INTERNATIONAL MAX PLANCK PARTNERSHIP
'Measurement and Observations at the Quantum Limit'

Annual Report to the Scottish Funding Council

For the period 1 August 2013 to 31 July 2014

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Chief Executive Officer

Introduction

Following the award of seed funding from SFC and EPSRC/STFC, the International Max Planck Partnership (IMPP) was initiated with a technical start-up meeting, with representation from all interested parties, at the Crieff Hydro in April 2013 and then formally launched by Dr Alasdair Allan on 19 December 2013 at the Royal Society of Edinburgh.

The IMPP is a collaboration between the Universities of Glasgow, Strathclyde, Heriot-Watt, St Andrews and Edinburgh and the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) (Hannover and Golm), the MPI for the Science of Light (Erlangen), the MPI for Chemical Physics (Dresden), the MPI for Quantum Optics (Garching) and the MPI for Solid State Research (Stuttgart). The collaborative area of research is *Measurement and Observation at the Quantum Limit*, which is highly relevant to the new Quantum Technologies initiative in the UK and more locally to the Scottish Innovation Centre CENSIS.

The web page for the partnership can be found at http://www.impp.uk/.

Funding

Seed funding of £500K has been provided by SFC and £243K by EPSRC/STFC and this has leveraged a high level of funding from a number of other areas, including the Universities, the Humboldt Foundation and STFC. In total, leveraged funding in the Universities in posts and infrastructure exceeds £10M, supporting research related to the IMPP.

New academic posts include:

- Prof Steve Barnett and Dr Sarah Croke at Glasgow;
- Prof Andrew Daley and Dr Alison Yao at Strathclyde;
- Prof Sven Höfling at St Andrews

with research staff and infrastructure investment in each case.

Further, a Humboldt Fellow, Dr Sebastian Steinlechner, has taken up his 2 year fellowship in Glasgow and Dr Jessica Steinlechner has been appointed to a 2 year research assistant position, funded by STFC for the IMPP, also in Glasgow.

The Universities are also providing direct operational funding. For example, Glasgow is contributing £470K over four years and St Andrews has committed £250K as a start for its IMPP chair, Prof Sven Höfling, over five years. Strathclyde University has invested in excess of £700K for the start-up packages for Prof Andrew Daley and Dr Alison Yao.

How External Funding is Being Used

EPSRC/STFC

The seed funding from EPSRC/STFC plus some University money is being used to fund visits and workshops. To date four workshops have received support:

- Condensed Matter Systems for Future Quantum Technologies (http://www.mqt2014.co.uk/), August 2014.This meeting held at St Andrews is organised by Dr P Wahl (St Andrews), Dr P King (St Andrews), Dr J-P Reid (St Andrews) and Prof A Mackenzie (Max Planck Institute for Chemical Physics of Solids, Dresden, and St Andrews). (£22K support from IMPP)

- Workshop on Many-body Dynamics and Open Quantum Systems (http://doqs2014.phys.strath.ac.uk/), October 2014. This meeting, to be held in Glasgow, is organised by Prof S Kuhr and Prof A Daley at Strathclyde. (£25K support from IMPP)

- Optical Analogues for Fundamental Quantum Field Theories, January 2015. This meeting (to be held close to Edinburgh) is organised by Prof D Faccio (Heriot-Watt), Dr A Di Falco (St Andrews) and Dr A Aiello (Max Planck Institute for the Science of Light, Erlangen). (£12K support from IMPP)

- Engineering Photonic States for Quantum Information Applications, Summer 2015. This meeting (exact venue in Scotland tbd) is organised by Dr J Leach (Heriot-Watt) and Dr S Franke-Arnold. (£24K support from IMPP)

A fifth short workshop on quantum technologies with Prof Leo Hollberg from Stanford as the main guest speaker was jointly funded with SU2P, the Scottish Science Bridges Partnership. This meeting additionally included talks by Dr Hild (Glasgow) and Prof Kuhr (Strathclyde).

Also a visit by a researcher (Dr M Lavery) from Glasgow to visit an IMPP collaborator (Prof G Leuchs) in Germany was funded, as was a month long visit from a researcher (C Peuntinger) at Erlangen to the University of St Andrews (Dr N Korolkova).

Further, in May 2014 a workshop with 60 participants, funded by the Max Planck Society and organised by Heriot-Watt under the auspices of the IMPP, called "The Nonlinear Meeting 2014" was held. This was the highest-profile meeting in the field of non-linear optics in the last 20 years.

SFC

The majority of the seed funding from SFC of £500K is being split evenly between the four main collaborating Scottish Universities – Glasgow, Strathclyde, Heriot-Watt and St Andrews each receiving £120K – with the remaining £20K going to Edinburgh with the intention that the funding is used to support graduate student stipends, training, etc.

The Glasgow student – Mariella Masso – will work on opto-mechanics relevant to allow gravitational wave detectors to reach the quantum limit, and the Heriot-Watt student – David Carvalho – will work on non-linear effects in graphene. In addition St Andrews has leveraged several PhD students linked to the IMPP work from other funding sources: 5 PhD students currently based at the MPI in Dresden (Jack Bartlett, Lishan Zhou, You-Sheng Li, Dan Brodsky and Mark Barber), 1 PhD student currently based at the MPI in Stuttgart (Ramakrishna Aluru) and another 2 just starting in St Andrews on joint MPI-SUPA projects (Matthew Neat and Christopher Trainer).

Strathclyde will start recruiting two IMPP students this autumn in addition to 5 new experimental students starting in this research field this year and 4 that were a part of Prof Daley's start-up package. It is expected that further studentships at the partner institutions will commence in 2015.

Further, Glasgow and Hannover are planning a joint summer school for the IMPP and the International Max Planck Research School (IMPRS) on Gravitational Wave Astronomy. In total 40 students and 10 lecturers from Germany and Scotland will participate in the lecture week taking place in Crieff in June 2015. The Glasgow end will be supported partly from the SFC funding and partly from funding for the IMPP from Glasgow. In addition, lecturers from Scotland (Hammond and Reid) have been invited to teach on an IMPRS week in October 2014 taking place in Spain.

Researchers at Strathclyde are planning a Scottish Universities Summer School (SUSSP71) in 'Frontiers in Quantum Dynamics and Quantum Optics' in Glasgow in July 2015. The speaker list includes Prof Gerd Leuchs, Director at the Max Planck Institute for the Science of Light, Erlangen, and an additional lecturer from the Max Planck Institute for Quantum Optics, Garching, is expected. A request for IMPP cofounding for up to 10 students to attend is imminent.

Prestigious Awards and Fellowships

Three new ERC Advanced Grants were awarded to IMPP researchers in Glasgow (Padgett), Hannover (Schnabel) and Erlangen (Leuchs) during 2013 and Dr Mohammed Saleh at Erlangen won a prestigious Royal Society of Edinburgh Fellowship, which lasts for 5 years, to be held at Heriot-Watt University. Prof Miles Padgett was elected in 2014 as Fellow of the Royal Society (FRS) and was also awarded the Lord Kelvin Medal from the Royal Society of Edinburgh. Prof Steve Barnett was awarded the 2013 Dirac Medal and Prize of the Institute of Physics (IoP).

Further Funding Applications

A number of new grant applications to Horizon 2020 have been submitted or are in the process of being worked up with German partners under Integrating Infrastructures, Marie Curie Training Networks and Future Emerging Technologies. However, it is too early for any award announcements. Further, Glasgow, Strathclyde, Heriot-Watt and St Andrews are involved in a number of separate bids to EPSRC under the Quantum Technologies initiative. One of these bids being led by the University of Glasgow and involving 40 companies is currently in the final stage review.

Notable Publications Relevant to IMPP

Real-space imaging of the atomic-scale magnetic structure of $Fe_{1+y}Te$
M. Enayat, Z. Sun, U. R. Singh, R. Aluru, S. Schmaus, A. Yaresko, Y. Liu, C. Lin, V. Tsurkan, A. Loidl , J. Deisenhofer, P. Wahl
Science, 345, 653-656 (2014)

Strong increase of T_c of Sr_2RuO_4 under both tensile and compressive strain
C.W. Hicks, D.O. Brodsky, E.A. Yelland, A.S. Gibbs, J. Bruin, M.E. Barber, S.D. Edkins, K. Nishimura, S. Yonezawa, Y. Maeno, & A.P. Mackenzie
Science, 344, 283-285 (2014)

Optomechanical self-structuring in a cold atomic gas
G. Labeyrie, E. Tesio, P. M. Gomes, G.-L. Oppo, W. J. Firth, G. R. M. Robb, A. S. Arnold, R. Kaiser & T. Ackemann
Nature Photonics 8, 321–325 (2014)

Optical Activity in Twisted Solid-Core Photonic Crystal Fibers,
X. M. Xi, T. Weiss, G. K. L. Wong, F. Biancalana, S. M. Barnett, M. J. Padgett and P. St. J. Russell;
Physical Review Letters **110**, 143903 (2013)

Thermal noise of folding mirrors
Heinert, D.; Craig, K.; Grote, H.; Hild, S.; Lück, H.; Nawrodt, R.; Simakov, D. A.; Vasilyev, D. V.; Vyatchanin, S. P.; Wittel, H:,
Physical Review D, Volume 90, Issue 4, id.042001 (2014)

Single-site- and single-atom-resolved measurement of correlation functions
M. Endres, M. Cheneau, T. Fukuhara, C. Weitenberg, P. Schauß, C. Gross, L. Mazza, M. C. Bañuls, L. Pollet, I. Bloch and S. Kuhr
Applied Physics B, **113**, 27-39 (2013)