Mac Robertson Travel Scholarship Report

By Lewis Hill

About me and my PhD Research

My name is Lewis Hill and I am a final year PhD student at the University of Strathclyde, in industrial partnership with NPL (the National Physical Laboratory). While at Strathclyde, I belong to the CNQO (Computational Nonlinear and Quantum Optics) group, of the Department of Physics [1], within the Faculty of Science, but when at NPL (approx. 10% of the time) I am a part of the Microphotonics group [2] within the Time & Frequency department.

My chosen area of research for this PhD in Physics originated in the generation of optical frequency combs in Kerr ring resonators. Without going into too much detail on this, Optical frequency combs can be thought of as a 'ruler' for the measurement of optical frequencies [3] – rather than the measurement of distance for a traditional ruler. In 2005 Optical frequency combs led to the Nobel Prize in Physics in part being awarded to John L. Hall and Theodor W. Hänsch for "their contributions to the development of laser-based precision spectroscopy, including the optical frequency comb technique." [4] One way of generating these combs is utilising a spontaneous symmetry breaking of light fields circulating a Kerr ring resonator – and it is this symmetry breaking phenomenon which forms the focus of my studies.

The Mac Robertson Travel Scholarship

A spontaneous symmetry breaking of the intensities, or strengths, of two light fields circulating a Kerr ring resonator can occur when the system is subject to certain conditions, fig. 1(a). The background to this topic is quite technical (for those interested, please read my recent publication [5]), but in its essence, it be thought of as a fork in a road, up until some point in your journey, only one choice of path is available for you to walk along, but beyond that point your path splits and 'spontaneously' you must decide which of the avenues to take.

This phenomenon takes place in two systems relevant to my research, fig. 1(b) and (c) which, given certain assumptions, are described by the exact same mathematical formula. [6] As a theoretical physicist this is great, it means I can study both systems simultaneously, increasing impact while maintaining the same workload, but, for experimental physicists, the two systems are extremely different. My collaborators and colleagues from the Microphotonics group at NPL currently study only the system described by fig. 1(b), and while this has been a very fruitful field of research for them, both in collaboration with myself and my Strathclyde supervisor, Prof. Gian-Luca Oppo,[5-8] and without our collaboration,[9-13] the study of fig. 1(c) promised to be just as bountiful.

While the system of fig. 1(c) is not currently studied in the Microphotonics group, it is studied by a group at the University of Auckland, New Zealand. In order to visit this group and aid the experimental physicists there with my theoretical expertise and knowledge of the system of fig. 1(c), I applied to the Mac Robertson Travel Scholarship to cover much of the trip's high costs. The visit was originally planned to be for two months, from the end of January to the end of March but was later extended due to unforeseen global circumstances. Without the funding from the Mac Robertson Travel Scholarship, or alternative, this trip simply could not have happened and the considerable research outcomes of the visit, which I will describe later, may have remained undiscovered. In total I was awarded £3,280 by the Mac Robertson Travel Scholarship.

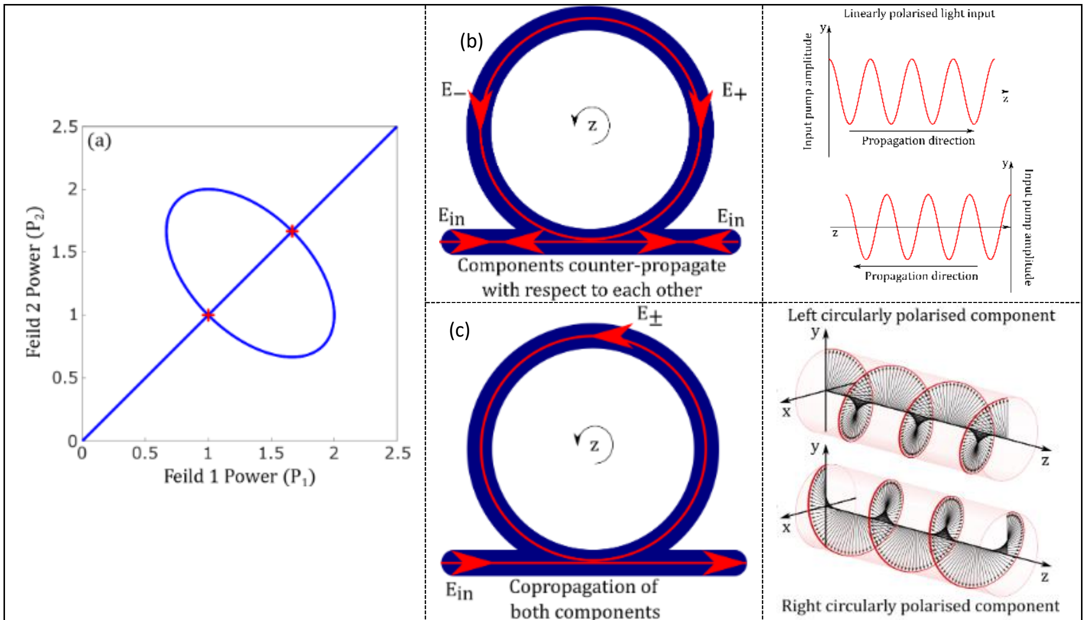


Figure 1. The spontaneous symmetry breaking of light in ring resonators.

Details of My Visit

As mentioned, I used the Mac Robertson Travel Scholarship to visit the University of Auckland. The original plan for this trip was to arrive in New Zealand on the 28th of January and leave to return to the UK on the 22nd of April with 10 weeks in total being spent researching at the university. With the unpredicted emergence of COVID-19 my stay in NZ was extended until the new planned return date of 25th of July 2020. This extension was financially supported by the University of Strathclyde. The purpose of my visit was to not only further the research topic of my PhD but also to nurture a strong academic network by meeting leaders and others in the field.

My visit to the university was well timed with two other academic visitors visiting the group while I was there a photo of the entire group, and visitors, can be seen in fig. 2.

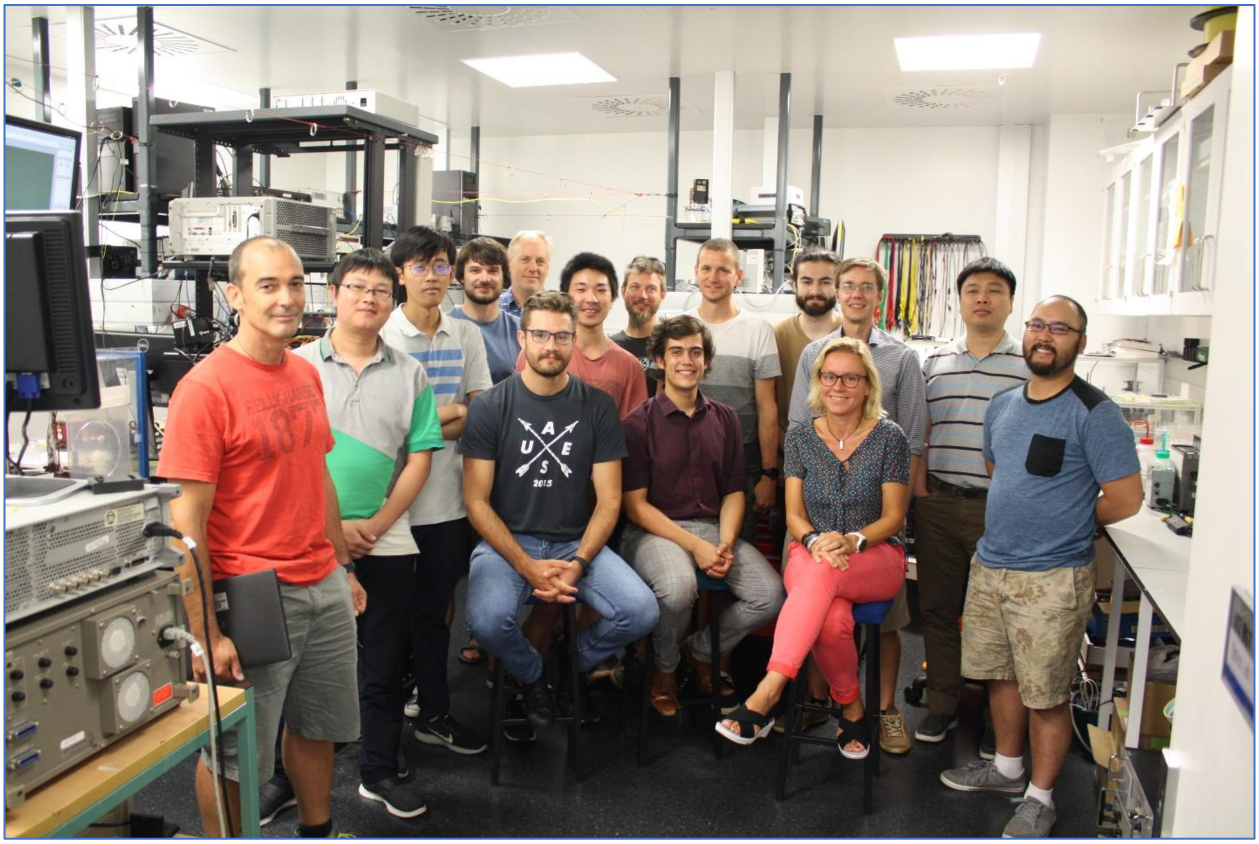


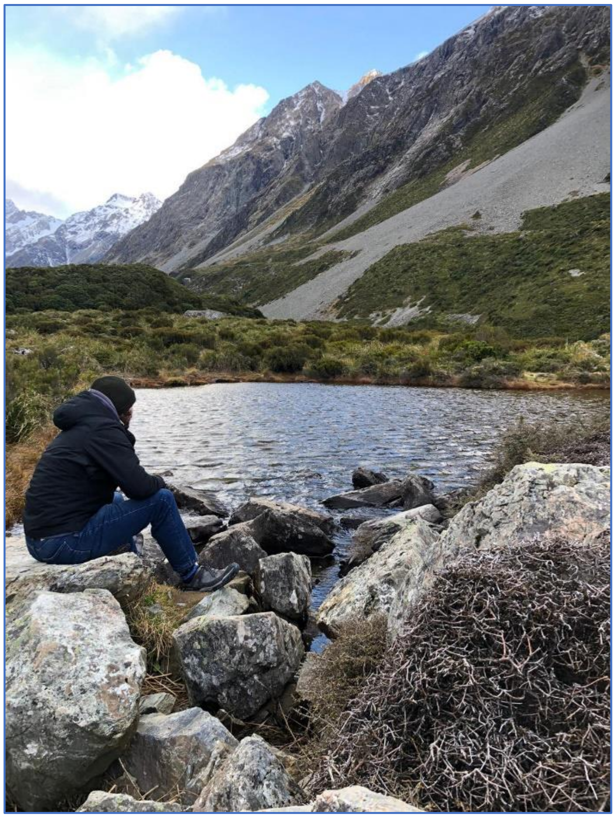
Figure 2. Group photo of researchers at the University of Auckland.

Scientific Impact of the Scholarship

Although there was significant disruption to my visit due to the, at time of writing, ongoing COVID-19 pandemic, the visit led to much scientific progression. Two research papers are currently being prepared with two abstracts for the upcoming Advanced Photonics Congress. Details of these paper topics can be provided soon once the abstract are published. These two paper topics concern the symmetry breaking of local temporal structures known a solitons and breathers.

Touring New Zealand

While COVID-19 brought about a nationwide lockdown in New Zealand, which interrupted a large part of my planned research period, NZ opened up internally during my extended stay which meant I had some time to take annual leave an visit some of the amazing attractions NZ had to offer. A small selection of photos is included here.




Impact of the Travel Scholarship

The Mac Robertson Travel Scholarship has brought tremendous impact to my postgraduate research experience, not only has it led to greatly increased research outcomes of my PhD but also it gave me the opportunity to travel to New Zealand and broaden my professional network. COVID-19 had major impacts on my visit, however much was still achieved. I would like to thank all involved in my trip and especially the funding providers who made it possible.

References and Links

[1] www.strath.ac.uk/science/physics/

[2] www.npl.co.uk/time-frequency/microphotonics

[3] "Rulers of light." *Nature Photon* **13**, 137 (2019).

[4] www.nobelprize.org/prizes/physics/2005/summary/

[5] "Effects of self- and cross-phase modulation on the spontaneous symmetry breaking of light in ring resonators." *Phys. Rev. A* **101**, 013823 (2020).

[6] "Universal symmetry-breaking dynamics for the Kerr interaction of counterpropagating light in dielectric ring resonators." *Phys. Rev. A* **98**, 053863 (2018).

[7] "Spontaneous Symmetry Breaking, Oscillations, and Chaotic Regimes in Bidirectionally-Pumped Ring Resonators." *2019 Conference on Lasers and Electro-Optics Europe & European Quantum Electronics Conference (CLEO/Europe-EQEC).* IEEE (2019).

[8] "Self-switching Kerr oscillations of counter-propagating light in microresonators." *arXiv*:2005.01411 (2020).

[9] "Symmetry breaking of counter-propagating light in a nonlinear resonator." *Scientific reports* **7** 43142 (2017).

[10] "Microresonator isolators and circulators based on the intrinsic nonreciprocity of the Kerr effect." Optica **5.3** 279-282 (2018).

[11] "Interplay of polarization and time-reversal symmetry breaking in synchronously pumped ring resonators." Physical review letters **122.1** 013905 (2019).

[12] "A nonlinear enhanced microresonator gyroscope." *CLEO: Science and Innovations*. Optical Society of America (2017).

[13] "Logic gates based on interaction of counterpropagating light in microresonators." *Journal of Lightwave Technology* **38.6** 1414-1419 (2020).