Virtual Facility for Quantum Engineering

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Today many deeply interesting scientific questions remain at the level of one or two qubits. The questions which qubit representation works best for a future quantum computer or which realization of a quantum repeater is most viable, remain open as well. At the same time, within a few years, large numbers of quantum bits must be incorporated and integrated with classical electronics to realize scientific goals such as demonstrating a CNOT in a surface code (which requires of order 50 qubits combined with fast feedback for error correction). This poses important new engineering challenges in quantum computer architecture, integrated quantum-classical circuit design, and high-yield qubit fabrication.

When going from 50 to 500 or 5000 qubits in say 10 years, the role of quantum engineering will grow even more important. It also raises important engineering challenges in Quantum Information theory, such as practical quantum compilers, languages and protocols for testing algorithms and simulations. In Quantum Communication typical engineering challenges involve network complexity, interfacing with other technologies, etc. and using quantum bits in metrology and sensing also requires solving engineering challenges. Some of the engineering challenges that must be overcome are either so pressing or so complex that work must be started today, despite the many important unknowns in our field.

Quantum Engineering has therefore a two-fold objective. The first objective is to enable us to address important scientific questions in the coming years, from the demonstration of fault-tolerance and logical qubit operations to the realization of multi-node quantum networks. The second objective is to lay the foundation for real-world applications of quantum technologies, for which typical engineering challenges such as manufacturability, reliability and affordability all need to be addressed. The ability to perform high quality quantum engineering will turn out to be one of the main defining factors in moving forward both advancing science as in ultimately realizing innovation and economic value from quantum technologies.

Over the past few years Quantum Engineering has gained momentum. The field is still in a nascent stage, but has reached a size to be self-supporting. Shared visions on research challenges have emerged. Main challenges lie in device construction, devising architectures, developing (cold) electronics, multiplexing and routing of electrical and optical signals.

Several main challenges for quantum engineering are aligned with research challenges in other fields. Examples are cold electronics used in LIDAR, IR applications, pedestrian/vehicle detection in cars, and 3D integration is an important new development in classical circuit design. Early application of quantum engineering may in fact lie outside the field of quantum technology, which will help to maintain funding, but it will be the quest for quantum technology that drives the process.

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