Report: Commercial Feasibility for Sub-Shot Noise Quantum Technology Sensing and Imaging by Unitive Design and Analysis in collaboration with the University of Bristol

Introduction

Unitive Design & Analysis (UDA) are a small SME based in London, with in-depth technical and market experience in designing, developing and delivering systems for industry, across the visible and non-visible spectrum, from medical device imaging to radiation detection.

Collaborating with teams at University of Bristol including Dr Mateusz Piekarek, Dr Jonathan Matthews, and colleagues, as well as Dr Andy Collins of QTEC, on an Innovate UK funded project, UDA investigated the commercial possibilities for future applications for a sub-shot-noise photon pair light source (SSNPPS) which had been developed to prototype level by the Bristol team.

The end result is a substantial and detailed report, representing the culmination of the year long project which responds to the call, articulated within Quantum Technologies programme (supported by the Blackett Review, The Quantum Age: technological opportunities), and through the Quantum Hub, QuantIC, to encourage organisations to identify routes for translation of Quantum Technologies from research to real world adoption.

The outcome is based on a series of in-depth interviews, technical investigations, simulations, analyses, and market research and can be broadly summarised as delivering:

- identifying further detector development as a key and necessary element of the value proposition for a future positioning of SSNPPS
- a more thorough understanding of the need to 'translate' the language of physics, and more specifically that of quantum optics and information theory, to a language which is more easily communicated to industry in order to accurately identify true end user needs
- a future direction for further development of academic research
- a view of the most appropriate markets for future commercial exploitation of this technology, and some idea of the sizing and models of these markets

Project funded by: Innovate UK

The Quantum Technology Landscape

The Quantum Technology landscape today in the UK is framed by the vision provided through the UK National Quantum Technologies Programme – a coordinated national effort involving universities, NPL, EPSRC, MOD, GCHQ, and Innovate UK, providing a comprehensive funding vehicle for the support of research and development supported through four Quantum Technology Hubs.

There is a clear sense that research must increasingly pay attention to market needs and to developing technologies towards a future with a commercial goal. Demonstrating a return on investment and maintaining a leading position is a central imperative. The importance of imaging and sensing with photons within quantum technologies is well understood by the community and the UK government. Two of the four national quantum technologies hubs are dedicated to this field.

QuantiC, the UK National Quantum Technologies Hub in Quantum Enhanced Imaging, is focussed on the direct interaction of matter with light, and supports the SSNPPS development.

Approach

At the start of the project, research on the SSNPPS had already reached a point where the University of Bristol could readily demonstrate the principle of using correlated photon pair sources for noise suppression in absorption measurement.

Demonstrable prototypes were shown at the 2016 and 2017 National Quantum Technologies Showcase exhibitions in London, each year growing more compact and with higher efficacy.

The task was to identify when and how this prototype might be further developed to address a real world need, today or in the future.

The approach needed to be able to examine the market from several aspects:

- a thorough and in-depth understanding of the prototype in terms of key performance indicators and the challenges involved in moving towards a commercial instrument.
- a series of discussions and interviews with key potential stakeholders in academia (outside of quantum technology) and in different industry sectors
- a review of the commercial context today and likely future developments in light source technologies for a variety of purposes
- a selection based on likely markets for the technology based on factors including market needs, growth prospects, size, behaviour, current players, potential routes to market

Lessons Learnt

Photometry systems in the market do not necessarily conform to a standard set of methods for performance measurement. Often metrics are more closely aligned to the specific use case rather than the properties of the internal light source. It is not a straight-forward operation to produce a like-for-like comparison for some of the technology based on certain key performance indicators.

In order to position a future SSNPPS within a market context, it became obvious that a detailed technical model, formulated in closed form and validated with Monte Carlo simulation, for comparison and gap analysis was therefore required.

The work undertaken by UDA focused on optical measurements in real word scenarios and simulated the SSNPPS in that scenario, resulting in a broad base model for comparison, enabling the SSNPPS advantage to be positioned alongside contemporary technologies.

Summary

The report gives a detailed view of the value proposition for a SSNPPS.

Possible future areas of commercial interest cover several markets across a wide range of industry sectors. As the specifics of the SSNPPS technology requires benefits to be derived from use of a correlated light source at extremely low intensities, this indicates imaging requirements based on samples or materials with very low absorption / interaction or very high reflectivity. Branches of science and engineering associated with photosensitive materials are therefore potential markets for this technology.

There are areas of imaging today which are “photon starved” and where photon shot noise is problematic. These are areas of where ionising high energy photons are used such as in X-ray or CT imaging. In these cases photon flux is restricted by dose. These photon energies are not within the reach of current technologies, but there is a clear market need and therefore research interest.

In addition, it is clear (as demonstrated by a number of other authors), that the SSNPPS could be further extended in its functionality to generate entangled photons which opens up additional improvements in performance, at the expense of complexity.

The continuing development of Quantum Technologies, and further improvements in the wider understanding of the possibilities derived from quantum photonics as opposed to classical optics, will increasingly reveal new potential applications. Rapid innovation in high growth markets will inevitably lead to as yet unknown needs for imaging. Although a real end user application may be 5+ years away, this project has identified the strengths and benefits of the SSNPPS in a way that will shape future research and prepare the technology to be capable of rapidly impacting real world challenges.

The recommendations in the report provide a pathway to guide development to address these needs. One element of this pathway is to implement a programme in partnership with industry to develop cutting-edge manufacturing technologies to address scale-up challenges and drive up productivity. A collaboration between the Bristol group, UDA and experienced product manufacturers in industry is the likely next stage.

UDA and the University of Bristol welcome any interest from researchers or industry regarding future developments of the SSNPPS, and are open to sharing large parts of the full report under a non-disclosure agreement.

Supporting literature

1. Quantum Technologies Flagship Final Report (http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=46979).
2. Quantum Manifesto (http://qurope.eu/system/files/u7/93056_Quantum%20Manifesto_WEB.pdf).
3. The UK Market for Quantum Enabled Photon Sources (https://goochandhousego.com/wp-content/uploads/2018/05/GH-Market-Report-UK-Market-for-Quantum-Enabling-Photon-Sources-2018-2022-Report.pdf).
4. IOP Health in Photonics (https://www.iop.org/publications/iop/2018/file_71498.pdf).
5. QuantIC Annual Report 2017 (https://quantic.ac.uk/quantic/wp-content/uploads/2018/05/Annual-Report-Year-3-WEB.pdf).
6. Quantum Technologies: Blackett Review https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/564946/gs-16-18-quantum-technologies-report.pdf.

All hyperlinks active at time of publication.

Contact

Dr Jonathan Matthews
HH Wills Physics Laboratory
University of Bristol
Tyndall Avenue, Bristol BS8 1TL
jonathan.matthews@bristol.ac.uk
http://www.bristol.ac.uk

Dr Philip Marsden
Unitive Design and Analysis Ltd
3 Skylines Village
Limeharbour, London.
phil@unitivedesign.co.uk
http://unitivedesign.co.uk

Date of publication 23/11/2018