KEYWORDS:
QUANTUM LAW, QUANTUM COMPUTING, QUANTUM MECHANICS, QUANTUM IMPERATIVE, ETHICS OF TECHNOLOGY
DOI:
https://doi.org/10.5771/2747-5174-2021-1-52

The Quantum Imperative: Addressing the Legal Dimension of Quantum Computers

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ABSTRACT:

Quantum computers are legal things which are going to affect our lives in a tangible manner. As such, their operation and development must be regulated and supervised. No doubt, the transformational potential of quantum computing is remarkable. But if it goes unchecked the development of quantum computers is also going to impact social and legal power-relations in a remarkable manner. Legal principles that can guide regulatory action must be developed in order to hedge the risks associated with the development of quantum computing. This article contributes to the development of such principles by proposing the quantum imperative. The quantum imperative provides that regulators and developers must ensure that the development of quantum computers: (1) does not create or exacerbate inequalities, (2) does not undermine individual autonomy, and that it (3) does not occur without consulting those whose interests they affect.

ACKNOWLEDGMENTS:

I benefitted greatly from discussing drafts of this text with my fellow Quantum Law Project members Jeffery Atik, Karl M. Manheim and Timo Minssen. I also wish to thank Tova Bennet, Hanna Drimalla, Jordi Mur Petit and Christian Neumeier for their most helpful comments on earlier versions of this text. The Quantum Law Project at Lund University is funded by the Wallenberg Programme on AI, Autonomous Systems and Software – Humanities and Society (WASP-HS).

1. INTRODUCTION

Quantum computers are legal things. They may also be strange,[1] spooky[2] or 'weird and wonderful'.[3] But the tendency to describe them in such colourful terms must not distract from the fact that quantum computers are ultimately not a thing of magic, but technological tools that are bound to affect our lives in a tangible manner. As such, their development and their operation raise a host of legal questions. Some of those questions relate to the way in which technology conditions human behaviour. Like legal norms, technological norms can give effect to human choices by granting rights or restrict choice by prescribing specific modes of action. Other legal questions arise in connection with the long-recognized propensity of tools to enhance the powers of some and to deprive others of it. Indeed, the ability to access tools was deemed to be of such significance for the relative status of a species that the qualifier *Homo* (*Homo sapiens*, *Homo habilis* etc.) was reserved to those of our human ancestors who could access tools and was withheld from those who could not. [4]

It might be an exaggeration to equate the relation between those who have access to quantum computers and those who do not with the relation between the first humans who could make Oldowan tools and those who could not.[5] But there is no doubt that the remarkable potential of quantum computing will, if unchecked, also impact social power-relations in a remarkable manner. In order to hedge the risks associated with quantum computing it is important to develop legal principles that can guide regulatory action concerning quantum computers. This article aims to contribute to the development of such principles by proposing a three-pronged quantum imperative. The quantum imperative provides that regulators and developers must ensure that the development of quantum computers:

1. does not create or exacerbate inequalities,

2. does not undermine individual autonomy,

3. does not occur without consulting those whose interests they affect.

Before turning to a detailed consideration of the quantum imperative in section 4 of the article, it is helpful to consider briefly the essential characteristics of quantum computers (section 2) and the legal issues associated with their development and operation (section 3).

2. CHARACTERISTICS OF QUANTUM COMPUTERS

When describing the characteristics of quantum computers it is tempting to begin by explaining the difference between qubits and bits, the collapse of the wave function or by relating the tale of Schrödinger's Cat. I shall not do this here.[6] Often, the presentation of the technical details of quantum computers makes it harder to detect the underlying legal questions. No doubt, a detailed regulation of quantum computers eventually requires a detailed understanding of their characteristics. However, for the purposes of understanding the big picture – the overarching legal questions – it suffices to know three things: first, quantum computers exploit several phenomena of quantum mechanics – including superposition and entanglement – to perform extremely complex calculations. Second, the construction and operation of quantum computers involves high costs and expertise. Among other things, they require an ultra high vacuum and ultralow temperatures (at times as low as -273.15°C). This means that it is unlikely that quantum computers will be widely available for the foreseeable future. Finally, the computational power of quantum computers is superior to that of classical computers but only with respect to very specific use cases. This means quantum computers will not replace classical computers. But they can perform specific tasks that classical computers cannot perform or take a very long time to execute. For example, Google has claimed that its quantum computer can resolve a mathematical problem which would take conventional computers around 10,000 years to complete in less than 4 minutes.[7]

Consequently, states and companies are investing significant sums into the development of quantum computers. The European Union is funding quantum computer technology with €1 billion, the German government committed €2 billion. The USA and China are also fighting for dominance in the field with the help of ambitious funding programmes and in close cooperation with private companies such as Google, IBM, Alibaba and Baidu. It is still too early to predict the applications of quantum computers in an exhaustive manner. But likely use cases concern the resolution of problems that could help, for example, to optimize the distribution of limited resources like vaccines (*quantum optimization*).[8] In the field of communication, quantum computers could be used to transmit information in a way that is impossible to decrypt (*quantum communication*).[9] Quantum computers could also facilitate the simulation of molecules, in the context of medical research (*quantum simulation*).[10] Finally, quantum sensors, which are significantly more sensitive than conventional devices, could improve the function of navigation instruments (*quantum sensing*).[11]

There is no question that quantum computers have the potential of making positive contributions to society across all of these four fields of application. However, from a legal point of view, their development and operation is far from unproblematic. In the next section, I will explain why that is the case before proposing the quantum imperative as a strategy to address these issues in the final section.

3. LEGAL ISSUES ASSOCIATED WITH THE DEVELOPMENT AND OPERATION OF QUANTUM COMPUTERS

In order to explain the urgency of legal guidance in this area, this section provides a sketch of the most pressing legal questions associated with the development (A) and the operation of quantum computers (B).

A) LAW AND THE DEVELOPMENT OF QUANTUM COMPUTERS

The most important legal issue with respect to the development of quantum computers concerns the way in which the standards conditioning the operation of quantum computers are set. The development of quantum computers does not follow a pre-determined logic. It is shaped by countless decisions of those who build and programme them. These decisions are never normatively neutral and they have long-lasting consequences.

The decisions concerning the design of technology are never neutral because they are, by necessity, coloured by the values, the convictions of the developers, by imagined use cases and by the historic and social context within which they are embedded. The discovery of the exact features of the atom, for example, did not necessitate the construction of a nuclear bomb. The nuclear bomb was constructed because individual scientists and individual politicians decided that this was a desirable course of action in light of a raging world war.[12] With respect to classical computers, the fact that modern computers were developed in the English-speaking USA meant, for a long time, that standard internet protocols could only handle standard English characters as opposed to non-Latin scripts or non-English characters of the Latin alphabet. The focus on the standard English alphabet was not mandated by any technical necessity. It was simply a reflection of the language spoken by the early programmers. The implications of the decision to develop the nuclear bomb are of course more profound than the linguistic limitations of internet protocols. But both decisions are value judgments and affect the interests of a significant number of stakeholders. They are political decisions and they are also decisions of legal significance because they engage questions of how best to coordinate competing interests within a society.[13]

Decisions concerning the design of technology can also have long-lasting consequences because decisions once taken 'tend to become strongly fixed in material equipment, economic investment, and social habit'.[14] Thus, the decisions of quantum computing's pioneers will inevitably shape the development and use of quantum computers in the future. Already, it has been observed that the commercial actors involved in the development of quantum computers have started to protect their developments by patents,[15] making subsequent modifications difficult.

One area where early standard-setting is going to be of particular significance relates to the fact that quantum computers output the results of their calculations in terms of probabilities.[16] In other words, they present the result of their calculations as the result that is most likely correct. This probabilistic nature of quantum computers means that they can at times produce wrong results.[17] Thus developers of quantum computers and quantum algorithms must decide which margin of error they are willing to accept and which degree of probability they require before a result can be communicated as the correct one. In cases where the stakes are low, a low degree of certainty might be defensible. In other cases, when the stakes are high – in the medical sector, for example, a higher degree of certainty might be required.[18] With respect to these standard-setting decisions developers of quantum computers can exercise a significant degree of discretion. From a legal point of view, this is concerning since these decisions could affect the interests of others even at a very early stage of development.

B) LAW AND THE OPERATION OF QUANTUM COMPUTERS

The most pressing legal issue concerning the application of quantum computers relates to their anticipated ability to overcome conventional encryption protocols. Conventional encryption methods utilize mathematical problems that are easy to solve in one direction but very difficult to solve in the opposite direction. An example of such a problem is prime factorization which is commonly used to encrypt information. Using two prime numbers, eg. 4513 and 5693, it is easy and fast to determine their product (25 692 509). However, it is much more difficult to identify the two prime factors that, when multiplied, provide the pre-defined product of 25 692 509. While there is presently no known (non-quantum) algorithm that could identify these prime factors, one of the first quantum algorithms, 'Shor's algorithm', is able to determine the prime factors even of large numbers relatively quickly.[19] This means that quantum computers will sooner or later be able to circumvent existing encryption mechanisms,[20] threatening to undermine the integrity of 'digital signatures that protect financial transactions, secure communications, e-commerce, identity and electronic voting',[21] for instance. Consequently, privacy interests of individuals, intellectual property and financial interests of companies and national security interests of states would be at risk.

Although large scale quantum computers do not yet exist, the risks associated with quantum cryptography are particularly serious since future quantum algorithms could be used to decipher information retrospectively.[22] That means it is possible to collect conventionally encrypted data now and to decrypt it once sufficiently powerful quantum computers become

available at a later stage.
Against this background, it is crucial to develop strategies to avoid that the development and operation of quantum computers leads to a situation where, on the one hand, there are actors who have unlimited access to previously protected data and can communicate in encrypted form and, on the other hand, actors who have no access to quantum technology and are more or less at the mercy of the former.

4. THE QUANTUM IMPERATIVE

Recognizing both the potential and the risks associated with the development and operation of quantum computers, the quantum imperative proposed here provides that regulators and developers must ensure that the development of quantum computers:

1. does not create or exacerbate inequalities,
2. does not undermine individual autonomy,
3. does not occur without consulting those whose interests they affect.

The imperative's first element addresses the problem that quantum computing, like any technology,[23] risks privileging in the first place those that have access to it.[24] The ability to analyze larger masses of data, to produce better measuring instruments, to develop vaccines or to transmit information more securely will be of little benefit to those who lack access to quantum computing. This inequality can play out among individuals, between individuals and companies, among companies, between companies/individuals and states, and, on a geopolitical level, among states. In view of the high costs and expertise involved in the construction and operation of quantum computers there is a risk that the high-tech global North will gain a significant 'strategic advantage, while other nations fall into "quantum poverty".'[25] Steps must therefore be taken to ensure that the advent of quantum computers does not lead to the creation or exacerbation of inequalities between the privileged and underprivileged, between the rich and poor, between North and South. One way for states and corporate actors to avoid being left behind is of course to invest in their own quantum infrastructures if they are able to do so.

However, the singularly most important implication of the first element of the quantum imperative is to take measures that grant equal access to quantum technologies. This could be achieved, for example, by granting access through cloud services: companies, organizations, states who own quantum computers could make certain computer capacities available to others via the internet for certain periods of time. This model is particularly attractive because it provides access to quantum computers from any location. A prominent example of such a cloud solution is IBM's 'Quantum Experience.'[26] Of course, cloud solutions do not solve the problem of hardware standard setting by a very limited number of actors. But they could at least mitigate the uneven distribution of hardware and enable the participation of scientists/enthusiasts from all over the world in the research and development of quantum computers.

In cases where those possessing quantum technology provide access to their infrastructures voluntarily, legal, regulatory measures might not be required. However, states should certainly be prepared to consider enacting legal norms in this area. Experiences concerning the management of shared resources in space, in the deep sea and, most recently, concerning the distribution of Corona vaccine dosages show that it might be necessary to keep profit-favouring tendencies in check by legal means. Examples of such regulatory measures could include limiting the material or temporal scope of patents or to make technology transfers obligatory in certain areas.[27]

The imperative's second element urges regulators and developers to ensure that the advent of quantum technologies does not undermine the ability of individuals to lead self-determined lives. This element differs from the first since it is not defined in relational terms but stipulates that individual autonomy is in itself a good worthy of protection. As explained above, it is especially the ability of quantum computers to overcome conventional encryption mechanisms that threatens individual autonomy. Regulators must ensure that the potential of quantum communication is not used to undermine existing security infrastructures or data protection. Quantum technologies offer authoritarian states (or, indeed, any state) very potent tools to control their populations, putting at risk civil society actors in particular. Certainly, quantum technology could also enhance the autonomy of civil society actors by offering them a possibility to communicate in a tap-proof way. But the advent of quantum communication could also lead to a lack of access to information, to less transparency and to a loss of autonomy if states use quantum technology to fragment the global internet by setting-up self-contained, impenetrable online environments.[28]

Regulatory measures to pre-empt such developments could entail licensing requirements for quantum algorithms capable of overcoming conventional encryption protocols or contemplating whether already existing export restrictions on arms and related goods should be extended to cover quantum technologies. States have already taken first steps in this regard by adding certain quantum technologies to the list of goods whose export is controlled by the provisions of the Wassenaar Arrangement.[29] However, the Wassenaar Arrangement is not legally binding and regulates only the export of quantum technologies as opposed to the use of quantum technologies by states against the interests of their domestic populations, for example. Thus, additional steps might be necessary in the future.

Additionally, individuals can make autonomous choices concerning their interaction with and acceptance of quantum technologies only if they possess at least a basic understanding of their power. The physicist Richard Feynman once said, ‘anyone who claims to have understood quantum theory has not understood it.’[30] Such descriptions of quantum computers are unhelpful. They erect a barrier between experts and ordinary members of the public.[31] Those who develop quantum technologies must make a serious effort to explain both the potentials and the risks associated with quantum computing in the interest of protecting the ability of individuals to make autonomous choices concerning their relationship with and view of quantum computing. This can be done without entering into intricate debates of quantum mechanics: one does not need to know how nuclear fission works in any detail in order to get a sense of the devastating consequences of a nuclear bomb. Possible formats for educating the public about quantum technologies include outreach programmes by scientific institutions, teaching the basics of quantum physics at school, or public/private awareness campaigns. A good example is a current initiative by CERN, which offers a range of free online lectures that introduces interested members of the public to quantum computers.[32]

The imperative’s second element is closely related to the third which provides that the development of quantum computers must not occur without consulting those whose interests they affect. This third element responds in particular to the problems identified above concerning the setting of technological standards by a select group of actors. The personal, scope of this element is intentionally broad. If social acceptance of quantum computers is to be achieved, it is crucial that developers of quantum computers do not merely educate others about quantum computers but discuss the potentials and risks of quantum computers openly and ensure that the teams of engineers and programmers working on quantum computers reflect the diversity of society.

Further, regulators must ensure that fundamental decisions concerning the design and operation of quantum computers do not escape democratic oversight and control. Acknowledging that technical norms can have the same enabling or limiting effects as legal norms, their establishment should be subjected to the same scrutiny. This means states should consider making institutional arrangements that allow for the public supervision of the decision-making processes that concern the development of quantum computers. Given the complexity of both the issues raised by quantum computing and of regulatory approaches in the innovation sector, it is too early to make detailed recommendations in this regard. One possible approach could be the establishment of an authority licencing and supervising those entrusted with the development of quantum computers. Such an authority could be modelled on existing systems regulating the legal or medical professions. An alternative approach could be to regulate not (only) the developers but (also) their products by imposing registration requirements on hardware or software, for example.[33] Of course, care must always be taken to ensure that regulatory measures do not hinder the development of quantum computers or deter investment in this technology. However, given the enormous potential of quantum computers to exacerbate inequalities and to undermine individuals’ autonomy it is essential to ensure that quantum computers do not escape democratic oversight.

The quantum imperative is intentionally addressed to both the regulators and developers of quantum computers. The primary responsibility, at least from a legal point of view, of ensuring that the development and operation of quantum computers complies with all relevant legal norms lies of course with legislators and governments. However, given the technical complexity of the subject matter at hand it is also crucial for scientists and developers of quantum computers to be aware of and to act in accordance with the significant degree of responsibility that they bear for developing quantum computing in a manner that is politically, legally, socially acceptable. In the words of Carl Friedrich von Weizsäcker, scientists must at all times ‘carefully consider the larger context within which technical-economic progress occurs.’ [34] This requires critical reflection upon the reasons for developing a particular quantum device and whose interests the development of that device affects.

5. CONCLUSION:

It should be acknowledged that the quantum imperative proposed here can only be a first sketch of the key principles that regulators and developers need to keep in mind. As the development of quantum computers progresses, the contours of the legal framework governing the development and operation of quantum computers will emerge more clearly. In some respects, new legal norms will need to be enacted. In others it might become apparent that the three elements of the quantum imperative are already adequately reflected in existing norms concerning, for example, non-discrimination, equality, democratic governance structures. In either case, key questions that will need to be answered concern the tolerable degree of inequality between stakeholders affected by quantum computing, a better understanding of the way in which quantum computing interferes with or enhances an individual's autonomy, and how to strike a balance between commercial and public interests. The imperative's third element explicitly allows for engagement with these questions. In particular, it invites the question whether there might be other important values, apart from equality and autonomy, that should be taken into account when regulating quantum computers.

When contemplating the regulation of quantum computers, one should, however, also keep in mind that despite their novelty, many of the issues they raise are not new. As indicated in the introduction, questions concerning the power-conferring nature of technology have been around since the first humans discovered the first tools. For sure, just like quantum mechanics, quantum computers approach 'very old problems from a new direction.'[35] And it is a significant challenge to identify how exactly existing legal norms concerning non-discrimination or equality apply to quantum computers. But one should be careful not to overstate the extraordinary nature of quantum computers from a legal perspective. Doing so risks calling into question long-established norms protecting individual autonomy, regulating power-imbalances and addressing inequalities in society.

Finally, one could argue that the legal assessment of the risks associated with quantum computers is unduly pessimistic. Certainly, the development of quantum computers can impact society positively. The advent of quantum computing could allow, for the first time, for the truly private and anonymous exchange of information, it could revolutionize medical research, optimize financial transactions and assist states with law enforcement. But pursuing these objectives does not conflict with addressing the concerns outlined above. To the contrary: leaving the detrimental risks associated with quantum computers unaddressed could hinder the full realization of quantum computing's positive potential. Individuals, corporations and states are going to be much more open to a technology whose detrimental side-effects have been acknowledged and hedged by the quantum imperative.

1 Daniel F Styer, The Strange World of Quantum Mechanics (Cambridge University Press, 2000).
2 Sean Carroll, Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime (Penguin 2019) Part 1.
3 Tony Leggett, 'Quantum Theory: Weird and Wonderful' (1999) 12 Physics World 73.
4 PV Tobias, 'Australopithecus, Homo Habilis, Tool-Using and Tool-Making' (1965) 20 The South African Archaeological Bulletin 167, 188
5 Oldowan tools are the first (known) stone tools made by humans. Randall L Susman, 'Who Made the Oldowan Tools? Fossil Evidence for Tool Behavior in Plio-Pleistocene Hominids' (1991) 47 Journal of Anthropological Research 129.
6 I have done so elsewhere together with Jeffery Atik, see Jeffery Atik and Valentin Jeutner, 'Quantum Computing and Algorithmic Law' (Social Science Research Network 2019) SSRN Scholarly Paper ID 3490930 <https:/papers.ssrn.com/abstract=3490930> accessed 29 April 2020.
7 Madhumita Murgia and Richard Waters, 'Google Claims to Have Reached Quantum Supremacy' Financial Times (20 September 2019) <https://www.ft.com> accessed 23 March 2021. This claims has recently been challenged by Chinese scientists, Matt Ho, 'Chinese Scientists Challenge Google's "Quantum Supremacy" Claim with New Algorithm' South China Morning Post (16 March 2021) <https://www.scmp.com> accessed 23 March 2021.
8 Sara Castellanos, 'D-Wave Opens Quantum-Computing Resources to Coronavirus Research' Wall Street Journal (1 April 2020) https://www.wsj.com/articles/d-wave-opens-quantum-computing-resources-to-coronavirus-research-11585763422 accessed 23 March 2021.
9 Pieter E Vermaas, 'The Societal Impact of the Emerging Quantum Technologies: A Renewed Urgency to Make Quantum Theory Understandable' (2017) 19 Ethics and Information Technology 241, 242.
10 Cornelius Hempel and others, 'Quantum Chemistry Calculations on a Trapped-Ion Quantum Simulator' (2018) 8 Physical Review X 031022; Richard P Feynman, 'Simulating Physics with Computers' (1982) 21 International Journal of Theoretical Physics 467, 467.
11 Hayley Dunning, Quantum "compass" Could Allow Navigation without Relying on Satellites' (8 November 2018) <https://phys.org/ news/2018-11-quantum-compass- satellites.html> accessed 13 November 2020.
12 Sheila Jasanoff, The Ethics of Invention: Technology and the Human Future (Norton 2016) 18. The nuclear physicist Werner Heisenberg appears to call this view into question, see Werner Heisenberg, Quantentheorie und Philosophie (Jürgen Busche ed, Reclam 2019) 81–82.
13 Langdon Winner, 'Do Artifacts Have Politics?' (1980) 109 Daedalus 121, 122.
14 ibid 127–128.
15 Ronald de Wolf, 'The Potential Impact of Quantum Computers on Society' (2017) 19 Ethics and Information Technology 271, 274–275.
16 Quantum computers share this feature with certain AI/machine learning applications.
17 Marty J Wolf, Frances Grodzinsky and Keith W Miller, 'Is Quantum Computing Inherently Evil?' [2011] CEPE 2011: Crossing Boundaries 302, 303.
18 ibid 304.
19 Scott Aaronson, Quantum Computing since Democritus (Cambridge University Press 2013) 101–108.
20 Michael JD Vermeer and Evan D Peet, 'Future Quantum Computers May Pose Threat to Today's Most-Secure Communications' Rand Corporation (9 April 2020) <https://www.rand.org/news/press/2020/04/09.html> accessed 24 March 2021.
21 Sadie Creese and others, 'Cybersecurity, Emerging Technology and Systemic Risk' (World Economic Forum 2020) 34.
22 Lukasz Olejnik, Robert Riemann and Thomas Zerdick, 'Quantum Computing and Cryptography' (2020) 2 Tech Dispatch <https://data.europa.eu/doi/10.2804/ 36404> accessed 24 March 2021.
23 For a discussion of the legal and ethical challenges related to inequality in connection with the management of the on-going COVID-19 pandemic, see Timo Minssen and Sara Gerke, 'Ethische und rechtliche Herausforderungen digitaler Medizin in Pandemien: Chancen, Risiken und Kompromisse' in Andreas Reis, Martina Schmidhuber and Andreas Frewer (eds), Pandemien und Ethik (Springer 2021) (forthcoming).
24 Jasanoff (n 12) 5. See also Werner Heisenberg, Physics and Philosophy (HarperCollins 2007) 163.
25 Creese and others (n 20) 36.
26 IBM, 'IBM Quantum Experience' (IBM Quantum) <https://quantum-computing.ibm.com/> accessed 25 March 2021.
27 For a comparatively early argument casting doubt on the utility of the contemporary approach to patents of innovations, see Norbert Wiener, The Human Use of Human Beings (Free Association of Books 1989) 113–114.
28 See, for example, David C Gompert and Martin Libicki, 'Towards a Quantum Internet: Post-Pandemic Cyber Security in a Post-Digital World' (2021) 63 Survival 113.
29 US Bureau of Industry and Security, 'Implementation of Certain New Controls on Emerging Technologies Agreed at Wassenaar Arrangement 2018 Plenary' (2019) 84 Federal Register 23886–23887.
30 Alexei Grinbaum, 'Narratives of Quantum Theory in the Age of Quantum Technologies' (2017) 19 Ethics and Information Technology 295, 302.
31 See also, Harold J Laski, 'The Limitations of the Expert' (2020) 57 Society 371, 372.
32 CERN, 'Online Introductory Lectures on Quantum Computing from 6 November' (2 November 2020) <https://home.cern/news/announcement/computing/online-introductory-lectures-quantum-computing-6-november> accessed 25 March 2021.
33 Similar proposals exist concerning the supervision of the development and operation of robots. See, for example, European Parliament Resolution of 16 February 2017
th Recommendations to the Commission on Civil Law Rules on Robotics (2015/2103(INL)), [2017] OJ 1 252/239.
34 Carl Friedrich von Weizsäcker in conversation with Werner Heisenberg in the summer of 1945. Cited by Heisenberg in, Heisenberg (n 13) 83.
35 Heisenberg (n 25) 161.