Written evidence submitted by QLM Technology Ltd (QUA004)

Re: UK Parliament - Call for Evidence, 'Commercialising Quantum Technologies'

QLM Technology Ltd is a UK-based photonics technology company formed in 2017. QLM developed a new type of gas imaging camera – based on quantum technology developed at the University of Bristol Quantum Technology Enterprise Centre – that combines lidar and gas absorption spectroscopy with single-photon detection, to enable rapid and highly sensitive detection of greenhouse gas leaks to tackle climate change. QLM's successful growth has focused in the South-West of the UK, with headquarters in Cardiff and additional operations in Bristol, Paignton and also in San Francisco (USA).

QLM's gas-imager is amongst the first technologies to market exploiting quantum technology in mass-produced commercial systems. Whilst the innovative technology has been developed and pioneered in the UK, many of the semi-conductor technologies for the photonics and detectors are not commercially available from the UK supply chain. Future growth requires custom component development and manufacture, and QLM urges the government to support UK research and manufacturing to secure the future of the UK Quantum and semiconductor industries.

QLM raised Series-A funding of £12M in 2022, with a significant fraction committed by SLB, a strategic investor from the oil & gas (O&G) industry. QLM combines innovative quantum technology with scientists, engineers and inventors with business and product development experience. QLM's novel imaging technology can detect, visualise, localise and accurately quantify emission rates of greenhouse gases (GHGs). The solution has demonstrated industry-leading quantification performance and enables customers in GHG-intensive industries to identify and prioritise the most consequential emitters for remediation in the most cost-effective manner. QLM's lidar technology is inherently scalable to low cost at high volume mainly utilizing telecoms semi-conductor components, enabling wide deployment, however, to fully realise its potential to be low cost and thereby widely deployed, will require investment into integrating photonic technology and quantum (single-photon) detection, beyond what has been done to date.

Climate change is the major challenge of our times, and QLM's innovations are an example of how the commercialization of quantum technologies can indeed have a positive impact on society, the economy and the environment. In fact, QLM's commercial success is due in large part to UKRI funding, importantly from the Single Photon Lidar Imaging for Carbon Emissions (SPLICE) project, among others. For the UK to reach a zero-carbon economy by 2050 as pledged, the regulation and enforcement of GHG emissions needs to expand rapidly. Carbon dioxide (CO2) represents around 80% of the GHG emissions from human activities and its concentration will reach the historical mark of 420 parts per million (ppm) in 2023. Energy production is estimated to generate around 60% of global CO2 emissions. Oil and its derivatives (gasoline, polyethylene, fertilisers and detergents) emit a total of 8.4 thousand million tonnes of CO2 per year. Methane (CH4), which is the primary constituent of natural gas, is far less abundant than CO2 in the atmosphere. However, its effect as a GHG is much more pronounced, so leakage in production and transportation is overwhelming the

environmental benefits of natural gas use. More than 50% of total O&G industry carbon dioxide equivalent emissions are related to methane venting and fugitive leaks. These figures are unsustainable and make the energy sector amongst the worst polluting on the planet.

There are two main ways to solve this problem. Firstly, promoting alternatives for energy production from renewable energy sources. Secondly, decarbonizing the energy industry through process optimization and emissions reduction. Gas sensors are critical in identifying those emissions, especially sensors based on optical techniques that can provide sensitivities in the ppm level. These sensors should be implemented at many different levels, from fixed permanent stations to portable, hand-held or drone-mounted devices. Sensing should be at the core of a digital platform for monitoring emissions, allowing policy makers and companies to act upon addressing emissions in order of priority based on emission severity. It is therefore necessary to develop compact, energy-efficient and high-sensitivity sensors for these tasks. The deployment of low-cost gas sensor systems, based on integrated photonic technologies, is required for controlling GHG emissions and helping to achieve a greener energy industry.

QLM's current generation of quantum gas imaging lidar, shown in Fig. 1, is capable of detecting, imaging, pinpointing and accurately quantifying GHG emissions and providing detection abilities well beyond those possible from other gas detection techniques – seeing very small emissions from great distances, up to 200m from the source. This system uses Tuneable Diode Lidar (TDLidar), combining aspects of Tuneable Diode Laser Absorption Spectroscopy (TDLAS) with Differential Absorption Lidar (DIAL) and Time Correlated Single Photon Counting (TCSPC) to enable remote spectroscopy and ranging with low-power semiconductor diode lasers. It uses the TDLAS principle, wherein a single laser is tuned in wavelength across the absorption line of the gas. The laser output is modulated in intensity in a pseudo-random pattern of nanosecond-long pulses. As the laser beam is scanned over a site, a small amount of the light is scattered back from surfaces and received by the highly sensitive Single Photon Avalanche Detector (SPAD). The returned pulse modulation pattern is correlated with the transmitted pulse pattern (synchronised to the tuned wavelength) to allow the signal to be recognised above background light and the distance to the remote objects to be measured. The change in absorption with wavelength, which is compared to that of an internal methane gas cell, allows a very sensitive measurement of exactly how much gas the laser beam has passed through, down at the parts per million-metre (ppm.m) level. As the laser beam is scanned in a raster pattern across objects in the distance, the system builds up an image of the methane gas between it and the objects in the distance that scatter the laser light back to the sensor. This provides a fast, accurate leak identification, quantification and mapping system.

Our next-generation solutions will be based on – and require the development of – new optical transmitter modules for gas sensing systems. Future products will exploit greater integration of the semi-conductor components at the heart of QLM's optical sensor. Lasers, optical amplifiers and modulators can be integrated into smaller, lighter, lower-power consumption packages, reducing manufacturing complexity and cost. Options to achieve this include co-packaging semiconductor chips, or Photonics Integrated Circuits (PICs) and associated drive electronics. PICs can be tailored to cover a wide band of wavelengths, enabling extension of QLM's measurement capability to a wider variety of gas species, each of which have unique absorption wavelengths.

In addition to investment in PIC development for the transmit side of our next-generation sensors, concomitant investment in maturing the single-photon detection aspect (SPAD) of the sensors will be required. As an example, QLM is participating in the recently awarded project titled "AIR-SPAD", under the Innovate UK "commercialising quantum technology" competition. This feasibility study brings together Phlux Technology the University of Sheffield and QLM Technology to develop innovative advances in single-photon avalanche detectors (SPADs) for the detection of methane. The new material AlGaAsSb Infra-Red SPADs (AIR-SPADs) aim to be capable of delivering 4X higher single photon detection efficiency than current commercially available InGaAs/InP SPADs at 1650nm, used for detecting methane absorption. QLM specifies exacting demands for detector technology, utilising the sensitivity of single-photon-sensitive devices to accurately detect and quantify methane emissions. QLM will aid with detector requirements definitions, testing and evaluation of the new technology being developed. We will test the performance of these state-of-the-art detectors in applications where the implementation of quantum technology can make a meaningful real-world impact to help tackle climate change. Further investment beyond this project will be required to fully commercialise these AIR-SPADs for wide deployment, requiring that they be low cost at high volume.

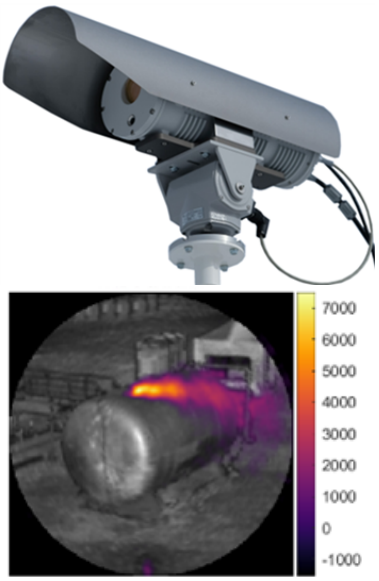

Fig. 1. Top: current QLM gas imaging system. Bottom: Measurement of a methane plume, showing methane density [ppm*m].

QLM will use these next-generation technological advances to offer multi-gas sensing at a much lower price than our current systems, with the ability to extend operation to other gas species, significantly increasing the market size and enabling wider deployment of systems to help reduce climate change. QLM will utilise existing sales channels to O&G majors as end users, such as the commercial partnership with SLB as the end service provider for upstream (O&G production) applications. QLM estimate the upstream and midstream (O&G transmission) market to be worth around £5B annually. Downstream (i.e. gas distribution) applications, such as Liquefied Natural Gas (LNG) terminals where gas is unloaded, regasification plants, compressor stations, metering & regulations stations, pipelines, power plants, some chemical plants, refineries, etc. plus other GHG-intensive industries including wastewater treatment, represent an adjacent market of a similar size.

QLM's expertise in optical gas leak detection, analysis and reporting will be further enhanced by developing cloud-based leak reporting software, enabling operators to see data from multiple imagers, and multiple sites all in one place. We aim to deploy artificial intelligence and machine learning AI/ML algorithms on the detection and quantification gas. We will apply advanced encryption and authentication to protect the system against industrial cyberattacks, such as hacking or denial of service, a major customer concern. All activity will be logged, and any leaks will be automatically reported.

QLM will generate additional revenue to hardware sales based on multi-year service provision and subscription agreements to cloud-based data analytics that help prioritise the largest emitters for accelerated remediation. Considering the downstream opportunity for example, relating miles of pipeline to the number of fixed-site monitoring points addressable by static QLM sensors within a typical gas network, yields an estimated short-term global requirement to monitor 40,000 sites.

Other substantial industrial GHG-intensive markets include CH4 monitoring in the petrochemical industry and the gas-to-electrical power industry. Another market is CH4 capture from wastewater, agriculture, and landfill bio digestion, and CO2 capture and storage. QLM see significant increase in interest from waste stream managers. There are an estimated 10,000 landfill sites in the UK/EU which require monitoring for CH4 emissions. Utility companies and recycling plants are pushing to generate gas from renewable food, municipal, water and agricultural waste. In the UK, the East Coast Cluster project combines industrial emissions reduction, carbon capture and storage, waste-to-energy, and new fuels generation.

To see (and stop) more than 10% of all global GHG emissions would require deployment of one million QLM cameras, just half the number of Mercedes cars sold every year. To see (and track) all the GHG emissions globally would require deployment of one billion QLM cameras, just half the number of mobile phones discarded globally every year. On current trajectory, QLM will enable removal of between 1.5 – 2.0 $TgCO_2e/a$ by 2027, depending on market segment mix, and that market potential based on global emissions calculations place no restriction on achieving this. QLM's revolutionary technology is changing the rules for global monitoring of green-house emissions and will enable the control of this most fundamental threat to our environment, but to do so will require external investment in maturing the core technologies upon which the QLM system is based.

Currently, many semiconductor devices originate from foundries based in Asia. International supply chains are potentially insecure under current global political tensions. The UK needs to develop its own native capabilities to deliver photonics components and detector technology, with support not only for R&D, with academic and industry collaborations, but also assistance with the transition to manufacturing and scaling up production. Many components produced in the UK cannot compete with the pricing advantage of international suppliers.

QLM's products align with the Government's commitments to reduced greenhouse gas emissions. The technology aligns with the Department for Science, Innovation and Technology (DSIT) Science and Technology Framework criteria for Sustainable

Environment, in-turn impacting upon Health and Life Sciences. There is clearly a large Market Potential for the technology, the core components of which are foundational to the Quantum communications and sensing industry. With mass-deployment of internet-of-things enabled sensing, cloud-computing and artificial intelligence are also key technologies that QLM are building in to their products.

QLM's geographic distribution aligns well with the Government's aim to level-up investment outside of the South-East of England. QLM's presence in the US also aligns with the GREAT Tech campaign targeting relations with the West coast of the US.

The UK has championed investment in Quantum technology and the rest of the world is following suit with global investment exceeding $36 B [Qureca.com]. The UK needs to continue with strong investment to consolidate its position and continue to be a key part of the global quantum infrastructure as this industry grows. China has invested up to $15 B, with the US nearly $4 B not including defence spending, and Germany $3B and France over $2B. With increased automation of many manufacturing processes, combined with maturing industrialisation of many international countries, the historically reduced production costs associated mainly with lower labour costs are diminishing. This is the opportune time for the UK to invest in UK-based manufacturing of components and systems based on quantum technologies, developing the infrastructure to build a quantum supply chain.

Yours sincerely,

QLM Technology Ltd

26 April 2023