Quantum information science and the technology frontier
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Office of Science and Technology Policy

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Quantum Sensing

Accuracy via physical law
Concept: atoms are indistinguishable. Use this to create time standards, enables global navigation.

Concept: speed of light is constant. Use this to measure distance using a time standard.

Concept: electrons are quantized, have the same charge. Use this to calibrate electrical currents and voltages.

New modalities of measurement
Challenge: measuring inside the body. Use quantum behavior of individual nuclei to image magnetic resonances (MRI)

Challenge: estimating length limited by ‘shot noise’ (individual photons!). Use quantum correlations between photons to reduce this noise (LIGO v3)

Challenge: measuring brain activity must be fast, sensitive. Use entanglement between magnetic sensors to increase bandwidth

New worldwide approach: the Quantum SI, started May 2019
Quantum Computing

Quantum simulation
Chemistry, biology, materials science all depend on solving quantum mechanics problems

Recall: Simulating quantum mechanics is hard…

Solution: Use one system to simulate another

Quantum computation
Ideal case: programmable quantum computer, which is now moving from the lab to systems and engineering.

- Atomic qubits
- Superconducting qubits
- Semiconductor spins
- Topological qubits
Quantum Computing

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Atomic qubits
Superconducting qubits

Semiconductor spins

And beyond: QUANTUM NETWORKING!
Q networks
Q sensing
Quantum chemistry
Factoring (Shor's algorithm)
Q simulation
Machine Learning???
NISQ algorithms?
HHL
Q networks
Q sensing
Quantum chemistry
Factoring (Shor’s algorithm)
Q simulation
Machine Learning???
NISQ algorithms?
HHL
The outfield
Entanglement enhanced sensing
Q computing
Q algorithms
Classical control
Heuristic Q algorithms
Q information science
High sensing simulation
Q simulation (materials)
Q control
Q compilers (next gen)
Q programming

The Infield
Q chemistry
Q enhanced optimization
New paradigms for ML
Q sensing
Middleware
Full stack
The National Quantum Initiative

Signed Dec 21, 2018
11 years of sustained effort
DOE: new centers working with the labs, new programs
NSF: new academic centers
NIST: industrial consortium, expand core programs
Coordination: SCQIS combined with a National Coordination Office and an external Advisory committee
Policy recommendations

• Focus on a science-first approach that aims to identify and solve Grand Challenges: problems whose solutions enable transformative scientific and industrial progress;

• Build a quantum-smart and diverse workforce to meet the needs of a growing field;

• Encourage industry engagement, providing appropriate mechanisms for public-private partnerships;

• Provide the key infrastructure and support needed to realize the scientific and technological opportunities;

• Drive economic growth;

• Maintain national security; and

• Continue to develop international collaboration and cooperation.
Building the research environment for transformative quantum science

• The quantum workforce? Need more people, from a broader set of backgrounds; requires a safe and inclusive work environment.

• Science-first approach? Need to maintain an open, rigorous approach to the research.

• Connecting science to society? Must continue to balance innovation and disruption, from industry to security to citizens.

• Efficient and effective? Leverage existing approaches, minimize administrative burden, nurture a culture of discovery, and enable responsible risk-taking.
Quantum industry and the frontier

• Current quantum technology: atomic clocks, nuclear magnetic resonance, modern telecom, LIGO

• Next generation quantum?
  • Improved computational approach to materials, chemistry
  • Fundamental advances in condensed matter, high energy theory
  • New understanding of optimization, machine learning
  • Spin-offs: Quantum random number generators, new sensing modalities, better PNT, new qubit technologies, new analog microwave and optical technologies

• The 10 year outlook?
  • The beginnings of a sea change for corporations and government – the need to incorporate quantum computing and technologies into their business model
  • Unimagined applications are around the corner, but only if we explore!
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