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IYQ2025 in Europe and Poland

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Abstract—**Quantum information technologies QIT have two separate but entangled layers – material and ideological. Material layer embraces algorithms, physical devices and systems. Cognitive layer is related to the boundaries and structure of our knowledge, including the magic of nonlocal interactions and subtleties of contextuality. The paradox is that QIT should use quantum magic as a resource to turn into functional utility. The International Year of Quantum Science and Technology is celebrated in Europe, Poland and elsewhere. Opening conference at the UNESCO headquarters in Paris was attended by representatives of the Polish Ministry of Science and Higher Education, and some quantum science groups. Several scientific conferences organized in Poland were announced to the IYQ25 calendar, including: May Symposia of Information and Quantum Horizons in Gdańsk, August Max Born Optical Symposium in Wrocław, September Congress of the Polish Physicists in Katowice. Quantum research projects are realized in Poland, QuantERA, tasks included in the European Quantum Flagship EQF, construction of quantum equipment by university consortia MIKOK, quantum networks and others.**

Keywords—**quantum year; IYQ2025; quantum science and technology; quantum computing; quantum networks**

I. Introduction

THE year IYQ2025 is very rich in quantum scientific and technical, business and cultural events, in Europe, Poland and around the world. Over 200 events have been reported from all over the world and more are subscriboing. IYQ2025 is a year-long celebration of the quantum century. In addition to looking back at the quantum century, IYQ2025 inspires, indicates directions for research, development, innovation, emphasizes the importance of quantum science and technology for decades ahead. On one hand IYQ2025 popularizes quanta and on the other raises them to the industrial, economic and political level. It reminds us all that our civilization, if we want to survive, must inevitably move in quantum and cosmic directions.

Descending lower and lower into the quanta, or what is in some sense equivalent, climbing higher and higher into the galaxy clusters of the universe's structure, may inevitably lead some scientists to frustrating conclusions about bottled-up nature and insurmountable determinism. The universe knows the distribution of all prime numbers precisely, right down to the infinite end. In our hot, noisy thermodynamic world, it's impossible to generate a truly random number. In the quantum world, the one we technically use, the quality of generated random numbers is superior. But they are also not infinitely random. For us, they are random, which stems from our ignorance. This ignorance is strictly protected, among other things like quantum no-go theorems, by the Schrödinger limit. Future quantum computing and telecommunications will operate under such conditions, and this is precisely what they will be like.

II. QIT is the Engineering of Lack of Knowledge

We could say that the information resource, instead of classical current and voltage in electronics and Quantum 1, will be in Quantum 2, and will forever remain, the lack of knowledge. QIT possess two intertwined layers: material and ideological. The material layer is the engineering of various quantum systems, both natural and synthetic. The ideological layer, named in this way only to clearly distinguish it from the material one, is the engineering of the lack of knowledge. The category of "lack of knowledge" is not trivial; it has its own internal structure and forms. It is governed by its own laws. Some forms of lack of knowledge are incommensurable, infinitely different from others. Some of them we call magical. Attempts are made to categorize and organize the lack of knowledge, sometimes giving it the form of energy, information, entropy, etc. Many paths are still being explored. For now, our level of the engineering of lack of knowledge is very rough, incomplete, and rather simplified.

Fundamental laws are constantly being discovered in this area. Some basic laws have already been discovered that allow us to begin working effectively with QIT. We say that the lack of knowledge is an open system, but the problem of openness remains in our bottle. This means that the lack of knowledge always leaks between the quantum and thermodynamic levels, through various coupling channels. The ability to effectively manage the lack of knowledge at the quantum level is the key factor in quantum computing and communications. If we possess complete knowledge, it is not a quantum system. The less we know, the better. Yet, for practical action, we still need to know a lot to do any practical action. This is a paradox of this field.

The engineering of the lack of knowledge, means the ability to manage the leakage of resources and information between two coupled worlds. Perfect isolation of the quantum and thermodynamic worlds would completely deprive us of the ability to do anything. Such perfect isolation would prevent the emanation, the emergence of the thermodynamic world from the quantum world. The multichannel nature of connections, in the interface region we don't fully understand, is referred to as choice laws. We know the effects of these choices; we don't

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know why the Universe chose them. It's like a perfectly unidirectional mathematical equation: we know the solution but can't solve it. We search for such relationships, even if only imperfect, but with the strongest possible uni-directionality.

III. QIT - Quantum Computing and Communications

The IYQ2025 celebrates all the quantum field – historical, fundamental research, technical fields – computing, communications, sensing and timing, but also education and training of HR, business, social and outreach. The developments are not running at equal pace in these areas. QIT changes the meaning of classical names of some of them. Should we call the Quantum Internet still the Internet. Quantum communications and networks may turn in the future. to be something completely different what we see today. Historical name of telecommunications seems to fail to capture its expanding functionality today. ICT is also too narrow a term, completely out of step with the level and pace of technological development. Is the Internet too narrow a term? The Internet of Things, the Internet of Everything, are also terms too narrow given the phenomena taking place. Clouds, fog, networks, big data—acquisition, storage, processing, and transport—even machine learning, artificial intelligence, and its generative versions—are merely components in such an integrated quantum – classical environment. What if we add intelligent transportation to the mix? The transport of data and matter might share many similarities? A powerful quantum impulse is added to all of this. We are beginning to build an intelligent civilizational infrastructure in which computing, communications and other networks will dissolve and integrate?

Quantum communications/networks seems currently to be not fully understood term by the broader public. So how should we name this changing fundamental layer of civilization infrastructure? Quantum communications and quantum computing are developing in parallel. A node in a quantum communications network is a specific type of quantum computer. Such a node could theoretically be performed by a single qubit, qudit, a small register of them. In practice, it will be a specialized quantum processor.

Currently, we have imperfect NISQ-class quantum processors, implemented by different technologies. Computing is pursuing the dream of a universal quantum computer. NISQ is far from universal. Communications is currently offering a better level of quantum cybersecurity, provided by key transmission over a point-to-point quantum link. This is a very early stage combining quantum techniques with classical bit transmission. Quantum distribution is a completely different level, theoretically completely prohibited by the quantum no-go no-broadcasting law. However, we know that this law can be circumvented. It just needs to be implemented practically in a specific quantum technology.

IV. Will QIT omit Communications?

What would happen if QIT bypassed telecommunications? Telecommunications is a vast field, as is the even broader field of quantum. The goal is to find potential overlaps between these yet completely different fields. Quantum will not bypass telecommunications. We know this today with certainty. However, we do not yet know how deeply and in what areas telecommunications will be transformed by quantum. Searching for the poles of such potential changes, we can draw two edge scenarios and many levels between them. We assume complete integration between the infrastructure, transport, computational, and functional layers. We assume the ubiquity of such a super-layer.

We are still a long way from the point where quantum technologies will completely permeate such an integrated information environment. This not only concerns technical, transport, and computational solutions, but also a much deeper understanding of the quantum components that can be used as integrated resources permeating such a ubiquitous information environment. Candidate resources appear to be exclusively non-classical quantum phenomena. Resources cannot be traditional at the quantum level, they have no right to be classical.

We connect quantum phenomena from the Quantum-1 era of bandgap engineering and the Quantum-2 era of superposition, contextuality, entanglement, and emergence. Such a connection will be maintained with classical VLSI nanoelectronics, but the functional resources of QIT must be non-classical. These cannot be classical resources such as current, voltage, Poisson light and EM waves. In satellite telecommunications, The frequency of visible, near-infrared, and near-UV light, i.e., 100 THz - 1 PHz, used in SatCom may prove too low for further system development. It is difficult to build an effective system with attosecond pulses on such carriers. Up to 3 PHz (100 nm) we have non-ionizing waves. We may use bigger frequencies in space what depends on the technology of transmitters, receivers and efficient modulation and demodulation methods of sub 100 nm waves.

For communications to be quantum even in these high, hyperluminous frequency bands, the wave must be sub-Poissonian, or single-photon. Quantum communications light must be either squeezed multiphotons or countably, distinguishably single-photon. This cannot be the classical Poissonian light. If we do not master these quantum satellite techniques to a functional level, will quanta bypass telecommunications in this area? Other areas of future communications are different, and quantum techniques there will also be different, and they may or may not bypass telecommunications for other reasons. Such a reason may be the difficulties, in quantum integrated circuits but also in large-scale quantum networks, in mastering the massive generation and management of quantum entanglement and the efficient distribution and distillation of entanglement and the massive creation of quantum magic states.

There may be many more such reasons for the failure of quantum communications, bearing in mind that the space of quantum technology is strictly limited by such fundamental laws as Pauli exclusion principle, Heisenberg uncertainty principle, conservation of momentum and energy, superluminal velocities, Bell's inequality, and quantum no-go theorems - no-copying, no-erasure, no-broadcasting, no-hiding, no-teleportation, no-communication. The no-go theorems can be circumvented to some extent using technical methods. This is similar to the way in which the Abbe optical resolution limit is circumvented in super-resolution microscopy. Bypassing quantum no-go theorems becomes the more effective the better we understand the properties of non-classical states and the differences between them.

V. Why the World established IYQ25?

We celebrated the International Year of Light in 2015 [1]. This unique honoring of this sector of science and technology was associated with the impact of optics and photonics on our civilization. Photonics primarily embraces quantum devices, including communications, displays. Optics and photonics were honored indirectly again in 2022, which was the International Year of Glass [2]. Glass is the optical fiber used in communications. Currently, the unique quadratic year 2025 is dedicated to quantum science and technology, marking the centenary of its development. Traditionally, the United Nations and UNESCO stand behind these proud vocations of photonics, quantum, and other fields [3]. IYQ25 quantum events span the globe [4]. In this way, the Quadratic Quantum Year also honors the current exponential development of these technologies in Europe and worldwide [5], [6], [7], but also in Poland [8], [9], [10], [11].

This technical quantum avalanche is made possible by synergy with advances in nanotechnology, photonics, artificial intelligence. This avalanche is made possible by the fact that light can interact as waves and as particles, electron can exist in a state of superposition in multiple locations simultaneously, spatial and temporal location are relative, two particles can remain entangled regardless of the distance between them, measurement at the quantum level is always contextual, some quantum states are magical, quantum entanglement can be treated as a resource and subject to distillation, matter can remain in states of superconductivity, super-fluidity, other quantum emergences, and that the concepts of statistics, randomness, correlation, simultaneity, indistinguishability, and presence in time and space have fundamentally different meanings than in macro-thermodynamic world. This macro-thermodynamic world of ours, from the quantum point of view, is a hot melting pot in which everything mixes.

Our task in the search for functional QIT is to answer a question: can specific properties of matter and waves at the quantum level be transformed into a useful technology that operates efficiently at the thermodynamic level, in such a hot, noisy melting pot where everything mixes, including all types of energy? Until recently, the goal was to identify precisely those properties that could potentially provide a solid quantum foundation for technology. We are identifying these properties increasingly well. We are constantly finding new ones for potential development. Quantum properties alone are not enough, methods for their functionalization must be developed. Properties for functional development manifest themselves in fundamentally different ways depending on the technology. There are many such technologies, and for now, it is impossible to predict the future. The choice of QIT systems is very wide.

The simplest division is between natural and synthetic systems. Other divisions include photon, electron, atomic and ionic, topological, transmon, other superconducting, temporal, spatial, energy-frequency, collective. Another division is between digital systems: two-level qubits, multilevel qudits, and analog q-mode systems. Another division is between quantum fflying, locally mobile, and stationary systems. Flying systems, the ones for communications, are quantum photonics. In quantum communications, we will combine flying and stationary systems unless technology masters the construction of quantum-transparent systems. This has happened to fully optically transparent fiber-optic systems. The quantum frontier is very broad, and we do not know which path is best for some time. Progress in the development of quantum technologies will help guide future choices.

Synthetic superconducting systems currently have advantage in quantum computing. These are planar systems, and possess topological constraints that translate into programming of quantum gates and entanglement. Natural ionic and atomic systems do not yet possess easy methods for gate entanglement as photonic systems. Ionic and atomic systems are stationary or locally mobile. Photonic systems can be quasi stationary using QPIC/PIC technology or flying using fiber optics or open space. There are many possible development paths that hundreds of academic and industrial laboratories worldwide are currently pursuing them. The quantum scientific and implementation movement is so massive that it has undoubtedly become one of the reasons, alongside the historical breakthrough, for establishing the quadratic, unique year IYQ2025.

VI. Quantum Personalities

Planck, Bohr, Einstein, Podolsky, Rosen, Heisenberg, Schrodinger, Bohr, Bell, Clauser, Aspect, Zeilinger, Shor, Groover, … We must begin with the events of 125 years ago. These names are worth remembering. There are many more. Fundamental discoveries are constantly being made. First, the foundations of quantum mechanics had to be established and organized. The discovery of nonlocality could not overcome reality, locality, and cause-effect law. It was necessary to more thoroughly understand the contextuality and squeezing of the quantum vacuum. The year IYQ2025 honors these scientists, who built the foundations of quantum mechanics, noticed gaps in description and understanding, overcame the inertia of the reality environment and hidden variables, demonstrated the beauty of the nonlocal universe, continue to explore the properties of this universe universally nonlocal and entangled, are diligently attempting to translate these fundamental properties of nature into functional applications, technology, and into fundamental infrastructure of our civilization. Who would have guessed 100 years ago that quanta and their non-locality would give rise to QIT?

During the first two decades of the twentieth century, the works of Max Planck [12], Albert Einstein [13], Niels Bohr [14], Walther Gerlach and Otto Stern [15], Arthur Compton [16], and others laid the foundations of quantum physics. These sufficiently solid foundations allowed the field to develop rapidly. In 1925, Werner Heisenberg [17], Wolfgand Pauli [18], Louis de Broglie [19] published their groundbreaking works, and even before 1930, Erwin Schrodinger [20], Max Born [21], Paul Dirac [22], Felix Bloch [23] and others. Quantum mechanics became mature in a sense only in 1935, when Albert Einstein, Boris Podolsky, and Nathan Rosen could notice, as published in the EPR paper [24], that the previous description of such quantum mechanics did not agree with the a priori assumed so-called reality, or in other words, locality and the resulting cause-and-effect sequence.

The EPR work then triggered a discussion that has essentially continued to this day. However, first, in 1935, the works of Niels Bohr [25] and Erwin Schrodinger [26] appeared, directly referring to EPR. The background for this breaking work was laid slowly in the meantime, over almost 30 years, during various discussions on hidden variables, David Bohm [27], Yakir Aharonov [28], and others. John S. Bell's breaking work, proposing the correlation inequality, was published in 1964 [29]. There was again a pause of almost twenty years, resulting from disbelief and holes in the reasoning in the proposed correlational measurement method. However, the break was filled with further discussion on hidden variables, but this time in a completely different light. An example of this discussion is the fundamental publication by Simon Kochen and Ernest Specker from 1967 [30]. The domain of hidden variables is increasingly restricted. The relevant Kochen-Specker KS and Bell-KS BKS theorems are formulated, strictly limiting the domain of potential validity of local hidden variables. These theorems belong now to the group of quantum no-go laws. Doubts about the existence of local hidden variables are increasingly emerging. However, there seems to be no decisive breakthrough; the debate over holes and the potential presence of hidden variables within them continues. Even quantum conspiracy theories are emerging. Subsequently, (almost) all of these holes were closed.

Conspiracy theories, though we shouldn't really call them that, still exist here and there. However, we assume something in our bottle. We adopt a model. One of them is the formally valid Big Bang model. Therefore, we can't close the bottle's hole in this model. We don't see the bottle's label. However, there are other models, such as multi-worlds, but even assuming this model, quantum mechanics remains observationally the same for us, only its anchoring at the very beginning, if any, differs, which we don't see anyway. However, we can approach the study of this potential anchoring differently. In the strongly confirmed Big Bang model, we examine the anchoring of potential quantum determinism by approaching ever closer, theoretically and by measurements, to the very beginning, to the singular point.

In the BB model, one of the no-go quantum laws, the no-hair theorem, concerns black holes and the problem of the disappearance of information accessible to us after passing through the event horizon. A black hole is bald and hairless, meaning that for us it is defined only by the measurable quantities: mass, electric charge, and angular momentum. All the remaining information is hidden inside, but it escapes through Hawking radiation. In our bottle, the no-go quantum principle of information must be satisfied, only by its transformation into another energy form. This is one consequence of the necessary anchoring of quanta somewhere and the fulfillment of initial and boundary conditions. The BB model is associated with the period of inflation that occurred at the beginning of the transformation of our Universe. It is associated with the state of contraction of the quantum vacuum. We begin to use these states functionally. If the quantum interferometric experiment to discover gravitational waves had not employed squeezed light, their detection would have been completely impossible. Squeezing the quantum states of light increased the measurement sensitivity of the gravitational wave interferometer by many orders of magnitude.

Quantum communications doesn't have to worry about such extreme conditions, even when transmitting signals over distances of billions of light-years. However, it is known that both classical and quantum communications are subject to constant, inevitable processes of information leakage and transformation of its energy forms. This information, in the quantum sense, is never lost.

Looking back today at John Bell's publication [29], it is obvious that this then-only proposed experiment applies directy to QIT. Bell's inequality have received various interpretations and proofs. It is presented in the form of the widely known Clauser-Horne-Shimony-Holt CHSH relation, formulated in 1969 [31]. In 1972, Clauser and Friedman demonstrated the violation of this inequality experimentally in a measurement system of linearly polarized photons emitted from a cascade of calcium atoms [32], proving the absence of local hidden variables. In 1980, Tsirelson generalized Bell's theorem [33] from a double-sided to a multi-sided system and derived strict constraints on the maximum strength of violation of Bell's inequality. Finally, there is Aspect's team first experiment, with transmitted photons, full of imperfections and all possible holes, but also unambiguously demonstrating, under the then-attainable conditions, a strong violation of Bell's inequality [34]. A quantum avalanche is underway. Interest in eliminating hidden variables and metrological proof of nonlocality is growing, and an avalanche of measurement tests and, consequently, publications is starting.

Measurement holes related to the existence of other correlation channels between parts of the test system, including detectors, polarizers, operators, hardware, and the environment are removed. Locality and classical correlation are eliminated by introducing superluminal measurement distances. The correlation between photons from distant astronomical objects is investigated. Quantum no-go theorems are proven [35]. Cybersecurity uses QIT [36]. A theory of a universal quantum computer was developed, with a proof for the nondeterministic quantum Turing machine [37]. Quantum version of the information theory by Claude E. Shannon, Harry Nyquist, and Ralph Hartley was developed. The properties of various types of entanglement are investigated. Three-party GHZ and W quantum systems show various types of entanglement and separability [38].

Strict laws of separability of quantum systems are being formulated. The separabilities of GHZ and W systems are completely different. Quantum nonlocality is being accepted as a universal feature of the Universe [39]. Increasingly complex gate and analog quantum systems are being constructed. Models and algorithms for mitigating and suppressing quantum errors are being developed. Hundreds of efficient quantum algorithms are being developed, including such fundamental ones as Shor's [40] prime factorization, Grover's [41] ordering of large unordered data sets, and HHL's Harrow-Hassidim-Lloyd [42] solution of large systems of linear equations. Theoretical computational speedup coefficients are being calculated for quantum algorithms. Shor's and HHL's algorithms offer exponential speedup, written in big O notation. Grover's algorithm provides square-root speedup. The persistent and very intense battle for quantum continues with a considerable success. Alain Aspect, John F. Clauser, and Anton Zeilinger have been awarded the 2022 Nobel Prize in Physics for their pioneering research on quantum entangled states, which underpin quantum computing and telecommunications. Previously nominated for the Nobel Prize, Irishman from Belfast, John Stewart Bell, was not so fortunate; he died prematurely in 1990 in Geneva before receiving his award.

For now, there is no factor in sight on the research and technological horizon that could halt such a technological quantum revolution. However, the remaining problems are increasingly difficult. Conducting quantum computations, fiber-optic and satellite quantum transmission over long distances requires significant quantum coherence times. Combining computational and transmission systems may require transformation of quantum form while fully preserving the information encoded in non-classical quantum states. Building quantum registers may require either the use of appropriate fast dynamic processes or non-volatile quantum memories. Maintaining the appropriate quality of quantum computation and transmission may require the use of quantum regenerative systems, involving the extraction and distillation of non-classical quantum resources. Building quantum networks will likely require nodes that are not only multi-channel and multi-party, but also multi-level, energetically and spatially. The task is to master the entanglement engineering of magic states and other non-classical quantum resources.

VII. Understanding Quantum Entanglement

Without quantum entanglement and its complex nature, the QIT would make much less sense. Without quantum entanglement, however, Many quantum devices would still function without entanglement. Quantum 1 is limited to the bandgap engineering. Quantum 2 is the engineering of discrete qubits, qudits, continuous q-modes, and their systems. Without entanglement, Quantum 2 systems can be reduced to classical ones. The advantage of system quantumness, measured by some indicator of advantage, may disappear. Many systems with entanglement can also be reduced to classical systems.

To build irreducible quantum systems, it is necessary to use magic states and entanglement distillation. Knowledge of the general irreducibility conditions for QIT systems is necessary. This may also be insufficient. The technical ability to provide appropriate irreducibility conditions, tailored to the type of quantum system, is essential. A quantum internet, reducible to a classical one through simulation, lacks an intrinsic quantum advantage. Quantum entanglement must be a fundamental resource for the operation of the quantum Internet, but this is still insufficient to reach the level we would perhaps call deep quantumness, irreducible and unsimulable.

The simplest type of entanglement is two-sided, two-level, between two qubits. Such entanglement has an allowed maximum value defined by Bell's CHSH inequality and Tsirelson limit. Nothing further can be added to such an entangled pair. The entanglement can be weaker than the maximum. Two-sided entanglement is simple. It's fortunate that it is simple, as it provides an excellent sandbox in which one can practice building QIT systems. Two-sided, multi-level entanglement is more complex. A significant obstacle to further development is the fundamental difference between two-sided and multi-sided, multi-level entanglement.

Even three-sided entanglement is different and more difficult to manage than two-sided entanglement. The complication stems from the need to describe the operation of multi-sided entanglement in a multidimensional Hilbert space. Bell's inequality in a multidimensional space takes the form of increasingly complex multi-cell polytopes as the number of dimensions increases [43]. For a quantum computer and a communications network operating with a qudit system, it is necessary to calculate the shape of such polytopes, create their cross-sections in a space, one dimension less, and derive their individual Bell inequalities. These inequalities are different for each individual QIT system and have to be recalculated with the changes in QIT topology.

This is currently a task in analytical geometry that exceeds the capabilities of classical computational techniques, even for a small number of dimensions. It is necessary to build efficient quantum processors and develop algorithms for solving polytope geometry, which will aid progress in this area. Fortunately, many polytopes exhibit significant symmetries in high-dimensional space, which greatly simplify computation. The task is simplified to determining the nature of these geometric symmetries and using them to create simplified cross-sections. These calculations reveal the properties of particular QIT circuits.

Without nonlocality and entanglement, the universe would be significantly poorer. We know this today, quite precisely but not completely. Entanglement seems to be a strong, inherent property of the quantum world, but is it also a property of the entire universe? Nothing in this quantum world remains un-entangled. Lacking effective tools for widespread detection, measurement, qualification, and quantification of entanglement, we are currently beyond the full understanding of a significant portion of this universe and its quantum component. Universal quantum entanglement carries enormous amounts of information. Therefore, one could say that entanglement is better understood as information, and its measure as entropy. However, entanglement has deeper nature. It turns out that we can begin to build efficient quantum devices without fully understanding the nature of entanglement.

Why entanglement cannot be easily and unambiguously defined? If it is an inherent and complete feature of the quantum world, it depends on the adopted model of the universe. In a strongly deterministic world, it is simply an expression of existing information, implemented according to a plan, distributed evenly throughout space. In the standard BB model of the universe, we can perhaps define entanglement as an extension of classical thermodynamic correlation to the quantum level. Astronomical experiments demonstrate with high probability the entanglement of photons separated by billions of years and originating from other quasars. These photons, interacting billions of years ago, and all other photons, carry a significant amount of information about their origin, mode of generation, certain interactions along the way, and so on. We can decipher very little of this information.

And how will entanglement be found if we adopt a model with quantized gravity, quantized space, or perhaps a model of interconnected multiverses? And what happens to entanglement if we adopt a simulation model of the universe and begin searching for its signatures, for example, in the form of non-zero information weight? After all, intensive searches in all these directions are being conducted, and where possible, cross-sections for their existence are being determined theoretically and experimentally. Entanglement is beginning to be tested as one of the potential tools in high-energy physics for particle acceleration, medical imaging, and even for military purposes. Entanglement has potentially unique value as one of the tools for potentially peering beyond our bottle, looking into the BSM, beyond our Finis Terrae.

VIII. Life without QIT?

The vision of a future in which we are unable to master QIT is dire. The vision of a future in which we are forever trapped on a single planet is grim. QIT potentially enable the acquisition, generation, processing, storage, transmission of information with classically unattainable efficiency—a quantum extension of intelligence. QIT offer precision in domains of energy, time, and space impossible to achieve by other methods. The quantum realm is not just a technology. It potentially represents a fundamental information layer, a functional and sustainable infrastructure for civilization development. QIT is a window onto the universe, without which we will not be able to fly very far into space.

QIT is a set of methods for understanding the essence of the universe, including here on Earth, as well as functional, practical tools for biomedicine, security, industry, ICT, and culture. The essence of space technology development lies in the efficiency of matter transport and equipping it with intelligence. The essence of quantum technology development lies in understanding and mastering entanglement as a resource. Space and quantum technologies, although fundamentally different, are arguably the most important correlated mega-directions in the infrastructural and global development of civilization.

Let us return once again, on the unique quadratic occasion of IYQ2025, to the quantum classics. Einstein's general theory of relativity assumes a strictly local reality. Similarly, the standard formulation of quantum mechanics by Max Planck, Niels Bohr, Werner Heisenberg, John von Neumann, and others fails to account for nonlocality. This omission was noticed and described, with some dismay, in a 1935 article by A. Einstein, B. Podolsky, and N. Rosen, "Can quantum-mechanical description be considered complete?" We now refer to the article and phenomenon as EPR.

The term "quantum entanglement" was coined by Erwin Schrödinger, also in 1935, as a reaction to an EPR paper, along with the creation of a quantum cat. The fear was associated with the potential for interaction between entangled particles at any distance at superluminal speeds upon the collapse of their wave functions. This likely explains Schrödinger term "entanglement." At the time, the entanglement was an expression of scientific helplessness. The impossibility of a general theoretical explanation for nonlocality, and its signature, entanglement, resulted in the introduction of hidden variables in the EPR. This is said to have stemmed, among other things, from Einstein's stubbornness and his strong commitment to the local universe model.

The search for and interpretation of these variables took decades. Einstein's authority was at work. One of the many zealous seekers was John S. Bell. His sincere intention was to finally find these hidden variables. And by accident, he demonstrated theoretically, using a very good and trivially simple model of a correlation experiment and measurement system for photons, and an appropriately formulated inequality, the complete opposite. He showed that local hidden variables are meaningless and that the quantum world is strongly and clearly nonlocal. Later, it was also shown that nonlocal hidden variables also have no effect. He was so dismayed by this that he published it in a marginal journal, probably also because another journal refused to publish his discovery. For a long time, the work remained unnoticed by the scientific community, and even had strong critics, and in a sense, it was a local hidden variable. For a breakthrough, an actual experiment had to be performed, correlations had to be measured, and specific values had to be inserted into Bell's inequality. Today, in the year IYQ2025, we know that it is impossible to live without QIT.

IX. IYQ2025 - the Meaning in Europe and Poland

Proclaimed by the UN on June 7, 2024, the International Year of Quantum Science and Technology IYQ2025 commemorates the centenary of the development of quantum mechanics. Traditionally, the UN and UNESCO declarations for such events bring together events from around the world organized by the scientific, technical, and business communities. Various events are added voluntarily to these celebrations and are brought under the umbrella of IYQ2025. As always, the goal is to increase public awareness and understanding of the principles of quantum science and technology and their rapidly developing applications. Many organizations and institutions, public and private, from the research, innovation, business, and financial sectors around the world have already declared, and continue to declare, their active support for the IYQ2025 initiative. The opening conferences of IYQ2025 took place on February 4-5 at UNESCO Headquarters in Paris and on February 21 in Geneva.

The announcement of IYQ2025 has a dual purpose: to commemorate the centenary of Quantum Mechanics which builds the foundation of our thermodynamic world, and to provide the broadest possible global support for future applications of quantum science and technology. Key goals of IYQ2025 include raising public awareness of the impact of quantum technology on the development of civilization, building the necessary capabilities for further development, and ensuring conditions for continuous and sustainable development.

IYQ2025 is based on a strong multilateral framework of cooperation involving leading scientific societies, prominent industry players, and academic institutions worldwide. Only in recent decades has quantum mechanics proven to be incredibly useful in building new functional technologies. Preparations for this commemoration of quantum mechanics and its current, growing role in building a new layer of civilization's infrastructure began in 2018 at the initiative of the American Physical Society. It took years to achieve consensus on IYQ2025 at the political and organizational levels, and then establish a strict logistical framework and sponsorship among over 60 countries.

In Poland, a number of meetings and initiatives related to the development and implementation of quantum technologies were held and are still taking place in 2025. The Center of Excellence for Quantum and Nuclear Technologies C-QuaNT PW was established at the Warsaw University of Technology and launched in early April 2025. Also at the Warsaw University of Technology, in cooperation with the Polish Chamber of Commerce, a seminar entitled "The World of Science and Business for the Development of Quantum Technologies in Poland" was organized on April 9, 2025. Universities and polytechnics in Warsaw, Krakow, Gdańsk, Poznań, Wrocław, Toruń, and other cities have very strong research groups specializing in quantum information technologies, organizing scientific meetings and educating staff.

Quantum research activities in Poland are coordinated, among others, by the National Centre for Quantum Information, a consortium of universities and institutions [44]. The International Centre for Quantum Technologies, organized at the University of Gdańsk, is connected to this centre. Hundreds of such scientific and technical meetings and economic initiatives are held in Poland, Europe, and worldwide, demonstrating the development potential of quantum technologies. Since 2018, a flagship quantum technology program, QTF, worth one billion euros, has been implemented in Europe for a decade. The project aims to support the transformation of European quantum research into commercial applications. In Poland, under the leadership of the National Science Centre, a large European project, QuantERA, is being implemented [45]. A technological project to build the MIKOK ion quantum processor was implemented at the Warsaw University of Technology. In Poznań, the scientific Supercomputing and Networking Center coordinates quantum activities. Such initiatives are becoming increasingly common across the country.

In the USA, at the central government level, quantum technologies are coordinated through the National Quantum Initiative, which is to some extent a counterpart of the European EQF initiative. The NQI program also participates in the IYQ2025 celebrations [46]. Numerous major and minor scientific and technical organizations organize their key conferences with strong quantum sessions. OPTICA dedicates the Frontiers of Optics FIOLS conference [47] largely to quantum technologies and their correlation with laser technologies and virtual reality [frontiersinoptics.com]. The IEEE coordinates its quantum activities through the activities of the Quantum Technical Community and the organization of the Quantum Week multi-conference during the IYQ year [48].

It is undoubtedly safe to say that photonics, nanotechnologies, quantum technologies, space technologies, new algorithms, computational techniques, information networks, and artificial intelligence collectively constitute an extremely promising scientific and technical environment for the further development of civilization. Quantum technologies can be described as the common denominator of these areas, as they hold the strong promise of a transition, not only evolutionary but even as a leap-forward, to completely different methods for building quantum-based telecommunications networks, computers, measurement systems, precision clocks, information processing, imaging, knowledge generation, security, and cybersecurity. Quantum materials are also undergoing evolutionary functionalization. Quantum technologies are inspiring the development of biology and medicine, facilitating the search for new drugs—particularly biological ones—and influencing the pharmaceutical, chemical, agricultural, and manufacturing industries, financial markets, and the global economy. This anchoring of the currently ongoing technological quantum revolution was likely a powerful factor in establishing IYQ2025. Everything is, after all, quantum entangled [49], [50] which, not without doubt, seems to be a consequence of the BB model.

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