January 10, 2019

Richard Ashooh
Assistant Secretary for Export Administration
Bureau of Industry and Security
Department of Commerce
1401 Constitution Ave, NW
Washington, DC 20230

Assistant Secretary Ashooh:

Thank you for the opportunity to provide input as requested in the advanced notice for proposed rulemaking (ANPRM) BIS 2018-0024. The National Photonics Initiative (NPI), along with the listed quantum industry and university stakeholders and scientific societies, would like to submit the following response.

Summary of quantum state of the art

Many reports detail the state of the art in quantum information science and technology (QIST). As a brief synopsis, the important areas of research and development can be categorized as:

1. Quantum Information Theory and Basic Science:
- Foundations of quantum mechanics
- Applications of quantum theory to scientific problems such as black holes and nuclear structure
- The nature of, creation of, and implications of quantum superposition and entangled states
- Manipulation and control of quantum states of atoms, ions, solid-state systems and photons

2. Quantum Communication:
- Quantum key distribution, QKD, for creating shared secret (but classical) encryption keys across large distances
- Quantum entanglement distribution, for connecting separated quantum memories to share quantum resources and to enable distributed quantum computing across a communication network
- Quantum repeaters for extending the distance possible for quantum entanglement distribution

3. Quantum Sensing:
- Using the extreme sensitivity of quantum systems to detect, sense, or measure weak influences such as gravity, acceleration, rotation, electric and magnetic fields
- Applications in geo-sensing, natural resource exploration, inertial navigation, bio-imaging, and time keeping

4. Quantum Simulation:
- Using one set of well controlled physical quantum objects (e.g. trapped ions) to mimic or simulate the behavior of another set of quantum objects that have unknown behaviors (e.g. a protein). Underlying this scheme is the Schrodinger equation, which governs or describes all quantum dynamics.
- Quantum simulation is considered more feasible in the short term than fully general quantum computing, and the two will have different applications.

5. Quantum Computing:

- Whereas quantum simulation applies to systems that are inherently subject to quantum dynamics, such as molecules, quantum computing attempts to map non-quantum problems onto a set of well controlled physical quantum objects comprising the quantum computer memory elements and logic operations.
- Quantum computing is projected to solve a myriad of previously intractable problems efficiently, implying the possibility to obtain answers" or "solutions" in practically short times. Examples include factoring large numbers, optimizing models from logistics and finance, pattern recognition, and artificial intelligence.

Categories of Quantum Computer Platforms:

a. Solid State Spins: electron spins located on atomic or atomic-like sites within a solid, usually a crystal such as diamond or semiconductor. Controlled by combination of gated electrodes and other electromagnetic fields including laser light.

b. Trapped Atoms and Ions: Neutral or ionized atoms levitated in high vacuum by electromagnetic fields, controlled by electromagnetic fields including laser light.

c. Superconducting Currents: currents flowing in superconducting wires through Josephson junctions and coupled to microwave fields inside resonant circuits.

d. Exotic States in low-temperature solid-state materials: such as confined electrons in quantum dot structures or topological qubits.

e. Photonic States: all-optical implementations using states of light to represent information, either single photons, or the amplitude and phase of light are manipulated and controlled.

Stages of Development

1. Quantum sensors are probably the quantum technology closest to viability. In many cases sensors have export sensitivity (e.g. guidance gyroscopes, precision accelerometers). Current controls, based on performance capabilities, adequately cover these items under U.S. export regulation, so new quantum-specific controls are unnecessary.

2. Quantum communication systems (key distribution) are already available commercially and offered by a number of companies, many outside the U.S. These are at present considered to be research systems, as none have been widely adopted by companies such as financial institutions for the benefit of secure communications.

3. Quantum entanglement distribution across large distances has been demonstrated outside of the laboratory. The techniques used to achieve it are not unique to these demonstration systems, and rely on widely known methods that can be further deployed over longer distances or with more user channels. Because of the pervasiveness of these techniques, it is extremely difficult to conceive of controls that would not inappropriately capture unintended technologies, and quash broader research. Recent examples of entanglement distribution over 1200 km of terrestrial free space and ground to space-orbit teleportation using satellite technology might prompt placing controls on space-qualified hardware, but the general techniques do not merit export controls. Even so, due consideration needs to be given to the worldwide research being published in the open literature on space-qualified quantum hardware.

4. Quantum simulation is still in early stages and is widely considered a research endeavor at this time. Its applications are similarly in early stages, and in many cases speculative. It is thus too early to consider export controls.

5. Quantum computing is still in its infancy and is thus considered research only at this time. Its applications, when they become available, may include areas of concern meriting export controls. However, it is equally likely that these applications will provide substantial, and possibly extraordinary, economic benefits to those that can commercialize and exploit these applications, motivating a less controlled environment that will favor those companies and countries that innovate quickest.

Recommendations for Export Controls: QIST

Upon consultation with the stakeholder community currently working to develop QIST technology, we believe that overly restrictive export controls will impede research progress and greatly diminish the U.S. lead in this technology area. Much of quantum technology is in too early stages of research to merit export controls, with the exception of quantum sensors that are adequately covered by current controls.

While controlling export of actual quantum-enabled hardware systems to a very limited set of countries could result in limited disruption, this is not the case for deemed export, as the supply of researchers with the knowledge capable of working in this area, and being utilized to further quantum research in the U.S., is very limited and highly international. Non-US citizens are a vital portion of the research and workforce community for both universities and companies, including Chinese researchers. Limiting, by any measure, the availability of the few brilliant minds capable of keeping the U.S. in the lead in this highly competitive space could prevent the U.S. from being the first to produce technologies that fully realize the quantum advantage.

Therefore, the NPI recommends that export controls be considered only when a specific item within a given quantum technology area (as described in the above summary of quantum technology) is deemed critical to national security, is determined to be a commercially viable product, and is defined by some performance metric. "Specific" means that specific performance parameters can be established for particular systems rather than just broadly controlling a certain type of item. Even when technology reaches this stage of development, foreign availability should be a significant mitigating factor when considering controls, as well as the effect controls will have on commercial growth in the U.S. It is critically important that the economic potential be included in decision making to avoid diminishing what could be vast market opportunities.

Because much of the landscape of quantum technology and the ultimate applications of quantum technology are unknown, decisions on which specific items require export controls should be deferred until after they are developed and determined to be critical. NPI recommends that BIS take advantage of the structures recently enacted by the National Quantum Initiative (NQI) legislation, and request that these stakeholders determine which specific items in the above categories are considered fully functioning or reaching a stage where very specific control parameters can be identified. BIS should routinely work with the National Quantum Coordination office, as well as the Subcommittee and National Quantum Advisory Committee established by this legislation. The Coordination Office is charged with serving as the point of contact for government organization, academia, industry, professional societies, and others, and thus is uniquely suited for making these determinations. NPI also recommends explicitly including the NIST-sponsored Quantum Economic

Development Consortium (QEDC) and the Department of Commerce Technical Advisory Committees in these discussions.

Cloud access to U.S. based quantum computer and communication systems should not be considered for export control. Such access allows only “front-end” access to such systems, not to their internal workings or components. Such access provides important feedback to U.S. companies providing the service, as well as providing a marketplace for these U.S companies to perfect their product and learn the structure of the application spaces. Control of such access would hinder development progress by U.S. companies. A quantum computing and communication access program is an element included in the National Quantum Initiative (NQI).

In regards to technologies that are not “quantum” by nature, but are key enablers in development of quantum technologies, controls on these classical support technologies should only be considered on a very limited basis when the systems they are supporting have reached technological maturity. Additionally these critical key enabling technologies must be of a nature that they cannot be duplicated or reversed engineered, or available by a foreign supplier. The ability of U.S. scientists to purchase or acquire such items by scientific collaboration is crucial. Therefore, reciprocity requires that U.S. companies providing such technologies be free to market these overseas with minimal control. Moreover, supply lines are increasingly international given the complexities of the technologies that being built.

Again, thank you for the opportunity to provide comment to this notice. The NPI and the stakeholder community stands ready to serve as a resource to the U.S. government as this process of identifying and controlling emerging technologies moves forward.

Sincerely,

Atom Computing Inc.

American Physical Society (APS)

Duke University

Intel Corporation

The National Photonics Initiative (NPI)

The Optical Society (OSA)

The State University of New York

The international society for optics and photonics (SPIE)

SUNY Polytechnic Institute

TOPTICA Photonics

University of Chicago

University of Pittsburgh