FIELD GRAND CHALLENGE
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Frontiers in Quantum Science and Technology

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The recently emerged field of quantum technology is aiming to employ quantum coherence and entanglement for realization of next generation sensors, standards, imaging systems, secure communication and computers. Although applications of quantum technologies cover a broad spectrum and their development stage varies from early demonstrations to commercially available devices, many challenges have been identified.

The first includes tailoring materials for quantum technologies, which is playing an essential role in technological applications of quantum science. Solid state systems allowing long coherence time are essential for quantum computation and quantum sensing. Ultrapure materials with tailored isotopic content are important for reaching long coherence time of spin qubits (Awschalom et al., 2013). The ability to place single dopants with high precision and form spin qubits at desired location is essential for both quantum computing and quantum sensing applications (McCallum et al., 2012; Smith et al., 2019).

The performance of different types of qubits is usually benchmarked in terms of controllability and coherence time. Usually solid-state systems allow fast control, but exhibit fast decoherence owing to complex environment. It is therefore important to search for new types of qubits combining isolation from environment and access via fast coherent control and readout. Novel approaches combining different quantum systems into build hybrid quantum devices for optimal performance is a promising avenue. Examples of such hybrid approaches are spin systems coupled to superconducting qubits (Kubo et al., 2011) and hybrid nuclear–electronic qubits (Morley et al., 2013).

Optimal protocols for quantum technologies requires extension of coherence time of qubits beyond the coherence time of the isolated quantum system. The efficient protection toolkit includes dynamical decoupling (Yang et al., 2011) and quantum error correction (Terhal, 2015) based techniques. Although general principles of qubits protection were developed and tested experimentally in different model environments, it is essential to adapt them to realistic environmental noise. In the field of quantum sensing, it is also essential to combine protections against noise with non-reduced sensing performance. Experimental imperfections can be addressed using optimal control tools (Glaser et al., 2015).

The development of efficient quantum algorithms is another growing field belonging to quantum software area. On one hand, it is essential to find problems where a quantum computer can outperform classical computers. On the other hand, it is essential to develop an application scenario for a limited number of qubits (Montanaro, 2016). In addition, in order to develop new algorithms, future work must include discoveries of application scenarios of already known algorithms. Application of quantum Fourier transform for sensing is a promising example of such new applications (Vorobyov et al., 2021).

Signal processing is another field of quantum software that is becoming essential in applications. Advanced signal analysis protocols, like quantum compressed sensing, can be employed to quantify entanglement in large quantum devices *via* efficient quantum tomography (Riofrío et al., 2017).

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Machine learning can also be applied to extract information from naturally noisy datasets of quantum sensors (Santagati et al., 2019).

Quantum technology translation into the field of application is critically dependent on the possibility to integrate quantum devices. Classical periphery including laser sources and microwave sources, photon detectors and nanofabrication is crucial for successful translation of laboratory proof of concept demonstrations to commercially available devices. The availability of periphery and tailored quantum materials in sufficient quantities is essential for large scale fabrication of quantum devices. The realization of commercially available quantum devices relies on the involvement of industrial research laboratories which are capable to integrate qubits and provide user-friendly interface and services. Integration of qubits into functional devices requires joint effort of quantum scientists and engineers. New educational programs focused on quantum engineering will be essential for future development of this field.

Basic quantum science will remain essential for future development of quantum technologies. An understanding of the dynamics of complex quantum systems is important for both theoretical and experimental perspectives. An important open question in the field of basic quantum science is related to the unravelling of novel phenomena where quantum coherence and entanglement are playing essential roles. This includes biological processes like olfaction, photosynthesis and magnetoreception (Brookes, 2017).

Frontiers in Quantum Science and Technology will provide an open platform welcoming high impact publications addressing the above challenges. Its specialty sections will cover a broad research spectrum including basic research, development of quantum software, quantum hardware and applications of quantum technologies. Our journal will include regular research papers and review articles essential for education in the field of quantum science and technology.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work.

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