House of Commons

Science, Innovation and Technology Committee

Oral evidence: Commercialising quantum technologies, HC 270

Wednesday 22 November 2023

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Watch the meeting

Members present: Greg Clark (Chair); Dawn Butler; Tracey Crouch; Katherine Fletcher; Stephen Metcalfe; Carol Monaghan.

Questions 88-177

Witnesses

I: Professor David Cumming, Professor of Electronic Systems, University of Glasgow, and Professor Alessandro Fedrizzi, Professor of Engineering and Physical Sciences, Heriot-Watt University.

II: Dr Chris Erven, Chief Executive Officer, KETS Quantum Security, and Dr Murray Reed, CEO, QLM Technology Ltd.

III: Simon Andrews, Chief Executive, Fraunhofer CAP, and Dr Anke Lohmann, Founder, Anchored In.

Written evidence from witnesses:

- University of Glasgow
- QLM Technology Ltd
- Fraunhofer UK Research Ltd

Examination of witnesses

Witnesses: Professor Alessandro Fedrizzi and Professor David Cumming.

Q88 **Chair:** The Science, Innovation and Technology Committee is in session. This morning, we are continuing our inquiry into commercialising quantum technologies.

To look in particular at the commercialising aspect, I am pleased to welcome our first panel of witnesses. Professor Alessandro Fedrizzi is a professor of physics at Heriot-Watt University and senior co-investigator of the NQTP quantum communications hub—we will go into the details behind that acronym in a second. Professor David Cumming is chair of electronic systems at the University of Glasgow and director of the NQTP quantum enhanced imaging hub. Welcome, both, and thank you for coming to give evidence to us in person.

Professor Fedrizzi, could you give us a thumbnail sketch of the NQTP—the national quantum technologies programme—and how it operates?

Professor Fedrizzi: The national quantum technologies programme has been running for 10 years, so this is the last year of the 10-year vision. It was endowed with £1 billion, and it will continue into the next 10 years—into the next phase—with another £2.5 billion. It has been a large programme to turn the UK into a leader into this nascent field of quantum technologies, where we expect breakthroughs in computing, sensing and communication. The money has been used for a series of programmes including establishing the quantum hubs that we are part of, but it has also been used for fellowships, for centres of doctoral training, for a lot of Innovate UK projects, for commercialisation and other associated programmes.

Q89 **Chair:** To what extent is it about translation—in other words, commercialising and finding real-world applications for quantum technologies?

Professor Fedrizzi: That is a large part of it. A lot of this money has been coming through Innovate UK to fund pioneering projects as part of, for example, the industrial strategy challenge fund, to make sure that we translate this technology out of the labs and into the commercial market.

Q90 **Chair:** In that sense, the programme has something in common with the catapults, with which you will both be familiar. Are they the same? What are the differences?

Professor Fedrizzi: The catapults are sector-specific and are location-specific, so they are attached to, for example, universities. They are smaller in size overall. They have not got that much money to play with. The national quantum technologies programme has been a much bigger and wider-ranging exercise.

Q91 **Chair:** I see. From your point of view, Professor Cumming, should we want to see, and would it be useful to have, a quantum catapult to add to the family of catapults? Or is the programme as currently conceived a better way to operate?

Professor Cumming: The current programme provides a lot of flexibility. It brings in a very large proportion of the academic community. It is very inclusive, and all the hubs have been very effective in bringing relevant industries into their activity. It would be very hard to say that a catapult might be a better way forward, because I think the existing programme works very well.

Q92 **Chair:** There have been two phases of the existing programme. You have just said that it has worked very well. What do you consider the key elements of that success?

Professor Cumming: For example, QuantIC, which is the quantum enhanced imaging hub, is one of four hubs funded through EPSRC. EPSRC is perhaps best associated with basic fundamental research, but the hubs are different in the sense that they very much stimulate academics to think beyond basic research and engage with industry. We have been particularly effective in QuantIC in bringing in about 150 companies to work with us, setting up projects of a very wide-ranging scale with these companies and developing that engagement. I think that is a great success, and that is something that is quite different about these hubs, as opposed to more conventional programmes of funding in universities.

Q93 **Chair:** Could you give us some examples of the specific types of collaboration in your field? Have they gone into practice yet? Are they being used in the outside world?

Professor Cumming: A particularly important kind of collaboration we have with industry is joint funding of PhD students, so that the student is more embedded in the company as well as being embedded in the university. QuantIC has supported 38 students like this in its second phase, and it has led to successful outcomes where we have new projects that are emerging with companies that we work with. We have had, for example, engagement on cryogenic technology going into one of the arch scanners that you might see in airports. We have had engagement on imaging technologies, which has been particularly successful with single-photon avalanche detection technologies being used for ranging or in biomedical imaging. We are seeing the proceeds of our work leading to successful outcomes.

Q94 **Chair:** Professor Fedrizzi, is your hub successful in the way that Professor Cumming has described? If so, what are some of the examples of success?

Professor Fedrizzi: Yes, very much so. The mission of our hub has been to provide quantum communication for safe encryption at all distance scales. For every distance scale, we have an example of a success story, starting with consumer-grade quantum communication devices the size of a shoe box on one side and the size of a credit card on the other, which could be used at the cashpoint to refresh key material on a credit card, for example. This has taught us to scale up these devices and get them out of the lab, reduce the cost, reduce the size and make them consumer-usable.

At intermediate distances, we have established a national quantum communication network. It lives on top of the National Dark Fibre Facility, which is a fibre network in the south of England that connects Bristol through to London and Reading and all the way to Cambridge on the other side. We have put research metropolitan networks on the endpoints in Bristol and Cambridge. We have connected commercial users such as BT at Adastral Park: this is one of the first examples of a commercial link to a quantum communication network.

Beyond intermediate distances—and this is a big success—we have designed, developed and commissioned a quantum communication satellite. It will be launched next year and will be able to transmit quantum keys from space—from a low Earth orbit to the ground. We have a network of optical ground stations developed for that purpose, which are big telescopes that will be able to do long-distance, intercontinental quantum communication.

We have also done a lot of work with international partners, such as the Singaporean Government and the Canadians, on device assurance and standardisation with the NPL. We have worked on post-quantum cryptography with the NCSC. So not only have we been a basic research hub, but our mission has been to link up with commercial entities and spin out technology into commercial efforts.

Q95 **Chair:** Looking back over the initial period of the last 10 years, would you say that your particular hub has developed in the way that was envisaged at the time, or has it gone in different directions, following the research findings?

Professor Fedrizzi: If you look at where we are now, it has been an amazing journey: 10 years ago, these hubs were almost put together according to who was available in the country, whereas now there are far more people than we can accommodate for the funding that we have. There has been a lot of strategic hiring, all with a very specific mission in mind, which in our case has been to enable quantum communication at a national scale. With that strategic hiring and the emergence of an ecosystem in the commercial market, we have come a long way. I am looking forward to, hopefully, continuing the work into the next phase.

Q96 **Katherine Fletcher:** Thank you for coming, gentlemen; I am very grateful for your time. Part of our role on the Committee is to scrutinise Government. The Government's national quantum strategy has been in existence for 10 years, and we have an ambition to be a quantum-enabled economy by 2033. How is it going? Which parts of that high ambition are your respective hubs fulfilling?

Professor Fedrizzi: I think we are well on the way to being a quantum-enabled economy and society. We have seen the emergence of a very strong and world-leading ecosystem in quantum technology start-ups, but not only start-ups: established and big industry players such as BT have

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also taken on board the quantum technology revolution and are now looking at providing quantum-enabled solutions to the market. A wide range of supply-side specialists have also now started to look into quantum, which partially builds on our strong photonics sector.

Q97 **Katherine Fletcher:** I like to ensure that the evidence that we take in this Committee is understandable to an interested constituent. Could you crystallise that, maybe with two or three examples of what has gone well with this quantum technology? Is it faster between Bristol and Cambridge? Is it more secure?

Professor Fedrizzi: In my specific sector, what we are trying to do with quantum communications is enable you to communicate securely, for example with your bank when you do online banking. We lose a huge amount of money from the economy every year to cyber-crime. That is partly because the messages that we send can be decrypted with sophisticated computers. In particular, there is the threat of emerging quantum computers, which will be able to crack currently used codes very quickly. We are trying to address that and enable society to be sure that messages will stay safe in transit and in storage by deploying quantum communication into the commercial market.

Q98 **Katherine Fletcher:** So you cannot crack it, because of the uncertainty principle that sits underneath it?

Professor Fedrizzi: Well, certainly the laws of quantum mechanics ensure that quantum keys that are established by the exchange of weak light signals cannot be tampered with or eavesdropped on. Any attempt to tamper with these signals will be detected, and the protocol can be abandoned before any encryption happens.

Q99 **Katherine Fletcher:** With a lead in a quantum-enabled economy, we will be more secure than anybody else. Professor Cumming, from the imaging side of things, how are you contributing to that quantum-enabled economy ambition?

Professor Cumming: I will give you an example of a really nice technology that has emerged from our programme. A company called Digistain has been set up, which basically uses mid-wave infrared imaging to do histological examinations of sections from breast cancer tumours. It allows a more precise diagnosis and staging of the cancer, which then leads to a better care path.

Q100 **Katherine Fletcher:** Is that sitting within AI algorithms? Is the quantum providing the raw computing power?

Professor Cumming: No, it is not computing; it is purely an imaging technology. We all have excellent digital cameras in our mobile phones working in a visible wavelength, but different wavelengths, which are far away from those that can be detected by a camera in your iPhone, give you contrast mechanisms that carry information that is incredibly useful for diagnostic purposes.

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To build a mid-wave infrared imager with very high resolution, operating at high speed, is quite a challenge—it is something that QuantIC is working on as well—but you can indirectly do that by using a quantum technology technique to basically generate pairs of photons, one of which is at a short wavelength and one of which is at a very long wavelength. You send the longer wavelength—this is the mid-wave infrared—on to the histological sample that you want to inspect. You bring that back into the detection system, and then you produce another photon, which is in the visible wavelength, carrying the information collected from the sample you were looking at, and hey presto: you have a very nice image. That sounds incredibly complicated, but it is a very elegant piece of work.

Q101 **Katherine Fletcher:** No, that's so cool. I love all this stuff. Are we in a place to achieve our ambitions? What is needed? Do you need more? The £2.5 billion for another 10 years of funding that you mentioned in your opening remarks is a large sum of money. As a sector, do you have what you need in place to progress?

Professor Cumming: I hope we will continue to be well supported for the research that we do in the university, and for the seeding of ideas and taking them to the point at which we can start talking to industry. Like all commercialisation problems, it becomes increasingly difficult as you move up the technology readiness levels to go from a good piece of research indicating that an idea is feasible, with proof of concept, to actually converting it into a product. There is scope for investment in that space.

Q102 **Katherine Fletcher:** Would that be unlocking private capital and investment, or would it be further public investment? Could you elaborate on that point a bit?

Professor Cumming: In my experience it is probably both, in that you stimulate one with the other.

Q103 **Katherine Fletcher:** Professor Fedrizzi, do you have what you need to make us a quantum-enabled state, if not a quantum superpower, by 2033?

Professor Fedrizzi: We are already seeing examples of private capital following the capital that has been invested. You heard a bit about that from Sir Peter in the previous inquiry. What we need specifically in the quantum communication sector is Government procurement.

Quantum communications, as opposed to quantum computing, do not hold this immediate promise of a shiny thing around the corner. If you invest $1 billion, perhaps, in a quantum computer, you can go and design new drugs. This is an exciting prospect for big pharmacy companies, for example.

In quantum communication, it is more a case of requiring investment to avoid financial loss through cyber-crime, for example. That is not something that any particular company can solve on its own. It requires the entire network to be upgraded: it requires satellites and a lot of terrestrial infrastructure. No individual company can establish a market on

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its own; it needs to come through a regulatory framework where you require higher security standards for certain critical applications.

It also requires the Government, in addition to the £2.5 billion that has already been allocated to various things that we have been doing in the past, to procure satellites and roll out networks. In China, the Government are already spending that money. They have established the world's biggest quantum network by far, thousands of kilometres long, aided by satellites. Currently, we do not see that in the strategy.

Q104 **Katherine Fletcher:** Listening to you, I was about to say that your problem is that you are trying to sell a solution to a problem that hasn't quite become extant yet—the ability to crack encryption—but actually your point is that there are others who are engaging in commercialising this technology.

This is my last question. In terms of commercialising it in various different fields, from SMRs to quantum to AI, what is mentioned again and again is the SME spin-out landscape that is part of that bridge between pure research and successful technology. Professor Cumming, you have already started to mention some potential commercial opportunities. What are the prospects for that? What do you need in order to improve those prospects further? Is it reform of pension funds to get more capital in? I don't know—I don't want to put words in your mouth.

Professor Cumming: That is maybe a little beyond where I would normally be thinking. As I say, we benefit enormously from access to Innovate UK funding, and we have had the ISCF, which has been very helpful. We also have a project running at the moment through the levelling-up agenda where we have an innovation accelerator in the Glasgow city region, working with major companies in the area to try to develop camera technology, which will be of use to the defence sector. The message is that if we can bring in Government support, we will get companies to come along behind, and they will put their money down as well. That will lead to product development pathways, which take it far beyond what a university would do and start to deliver new technologies that go into the marketplace.

Q105 **Katherine Fletcher:** That is not dissimilar to the advanced manufacturing research centres we have in Lancashire, for example, which bring together a hub of people around a technology and let them spin out their own innovations. I just want to make sure I'm understanding you correctly.

Professor Cumming: There are two main mechanisms. One is that an academic might be inspired to start up a company, and then they will go and look for investors to help them to start up that company and get it funded. We have examples of that coming out of QuantIC. There is Digistain, which I have already mentioned. Another one that is very interesting is Singular Photonics, which is based around single photon detection. The other mechanism is working with existing industry and getting companies that are already up and running in the UK to take on

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technology and develop new products that they would not otherwise have been able to develop by themselves.

Katherine Fletcher: Professor Fedrizzi, would you add anything to that?

Professor Fedrizzi: We have had our own successes as far as commercialisation goes. We have examples of primary quantum technology start-ups, as you will hear from the CEO of KETS in the next section. We have had companies like Aegiq, which is a specialist in quantum light source development—their chief scientist was a Hub PI. In the space sector, we now have companies in the UK with sovereign capability where we can provide market solutions through satellite-based quantum communication devices.

I would say again what I mentioned earlier: if you are a start-up in the quantum networking sector, you don't have the enormous market that someone in quantum computing might have. If your start-up specialises in quantum communication, then you might be looking at maybe £5 million of VC money; if you are doing quantum computing instead, you are looking at £50 million or £500 million. So we haven't seen as many quantum technology start-ups emerge in the quantum communications sector specifically. However, the established players that you have already heard about have technology that can also be used for quantum communication. I think that has worked well.

In connection with what David was saying, it is also a matter of working with already established players, like BT and Toshiba UK, in our case, who have been market leaders in commercial quantum communication devices. The interaction with the hub and the availability of all this money in Innovate UK has helped them tremendously to translate research know-how into what they do in-house. We have now seen the first example of a commercial network in London between Toshiba and BT and EY as a customer. This is all successful.

Q106 **Stephen Metcalfe:** Following on from that, briefly, are any of the technologies that you are both working on sufficiently advanced that the Government can use their buying power—that is, procurement—to support them?

Professor Cumming: We are getting a lot of interest from defence and security in new imaging technologies. For example, working with Dstl, there are clear opportunities to invest in quantum technologies; I know that Dstl is incredibly interested in those technologies. So, yes, there definitely is a route for Government procurement to actually take technology forward more quickly.

Q107 **Stephen Metcalfe:** Is that technology advanced enough yet to be an actual product or service that can be procured, or is it that procurement that will get it over the line?

Professor Cumming: If we see investment coming through into projects with major defence primes, for example, or smaller companies operating in the sector, it would pull technologies forward more rapidly. We have

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some technologies that are already advanced and that could probably go into products quite quickly, but whether it is the right product that would deliver the right characteristics needed for any given purpose is another question. That has to be addressed as well. But we do have technologies that are eminently commercialisable.

Professor Fedrizzi: In quantum communication, we already have commercial suppliers, and you can now buy these things from Toshiba directly. Also, in the satellite sector, there is probably a case to be made that these things can now go commercial and be procured. The current generation of quantum communication devices is limited to point-to-point connections in what we call trusted node networks, where each node knows what the key is. That is because we cannot daisy-chain quantum communication links for further than maybe 100 km at present. The technology to go beyond that, which would be a full quantum network with so-called untrusted nodes, which would have quantum repeaters and quantum memories, is not yet commercial. I don't think procurement would do a great deal for that, because that is very much still at the lower TRL level, but trusted networks can certainly procure right now.

Q108 **Stephen Metcalfe:** For those at the lower TRL level, what would get them to the point at which they could benefit from being able to be procured? How far are we from that?

Professor Fedrizzi: Specifically in the area of quantum memory—these are devices that can take a quantum state and then store it for some time, such that you might then be able to synchronise it without other quantum states coming from other directions—there has perhaps been a little bit of a gap in the national programme so far. It was always attached only in a minor role to the various research hubs. The hubs that are now proposed for the next phase have a much larger emphasis on matter qubits and quantum memories, and this is something that we now need to focus our efforts on. We also see this already happening in the US and on the continent, where people are now really pushing hard on quantum memory technology.

Q109 **Stephen Metcalfe:** So the concept is proved; you now just have to get it to work.

Professor Fedrizzi: Yes. There is still a lot of basic research to be done but, again, it is just lack of a market. Since we do not yet have a quantum internet, we do not yet have the private investment into these areas.

Q110 **Tracey Crouch:** Professor Cumming, before I ask my other questions, two of us have unfortunately faced breast cancer. Is the example you were giving something that is happening now, or is it something that is in development and could be used in future?

Professor Cumming: This is a technology developed by Chris Phillips, who is at Imperial. He has been working on it for some years now. As with any research project, QuantIC is one of many funders he has probably had over the years, but he now has a working system that is demonstrable. He has gotten investment funding from VCs, is developing a product and has

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done a lot of clinical trials. You are not going to find it in use on a day-to-day basis in the NHS or any other health service at the moment, but it is a nascent technology that is showing tremendous promise and is definitely worth further investment and development.

Q111 **Tracey Crouch:** What is the significant difference between this piece of research and what is happening now? Does it make it faster or more accurate?

Professor Cumming: It is more accurate. The standard technique is to take a histological sample and then visually inspect it—a skilled person will know what they are looking for. This device basically moves into looking at the same sample that was already taken, so you don't need to take a second sample—that is the great advantage of the technology—but it looks at it in a so-called different contrast mode. It is looking for different information that is actually related to a DNA signature that comes from the sample, and it is analysing it to understand the extent and staging of the tumour in a way that cannot be done so easily. It increases accuracy by reducing the false negatives and increasing the number of positive outcomes.

Q112 **Tracey Crouch:** Thank you. I didn't want to get diverted—it is just a really interesting example. As I say, two of us have had to have tumours analysed, and it is a real-life example.

I want to ask about the Government. I was going to ask what interventions you would like to see from the Government to ensure that quantum research is translated into commercialised products, but I want to slightly rephrase that: do you want to see Government intervention, and do you need to see it?

Professor Cumming: Yes. Ultimately, if you try to build an industry, it is all about bringing in people of different skills and capabilities. Right now, we are doing a very good job of doing research and training PhD students, but industries will require everybody down to technician grade. There is a big skills and training piece that I think Government can intervene with and make a good contribution to. We have already covered in the discussion today the fact that it is about investing in translational research and taking ideas out of the laboratory, off the bench and into products.

Q113 **Tracey Crouch:** Professor Fedrizzi, in your evidence to the Committee, the Communication Hub has stressed that immediate actions are required to expand intake of appropriate overseas students and early-career research staff. What interventions would you recommend?

Professor Fedrizzi: The vision for the next 10 years—this has also been mentioned in previous inquiries—is to train around 1,000 PhDs in quantum technologies. There is also the Government target of 2.4% research intensity, which would require, according to Universities UK, about 130,000 researchers overall for the UK by 2030. Where you will find all those people is a good question. Through Brexit, we have lost easy access to researchers coming in from the continent, and the environment has been quite hostile. While there is a good range of avenues available for

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obtaining visas for highly talented people, the cost is unfortunately prohibitive, especially in the academic sector, where you are looking at PhDs, post docs and even junior professors who are on comparatively very low salaries, especially compared with those in high-performing countries such as the US or on the continent.

To give you an example, if someone wants to come here on a highly talented visa on a five-year job and this someone brings along their family, with a partner and two kids, they are looking at up-front costs, with the recent increase, of almost £25,000. That is not something that someone coming in will have available immediately, and it will take them a very long time indeed to make that money back on these low salaries, and also given the cost of living crisis. That high cost has already seen us lose out over candidates who say, "You know what? On the continent, I am not paying a single penny. Why should I pay this much money?"

The NHS surcharge, especially, is a huge problem. For every single year that you intend to stay, for yourself and every single dependent you have to come up with this NHS surcharge up front. There have already been lots of suggested improvements. A very simple one would be to not charge that all up front, for example. There could be other improvements, where, for example, you make it non-taxable when universities offer to pay the visa costs. Right now, if a university were to say, "We are going to pay that for you," it is a benefit in kind and the state helps itself twice to that money by taxing it on top of what it already costs.

There are also huge problems in the bureaucracy involved. The nature of what we do with the funding means there is always an underspend here, a new project there, a six or three-month extension or another year of a contract. That means that every time that happens for someone who came from overseas on a visa, they need to renew their visa. There are bureaucracy and rules attached about whether they can be in the country or they have to get out of the country to ask for a new visa. There are costs attached to getting the visa processed quickly so that you can keep them in the role. All that adds up to, frankly, quite an uncompetitive environment in high-tech sectors—not only quantum technology but many others, such as robotics and AI.

Q114 **Tracey Crouch:** Do you think the target of 1,000 PhD students is achievable?

Professor Fedrizzi: I think it is achievable for quantum technology. We see that in the current demand that we have from domestic students and the interest we have from international students. It will, however, take away from other areas where those PhDs are also needed. Therefore, it would be important to enable us to increase our international intake again from where we used to be before Brexit.

Q115 **Tracey Crouch:** So what you are saying is that quantum is the place to be, but at the cost of other potential areas.

Professor Fedrizzi: We certainly see a big push into quantum still from graduate students, yes.

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Professor Cumming: My son is an undergraduate studying physics. He is thinking of doing a PhD, and quantum is very high on his agenda as a potential priority topic because it is exciting and people want to do something that is exciting when they are at that stage.

Tracey Crouch: Wonderful.

Katherine Fletcher: You do not seem to have dropped the excitement for quantum.

Q116 **Chair:** To follow up, in terms of the quantum PhD programmes, what proportion at the moment is taken up by domestic students versus overseas students?

Professor Fedrizzi: For UKRI students, UKRI imposes a limit of 30% international students on the fees that they will fund. What you do with externally funded PhD students is your problem. An industry-funded student can always be from outside the country if the company is willing to pay the higher fees that are required. It used to be the case that EU students would fall under the same rules as domestic students in terms of the fee structure, and they did not need a visa. This is no longer the case, and even people coming in from France, Italy, Spain and so on are treated like someone coming in from very far away.

Q117 **Chair:** At Heriot-Watt, how do your PhD students split between home and overseas?

Professor Fedrizzi: With this 30% cap, we can normally fill it. We normally have high enough demand from students to come in from overseas, and we have been very successful in our own grant portfolio, where there is always some money to be found to top up the fees required for getting international students in.

Q118 **Chair:** In terms of industry sponsorship—leaving aside the source of the funds—for the PhD students you have at Heriot-Watt, how do they split between UK and overseas?

Professor Fedrizzi: For industry-funded students, I would not be able to tell you. There are certainly specific requirements when you work with defence, for example. I would hazard a guess that most of our industry-funded PhDs are probably from within the country, but Professor Cumming can probably say more about that.

Chair: Professor Cumming, how is it with you?

Professor Cumming: I would say that we actually have to recruit when we are looking for UK students, but we are selecting when we are looking at international students, because we have way more demand from the international market. It would be nice, obviously, to be able to find it easier to bring international students in. Universities actually have their own scholarship schemes, and that creates many opportunities to be able to fund studentships with internationals. But the EPSRC funding, for example, has rules, which Alessandro has already described.

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Q119 **Chair:** You have just described that you have to recruit UK students but you select from overseas students. What are the reasons for that? Is it a relative lack of interest on the part of domestic students or a lack of appropriate qualifications?

Professor Cumming: One of the arguments that is frequently presented to me is that our graduates from British universities have many opportunities. Doing research is just one amongst many opportunities, and other opportunities are much more lucrative. Quite often, after graduating with debts, students want to go and make some money.

Q120 **Chair:** Why doesn't that apply to overseas students in the same way?

Professor Cumming: Well, there is a much larger population of people out there, so it creates pressure.

Chair: So there is a bigger pool.

Professor Cumming: Yes.

Q121 **Dawn Butler:** Professor Fedrizzi, you mentioned China. When we took evidence around 5G and so on, we established that China was essentially 20 years ahead in terms of investing in microchips and so forth. You said China has already invested a lot in quantum technology. What does that investment actually look like?

Professor Fedrizzi: They have spent a lot of money on developing quantum technology, to a point where they are probably now the market leaders in various technologies—maybe not quite yet in computing, but certainly in communications they are much further ahead than anyone else. They can go the furthest, they can go the fastest and they can go into space. A lot of this was enabled through focused Government investment very deliberately because, probably around 10 to 15 years ago, they saw the opportunity of an emerging technology where they could get ahead of the world by making a very targeted investment in this sector. It was based on some very talented people who were trained in Europe and the US, and who came back to China to bring back those skills.

Dawn Butler: This was 15 years ago.

Professor Fedrizzi: That is probably when it started, yes.

Q122 **Dawn Butler:** Interesting. What is the infrastructure that we need to invest in? You talked about the students who are needed. What else is needed, like space or water? What else do we need to invest in?

Professor Fedrizzi: I think the national programme is fit for purpose—the way it is drawn up for the next 10 years. That is something that, hopefully, will continue to put us maybe not quite on top, but certainly second to the US and on an equal footing with China. What we haven't got is something that I mentioned earlier: investment by Government, as a first customer, for things like secure communication, which is a very niche product that is only required for people who have the highest demand for

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security. This is something where China is years ahead of everyone else with the large-scale quantum network that it has already deployed.

Q123 **Dawn Butler:** So we can catch up if we put the investment in.

Professor Fedrizzi: I think we have the basis for catching up. We have the expertise, the skills and the technology, but we need someone to deploy it.

Chair: Thank you very much for starting off our session this morning with your evidence. We are very grateful for your attendance.

Examination of witnesses

Witnesses: Dr Murray Reed and Dr Chris Erven.

Q124 **Chair:** I invite our next panel of witnesses to join us. One is in the room, and one is appearing virtually. Dr Murray Reed is the chief executive officer and co-founder of QLM Technology Ltd, which was formed in 2017 as a spin-out from Bristol University’s Quantum Technology Enterprise Centre. We will ask Dr Reed what the business is in a second. I see on the screen Dr Chris Erven, chief executive and co-founder of KETS Quantum Security Ltd. It is involved in a number of sectors, including telecoms, defence and finance. It was a direct spin-out of the NQTP Quantum Communications Hub. Thank you both for joining us.

Dr Reed, could you describe your business a bit, and talk about its origins, and how relevant the starting point of the hub was?

Dr Reed: Thank you very much for inviting me, and pardon my scratchy voice if I cough. I am just recovering

Dawn Butler: It is fine; it is that time of year.

Dr Reed: It is. I am over it. We started, as Chris’s company did, as part of the Quantum Technology Enterprise Centre at Bristol, as you heard. Our focus has always been on climate change, and specifically better ways of measuring and quantifying greenhouse gas emissions. From the beginning, methane has been our core focus.

We received a good amount of support from the University of Bristol. One of our founders was a graduate student there; that is how we at QLM started. I joined from outside; I am a businessman from way back. I got a PhD at Stanford a long time ago. I am a New Zealander, as you can tell from the accent. QTEC is really a combination of high-tech beginnings and business experience, which we have been putting together all the time. We have been building prototypes and demonstrations, and building up more and more industrial support for what is effectively a lidar system. This is a photonics technology, and we are using single photon detectors—SPADs; you may have heard of them. They are a fundamental part of the quantum toolbox. We have put this together in a unique way, and are proving to have a better mousetrap for greenhouse gases, effectively.

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Q125 **Chair:** Give us some examples of how what you do is, or will be, used in practice.

Dr Reed: We are already being used. We have effectively a security camera for greenhouse gases. It is a lidar system, not a camera; the light goes out and comes back, and you make accurate measurements with it. We can identify plumes of gas in a fairly large area—within a radius of a couple of hundred metres. You may have seen a lot of press lately about how important methane is in driving climate change, and how the best opportunity for reducing climate change in the short term is through controlling methane leaks. We can identify these leaks at industrial sites.

We are being deployed now at gas refineries and gas production sites. We are in partnership with a company called Schlumberger, which rebranded as SLB. Possibly more specifically, in the UK, we work at waste water sites, where there are substantial methane emissions, and at gas utilities, so we also work with National Gas Transmission, which used to be National Grid. All of these have emission problems, and have made promises to keep emissions under control. We are starting to help them keep their promises.

Q126 **Chair:** Are the companies operating these sites choosing to work with you and commissioning you, or are they being required to do so by the regulators?

Dr Reed: So far, the regulations are not there, so this is certainly an opportunity for Government to help, but the people are interested mainly because of ESG commitments and safety issues, initially. The cost of gas is also going up all the time, or at least it has fluctuated a lot and is reasonably high. A lot of these initiatives basically pay for themselves relatively quickly, but yes, it is the operators that want to control their leaks.

Q127 **Chair:** One of the long-standing problems in the research environment in this country is that sometimes things have been discovered but not necessarily translated into commercial practice; other companies, often in other parts of the world, have done that. Your example stands out against that general trend. In that translation, how important was the support from public funding, and why would it not have been possible to do it with commercial funding?

Dr Reed: It was absolutely fundamental. I spent 35 years in Silicon Valley, but one of the reasons that I have been in the United Kingdom for almost 10 years is that the United Kingdom is good at supplying that early money. Innovate UK was essential to us, especially during covid, when things were very difficult. It has been absolutely foundational. The seed money is vital.

We had to move on, because it was not enough; I could always ask for more, obviously. We had to move on to angels in the UK, which have been very important, and then on to corporate strategic investment. The Government money is still there, and is helping with new ideas. We have a first minimum viable product, and we really want to integrate it.

Our technology is very similar to the lidar systems that you might see on autonomous vehicles—in the future, anyway; people are slowly building these up. In 10 years, they went from this big box on top of a Google car down to something that you can hold in your hand. We are still a big box on top of a Google car, and we want to go down to something in our hand in a lot less than 10 years. A lot of research is definitely still required, and we are still trying to build up a UK supply chain. We are still getting money to do that.

Q128 **Chair:** My colleague Tracey Crouch will have more detailed questions on funding, but perhaps I could turn to Dr Erven with a similar question. Could you describe your business, your technology, how it is being used now, and how it will be used?

Dr Erven: Sure. At KETS Quantum Security, we develop quantum-safe, chip-based encryption that can protect basically all critical data from any advanced computing attacks. Quantum computing gets the lion's share of the interest, but you have AI, machine learning and all sorts of other things. Our chips can help you distribute keys—Alessandro spoke very eloquently about this—in such a way that no one can listen in without legitimate users knowing. It is keys first, before you actually trust any of your data to be locked up.

I have had a bit of an interesting history. I came to Bristol when it was still the Centre for Quantum Photonics; then it got enlarged to Quantum Engineering Technology Labs, and we added the Quantum Engineering CDT. I was in there for two years. QTEC has been mentioned; it is a sort of start-up incubator for quantum. I had a hand in that. That helped us take KETS out and get two rounds—so far—of VC funding. We have also really benefited from Innovate UK funding.

Q129 **Chair:** Very good. On the commercial applications, can you describe who your customers are and who they will be in the future?

Dr Erven: Sure. We are going after three markets. The first is telecoms. As you can imagine, most people do not own their own fibre network; we are relying on the BTs of the world to connect us up. They are a customer in their own right, because they need to secure their systems. You can imagine: they have this distributed network, and have to send all sorts of control signals out to calibrate and deploy how it will act today—it will enable the streaming of a football match tonight and something else tomorrow. They have to upgrade to make sure that all those control systems stay under their control, not somebody else's, but they also want to start offering quantum-safe services to their customers, so that they can have a pipe of information. We are in Bristol, where there is lots of aerospace; you can imagine information going from an Airbus head office into the cloud and back out to design the next jet engine. Definitely telecoms is a key one.

Some of these services were launched just a week ago in South Korea. They launched a subscription-based service for quantum-safe services. Alessandro was talking about markets and how they are not so there yet.

It is a bit of a sad fact that they are not so there yet in the UK, but outside in the world, we have the EuroQCI project, which is spending €154 million in basically 12 months' time. We also talked about China and South Korea. There are other places in the world where there is a big market and they are spending.

Data centres are a second one. They are a Pandora's box of use cases. You can start from a simple one: any of the hyper-scalers are continuously backing up their data in triplicate, because it makes national headlines if any of their services are interrupted due to one of their data centres being on fire. You also have whole banks moving their infrastructure to the cloud, so that is an entire banking system's customer data being backed up continuously over lines within 40 miles of each other to other sites. Obviously, you want that to be as secure as possible and not leak out. You can get into all sorts of other interesting applications with data centres.

The last is defence and Government. The Government obviously have secrets; they want to keep all their envoys around the world safe in their communications, and defence has a huge interest in keeping secure communications for all the stuff that it does. Those are the three markets that we go after.

Chair: Fantastic. Let me turn to my colleagues, starting with Tracey Crouch and then Dawn Butler.

Q130 **Tracey Crouch:** You have both received financial support. What other kinds of support have you received to form a quantum technology start-up? Do you get any advice and guidance on recruitment, workforce and so on?

Dr Reed: We have had university support from Bristol on the specifics of the underlying technology that we are using. It is tricky stuff, so it pays to have some smart people in the background to talk to. We continue to do that all the time.

The other essential thing is to have somewhere to live and grow. We were initially in an incubator, and we still are in a facility in Bristol, but more importantly for our commercial expansion, we have taken up residence in something called the Electronics and Photonics Innovation Centre—EPIC—in Paignton in Devon. That is important because it is sponsored. It is a local body's building, sponsored specifically for photonics and start-ups like us, so it really meets the brief. It has accumulated about £5 million-worth of equipment in a clean room, with shared facilities that we can use, so it is all very valuable. Being part of an ecosystem is very valuable.

Probably the most important thing is that it is in Paignton, which does not have a university—I don't know whether that is a good thing; sometimes I think it is—but it has an incredible industrial base of photonics that has been built up in the last 15 years, peaking with many thousands of engineers working for Nortel in the 2000s, during the internet boom. What we are really tapping into is that skill base. The university is great, but you don't build a company with PhD students, I'm afraid—not unless it is an AI

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company, and look what happens to them. We are talking about hard tech. With us, it is hardware. We are taking on a very mature market with tough industrial customers. There is no forgiveness whatsoever; reliability is absolutely crucial, as is quality and consistency, and the ability to scale up. None of those are things you learn at university.

Q131 **Tracey Crouch:** Dr Erven, I suspect you will give a similar reply about the other types of support. Going back to the financial support that you have received, what is the time gap between receiving the support to form the start-up and scaling the business? What determines that? Is it the speed of developing the product through technical readiness, or something else?

Dr Erven: I guess the time gap is greater than five years, because we are still in the process of scaling up, and that is really the point at which we got team-funded. I do not know the exact time for KETS yet.

I second everything that has already been said, but we also really benefited from something called the Quantum Technology Enterprise Centre. Xiao from QLM went through it. Phil, our CTO, went through it. It lasted for five years. TPS received the credit; they funded it. This was two years into the quantum programme, and there was another skills and training call. You can picture the dingy room in Bristol where we were sitting around asking, “How do we apply for funding? What do we do? Do we just add more CDT students?” I meekly held up my hand and said, “If you believe that there is this new quantum industry they want to build, you need start-ups as this little insulating layer.” Academics are great at getting that paper out—there is that single chip that worked at 4 am on a Tuesday, and you write the *Nature* paper—but then they are on to the next thing, versus big industries, which want version-controlled multiple systems that they can essentially break and turn into sawdust, and then you give them the next one. Start-ups are an insulating layer.

For five years, we had a quantum start-up incubator in Bristol called QTEC. I think we now lay claim to at least a third of the start-ups in the UK in quantum, having given them a hand. It was unique in training PhD students—post-docs—in how to be entrepreneurs. They knew the tech, but it is a different story to go out, get funding for it, build it into early products and things like that. They got a year and they got a salary, as was already said, with Murray. They got a place to live and that kind of stuff. That really gave us huge help. Phil went through it, and I lived vicariously through it, attending all the sessions. That gave us the chance to get a business plan together and get some VC funding.

There are a couple of different pieces, and we are still on the scale-up piece, really. The Innovate UK funding, certainly in the early days, was huge. You do not quite know the goodness of what you get, because we worked on a recent project with some Canadian partners, and I did not realise that the equivalent there is that companies pay into a grant; we got money from an Innovate UK grant. I know that they are changing it on their side, and they have different instruments, but in the early days,

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Innovate UK grants were definitely a huge, non-dilutive source of funding that let us get off the ground.

Q132 **Tracey Crouch:** Dr Erven, this is a very competitive market. Are we good at supporting start-ups? Looking across the world, are we doing okay at supporting start-ups in quantum technology?

Dr Erven: We are doing okay.

Q133 **Tracey Crouch:** But we could do better.

Dr Erven: A lot of this is coming out of universities. You are getting into something close to my heart. I went to Waterloo in Canada—that is the odd accent on my side—and they have an inventor-owned policy. I did not think twice about it while I was there. I then came here, and let us just say that the early-day IP policies of universities were archaic at best. I think we have brought a lot of them into the medieval age now, maybe even into the Enlightenment, but certainly not into the 21st century. That is something that Government can do, right? They are all independent institutions, but you dole out funding to them, and you can dole out more funding to those who will be more liberal. They are academics; they try to pick and choose what is going to win. VCs learned long ago that it is a numbers game, and there is a lot of luck and other things involved. Just get them out there in the largest numbers possible. We could definitely do that better.

I have always liked an inventor-owned IP policy. You will get more start-ups; you will build an ecosystem, because they fail fast and learn, and this recycling goes on in a start-up plan. It is all right to fail a couple of times; you will learn a bunch of stuff, and the third time's the charm. It will be fine. More than anything, it is the culture in start-up land, because it is a pay-it-forward culture. Funnily enough, with academics, it is quite cut-throat, and you do not find that as much.

We are doing okay. There is lots more that you could do, and I would definitely start with IP policies in the universities.

Tracey Crouch: Dr Reed, do you have anything to add to that?

Dr Reed: I would certainly echo the point about the strength of the QTEC programme. The strength there was in the interaction between the students, fellows and industrial mentors. A wide variety of industrial mentors were brought in; I was one of them. It was not the academics who were telling them what to do; it was us. They were really listening to a whole new bunch of people about where to go, and I think that has paid off, because to build businesses, you need experience in business. As I said, after 35 years in Silicon Valley, I know how that works, and it is not one of the strengths of the UK.

Q134 **Tracey Crouch:** One of the roles of the Committee is to provide helpful suggestions and recommendations to the Government about how they could do things better. Where could the Government provide interventions to achieve the ambition of the UK being the go-to place for

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quantum business?

Dr Reed: Setting up the sorts of centres that extend well beyond academia is important. If you give all the money to academia, you will not get that. You need to spread those centres. The catapults are an interesting example, but I have to say that there was mixed success. Certainly, there should be an attempt to get research away from academia, or to bring more voices to the table. As Chris said, business is very collaborative. Real business is extremely collaborative. It is the cross-disciplinary stuff that really works and takes off, so you have to bring more people to the table from different experience backgrounds.

Q135 **Tracey Crouch:** Dr Erven, a final word to you: what could the Government do and where could it provide interventions?

Dr Erven: I will not take away from the fact that they are doing a whole bunch already. The quantum programme is working, so it is always just, "What can we do to augment that?" But there is a gap, because we are talking about scale-up, right? There is lots of early-stage funding, and lots of help there. Then you have got British Patient Capital, but it comes in when you are at a £30 million round and upwards. You heard from Alessandro earlier saying that rounds are around the order of £2 million or £5 million, and then £30 million. What the heck happens in the middle? We do not really have a sovereign wealth fund. That is one thing that could be done: maybe expanding the remit of BPC or finding another vehicle.

Other than that, I have not worked out how. There is this nugget of getting major industry, which wants to learn about quantum, into quantum companies and universities. How do you do a secondment? Ideally, it takes someone from, for example, Airbus, who wants to learn about quantum, and they come and spend a year in KETS. We would not be able to afford hiring out this RF engineer anyway. They can help us get something off the ground to product quicker, and then they can take all that knowledge about quantum back to their companies. It is an ill-formed idea, but there is not enough mixing with big companies and start-ups. They could really benefit from each other. That would be another one.

Q136 **Dawn Butler:** Dr Erven, how does what you have just described actually look like? Is it a scholarship programme? Is it an interchangeable programme?

Dr Erven: I honestly do not know. I do not have that time in my day to fully form it. I just know that there are lots of big companies out there that hear the word "quantum" and they are starting to put resource in it, but they do not really know about it. The best experience is first hand. There are a bunch of start-ups that just don't have the money to hire that RF expert with 25 years' or more experience. There is something here, but I do not have a fully-formed answer for you; I do not have the time in the day to think about it. We already do well with secondments and stuff at the PhD level, and there are plenty of ways that start-ups can interact with students. Certainly, at the bigger company level—sorry, I wish I had a perfect answer for you. I just know that—

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Dawn Butler: That would have helped us with our report, but never mind, we will work through it.

Dr Erven: I know there is opportunity here, but I have not had the chance to figure out exactly how.

Q137 **Dawn Butler:** No problem. Have you had any problems recruiting people to your organisation?

Dr Erven: Yes, recruitment is incredibly challenging at the best of times, and it has been over the last two or three years. In the pandemic, there was this mass switching of people, especially now that people can work remotely and hybrid. We are competing with Silicon Valley salaries that are five, six, or seven times higher. Forget Alessandro's problem and David's problem of hiring people into universities, which are already smaller salaries than I can pay; I am still paying a fifth of what a Silicon Valley salary is. It is really challenging and it was already mentioned in terms of visas. The cost of a visa is expensive—a couple of grand—but we put another £10,000 in all the legal fees to get that efficiently done, and then half these people get another offer for a bigger salary and do not come. It is incredibly challenging at the moment because we have to look internationally. These are very specialised roles a lot of the time. There is only a handful of them in the UK, so you have to look internationally.

Q138 **Dawn Butler:** All right. What specific qualifications are there a shortage of?

Dr Erven: It will depend on the start-up. They will all have different ones. For us, we are always looking for high-speed RF engineers.

Dawn Butler: RF—radio frequency?

Dr Erven: We do not actually look for a lot of quantum people, because we have two wonderful CDTs at the moment. I had a hand in the Bristol one. We get a lot of quantum people applying. We actually have a few of those, and we're fine, but we also need software engineers, mechanical engineers, firmware engineers and electronics engineers. It tends to be that end of the spectrum, especially with high-speed signals. It is a bit more tough.

Q139 **Dawn Butler:** Dr Reed, I will put the same question to you. I quite like the idea of this transfer of technology and information, and how businesses can work together. What does that look like to you?

Dr Reed: We have been fortunate in that we are focused on climate change. That is a pretty big and important goal and one that is shared more and more by industry and business in general. People are seeing that being good for the climate can be good for business, so we have not had as many problems as have been described, because we have had that goal up front all the time. We are looking at a specific market application, and that is the way business always thinks. It has also been very good for hiring a really diverse range of people. We stand out, and we are doing, or are perceived to be doing, something very good, so people come to us.

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Q140 **Dawn Butler:** So you don’t have any problems recruiting?

Dr Reed: No, I have a problem: I don’t have enough money.

Dawn Butler: You do have a gorgeous location.

Dr Reed: That helps a bit, although it is a little bit out of the way.

It is always hard to recruit—I am not trying to trivialise it—but I think it is an important hire lesson in terms of how to attract business as well, not just people. You need to have a very clear vision of what the business is about, what the commercialisation path is, where the opportunities lie and what the competitive situation is. We had all that pretty early on because of my history and experience to make sure we had that upfront, so we have been good at getting business associates.

Chris is absolutely right: it has been long. We have been very low many times, and we continue to go up and down. We are not sustainable at this point, so capital is always a question. We are very credit-constrained, and we are looking at a very big problem, so it is hard to get off the ground with this sort of stuff. There is certainly a lot of support we can get.

Chair: Before I bring Stephen in, Carol Monaghan has a supplementary question.

Q141 **Carol Monaghan:** Before I ask any questions, I should declare an interest as the chair of the all-party parliamentary group on quantum and photonics.

Dr Erven, you mentioned the types of people you are hoping to recruit. They are the types of people who, I would imagine, lots of companies and organisations are looking to recruit. Many people are after the same small pool. We are talking about numerate, bright people. Why can’t we get numerate, bright people and train them up ourselves? Why do they need to be PhDs or postdocs?

Dr Erven: In case it didn’t come across, they don’t need to be PhDs and postdocs. I went through the first phase and a half of the hub, and, to its credit, Bristol University let me hire in an FPG engineer and a software engineer as a postdoc. That did not quite compute at first. They said, “They don’t have a PhD,” and I said, “I know. I need someone to build something, not just think about building something.” We can definitely hire at the engineering undergrad level. Sometimes, we have had somebody come in who didn’t even finish undergrad, and they were perfectly fine, so don’t get me wrong.

Q142 **Carol Monaghan:** That is kind of what I’m getting at. I was a physics teacher in a former life, a long time ago. Some of the young people I was teaching were incredibly bright, far brighter than I was. I could see them going into a company and being trained to be brilliant in that company. Instead, they have to go through years and years of academia in order to be something that someone is going to look at. I wonder why we are not looking more at young people and training them within companies to do what we need them to do and to think about problems that we need them to think about.

Dr Erven: I would definitely like to claim that the start-ups have a hand in doing exactly what you say. We are unconstrained by just a title; we just want somebody who can show us that they can do the job. It comes down a bit to resources. They still need training, right? We would love to take more masters, undergrad and PhD students—the whole gamut, because high-school people are applying for internships. It is a bit of a challenge when you are a start-up, with not enough money to do everything that you need—because these people will still need training. You need a perfect project that is not time-critical and can fail for a little while; this is the type of work that you can give these people. If, as a company, you have bigger resources, this is an easier thing to do. But when you are in a start-up, and every penny counts, you are highly constrained. Even so, I would like to claim a little bit of credit for the start-ups pushing this. We can take anybody's agenda, as opposed to universities, which have a little bit more of a classical view on who they want to bring through their programmes.

Chair: Thank you very much indeed. Stephen Metcalfe, and then back to Carol.

Q143 **Stephen Metcalfe:** If I may, I will start with you, Murray. You talked about the facility in Paignton, and you sounded quite positive about it. Is that a one-off place, or is it part of a national network of what might be described as national facilities.

Dr Reed: It's a one-off. It was funded with European money, at a time when that was available. I think it cost about £8 million in all, which they got the funding for. As you say, happily there is now a new tranche of that coming through with the levelling-up funding—I think we have got another £8 million—so it is possibly not a one-off and there could be another; but probably not. We will probably just use that to continue to expand the infrastructure.

Yes, it is not a generic model, but I think it is replicated in a lot of different places. Exeter Science Park is one that is similar, and that is just down the road. Obviously, Science Creates in Bristol is doing something similar as well, which is creating a facility that becomes an ecosystem.

Q144 **Stephen Metcalfe:** How do you benefit from these types of places? There are presumably other companies, and these allow you to—what? Share? Communicate?

Dr Reed: Shared equipment, and certainly shared facilities as well, makes it feel a little more like a substantial enterprise. One of our main suppliers is a co-tenant, so we are working very closely with them on developing processors for manufacturing. We have also looked into doing research grants together with other co-tenants. As I say, it is an ecosystem. It is complicated, as I'm sure you know, but there are many different network connections that pay off.

Q145 **Stephen Metcalfe:** If I may turn to you briefly, Chris. Are you aware of

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these sorts of shared facilities, including Paignton. Are there other examples that you are aware of?

Dr Erven: Yes. I was going add that there are more of them, but still not enough first-step, second-step incubation places. Like Murray, I know Bristol well; there is Science Creates, Unit DX, Engine Shed and SETsquared as well. All these things got us started.

One that we visited recently was Kildare Campus in Ireland. They are billing themselves—and it makes a lot of sense; call it a third step—as the pilot manufacturing facility. This is the step we are at: we have made a few in-house which are in the ones, maybe the low tens—now we need to make a couple of hundred. There really aren't facilities out there; they are all geared towards that first step. We are not ready to make a million and use all of that cost and scale, and stuff like that; we need to make a thousand. Again, it comes down to how do you reduce your capex costs, do you have to put that all up front? Shared facilities, shared equipment, and just space—is there the right space there to have an office, a clean lab and manufacturing facility?

That was the one we visited not too long ago, and we are eyeing up facilities. I'd love to have more of those in the UK, but that kind of thing is very unique. Maybe you would call it step B. You have got an inkling of something that you have made a few of, now how do you make a hundred of them still cost-efficiently? Space, and these facilities, can be a big part of that.

Q146 **Stephen Metcalfe:** Thank you very much. I want to move on to a quick question around national strategies. There is some suggestion that there should be a better alignment between the national quantum strategy, and the semiconductor strategy. Do you agree with that statement, and if so, why is it important? Please carry on Chris, and then I will come back to Murray.

Dr Erven: The simple answer is yes. Anytime you get better alignment, you will get more wins for the same dollars. That is especially the case for us, specifically. The heart of our product is a little tiny chip that is a sixth the size of your pinkie fingernail. The original ones were fabricated in the south of England at Oclaro—it has since been bought by Lumentum—but, more often than not, we go to Europe for fab facilities. We would love to stay in the UK, especially for a number of our customers who would really love a sovereign solution with every key piece being manufactured and put together in the UK. But the simple answer is, yes, I would love to see more alignment.

Dr Reed: It is exactly the same for me. KETS and QLM share the underlying technology: the photonics, working out of Bristol, which is quite strong. That is all about chips and semiconductors. Just as described by Chris, we are absolutely enabled by detectors and lasers, but we are buying them expensively and fully packaged from Asian companies at the moment, which doesn't seem ideal, so we are definitely very interested in joining that up with the compound semiconductor cluster in south Wales,

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and we have an office for just that purpose: to make sure that we are as close as possible to Cardiff and to IQE. Join these up anytime you can. I would also suggest joining it up with net zero in general. We are in the middle of these three different groups, and sometimes it is lonely in the middle; they do not always talk to one another.

Q147 **Chair:** On that point, Dr Reed, we now have a Department for Energy Security and Net Zero, where, previously, that was part of the same Department as business and science. Has that posed any barriers?

Dr Reed: They have not reached out to us at this point. We are an interesting part of the net zero campaign, in that we are working very closely with the oil and gas industries, of course, and we have found that that is an obstacle, sometimes, with some of the net zero NGOs. I am not sure whether that is the case with the Government Department here, and I hope that it wouldn't be with the initiatives that are going on at the moment,

We work very closely with the National Physical Laboratory, as well, and are really happy to have had their support for a long time. They have a very strong atmospheric emissions metrology group that has been absolutely essential in our validation. When we first turned up, no one believed what we said—they thought it was impossible—but it turned out that we can do it, and NPL has been great for that. So, yes, the more this stuff can be joined together, the more powerful it will be.

Chair: The NPL is certainly a very widely respected body to work with.

Q148 **Carol Monaghan:** Can I ask both of you about the semiconductors strategy? Is the strategy adequate? Is the funding sufficient? Maybe we could start with you, Dr Reed.

Dr Reed: I don't think so. I was not part of the formation of the strategy, so I cannot talk with too much authority about all of the details. I know that a significant section of that is leading towards south Wales, to the IQE and the compound semiconductor activity that is there. That is certainly a strength that needs to be recognised in the UK; it needs to be doubled down on and supported as much as possible. I would certainly say that that aspect of it is looking healthy, but you just cannot spend enough on this; honestly, you have to keep working this. It is a very competitive situation, and you cannot think that whatever you are doing at the moment is adequate; the prize is continually slipping away.

Carol Monaghan: I think that £1 billion has been earmarked.

Dr Reed: That is not much, is it?

Q149 **Carol Monaghan:** You tell us. Is it? What sort of figure would be more realistic?

Dr Reed: I am not sure, but I am sure that China, Taiwan and US are vastly outspending that.

Carol Monaghan: I think—I will be corrected if I am wrong—that the US

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has committed $52 billion.

Dr Reed: There you go. You have to pick your winners. We have to punch above our weight, and I am happy to say that QLM punches well above its weight; we are only 25 people at the moment, so we are doing okay in what we are doing. Part of the strategy is to pick the winners.

Q150 **Carol Monaghan:** You mentioned south Wales, which is obviously quite an important area. What about more diverse and specialised semiconductors across the UK? Does the focus on south Wales bring everybody up, or does it pull from other places?

Dr Reed: If you can get a centre of excellence, that can go a long way to pulling everyone up as well, if you work with that centre of excellence. Of course, Scotland, Sheffield, London, Cambridge and Oxford all have strong plays in semiconductors as well. As I said, my specialty is photonics, so I cannot speak much beyond compound semiconductors in terms of where the right places are to put effort and emphasis. Yes, it is a very, very competitive situation at the moment. As I said, we are enabled by cutting-edge semiconductors and we are struggling mightily to have any way of seeing that being a UK supply in the next five years. We have tried.

Q151 **Carol Monaghan:** How do we get a UK supply chain developed?

Dr Reed: I think you have to put money into concentrated efforts. You have to back companies who are going to work on specific, winning technologies that are going to dominate, or at least be extremely successful in, their market space. It has to be commercially funded in the end, so you have to find the right opportunities to succeed, and then back that. As Chris said, I see the UK being weak at following through on that backing—great at R, but having a bit of a struggle with D, in terms of getting that development continued and doubling down on it. We have been told, for instance, that we are too advanced, we are too commercial—you know, we are not second generation any more. That makes it hard, and I think that is a challenge for the UK.

Q152 **Carol Monaghan:** Dr Erven, I will come to you in a second, but is there enough understanding among Government civil servants of the requirement for very specialised semiconductors for photonics and quantum?

Dr Reed: I would think not.

Q153 **Carol Monaghan:** Dr Erven, what are your thoughts on the questions I have asked? Is the semiconductor strategy adequate? Is the funding sufficient? How do we develop a UK chain or chains?

Dr Erven: Full stop, I am pretty ignorant when it comes to the semiconductor strategy. I am in full-fledged fundraising mode, so that is about the only thing I live, breathe and sleep at the moment. I get little updates from the Bessemer Society—I know a lot of their members are involved—so that has basically been my news source.

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Besides money, I will go in the direction of people and time. There are facilities: our first chips were made in the south of England. The company have since been bought by an American company and don't do small runs any more, but we would love to do more small runs with them. So I know there is capability here, and there is now this wider semiconductor strategy.

It feels like you could go a long way with a couple of key hires that are outbound—like, I have had no reach-outs—and people willing to get into the nitty-gritty of what we need. That could really help us to make use of what is here, because we have limited time, money and resources to go and find it ourselves, and often—certainly when you are in accelerator land and stuff like that—that is the key resource: people making connections.

Besides the ridiculous sums to invest in the equipment, you can get a long ways with just a bit of investment in people, and they will speed up the time bit, because we cannot wait: we need to get on with it, and if the facilities are available elsewhere, we will just do it quick. If you have a few more people out there making the connections, that could help to speed up the time thing and maybe make more use of what's out there. But again, full stop, I'm pretty ignorant of the semiconductor strategy, so take that with a pinch of salt.

Q154 **Chair:** I have a general question to Dr Reed. Carol mentioned the £52 billion that China is spending, compared with the £1 billion that we are investing in semiconductors. That is a general problem, is it not—that we are a much smaller country, and therefore economy, than the US and China, so we will never be able to match that level of resource? What should our strategy be, given that we cannot go head to head in financial terms?

Dr Reed: As I admitted at the beginning, I am a New Zealander, so the UK looks pretty big to me. As a Kiwi, I think the lesson is clear: you pick your battles, and you beat everybody in those battles. You find areas in which you can win.

I do not think that you should underestimate the size of the UK economy. It is a fantastic economy from my perspective, and has incredible manufacturing strengths still, and scientific strengths of course. It is joining those two together that seems to be the challenge. It is a good challenge to have. There are plenty of opportunities in that space—but be focused.

As Chris said, it comes down to a few key people making the right decisions. That is how business works. That is why we have all those mega-billionaires at the moment: they manage to pick some of the right connections at the right moment. It is a matter of finding the right talent into leading roles.

Chair: Thank you both for your evidence. It has been extremely helpful. We will now turn to our last panel of witnesses.

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HOUSE OF COMMONS

Examination of witnesses

Witnesses: Dr Anke Lohmann and Simon Andrews.

Chair: Let me introduce our witnesses as I invite them to join us at the table. Dr Anke Lohmann is a co-founder of Anchored In, which helps companies, academics and entrepreneurs to explore market and funding opportunities to bring their ideas into commercial practice. Both witnesses will talk about the translation of ideas of into practice. Dr Lohmann is also the chair of the Institute of Physics quantum business innovation and growth hub.

We are also pleased to see Simon Andrews, executive director of Fraunhofer UK; its centre for applied photonics is a world-leading research-and-development centre, noted in the national quantum strategy. The Fraunhofer CAP is located at the University of Strathclyde, which the Committee has visited during this Session of Parliament.

Thank you both for joining us. I think Carol wants to make a declaration of interest.

Carol Monaghan: Yes, I want to make a further declaration of interest, because my son is doing an EngD at Fraunhofer.

Q155 **Chair:** That is a good endorsement. Mr Andrews, will you describe the work of the Fraunhofer in this space and how it works?

Simon Andrews: It has been a fascinating morning already. An early question was about whether the UK should have a catapult in quantum. A catapult is an example of one type of research and technology organisation, so I would say that we were very much fulfilling that role already. Our role is not to be a university or a for-profit industry, but to provide professional applied R&D services to industry.

In that space, we have a very strong track record of evidence in the industrial strategy challenge fund aspect of the national quantum tech programme, and the Innovate UK projects of collaborative research and development. We are working on more projects than anyone else, we are working with more partners than anyone else and we have received more of the financial support than anyone else. Our role is to accelerate development and to get that cutting-edge research through towards demonstrators and prototypes for industry to commercialise.

We are neutral, not for profit and here to help the UK economy. Sir Peter Knight, in his evidence, described us as an "incredibly good bridge between research and industry". He often calls us the "oil in the machine" or the "glue" that holds the thing together in the ecosystem. There is a time and a place for wonderful research and for those who commercialise, but there is also a role for different RTOs—more than 80 are members of AIRTO, the association for RTOs in the UK—and we have heard about the NPL playing its role on the metrology side of things. We have a very important role to play in this space. We work across the four key headings

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of quantum tech, which are very different technologies: sensing, imaging, communications and computing—all those four big sectors.

We are meant to be helpful. Sometimes it is a laser source, sometimes an entire gravimetry system. It depends how companies want to use us, and I hope we have been a key part of the agility and speed in what the UK has done. It has been very important, and we pulled SMEs together very quickly into collaborations. As the past few years have progressed in quantum tech, we have been able to draw in the larger companies as well to help bring things through.

Q156 **Chair:** How would you characterise the difference between Fraunhofer and catapults?

Simon Andrews: We share similar goals of economy and society and making good use of technology. Catapult and Fraunhofer UK both had their origins in the inspiration of the Hauser and Dyson reports. We are here because UK Government invited Fraunhofer into the UK. We very much follow the German model, which is very deep technology—emerging, enabling, disruptive, transformative technologies—applied to multiple sectors. We work in wind energy, agri-tech, medical and so on, across all those spaces, using our photonics and quantum expertise.

There are different types of catapults. Most of the catapults have a sector focus, rather than a deep technology focus that they then apply to different sectors. I would argue that they are apples and oranges. There are many, many factors—I could give you a very long answer—in the motivations and structures that then influence their behaviours. We are professor-led, per the German model, as opposed to being industry-led. That gives us such a strong anchor in the research base. This model is good at what it does in pulling that research through for industry.

Q157 **Chair:** Let me turn briefly to Dr Lohmann. Through the Institute of Physics and other organisations, you have been pulling businesses into collaboration with researchers, I think it is fair to say. Could you say a bit about that? What are the barriers to the connections between businesses and researchers in this field?

Dr Lohmann: I was involved at the beginning of the national programme in 2014-15. At the time, I was working in the knowledge transfer network, where I was responsible for photonics, and I was asked to make a business case for the special interest group to bring industry into a new national programme. Things have changed, but it was extremely difficult at the time, because quantum then sounded very esoteric.

The key question people have in industry is, “If I get involved, what will I be able to sell and to whom?” This is an ongoing question. It is not that we have a significant market pull for quantum technology. It is an emerging technology that is evolving. To get industry participating, they need to see where their next product is. QLM knows exactly where it wants to go and what problem it is solving. If quantum technology fits that problem, it is easier to get companies to be interested and participate with that.

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Q158 **Dawn Butler:** Thank you both for coming in today. How effective have the UK Government been in providing strategic investment in quantum technologies?

Dr Lohmann: I have worked with Innovate UK quite a bit, and the other thing I do for Innovate UK is that we view the ISCF quantum technology programme, so I see the output—I have done it for two years—and how things are progressing. The hubs that have been created have encouraged companies to participate with the universities, which has been successful, because there are not many other models early on that had that type of approach.

I am particularly engaged with the sensing hub and the imaging hub. If you look at their involvement with industry, they really created a community around them, particularly in Birmingham. Covid was a bit of a problem later on, but before covid the industry came together from different sectors. You had end users there, and you had part of the supply chain there, and they were discussing how they could take this technology forward, working together.

Getting Innovate UK funding de-risks development. It gives companies an incentive to explore something that they otherwise would not, and for quantum that is essential, because we still need to understand what we can do and how it can be used. It is getting better. Things are moving forward. Without that funding, in some ways, that would not have happened. From what I have seen, I am really quite happy with how it has evolved so far.

Q159 **Dawn Butler:** Simon, are you happy? Do you think the funding is enough?

Simon Andrews: I think the UK national quantum tech programme overall has been a tremendous success. The early shaping of the hubs rather than having individual universities competing for small grants—that programme aspect—has been marvellous. It has pulled them together to collaborate more, with strong themes. The creation of the national quantum computing centre is entirely appropriate, and I am all behind that.

The industrial strategy challenge fund and Innovate UK does not just fund individual companies. It is collaborative research. I think if the UK has had a particular advantage toward commercialisation, it has been the agility and speed of those collaborations helping to build up supply chains. Those projects involve multiple people at multiple tiers in the organisation—someone with a specialist coating, someone with a crystal, and someone doing some packaging. No one knows the right answer to what these technologies will look like. There are some products on the market, but it is very immature. We are rushing through to make systems to do something, but all the components and sub-systems require work as well.

The Innovate UK programmes have been incredibly good at agility. It has let all those companies take the risk, because they could not on their own fund the entire collaboration and all the partners, or pay our bill for how we help to put them together. All that is very good.

I hope I don't say this too many times today, but the national quantum tech strategy is missing one particular item. The key strengths in the strategy are the academic hubs, the NQCC and the NPL, and it also cites the Fraunhofer centre for applied photonics as a critical part of the infrastructure. We are the only one of those four that does not receive any core funding from the UK Government. The UK Government invited us into the UK and we have been surviving on the limited core funding we are able to get from the Scottish Government. We really need to crack that. We are growth-limited.

The industry demand is there. They keep coming back to us time and again, and we are reaching a point where we absolutely have to put more funding into the quantum RTO that is well established, very well recognised and very successful. Modesty aside, I shall be quoting what Sir Peter says about us and what our industrial partners say about us—that they want that facility to be there and to grow to continue to help them. The technology maturity level of all the components all the way through the systems is still very low and needs a lot of work. Having a centre that is dedicated to help that new product and new process introduction type of work is a vital part of it. What is missing from the strategy is a commitment to give core funding to that RTO.

Q160 **Dawn Butler:** You have made that point loud and clear. Thank you. The UK Government aim to generate £1 billion of private investment alongside the £2.5 billion investment over 10 years. Taking into consideration that you have just said that not all the investment is going into the right places, do you think that is realistic and achievable?

Dr Lohmann: I think it has to happen. We see already the core investment, and I am talking about not just VC or equity investing but from companies. There is over £400 million—I think almost £500 million—in investment already, and we can see more investment coming from the companies now. They are generating revenue that they can feed back in. So I think it is realistic.

Simon Andrews: I do think it is realistic, but we also need to be aware of the global race and the global competition here. It is wonderful that we are putting £2.5 billion over the next 10 years into this, but that needs a very clear delivery plan. You'll hear from the companies as well about the lack of patient capital and the lack of substantial VC funds in the UK for A and B rounds. These companies are getting started. They are also being approached by foreign investors who want them to relocate. That is a very real threat. I think there is work to be done to make sure that that is there, but the track record we have so far is terrific, because they recognise that the skills and expertise are there. That is why the investment is here: it is because of that early start.

Q161 **Dawn Butler:** Are you saying that if we don't move quick enough, we run the risk of having a brain drain, where people get poached?

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Simon Andrews: Yes. Whole companies have relocated because foreign investors have insisted on their relocation.

Q162 **Dawn Butler:** Lastly, what are the current barriers to achieving series A and B investment, besides the money aspect?

Simon Andrews: Investors need a lot of expertise to make a commitment to quantum technology. Our national quantum computing centre has the experts. They are looking at five or six totally different platforms to explore which one might be the winner. If someone who has a pension fund is encouraged to invest in technology, how will they have the confidence to understand the technology and the market when the NQCC has explained how complicated it is already? They need in-house expertise to learn about quantum technologies as well as the opportunities.

Patience is vital. Even for the pension funds that sound very long term, they will manage their portfolio and look to see progress in a small number of years. We are talking about timescales that are very challenging for investors. We see some good, specific funds set up with quantum. I have to mention the one led by Steven Metcalfe—not the one on this Committee but another one—which is Quantum Exponential Group.

It has put together a fund of around £100 million. Some people would say a series A is £2 million; I believe the average is more like £20 million. Steven will not be looking to make five £20 million bets; he will be looking at much smaller, earlier investments. We need much more investment.

Dr Lohmann: For a larger investment, it depends on the style of funds that are being invested. If you are looking at pension funds or people who come in and scale up, they do not necessarily look at the high-risk technology companies. They want to have a de-risking part. They put more money in, but they want less risk.

With quantum technologies, as Simon said, it takes a long time to develop, especially hardware, and the software is linked to the hardware we are developing. The potential is there, and that is great, but there is still too much risk associated with it. It will be hard to attract investors that are not really that knowledgeable and not part of the sector. An educational element is important on that side.

On the other side, we see that investors in deep tech are also investing in quantum computing. There has been significant funding, but as far as I understand—everyone is a bit different—they make some high-risk investments. Maybe they have taken two companies, or a few, and say, "Yes, we will take a risk on them. We believe that this area will move forward, but we don't want to put everything in this area." The fear is that these funds have put their investment in the companies, and they now need to see a return from those investments before they invest again. There will probably be a gap for the next five years.

Q163 **Stephen Metcalfe:** For clarity, is every company in this field a start-up, or do companies with a certain level of maturity go to different people for

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their funding and investments?

Dr Lohmann: It is a complex question in some ways, because you have companies that supply into quantum technology and have heavily benefited from quantum technology, such as Alto Technologies or Bayer. They are established companies, and they do not really look for investment, especially Alto. A lot of computing companies, at least in the UK, are start-ups. The reason is that we do not have the companies that they have in the US that have the equity to invest. Also, the established companies have a three-year horizon, so investing in something quite high-risk is also a risk for the management of the company. There are some companies that invest in the area, but not as many as we would like.

Simon Andrews: I agree with Anke, but I would also say that one reason for the agility and speed of progress of the entire quantum tech community in the UK has been the existing companies just seeing it as another market. There are various aspects to quantum technologies, from the software to the cryogenics to the vacuum. Some of us would argue that photonics is about 60 to 80% of quantum tech. Estimates vary enormously. Those photonics companies are used to producing very precise laser sources, and detection systems that trap and manipulate atoms and so on.

I was delighted to hear more about QTEC this morning. Scotland takes the lion's share of quantum tech investment in the UK. We have a very strong photonics community with very few start-ups. Our quantum valley, which we call Glentanglement, is dominated by those who have seen this as a new opportunity. I would love to see another intervention in the quantum tech strategy delivery, rolling out that Bristol QTEC-type of encouragement of spin-outs. It is strange that there are so few spin-outs in Scotland in quantum tech when there is so much activity. It is partly that the incumbents have seen it as a new market, and there have been job opportunities for the young people, but spin-outs could be stimulated. That was a very modest amount of money—£3 million or £4 million—but buying out people's time to write a business plan rather than do research, and the training that goes alongside that are not usually funded by EPSRC, Innovate UK or anyone else.

On finding those high-impact mechanisms and making sure there is a source of money for them, written evidence from Steven Metcalfe suggests that that should be rolled out across the UK as a model. There are various strong clusters, but Bristol had a disproportionately high number of spin-outs—something like 30—and I am sure we can all build on that.

Q164 **Stephen Metcalfe:** The spin-outs are the start-ups, and the established companies already have a market, as you said, in photonics and are moving into this. Do those start-ups face specific challenges in to attracting venture capital, or patient capital, that are not faced elsewhere by start-up companies? Is the problem specific to quantum, because there isn't greater understanding out there among those who might have the money to invest?

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Simon Andrews: My personal view is that quantum computing has attracted huge amounts of investment; hundreds of millions are going in at a very early stage. If I were an investor, and were looking, as someone said, to spread my bets and take various risks, I would look on the likely return on investment, compared to the risk. The potential return on investment in quantum computing is so enormous that that compensates for the huge and undefinable risk, so you get those huge bets.

It is more challenging to get investment in quantum sensing, quantum imaging and some aspects of communications, where there are enormous technical risks, the market is very immature, and it is not quite clear that the pay-off will be so enormous that you can waive your expectations of ratios.

Q165 **Stephen Metcalfe:** I get that bit, but is that specific to quantum, because you need a lot of investment, or does that apply to lots of start-ups?

Simon Andrews: I think it is particular in quantum, because the market is so immature, and because the technical risks are difficult to understand and difficult to quantify. It is difficult for the investors to be confident that they have made a rounded, traditional decision.

The establishment of groups such as Quantum Exponential, who are bringing in people with a PhD in quantum physics to help them make their investment decisions, will help. If they are willing to behave as lead investors and to do the due diligence, and have the technical confidence to say that they have assessed the risks meaningfully, that may help other investors to crowd in with them, even if they are the smaller party. I think that is a mechanism we should look for.

Q166 **Stephen Metcalfe:** You said just that the market is very immature. While recognising that you can't foresee the future, how immature is it? Are we overestimating its maturity? I talked earlier about Government procuring great swathes of technology. Is all that a pipe dream at this point?

Simon Andrews: I wouldn't say it's a pipe dream. There are very real products out in the market. You can buy a quantum computer with a certain degree of capability. You can buy a quantum key distribution system from Toshiba for point-to-point comms. There are wonderful brain imaging things on the market. Those are some specific examples.

Overall, the maturity is very, very low. I would describe a lot of the projects that we have developed in the UK through the challenge fund as heroic demonstrations of systems. We have had gravimeters 50 metres down a well in Birmingham, measuring gravity, and lamp-post to lamp-post QKD outside with BT; we're measuring hydrogen for BP; and we're putting another atom sensor on a plane with British Aerospace. We are doing all these things.

Those incredibly complex systems have been dragged kicking and screaming out of the lab, and a lot of components are also heroic components and heroic subsystems. They need to go through rounds and

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rounds of maturity. I think we are in a position to get great gains in the UK, because the company that makes the first atom-trapping laser that is the right format, the right size and at the right price point may then dominate the supply of that component. That's a great win for that company, and for the UK. The market is very immature.

Dr Lohmann: I agree. I think there is a little bit of a difference in some areas, such as brain scanning. It is closer. Earlier, there was mention of cancer screening. On these things, people understand the market very well. When you can see the potential of the technology, it is much easier to attract investment, because you can see where this might go.

Quantum computing is very special because that is disruptive. We do not know what the market is. Sensing and imaging is relatively easy. If there is a market, you can compare what others do. Communication is a different part; some of that is about secure communication and some is about networks. Our networks are further away than quantum computers, but have a lot of potential. There are all these factors. Where companies invest, you might not need as much investment in sensing, but the market is potentially smaller, because you have a lot of sensing applications already.

There is a variance, but the technology is still at an early stage. There is still a lot of technical risk. Because it is hardware, there is a lot more investment needed than in, say, software. Also, software can only go so far without the hardware.

Q167 **Carol Monaghan:** Simon, are there other RTOs like you in the quantum sector, either in the UK or internationally? If so, are you collaborating with them?

Simon Andrews: There is a wide range of RTOs around the world—NIST springs to mind. It is the equivalent of NPL in the US. There are various Fraunhofer institutes that I am familiar with, pursuing various aspects of quantum technology. Lots of other countries use these important mechanisms to help their industry. Our international collaborations with RTOs right now are very small, if any. I am delighted to see that we are back as an associate member of Horizon Europe. That is fairly recent news. We all need to work very hard to get the most out of that, and to get the UK investment out of that.

Q168 **Carol Monaghan:** Correct me if I am wrong, but there are challenges with quantum in terms of Horizon funding. Is that correct?

Simon Andrews: That is right. The community will hopefully get together and speak constructively with Brussels about where the limits of national security concerns are on particular calls. I know that the national quantum tech programme is pushing for us to be fully involved in Horizon Europe. That would be incredibly constructive. This is a global competition. We have China putting huge siloed investments in. We have individual US companies putting siloed investment in. The UK's advantage has been in speed of collaboration, in building up supply chain, and in having collaborative projects, where people learn about the specifications of what

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other companies need. When you work together, you do that and develop your products very well. More international collaboration with friendly countries—nearby, across the EU—would be wonderful.

We have customers in Five Eyes and AUKUS countries, where their MODs or associated organisations are dealing directly with us. We have established the reputation of UK leadership in this, so we deal with those sorts of organisations as well.

Q169 **Carol Monaghan:** You mentioned AUKUS and Five Eyes. A lot of the stuff you are doing is defence-related. You have also mentioned health-related products. Does it cover everything?

Simon Andrews: It does—photonics and quantum, both with sensing and imaging communications and computing. Communications are a particular interest for defence and security. The computing one is well known for the potential destruction of secure financial transactions. There is sensing and imaging, too, for military concerns. Defence and security concerns, broadly, are important in photonics and quantum. We are active in those areas with Dstl—lots of DASA projects—as well as appropriate international trusted partners.

Q170 **Carol Monaghan:** On the commercialisation side, are there barriers to RTOs like you doing more to commercialise products, particularly in quantum?

Simon Andrews: We are absolutely flat out. I made this point earlier. We are now growth-limited. I hate to say it, but we will be turning down an industry that wants to work with us. We will be turning down opportunities. We are not able to grow next year. DSIT have said clearly that they appreciate we are a very important part of the programme and are looking to write us into the next CSR. That is far too far away. We will not be able to grow next year, and that means, effectively, that we will be turning down industrial opportunities that people want to commercialise. We just will not be able to deal with that, because of an absence of UK core funding.

On other barriers, there are longer-term things. Taking an international perspective, would I invest in the UK? £2.5 billion over 10 years is wonderful, but we need a very clear delivery plan, with timescales and clarity, and a long-term commitment to that. The visa issue, and getting people in here—NHS visas were raised earlier—is absolutely a barrier to RTOs and everyone growing in this space.

Stephen touched on procurement; I think that we should have the best possible education for all those in Government doing procurement, so that it is done strategically. It is not just about buying a finished article; procurement in SBRI was set up to buy applied R&D. The US invented that, so that it did not look as though it was helping its companies too much. We need to use procurement and understand, "Are we getting a research report, are we getting a novel device to test for three months, or are we buying 10 computers that we expect to work?" Procurement covers all those things.

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One fundamental barrier, if I was looking in from the outside, is that the UK is really struggling to recruit physics and maths teachers. I would love to see a joined-up industrial strategy, where we put not just the compound semiconductor and QT strategies but our defence strategy, our space strategy and all our other strategies into the science and technology framework. We are not able to recruit maths and physics teachers; the target has not been hit in the past 10 years on either of those. Looking internationally, people are making investments in the UK because of the skills and the research excellence. If the right people are not going to be coming through in the long term—and companies think in the very long term—then I would not be investing here. That is a very long-term thing, but it really does need immediate action.

Q171 **Carol Monaghan:** Can I ask a simple question, Simon? How many people are based at Fraunhofer?

Simon Andrews: There are about 80 of us, altogether.

Q172 **Carol Monaghan:** You have talked about your inability to grow next year, given current funding restrictions, and you have also said that the funding just now is coming from the Scottish Government—Scottish Enterprise—and you are not getting core funding from Westminster. What if the Scottish Government and Scottish Enterprise pulled funding? Where would that leave you?

Simon Andrews: The Fraunhofer model that the UK asked for is predicated on an element of core funding, which does not pay for everything. You have capital equipment, you can train students and you can do a little bit of internal research, so that you are ready and ahead of industry. The model works beautifully. We have run it for 11 years. It is an unqualified success, but without core funding, it doesn't work. It is as simple as that. It would close if there was no core funding.

On the number of staff that we could support with Scottish core funding, we have been burning reserves to continue our growth; we are acting in good faith on signals that we have had from people in DSIT, and previous science Ministers, who said that this would be funded in due course. However, the money is tight and we are pushing that to the very limit. We are talking about a very efficient organisation. I did the sums: we are talking about something like 0.015% of the R&D budget. It is 0.0-something of the QT budget to enable this critical part of our infrastructure to grow. I think it is achievable, but I would like it to happen with some urgency.

Q173 **Carol Monaghan:** "In due course" is a favourite Government phrase, so we hear it quite a bit. You have 80 people now. If funding came from DSIT, what would your ambitions be for the workforce at Fraunhofer?

Simon Andrews: This will be a puzzling answer. On Fraunhofer-Gesellschaft in Germany, just to calibrate, there are 76 institutes, 30,000 employees and a €3 billion annual budget. In Germany, it is very clear-cut: you have university, Fraunhofer, and industry, and it works. It has tremendous manufacturing and engineering because of it—not just in

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photonics, but in a whole range of scientific and engineering disciplines. It is run by scientists and engineers, it is a very conservative organisation and it is very proud of its reputation and its brand. Recruiting the expertise that we have built up over 11 years to the 88 staff and students we have is a very considered exercise. It is about making sure that you have the right people delivering, with the right skills, and that motivations are there to help industry.

To put a figure on it for you, we would not grow faster than about 20% a year, so we would double in 5 years. That is something I argued about in the boardroom with my colleagues with more experience of the Fraunhofer model. They think 10% is about the limit of what you can do, but they are accustomed to Fraunhofer institutes with perhaps 500 or 600 people in them, where 20% is particularly aggressive. We settled and compromised—I won—and 20% would be what we are looking for. You are looking for really deep technical expertise. This is not a straightforward recruitment exercise.

Q174 **Chair:** Thank you very much. On the point about constrained growth, do you operate on a model of a third, a third and a third—a third public funding, a third from industry and a third from the institution—

Simon Andrews: From collaborative activities.

Chair: From collaborative activities, yes.

Simon Andrews: That is a well-known headline, and there is a lot of subtlety underneath it. There is a feedback mechanism, so that if a Fraunhofer centre was not relevant to industry, it would decline and close. If industry was coming along, it would grow. So, yes, within the first three years, we were able to show roughly thirds: core funding, direct contracts from industry, and what we call collaborative, which is Innovate UK, Horizon Europe, ESA, UKspace—all those people have funded us.

Q175 **Chair:** Given the commercial and industrial interest, is it not possible to go beyond that third and have a bigger proportion, and to pay for the growth costs from willing industrial partners?

Simon Andrews: That is a wonderful question. We are way beyond that. It may look like a measure of success that we currently receive £1.3 million a year from the Scottish Government and Scottish Enterprise. That is our core funding. Every penny is precious, but that is a modest amount. You might expect from the £1.3 million that we would bring in something like £2.6 million for the other two thirds. We will be bringing in £4.7 million this year. That is not good news. It is okay this year, but it tells me that I am not investing enough in capital equipment, I am not training enough students, and I am not doing enough for the future. I am meeting an immediate need, and getting the books to balance by burning reserve. Superficially, it looks like a great success story, but in the long term—

Q176 **Chair:** Why can't you charge more to the over-subscribed commercial partners, so that you can invest their money in the students and the capital equipment?

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Simon Andrews: I don’t think the industrialists sitting behind me would welcome that model. We have to charge a market rate, so that we are not anti-competitive, but we do charge an absolute full cost to industry, and I think it is at the limit of what industry can support. Industry has made great use of the other schemes, such as Innovate UK, and therein lies a problem, because Innovate UK does not pay full overheads, so I am subsidising some of that £4.7 million from reserve to make sure I can do my job and deliver for industry.

Q177 **Chair:** I guess my question is: if you are literally having to turn industrial partners away, why don’t you ask if they can make a higher contribution? It would still be worth their while to collaborate with you than not at all.

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Simon Andrews: We do put that to people. If a customer comes along, they have the option to pay us to do direct contract research—many do, and that’s great. When companies want to do collaborative projects with multiple other companies where Innovate UK would pay most of our costs—but certainly not all of them—that is such a great bargain, because they are not just getting our expertise paid for by Innovate UK, but the supply chain development of the other partners in the project. The SMEs, start-ups and spin-outs we are talking about would much prefer those sorts of projects to coming along to do one part of that project and putting their hand in their pocket to pay us, let alone paying a premium. It is just the reality of the commercial dynamic and what the companies are willing to pay for.

Chair: I thank both of you very much indeed for coming to give evidence in person. It is very much appreciated. Thank you to all our witnesses this morning for looking at some of the translational aspects of quantum technologies.