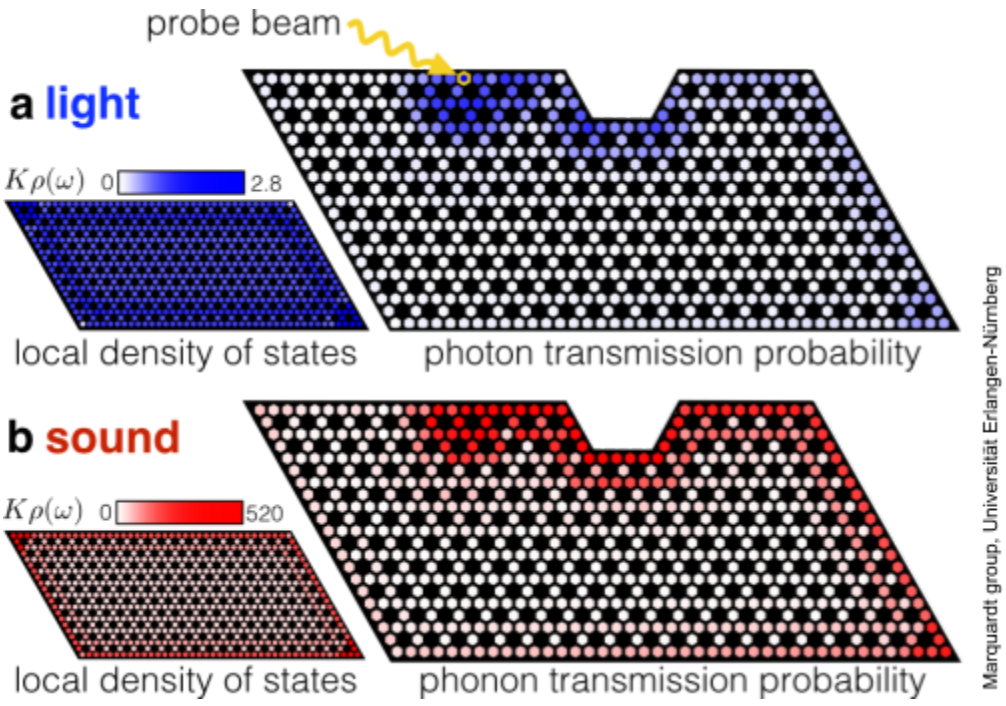
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# Funded PhD: Transport in mechanical metamaterials

Deadline: 27th November, 2016

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# Broad overview

Transport through quantum systems is a topic of much technological interest as well as academic. Technologies based on the exotic behaviour allowed by quantum mechanics are starting to become viable, and in this context it is important to know how such systems are expected to behave under non-ideal conditions, as well as how their quantum properties can be exploited to improve performance. It has also been suggested that quantum mechanics plays a role in the energy-harvesting mechanisms of biological systems [1]. From the point of view of pure science, on the other hand, it is not obvious how complex quantum systems behave, and studying their transport properties, under the guise of how energy flows between two points in a given system, provides a window into such complex systems that could lead us to understand them better [2].

Another distinguishing feature of quantum mechanics is the degree to which seemingly separate objects can be correlated; strong correlations such as entanglement are known to allow computations to be carried out quicker than in any classical system, for example, or to allow one to manipulate the quantum state of a remote object. It is a question of much current interest how correlations such as these "flow" through networks of complex quantum systems [3].

## Forecast main tasks

- Consolidation of current knowledge, pulling together strands from full-counting statistics, topological transport, quantum many-body and information theory, etc.
- Development of computational and analytical techniques to describe the relationship between structural properties of quantum networks and their transport properties
- Answering questions such as the following:
    a. Can we engineer networks to optimise transport along certain "routes"? Can this optimisation make use of quantum coherence to overcome classical limitations?
    b. Does synchronisation play a role in transport across networks? Is the interplay between disorder and synchronisation significant?

## References

[1] N. Lambert, *et al.*, arXiv:1205.0883 (2012); Nat. Phys. **9**, 10 (2013).

[2] S. Pigeon, A. Xuereb, *et* al., Phys. Rev. A **92**, 013844 (2015); New J. Phys. **17**, 015010 (2015); New J. Phys. **18**, 013009 (2016); J. Stat. Mech. **2016**, 063203 (2016).

[3] G. Manzano, *et al*, Sci. Rep. 3, 1439 (2013); F. Nicacio, and F. L. Semião, Phys. Rev. A **94**, 012327 (2016).

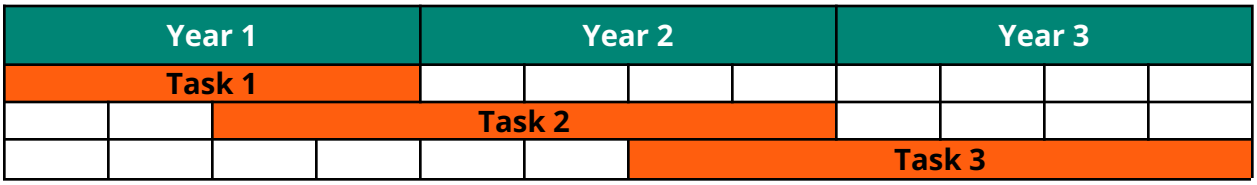
## Work breakdown

This project will be broken down into three major tasks. **Task 1** will deal with investigating dissipative mechanisms for signal transport, and it will involve interaction with colleagues from the University of Cambridge. In this task, the student will consolidate knowledge about transport along networks of quantum systems that makes use of dissipative mechanisms, i.e., the coupling of one or more of these systems to baths. The student will then seek to extend these ideas to cover also non-standard baths or systems with time-varying control fields.

**Task 2** will build on the previous task, and will delve deeper into the topological properties of networks of oscillators. A strong interaction with the Max Planck Institute for the Science of Light is expected here. The student will extend current knowledge on topological transport, seeking to understand also the transport of correlations as well as signals in such systems.

Finally, **Task 3**, which will involve interaction with the Max Planck Institute for the Science of Light and the University of Constance, will explore and seek to understand the effects of noise and disorder in 1D and 2D networks of mechanical oscillators. Such disorder, on the one hand, restricts the level of control that one can exert over such systems; however, it also gives rise to novel properties such as localisation effects.

### Provisional Gantt chart




#### Task 1

- Consolidation of knowledge, and study of dissipative transport (months 1 to 6)
- Extension to non-standard baths or time-varying control (months 7 to 12)

#### Task 2

- Investigation of topological properties of (an)harmonic networks (months 7 to 15)
- Study of use of transport making use of topological properties (months 16 to 24)

#### Task 3

- Study of localisation induced in mechanical networks (months 19 to 27)
- Exploration of noise-assisted transport through networks; writing (months 28 to 36)

## Target student profile

- Knowledge of quantum mechanics at an advanced undergraduate level
- Preferably a master of science degree in a related field of science; candidates with an exceptional first degree will still be considered
- A good grasp of mathematics at an undergraduate level (e.g., calculus)
- Knowledge of, or the willingness to learn, numerical computational techniques in high-level programming languages (e.g., C and/or Python)

## Local context

The University of Malta has been active in the field of quantum optics since 2014, when a quantum optics group was established there. In late 2016 the number of faculty in the field grew to three, with the addition of Dr Vittorio Peano (formerly Universität Erlangen-Nürnberg), who is an expert on many-body quantum systems including the topological effects, and Dr Jacob Biamonte (formerly ISI Foundation), whose expertise lies in the field of network theory and complexity. The quantum group at the University of Malta is part of many international networks, including several COST Actions, and is continuously participating on proposals at the local, European, and international level. It is envisaged that this project will include significant interaction on the part of the student with all three faculty members, as well as with occasional visitors to the group, physicists in other institutions, etc. This project will also involve working closely with a post-doctoral researcher employed at the University of Malta as part of the same project.

The successful student will be given the opportunity to present their results at major international conferences several times during the course of their PhD, and will have sufficient travel funds to visit groups elsewhere in Europe and internationally. This PhD position is fully funded for 36 months, with the possibility of an extension, and includes a generous salary. The University of Malta is an equal opportunities employer.

This project is funded by the European Commission through its Horizon 2020 framework programme, as part of the project “HOT—Hybrid Optomechanical Technologies.”

## Contact details & How to apply

Please contact Dr André Xuereb <andre.xuereb@um.edu.mt> for any queries you may have in relation to this project.

To apply please follow the instructions in the call: https://goo.gl/zpV6BS