Centre for Theoretical Atomic, Molecular, and Optical Physics

Ph.D. Project 2022-2025

Quantum-classical interfaces for the emulation of quantum communication algorithms

Project supervisors: **Mauro Paternostro**
Contacts: **m.paternostro@qub.ac.uk**

State of the art and motivations

Fibre-optics communication, one of the most prominent architectures for (tele-)communications, is widely used to transfer telephone, internet, and cable-TV signals. Despite the high rate/long-haul range of information transmission allowed by such technology, it is well established that the use of quantum light would open new, so far unavailable opportunities for the transmission and manipulation of information. This avenue is currently pursued by academia and companies alike (Google, Microsoft, IBM) towards the establishment of a quantum internet using optical-fibre channels to sustain and transmit quantum light. However, a fully working quantum network has stringent requirements of network reconfigurability, efficiency of information transmission, and robustness to noise. All these features have to be met in order to push the progress and development of the paradigm of a quantum internet. Validation and development through physical prototypes are costly and resource wasteful.

Objectives & Methodology

We will explore an entirely new approach to such issues by developing an emulation platform – based on the framework provided by the network simulator Mininet Optical [1] – to simulate, control and design paradigmatic quantum communication protocols. This will provide a crucial contribution to the development of a successful quantum internet by allowing for the full network-scale simulation of a network of interconnected sending & receiving stations, the assessment of their ability to cope against imperfections and environmental noise, and the design of new schemes for efficient quantum-enhanced communication.

We will address paradigmatic quantum algorithms for networking, including open-destination teleportation (ODT) [2, 3] and quantum telecloning [4] from a single information carrier to a network of N other. These are crucial quantum-protocol primitives that aim to demonstrate the full capabilities of the emulation and simulation platform built within this project. We will explore the performance of noisy quantum/classical simulators by making us of models for open quantum dynamics. Finally, we will assess the role played by quantum resources in quantum networking, focusing on the potential for effective quantum communication offered by weaker-than-entanglement quantum resources, such as quantum discord.

Collaborations

The work entailed by this project will be performed within the context of a collaborative network involving Trinity College Dublin (Prof. Marco Ruffini), the Irish CONNECT research centre (Prof. Dan Kilper) and the University of Arizona.

The project will benefit from in-house interactions with members of the Quantum Technology Group, specifically Dr. Hannah McAleese, Dr. Alessandro Ferraro and Dr. Gabriele De Chiara.

Required skills
The candidate student will have excellent mathematical and physical background. A good knowledge of Quantum Theory and Mathematical Methods of Quantum Information Processing are required. A natural inquisitive and curious mind associated with originality and creativity in the approach to problems will be appreciated. Advanced computing skills are not required, although the student will become familiar with instruments such as Python and Mathematica.

Further information
For further information contact Prof. Paternostro: **m.paternostro@qub.ac.uk**

References

[1] http://www.tara.tcd.ie/handle/2262/91430

[2] A. Karlsson and M. Bourennane, Phys. Rev. A **58**, 4394 (1998).

[3] Z. Zhao et al., Nature (London) **430**, 54 (2004).

[4] M. Murao, et al., Phys. Rev. A **59**, 156 (1999).