NPL
National Physical Laboratory

NPL REPORT TQE 26

Quantum Industry Needs Assessment 2022-2023

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Abstract

This report shows the support needs expressed by various organisations who are part of the UK's Quantum industry. The report pays particular attention to tests and evaluation needs in support of the UKs quantum industry.

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Approved on behalf of NPLML by

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1.0 Executive summary

This report aims to summarise the needs expressed to NPL by the UK's quantum industry. It looks at commonalities of the responses made by people connected to the quantum industry, as a supplier, manufacturer, or end user. The report looks at 377 responses made to us by industry representatives between 10th November 2022 and 24th January 2023. The report reveals six areas of common needs.

1. A need for testing and evaluation
2. A need for information and documents to demonstrate the value chain
3. A need for standards
4. A need for support with commercialisation
5. A need for skilled people and learning
6. A need for free international trade

The most frequent area of need is testing and evaluation. Within this need area, photonic sensors such as Single Photon Detectors and the characterisation of lasers are the largest area of industry need.

The report makes five recommendations:

1. Increase efforts for certain testing capabilities
2. Provide good practice guides to support the characterisation of lasers
3. Encourage transparent metrology in support of trust and standard development
4. Enhance trade body efforts to champion and strengthen the industry
5. Increase funding for supportive skills

2.0 Introduction

A Test and Evaluation Needs Assessment for the Quantum Industry (Industry Needs Assessment or INA) was made by NPL in 2020-21[1]. To keep pace with the changing nature of the quantum industry, NPL has opted to undertake a similar industry needs assessment. It is the intention that the information learnt through this assessment might offer timely suggestions for both the final year of the current NPL programme and for the content of any future programme.

[1] Dandridge, R. A Test and Evaluation Needs Assessment for the Quantum Industry. NPL Report 380, March 2021.

3.0 Methodology

The first assessment used one-to-one interviews conducted over MS Teams and a summary of interviewer's notes. Building upon the first assessment, the method used has been enhanced.

3.1 Mediums to gain input

Four input methods are used:

1. 173 comments were obtained through 8 round table discussions conducted with 33 members of industry at Central Hall, Westminster on 24th January. This makes up the majority of the comments analysed.
2. One-to-one interviews were used. These were conducted during November and December 2023. The interviews took place on three occasions: 10th November Joint Quantum R&D Call UK & Canada, 11th November, UK Quantum Showcase and 11th November, and Photonex Exhibition 7th December 2023. With 106 comments, this method is beneficial to the research.
3. The meeting minutes of the Quantum Metrology Institute Board meeting on 22nd November 2022 were used; a meeting where time was made available to discuss industry needs. 66 comments were obtained.
4. Online surveys. Links to an online survey were sent directly to people approached at the above events who indicated this as a preferred way to participate. The same online survey was promoted via the Manufacturers Measurement Network. A similar survey was used in NPL email communications promoting upcoming events and industry days. 32 comments were obtained via online surveys.

3.2 Questions Asked

In each of the different input methods, participants were given the same or trivially different questions. Three questions were asked:

1. What are the barriers limiting your use of quantum technologies and how could they be better overcome with the support of NPL?

2. What measurement capabilities do you need NPL to make available to enhance your quantum development plans over the next 2-5 years?

3. What are the necessary test and evaluation facilities required to help your product innovation?

In some cases, attempts are made to provide additional details. This was done by the interviewer. The online survey gave prompts to encourage participants to consider additional comments.

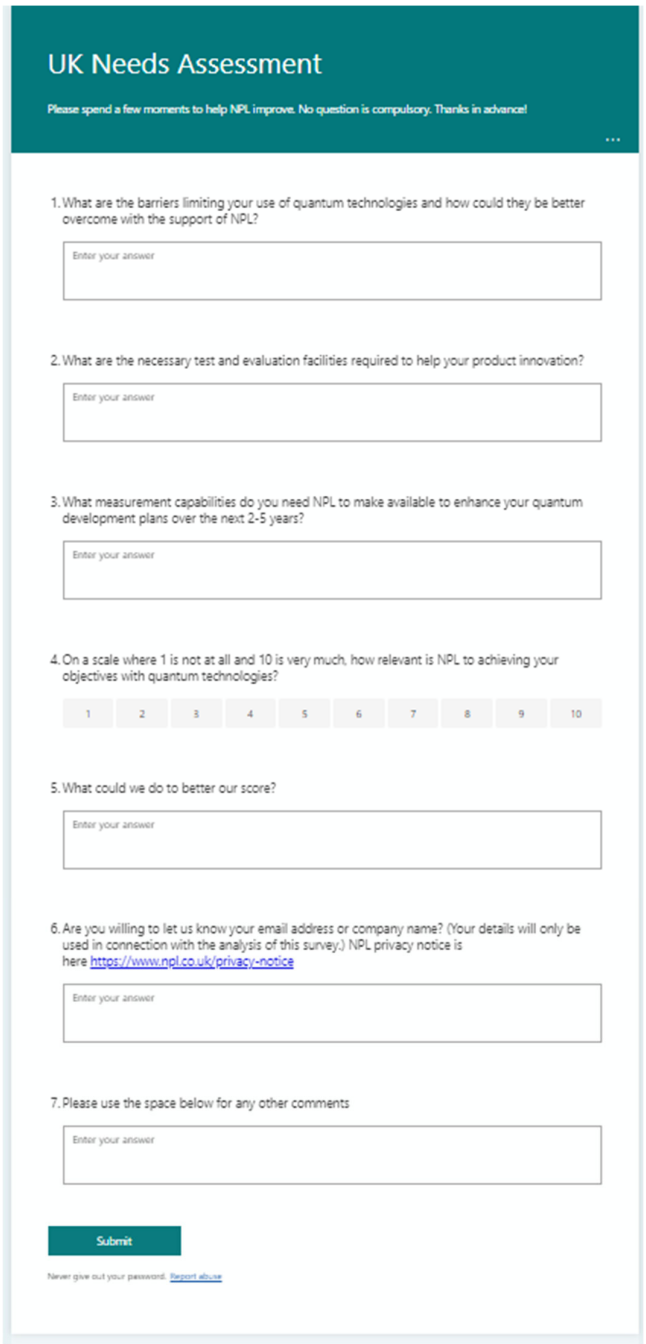

Figure 1 above shows the online survey as a method to gain input from participants.

In some cases, attempts are made to provide additional details. This was done by the interviewer. The online survey gave prompts to encourage participants to consider additional comments.

At intervals between November 2022 and January 2023, findings were typed up verbatim or agreed with the individual scribes and facilitators (9 people in total). Initially each statement was placed as one data point or comment. In the case where one statement made multiple matters of interest, a deliberate duplication of the statement was performed. In this way, comments made have been captured as 377 data points.

3.4 Need Labels

Each data point/comment was given a label to associate it with a type of need. For example, the data point of the comment “A barrier is being able to test lasers on NPL clocks” has been attached to the needs label “A need for test or evaluation”.

It was not decided before the work began which labels would be used for the data points. An initial set of labels was proposed in early January after an analysis of the comments captured to date. This exercise was repeated when all the data was captured. An iterative process was used to retitle or retire need labels and distribute their contents more accurately. The final set of need labels was decided once all the data points had been reviewed, but with a preference for there to be about 6 labels.

The final set of labels are:

1. A need for testing and evaluation, 132 comments/datapoints
2. A need for information and documents to demonstrate the value chain, 85 comments/datapoints
3. A need for standards, 52 comments/datapoints
4. A need for support with commercialisation, 44 comments/datapoints
5. A need for skilled people and learning, 31 comments/datapoints
6. A need for free international trade, 18 comments/datapoints

Figure 2 above pie chart to show types of findings (labels given to the needs)

Several comments were captured that were not able to be attached to a need label.

Each major need label was analysed in turn to spot sub themes using a similar method of attaching a sub theme label.

3.5 Participants

68 participants representing 51 organisations participated in the work. Only one organisation was a non-UK business. 4 participants were from academia.

4.0 Findings

4.1 A need for Test and Evaluation

Just over a third (35% or 132) of the comments can be labelled as a need requiring testing and evaluation.

The main finding of this report is that testing and evaluation is needed in the following areas:

1. Single photon detectors
2. Lasers
3. Quantum products in varying environmental conditions (including cryogenic and lifetime testing)

The findings are broadly consistent with the earlier industry needs assessment report. It is noticeable that the largest ask (6.9% or 26 comments) is for testing of photonic components. There are 25 comments asking for tests on some form of Single Photon Detector (SPD). It is assumed this is because these components play a pivotal role in early-to-market quantum products and the quality of them is unreliable. There are 14 laser characterisation requests (3.7%). Lasers of all sizes and linewidths take on multiple roles in the quantum industry, and so this will not be surprising to those working in it.

There are signs the industry is keen to show the quality of their products to early adopting customers. 7 comments (1.9%) ask for lifetime testing. 14 comments (3.7%) ask for testing in environmental conditions (temperature cycles, radiation, vibration). 5 (1.3%) of the comments request for testing in cryogenic conditions. A need for test and evaluation is required from materials research, early-stage R&D (6 comments) through to interoperability of systems (1% or 4 comments).

Of note are 5 comments (1.3%) that show there remains a challenge to access testing facilities, although only one mentions cost as the barrier. 3.2% (12 comments) suggest a creeping level of distrust of companies trading in the industry. Quantum computing companies are concerned here.

4.2 A need for information and documents that explain the value chain

The second largest need, 22.5%, is the need for information (85 comments).

There are 21 comments (5.6%) asking for documentation explaining the advantage quantum has over existing traditional solutions. Computing appears to be the most affected area. There are 11 requests (2.9%) for support relating to independently produced documents describing the advantages of quantum computing. There are eight requests for information showing the advantage the quantum industry can bring. Information to explain the advantages of quantum clocks and quantum random number generators are also mentioned.

A total of 11 requests (2.9%) asks for information on the whole value chain for the quantum, including how to explain pockets of agreement on the science or relevant components as well as less explored areas. Similarly, there are 11 (2.9%) requests for information to help organisations see who they could form commercial relationships with. The report finds nine requests for financial data about the market. Financial data around QKD systems and lidar are also referred to.

4.3 A need for standards

The report finds a need for benchmarks and standards with the strongest requests from organisations connected to communications and quantum computing (52 comments or 13.8%).

The largest call for standards came from the communications industry (24 comments or 6.3%). The need for standards appears to be motivated by accelerating the uptake of technology, both in the UK and internationally. Standard for the interoperability of components is requested. Standards to support Random Number Generators (RNGs) and clock components are also mentioned.

The report finds a request for standards in computing (8 comments, 2.1%). The comments are often connected to a desire to eradicate the possibility of rogue claims for qubit quality made possible by inconsistent application of tests or testing procedures.

Clock component standards received 3 comments (1%). Ghost imaging was mentioned but was considered to be too early in the development process for industry to become interested.

4.4 A need for support with commercialisation

A number of needs are identified in the report for better coordination to commercialize the technologies (44 comments, 12 %).

Six comments (1.6%) ask for stock-holding of certain quantum components. This is because as the industry matures, it requires larger quantities of components numbers than a bespoke manufacturer can produce. However, order volumes have yet to be significant enough to justify a bulk purchase of components from a volume-based manufacturer. There is a need for an industry body to coordinate bulk purchases for a small number of organisations.

There is a need for a trusted advocate to support the industry through complicated procurement processes and perhaps offer timely information to buyers. There are six comments (1.6%) noting the challenges (e.g. complicated procurement procedures) a micro or small company would face selling to bigger organisations. (Big organisations are often the first to purchase new quantum technology). There is a need for a sector advocate to explain the benefits quantum solutions bring (and threats they help to avert). 5 (1%) of comments ask for an intermediary to broker introductions between buyers and sellers.

As the industry grows so does the risk of pockets of duplicate efforts flowing from overlapping interest groups. Six (1.6%) other comments reflect the need for increased coordination.

The challenge of securing knowledge assets or Intellectual Property (IP) received six mentions (1.6%). There is an acknowledgement that while IP is required for growth, its

ownership is complicated by the volatility and budgets of small companies selling into nascent markets.

4.5 A need for skilled people and learning

In the research, 31 comments (8.2%) mention the need for skilled people and learning.

A frequent request is for more engineers or those in adjacent industries to be cross trained with quantum skills. A notable difference from earlier work is that no call was made for PhD students. Perhaps this is a result of a maturing industry which is now more concerned with support with commercial operations and the practical realisation (manufacturing) of quantum products in low volumes.

4.6 A need for free international trade

The report finds 18 comments (4.7%) about international trade. Here the main point raised is about import-and export challenges. Talent and the need to recruit from outside of the UK is only mentioned once, although this is possibly because the participants perceive this to be far from NPLs ability to influence and operate (and the questions asked of them).

5.0 Recommendations

In response to the challenges identified, this report makes five recommendations.

5.1 Increase efforts for certain testing capabilities

NPL should increase its efforts to make testing and evaluation available for single photon detectors, lasers and quantum products in varying environmental conditions (including cryogenic and lifetime testing).

Given that efforts have already been made towards these goals (e.g. a testing facility for the calibration of single photon detectors is available at NPL) work should be done to better understand why the need remains. First, exploration should consider if the capabilities in the current form are not known to UK organisations or if the capabilities have other shortcomings (price, access or restricted to certain forms). Remedial work to cover the shortcomings will be needed.

Support for the characterisation of lasers remains a need for industry. It is complicated by varying laser wavelengths, form types and associated methods of measurements. Plans for an enduring laser characterisation facility that includes skilled operators should be considered.

Corrective measures should be given priority based on these findings.

5.2 Provide good practice guides to support the characterisation of lasers

Given the role lasers play as components in various enabling and quantum technologies, good practice guidelines are required for the characterisation of the most impactful forms. Specific attention should be given to the duration of laser linewidth measurements. Action will be needed to make certain the guidelines are well known. An appropriate testing house should be enabled and encouraged to offer independent testing based on the guidelines provided.

5.3 Encourage transparent metrology in support of trust and standard development

Efforts are needed to encourage organisations to report openly, or to a trusted intermediary, how a measurement was made. Organisations willing to divulge their testing methods may become more influential in the emergence of international benchmarks and standards for quantum technologies. In the short term, a growing lack of trust in reported figures (especially in quantum computing) can be overcome.

To build trust in the UK value chain, support for the creation of a voluntary industry-wide inspection scheme should be considered. The independently managed scheme would provide an open register of an organisation's overall ability to demonstrate adherence to its own standards in metrological practice. Investors without a science background may also gain a sense of confidence from the register.

5.4 Enhance trade body efforts to champion and strengthen the industry

The report recommends that efforts are increased to offer temporary support to micro and small companies as they scale their operations.

The body should consider gaps in the UK supply chain and facilitate buying groups for key materials and components currently only available in bulk. It should consider stock-holding for identified materials or components most at risk of creating drag.

The body should champion the impact of new technologies. Multiple reports should be written (or existing work made more accessible) addressing non-science individuals, about how new quantum technologies (e.g. Quantum Random Number Generators) offer commercial outcomes not possible with existing solutions (e.g. True Random Number Generators). Financial data about the value chain of the emerging quantum technologies should be included.

Additionally, the body should take the role of offering commercial introductions between buyers and sellers

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To cover a skills gap in non-science projects, the body should facilitate secondments of skilled people to support non-science activities such as Innovate grant applications and IP registration.

5.5 Increase funding for supportive skills

Efforts should focus on engineers. Here the training may include courses of a practical nature (higher level apprenticeships) to help the industry with low to mid volume production levels and the realisation of complex demonstrations (for example, in quantum computing).

To help solve the challenge of commercialisation, skills are needed in a range of matters such as the registration of IP and selling novel solutions to large corporates. The report recommends funding should be considered to encourage people skilled in adjacent industries, e.g. commercially minded (non-science) individuals, to take advantage of courses about quantum technologies and science (up to degree level 7, MSc).

In support of laser characterisation skills, training should be considered alongside good practice guidelines.

6.0 Conclusions

Seen in totality, the comments made indicate the industry is maturing away from a sector characterised by early-stage R&D to an industry looking for support to trade with early adopters.

A lack of trusted metrology for critical components is a challenge and may slow down the development of quantum in the UK. There is a density of comments about the need for tests to enhance trust in Single Photon Detectors and the characterisation of lasers. Given the wide range of applications of these two component types, increased efforts here could see significant progression of the industry.

The industry perceives it is missing out on opportunities for growth. Another large group of comments refer to a need for information throughout the value chain and the need for supportive engineering and commercial skills. The comments here are varied but are consistent with lowering the boundary to enable buyers to act with confidence and sellers to engage with customers.

There are established models of hype cycles (e.g., Gartner's Hype Cycle). The industry is keen to keep market hype realistic. Comments here cover an ask for independent verification of certain specification sheets, to the publication of an independent analysis of areas of coalescence and areas to be watched for progress

7.0 Further work

Attention should be paid to commonalities between this report, earlier work at NPL and external bodies such as the IOP A Vision for Quantum Technologies in the UK[2]. An international perspective should be considered too, perhaps looking at bodies such as QED-C.

Work should be done to show which quantum materials and components have the broadest adoption into quantum technologies for UK industry now and into the future. The available metrology methods for the most common materials and components should be made clear so commercial decisions can be made by industry. Institutions such as NPL may take informed decisions to progress available metrology on the findings

The quantum industry is emerging and far from static. It is important to maintain close connections with industry players. This will enable NPL to keep current its understanding of needs and how NPL and wider government can continue to support and accelerate UK commercial success. Further opportunities should be provided for industry to tell NPL of their evolving requirements.

[2] https://www.iop.org/sites/default/files/2022-11/iop-a-vision-for-quantum-technologies-in-the-UK.pdf