Quantum computing and Copyright Law:

A wave of change or a mere irrelevant particle?

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Abstract

This article argues that quantum computing will radically change the copyright landscape, to a degree far beyond that wrought by digital technologies. Quantum computing brings exponentially greater possibilities in the tracking and tracing of content. The author has programmed quantum computers created by IBM. This research helps to demonstrate how quantum technologies operate differently to digital computers when it comes to copyright law. Under current law, certain types of tracking technologies are favoured over others. The quantum nature of quantum computing poses a challenge to our long-held notions of copyright works having a clear notion of fixation, and the concept of fixed proprietary boundaries. Quantum computers were conceived as a way to understand quantum physics, and this feeds through into how users utilise the computers, and the copyright works made by such computers. In short, quantum computing will radically alter not just our relations with copyright law, but also with the State and society. There will need to be some consideration of how to reframe copyright law, not just in terms of the challenges that quantum computing poses, but the changing way in which such technology alters our perception of the world.

Copyright; quantum computing; reform

1. Introduction

Quantum computing is a technology that will bring profound change to the way in which copyright law functions. Whilst there have been multiple technological revolutions in recent history[1] - such as digital computing, the Internet, and artificial intelligence ('AI') - quantum computing is likely to bring seismic changes to the copyright landscape, both for copyright holders and copyright users. The reason for this relates to the quantum nature of quantum computing. The key challenge will be how law deals with the unique goods created by quantum computing. [2] Whilst the speed of computing and challenges to the nature of proprietary boundaries is nothing new, the quantum nature of quantum computing means that it can simultaneously both expand and shrink the use of copyright rights in novel ways. This paper considers, first, how quantum computing interfaces with existing copyright law, second, how this can lead to quantum change in the existing law, and third, proposes reforms to deal with the quantum challenge. The paper discusses quantum computer programming at logic gate level to explain the difference between digital and quantum computing. The current focus on artificial intelligence appears to have led to a distinct lacuna in literature focusing on quantum computing.[3] However, quantum computing is likely to become the more significant technology, being a computing platform on which such artificial intelligence can run. It is

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[1] For a broad historical view of technology see Basalla, The Evolution of Technology CUP (1988); Forbes, The beginnings of technology and man, in Kranzberg and Pursell (eds), Technology in western civilisation (Volume I) OUP (1967); Singer, Holmyard, Hall (eds), A history of technology, OUP (1954).

[2] E.g. Casati, Shepelyansky and Zoller (eds), Proceedings of the International School of Physics "Enrico Fermi", course CLXII, 'Quantum Computers, Algorithms and Chaos, ' IOS Press, Amsterdam (2006) available at https://www2.physics.ox.ac.uk/sites/default/files/ErrorCorrectionSteane06.pdf pp. 1–32; Grumbling and Horowitz, Quantum Computing: Progress and Prospects, National Academies Press (2019).

[3] Outline discussion can be found in Schmit, Intellectual Property's Upcoming Quantum Leap, 95 Journal of the Patent and Trademark Society 271 (2023); Kap, Quantum Computing and Intellectual Property Law, [2022] Berkeley Technology Law Review, Comment 101; general discussion about quantum technologies and policy see Johnson, Governance tools for the second quantum revolution, Comment, 59 Jurimetrics 487 (2019); Atik and Jeutner, Quantum Computing and Computational Law, 13 Law, Innovation and Technology 302 (2021); Reed, How should we regulate artificial intelligence? Philosophical Transactions of the Royal Society A 376:20170360 (2018).

therefore imperative that we consider the characteristics of quantum computing, the challenges that it brings, and how to deal with these challenges if copyright law is to remain relevant in our quantum future.

2. What is quantum computing?

Quantum computing is inextricably bound up with our understanding of quantum physics and quantum mechanics.[4] It is only in recent history that we have begun to accept and understand that the world in which we live is a quantum one.[5] Quantum physics revealed to the world that physical objects are comprised of matter that is both simultaneously a wave and a particle; that these quantum objects are inextricably bound to one another in ways that we do not fully understand.[6] Quantum computers were specifically designed to enable scientists to understand the quantum[7] - thus quantum computing has come to change our understanding and perception of the world as a quantum entity. This is why quantum computing poses such a challenge to our belief in traditional proprietary boundaries compared to earlier so-called disruptive technologies such as digital computing.

Currently quantum computers are being utilised in areas related to finance, which will undoubtedly expand to more areas as the technology progresses.[8] The core of a quantum computer is a quantum bit, or qubit.[9] Bits that exist within digital computers can either be zero or one. Digital bits are either open or closed,[10] creating a traditional logic gate and thus a direction for electrons to flow. A quantum bit, however, exploits quantum mechanics. A qubit could represent a 0, a 1 or any linear combination of the two[11] This means, in effect, that a quantum bit can provide more than one result at any particular time; this can be extrapolated to enable a system of bits that can be any number whatsoever. This enables quantum computers to act exponentially faster than a digital computer performing traditional style calculations, but it also means that a quantum bit can be involved in performing more than one calculation at the same time. Currently error correction is used to provide intelligible results for non-quantum calculations, but compute errors can be invoked directly, *e.g.* for quantum watermarking.[12] This will likely result in law favouring certain types of quantum technology due to the interface of quantum computing with existing copyright laws. At the

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[4] See Heisenberg, Physics and Philosophy, Penguin (1990).

[5] See e.g. Odenwald, Quantum Physics: From Schroedingers Cat to Antimatter, Arcturus (2022).

[6] For a critique see Einstein, "Does the inertia of a body depend upon its energy-content?" (1905) in Einstein, Lorentz, Minkowski and Weyl, The Principle of Relativity, (trans Perrett and Jeffery), Dover (1952).

[7] See Heisenberg, *n*. 4, Heisenberg, Uber den anschaulichen Inhalt der quantentheo retischen kinematik und mechanic, 43 Zeitschrift für Physik (1927) 172; trans. as The physical contents of quantum kinematics and mechanics, in Wheeler, and Zurek (ed), Quantum Theory and Measurement, Princeton University Press (1983);Heisenberg, Die rolle der Unbestimmtheitsrelationen in der modernen physic, 38 Monatshefte für Mathematik und Physik 365 (1931); Feynman, Simulating Physics with Computers, 21 International Journal of Theoretical Physics 467 (1982).

[8] For details see McNamee, Quantum Computing in banking heats up with another entrant, Insider Intelligence (2022) at https://www.insiderintelligence.com/content/quantum-computing-banking. Details include portfolio hedging between D-Wave and Caixa Bank, Goldman Sachs and QC Ware; also see https://www.goldmansachs.com/careers/possibilities/quantum-computing/ ; Leprince-Ringuet, Seven ways that quantum computing is making an impact in the real world, Sifted, at https://sifted.eu/articles/seven-applications-quantum-computing(2023) citing bank BBVA working with Multiverse Computing; Swayne, Report: China and Russia test quantum communications link, The Quantum Insider, at https://thequantuminsider.com/2024/01/02/report-china-and-russia-test-quantum-communication-link/ (2024). As noted further into the article, the rise of streaming technologies is likely to apply to quantum computers, and thus the size of quantum computers (whilst ever shrinking) is unlikely to be a significant obstacle.

[9] Grumbling and Horowitz, *n*.2.

[10] There can also be a floating state, neither 0 or 1, if an internal logic gate is indeterminate. An example is a FGMOSFET, but these are typically not used in computers and instead are in EEPROMs, NOR Flash and NAND memory (hence the erasure effect of the window on an EEPROM when exposed to UV). FGMOSFET can be used in neural arrays implanted into digital chips to replicate human thought (or more specifically, as part of the thought process, forgetfulness!)

[11] For detailed discussion see Grumbling and Horowitz, *n*.2.

[12] The latter is based on work by the author using Qiskit as demonstrated at an IBM workshop held at the University of Exeter (Quantum watermarking, Quantum watermarking workshop (AHRC AH/V015761/1), University of Exeter, October 2022); the error correction is known as Shor's Algorithm.

same time, the impact of quantum computing on existing copyright law will not be insignificant.

Currently, quantum computers have tended to be used as a compute unit for digital computers.[13] However, it is possible to program a quantum computer directly, and it is important to distinguish these two methods of programming. A quantum computer has unique logic gates that can go considerably beyond the use of logic gates in digital computers. Anyone reading this paper can gain first-hand experience of this utilising programming software called *qiskit*, which is implementing Python code to be able to perform logic gate programming and simulation.[14] The author has demonstrated the operation of *qiskit*, showing logic gate programming.[15] This simple programming demonstration shows that quantum gates are capable a providing simultaneously different results, and it is possible to observe the outcomes of the operations graphically and in terms of probabilities. When quantum logic gates are programmed, they do not necessarily perform or lead to a certain conclusion. They produce probabilities. If one were to program a simple computer game, it would be possible to exploit these probabilities efficiently so as to be able to perform parallel computation of outcomes, e.g. to have a programme simultaneously running a state where a player is both alive and dead (as opposed to being part of a procedural pathway).[16] Whilst that could be achieved less efficiently with a digital computer, the difference becomes more obvious when considering quantum watermarks or other advanced calculations. The same method can be applied to quantum watermarks using quantum cryptography combined with logic gate probability error. The computation of probability, combined with a degree of error, means that it is possible to do logic with a degree of creativity, to a level hitherto not even seen with digital computing. Quantum computers at their own logic gate level, and at the level of their programming, are capable of much more than if they are used as a mere compute unit for a digital computer.

3. An example of the quantum challenge

Before embarking on a more detailed interrogation of the existing law, the reader might benefit from an example of how quantum computing could become so legally disruptive. One example would be artificial intelligence. Currently, artificial intelligence is primarily designed to run on digital computers.[17] Digital technology is based entirely upon the notion of being able to make perfect reproductions. If there is an error in a digital computer, the computation will typically fail. This is fundamentally incompatible with the notion of an inventive independent creative artificial intelligence. However, a quantum computer can (in fact, has to) operate with errors.[18] The same is true of analogue or biological computing. These errors can introduce a degree of randomness that could go beyond that of current random number generators, and thus provide a more inventive means by which the computers could operate. Quantum computers can also search for content more quickly on their own systems. Quantum computing can provide calculation at speed unlike the latter two, and this means that it is the

[13] See for example D-Wave 'Product Overview' at https://www.dwavesys.com/solutions-and-products/product-overview/

[14] See for example Qiskit, above, other systems include cQASM, Quil, OpenQASM; development kits with Perceval, Ocean, ProjectQ, Qibo, Forest, Strawberry Fields, PennyLane, QDK and Cirq.

[15] See *n*.12.

[16] E.g. see Wootton, Making games with quantum computers, at https://decodoku.medium.com/games-computers-and-quantum-84bfdd2c0fe0 ; Becker, The magic of quantum computing: A beginners guild to writing a magic number guessing game, at https://towardsdatascience.com/the-magic-of-quantum-computing-a-beginners-guide-to-writing-a-magic-number-guessing-game-c1cdb384f457

[17] For discussion of AI on digital computers and the relationship with copyright law, see Bonadio and McDonagh, Artificial intelligence as producer and consumer of copyright works: evaluating the consequences of algorithmic creativity [2020] IPQ 112; Guadamuz, Do androids dream of electric copyright? Comparative analysis of originality in artificial intelligence generated works [2017] IPQ 169; Barfield and Pagallo, Advanced Introduction to Law and Artificial Intelligence, Edward Elgar (2020).

[18] Note that errors may nonetheless require coding out for stable operation: Guardia, Quantum Error Correction: Symmetric, Asymmetric, Synchronizable, and Convolutional Codes, Springer (2020).

ideal medium on which to run artificial intelligence programs. Commentaries relating to artificial intelligence and copyright law identify that AI poses a challenge to traditional notions of copyright authorship and will note the possibility of large-scale unauthorised reproductions of copyright works.[19] Running AI on quantum computers will magnify these issues to a considerable degree. Because quantum compute can utilise the notion of error to give an action a degree of spontaneity rather than pure reproduction, it is easier to mimic human creativity.[20] It would not be unreasonable to expect an apparent level of creativity (as might be measured by a human mind) in the work that a quantum computer could produce. That will make it more difficult to differentiate between AI generated and human generated works. In addition to that, AI scours the Internet for existing works faster than humans can, particularly when it comes to interactive media and video.[21] Reproduction could take place on a large scale, but potentially with enough directed 'errors' to avoid possible copyright infringement suits. On the other hand, AI could be used to implement anti copy protections, which could result in a situation where only more advanced AI can break protections and thus perform reproductions.[22] As will be detailed below, the law will also need to be more precise in terms of what is a permissible technical limit to reproduction.

4. Challenges for copyright laws: a quantum paradox

Quantum technology provides a quantum paradox for copyright law. On the one hand, copyright infringements could become more commonplace due to the use of quantum computers, but on the other hand the enforcement of such laws could also increase. The combination of the two developments will potentially favour certain forms of content over others. As will be argued below,[23] content with embedded quantum watermarks will be more likely to be protected than earlier forms of content without such watermarks.

It is the exponential speed increases that quantum computing brings that will make it easier to be able to produce more copies of existing copyright works. This infringement challenge is nothing more than a continuation of the challenges that have been facing copyright law since better methods of making copies have become available. Whilst the printing press originally enabled the distribution of copyright works at the time of the first copyright statute, the Statute of Anne 1710,[24] since that time newer methods of dissemination have tended to pose a challenge to those publishers who originally held licencing monopolies at the time of the original copyright statute. The use of such technologies for copying has frequently seen clashes with existing copyright holders, for example online file sharing of music with the rise of file sharing services such as *Napster* in 2001.[25] Right holders responded quickly to the threat to their markets in bringing these legal actions.

As well as wholesale reproduction, we can expect re-use of existing artworks being altered on a large scale for use in AI generated artistic works.[26] Enhanced compute power will see the

[19] See *n*.17.

[20] For a discussion of the potential conflict between current considerations of digital machine learning and quantum computing see Wang, Quantum algorithms for machine learning, 23 XRDS Crossroads 20 (2016); see also Dodge and Karam, A Study and Comparison of Human and Deep Learning Recognition Performance Under Visual Distortions, arXiv: 1705.02498 (2017) available at https://doi.org/10.48550/arXiv.1705.02498

[21] Bearne, New AI systems collide with copyright law, BBC News, 1st August 2023, at https://www.bbc.co.uk/news/business-66231268. The reader can search google chrome extensions for examples of AI video search – e.g. SkmAI at https://chrome.google.com/webstore/detail/skmai-ai-powered-video-se/nkkklchgighdppjfponpogcfgggchjef and Eightify at https://chrome.google.com/webstore/detail/eightify-youtube-summary/cdcpabkolgalpgeingbdcebojebfelgb

[22] Similar to the current Captcha situation, where Captchas can now be solved more quickly by AI than a human. See Sankaran, Bots are better than humans at cracking 'Are you a robot?' Captcha tests, study finds, Independent 9th August 2023, at https://www.independent.co.uk/tech/captcha-test-bots-better-humans-b2389998.html

[23] See below, section 10.

[24] Statute of Anne 1710, 8 Ann. c.21. For discussion see Kaplan, An Unhurried View of Copyright, Columbia University Press (1966).

[25] *A&M Records, Inc.* v *Napster, Inc* 239 F.3d 1004 (9th Circuit, 2001).

[26] Consider the outcomes from AI systems such as Stable Diffusion at https://stability.ai/blog/stable-diffusion-public-release

reuse of elements of films (*e.g.* scenes, characters, music, scripts) to create new films. These are the two main likely avenues of challenge to copyright law that we are likely to observe with the initial uses of quantum computing. However, quantum computing poses challenges to the operation of copyright law more generally. For example, it poses a challenge to the categorisation of copyright works for subsistence purposes;[27] it poses a challenge to the tests of copyright infringement where works have been altered;[28] and it poses a challenge for the applicability of the permitted acts and defences[29] – each of which will be dealt within the subsequent sections of this paper.

Whilst the above challenges could lead the reader to suppose that quantum computing will lead to more infringements, the nature of quantum computing also means that there could be more enforcement of copyright law. To begin with, it is likely that there will be an increase in the use of technical access rules for quantum computer software.[30] There are two reasons for that, firstly that the fastest quantum computers are likely to be remote computers and therefore remote access will be governed by local access rules, and secondly that quantum computers can more closely monitor the use of content due to their enhanced computing power compared to digital computers. Micro-scale contractual relations are also more possible and therefore it can be easier to be able to manage (both legally and technically) the licence agreement between a software company and a user of content. For example, it will be possible for on demand licensing according to how a work is used in real time, without a significant hit on computational power.

Following on from an increase in the use of contracts, we can expect that there will be more use of technological protection measures, as well as copyright management information devices such as watermarks, and also more use of filtering mechanisms to be able to detect, prevent and contain copyright infringements. These mechanisms are not dissimilar to current day digital rights management systems employed using digital computers, but they do have the potential to be more developed. Copyright management information techniques are better suited to quantum computers because they allow for more finely grained analysis of potential infringements, and because they require greater computing power to be able to be applied both broadly to computer software and the actions of the users of such software. This will mean that there are certain rules in copyright law that already exist but which will have enhanced utility when applied to a quantum computer. It is already the case that a lot of copyright law has very fuzzy boundaries when it comes to rights that provide new avenues of protection, for example digital rights management and the manner in which they could protect non-copyrightable elements - cases exist which indicate these areas could provide protection even where there is no copyright work.[31]

Quantum computing will further challenge these boundaries, because of the enhanced levels of protection that the technology can bring. However, that is against the backdrop of the earlier points raised in this section, namely the possibilities for enhanced infringement of copyright works. A quantum paradox is thus developing, in that there are likely to be more infringements possible, whilst technical devices will simultaneously develop in an attempt to prevent any alleged possible or potential copyright infringements. Authentication handshakes with remote quantum servers will increasingly need to be broken to stop communication with content verification servers; content will increasingly be made in a manner difficult to break, with enhanced encryption Meanwhile, due to the expense of large-scale quantum computing,

[27] E.g. see s.1 CDPA 1988.

[28] See s.16-21 CDPA 1988.

[29] Permitted acts – s.28-s.76A CDPA 1988; other 'defences' are in case law such as the public interest defence e.g. *Ashdown* v *Telegraph Group* [2001] EWCA Civ 1142 (but note s.171 CDPA 1988).

[30] Discussion of these points can be found below, infra.

[31] Consider the US case *MDY* v *Blizzard Entertainment* 629 F.3d 928 (9th Circuit, 2010); in the UK Nintendo Co Ltd v Sky UK Ltd & Ors [2019] EWHC 2376 (Ch).

we can expect more content to be streamed and less owned; content will be kept remotely in order to enhance the notion that utilising such data in breach of contractual terms would be akin to breaking into someone's physical house or committing a similar fraudulent activity. On balance, this would suggest that it will become more difficult to break encrypted content, and thus that protections on copyright content will become more secure.

This could lead to more pre-emption of copyright law than occurred with digital rights management (as applied by digital computers).[32] Right holders are not going to be an impartial arbiter of what copyright rules should be, due to their own inherent bias in wanting to protect what they claim as their own IP. It is therefore imperative that steps are taken to ensure that any use of copyright management information devices will not surreptitiously expand the use of copyright (and contract) rules. There will need to be particular attention paid to how quantum computing could enhance the rights of right holders in ways that could upset the copyright balance.

The view of the author is that it is likely that we will see increasing reuse of certain content by quantum AI. This will be content not protected by watermarking – such content will likely predate quantum computing, as this content will not have sufficiently complex embedded watermarking or filtering mechanisms within them. By contrast, works produced by a quantum computer will be more likely to have additional protections embedded within them. This could result in a two-tier situation: Earlier copyright works are more likely to be reused, whereas quantum-based works are less likely to be. It is also not unreasonable to assume that as quantum computing develops, embedded protections will also develop leading to a new form of balance between newer (technologically) protected works, and older less protected works.

There are therefore a number of distinct challenges against copyright law that will arise from quantum computing. This paper will now proceed to run through these issues, highlighting the specific challenges that quantum computing brings, and propose methods to resolve the issues that arise. Naturally, as the technology develops, we can expect new unforeseen challenges to also arise. Quantum computing is still a nascent technology, but it is developing faster by the day. Indeed, there is discussion about, and creation of, smaller scale quantum devices already.[33] Currently, quantum computing devices tend to be very large, housed in laboratories. However, technologies such as quantum dot promise to shrink quantum computers to an almost nanotechnology scale.[34] As noted above, there are also moves to align quantum computing with biological compute.[35] Whilst this article will consider potential developments of quantum computing, the majority of discussion by necessity is focusing on the current situation with quantum computing. Nonetheless, the proposed solutions do consider the likely directions that the technology is going to take in its development.

5. Impact on current laws – quantum boundaries

We can begin with the consideration of the impact upon copyright subsistence. Copyright subsistence concerns the elements required to have copyright protection in a copyright work. There is no need for registration of a work, although certain countries such as the United States may require a form of registration for a copyright infringement suit to be begun.[36] The

[32] See Reese, Will merging access controls and rights controls undermine the structure of anticircumvention law? 18 Berkeley Technology Law Review 619 [2003].
[33] See e.g. Flaherty, $18m to shrink quantum computer to chip size, EE News Europe at https://www.eenewseurope.com/en/18m-to-shrink-quantum-computer-to-chip-size/
[34] See e.g. Bernstein, Quantum-dot cellular automata: computing by field polarization, DAC '03 Proceedings of the 40th annual design automation conference (June 2003) 268; See also Pires, Quantum computing on a chip, Toms Hardware, at https://www.tomshardware.com/news/quantum-computing-cambridge-riverland
[35] Griffin, The Cultural State of Biology: Regulating biological computing, Edward Elgar, 2023.
[36] 17 USC 412.

lack of a registration regime for obtaining copyright subsistence could pose more of a challenge for works that are created with a quantum computer. Quantum computers have the ability to enable creators to make a large number of small-scale works. Whereas traditional works such as books, movies and music, or even computer games, could be identified, and whereas elements within those works could also be capable of protection, for example fictional characters, quantum computers are more likely to be able to develop elements of copyright works and copyright works themselves more easily and on the spur of the moment. This could pose challenges regarding the tests of copyright originality, discussed in the section immediately below. As identified above, AI may also run on a quantum computer faster and in more novel ways than before, and be able to act in a way that is more creative but utilising more copyright works. A story written for (or within!) a quantum computer game could be constantly changing and evolving according to the actions of the player, and not just simply according to predefined paths but utilising complex AI algorithms. This poses the question as to which level of protection should exist, over a final completed work, or over some of the processional and computational elements which have led up to the making of that work? Currently, in copyright law concerning computer software there is distinction between levels of code such as object code and source code.[37] Will the law need to make differentiation such as this between final AI products and AI algorithms? Quantum computing raises these questions to an ever-greater degree, because one of the benefits of a quantum computer is to be able to alter code on the spur of the moment, according to the actions of the quantum computer user.

This is not the only way in which boundaries around a copyright work could be challenged by quantum computing. The existence of the qubit is something that is inherently uncertain and yet it is integral to the operation of a quantum computer. This manifests itself in several ways. One way is that it means that quantum computers can perform parallel compute to a greater degree at logic gate level, with reduced slow down due to greater computing power, but also what could be termed multidimensional coding that can react to ongoing user events to a greater degree than before, due to the efficiency of quantum logic gates. If a programmer is writing a computer game, it is possible to program it in a way say that a player is both simultaneously alive but also dead. This means that there is precomputation of potential outcomes, to a greater degree than is possible with a digital computer.[38] This means that the outcome of a work may not be as certain as it would be within a digital computer, as it will be possible to produce works of this nature more easily. That predictive code process would need to have copyright protection, and it may or may not do so due to originality concerns. Such code could become generic, even though it could result in other outcomes in computer games. A similar situation has already arisen in relation to digital computing and the use of automatic generation in computer games.[39] The compute processes may not be sufficiently novel to obtain copyright protection as computer generated works,[40] but they can result in novel outcomes. This reveals a potential lacuna in legal protection, which mirrors the same lacuna of protection that existed for databases until the introduction of specific *sui generis* protection for them, and it also mirrors some of the debates concerning whether AI should be given legal protection, e.g. as an author under copyright law.[41]

6. **Quantum Originality**

[37] See e.g. Lai, The copyright of computer software in the United Kingdom, Hart Publishing (2000).
[38] Wootton*, n*.16.
[39] Consider for example the use of generative AI in No Man's Sky – Rambus, The Algorithms of No Mans Sky at https://www.rambus.com/blogs/the-algorithms-of-no-mans-sky-2/
[40] s.9(3) CDPA 1988.
[41] Council Directive 91/250/EEC of 14 May 1991 on the legal protection of computer programs, OJ L122/42; Directive 96/9/EC of the European Parliament and of the Council of 11 March 1996 on the legal protection of databases, OJ L77/20.

As technologies have developed, there have often been questions asked as to whether these have been replacing the originality of the author. For example, with the invention of the camera, labour, skill, and effort was arguably being provided by the device.[42] Copyright law developed various means to be able to deal with this question. For example, with photographs the law had required that a photographer imbue a photograph with his or her creative character.[43] Originality is required for works of literature, music, artistic works and dramatic works.[44] The traditional tests for originality were labour, skill and effort.[45] The formulations of this test as applied by the judiciary varied.[46] However, that sort of labour was an extremely low standard when technology made it easier to make the original work. Indeed, technology could significantly reduce skill, labour and effort. Quantum computing in this regard is but one in a long line of technologies that make it easier to be able to create new and original work. However, previous technologies acted in what could be called a machinic way. By this I mean the technologies would mainly act as an assistant in the making of something original. Quantum computing is different. As noted above, quantum technologies have inherent error, and this means that the creative processes of the individual could become more linked with the 'creative' processes of the computer.

In response to this situation, the reader might wonder about the newer tests for originality that are developing in UK law. These tests assess the creativity of the author, otherwise known as the creative fingerprint, as used in recent cases such as *THJ* in the Court of Appeal.[47] In applying a test such as these, in theory they could isolate the creative fingerprint of the computer from the creative fingerprint of the human author. However, it is not that easy. Already there have been disputes (albeit not argued in court) over the source of originality in artistic works, where it was not possible to be able to identify whether the work was created by human or by artificial intelligence.[48] As identified above, newer forms of compute more closely mimic the error process in creativity, so this process of differentiation is only likely to become more difficult to achieve. Whilst the earlier tests in UK law of labour skill and effort could focus more on the factual sweat of the brow, human creative endeavour might be more difficult to isolate even given the *THJ* ruling that there should not be any artistic merit requirement.[49] That notwithstanding, as will be outlined below, quantum technology is likely

[42] See *inter alia* Stokes, Graves' case revisited in the USA, 11 Entertainment Law Review 104 (2000); Saint-Amour (ed), Modernism and Copyright, Oxford University Press, 2011.
[43] E.g. *Antiquesportfolio.Com plc* v *Rodney Fitch & Co Ltd* [2001] FSR 345*; Temple Island Records* v *New England Teas* [2012] FSR 9 at 329-330.
[44] s.1(1) CDPA 1988.
[45] *University of London Press Ltd v University Tutorial Press Ltd* [1916] 2 Ch 601; *Ladbroke (Football) Ltd* v *William Hill (Football) Ltd* [1964] 1 WLR 273.
[46] Note also the similar test of whether the work originated with the author – also found in *Ladbroke (Football) Ltd* v *William Hill (Football) Ltd* [1964] 1 WLR 273.
[47] Consider the different approaches in *THJ Systems Ltd* v *Sheridan* [2023] EWHC 927 (Ch); [2023] EWCA Civ 1354; *Response Clothing Ltd* v *Edinburgh Woollen Mill Ltd* [2020] EWHC 148 (IPEC); *Islestarr Holdings Ltd v Aldi Stores Ltd* [2019] EWHC 1473 (Ch); *Martin* v *Kogan* [2020] FSR 3; see also *Martin* v *Kogan (No. 2)* [2021] FSR 10; *Pasternak* v *Prescott* [2023] FSR 293; *Wright* v *BTC* [2023] ECDR 1, [2023] ECDR 18.
[48] Greenberger, Artist Wins Photography Contest After Submitting AI-Generated Image, Then Forfeits Prize, ARTnews, 17th April 2023, at https://www.artnews.com/art-news/news/ai-generated-image-world-photography-organization-contest-artist-declines-award-1234664549/ ; see also Thaler v Comptroller-General of Patents, Designs and Trade Marks [2023] UKSC 49 and discussion in the US - Thaler v Perlmutterus, Register of Copyrights and Director of the United States Copyright Office, et al, US District Court for the District of Columbia, Civil Action No. 22-1564 (BAH); Thaler v Perlmutterus, Register of Copyrights and Director of the United States Copyright Office, et al, US District Court for the District of Columbia, Civil Action No. 22-1564 (BAH), affirming Copyright Review Board, Re: Second Request for Reconsideration for Refusal to Register Théâtre D'opéra Spatial (SR # 1-11743923581; Correspondence ID: 1-5T5320R); see https://acrobat.adobe.com/link/review?uri=urn%3Aaaid%3Ascds%3AUS%3Aea3099df-32e2-3767-b953-58cc252de9be Copyright Review Board, Re: Second Request for Reconsideration for Refusal to Register A Recent Entrance to Paradise, Correspondence ID 1-3ZPC6C3; SR # 1-7100387071 available at https://www.copyright.gov/rulings-filings/review-board/docs/a-recent-entrance-to-paradise.pdf (last accessed 18 June 2022).
[49] *THJ Systems Ltd* v *Sheridan* [2023] EWCA Civ 1354 at para. 24.

to lead to a surge in the use of tracking and watermarking technologies, which will make it easier to keep track of the re-use of some content.

7. Infringement tests – a further quantum paradox

In the UK, a common test for infringement of copyright is that which concerns the reproduction right.[50] The reproduction right controls the making of unauthorised copies of works that hold copyright protection. There are typically two stages to this test, firstly whether the later work was derived from an earlier work, and whether a substantial part has been taken.[51] The issue of derivation poses a potential challenge when dealing with the reproduction elements of prior copyright works. It has previously been stated that derivation can be implied where there is copying of inessential elements. That is quite likely to be so when dealing with an artificial intelligence that is scraping the Internet for data.[52] However, such data can be altered, and this might make the assessment more difficult to achieve if steps taken to obscure the source of the original data. As noted above, the use of watermarking and tracking technologies is more likely to influence the reproduction of works created on a quantum computer, because there is more likely to be embedded data regarding the origin of such works, where is more traditional digital analogue works are less likely to contain such data. This would make it easier to establish derivation, even though quantum computers may make copying otherwise easier to achieve.

When it comes to assessing whether its substantial part has been taken, there is also the question of whether the skill and judgement (or creativity)[53] of the earlier work has been reproduced.[54] When assessing an infringement, elements that do not meet the requirement of a derivation or a substantial part could *inter alia* be classified as an idea or an non-original element. Traditionally, this could include elements such as insufficiently developed plots, fictional characters, or themes.[55] When it comes to quantum computing, the computers themselves are more likely to be able to isolate and reproduce these elements. A quantum based computer will have the computing power to be able to assess to some degree whether what it is reproduced is a potential infringement. There is the possibility for an AI to carefully walk a path of non-infringement, reproducing what a court would have deemed unprotectable ideas but not more.

Ultimately, as noted earlier, there is a quantum paradox at work when it comes to infringement. Whilst there will likely be more infringements taking place, it is also the case that there could be more evidence to establish successful infringement actions and, as will be discussed below, quantum technical enforcement of access terms.

8. Permitted acts and quantum contractual obligations

In the UK, fair dealing is contained within statute, and was intended to be a codification of the fair use defences that existed prior to the Copyright Act 1911.[56] They are permitted acts, and they reside within the CDPA 1988. There are some elements that are outside of Fair Dealing, such as public interest which remains a defence.[57] With regard to quantum computing, on the face of it very little will change with regard to these permitted acts and defences. This is because these would remain regardless of which technology they are applied to. However, in

[50] See s.17 CDPA 1988.
[51] As per s.16 and s.17 CDPA 1988; see also *Designers Guild Ltd* v *Russell Williams (Textiles) Ltd* [2000] 1 W.L.R. 2416.
[52] Bearne, see *n*.21.
[53] See *n*.44-*n*.46.
[54] *Designers Guild* n. 51 at 2422 *Baigent* v *Random House* [2007] FSR 24 at 629-630; *Elanco* v *Mandops* [1980] RPC 213; Chacksfield, The Hedgehog and the Fox, a Substantial Part of the Law of Copyright, [2001] EIPR 259.
[55] Laddie, Prescott and Vitoria, The Modern Law of Copyright, 5th edition, Butterworths (2018) at 36.27-36.30, but note *Shazam Productions Ltd* v *Only Fools The Dining Experience Ltd* [2022] EWHC 1379 (IPEC).
[56] Now to be found in Chapter III CDPA 1988.
[57] See *n*.29.

a quantum computing ecosystem there is a significant issue for the fair dealing provisions, because it can be possible to contract out of them. Quantum computing is more likely to result in remote access to works, governed by access agreements.[58] It should be noted that a contract is an *in personam* agreement, meaning it is between individuals rather than against the world. This is the principle of privity of contract.[59] In an online environment, where users might not be able in practice to contract out of terms and conditions if they wish to make use of global services, this can be an issue because it will mean that users might not be able to rely on many fair dealing provisions.[60] For example, a user might find that they are legally unable to do certain acts such as reporting on current events, or make certain educational uses that they might otherwise be able to rely on. The UK has yet to have significant case law on the point, but it does appear to be common practise to contract out of certain permitted acts.[61] Significantly, s.28 CDPA 1988 makes it possible to contract out of them,[62] and as outlined above the nature of quantum computing means that we are likely to see the use of more contracts. In the US, where there is a system of Fair use that resembles pre-1911 copyright law, there have been cases where there has been consideration of the relationship between contract and copyright law.[63] However, the current situation is that some States will allow copyright principles to be overridden, whereas others will not.[64] There is also the additional issue concerning copyright misuse, where contracts have been used to extend copyright protection.[65] In some instances, the use of this doctrine requires anti-competitive conduct. [66] However, practice between different States is inconsistent.[67] Consequently, it is difficult to be able to say with certainty what the relationship is going to be between contract and copyright if a dispute breaks out within US jurisdiction. In the UK, it seems more certain that contracts can be used to contract out of the permitted acts, but as noted, we do not have sufficient case law to conclusively close the discussion. Notwithstanding the discussion above, there are a few, limited, Fair Dealing provisions that do not allow for contractual clauses to limit their applicability. These are provisions that have been implemented into the CDPA 1988 due to EU directives.[68] They concern issues such as the making of backup copies, interoperability, observation, and otherwise lawful uses. Important – but ultimately still a limited area compared to fair dealing more broadly.[69]

The utilisation of contracts is important for quantum computing. The initial widespread adoption of quantum computing is very likely to be through the use of special quantum computer servers. A server will provide access to programs and content that are stored on the server, and streamed to terminal devices. This could become similar to the use of servers and terminals common in the early period of digital computing.[70] Such a system also aligns with the growing use of cloud computing, involving the storage of data and programs on remote

[58] See *n*.12.
[59] Merkin (*ed*), Privity of Contract, Routledge (2000).
[60] For similar discussion in the US see *ProCD, Inc.* v *Zeidenberg*, 908 F.Supp. 640 (WD Wis. 1996); *ProCD, Inc*. v *Zeidenberg*, 86 F.3d 1447 (7th Circuit, 1996).
[61] See *SAS Institute Inc* v *World Programming Ltd* [2019] FSR 30.
[62] Note the wording of s.28(1) CDPA 1988: "The provisions of this Chapter specify acts which may be done in relation to copyright works notwithstanding the subsistence of copyright; they relate only to the question of infringement of copyright and do not affect any other right or obligation restricting the doing of any of the specified acts."
[63] 17 USC §107; see relevant cases such as Sony v Universal City Studios 464 US 417 (184).
[64] Consider for example *Feist Publications, Inc*. v *Rural Telephone Service Co*., 499 U.S. 340 (Supreme Court, 1991), *ProCD, Inc.* v *Zeidenberg* (WD Wis. 1996); (7th Circuit, 1996) *n*.60.
[65] *Lasercomb* v *Reynolds* 911 F2.d. 970 (4th Circuit, 1990).
[66] *BellSouth Advert. & Pub. Corp*. v *Donnelley Information. Pub.,* 999 F.2d 1436 (11th Cir. 1993).
[67] See Gervaise-Davis III, The affirmative defence of copyright misuse', 867 *Practising Law Institute/Patents, Copyrights, Trademarks and Literary Property Course Handbook* 103 (2006) at 134-138.
[68] See *n*.41.
[69] s.50A, s.50B, s.50BA, s.50C and s.50D CDPA 1988, implemented by reg 8, The Copyright (Computer Programs) Regulations 1992, SI 3233/1992.
[70] See e.g. Wurster, Computers, Taschen (2001).

servers. The adoption of this model relies heavily upon the use of contractual agreements. The use of these agreements enables a framework to control the access actions of a user, and also controls the ability of the user to be able to resell reuses of copyright works at a subsequent date. We can therefore expect the use of contracts to increase. Furthermore, because of the speed increase of quantum computers, we can also expect that more programs will be able to run efficiently over networks. This will mean that their technology is more biased towards the streaming of programs and content, more so than digital computing. This could have the consequent effect that contracts might be used to limit the use of permitted acts as permitted under statute.

The use of contracts could also result in a change in distribution methods. Moving back to the discussion concerning copyright infringement, the distribution right has traditionally been a right that will be exhausted after first sale. This is a right that has enabled the operation and existence of second hand book shops. There had been and increasing use of contracts on the Internet with digital computers to reduce the ability of individuals to be able to resell works. If a contract characterises access to work as a licence, then there is the possibility that there is no sale and hence no exhaustion of the right. The European Court of Justice has adjudicated on this issue. It has decided that if a piece of computer software is licenced in a way that looks like a sale, then it will be deemed a sale for the purposes of exhaustion.[71] However, in relation to works that are not computer software then it will remain possible for there to be a licence and US exhaustion.[72] The compatibility of these two cases is not yet fully resolved, and so this might change in future. In any event, it can be observed that the use of licences can be a way to limit the reach of the exhaustion doctrine. Given that quantum computing will see a rise in the use of licencing, this is another issue that requires attention. In addition to exhaustion concerns, if the scope of the rights are limited then it is also possible that the scope the permitted acts will be limited as a consequence.[73]

10. Quantum Technological Protection Measures

Digital licences can be extremely interactive with users and the content they are seeking to access. Indeed, one specific technology known for limiting access to unlicensed works is 'DRM,' or digital rights management – referred to as 'technological protection measures' in statute, meaning that more likely than not the provisions will apply equally to quantum computers as digital computers.[74] DRM mechanisms initially rose to prominence as ways to prevent un-authorised reproduction of digital copyright works, but they also used to ensure that users can only use works for licenced, contractual, purposes. As the name implies, the use of such technologies began with digital computers. They also began before the full realisation of the Internet, and consequently are more based within local machines. They are often dependent upon the existence of flags within digital data, which can be protected through the use of provisions collectively called CMI, or 'copyright management information.'[75] These will be discussed further below. Digital rights management mechanisms themselves are capable of running within quantum computers, but they could be considerably enhanced through the utilisation of faster computer processors, and also through the use of

[71] C-128/11 *UsedSoft GmbH* v *Oracle International Corp* [2012] 3 CMLR 44.
[72] C 419/13 *Art & Allposters International BV* v *Stichting Pictoright* [2011] E.C.R. I-9083.
[73] The reader may wish to note the recent trend in case law to refer to the fair dealing permitted acts as defences (although this might be more of a slip of the tongue than an intended radical change to the law) – see *Duchess of Sussex v Associated Newspapers Ltd* [2021] FSR 15 at 485; *Duchess of Sussex v Associated Newspapers Ltd* [2021] EWCA Civ 1810 at para 98.
[74] See, in the UK, s.296-s.296ZF; in the US, 17 USC §1201. There is a voluminous literature on DRM – see Reese, *n*.32; Lessig, Code, Basic Books (1999); Lessig, The Future of Ideas, Random House (2001); Lessig, Free Culture, Penguin (2004); Litman, Digital Copyright, Prometheus Books (2001); Vaidhyanathan, Copyrights and Copywrongs, NYU Press (2001); Vaidhyanthan, The Anarchist in the Library, Basic Books (2004).
[75] These provisions also have their own specific protections, in the UK in s.296ZG CDPA 1988; in the US, in 17 USC §1202.

quantum logic gates as well as quantum cryptography.[76] Given the discussion above about how quantum computers are likely to lead a return to the server environment, these secure mechanisms controlling access are more likely to be remotely stored. This will make these mechanisms more secure and difficult to break, because remote access rights will be required to be able to modify the technology. It also makes identification of potential hackers easier to achieve. Whilst this might seem to protect legitimate business interests, existing legal provisions assume that there will be a level of hacking taking place to maintain the existing copyright balance. Once a DRM mechanism is broken, a work will likely become widely available on the Internet.

Another balance to the extra statutory protections given to technical protection measures is that certain types of infringement have historically been possible - for instance, using a camcorder to record a DVD.[77] Quantum computers could upset this balance because their compute power could enable faster tracking of *any* copied content, in addition, the likely remote operation of quantum computers means that such content, whether or not protected by QRM, might be more difficult to reproduce. As even digital technical protection measures will undoubtedly morph into a form of QRM, there is a need for regulators to be aware of how quantum technologies may influence the operation of traditional DRM. The use of these technologies is akin to an interactive contractual device, and it will influence what users can and cannot do. In addition to the above issues, QRM is likely to be able to initiate pre-emptive decisions about the legality - or at least purported legality - of actions by users and pre-emptively enable or disable those actions. There have always been enforcement limits with digital computing, but those limits are significantly reduced with quantum computing. Users may also feel wary of surveillance technologies with quantum computing, because again quantum computing through its extra compute power can track and trace or actions by users. This is particularly true of copyright management information devices, as will be discussed below.

11. Copyright Management Information & Quantum Watermarks

To date, watermarking of digital content has been important for streaming services such as *Netflix, Spotify* and *YouTube* – it is used for assessing copyright infringement claims and identifying what users are watching.[78] There was nascent support for such technologies stemming from Article 12 WIPO Copyright Treaty 1996,[79] and the various implementing national and supranational legislations.[80] More recently, the EU Copyright Directive 2019[81] has favoured the implementation of filtering mechanisms for online content providers. Filtering is closely related to fingerprinting and watermarking (it is an important method to help identify potentially infringing content; as shown through the use of watermarking the *YouTube ContentID* system).[82] Taken as a whole, this demonstrates the support that exists for these technologies as an aid in combating piracy of copyright content. When it comes to quantum computing, the protection afforded by these mechanisms will become much more important, potentially even more important than copyright law itself.

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[76] Wang, Rohde, Ali, Quantum Cryptography and Simulation: Tools and Techniques, Proceedings of the 2020 4th International Conference on Cryptography, Security and Privacy 36 (2020); Elliott, Pearson and Troxel, Quantum Cryptography in Practice, SIGCOMM '03: Proceedings of the 2003 conference on applications 227 (2003).

[77] E.g. consider the comments made in the US case of *Universal City Studios, Inc.* v *Corley* 273 F.3d 429 (2nd Circuit, 2001) at 459.

[78] YouTube content ID - https://support.google.com/youtube/answer/2797370

[79] Article 12 WIPO Copyright Treaty, 36 ILM 65 (1997).

[80] E.g. Article 7 Directive 2001/29/EC of the European Parliament and of the Council of 22 May 2001 on the harmonisation of certain aspects of copyright and related rights in the information society, OJ/L 167 10; s.296ZG CDPA 1988.

[81] Article 17 Directive 2019/790 of the European Parliament and of the Council of 17 April 2019 on copyright and related rights in the Digital Single Market OJ L 130/92.

[82] See *n.* 78.

The ability of quantum computers to make un-hackable watermarks, whilst not absolute, is far more likely due to enhanced possibilities with encryption. There are equations out there that have been demonstrated to be robust (following similar techniques to as yet unbroken DRM mechanisms) using a variety of analogue comparison methodologies.[83] That quantum compute cannot produce identical copies at logic gate level means any copies made will more easily have automated watermarks than not – it will be extremely unlikely produce a perfect copy as opposed to it being easier to produce an imperfect one. A quantum computer is more analogue in nature just like the (real) quantum world in which we live; quantum watermarks can operate like extremely secure individualised paper watermarks - similar (but much more traceable) to the ways in which analogue prints are often different enabling tracing (e.g., ink marks make all prints traceable back to particular copiers for the purposes of crime prevention). [84]

Quantum watermarks are more likely to be secure than digital watermarks, and more likely to be embedded in quantum-based code and information. Quantum stenography is a growing area; indeed, there are articles written about quantum watermarking and error correction techniques in computer science journals.[85] As mentioned above, due to the methods of error correction that are required for the efficient and correct operation of quantum computing, such watermarks are going to become the bread and butter of everyday operation of quantum computing mechanisms. The current legal protection of such watermarks are through legal mechanisms that may or may not require copyright subsistence.[86] Chances are, these watermarks will become so commonplace that for copyright protection it will become usual for such marks to exist for copyright identification – raising the spectre of potential misuse. Another concern that the rise of searchable watermarking techniques poses is in relation to privacy laws, because it is very easy to track and trace the way in which content is being used. Just as the quantum nature of quantum computing seems to align with property, so in a quantum manner quantum computing also aligns with the notion of information flow. Quantum computing will be able to trace the use of content in ways and to degrees hitherto unknown. It is possible to combine such quantum cryptography with wider computing,[87] e.g. searching the Internet using quantum algorithms. It is not so much then that quantum computing is going to bring a revolution in terms of changes to the existing technologies, but more that quantum computing will bring unprecedented evolutions at a number of competing and overlapping quantum levels that will push and challenge our everyday use of content. That will be particularly so where we are dealing with quantum technologies such as quantum watermarking.

Whilst there are undeniable challenges to encryption and other issues, emphasis in any future regulation should be on how quantum computing will see an increased emphasis both on property and tracking of use, reflecting its 'quantum' nature. We should also keep in mind potential convergence between the law and quantum technology. As argued above, property principles could well be enhanced alongside tracking and tracing; this could have

[83] E.g. Windows Media Player DRM, Janus (WMDRM-PDF) limited to specific IBX.

[84] Machine Identification Code – MIC – see github.com/dfd-tud/dada; Richter, Escher, Schönfeld, and Strufe, Forensic Analysis and Anonymisation of Printed Documents, Proceedings of the 6th ACM Workshop on Information Hiding and Multimedia Security, ACM, New York, 127 (2018) available at https://doi.org/10.1145/3206004.3206019

[85] Abura'ed, Khan, Bhaskar, Advances in the quantum theoretical approach to image processing applications 49(4) ACM Computing Surveys, Article 75 (2017). Panjiyar, Sharma, Katiyar, A technical paper on quantum watermarking techniques based on DWT-DCT and DCT-DWT using PN sequence 6(4) International Journal of Computer Science and Mobile Computing 274 (2017). But do note that these journals focus on transposition of digital watermarks into quantum with the exception of Shaw and Brun, Quantum Stenography, quant-ph>aXiv:1006.1934 at https://arxiv.org/abs/1006.1934 True logic gate quantum watermarks have yet to be particularly evolved.

[86] See *n.*31.

[87] Wang, Rohde, Ali, Quantum Cryptography and Simulation; Elliott, Pearson and Troxel, Quantum Cryptography in Practice, see *n*.76.

consequences such as preventing private re-uses that are currently away from the eyes of the law, or any form of editing of works.[88] Quantum control crosses traditional borders, in that it impacts the way individuals think and work with content in the process of consumption and re-use to a degree not yet witnessed. The interactive nature of computers could be lost to quantum access controls; the acquisition of new skills required for the creation of new content could consequently become limited.

The challenges of convergence have travelled apace in recent history, with digital technologies combining numerous methods of accessing and using works. It has led to a direct challenge to traditional regulatory techniques. Quantum computing brings a new level of challenge due to the way interaction occurs between technology and people; of particular concern is that mirroring of process between creative thought and the making of content. The speed, invasiveness and consequences of that mirroring means that there is a compression in the space in which the individual has freedom of thought to be able to re-use, cogitate and consider the interpretation of content. It is a convergence between the machine mind of code albeit in quantum form, and the thoughts of the human mind in the quantum world which quantum computers were created to help understand.[89]

12. Future quantum regulation

Future quantum regulation needs to balance the flexibility that quantum computing brings (e.g. new types of work) with the certainty that it also brings (e.g. greater enforcement). There are competing needs for flexibility and certainty in law. Flexibility is useful in maintaining rationalities of law when individuals might wish to do something that the law otherwise strictly forbids, such as the making of remixes in the home, away from the eyes of the law. However, certainty is something that people often want provided in the law to meet their basic needs, such as when they produce their own copyright work.[90] With that in mind, what should the future hold for regulation of quantum computing? On the one hand, there is less certainty because of the amount of potential copyright infringements of older works, but more certainty because of the use of quantum watermarking techniques. With traditional copyright law, the balance to revolve around a mixture of a lack of enforcement and concepts such as non-protection of ideas and non-original elements, but the focus of the balance changes with quantum technology. With quantum copyright, the difference appears to be between pre-quantum and post-quantum works, with the amount of protection revolving around the amount of watermark protection that is possible.[91]

An important element underlying copyright protection has been that the protection is granted in exchange for investment (e.g. labour, skill and effort) in making, and distributing, that work. There is the possibility, sometimes, of making substantial profit from that work. This is akin to a basic principle of capitalism – that loans are given in exchange for the possibility of profit. This is what is known as the capitalist 'fiction.' There is a need to keep that 'fiction,' the ability to potentially profit in whatever way, from copyright works. Quantum watermarking thus needs to preserve this – but quantum watermarking can be the very reverse, because the purpose of it is to track uses, and thus make future investment more precise. Such watermarks - rather akin to the 'schizophrenic' realities of capitalism where 'winner takes all'[92] – can become self-defeating, leading to less investment because the potential possibilities for success might seem more difficult to achieve. If the quantum watermarking technologies indicate that the 'future bestseller' might not be such a bestseller after all, that it might not

[88] Helberger and Hugenholtz, No place like home for making a copy: Private copying in European copyright law and consumer law, 22 Berkeley Technology Law Journal 1061 (2007).
[89] Heisenberg, see *n*.4.
[90] See e.g. Frank, Law and the Modern Mind, Tudor Publishing (1930).
[91] See discussion in the above section.
[92] To borrow wording from Deleuze and Guattari, A Thousand Plateaus, Continuum (2004), Section 3, Chapter 10.

be considered worth investing in it. It is therefore imperative that quantum watermarking can keep some uncertainty present. As noted above, in the past this was due to a lack of knowledge about how works might be used, and uncertainties with enforcement. With quantum computing, this might be more to do with quantum watermarking developments. As the prior section discussed, protection might be greater for works with newer forms of watermarking (whether that be digital watermarks being displaced by quantum ones, or newer quantum ones displacing older quantum ones).

There are two ways to achieve this. Firstly, to permit market and technical forces to simply compete to develop new watermarks to help ensure earlier works are more likely to be re-used, and consequently their ideas and non-original elements. As outlined in the previous section, this is the likely default position without regulation. Second, there is a need to ensure that copyright does not then enable right holders to overprotect quantum copyright works. Quantum computing is likely to lead to more dissemination of works through licensing *and* sales because of its ability to do small scale unique transactions on an unprecedented scale, thus opening new avenues of investment and productivity. Quantum computing, as noted above,[93] can track and trace uses in new ways, enabling new forms of licensing, whilst doing so considerably faster than digital technologies. At the same time, there is a potential challenge in that the tracking of content could mean that every single small reuse would require payment of a licensing fee. In this scenario, the concept of an unprotectable idea under copyright might have less meaning if technological measures are being used limit reuses.

Notwithstanding a recent case establishing copyright in a fictional character (as opposed to the entire literary work),[94] courts have been keen to point out the dangers of cutting up larger works into smaller works as it means a greater likelihood of a finding of copyright infringement.[95] This could, in effect, have the impact of expanding the enforcement of copyright. Whilst quantitatively smaller works opens up the possibility to commercially exploit existing works to new audiences, it also reduces new markets for new types of work which might otherwise not have been deemed a copyright infringement. As noted above, though, quantum watermarking can potentially protect those elements, and automatically so if attached to e.g. DRM or QRM. This paper proposes a need to register works that are watermarked, before a copyright infringement suit can be brought using watermark evidence (similar to the US registration processes)[96] to prevent overreach by watermarking of ever quantitatively smaller elements, which would in turn lead to ever greater copyright enforcement. A limited mirrored provision under Fair Dealing could also be introduced similar to s.50A-C CDPA 1988, to limit the use of licenses in a manner to get around the registration requirement. Many nations have resisted any calls for registration for a long time, in large part due to the requirements of the Berne Convention,[97] but those rules were created in a different time, and do we want to continue existing methods of distribution when quantum computing could reinforce those traditional norms to the degree that they become self-defeating? By limiting the practical use of quantum watermarks over copyright works, the enforcement of quantum copyright becomes more difficult and can thus balance out potential overreach of copyright the more developed quantum watermarks become.

13. Forthcoming technological developments

[93] Section 11, above.

[94] *Shazam Productions Ltd* v *Only Fools The Dining Experience Ltd* [2022] EWHC 1379 (IPEC).

[95] *Baigent* v *Random House* [2007] EWCA Civ 247 at para. 131.

[96] See *n*. 36.

[97] Berne Convention for the Protection of Literary and Artistic Works, Sept. 9, 1886, as revised in Paris on July 24, 1971 and amended in 1979, S. Treaty Doc. No. 99-27 (1986) [The 1979 amended version does not appear in UNTS or ILM, but the 1971 Paris revision is available at 1161 UNTS 30 (1971)].

Quantum computing is the future of modern computing. What technologies in the immediate and long-term future might occur, and what would that mean for forthcoming laws? After all, a common complaint of any legislation is that it is merely responding to current events without taking sufficient account of the future. For the immediate future, we can expect to see a shrinking of quantum computers from their current size to something more portable – this is what we can already observe with silicon quantum dot.[98] This will allow for quantum computing to take place in wearable (e.g., watch) size devices. The technology is already being developed. We can thus expect quantum computing to be extremely portable, not just in terms of small devices but being transplanted in an almost quantum scenario throughout different substrates. It has been noted above that quantum computing holds much resemblance to human thought process – not to mention that quantum computing qubits could fit directly with DNA and RNA sequencing.[99] At the same time, the increasing speed of broadband alongside powerful remote quantum computing could see increasing streaming of data to otherwise dumb devices, meaning a further diversification of where quantum computing becomes relevant (e.g. quantum computing could be streamed to digital contact lenses). For more distant technologies, we start to enter the realm of speculation rather than technologies that are already under considerable development. Given increasing technological convergence and shrinking size of technologies, we can expect quantum technology to become more enmeshed with other developing technologies.[100] An example could be biotech, where DNA and RNA could become merged with mechanical quantum technologies - quantum compute could be merged with living cells.[101] There are numerous similarities between neuromorphic compute and quantum computing, and convergence frankly seems inevitable. This poses additional regulatory challenges e.g. in relation to the ability to regulate biological mechanisms which could even be printed and implanted at home; or how devices are regulated that might externally 'talk' to the human body (e.g. neurons) through quantum code.

Thus far, the proposal is that regulation should be aware of how quantum computing effects and interacts with traditional notions of property and content tracking; that there is a need to maintain the freedoms which an individual utilises when engaging in the making of new works. When the future of quantum technologies is increasingly moving towards closer interface with the human mind, the future could become one where the human mind is increasingly taking on technical characteristics of quantum code – not just with the abilities that this brings, but also the limits that this brings, namely ability to think utilising the freedom of thought that technologies have historically brought. There is a risk that quantum technologies develop in a manner that enhances and broadens existing technological protections, to the extent that the law itself becomes self-defeating by inhibiting creativity, by the use of enmeshed quantum protection measures. Currently there are limits to the enforcement of the law (e.g with regard to right holders being able to observe private uses of analogue or digital works in the home), but those could be overcome through such internet connected quantum protection measures, in particular quantum watermarking.[102] The laws designed to encourage investment into cultural works could very well end up having the opposite effect, and this is why the above proposals concerning the limits to quantum watermarks could become important in

[98] See also Pires, Quantum computing on a chip, Toms Hardware, at https://www.tomshardware.com/news/quantum-computing-cambridge-riverland

[99] Griffin, *n*.35.

[100] Ferraro and Prati, Is all-electrical silicon quantum computing feasible in the long term? 384(17) Physics Letters A, 12,6352 (2020).

[101] Tacchino, Macchiavello, Gerace and Bajoni, An artificial neuron implanted on an actual quantum processor, 5 npj Quantum Information 26 (2019).

[102] See *n*.88.

maintaining not just the copyright balance, but the balance between freedom of thought and copyright enforcement.

The application of laws inside quantum technologies warrants close consideration. We have seen with digital technologies that there are laws that are *concerning* digital technologies, and laws that are applied *through* digital technologies. The latter splits down into two further categories – laws applied by the State through technology (e.g. such as website blocking)[103] and access rules enforced through legally protected code (e.g. conditions of use under a licence enforced by legally protected digital rights management mechanisms).[104] Both are concerned with the enforcement of rules. As noted above, quantum computing inherently favours imperfect replication, thus actions on quantum computers are more likely to be traceable than with digital computers. This could make quantum enforcement of rules much easier to achieve. The complexity of the computers will mean that users can never be entirely sure if their actions are safe from being tracked or not; it is the issue of the digital Benthamite panopticon penitentiary writ large.[105] Users can be sure that the nature of quantum computing is likely to ensure that there is a breadcrumb trail of their activities in a way that has not existed with traditional digital computing. Existing right holders may argue that the faster copying and instruction speeds of quantum computers means that there is nonetheless the possibility of more copies being made of copyright works – and that is an undeniable possibility – but as with digital technologies, the more tracing and tracking becomes possible (as indeed it has with faster Internet speeds) then the possibility of enforcing copyright infringements becomes greater. The possibility of tracking ever smaller uses need not be an issue that delimits the use of content. As noted above, the key issue is that property concepts and content tracking might both simultaneously extend the covering of more content more completely. Tracking of smaller uses could lead instead to more nuanced licensing, and increased re-use of content. However, regulation needs to exist to encourage this nuanced behaviour, otherwise monopolistic right holders might clamp down on re-use of any content regardless of copyright protection. We could end up in a permission-based access quantum computing scenario, rather than one where more creative quantum re-uses are permissible, e.g. quantum logic re-uses of currently unprotected copyright elements.

The nature of legal interface with quantum computing is thus highly important. It is critical that quantum technologies are not used to simply enhance existing legal protections. We have, of course, been at this juncture before with new technologies and law – whenever a new technology arrives, there are clamours for reform by those who stand to benefit and those who stand to lose. However, on this occasion we are not simply dealing with a usual technological jump – this is one where the technology will quite literally be a 'quantum leap' forward, not just in terms of technologies that we use but also how technologies interface with the human body. Ideally, Governments and regulators should already be considering how to regulate quantum technologies, and consider the regulatory challenges that are likely to arise. Alas, we seem to be entering another period where regulation will respond to technical change rather than proactively anticipate it. This could be problematic with quantum computing due to the novel quantum way in which it is going to engage with existing technologies, with convergence leading to an acceleration in existing regulatory styles. This could well lead to an era of increased control by existing groups of right holders and decreased inventiveness by individuals. The copyright style monopolies granted by the law will become quantum monopolies, moving beyond their traditional (and digital) borders; in short,

[103] Romero-Moreno, 'Upload filters' and human rights: implementing Article 17 of the Directive on Copyright in the Digital Single Market 34 IRCLT 153 (2020).
[104] *Inter alia* Reese, Will merging access controls and rights controls undermine the structure of anticircumvention law? *n*.32.
[105] Bentham, The Panopticon Writings, Verso (1995); Rheingold, The Virtual Community: Homesteading on the Electronic Frontier, Harper Perennial (1994).

traditional approaches to regulation run the risk of significantly undermining the copyright balance to a degree not seen before, and it seems, not even yet anticipated.

The current focus on AI serves to skew the focus of regulators away from quantum. Debates about AI, and its alleged dangers to the future of humanity, fail to realise the importance of quantum computing.[106] The debates are couched in terms of digital AI – but, as outlined above, AI closely aligns with quantum compute (and also with biological compute). An AI based in quantum will be at an enormous advantage compared to digital AI. Digital AI is often a byword for 'complex looking machine software' rather than independently thinking code; quantum can utilise unique AI coding,[107] which could be used with error correction to induce 'creativity.'[108] If regulation pushes quantum compute towards enhanced property-based paradigms and to the tracking of content, then quantum AI could be less creative because digital norms will predominate. However, the human user might also become less creative because quantum compute will enforce strict adherence not just to copyright, but also to traditional access right norms. This will occur independently of AI development - the moment existing AI is placed within quantum compute logic gates, the direction of quantum technology will be what determines the direction of development in AI. This might mean development of quantum AI systems that control actions precisely and predict infringements of rules, rather than the development of quantum AI systems that would enable the open conditions of creativity by humans. The current focus on AI thus is a side issue to quantum computing and the regulation of such systems. If regulation is to direct development of AI, and indeed quantum computing, then there is a need to consider whether it is to be developed as a tool for enforcement of existing laws and as a means to accelerate the collapse of the human cultural and capitalist 'fictions', or whether it should be encourage do develop as a creative tool for encouragement of human development.

14. Conclusion

Quantum computing was originally conceived as a way in which to understand the uncertainties of quantum physics. To deal with the nature of quantum, a computer was required that could operate in a quantum way. It should come as no surprise that a computing technology designed to help our understanding of the world could have far reaching consequences in the way in which we interact with that world;[109] quantum computing provides not just a pair of reading glasses for the quantum physicist, but also provides a new way of thinking for anyone who engages with a quantum computer. It makes us aware of the low-level uncertainties in our everyday lives. In the same way that a computer programmer may use a quantum computer to write quantum code, so the computer user becomes aware of those uncertainties.[110] The user who considers how to protect legal property will begin to consider how uncertainties in quantum code not just provide an advantage to protection, but also how quantum concepts can undermine property protection. Quantum computing can allow for more unauthorised reproduction but also favour enhanced proprietary controls and the tracking of content. This means that whilst technologies such as generative quantum AI

[106] Consider for example the UK IPO consultation on 'AI and IP: Copyright and Patents' at https://www.gov.uk/government/consultations/artificial-intelligence-and-ip-copyright-and-patents ; also consider the upcoming 'AI safety summit' detailed by the Department for Science, Innovation and Technology, 'UK Government sets out AI Safety Summit ambitions' at https://www.gov.uk/government/news/uk-government-sets-out-ai-safety-summit-ambitions

[107] Consider, for example, discussion of the issue at https://research.ibm.com/topics/quantum-error-correction and also IBM, Error correcting codes for near-term quantum computers, at https://research.ibm.com/blog/error-correction-codes ; Bravyi, Cross, Gambetta, Maslov, Rall, Yoder 'High-Threshold and Low-Overhead Fault-Tolerant Quantum Memory, arXiv:2308.07915 [quant-ph] at https://doi.org/10.48550/arXiv.2308.07915; for a general overview see the presentation of Blume-Kohout, Quantum Computing and Creativity, available at https://www.osti.gov/servlets/purl/1561738

[108] On error correction see *n*.85.

[109] Heisenberg, Uber den anschaulichen Inhalt der quantentheo retischen kinematik und mechanic, *n*.7.

[110] Consider Wootton, *n*.16; Becker, *n*.16.

could lead to an exponentially greater number of re-uses of copyright works without permission, tracking of those uses is likely to be possible in many circumstances. Nonetheless, it has been argued that such tracking is going to be more likely with newer copyright works than older works, as older works might not have watermarks embedded in them. At the same time, quantum computers will have sufficient compute power to be able to make judgment calls as to whether or not re-uses are likely to be copyright infringements, skirting the boundaries of the law in a way that has yet to be fully tested in practice. Whilst that is occurring, there is likely to be a battle between newer quantum computers vis-à-vis existing watermarks, leading to a technology race where ever faster computers will be able to potentially break and get around watermark technologies, including older quantum watermark technologies. Even today, the use of digital technological protection measures can potentially provide legal protection enabling right holders to sue for breaches of those mechanisms rather than just relying on traditional copyright law – with the proviso that only those who break them can be sued. The likely development of quantum technological measures will enhance the effectiveness of protection measures further, and the rather probable development of a 'server' style model of content distribution could mean that more individuals can be sued for breaking what I termed 'QRM'. [111]

Ultimately, regulators need to be proactively aware of the issues that quantum computing brings in terms of potential control and the creative restrictions that it could bring. Due to the sheer exponential speed increases of quantum computing, we could find that regulation and private contracts are enforced to a far greater degree. Indeed, such contracts are likely to become ever more important in extending the scope of the rights that comprise copyright. However, at the same time, the increased enforcement through compute power could be complemented by the underlying ability of quantum computers to make imperfect (unique) copies. This can lead to more methods to track and trace use, which could also lead to further enforcement of the law in new and novel ways. In addition, current statutes provide additional legal protections for such technologies, in particular quantum watermarking technologies – and one might argue that these laws encourage even further technical development in them.

The future of regulation is thus one where quantum technologies are going to be engaged in a 'forever' war- not in the sense of replicating existing battles, but in a quantum way where the conflict is constantly evolving around the quantum characteristics of quantum computers. These evolutions mean a constant change in our understanding of proprietary boundaries – exactly in the same way that quantum computers were designed to help us understand how quantum physics behaved, and in the same way that the technology has enabled a challenge to traditional perceptions of the world. This is why quantum computing will challenge our existing conceptions of knowledge to a greater degree than ever before. Existing law clearly has a complex, almost quantum, relationship with quantum technologies, and there are certainly areas where reform might be possible. Existing laws strongly favour tracking, tracing, and protection technologies - as long as the law does not restrict our new ways of understanding, then quantum technologies will continue to drive new understandings of the world, and to take us into a new quantum future.

[111] See *n*.31, and section 10, above.