Written evidence submitted by the University of Strathclyde (QUT0004)

Background

The University of Strathclyde welcomes the opportunity to submit its views to the House of Commons Science and Technology Committee Inquiry into Quantum Technologies, an area we consider to have very high growth potential and important to the economic development of the United Kingdom.

Our collective vision for Strathclyde is of a leading international technological university inspired by its founding mission as ‘the place of useful learning’, that makes a positive difference to the lives of its students, to society and to the world. Our students benefit from an innovative and practical educational experience that is enhanced by its integration with our research capabilities, high-quality academic resources and an unparalleled industry engagement programme. The excellence of our research is evidenced by our position amongst the UK’s top 20 research-intensive universities and by the growth in range and scale of our unique research collaborations. We have also redefined how we collaborate and work with industry, government and the third sector to ensure that innovation and knowledge exchange are fundamental activities that deliver tangible impact.

Quantum Technology is set to provide significantly enhanced capabilities in timing, sensing and measurement, imaging, computing and simulation, and communications across a range of sectors and applications. The recent Blackett Review positions the UK joint 3rd in the world (along with Germany) on investment in R&D and commercialisation with only the USA and China ahead of the UK on rankings. Strathclyde's commitment to Quantum Technology has already led to 20 successful industry collaborations with an estimated value of circa £5.5m over the past 3 years. Quantum Technology has been selected as one of five key clusters around which the University will grow its renowned Technology & Innovation Centre, an area with the one of the highest concentrations of industry focussed academic research, innovation expertise, industry and translational research organisations. The cluster will also build on the presence in Glasgow of related spin-out SME businesses as well as the Fraunhofer Centre for Applied Photonics.

1. The progress that has been made on the recommendations in the Government Office for Science’s 2016 report

The recommendations in the Blackett Review have been welcomed with enthusiasm from the UK research and translational communities including the burgeoning Quantum Technology industry and associated supply chain. Particular engagement from the public and private sector stakeholders has been aimed at securing our international position of leadership in Quantum Technology translation through the discussions around the continuation of the UK National Programme and the establishment of innovation centres.

There is a clear realisation emerging among a number of academic institutions and private industry with particular interest in the development of this potentially disruptive technology, that the UK has the scientific and commercial basis for the formation of a small number of innovation centres aimed at the translation of Quantum Technology. These should be industry led, but with strong academic connections and involvement.

Quantum physics has unlocked new ways of controlling the states of light and matter. Early discoveries led to the first “quantum revolution”, delivering a range of transformative
technologies such as the transistor and the laser that we now take for granted. Today we are on the cusp of a second “quantum revolution”, which over the next 5-10 years will create new forms of ultra-secure communication, deliver computing capable of solving problems that conventional technologies cannot tackle, afford navigation systems that no longer rely on satellite links and provide cameras that make the hitherto invisible, visible. The innovation centres will be crucial in the UK’s potential for capturing a substantial fraction of the international Quantum Technology industry. There is a strategic imperative to the UK being a leading player in the effort at harnessing the capabilities and capturing the benefits in a fast moving international field.

2. The relative contribution/support from government, researchers and businesses needed to make quantum technologies a success

The UK model for establishing international leadership in translational Quantum Technology has been visionary and has led to the identification of a number of commercialisation and IP protection opportunities. The public support (e.g. through the EPSRC Quantum Technology Hubs and Fellowship Programmes) has enabled the focus on applied research while the Innovate UK programme has enabled broad engagement with the industrial sector, particularly rapidly growing SMEs. The University of Strathclyde is the only university participating in all four EPSRC Hubs and a major player on the UK and international scene. Following on from the University achieving the highest grade point average for the Physics Unit of Assessment in on the most recent Research Excellence Framework (REF2014) we have continued our investment in the area in terms of staff and infrastructure. We now host one of the largest UK concentrations of Quantum Technology researchers with 14 active academics working in core areas of Physics with a similar number of research staff and approximately 25 PhD students. In addition to this, about 10 researchers are developing underpinning technologies, mainly in Photonics. This included a close partnership with the Fraunhofer Centre for Applied Photonics collocated at University of Strathclyde. The 5-year research grant total is close to £16M with approximately £900k from Innovate UK projects and approximately £250k from UK and international industry.

Together with related activities at our sister organisations across the country this has established the university sector and industrial commitments to the National Programme. Significant technical progress has been made and roadmaps established to chart a further development phase through to societal impact over the coming 5-year period. To succeed this will require an aspirational approach including the continuation of the National Programme supporting training and an element of underpinning research as well as the realisation of the vision of the innovation centres articulated in the Blackett Review. This will require Government to invest to mitigate the commercial risks associated with the development of a new industrial sector.

The City of Glasgow and the wider Central Belt of Scotland has enormous strength in Quantum Technology as evidenced by a recent Science and Innovation Audit report (Enabling Technologies in Scotland’s Central Belt, Department for Business, Energy and Industrial Strategy). There is an unprecedented opportunity to take an international lead in the industrialisation of Quantum Technology by building on the assets of the universities and the surrounding technology and innovation ecosystem. This is to a large extent both led and inspired by the successful Photonics industry in the Central Belt of Scotland and its commitment to leadership of and investment in the developing Quantum Technology industry.
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is evidenced by the disproportionately large fraction of the Innovate UK Quantum Technology support, that has gone to this region. As an example a cluster of highly innovative Scottish Companies including M Squared Lasers, CSTGlobal, Optocap, Clyde Space, Coherent, KNT and Fraunhofer UK have won 14 out of 27 awards in the latest round of Innovate UK Quantum funding.

3. The current state of the UK quantum industry and its potential going forward, including particular strengths and challenges

Quantum Technology represents an emerging and disruptive industry. We have come a long way in identifying key applications and in establishing the corresponding supply chain. As such, the UK has an international leadership position in certain areas. This has to be nurtured and supported while seeking to extend the reach of the technology. A particular challenge in this process is to establish the network of supply chain, component manufacturers and system integrators for the major industrial users, who may not yet appreciate the opportunities afforded by Quantum Technology.

A particular UK industrial sector, that has embraced Quantum Technology, is the Photonics industry. This is a rapidly expanding, high productivity sector, based on a range of technologies, that are particularly suited for Quantum Technologies involving optical and atomic systems. From the perspective of the University of Strathclyde this represents a particular strength and development opportunity for UK quantum industry.

4. What oversight or regulation is needed

As an emerging and disruptive technology there will be a need for setting standards, validation and regulation. It is critical that the UK is fully engaged in this process in order to ensure that the economy can fully benefit from the new industry that will emerge. There are particular roles for the National Physical Laboratory and the British Standards Institute, working with industrial and academic partners, to take the lead in calibration, validation and regulation.

5. Potential barriers for developing quantum technologies, and how these might be overcome

One of the key challenges in extending the reach of Quantum Technology is the establishment of a wide understanding of the capabilities across the industrial sector (including investors and entrepreneurs) and identification of applications in sectors hitherto not engaged in the process. The diversity of applications is part of the strength and excitement of the field but represents a challenge in terms of getting the message out. This can be facilitated by the continuation of the National Programme, which can also mitigate the commercial risks in new areas. The establishment of innovation centres as partnerships between industry and academia can support this process and de-risk entry for new players.

A barrier one might expect a new and disruptive technology to encounter is the establishment of a strong supply chain. This is already well progressing in the Quantum Technology area through the existing activities of the National Programme including in particular the Innovate UK component.

6. What research priorities there should be for quantum technologies and their possible uses, and who is best placed to undertake/fund that work

The National Programme identified four sub-areas of Quantum Technology, which subsequently largely mapped onto the EPSRC funded Hubs. These now represent the core
areas of UK international leadership in terms of research expertise and translational activity. These Hubs with their extensive industrial network would be in a strong position to form the basis for a continuation of the National Programme in terms of training, underpinning basic and applied research and as core partners in innovation centres. While significant industrial commitment to investment has been demonstrated there will still be a need for Government co-investment to mitigate the commercial risk.

From a University of Strathclyde perspective the core research and translational opportunities for future Quantum Technologies lie in:

- Systems based on ultra-cold atoms and ions. These include:
  - **Atomic clocks** including new generations of portable devices with low size, weight and power consumption for use in GPS denied environments and for autonomous local time-keeping with applications such as navigation, space, time-stamping in the financial sector, telecommunications and geological surveying.
  - **Gravitational sensing** including surveying for underground structures, prospecting for minerals and hydrocarbons, space and geodesy.
  - **Atomic gyroscopes** based on atomic interference for use in novel rotation sensors for navigation.
  - **Quantum simulators/computers** based on atoms and ions in compact micro-fabricated devices are among the front-runners in the drive towards establishing new quantum information processors with unprecedented computational power.
  - **Quantum memory** will be an integral part of any future quantum communication system in particular ones based on quantum key distribution via satellites.

- Systems based on hot atomic vapours. These include:
  - **Atomic magnetometers** with applications in geomagnetic surveying (incl. prospecting for minerals and hydrocarbons, archaeology and navigation), health care (incl. imaging of brain and other neurological activity, magnetic cardiography for humans and livestock and magnetic imaging of organs, e.g. the heart), defence and security (incl. monitoring of submersed vessels, navigation and trace element detection), monitoring of space weather, magnetic detection and imaging of material defects (oil & gas sector, nuclear, transport).
  - **Atomic gyroscopes** for compact, high bandwidth rotation sensors for navigation.

- Secure communications systems. Primarily:
  - The establishment of a **secure key** for ground and space-based optical communications systems is of paramount importance in areas such as finance, security and information technology.

- Imaging systems – ‘seeing the invisible’. Based on the integration of a suite of optical and atomic detection systems a broad range of applications are envisaged in sectors such as defence, biomedical imaging, geophysical surveying and space.
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- A particular aspect would be the integration of multiple sensor platforms in autonomous systems including driverless cars. This will also leverage on progress in Artificial Intelligence.

7. The role of international collaboration in quantum technology research and development; and the risks and opportunities of Brexit in this area

The UK has demonstrated a strong international leadership position in Quantum Technology. The UK programme was one of the pioneering ones internationally and is now being copied across the world. In particular, there is a €1bn EU Flagship programme, that researchers from the UK are seeking to participate in at least in the initial phase. Due to the leadership in the field and high international recognition of the quality of UK quantum research, the UK is a desirable partner in the EU Flagship. It would be desirable if this as well as other collaborations in research would still be available for UK researchers after Brexit. It is also important to recognise that many of the industrial partners we need to engage with in order to establish the Quantum Technology sector have European operations and would be looking to partner in EU programmes.

It would appear that the UK programme aims at higher TRL levels than the EU one and indeed some of the other international initiatives. This may partly be due to our head start but most definitely also due to the vision behind the UK National Programme. This competitive advantage in terms of translation needs to be maintained and extended.

8. Any challenges from potential civil/military ‘dual-use’ applications of the technologies, and how these can be addressed

The MOD programme on Quantum Technology represents roughly 10% of the UK investment to date. This is motivated by the prospect for novel precision devices for applications such as navigation and surveying (atomic clocks, accelerometers, gyroscopes and magnetometers) and secure communications. Many of the envisaged applications will also have civilian counterparts (e.g. commercial navigation, autonomous systems and communications) and share sensor platforms (e.g. magnetometers for healthcare). A key difference is the civilian market’s requirement for lower size, weight, power consumption and cost compared with that of an early military adopter albeit at potentially a less stringent technical performance requirement.

The military applications of Quantum Technology are therefore seen as a vehicle for early adopters of what is genuinely dual-use technology with substantial societal impact across a wide range of applications and industrial sectors. The military applications can be used to accelerate translation to civilian applications with genuine societal impact. A valid analogue would be the GPS system, that was developed for military purposes and now is a ubiquitous technology of substantial economic impact in a diverse range of areas in society.

9. Any potential societal implications – positive and negative – of the development of quantum technologies, including on health, security, privacy or equality

As outlined above we envisage a range of applications with significant positive impact on society including sectors such as health, communication, transport, energy and security. Quantum is likely to be a disruptive technology with applications well beyond what has so far been considered. We find it overwhelmingly likely that the new societal impacts will be positive and bring increased resilience to the UK and its infrastructure.
10. Is there anything else you feel would be pertinent to mention within the scope of the inquiry?

Based on an internationally leading science and technology base in the UK Quantum Technology provides an opportunity to accelerate the development of a highly productive industrial sector. The University of Strathclyde has a strong track record in securing societal impact of academic research. Together with our industrial and scientific partners we envisage a substantial opportunity in the translation of Quantum Technology and the realisation of a second quantum revolution with the UK as a leading player. We are committed to investing with other stakeholders in realising this vision and see many potential parallels with the emergence and development of the photonics industry over the last 2-3 decade and which is of particular importance for our region. Photonics is an enabling technology, that is used heavily across the manufacturing sector. With an export of over 75% it adds £12.9bn (similar to UK pharmaceutical industry) directly to UK economy every year in manufactured products and services and has a productivity of three times the national average (https://photonicsuk.org/sound-bites). This has been achieved through steady investment and close engagement of industrial and academic sectors.

We are confident that the UK is well positioned to take the international lead in a similar transformative process in Quantum Technology. We would welcome the establishment of innovation centres, that would oversee, drive and support this. Success would require patient investment into an aspirational and industrially focused activity with strong technical leadership, with a strong commitment to training from apprenticeship to doctoral level and with the willingness to take risk. The UK’s strengths in Quantum Technologies create an opportunity to develop a fast growing, highly productive sector and can bring many benefits to existing sectors who will utilise Quantum products. There is also the opportunity for UK companies of scale to grow in the highly disruptive and global markets associated with Quantum Technologies. A Quantum Technology innovation centre can be the catalyst for this technology and market development.

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