Quantum Computing and Intellectual Property Law

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Abstract

What types of intellectual property (IP) rights can be vested in the components of a scalable quantum computer? Are there sufficient market-set innovation incentives for the development and dissemination of quantum software and hardware structures? Or is there a need for open source ecosystems, enrichment of the public domain and even democratization of quantum technology? The article explores possible answers to these tantalizing questions.

The article demonstrates that strategically using a mixture of IP rights to maximize the value of the IP portfolio of the quantum computer's owner, potentially leads to IP protection in perpetuity. Overlapping IP protection regimes can result in unlimited duration of global exclusive exploitation rights for first movers, being a handful of universities and large corporations. The ensuing IP overprotection in the field of quantum computing leads to an unwanted concentration of market power. Overprotection of information causes market barriers and hinders both healthy competition and industry-specific innovation. In this particular case it slows down progress in an important application area of quantum technology, namely quantum computing.

In general, our current IP framework is not written with quantum technology in mind. IP should be an exception -limited in time and scope- to the rule that information goods can be used for the common good without restraint. IP law cannot incentivize creation, prevent market failure, fix winner-takes-all effects, eliminate free riding and prohibit predatory market behavior at the same time. To encourage fair competition and correct market skewness, antitrust law is the instrument of choice.

The article proposes a solution tailored to the exponential pace of innovation in The Quantum Age, by introducing shorter IP protection durations of 3 to 10 years for Quantum and AI infused creations and inventions. These shorter terms could be made applicable to both the software and the hardware side of things. Clarity about the recommended limited durations of exclusive rights -in combination with compulsory licenses or fixed prized statutory licenses- encourages legal certainty, knowledge dissemination and follow on innovation within the quantum domain. In this light, policy makers should build an innovation architecture that mixes freedom (e.g. access, public domain) and control (e.g. incentive & reward mechanisms).

The article concludes that anticipating spectacular advancements in quantum technology, the time is now ripe for governments, research institutions and the markets to prepare regulatory and IP strategies that strike the right balance between safeguarding our fundamental rights & freedoms, our democratic norms & standards, and pursued policy goals that include rapid technology transfer, the free flow of information and the creation of a thriving global quantum ecosystem, whilst encouraging healthy competition and incentivizing sustainable innovation.

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1. What is Quantum Computing?

Quantum computing derives its constituent elements from principles of quantum mechanics (superposition, entanglement and tunnelling), the theory of the very small. Quantum mechanics describes the interaction between matter and energy and the building blocks of atoms at the subatomic level, beyond classical physics. Subatomic particles such as protons, neutrons and electrons. Einstein's general theory of relativity on the other hand, is the theory of the very large, and describes the operation of laws of physics, including gravity, speed of light, time, space, mass and energy (E = mc squared)[2].

Quantum bits or qubits are the quantum version of classic (binary) bits.[3] A qubit can be a 1 or a 0, or both. We call this superposition.[4] A qubit represents a quantum particle in superposition of all possible quantum states.[5] In addition to superposition, quantum particles can be in several places at the same time, while they remain "aware" of each other. This is known as entanglement.[6] Quantum tunnelling refers to the observable fact in which subatomic scale particles penetrate a potential energy barrier that is higher in energy, such as a steel door. For us humans these are counterintuitive quantum states.

What Can We Do with a Quantum Computer?

In general, quantum computing is ideally suited for solving mathematical optimization problems, solving some of the computationally hard problems on which we build current cryptography,[7] and simulating the behavior of atoms and elementary particles. Quantum computers are useful when modelling nature[8] or searching large amounts of data using parallel quantum query algorithms.[9] They excel when complex systems have to be simulated. Quantum machines also have limits. Quantum computers can help finding approximate solutions to computational complexity NP-hard and NP-complete problems, such as the travelling salesman problem.[10] They can however not solve them by delivering exact answers.

Quantum & Artificial Intelligence Hybrids

The combination of artificial intelligence, machine learning and functioning quantum computers & simulators can theoretically solve mathematical, physical and chemical optimization problems.

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[2] Albert Einstein, On the Electrodynamics of Moving Bodies, by Annalen der Physik, 17, 1905. Reprinted in The Principle of Relativity, Dover Pub. E = Energy, M= Mass, C= Speed of light.
[3] *See, e.g.,* Xiang Fu, Quantum Control Architecture: Bridging the Gap between Quantum Software and Hardware, (2018), https://doi.org/10.4233/uuid:8205cc34-30df-45f0-b6eb-8081bdb765b8.
[4] Xiang Fu, Quantum Control Architecture: Bridging the Gap between Quantum Software and Hardware, (2018), https://doi.org/10.4233/uuid:8205cc34-30df-45f0-b6eb-8081bdb765b8.
[5] *See,* https://docs.microsoft.com/en-us/quantum/overview/understanding-quantum-computing.
[6] Fu, *supra* note 4
[7] For quantum-safe cryptography using an advanced security proxy (ASP), *see,* https://www.tno.nl/en/focus-areas/information-communication-technology/roadmaps/trusted-ict/quantum/quantum-safe-crypto/.
[8] *See,* https://www.ias.edu/ideas/2014/ambainis-quantum-computing. Quantum information can lead to a better understanding of the principles of quantum systems.
[9] *See,* Jeffery, S., Magniez, F. & de Wolf, R. Optimal Parallel Quantum Query Algorithms. Algorithmica 79, 509–529 (2017). https://doi.org/10.1007/s00453-016-0206-z.
[10] *See,* https://ocw.mit.edu/courses/electrical-engineering-and-computer-science/6-845-quantum-complexity-theory-fall-2010/.

Technological synergies can disentangle problems that are currently not soluble with the help of binary computers. Synergies such as AI & quantum computing hybrids consisting of bits, neurons and qubits. Combining powerful AI algorithms using classical computers together with quantum algorithms that utilize the quantum mechanical principles, have the potential to revolutionize bio engineering - including synthetic cells[11] - and nano engineering. Quantum will enhance AI. In the coming years, interaction between quantum technology and AI will give a new perspective of science itself to the world. Techno-optimists expect that quantum computing and quantum software will play an important role in the development of autonomous artificial beings, and in the awakening of Artificial Super Intelligence ('**ASI**'). A downright paradigm shift.

2. IP on the Components of Quantum Computers

Let us link quantum computing to intellectual property law. Quantum computers can be protected by different types of intellectual and industrial property rights, such as chip rights (semi-conductor topography protection), patents, copyrights, trade secrets, design rights and trademarks. Per component, we discuss which IP rights can be established. We also discuss whether there are gaps / loopholes in protection or whether there are overlaps. Although IP rights are territorial rights, we make these qualifications as much as possible from the perspective of an international IP acquis.[12] There may be regional differences in formal and material requirements, flexibilities, scope and term of protection in the EU, China, India or the US.

The Components

Quantum computers, depending on their specific application in the domains listed above, and depending on their precise implementation method, may contain the following layers of components[13]: the technology building blocks (qubits), quantum gates & multipliers, quantum integrated circuit chips, the various types of quantum processors such as spin qubits and superconducting[14] transmon qubits[15], quantum interference devices[16], compiler engines (i.e. optimizers, translators, mappers)[17], 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 software[18],

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[11] *See,* https://www.genome.gov/about-genomics/policy-issues/Synthetic-Biology.

[12] *Cf.* Paul Goldstein & Bernt Hugenholtz, *International Copyright: Principles, Law, and Practice* (4rd edn, OUP 2019), and Maciej Szpunar, Territoriality of Union Law in The Era of Globalisation, in: « Evolution des rapports entre les ordres juridiques de l'Union européenne, international et nationaux » Liber Amicorum Jiří Malenovský, D. Petrlík, M. Bobek, J. Passer et A. Masson (dir.), Bruylant 2020.

[13] 5 Essential Hardware Components of a Quantum Computer." National Academies of Sciences, Engineering, and Medicine. 2019. *Quantum Computing: Progress and Prospects*. Washington, DC: The National Academies Press. doi: 10.17226/25196, https://www.nap.edu/read/25196/chapter/7#114.

[14] *Cf.* Glennda Chui, Stanford physicist's quest for the perfect keys to unlock the mysteries of superconductivity, September 10, 2020, https://news.stanford.edu/2020/09/10/unlocking-mysteries-superconductivity/.

[15] *See,* https://qutech.nl/demonstrators/.

[16] *See,* Loft, N.J.S., Kjaergaard, M., Kristensen, L.B. *et al.* Quantum interference device for controlled two-qubit operations. *npj Quantum Inf* 6, 47 (2020). https://doi.org/10.1038/s41534-020-0275-3.

[17] *See,* Epiqc, New compiler makes quantum computers two times faster, University of Chicago, October 11 2019, https://phys.org/news/2019-10-quantum-faster.html.

[18] 6 Essential Software Components of a Scalable Quantum Computer." National Academies of Sciences, Engineering, and Medicine. 2019. *Quantum Computing: Progress and Prospects*. Washington, DC: The National Academies Press. doi: 10.17226/25196, https://www.nap.edu/read/25196/chapter/8#137.

smart quantum algorithms[19], the API's (application programming interface),[20] quantum arithmetic unit (quantum addition, subtraction, multiplication, and exponentiation), runtime assertion & configuration, quantum computing platforms, program paradigm & languages, the Bacon-Shor stabilization code, three dimensional color codes[21], and surface codes.

Furthermore, the actual casing (the dilution refrigerator) of a quantum computer contains -*inter alia*- a cryoperm shield, quantum amplifiers, cryogenic isolators, a mixing chamber, superconducting coaxial lines[22], input microwave lines and a qubit signal amplifier.

In addition, a conventional computer is used to be able to access the output of the quantum computer in human and machine-readable formats. This means there is a certain amount of 'classical control', through the quantum-classical interface. In case we are dealing with quantum & AI hybrids (or hybrid quantum-classical co-processing systems) we have to add all the parts of the AI system to this list of components, including the inference engine that processes the rules.[23]

Creations & Inventions

Only novel, useful, inventive and non-obvious inventions made by a human inventor, can be patented. Copyrights generally require a minimum of creativity, originality and a human author.[24]

Technical discoveries that have been developed and embedded into hardware, can be patented. Software can be copyrighted. From the perspective of IP rights, we can group the components of a quantum computer by hardware (chip rights, design and utility patents), software (copyrights, creative commons), and algorithms (open source[25] or public domain). The protection term for patents is 20 years, compared to 70 years for software. One of the reasons for this difference, is that the copyright system and the patent system both have distinct objectives.[26] In general, quantum computing hardware is much more difficult to develop and replicate than the accompanying software and algorithms. It requires more investments to make than writing the code. As a result of

[19] *See,* Montanaro, A. Quantum algorithms: an overview. *npj Quantum Inf* 2, 15023 (2016). https://doi.org/10.1038/npjqi.2015.23 and "3 Quantum Algorithms and Applications." National Academies of Sciences, Engineering, and Medicine. 2019. *Quantum Computing: Progress and Prospects*. Washington, DC: The National Academies Press. doi: 10.17226/25196, https://www.nap.edu/read/25196/chapter/5.

[20] *See, e.g.,* https://en.wikipedia.org/wiki/Quantum_programming.

[21] *See,* Aleksander Kubica, Michael E. Beverland, Fernando Brandão, John Preskill, and Krysta M. Svore, Three-Dimensional Color Code Thresholds via Statistical-Mechanical Mapping, Phys. Rev. Lett. 120, 180501 – Published 4 May 2018, https://journals.aps.org/prl/abstract/10.1103/PhysRevLett.120.180501.

[22] *Cf.* Yufan Li, Xiaoying Xu, M.-H. Lee, M.-W. Chu, C. L. Chien, Observation of half-quantum flux in the unconventional superconductor β-Bi_2Pd, https://science.sciencemag.org/content/366/6462/238 *Science,* 11 Oct 2019 : 238-241 and Johns Hopkins University, New Superconducting Material Discovered That Could Power Quantum Computers of the Future, October 11 2019, https://scitechdaily.com/new-superconducting-material-discovered-that-could-power-quantum-computers-of-the-future/.

[23] Mauritz Kop, *AI & Intellectual Property: Towards an Articulated Public Domain*, 28 Tex. Intell. Prop. L. J. 297, 2020, http://tiplj.org/wp-content/uploads/Volumes/v28/Kop_Final.pdf.

[24] *Cf.* Kop, *supra* note 23.

[25] *See, e.g.,* the Qiskit Open-Source Quantum Development, https://qiskit.org/. Qiskit is an open source SDK for working with quantum computers at the level of pulses, circuits and algorithms.

[26] Menell, Peter S. and Lemley, Mark A. and Merges, Robert P. and Balganesh, Shyamkrishna, Intellectual Property in the New Technological Age: 2020 (Clause 8 Publishing, 2020).

this, computer chips can become subject to geopolitical conflicts and export control reforms[27], as observed in today's trade war between the US and China.[28]

Patents

The patent system aims to incentivize inventors to disclose, produce and market their invention with the prospect of return on investment.[29] It intends to encourage the detailed disclosure of innovative ideas and optimize the allocation of R&D capacity, by granting exclusive rights to the inventor. At the same time, it incentivizes inventors to improve and build upon earlier patents.[30]

The following components are eligible for patent protection:

The technology building blocks (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. The 'quantum computing process' can be protected by patent as well. The dilution refrigerator as a whole, including its individual cryoperm shield, quantum amplifiers, cryogenic isolators, a mixing chamber, superconducting coaxial lines, input microwave lines and a qubit signal amplifier component, are also eligible for patenting.

Copyrights

Copyright intends to incentivize and maximize creativity, cultural diversity, technological progress and freedom of expression. An important objective of copyright is to stimulate creation and dissemination of diverse cultural expression by enabling successive generations of authors to draw freely on the works of their successors.

According to TRIPs and WTC, creative aspects of software source code and firmware can be protected by copyright, as where they literary works. Expression of computer software is protected, not its functionality.[31] The idea/expression dichotomy prescribes that ideas are not protected by copyright. Algorithms, functionality, principles and ideas on the other hand, are not protected.[32] These are part of the public domain. Before the expression of an idea is captured in a tangible medium, it can be time-stamped by an i-Depot. Ideas can also be protected contractually, by an NDA.

The following components are eligible for copyright protection:

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[27] *See,* https://merics.org/en/report/export-controls-and-us-china-tech-war and https://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI%282019%29644187.
[28] *See, e.g.,* https://www.bbc.com/news/business-45899310.
[29] Menell et al., *supra* note 26.
[30] Kop, *supra* note 23.
[31] *See, e.g.,* Directive 2009/24/EC of the European Parliament and of the Council of 23 April 2009 on the legal protection of computer programs (EU Software Directive).
[32] Daniel Gervais and Estelle Derclaye, 'The scope of computer program protection after SAS: are we closer to answers?' 34(8) European Intellectual Property Review, 565 (2012) (pp. 565-572)

Quantum software, the API's (application programming interface), quantum arithmetic unit (quantum addition, subtraction, multiplication, and exponentiation), runtime assertion & configuration, quantum computing platforms, program paradigm & languages, the Bacon-Shor stabilization code, color codes, and surface codes. These components fall within the scope of copyrightable subject matter.

It is possible that certain applied program languages, such as eDSL in Python[33], will be open sourced instead of copyright protected, or licensed for use via Creative Commons.[34] As with classical computing, it is expected that both commercial and open source operating systems will come onto the markets.

A few uncrystallized areas require specific attention and perhaps some legal pioneering. Functionality for instance, is not protected by copyright.[35] This raises the question whether software and API functionality should be protected by patents. Arguments for and against patentability of software functionality and computer implemented inventions can be made.[36] Legal uncertainty about IP protection, whether concerning copyrights or patents, usually results in a shift to trade secrets, which generally stifles innovation.[37]

Input & Output Data

Depending on the application area, current quantum computing systems input consists of problem definitions. It is also possible to feed input data from a classical computing device into a quantum circuit, via the quantum-classical interface.

In case of AI hybrids that utilize machine learning training datasets, clearance of the input information is needed in the event this data represents IP subject matter.[38] Besides a rainbow of potential IP rights potentially vested in the data that need to be licensed under current law, including a *sui generis* database right on the training corpus itself (in territory Europe), the main roadblocks for the uptake of AI & data are privacy and GDPR concerns, and uncertainty about ownership of data.[39] There is a lack of trust in the existing rules, because they are complex and abstract and not written specifically for AI and machine learning training data. database EU. As for AI, there needs to be a broad exemption, or even a superior right to process data for quantum computing purposes, that respects privacy and other fundamental rights.[40]

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[33] *See,* https://github.com/topics/edsl.

[34] *See,* https://creativecommons.org/.

[35] Pamela Samuelson, 'Functionality and Expression in Computer Programs: Refining the Tests for Software Copyright Infringement' (January 31, 2017). Berkeley Technology Law Journal, Forthcoming. Available at SSRN: https://ssrn.com/abstract=2909152 and Peter Menell, Rise of the API Copyright Dead?: An Updated Epitaph for Copyright Protection of Network and Functional Features of Computer Software (January 18, 2017). 31 Harvard Journal of Law & Technology 305 (2018), UC Berkeley Public Law Research Paper No. 2893192, Available at SSRN: https://ssrn.com/abstract=2893192.

[36] For case law on this subject, *see,* Péter Mezei, Dóra Hajdú, Luis Javier Capote-Pérez and Jie Qin, Comparative Digital Copyright Law (Vandeplas publishing 2020).

[37] Kop, *supra* note 23

[38] *See,* Mauritz Kop, *Machine Learning & EU Data Sharing Practices*, TTLF NEWSLETTER ON TRANSATLANTIC ANTITRUST AND IPR DEVELOPMENTS STANFORD-VIENNA TRANSATLANTIC TECHNOLOGY LAW FORUM, STANFORD UNIVERSITY 2020, VOLUME 1, https://www-cdn.law.stanford.edu/wp-content/uploads/2015/04/2020-1.pdf. *Cf.* Kop, *supra* note 23.

[39] *id.*

[40] Mauritz Kop, *The Right to Process Data for Machine Learning Purposes in the EU* (June 22, 2020). HARVARD LAW SCHOOL, HARVARD JOURNAL OF LAW & TECHNOLOGY, VOLUME 34 DIGEST SPRING 2021, pp. 1-23, https://jolt.law.harvard.edu/digest/the-right-to-process-data-for-machine-learning-purposes-in-the-eu. *Cf.*

In case quantum computing output represents IP subject matter, this output is eligible for IP protection. It can then be licensed or sold. If desired, IP rights on the output can also be waived and pushed into the public domain.

IP Ownership: Legal Subjectivity and Public Domain

Output created or invented by autonomous quantum/ AI systems without human upstream or downstream intervention should be public domain. The output lacks human creativity and inventiveness and society benefits from a robust public domain. Besides that, IP rights can only be owned by legal subjects, such as people, universities or corporations. Autonomous systems lack legal subjectivity or legal personhood needed to own rights and carry responsibilities. Machine generated Quantum/AI Creations & Inventions should be *Res Publicae ex Machina*.[41] These belong in an articulated public domain.

Trade Secrets & Trademarks

On top of copyrights and patents, virtually each component can contain trademarks (and in some circumstances trade-dress) and trade secrets[42], with potentially unlimited duration of IP protection. Further, cybersecurity law and national security considerations could, beyond the scope of the IP toolkit, play a role in keeping technological breakthroughs a state secret. As is the case with AI system, legal uncertainty about the patentability of quantum computing systems together with the unlimited duration of trade secret rights, could ultimately cause a shift towards trade secrets, in order to protect assets and commodify quantum computing applications. This trend might ensue in a disincentive to disclose ideas and impedes dissemination of information, technology transfer to the market[43] and follow on innovation.[44]

Note that a trade secret right does not protect against reverse engineering. This IP loophole can be filled by concluding contracts that prohibit unwanted reverse engineering. [45]

Additionally, both a quantum computer's looks, brands and functional design can be protected. Product design, artwork, logos, software interfaces, layouts and hardware modelling can, depending on the territory for which protection is sought, be protected by an arrangement of IP instruments such as design rights, tradename rights and trade dress.

IP Overlap & Overprotection

Christophe Geiger, Giancarlo Frosio, & Oleksandr Bulayenko, *The Exception for Text and Data Mining (TDM) in the Proposed Directive on Copyright in the Digital Single Market - Legal Aspects*, CENTRE FOR INTERNATIONAL INTELLECTUAL PROPERTY STUDIES (CEIPI) RESEARCH PAPER NO. 2018-02 (March 2, 2018). *Cf.* Sean Flynn, Christophe Geiger & João Quintais et al., *Implementing User Rights for Research in the Field of Artificial Intelligence: A Call for International Action,* EUROPEAN INTELLECTUAL PROPERTY REVIEW 2020, ISSUE 7 (April 20, 2020). Available at SSRN: https://ssrn.com/abstract=3578819.

[41] Kop, *supra* note 23.

[42] *Cf.* Drexl, Josef, 'Designing Competitive Markets for Industrial Data - Between Propertisation and Access' (October 31, 2016).

[43] *See, e.g.,* https://www.tno.nl/en/focus-areas/techtransfer/.

[44] Wachter, Sandra and Mittelstadt, Brent, 'A Right to Reasonable Inferences: Re-Thinking Data Protection Law in the Age of Big Data and AI' (October 05, 2018). Columbia Business Law Review, 2019(1).

[45] Kop, *supra* note 23.

Strategically using a mixture of IP rights to maximize and protect the value of the IP portfolio of the quantum computer's owner, can result in an unlimited duration of global exclusive exploitation rights for first movers, absent compulsory licensing of standard essential patents (SEP) in certain territories. Thus, there are no consequential loopholes in IP protection possibilities. Far from it. Instead, there is an overlap of IP protection regimes.[46] At this time, new layers of rights do not seem appropriate.

Other quantum technology applications, among which quantum sensing, quantum simulation and the quantum internet are equally eligible for IP protection, using the same amalgam of IP rights. From a beyond IP innovation law perspective, future quantum internet functionality[47] ought to be public domain and net neutrality should exist. Its constituting, enabling components, however, could in theory be protected by an array of IP rights. With each right protecting something different. The same applies to quantum sensors, quantum simulation, engineered/synthesized plants and novel materials invented with the help of quantum technology.

In general, our current intellectual property framework is not written with quantum technology in mind. Intellectual property should be an exception -limited in time and scope- to the rule that information goods can be used for the common good without restraint. From a dogmatic sustainable innovation policy perspective, IP rights holders should not be legally entitled to internalize the full social benefits of their creations and inventions.[48] There is no need to limit uncompensated positive externalities in a well-structured quantum technology market place, nor is there a need to internalize such positive spillovers in intellectual property, after initial investment costs have been retrieved.[49] Positive quantum technology creation and invention externalities do not need to be remedied by IP regulations, taxes or subsidies, beyond the break-even-point. Furthermore, there is no tragedy of the commons in IP on quantum technology knowledge goods.[50] Information cannot be overused.

Intellectual property cannot incentivize creation, prevent market failure, fix winner-takes-all effects, eliminate free riding and prohibit predatory market behavior at the same time. To encourage fair competition and correct market skewness, antitrust law is the instrument of choice.[51]

The question is whether the identified overlap in regimes benefits business dynamism and accelerated innovation.[52] The subsequent IP overprotection may create barriers for market entrants and raise concerns regarding fair competition, freedom of expression and the creation of new jobs.[53]

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[46] *id. Cf.* Deltorn, Jean-Marc and Macrez, Franck, Authorship in the Age of Machine learning and Artificial Intelligence (August 1, 2018). In: Sean M. O'Connor (ed.), The Oxford Handbook of Music Law and Policy, Oxford University Press, 2019 (Forthcoming); Centre for International Intellectual Property Studies (CEIPI) Research Paper No. 2018-10. Available at SSRN: https://ssrn.com/abstract=3261329.

[47] *Cf.* https://ec.europa.eu/digital-single-market/en/news/quantum-technologies-and-advent-quantum-internet-european-union-brochure.

[48] *Cf.* Lemley, Mark A., Property, *Intellectual Property, and Free Riding*. Texas Law Review, Vol. 83, p. 1031, 2005. Available at SSRN: https://ssrn.com/abstract=582602.

[49] *id.*

[50] Kop, *supra* note 23.

[51] To *inter alia* ensure that dominant online platforms can be challenged by new market entrants and existing competitors, so that consumers have the widest choice and the Single Market remains competitive and open to innovations, the European Commission recently introduced the Digital Services Act package, as part of the European Digital Strategy. *See,* https://ec.europa.eu/digital-single-market/en/digital-services-act-package.

[52] *Cf.* Deltorn, Jean-Marc and Macrez, Franck, Authorship in the Age of Machine learning and Artificial Intelligence (August 1, 2018). In: Sean M. O'Connor (ed.), The Oxford Handbook of Music Law and Policy, Oxford University Press, 2019 (Forthcoming) ; Centre for International Intellectual Property Studies (CEIPI) Research Paper No. 2018-10. Available at SSRN: https://ssrn.com/abstract=3261329.

[53] Kop, *supra* note 23.

Overprotection might hinder industry-specific innovation. In this particular case it slows down progress in an important application area of quantum technology, namely quantum computing.

A solution tailored to the exponential pace of innovation in The Quantum Age, is to introduce shorter IP protection durations of 3 to 10 years for Quantum and AI infused creations and inventions. These shorter terms could be made applicable to both the software and the hardware side of things. Clarity about the proposed limited durations of exclusive rights -in combination with compulsory licenses or fixed prized statutory licenses- encourages legal certainty, knowledge dissemination and follow on innovation within the quantum domain.[54] In this light, policy makers should build an innovation architecture that mixes freedom (e.g. access, public domain) and control (e.g. incentive & reward mechanisms).

On November 25th 2020 the European Commission presented its IP Action Plan, which promises an '*overhaul of the intellectual property system to strengthen Europe's ability to develop next generation technologies and reflect advances in data and AI'*.[55] The EC aims to set global standards in IP. The Action Plan announces Action announces measures in five key areas[56]:

1. Improving the protection of IP
2. Boost the uptake of IP by small and medium-sized companies (SMEs)
3. Facilitate the sharing of IP
4. Fight counterfeiting and improve enforcement of IP rights
5. Promote a global level playing field

IP Alternatives

With regard to innovation incentives and allocation mechanisms, IP rights are not the only answer - and not automatically the best answer. Policy makers could apply innovation policy pluralism (i.e. mix, match and layer IP alternatives such as anti-trust law, contract law, consumer privacy protection, tax law, standardization & certification, as well as prizes, subsidies, public-private funding, competitions, penalty's and fines) to enable fair-trading conditions, remedy externalities and balance the effects of exponential innovation within the markets.[57] Because innovation incentive & reward mechanisms, externalities and safety/security risks vary per industry and per technology, policy makers should differentiate more unequivocally between economic sectors, when designing regulatory solutions. Further, IP rights might be less necessary in a quantum and AI driven world where creation, reproduction, and distribution have become inexpensive.[58]

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[54] *id.*
[55] *See,* https://ec.europa.eu/commission/presscorner/detail/en/IP_20_2187 and https://ec.europa.eu/docsroom/documents/43865/attachments/2/translations/en/renditions/native.
[56] *id.*
[57] *See,* Daniel J. Hemel & Lisa Larrimore Ouellette, *Innovation Policy Pluralism*, 128 YALE L.J. (2019), Available at: https://digitalcommons.law.yale.edu/ylj/vol128/iss3/1 and Mauritz Kop, Beyond AI & Intellectual Property: Regulating Disruptive Innovation in Europe and the United States – A Comparative Analysis, https://law.stanford.edu/projects/beyond-ai-intellectual-property-regulating-disruptive-innovation-in-europe-and-the-united-states-a-comparative-analysis/.
[58] Lemley, Mark A., IP in a World Without Scarcity (March 24, 2014). Stanford Public Law Working Paper No. 2413974. Available at SSRN: https://ssrn.com/abstract=2413974.

Conclusion

Our current intellectual property framework is not written with quantum technology in mind. Anticipating spectacular technological advancements in quantum computing, quantum sensing and the quantum internet, the time is now ripe for governments, research institutions and the markets to prepare regulatory and intellectual property strategies that strike the right balance between safeguarding our democratic values, fundamental rights & freedoms,[59] and pursue policy goals that include rapid technology transfer and the free flow of information, whilst encouraging healthy competition and incentivizing sustainable innovation.

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[59] For a detailed description of ethical, legal and social guiding principles for quantum technology, *see,* Mauritz Kop, *Establishing a Legal-Ethical Framework for Quantum Technology*, (February 28, 2021), Yale Journal of Law & Technology (YJoLT) The Record, March 30, 2021, https://yjolt.org/blog/establishing-legal-ethical-framework-quantum-technology