FGQT Q03: Towards Standardization for Quantum Technologies

One of the main goals of the Focus Group on Quantum Technologies (FGQT) is the creation of a Standardization Roadmap guiding future standardization of Quantum Technologies (QT). This text provides some of the central ideas underlying the FGQT Standardization Roadmap. It gives a more detailed insight and accompanies the FGQT Work Programme (FGQT Q02). Its purpose is to encourage people to read, comment, and further improve the FGQT Standardization Roadmap (FGQT Q04).

Focus Group on Quantum Technologies

Even though quantum physics is over a century old, the last twenty years of progress in science and technology have led to a tremendous level of control over quantum systems at the most elementary level. It is now feasible to routinely prepare, trap, manipulate and detect single quantum particles such as (artificial) atoms, electrons and photons. Together with the possibility of creating and controlling distinct quantum states, such as superposition states and entangled ones, this second quantum revolution facilitates engineering of new classes of sensors, communication techniques and computers with unprecedented capabilities.

Quantum Technologies offer capabilities beyond any classical technique. Examples include, but are not limited to, achieving higher sensitivity, lower power consumption, and automatic, maintenance free quantum-referenced operation for more reliable industrial facilities. Furthermore, QT pave the way for novel methods for earth surveys in times of climate change, for the exploration of natural resources, as well as for information processing and transmission with unprecedented security. QT-based applications are approaching the market and will become a pivotal factor for success in a wide and diverse range of industries and businesses. Moreover, as these technologies do affect information processing, storage, and transmission, they are vital for protecting communications and critical infrastructures in Europe and the rest of the world.

A common way to categorize the range of quantum technologies, for instance also in the EU QT flagship, is to put them different domains (or “temple pillars”), being “Quantum Communication”, “Quantum Computing and Simulation” and “Quantum Metrology, Sensing and Enhanced Imaging”, as illustrated in Figure 1.

The components and systems of the domains are empowered by enabling technologies and subsystems common to all QT domains. Accordingly, the tools (as e.g. the control software or hardware used for exploiting quantum states) are typically universal. Combining elements from enabling technologies and tools enables the creation of sub-systems, which again can be combined in QT platforms and systems, as well as higher-level composite systems or infrastructures. From these, societally and economically relevant applications are built for the identified use cases.

In the FGQT Standardization Roadmap, we propose to consider the horizontal lower layer elements (of different levels of technological complexity and maturity) common to several of the “Components and Systems” domains (the pillars of Figure 1), together with the traditionally isolated view on the domains. Naturally, the latter are still highly relevant, but their connections to each

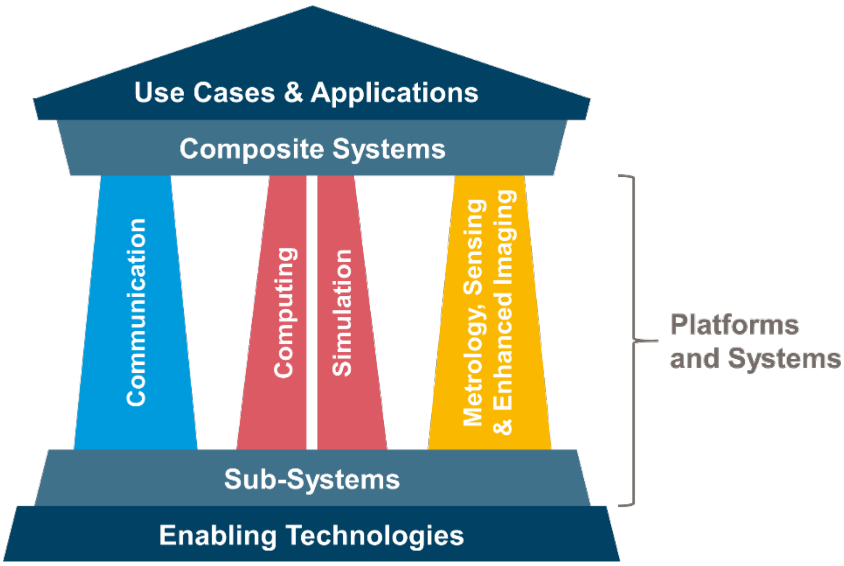

Figure 1, QT-Temple: The foundation are the **Enabling Technologies** and the multifunctional supporting layer of QT **Sub-Systems**. On top are the pillars of the **QT domains**, where **Components and Systems** are being implemented by a combination of sub-systems and enabling technologies. The **Components and Systems**, in turn, are assembled into **Composite Systems**, finally enabling the top layer of **Use Cases and Applications**.

individual horizontal layer, constituting an inherent “matrix structure”, need to be included. In Figure 1 we illustrate this idea of a hierarchy or matrix of QT with the architecture of the QT-Temple. In the matrix view, obvious standardization needs can readily be identified by inspecting the connections between the different horizontal and vertical layers. For instance, interoperability between components of different layers requires well defined interfaces. This idea is further reflected in Figure 2, where we explicitly show certain well-understood logical dependencies, which in a natural way identify standardization needs. Working on that structure, spanning most known domains of QT, requires a group of experts with corresponding broad areas of expertise.

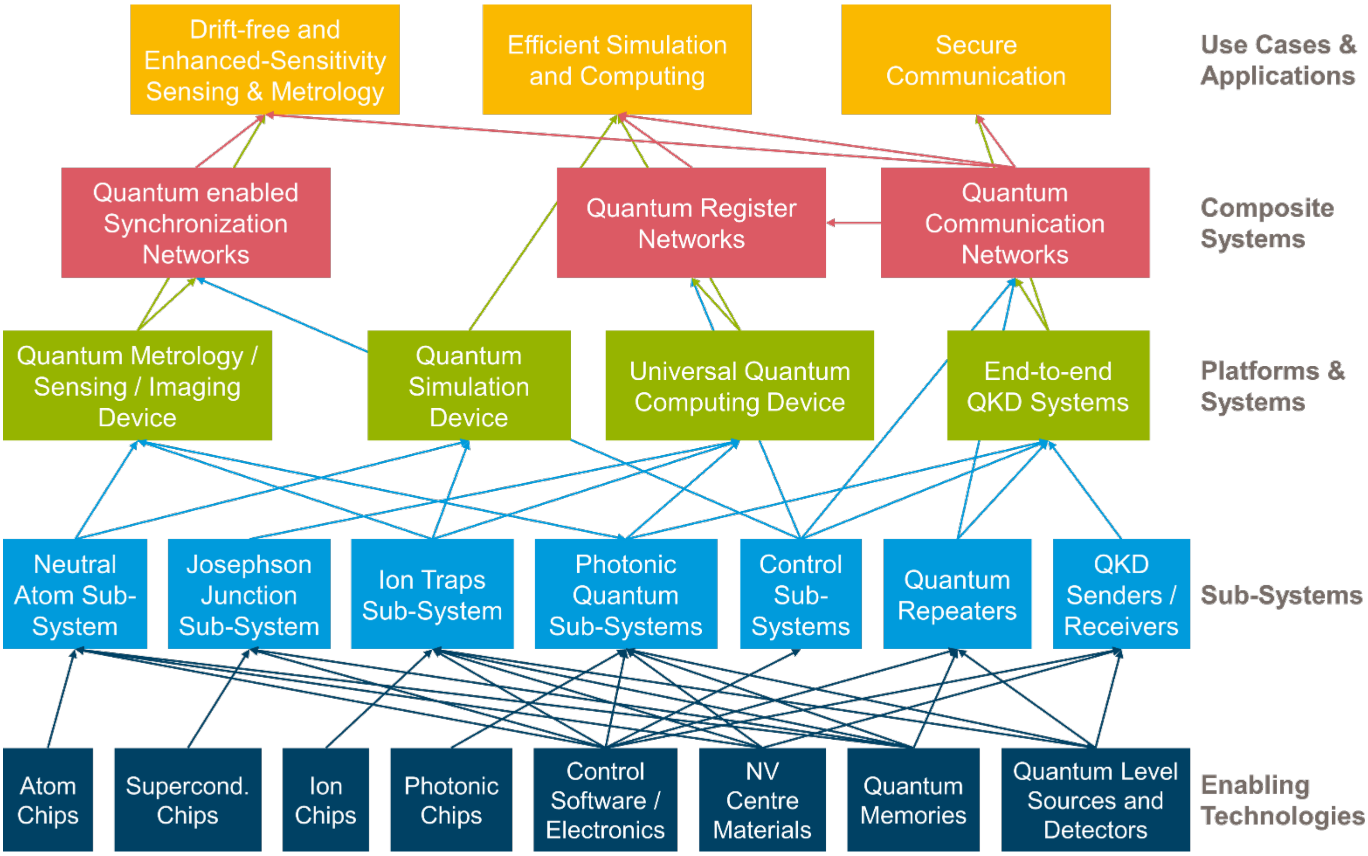

Figure 2, Connections between different technology levels

There are currently several ongoing standardization activities worldwide in QT in some but not all of its sub-areas. In many cases, these activities are constrained to a certain sub-field, and correspondingly to a specialized expertise. While this has the advantage of providing a relatively straightforward path for arriving at specific standardization results, the larger picture of QT, as sketched above, cannot be addressed, and the underlying matrix structure cannot easily be reflected. In particular, standardization needs shared among several of the sub-fields might be redundantly addressed, leading to road-blocking and incompatible specifications.

With its Standardization Roadmap, the FGQT is the first group worldwide to identify standardization needs for all aspects of QT. In doing so, the FGQT is entering new territory. Our approach of thinking of QT as organized in a matrix structure allows an early identification and consideration of technological segments suitable for use in multiple applications and use cases. In addition, an array of interfaces and requirements for different use cases is being identified from a generic perspective. We believe that this helps to reduce duplication of work as well as the need for costly later-stage adaptations. Our approach offers a systematic process as best solution for addressing standardization needs in the entire QT area. It is our goal to create a Standardization Roadmap reflecting the discussed matrix structure in one document and facilitating a straightforward identification of QT standardization needs.

The main objective of the FGQT Standardization Roadmap is to give a comprehensive and relational classification of QT, and to underline the interdependence of ongoing and prospective standardization efforts in this field. Specific standardization needs will be identified to the best extent, given the present state of knowledge. Naturally, the roadmap needs to be an open document, evolving with the progress of technological development, as well as with the progress in QT standardization itself.