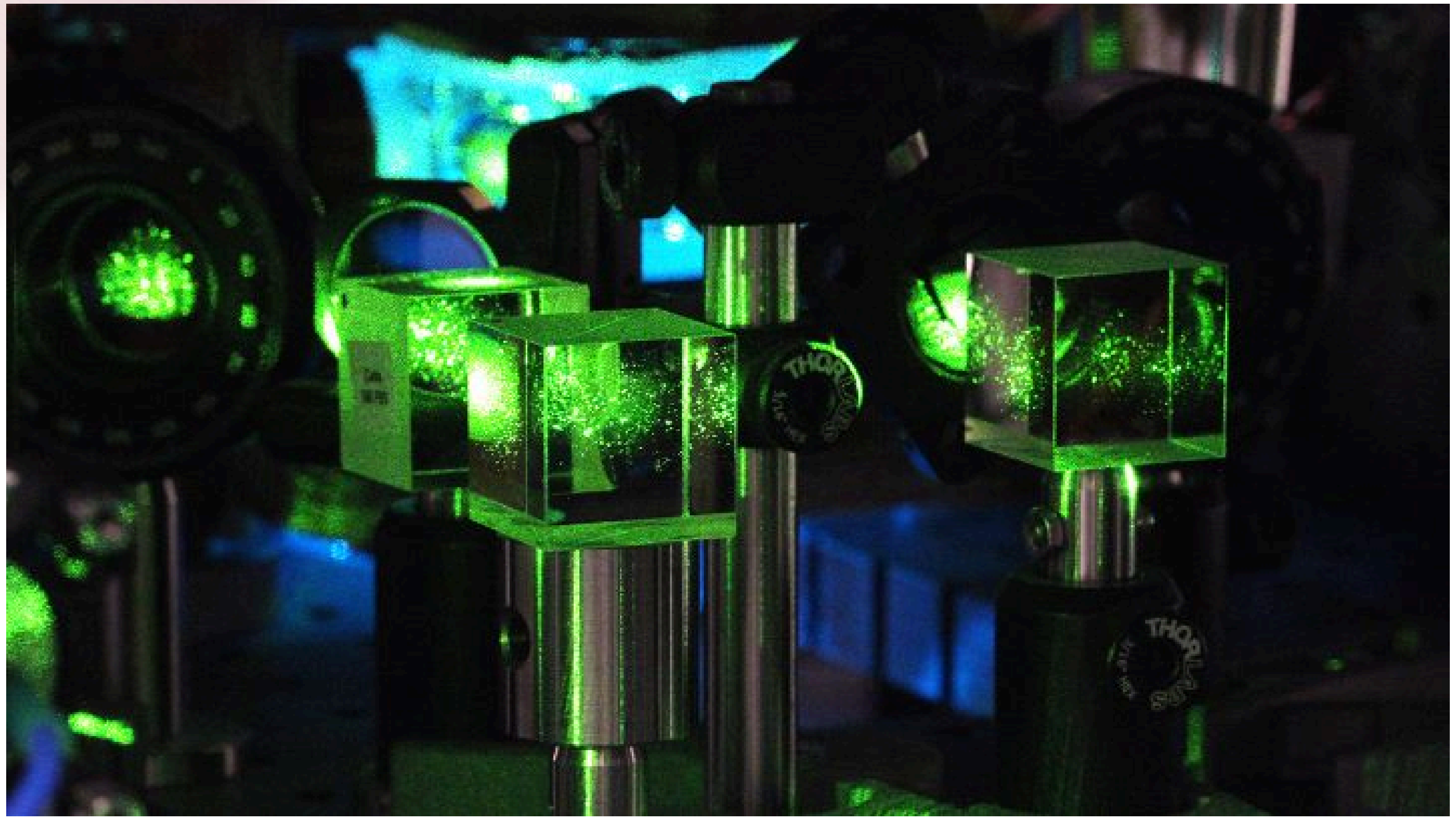
Companies like IonQ and Quantinuum use trapped ion systems, offering high-fidelity gates and long coherence times. Quantinuum's H2-1 (2025) achieved 99.9% two-qubit gate fidelity.



Chip ion trap for quantum computing from 2011 at NIST

Neutral Atoms:

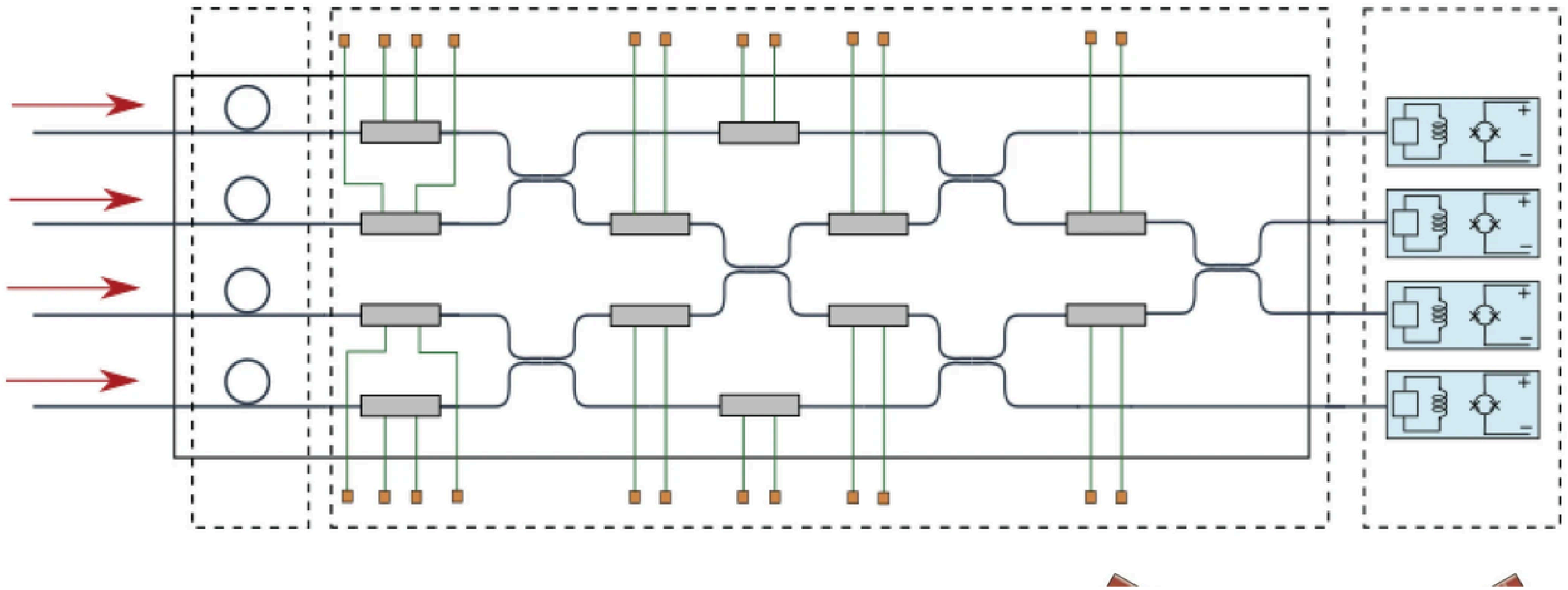
Pasqal and QuEra leverage neutral atom arrays for scalable qubit architectures, excelling in analog quantum simulation and combinatorial optimization.

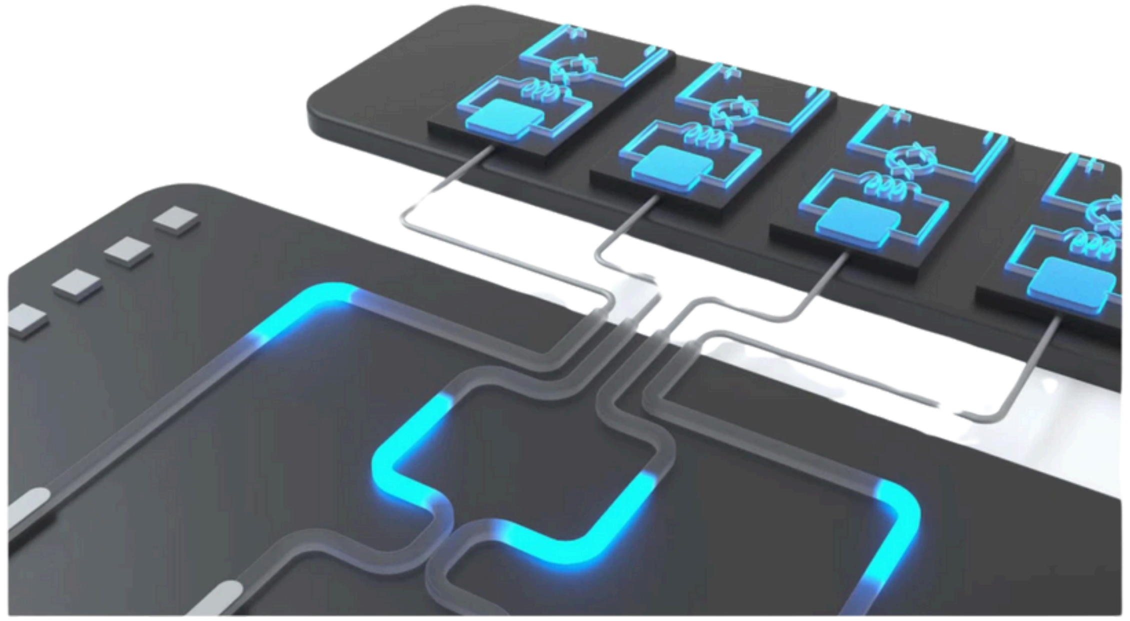


- A beam of laser light in Jeff Thompson's lab at Princeton University, where he and his colleagues recently demonstrated a new way of erasing errors in a neutral-atom quantum computer.

Photonic Quantum Computing:

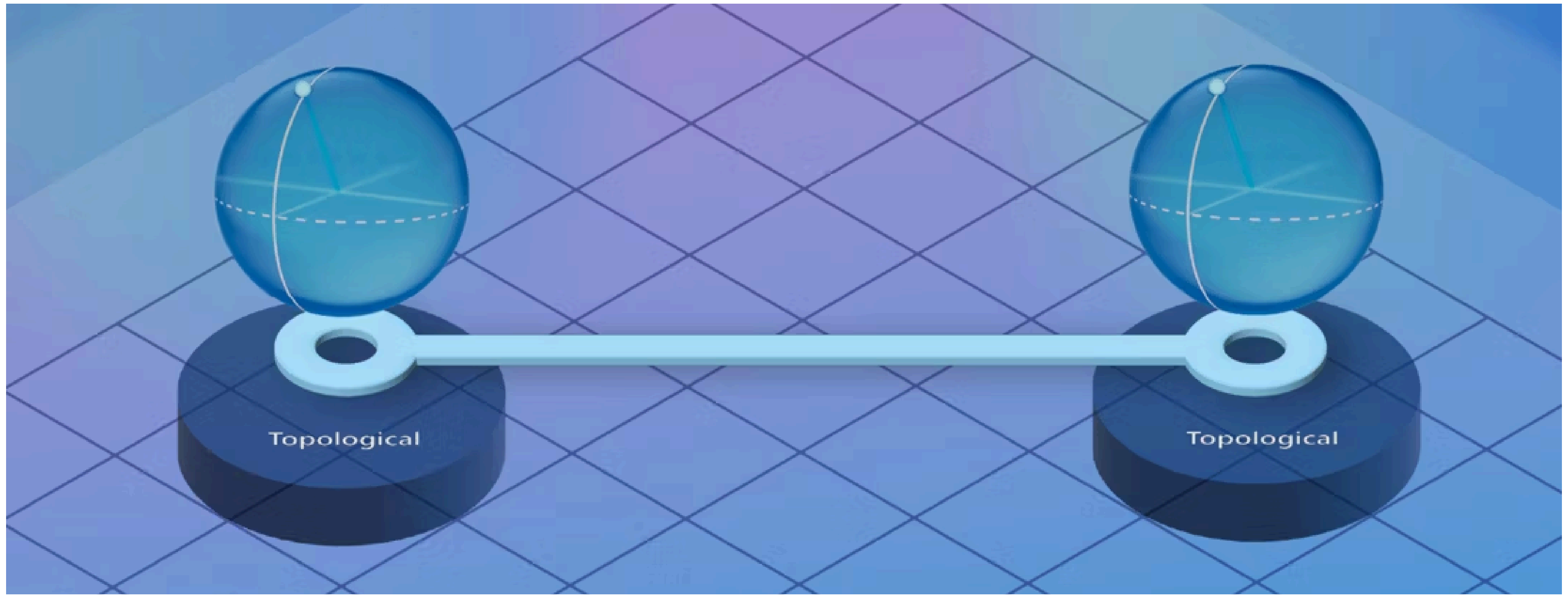
PsiQuantum and Xanadu focus on photon-based systems, promising scalability and room-temperature operation. PsiQuantum targets a million-qubit system by 2027.





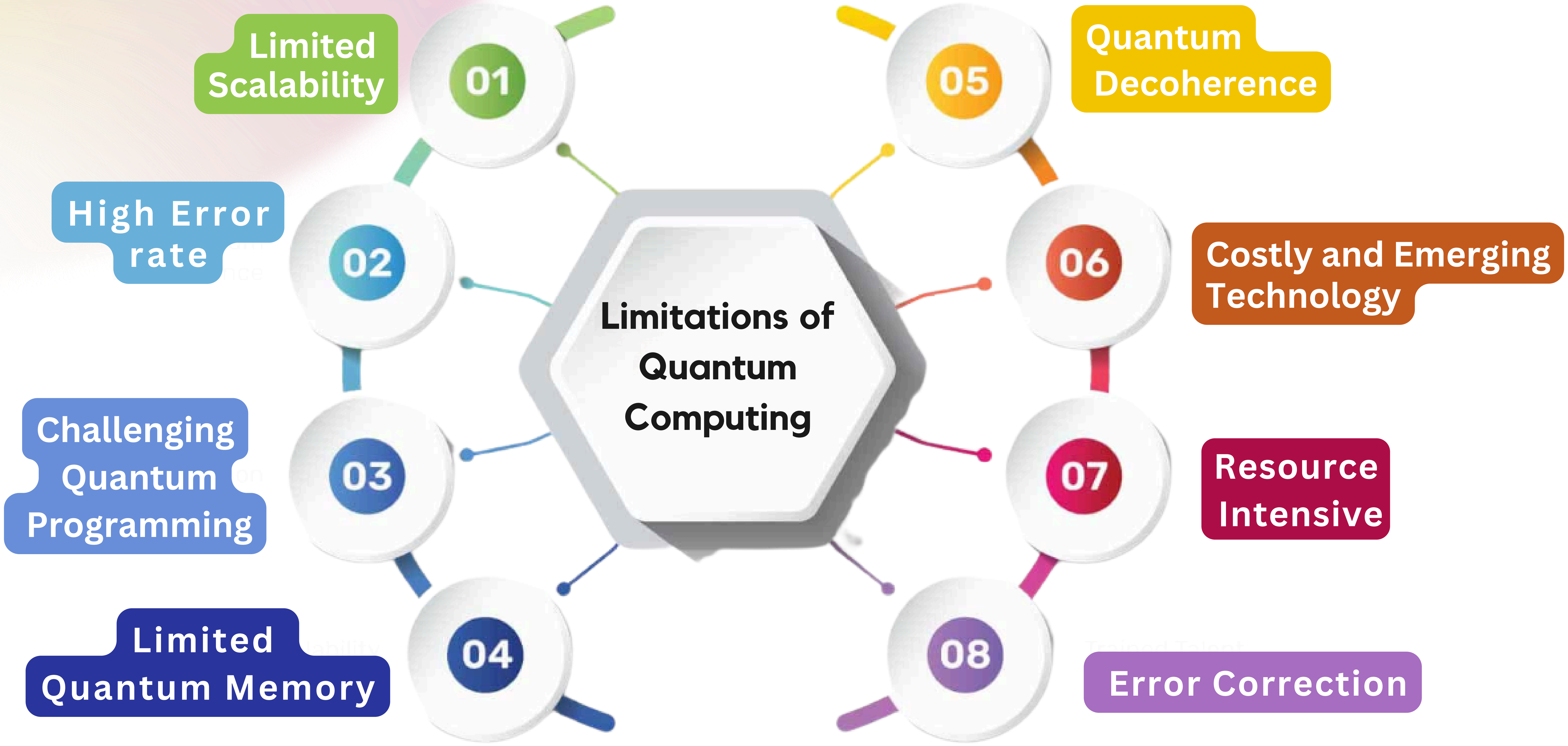
Topological Qubits:

Microsoft believes that quantum computers based on topological qubits are a promising path to scaled, low-error quantum computing. These qubits stores quantum information in the two ends of a superconducting nanowire. These qubits are less sensitive to noise at either end individually



8.2 Limitations and Future Scope

These are the limitations of Quantum Computing (as of 2025):



Limitations:

1. Limited Scalability:

Quantum systems have limitations in size and the number of qubits they can handle effectively, hindering their ability to solve complex problems at scale.

2. High Error Rates:

Quantum systems are prone to errors due to noise and interference, affecting the accuracy and reliability of calculations.

3. Challenging Quantum Programming:

Developing algorithms and software for these computers requires specialized skills and is more complex than traditional programming.

4. Limited Quantum Memory:

Maintaining and manipulating quantum information over time is challenging due to the fragility of quantum states.

5. Quantum Decoherence:

Quantum systems can experience decoherence, causing quantum information to dissipate and leading to data loss.

6. Costly and Emerging Technology:

These computers are still in early development stages, making them expensive to build and maintain, limiting accessibility.

7. Resource Intensive:

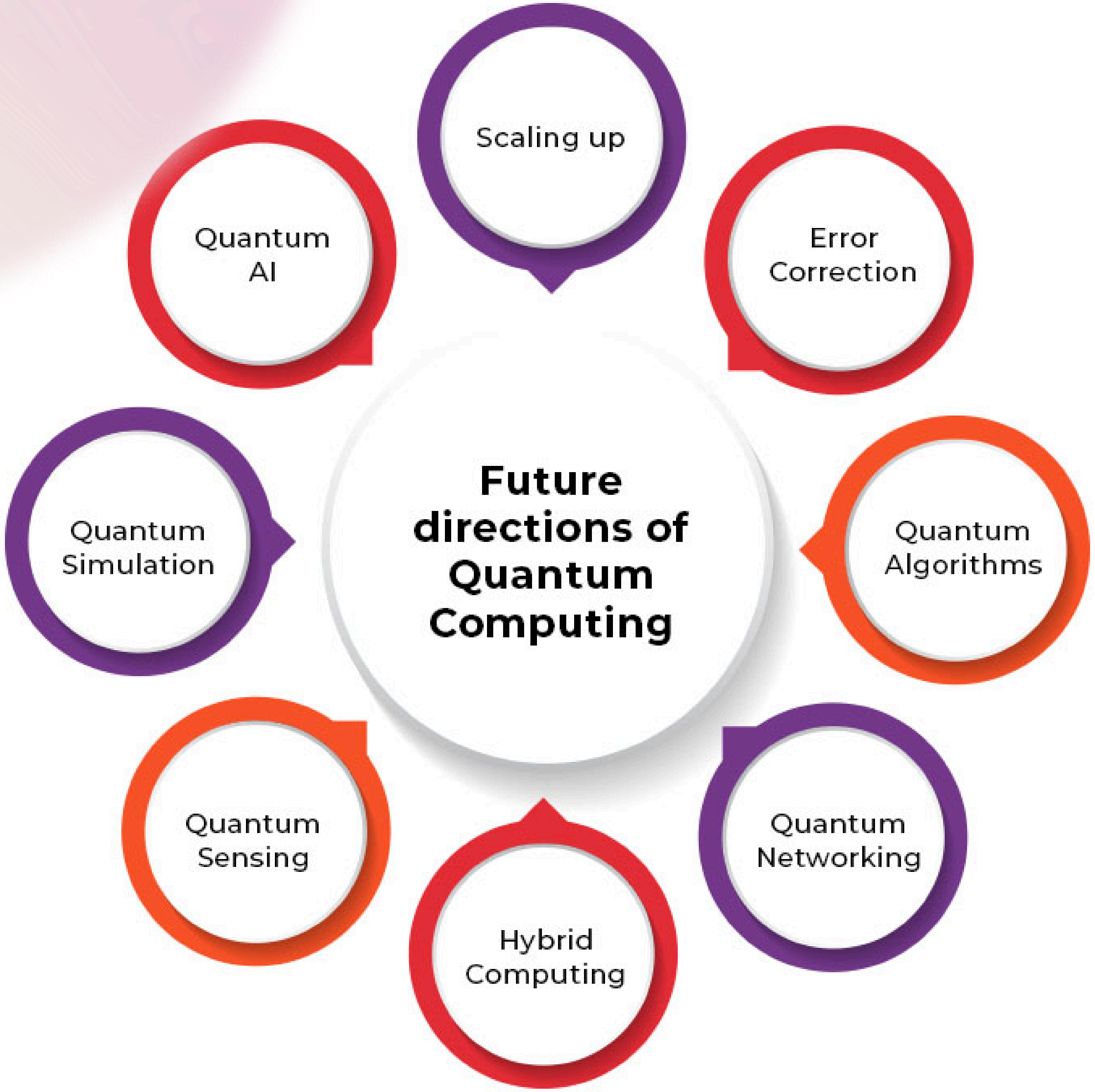
Quantum computations often require significant computational resources, including qubits, control systems, and cooling infrastructure.

8. Quantum Error Correction Challenges:

Implementing effective error correction techniques in quantum systems is complex, impacting the overall reliability of computations.

8.2 Limitations and Future Scope

Future Scope of Quantum Computing:



Future Scope of Quantum Computing:

1. Scaling Up:

Current quantum computers have limited qubits (50–100). Researchers are exploring better qubit designs and fabrication methods to scale systems for practical use.

2. Error Correction:

Qubits are error-prone due to noise and decoherence. New methods like topological qubits and error-correcting codes are being developed to improve stability.

3. Quantum Algorithms:

Quantum computing needs new algorithms for tasks like optimization and cryptography. Programming languages and tools are also evolving to support this.

4. Quantum Networking:

Focuses on connecting quantum devices globally for secure communication and distributed computing using technologies like quantum repeaters and routers.

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5. Hybrid Computing:

Combines quantum and classical computing to overcome limitations like low qubit counts and high error rates. Useful in machine learning and neural networks.

6. Quantum Sensing:

Quantum sensors can measure physical properties with extreme precision. They have applications in medical imaging, navigation, and geology.

7. Quantum Simulation:

Simulates complex systems (like molecules) more efficiently than classical computers. Useful in drug discovery, energy, and materials science.

8. Quantum AI:

Integrates quantum computing with machine learning to enhance performance in areas like NLP, robotics, and image recogn

8.3 Career Pathways and Further Learning

Entry-Level Technical Role

Beginning of technical career in quantum software

Mid-Level Technical Role

Developing quantum applications and systems

Technical Leadership Role

Leading teams and projects, mentoring juniors

Principal Technical Role

Designing and overseeing quantum system architecture

Entry-Level Research Role

Assisting in quantum research projects

Advanced Research Role

Conducting doctoral research in quantum science

Senior Research Role

Leading research and publishing scientific papers

Research Leadership Role

Directing research teams and securing funding

Entry-Level Strategy Role

Analyzing quantum market and technology trends

Mid-Level Product Role

Managing quantum product development and strategy

Senior Strategy Role

Leading quantum strategy and business initiatives

Top Leadership Role

Overseeing all quantum technology and vision

Thank you!