The research commercialisation office of the University of Oxford, previously called **Isis Innovation**, has been renamed **Oxford University Innovation**

All documents and other materials will be updated accordingly. In the meantime the remaining content of this Isis Innovation document is still valid.

URLs beginning www.isis-innovation.com/... are automatically redirected to our new domain, www.innovation.ox.ac.uk/...

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Taking a leap towards the quantum future

Dr Rakesh Roshan, Deputy Head of Technology Transfer

The UK government recently committed a £270 million investment in the UK National Quantum Technology Programme. Governments in Holland, Singapore and Australia are also providing large budgets for quantum computing programmes. Google, IBM and Microsoft have quietly been working on the basic building blocks of quantum computers.

But we're yet to see a quantum computer at an industry trade show. Quantum computers are still in their infancy and far from replacing the classic computing machines which are used ubiquitously today.

Today's quantum computers are laboratory-scale devices that often work at very low temperatures or in vacuum. We have not yet overcome all of the barriers to scaling that are required to build a full-blown computer. In this sense they not very different to the first primitive classical computers built for specialized tasks in terms of their readiness levels.

The device which is closest to market is probably the 512-qubit system built by Canadian company D-Wave. A qubit is a quantum analogue of a classical bit and a unit of quantum information. Their device works at extremely low temperatures, just 0.2C above absolute zero. D-Wave is also working on a faster 1000 qubit system.

And last year Cambridge Quantum Computing announced that Grupo Arcano has committed to fund their quantum computing goals to the tune of up to £32m.

The promise of speed

What is the huge promise of this technology that so many continue to maintain the faith despite little "real world" impact to date? Well, as Oxford Professor David Deutsch says: "Quantum computers can solve problems at speeds that would take a classical computer longer than the age of universe".[1]

This means that quantum technologies could lead to enormous changes in the way we live, sense, compute and communicate. Quantum devices have the potential to accelerate discoveries in fields including astronomy, drug development, genetics and data analytics.[2] Along with quantum computers, researchers are exploring many other commercial applications of quantum technology such as atomic clocks that will improve accuracy in next generation (beyond 4G) data communications and high-frequency financial trading.

A global community

Unlike the period of rapid uptake in the application of classical physics during the industrial revolution, the uptake of technologies derived from quantum physics will depend on the explicit contributions of research institutions and the academic community across the globe. And in the

[1] http://www.zmescience.com/research/d-wave-claims-wants-release-1000-qubit-quantum-computer-2014
[2] http://www.bloomberg.com/bw/articles/2013-05-30/what-quantum-computing-can-do-for-you

current climate these institutions are now benchmarked and rewarded in part on their ability to deliver this “real world” impact.

Professor Ian Walmsley, Oxford Pro-Vice Chancellor and Director of the University’s Networked Quantum Information Technologies Hub (NQIT, pronounced 'N-kit') led by the University of Oxford, believes that academic institutions will play a pivotal role in the growth of quantum technology industry. The prominent scientists in Universities and research institutes that are driving the research agenda in this area have extensive international academic and industry networks and are embedded in a strong innovation ecosystem involving stakeholders such as industry leaders, investment partners and entrepreneurs.

Governments around the world (in the USA, Australia, China, Canada, Singapore and several European countries) have continued to support the development of the quantum technologies. The UK National Quantum Technology Programme will have four hubs, NQIT led by Oxford and the three others led by the universities of Birmingham, Glasgow and York.[3]

The Dutch government, through its TNO research institute and other organisations, has recently agreed to invest €135 million in the development of a superfast quantum computer over a 10-year period. Singapore’s Centre for Quantum Technologies (CQT), supported by Singapore's National Research Foundation and Ministry of Education, was an early arrival in this space and has been in operation since 2007.

Professor Artur Ekert, Director at CQT and founder of quantum cryptography says that: “Exciting quantum research is being conducted at CQT and worldwide by highly motivated bright minds. It is equally important that a robust roadmap for commercialising the underpinning research is drawn in tandem”[4].

The road ahead

Many universities around the world have gained some mastery in the art of taking academic research to the market place. However, the jury still is out on whether existing commercialization models are fit for the specific challenges presented by the new quantum technologies.

The products and technologies such as displays and telephones that exploit classical physics have evolved over many years and performance boundaries continue to be pushed back. Quantum devices are likely to follow a similar trajectory: slow adoption, further improvement and a period of later slower growth as technologies mature – this is the well-known technology “S-curve”. We now have an excellent opportunity to learn from the evolution of the classical technologies, and perhaps find tactical or strategic opportunities to accelerate activities leading to quantum technology adoption.

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[3] https://www.epsrc.ac.uk/research/ourportfolio/themes/quantumtech/

[4] http://dialogues.qilabs.net/post/2015/06/01/dutch-invest-euro-135-million-in-quantum-computer-development-who-s-next.

The very fact that the quantum technology products will be protected by a portfolio of complex Intellectual Property (IP) bundles arising from a multitude of sources creates the need for more sophisticated and complex commercial models.

Avoiding patent wars

Quantum technologies draw contributions from optics, laser, photonics, structural design, sensor technology, electronics, ancillary components, packaging, hardware and software, and material science. This means the conventional commercialization models practised by institutions, where an attempt is made to transfer a single piece of the jigsaw into a spinout company or as a licence to an existing company may not be effective.

An interesting recent example from the "classical" approach of commercializing complex IP bundles is the mobile phone market where licensing on "fair, reasonable and non-discriminatory" (FRAND) terms has attempted to drive the adoption of new standards.

Despite this, there have been a number of "patent wars" as the marketplace has developed and it seems reasonable to expect similar issues to arise as quantum technologies emerge.

The 'license or spinout' dilemma

Several academic institutions have already had some success at licensing quantum technologies to industry. Of these licences, a number are revenue generating, returning royalties to their institutions as products and services are successfully marketed by the licensee to end users. Such examples are currently rare.

Isis Innovation, the technology transfer arm of the University of Oxford, regarded as the leading technology transfer unit in the world by Global University Venturing[5], has successfully licensed out a few quantum technologies and recently has seen a surge in the flow of quantum technology invention disclosures. For example a new optical scheme for generating quantum numbers with applications in computing, encryption, modelling and gaming is being patented. In 2007 Isis Innovation licensed a patented technique for measuring classical ultrashort laser pulses that owes part of its design to ideas learned in developing quantum light sources, and that has been licensed to APE Berlin[6]. The resulting product – LX SPIDER – was launched into the market in 2008. Customers from variety of sectors including materials processing and biomedical diagnostics are using LX spider for improved material characterisation. It is also used by manufacturers of pulsed lasers in the specification, verification and installation of their laser products.

Many quantum-related IP offerings are likely to be only stepping stones, incremental steps or single pieces of a larger jigsaw. There is also a widespread sense that quantum technologies are risky, and that this risk is hard to quantify.

In other words, quantum technologies involve "unknown unknowns" alongside the "known unknowns" that licensees have historically been prepared to accept.

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[5] http://www.globaluniversityventuring.com/article.php/4049/technology-transfer-unit-of-the-year-isis-innovation

[6] http://s3.amazonaws.com/zanran_storage/www.isis-innovation.com/ContentPages/21669672.pdf

Test driving ideas

What is the best way forward? I believe spinning out a “technology aggregator" companies or special purpose commercialization vehicle will be the most effective way to corral ‘early stage’ quantum technologies.

One example of this approach is Florida-based Resocator Inc a US company recently established to develop and market new technologies enabled by specific University of Oxford patents.

According to Billy Meadow, President of ResoCator, Inc: “After a broad review of global academic innovation in geo-location, communications and spatial technologies, we saw the huge commercial potential for Oxford’s Miniature Atomic Clock. Through precise time keeping, it will enable new forms of tracking and monitoring as well as communications enhancement. We acquired a world-wide license to this technology so that we can create next-generation GPS, which we call “Global Resource Locator” technology, a suite of devices and services that will enable the physical tracking and monitoring of virtually any item in the world indoors or out.”

Sketching a new strategy

Spin-out companies can take on the early stage risk and are nimble enough to accelerate product development. Investors are well aware of the high risk nature of these plays. In fact, they are looking for ventures which could result in high gain when they are successful.

Finding patient and well-informed investors for quantum technologies will be a challenge both because of the high risk and high reward profile and as timescales to return are long. Dave Norwood, the Chairman of Oxford Sciences Innovation Plc says: “Applications of quantum technologies have always been perceived as niche and a thing for the future which may always be unless a new innovative strategy is sketched and implemented”.

It falls to leading academic institutions which already have a robust technology transfer infrastructure and a strong innovation ecosystem in place to provide a platform to coordinate and test any newly-derived exploitation models.

Beyond comprehension?

Quantum science is difficult to understand and communicate: even its jokes can seem beyond comprehension. Quantum scientists are focused on pushing the boundaries of their science and may not be ideally placed to lead commercialization activities.

Support from suitably qualified technology transfer managers who have the ability to understand the complex science and then the skills to evaluate and build commercialization strategies and roadmaps would be required. Public engagement programmes and dedicated events will increase the awareness of the quantum world and the potential benefits of quantum-related technologies.

Bespoke programmes to promote the quantum field will help attract the most talented practitioners to tackle the commercial and technological challenges of the new paradigm.

Several research institutions have been filing patent applications on quantum technologies. However, as noted previously, finding commercial partners for quantum technologies is challenging and maintaining patents as their costs escalate during prosecution is difficult to justify in the absence of a commercial deal supporting the expense. As a result, patents risk being abandoned.

Sharing risk

One route forward might be to share the risk with funding bodies, for example allocating a small proportion of a research grant or translational award to the cost of patenting. Tom Hockaday the CEO at Isis Innovation, the technology transfer arm of the University of Oxford, said that some of the patents out of the many that have been filed in recent years could become of high value in the foreseeable future; hence we need to investigate creative ways to fund and support quantum technology patent portfolios for the next few years.

The supply chain and value chain partners interested in quantum technology related business opportunities need to be identified and engaged by the institutions researching quantum science. Relevant authorities should consider developing standards for various applications of quantum technologies.

With a deep understanding of the global research and innovation landscape it will be possible to construct a bespoke functional model which will allow quantum technologies to advance quickly.

Innovations at a components level and early market adoption will increase stakeholder's confidence level and act as stepping stones.

Oxford as a springboard

And does the UK have the capacity to lead in a new era of quantum computing? I would say "Yes!", and that the Oxfordshire technology hub with its broad and deep pools of expertise from many disciplines is poised to become one of its cornerstone sites.

Patient, experienced investors and the commercialisation skills to take the vision forward are the other pieces which must fall in to place. Tim Cook Co-Director for User Engagement at NQIT and former Board Member and Managing Director at Isis Innovation says: "The NQIT hub has identified the critical technology path for building quantum computers. The formula for success will include building a reproducible and functional qubit, followed by connecting them together reliably that preserves entanglement, and finally devising an architecture where the time taken for the errors introduced in the interconnects is long compared with the time entanglement can be maintained.

The leaders in these efforts will need to become expert at cross-border collaboration: working across national boundaries, across scientific disciplines, and also across public-private boundaries. They will also need to require building a strong industry network in order to canvass potential customers to tailoring products to real needs. Quantum computing may have been a slow burn until now, but from here on it can accelerate quickly.

The endgame will be a group of companies which not only builds a new generation of quantum technology products, but establishes a robust supply chain that will support the scaling of the technology into a worldwide success.

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