Quantum information science and the technology frontier

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Office of Science and Technology Policy

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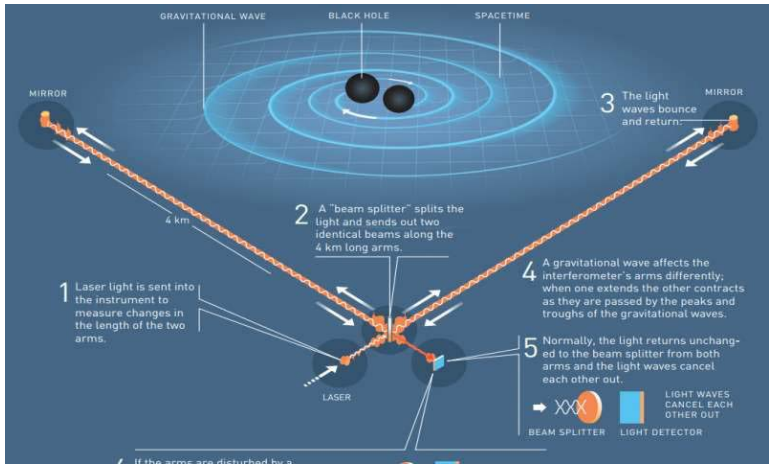
Quantum Sensing

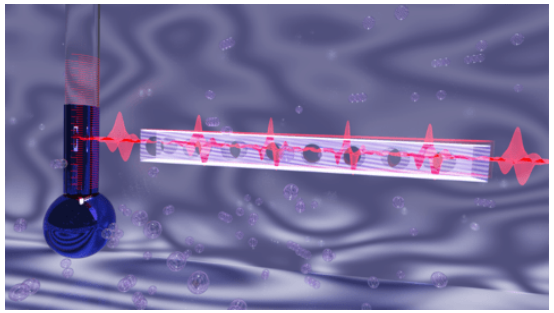
Accuracy via physical law

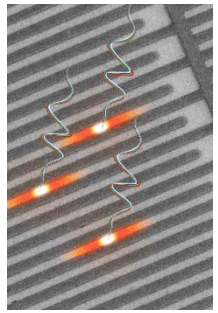
Concept: atoms are indistinguishable. Use this to create time standards, enables global navigation.

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

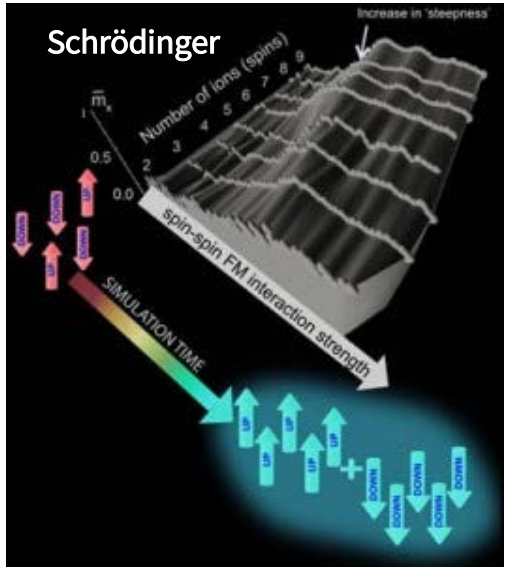
New worldwide approach: the Quantum SI, started May 2019

Quantum Computing

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

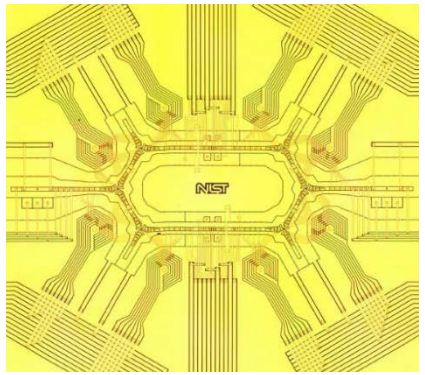
Recall: Simulating quantum mechanics is hard…

Solution: Use one system to simulate another

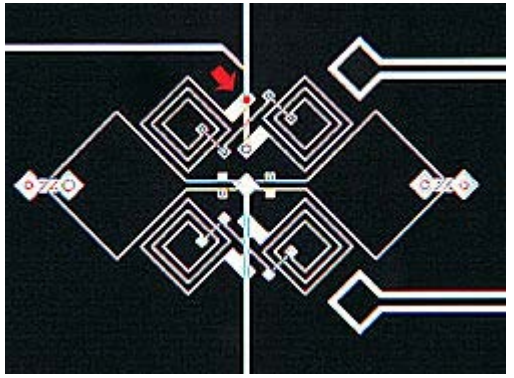


Quantum computation
Ideal case: programmable quantum computer, which is now moving from the lab to systems and engineering.

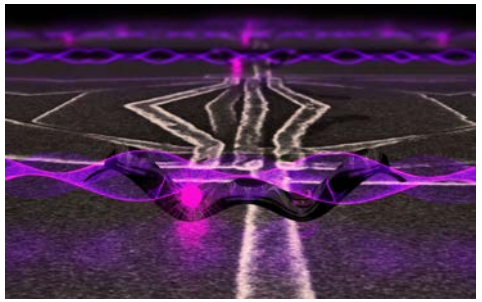
Atomic qubits

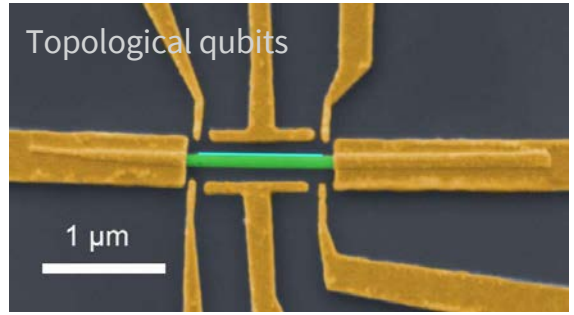


Superconducting qubits



Semiconductor spins





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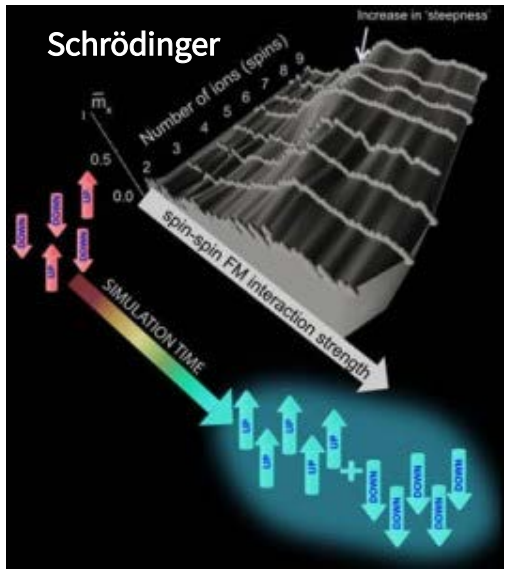

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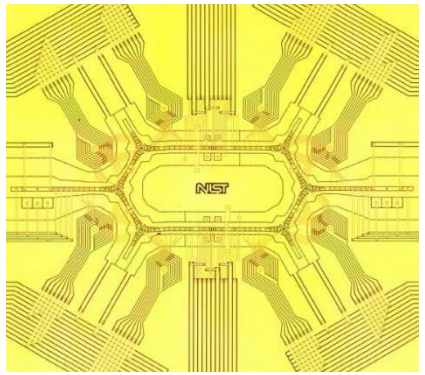

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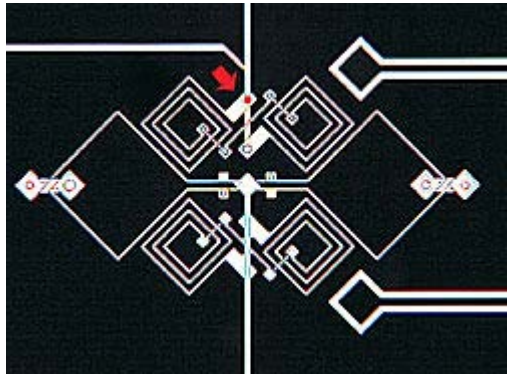

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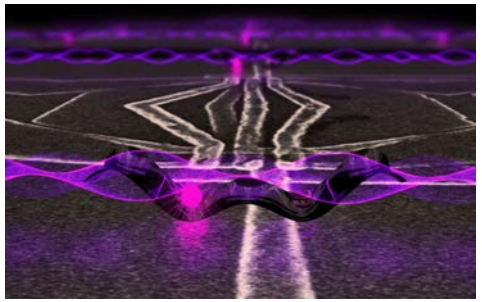

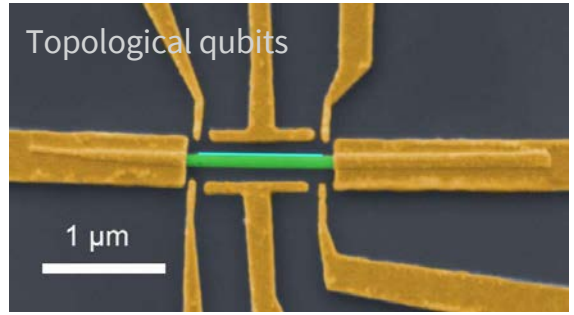

And beyond: QUANTUM NETWORKING!


Factoring
(Shor's algorithm)
HHL
Q simulation
Machine Learning???
NISQ algorithms?
Q networks
Q sensing
Quantum chemistry


Factoring
(Shor's algorithm)
HHL
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Q sensing
Quantum chemistry
The Infield
Q chemistry
Q enhanced optimization
New paradigms for ML
Q sensing
Middleware
Full stack
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 National Quantum Initiative

Signed Dec 21, 2018

11 years of sustained effort

DOE: new centers working with the labs, new programs

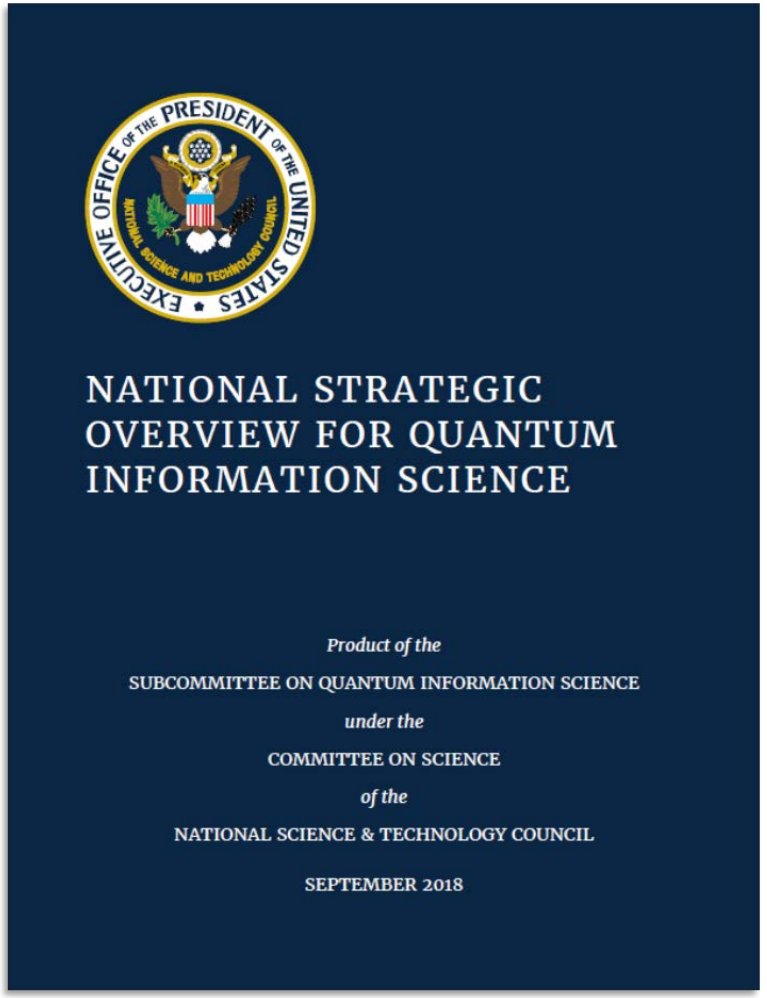
NSF: new academic centers

NIST: industrial consortium, expand core programs

Coordination: SCQIS combined with a National Coordination Office and an external Advisory committee

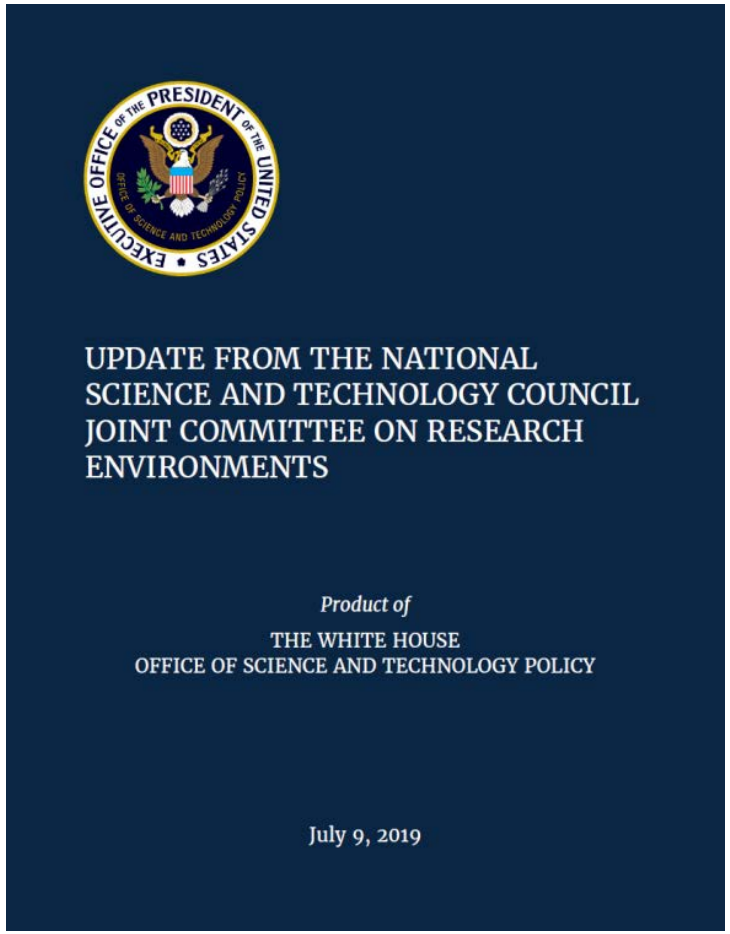
Policy recommendations

- 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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