Vol.1, No.1, 1-17,2023

Trends in Intellectual Property Research

# Legal Challenges of Intellectual Property Rights for Quantum Computing

Muhammad Zia-Ul-Haq[1]*, Ghulam Mujtaba[2]

[1] *Office of Research Innovation and Commercialization (ORIC), University of Engineering and Technology (UET), Lahore, Pakistan.*

[2] *Intellectual Property Organization of Pakistan, NTC Center, G-5/2 G-5, Islamabad, Pakistan. E-mail: mujtabakamal@live.com*

- *Corresponding Author Email: zia.haq@uet.edu.pk*



Abstract: Quantum computing is a very multidisciplinary field, a blend of materials science, electronics, electromagnetism, thermodynamics, quantum physics and the corresponding mathematical framework. The study aimed to evaluate the existing scenario of the choice of the intellectual property rights (IPRs) protection mechanisms for quantum computing, choice of best applicable type, and suggesting some key alternative innovation protection mechanisms. The methodology used in this research consists of general scientific and specific legal (historical-legal, formal-legal) methods besides law interpretation and legal modelling. We critically analyzed the norms for IPR protection of quantum computing from the viewpoint of obtaining protection of inventions and increasing the innovation activity in quantum computing. One of the regulatory mechanisms for every disruptive technology is offering it IP protection. Currently quantum computing hardware is protected by patents while software is mostly protected as copyright besides protection by industrial design and trade secret exist as complementary mechanisms for this revolutionary technology. All available approaches were considered, and amendments are suggested in current IPR legislation to correspond to the reality. This interdisciplinary research revealed the uncertain nature of quantum computing and the difficulty in selecting one type of IPR as the best choice. The best way to establish a sufficient IPR mechanism is to acknowledge quantum computing as an emerging technological cocktail, and to sustain the innovation cycle of this technology. The conclusions of this study can be used to overcome the lacunas in existing IPR system for the quantum computing. This research can be used as torchbearer when preparing proposals for making revisions and additions to the existing legislation.

Keywords: Quantum Computing; Patent; Copyright; Industrial Design; Challenges, Technology; Choice

## 1. Introduction

Quantum Computing (QC) built on the doctrine of quantum mechanics (QM), the physics of sub-atomic particles, is revolutionizing the world due to its wide spectrum use in everyday life. The surge of QC is aided by improvements in machine learning algorithms, explosion of digital data, accelerating computing and storage power, and progress in biological and medical sciences. An explosive growth is predicted in QC in this decade. Quantum computing can help solve various complicated problems including but not limited to physical simulation, optimization, and factorization problems, which are inadequately addressed by classical computing. The exceptional features and unconventional applications of QC technologies are huge ranging from (1) decoding computational complications through quantum or quantum-conventional hybrid algorithms; (2) extraordinary precision, resolution, and specificity in quantification by quantum metrology and sensing; (3) and smoothing a new paradigm of secured communication models (Singh, 2022). The QC may not be a next-generation successor to classical computing. It will complement them, and traditional computing will remain helpful for numerous daily tasks, as they are more affordable, require little maintenance and are easy to use. Quantum computing is based on doctrines of QM (e.g., superposition, uncertainty, entanglement, and tunnelling), the theory of the very small for computation leading towards a novel information processing and storage paradigm (Kop & Brongersma, 2021). Uncertainty principles in QM restrict the accuracy with which values of pairs of complementary physical quantities can be concurrently predicted, e.g., they apply to *position* and *momentum* besides *energy* and *time*. Quantum computing does not involve certainties; it involves probabilities. The QC will be especially helpful in numerical optimization (offering best possible solution for a problem where numerous variables interact in complex ways), the modeling of molecules (development of new drugs), replication of complex systems (for functions like modeling weather), and cryptography (important to protect storage and communication of digital data) (Kop & Brongersma, 2021). Logical operations performed by traditional computers are built on a blending of one of two physical states. These binary procedures are +ve or -ve electrical charges generally denoted as 1s or 0s and are called bits, or binary digits. Contrarily, QC utilize the unique physical properties of quantum particles, i.e., atomic, and subatomic particles like electrons, or photons which are used as the "quantum bits (qubits)" (Marella & Parisa, 2022).

These qubits enable a third state namely "superposition", whereby these are concurrently 1s and 0s. Hence while a two-bit/binary system can exist in any of 4 states (00, 01, 10, 11), a two-qubit system can exist in all 4 at the same time. This "uncertainty" in the state of the qubit helps perform multiple calculations simultaneously. This superposition leads to "quantum amplitudes," which can intervene like waves, in a constructive or destructive manner. This superposition enables a specific quantum behavior of "entanglement" indicating quantum particles in various locations simultaneously, being "aware" of each other. In short, two atoms are linked, or entangled, despite being detached, and operations performed on the first qubit influence the state of an entangled second qubit. Hence assessment of state of only the first qubit, two pieces of information; the state of the first qubit, and (by implication based on entanglement) the state of the second qubit are obtained. This phenomenon can be utilized for quicker computation as it immediately shares information between two very distant systems. The exponential performance of a quantum algorithm as compared to classical computing is due to this quantum entanglement. These phenomena help quantum computers store and process information uniquely and will solve various complex problems with several variables, providing a computational lead. Although there is still time to find" full-gate fault free" quantum computing, quantum annealers are being used by MasterCard, Deloitte, and Volkswagen to handle optimization issues (Kop, 2021 a & b).

Every new technology is not usually regulated and even when regulated, it's after social impact of a technology. The most proper time to study the effect of a technology is when that technology is still in the design and development stage as it allows for early involvement. QC has triggered social change, and pre-existing legal framework cannot accommodate this social change raising some serious legal, social, and ethical questions. Currently QC innovations fall into "legally grey areas" especially when observed from the intellectual property law prism.

It is well-known that 2$^{nd}$ quantum revolution, a title devised in the early 2000s (Dowling & Milburn, 2003), will change ways of designing technology just like first quantum revolution helped understand the world giving us MRI machines, lasers, and atomic clocks. Just as semiconductors replaced vacuum tubes and are now ubiquitous nowadays, the implements of QC and quantum optics will replace current technologies. The cold war race between USSR and USA in 1960 led to many inventions and so is expected now from China and USA (Wilson *et al.,* 2022).

Quantum computing is based on physics, mathematics, and computer science. Quantum computers usually are made up of numerous layers of software and hardware components, e.g., qubits, quantum gates, quantum circuits, quantum machine learning algorithms and the quantum-classical interface. Various constituents of a quantum computer can be protected by battery of overlapping IP rights, offering "evergreen" protection. It may however lead to overprotection, patent thickets, stagnation and missed opportunity costs which is not the aim of a good IP system which maintains a "freedom to operate", securing investments in research and development without violating third-party IP rights. Patents, copyrights, industrial designs, chip rights and trade secrets are possible modes of protection. A comprehensive methodology, using the benefits of each type of IP protection, is perhaps the best choice. The right IP strategy depends on several factors such as the type of QC, expected lifetime, standing of the QC and the budget required to acquire and enforce the rights. Current research will mainly focus on existing status of patents, copyright and trade secrets as available IP protection mechanisms for QC, the loopholes, lacunas and gaps in present IP system, suggestions of amendments and/or adoption of new mechanisms to keep running the QC innovation cycle, and suggestions how to use them more functionally to increase QC protection, and boost QC creativity.

## 2. Patenting QC

A patent system incentivizes inventors to disclose, produce and market their invention in return on their investment. It urges the detailed disclosure of inventions by granting exclusive rights to the inventor for a limited period. Patent law motivates inventors to enhance and build upon prior inventions. The functionality of sufficiently disclosed inventions (new, non-obvious/having inventive step, useful) coined by a human inventor is protected by patents. Theoretically, patent law is tech-neutral, but practically its tech-specific in application (Mason, 2021). Being fundamentally rooted in hardware, quantum inventions are mostly patent-eligible. The following QC components can be patented: qubits, quantum gates & multipliers, quantum integrated circuit chips, the various types of quantum processors such as spin qubits and superconducting transmon qubits, quantum interference devices, compiler engines (i.e., optimizers, translators, mappers), decoders, a simulator and an emulator, a circuit drawer, the microarchitecture (quantum execution (QEX) block & quantum error (QEC) block), the quantum-classical interface, the quantum instruction set architecture, quantum memory, quantum computing process, and a qubit signal amplifier component (Kop *et al*., 2022). EPO considers the below points for all patent applications including those of QC.

### 2.1. First Stage /Subject Matter Eligibility/ Low Hurdle

Claims of every patent are checked for eligible subject matter (Article 52(2)(c) & 3 EPC). Article 52(2) expressly excludes mathematical methods and computer programs from patentability when claimed as such (Foss-Solbrekk, 2021). The article indicates that “programs for computers” do not constitute inventions. However, article 52(3) indicates a grey area by restricting the exclusion of “computer programs” using the phrase “as such” (Sterckx & Cockbain, 2010). The phrase “as such” has been decoded to mean that computer related inventions are patentable if they exhibit technical character. Algorithms are patented for their concrete applications by solving a technical problem e.g., image analysis, and medical images classifications and are tailored for a special technical use e.g., neural networks implementations and graphics processing units. Surprisingly encryption/decryption systems are usually considered technical although they are based on mathematics. The European Patent Convention (52(2) excludes mathematical methods and computer programs from patentability however EPO has been issuing software patents since 1978. EPO guidelines reaffirm that if the patent claims a method ‘involving the use of technical means” like a computer, a technical character is bestowed on the subject-matter, making it patent eligible. An “objective technical problem” is derived from the differences constituting a “technical effect” or rendering “technical character” to the invention. Similarly, EPO can grant patents to “second use of machine learning model” just like second use of medicine by “purpose-limited product claims” (EPO GL G-VI, 7.1. 2). There is currently little information what makes “abstract” for a QC.

As the algorithms require a computer to operate, they may be patented either as part of the method claims of a computer program application (a), or separately as CIIs (b). Both are detailed below:

#### (a) Unlikely Protection of Algorithms as Part of Computer Program

The technical character indicates chances of patent protection of a computer program. The predictive algorithms and models enhance the performance of internal business operations, facilitating their applications on the internet. They neither increase a computer’s inner functionality nor yield a technical effect between software and hardware. Hence such predictive algorithms don’t meet the technical standard envisioned by the *technical boards of appeal* (TBA). Hence there are very few chances of patenting algorithms as computer programs.

### (b) Algorithms as Computer-Implemented Inventions (CIIs)

Algorithms can be patented as CIIs easily as per European Commission. For this, their method claims should describe computer executable steps, or execute a specific functionality when installed by a processor on a computer readable medium hosting a computer program. The TBA established that patents claiming mathematical models do not seal their patent ineligibility. Both unsupervised algorithms e.g., neural networks, and unsupervised algorithms can be protected since human involvement is essential in both.

## 2.2. Second Stage/ High Hurdle/COMVIK Approach

Novelty and inventive step are judged in the second stage. The QC system will be judged like other inventions for prior art (novelty) and difference between prior art and invention (inventive step). The "closet prior art (CPA)" should be a single prior art reference relating to the claimed invention. This CPA should belong to the same or closely related technical field of claimed invention. Very few functional and structural modifications are needed in this CPA to constitute the claimed invention. After identification of CPA, advancement from CPA to claimed invention suggests "objective technical problem" describing the technical problem that the claimed invention is posed to solve regarding the CPA. The CPA for QC is still fragmented and patchy. Coupled with the interdisciplinary nature of QC, it can create problems for IP protection of QC. For inventive step, all features contributing to the inventions' technical character (as defined above) will be considered. Traditionally, this stage is problematic due to mixed-type claims having both technical and non-technical features. Inventive steps can't be built upon non-technical features. The EPO's approach to examine mixed-type claims (guidelines G-VII 5.4) states the "problem and solution approach" for claims containing technical and non-technical features (Dydenko, 2018). Non-technical features contribute to inventive step only when they interact with the technical subject-matter of the claim to answer a technical problem or, to exert a technical effect.

Patenting algorithms may increase transparency as patent claims are publicly available. However, since patents contain esoteric sketches with elusive sketches, inconceivable by a person having average knowledge of the domain. Further corporations omit various features of the technology in patent applications making it difficult to replicate the inventions (Foss-Solbrekk, (2021).

## 2.3. Enablement/Sufficiently of Disclosure

The compulsory disclosure conditions (quid pro quo of patent law) present an extra challenge for QC inventions. As per article 83 of the EPC, a patent application shall reveal the invention suitably clear and sufficient for it to be replicated by "a person skilled in the art (PSA)". Further, rule 42(1)(c) of the EPC needs that the description discloses the invention, such that the technical problem and its solution can be identified. For QC machine learning algorithms, these requirements may be difficult to identify. Specifically, if QC inventions are mere theoretical in nature based on mathematics, physics, and computer simulations, without any accompanying physical Q computer implementing these inventions, it will be challenging to fulfill the disclosure requirements. Disclosure of source code for enablement of the PSA is still an open question.

## 2.4. Person Skilled in the Art (PSA)

The PSA is another mega question. Current PSA as described in patent laws globally has knowledge of the state of the art in the specific field but has no inventive capability. However, QC inventions are generally problem solvers, produced by combining different fields to obtain improved results and so may not meet the “non-obvious” criteria. As per EPO patent examination guidelines, PSA can be a team. To cope these challenges, we propose a new patent model with following characteristics:

Focusing the Utility of invention instead of Subject Matter eligibility: Highlighting the utility of the invention, ignoring the abstract idea limitation, will be an ideal step by modifying the subject matter eligibility condition. It means patent office should focus the benefit at large to the public instead of searching the subject matter. This will decrease the instability of patent validity challenges, encouraging QC patents.

Reducing the Utility of patent duration to 10 years for startups: Patent protection duration should be shortened to 10 years for new firms having less than 50 employees to cope with the challenges of paying maintenance fees.

A Depository for QC: Some QC inventions cannot be properly revealed yet. The same problem of disclosure for patenting microorganisms was solved by The Budapest Treaty. Inventors had to deposit a sample of their invented microorganism to test for extra characteristics if required later. The QC “uncertainty problem” can be handled by requiring patentees to submit their code to an online bank. As new experiments reveal the working mechanism of QC, interested inventors can download a patented algorithm and test it for additional features.

Raising the PSA standard to include ordinary QC tools: Presently, PSA is a knowledgeable yet uninventive fictitious person. However, PSA standard can be raised, and a QC invention can be considered obvious if PSA with common QC tools in the field thinks it obvious. This increased standard shall not include the most innovative tools but rather those that are common in the field. This will prohibit patent protection to inventions without any real inventive step.

Limiting Trade Secret Protection: QC can be protected easily by trade secrets. It will however unfairly advantage big resourceful firms by creating QC secretly. This advantage can be balanced by reducing the trade secret protection time to five years only. This will provide adequate chance and encouragement to share AI or patenting it. The goal is to make QC innovations public goods, rather than private properties.

Grading the invention as blanket: A single application should be filed in IP office seeking all types of IPRs protection. QC Inventions can be graded from 1-100 depending upon their importance, research and development costs, and life of technology. A minimum number should be necessary to seek protection.

Grading the sustainability of Inventions: Every QC invention should be raked for its impact on the ecosystem. Only those inventions should be protected which achieve a threshold marks.

Sui generis protection: EU can enact sui generis legislation customized to the complexities of QC. These laws can prohibit unauthorized extraction and use of an invention protecting investments. However, protecting QC through sui generis will be disadvantageous in a globalized society by weakening the patent system.

Potential shortcomings of model: Although above mentioned model seems a solution, it creates more questions. A new type of patent model for QC inventions will benefit key players of QC field only. This advantage can prevent the market entry of resource-scanty startups, accelerating market consolidation, a problem also triggered if trade secrets are key protection mechanism for QC. Various patent terms based on the inventor status can decrease these adverse effects. However big market players will benefit more than startups or independent inventors by ensuring many QC patents and getting returns earlier. Thus, a decreased patent term of ten years for these key firms can assist level the playing field. Startups will have a stronger incentive to innovate as they can secure the 20 years of protection, thus giving them sufficient time to secure monetary benefits.

The revised PSA criteria can lead to some difficulties also. Startups can’t decide easily if a QC tool will be popular in a specific field. It will also lift the inventiveness standard and innovators without these QC tools will be surpassed by their QC-powered competitors. However, the improved disclosure and commercialization of those tools due to the proposed QC patent category will lead to quicker access to these QC tools, possibly cheaper. For QC, PSA can include a group of physicists, engineers, and computer scientists.

Key Problems of QC Patents: Enforcement of QC patents will be difficult as it will be hard to detect infringement. Especially QC hardware may be inaccessible because much of QC computing is based in the cloud. Since mere observation of quantum states destroys them, reverse engineering will be difficult too. Since patent life is 20 years, quantum computing is currently nascent, and it may take time for common use of quantum computers. If inventions are not commercially mature during these 20 years, trade secret protection is a better option (Aboy *et al.,* 2022).

Being tech-specific in purpose, patent law can work differently even within the quantum sphere. Traditionally, courts interpret patent laws to specific technologies, such as AI, quantum, and the life sciences. Courts can tailor patent laws for QC, with stretchy standards, e.g., lessening or increasing the inventive step level and lowering or enhancing disclosure obligations. This can result in patents being simpler or difficult to gain in QC technologies. It will however be challenging for the legislators to arrange different IP laws. The patent applications should be drafted by keeping in mind both the nature of invention and infringement. Patents are territorial in nature and being a global technology, it may be possible that some processes of QC may be carried out in any other part of the world. It is therefore wise to evaluate whether a to-be-patented invention can be enforced on a contributory infringement basis (that the infringer provides the means essential to put the invention into effect). The USPTO and EPO use CPC G06N10 for "quantum computing" search and classification (Kop, 2020). Usually, QC hardware is hard to develop (costly and time consuming) and replicate as compared to the corresponding software and algorithms. The QC has a defined patent class, but for refrigerators (an essential component for proper function of QC), it's difficult to track progress since inventions are often multidisciplinary making it difficult to track progress of QC. Patents can be granted to QC hardware (i.e., qubits, circuitry, and processors), software involving quantum algorithms, simulation, and quantum-error correction, and more software and mathematical formulas.

Around 2014, the first quantum startups emerged. Quantum technologies include "unknown unknowns" besides "known unknowns" that licensees have historically been prepared to accept. Lens scholarly publications report (2023) indicates that patents have grown in the last 4 years in QC field especially in Qubit technology and QC hardware[1]. The qubit technology field patents have experienced exponential growth in super conducting loop methods of generating qubit and quantum dot method while same is true for quantum circuits and generic quantum hardware applications in hardware category (Merchant, 2023).

Patents growth over time, field of invention, cited patents, patent classification, legal status of patent documents as shown in Figure 1,2,3,4 and 5 respectively. An increasing trend in patenting the QC inventions is evident. The granted patents increase with time as initially all patents are filed and it takes time to mature and then subsequent grant from the patent offices. Similarly, citations increase with time. A search by "quantum computing" indicated 261,126 scholarly publications in this field[23] in Figure 6. Top fields of study, fields of study covered by most active institutions, most active authors, scatter plot of scholarly work, most active countries and regions, top publishers, publications over time, and top journals by publishers are shown in Figure 7,8,9,10,11,12,13, and 14 respectively.

---

[1] *Lens Scholarly Publications Report. (2023).: https://www.lens.org/lens/search/scholar/analysis?q=quantum%20computing&p=0&n=10&s=date_published&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedYear&orderBy=%2Bdate_published&presentation=false&preview=true&stemmed=true&useAuthorId=false(accessed on 20 May 2023)*

[2] *Lens Scholarly Publications Report. (2023). https://www.lens.org/lens/search/scholar/analysis?q=quantum%20computing&p=0&n=10&s=date_published&d=%2B&f=false&e=false&l=en&authorField=author&dateFilterField=publishedYear&orderBy=%2Bdate_published&presentation=false&preview=true&stemmed=true&useAuthorId=false(accessed on 20 May 2023).*

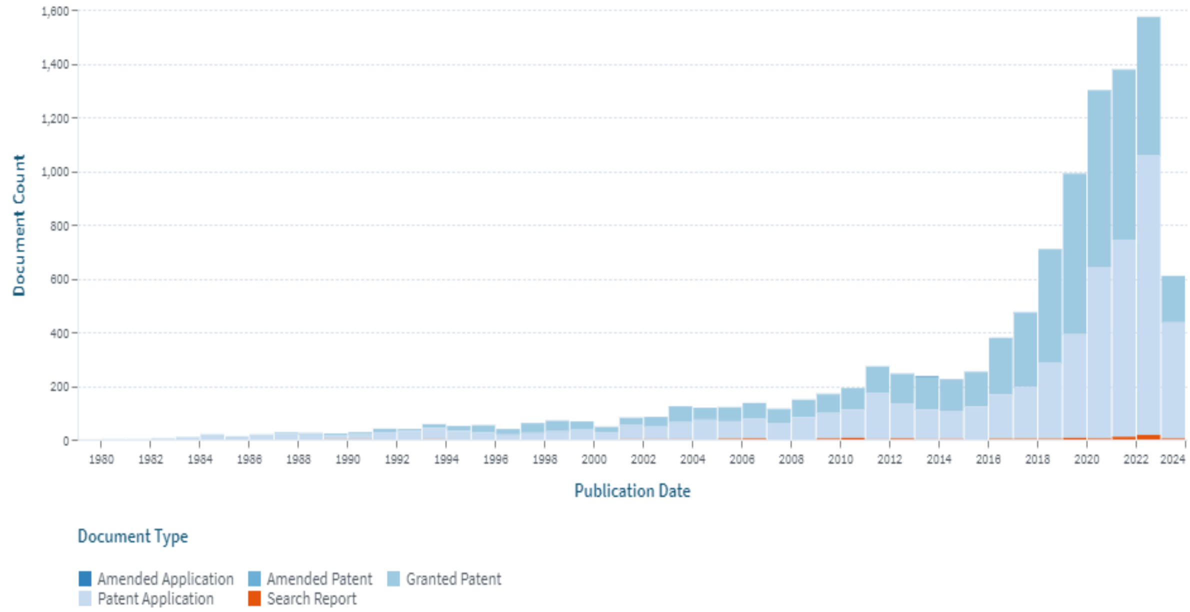


**Figure 1.** Patent documents types[4].

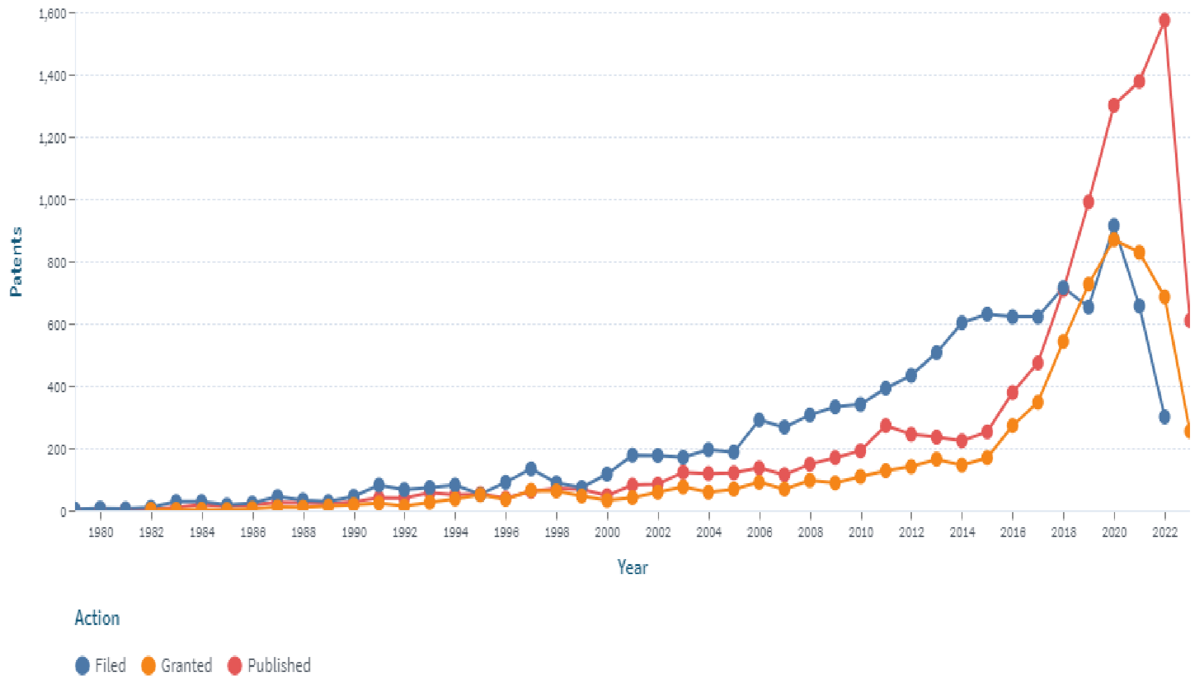


**Figure 2.** Patent documents by filed, published and granted date.

4 https://www.lens.org/lens/search/patent/analysis?q=(quantum%20computing)&p=0&n=10&s=_score&d=%2B&f=false&e=false&l=OT&authorField=author&dateFilterField=publishedDate&orderBy=%2B_score&presentation=false&preview=true&stemmed=true&useAuthorId=false&j.must=EP (Accessed on 20 May 2023)

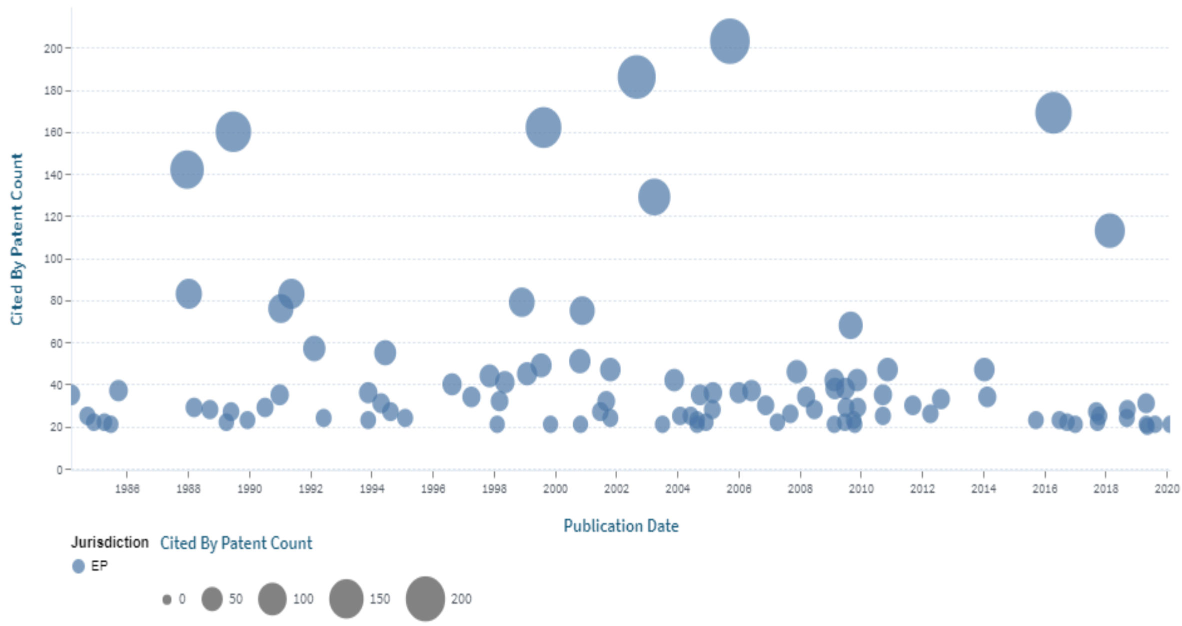


**Figure 3.** Key cited patent documents.

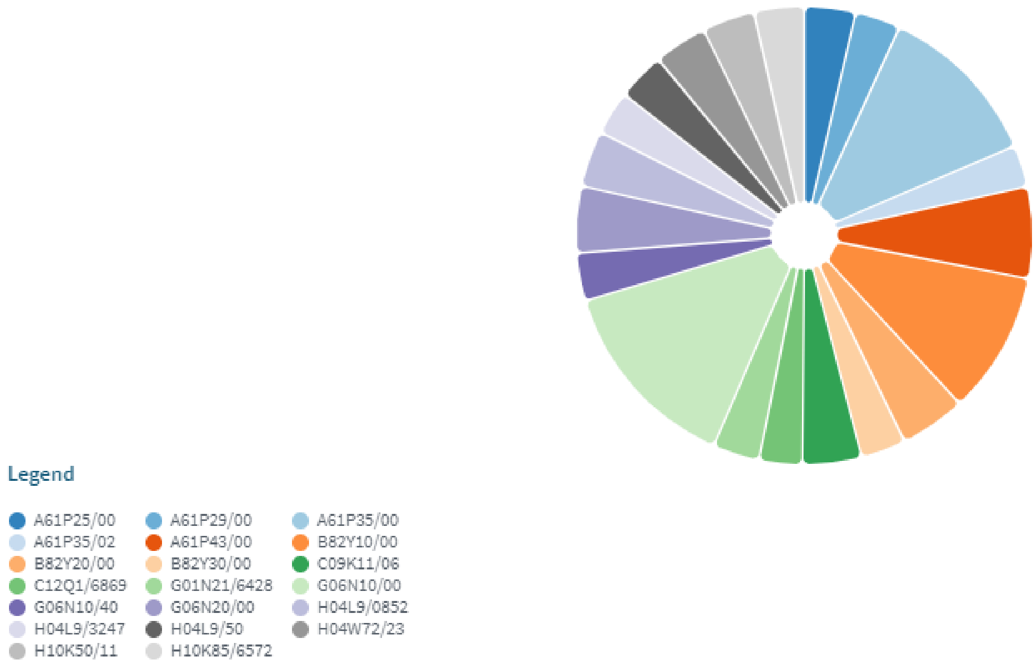


**Figure 4.** Top CPC of quantum computing inventions.

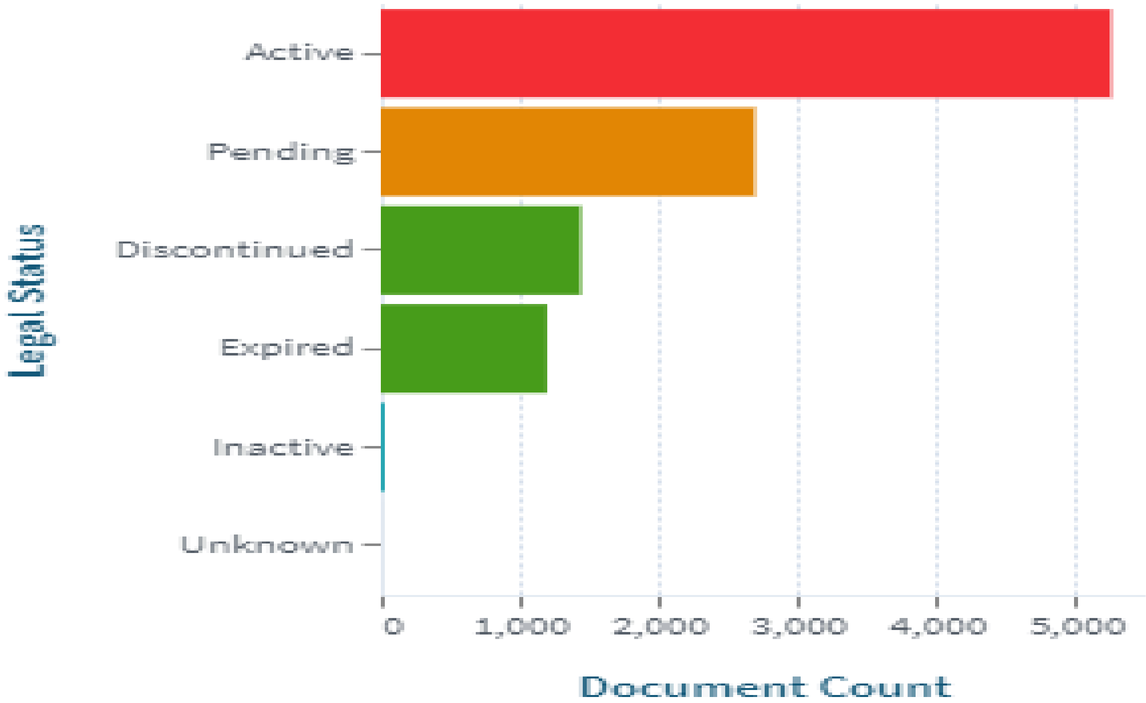


**Figure 5.** Legal status of patent applications of quantum computing.

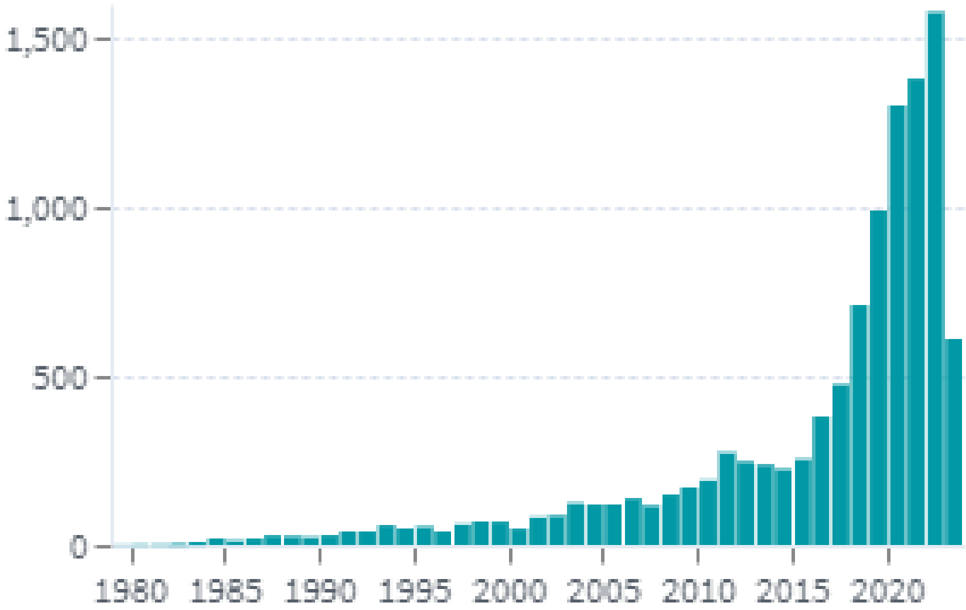


**Figure 6.** Growing trend of quantum computing patent publications over time.

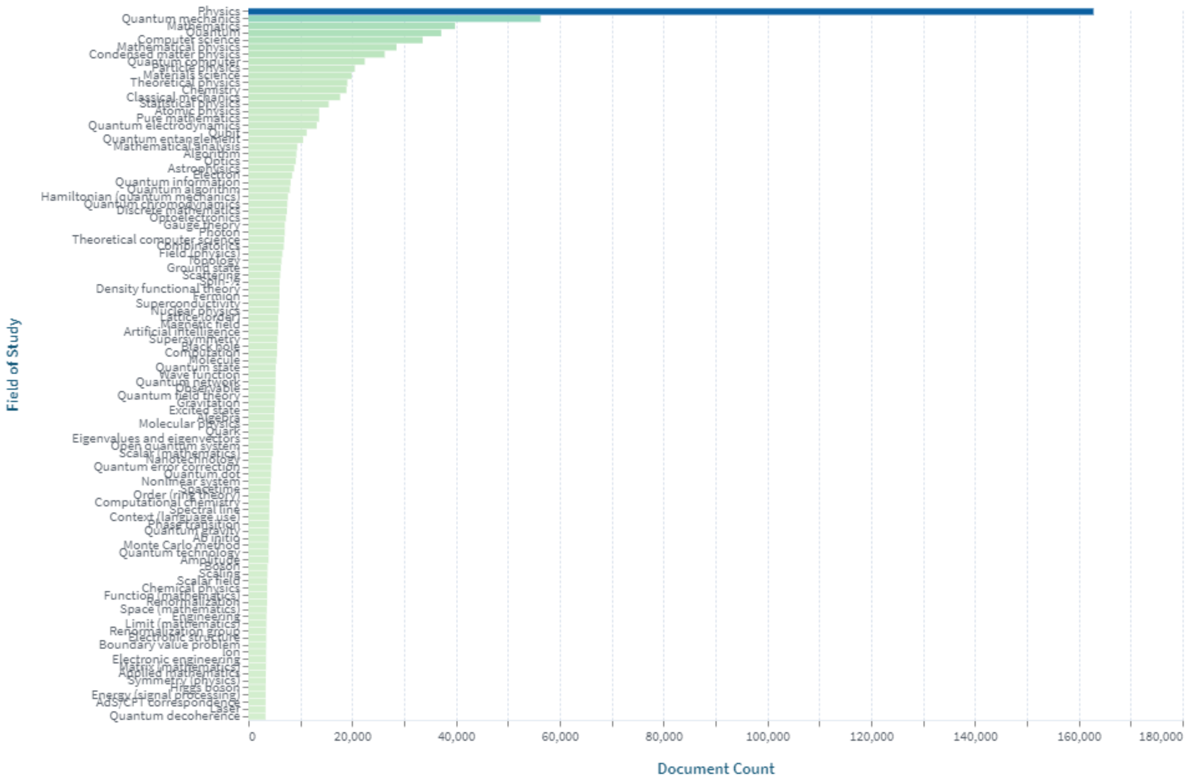


**Figure 7.** Top fields of study.

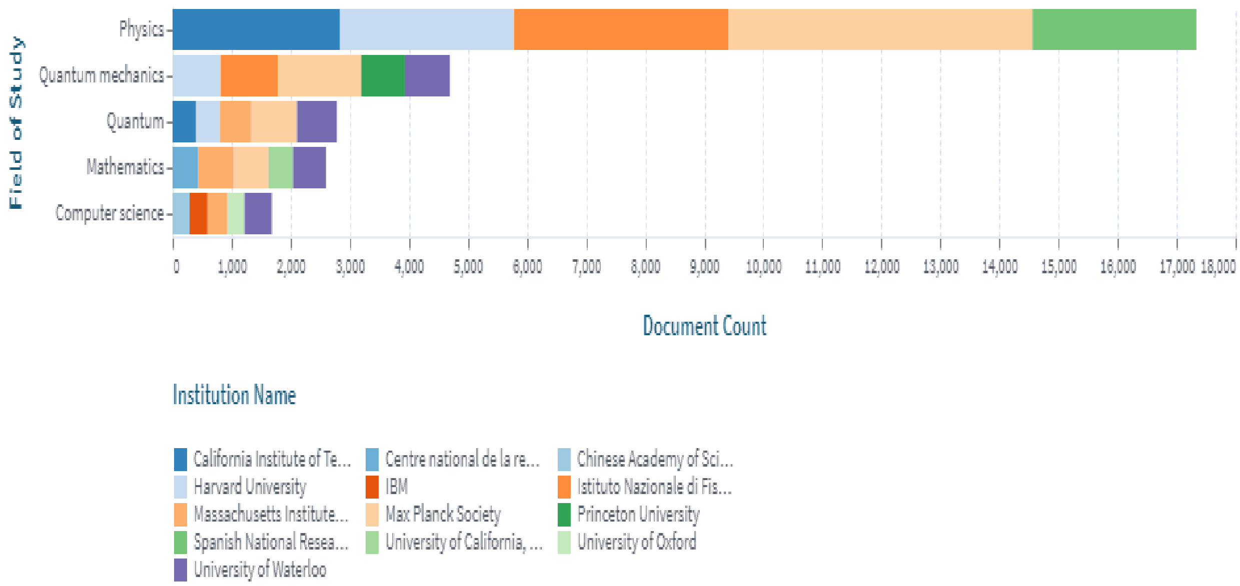


**Figure 8.** Fields of study as covered by most active institutions.

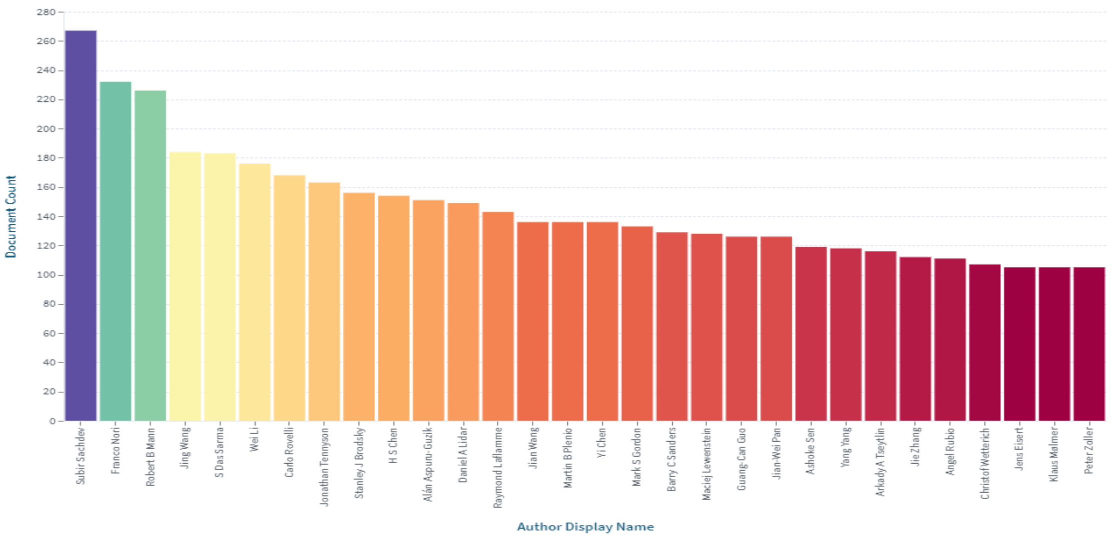


Figure 9. Most active authors.

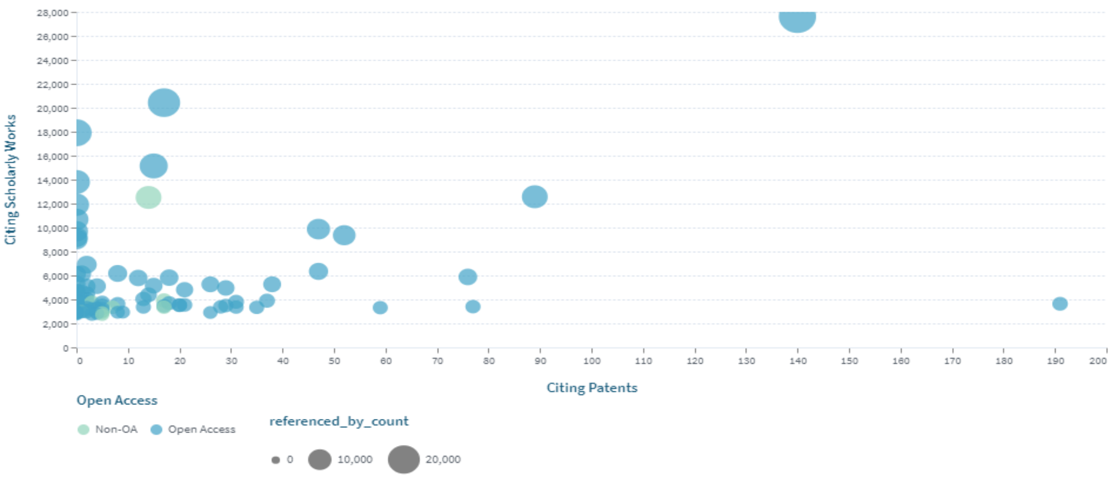


Figure 10. Scatter plot of scholarly work.

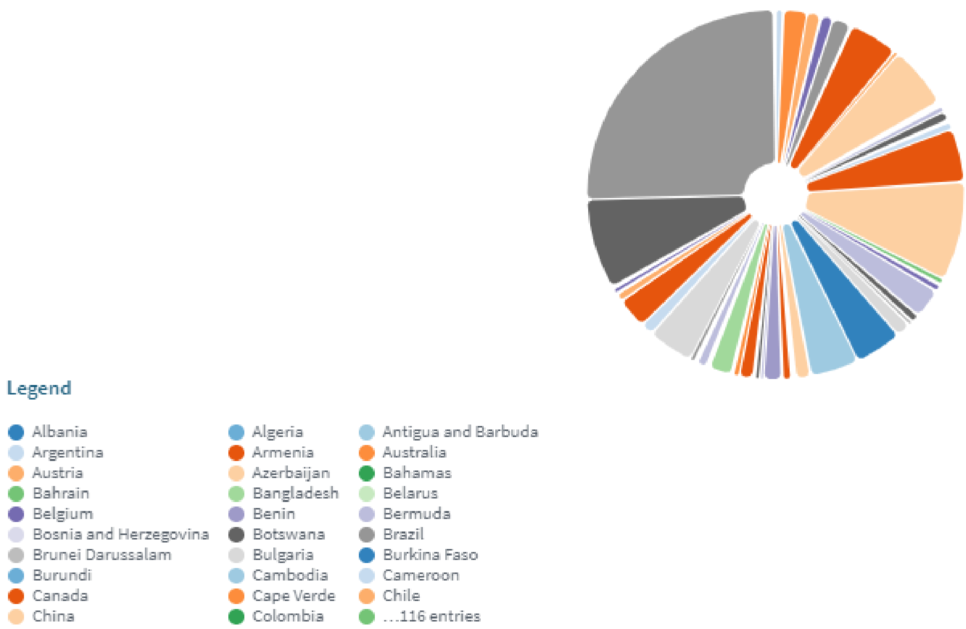


Figure 11. Most active countries and regions.

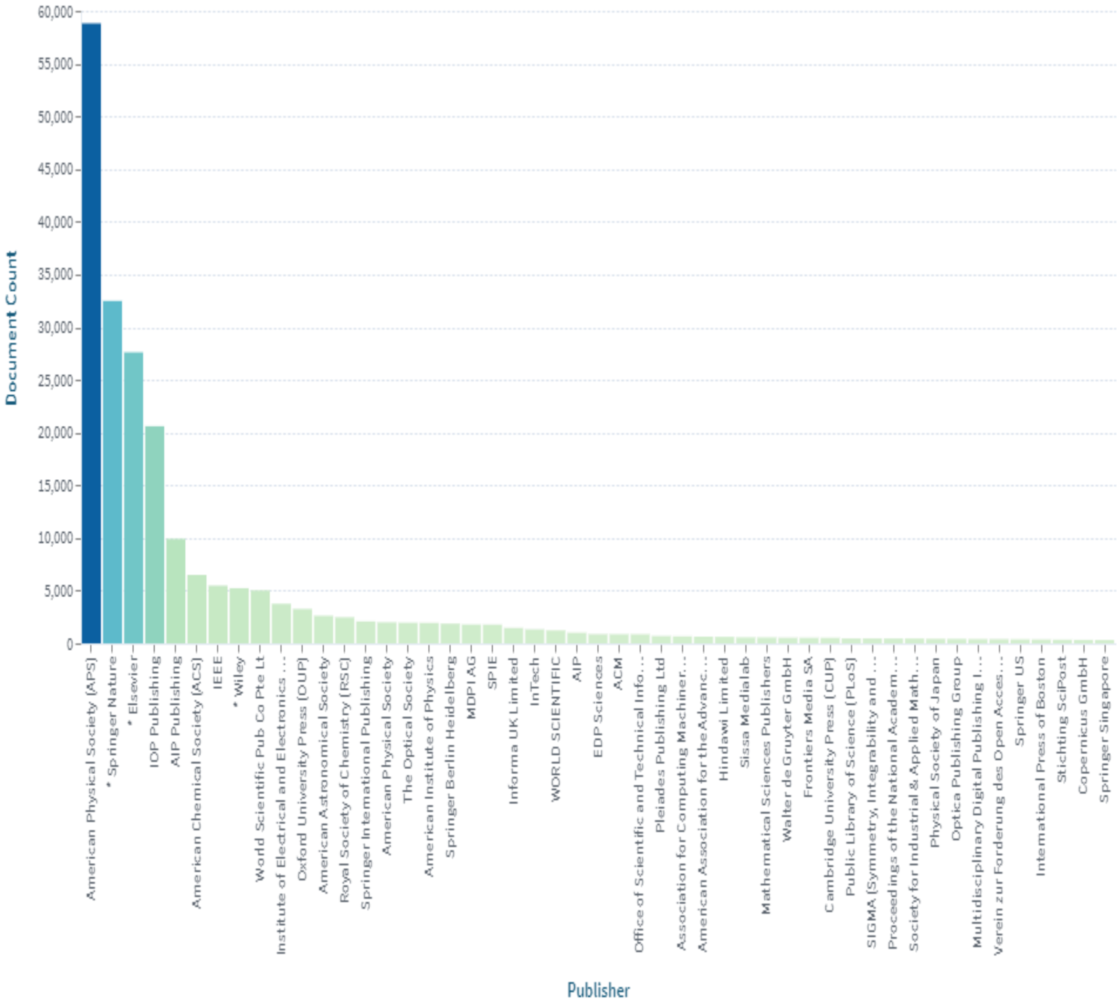


**Figure 12.** Top publishers.

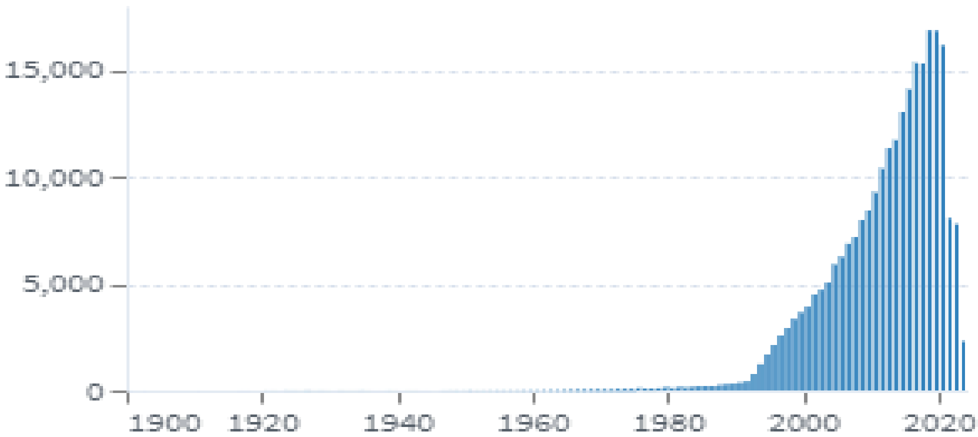


**Figure 13.** Publications over time.

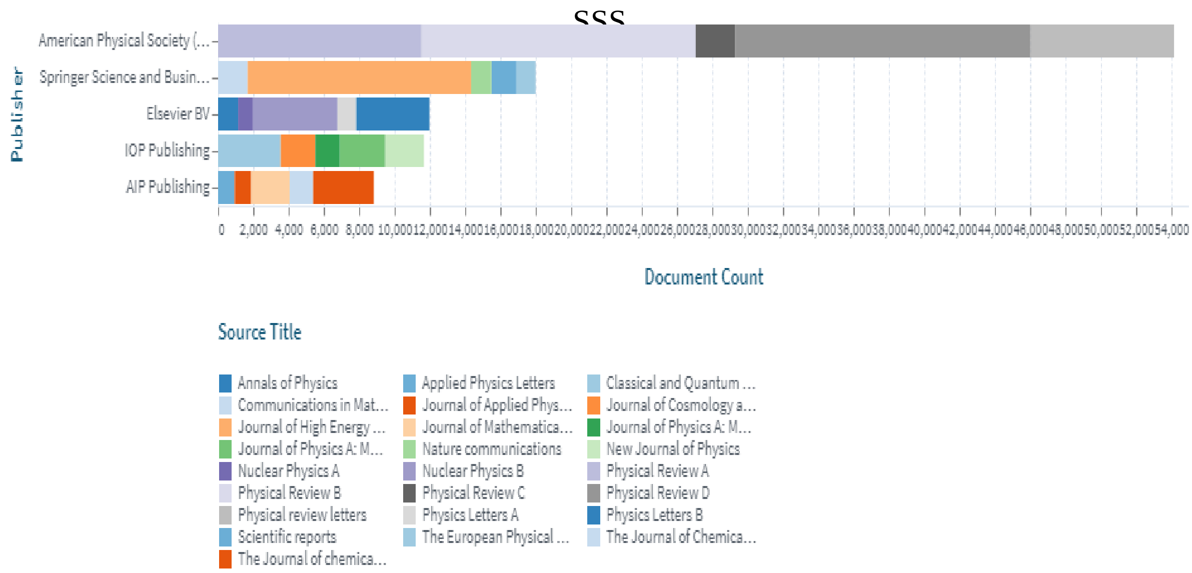


**Figure 14.** Top journals by publishers.

## 3. Copyrights for QC

Patents are not granted for data compilations, and here comes copyrights. Copyrights usually need a threshold creativity, originality, and a human author. It is well-known that copyright does not protect the functional aspect of software, programming language and consequently the algorithms. Algorithms and models, a key component of any QC possess abstract mathematical features and hence are excluded from patentability when claimed as such. However, when embedded in inventions possessing technical features can be protected as elements of invention.

The following components can be copyrighted: quantum software, quantum arithmetic unit (quantum addition, subtraction, multiplication, and exponentiation), runtime assertion and configuration, quantum computing platforms, program paradigm and languages, the quantum application programming interface; quantum software, the BaconShor stabilization code, color codes, and surface codes. These constituents can be copyrighted if these are original works created by humans in a tangible form. Quantum software, like other computer programs, is eligible for copyright protection. Software copyrights last much longer than patents granting the author exclusive rights for the life of the author plus 70 years. Both TRIPS and WIPO copyright treaty consider source code as literary work allowing copyrights. Copyright does not protect the functional aspects of software. Copyright protection is obtained by simply writing the code. Copyright does not protect the configuration that the source code is based upon and just protects the source code, just like not protecting the contents but merely the book cover. Accurate record of author and creation date of code should be maintained. The code can be filed by a lawyer or an escrow agency ensuring a "neutral" body recording the creation date.

TRIPS (article 10(1) indicates that computer programs "shall be protected". Article 4 of the WIPO Copyright Treaty (WCT) states that computer programs fall under the Berne Convention. But these international accords don't define computer programs, although WCT (article 2) excludes ideas, procedures, operational methods, and mathematical concepts.

**a.) No Copyright Protection under the EU Software Directive:** Software Directive (article 1) confirms that computer programs are protected under the Berne Convention. However, WCT (article 2, 7 &11) clearly excludes algorithms from CR.

**b.) Algorithms, Models, And Datasets under Copyright and Related Rights:** Copyright will not protect quantum algorithms as such, being general principles and abstract ideas. Since algorithms can be conveyed as computers programs and are a type of software, they can be copyrighted as "work" or as "computer programs". As per Infosoc Directive, 'work' should satisfy criteria of being original (author's own original intellectual creation) and should express that creation. Algorithms don't fulfill this criterion. Since developer has a minor role in the algorithms' functioning (due to not assembling the data in a novel approach), unsupervised learning algorithms and models do not constitute an author's own intellectual creation. Unsupervised learning algorithms therefore don't fulfill 'work' criteria under the Infosoc Directive. Supervised learning algorithms assembling algorithms and data to produce one complete model appropriate for a given objective indicate 'creative freedom' where the developer makes an original intellectual construction, meeting the first restriction.

A benefit of copyrights for algorithms are the exceptions that copyright law allows, permitting algorithmic knowledge to be shared without penetrating the IP protection. Copyrighting algorithms will challenge copyright's spirit of rewarding inventors for their creations. However, prohibiting creations not meeting the authorship criterion puts the copyright at risk. Currently, it seems that algorithms don't come under the scope of EU copyright law. Copyright does not protect ideas or the functional aspects of software. Similarly, copyright prevents only copying. Copyright will not protect the algorithm but just the source code. Accordingly, copyright will not prevent any person from creating a different QC by same algorithm if they different coding is used to implement the algorithm.

## 4. Trade secrets (TS) for QC

TRIPS article 39 protects "undisclosed information," which is described in terms like TS. Since EUTSD enactment in 2016, harmonized trade secrets protection has existed in EU. Article 39 of TRIPS is present in EUTSD. Trade Secrets Directive (EU) 2016/943 (article 2), defines a "trade secret" as information which:

i. is confidential, i.e., it is not, as a body or in the exact arrangement and fabrication of its parts, mostly known among or readily available to people that usually deal such information.
ii. is commercially valuable due to its secret; and
iii. has proper steps under the conditions, by the person lawfully controlling the information, to retain it secret.

Being anonymous and commercially valuable, algorithms are eligible for TS protection (training data, individuals' personal data and other proprietary information). As per recital 16 of the EUTSD, trade secrets do not 'create any exclusive rights to know-how or information'. The European Commission impact assessment of EUTSD states that, 'trade secrets are not IPRs'. Hence trade secrets offer weaker protection to AI, with decreased algorithmic transparency (since trade secrets are unregistered rights and algorithm information may be withheld on trade secret grounds). Due to the indefinite period of protection by trade secrets, AI systems may remain misty indefinitely (Kempas, 2020). QC inventions which can't be reverse engineered can be protected by trade secrets. Trade secret may be preferable due to (a) the infancy stage of Q technologies; and (b) the possible business models. (e.g., quantum cloud-computing as a service)". It will be helpful to sign non-disclosure agreements (NDAs) and opt for trade secrets if invention life seems very length.

## 5. Industrial Designs

New, non-technical, and appealing properties of inventions can be protected by industrial designs. Appearance and outlook of QC products including but not limited to unique shape of physical devices (e.g., household robotic devices) and novel and visible effects of computer-created graphical designs can be protected by industrial designs.

## 6. Privacy and Security

A quantum-secure digital world based on quantum-resistant security solutions will help protect privacy and manage data (Wadha 2022). Sometimes firms' owners store confidential information on the network using security mechanisms such as a firewall or encryption. Since QC can decrypt encrypted files quicker than traditional computers, hackers can use QC to penetrate network systems, break the potential unbreakable codes in a microsecond and steal trade secrets. Hence efforts should be made against the use of weaponized quantum computers. The enhanced information storage capacity of a qubit (@both number and variety) makes QC exponentially faster than their classical counterparts. It can lead to an unequal balance of power in cybersecurity. QC can easily bypass the safeguard of a standard device. Although quantum computing can mitigate potential data privacy violations, risks include the capacity to run powerful data analysis algorithms to estimate, deduce or initiate unconsented or unauthorized information from datasets containing personal data by combining QC with other technologies, such as AI (Harrison, 2022). QC will facilitate speedy and sophisticated processing of personal data. Currently, general data protection regulation 2016/679 ("GDPR") deals with such processing of data. GDPR may be inadequate to fulfill obligations of profiling, automated decision making and large-scale data processing. Further, some key GDPR principles such as data minimization, fairness and transparency may need to be revisited.

## 7. Alternative Innovation Protection Strategies

Alternative innovation protection strategies can be a better option depending upon the type of business and commercial strategy as one size does not fit all. Key alternative tools to encourage the innovation cycle are, e.g., government funding, contests, sponsorships, rewards, penalties, labor law, tax law, education and attracting talent (Hemel & Quellette 2013; Kop & Brongersma, 2021).

Innovation Policy Pluralism: by offering tax incentives and rewards to inventors and companies.

Defensive Publications/Sharing Knowledge in Public Domain: Inventions can be published without patenting. It is a cheap technique of reducing the risk of freedom to operate. Such publications prevent third parties from patenting the invention later or can be used defensively as prior art to invalidate a later patent. It will prevent patenting trivial inventions. The secrecy period until publication of patent application can be shortened to avoid making the efforts simultaneously.

## 8. Conclusions

Quantum computers are highly sensitive. Open-gate computers need extra energy, highly stable cryogenic conditions (@absolute zero, −459.67 °F), without atmospheric pressure, very peaceful and isolated in a still state without any external disturbances to work. Outside disruption called "noise" can easily disrupt the delicate qubit, disturbing its superposition state. Fluctuations in temperature, magnetic fields, and vibration can generate errors in a qubit's micro-systems destroying entanglement. These problems are difficult to overcome, at least till now. Overprotection of IP will create legal and economic monopolies for first-movers big corporations producing inequalities and patent thickets leading towards distorted innovation ecosystem.

## References

Aboy, M., Minssen, T., & Kop, M. "Mapping the patent landscape of quantum technologies: patenting trends, innovation and policy implications". *IIC-International Review of Intellectual Property and Competition Law* 53, no. 6 (2022): 853-882. https://doi.org/10.1007/s40319-022-01209-3 .

Dowling, J. P., & Milburn, G. J. (2003). "Quantum technology: the second quantum revolution". *Philosophical Transactions of the Royal Society of London. Series A: Mathematical, Physical and Engineering Sciences* 361, no.1809 (2003):1655-1674. https://doi.org/10.1098/rsta.2003.1227.

Dydenko, I. "Searching claims comprising non-technical features at the European patent office". *World Patent Information* 54, no. S (2018): S44-S50. https://doi.org/10.1016/j.wpi.2017.05.005.

Foss-Solbrekk, K. "Three routes to protecting ai systems and their algorithms under IP law: the good, the bad and the ugly". *Journal of Intellectual Property Law & Practice* 16, no. 3 (2021):247-258. https://doi.org/10.1093/jiplp/jpab033.

Harrison, R. "Quantum computing innovations". https://blog.shp.law/index.php/2022/01/15/quantum-computing-innovations/ (Accessed 20 December 2023)

Hemel, D. J., & Ouellette, L. L. "Beyond the patents-prizes debate". *Texas Law Review* 92, no.2 (2013):303-382. https://texaslawreview.org/wp-content/uploads/2015/08/HemelOuellette.pdf .

Keempas, T. "A note on artificial intelligence and intellectual property in Sweden and the EU". *Stockholm IP Law Review* 1, no.1 (2020): 154-165. https://www.lawpub.se/artikel/4778.

Kop, M. "Establishing a legal-ethical framework for Quantum Technology". *Yale Journal of Law & Technology*, (2021b). https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology (Accessed 30 December 2023).

Kop, M. "Regulating transformative technology in the quantum age: intellectual property, standardization & sustainable innovation". Transatlantic Antitrust and IPR Developments (2020). https://law.stanford.edu/publications/regulating-transformative-technology-in-the-quantum-age-intellectual-property-standardization-sustainable-innovation/(Accessed30 December 2023).

Kop, M., & Brongersma, M. "Integrating bespoke IP regimes for quantum technology into national security policy". Stanford University. (2021). https://dx.doi.org/10.2139/ssrn.4095763 (Accessed 30 December 2023).

Kop, M., Aboy, M., & Minssen, T. "Intellectual property in quantum computing and market power: a theoretical discussion and empirical analysis". *Journal of Intellectual Property Law and Practice* 17, no.8 (2022): 613-628. https://doi.org/10.1093/jiplp/jpac060.

Kop, M., "Quantum computing and intellectual property law". *Berkeley Technology Law Journal* 25, no.3 (2021a): 101-115. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3860456.

Mason, E. "Trends in quantum computing patents". *Quantum Economic development consortium* (2021). https://quantumconsortium.org/blog/trends-in-quantum-computing-patents/ (Accessed 20 December 2023).

Merchant, P. "International patent insights on quantum computing". *International patent insights on quantum computing* (2023). https://www.marks-clerk.com/insights/articles/international-patent-insights-on-quantum-computing/ (Accessed 20 May 2023).

Singh, P. "Role of intellectual property rights in the era of quantum technology". (2022). https://www.iiprd.com/role-of-intellectual-property-rights-in-the-era-of-quantum-technology/ (Accessed 30 December 2023).

Sterckx, S., & Cockbain, J. "The patentability of computer programs in Europe: an improved interpretation of articles 52 (2) and (3) of the European patent convention". *The Journal of World Intellectual Property* 13, no. 3 (2010): 366-402. https://doi.org/10.1111/j.1747-1796.2009.00390.x.

Marella, S. T., & Parisa H. S. K. *Introduction to quantum computing*. In: *Quantum Computing and Communication*; Ed.: Zhao, Y. (Rijeka-Croatia, IntechOpen:2022). DOI: 10.5772/intechopen.94103.

Wadha, V. "Why quantum computing is even more dangerous than artificial intelligence". (2022). https://foreignpolicy.com/2022/08/21/quantum-computing-artificial-intelligence-ai-technology-regulation/.

Wilson-Bilik, M. J., Bahar, M., Sand, F. L. A., & Bloomfield, C. "Getting ready for quantum computing: managing the quantum threat". https://www.lexology.com/library/detail.aspx?g=573f7bfd-e7b9-4df3-afa3-79807adf56b1 (Accessed 30 December 2023).