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|  | RESEARCH PROPOSAL | | EPS(RP) |
| **Engineering and Physical Sciences Research Council**  Polaris House, North Star Avenue  Swindon SN2 1ET | | You should read the separate notes for guidance and the funding guide before completing any research proposal. The form EPS(RP) must be accompanied by a case for support. The EPSRC will reject research proposals which are not complete. | |
| 1 DETAILS OF PROPOSAL | |

Organisation where grant would be held

|  |  |
| --- | --- |
| Organisation | University of Strathclyde |
| Division or Department | Department of Physics |
| Address | 16 Richmond St, Glasgow G1 1XQ |
|  | |

Investigators

|  |  |  |  |
| --- | --- | --- | --- |
| Total number of investigators | 3 |  | Please give details of each investigator below. Continue on a separate sheet if necessary. |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Details** | **Principal Investigator** | **Co-investigator 1** | **Co-investigator 2** | | |
| Title/Initials | Dr. K | Dr. L | Dr. C | | |
| Surname | Benedek | Russell | Iakovou | | |
| Post held | Professor | Senior Lecturer | Research Assistant (Postdoc) | | |
| Organisation | University of Strathclyde | University of Strathclyde | University of Strathclyde | | |
| Division or Department | Department of Physics | Department of Physics | Department of Physics | | |
| Telephone | 0712378987 | 07123456789 | 09124356789 | | |
| Fax | N/A | N/A | N/A | | |
| E-mail | k.benedek@strath.ac.uk | l.russell@strath.ac.uk | c.iakovou@strath.ac.uk | | |
| Hours per week on project | 25 | 35 | 40 | | |
| First EPSRC proposal? | YES  NO | YES  NO | YES  NO | | |
| Change in organisation? | YES  NO | YES  NO | YES  NO | | |
|  | | | |  |

# **Co-authors**

Give the name and organisation of the individuals other than investigators on this project who are co-authors of the proposed research.

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| --- |
| Dr. Chang Li - Beijing Normal University |
|  |

# **Scheme**

Indicate if proposal is

First Grant Scheme  Link  Overseas Travel

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Related proposals

|  |  |  |
| --- | --- | --- |
| a. If this proposal is a resubmission, please give previous research grant proposal Ref no. | | GR/ |
| b. If there is more than one organisation submitting an EPS(RP) for this project, please give details of the investigator(s) and project title(s). |  | |
| c. If this proposal has been submitted in response to a specific call for proposals please give title of call. |  | |
|  | | |

Title of Research Project *(Please do not exceed 150 characters, including spaces)*

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*“Mitigating the Joule Expansion in Multicell Atomic Quantum Memories”*

Summary of EPSRC Resources Required for Project

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| a. Financial resources required | |  | |  | | b. Summary of staff effort requested | |  |  | | c. Services and HPC total | |  | | |
|  | Total £ | |  | |  | | Months |  | | | |  | |  | |
| Staff | 183,790.00 | |  | | Post Graduate | | 0 |  | | | |  | |  | |
| Travel and subsistence | 17,500.00 | |  | | Post Doctoral | | 36 |  | |  | | |  | | |
| Consumables | 13,748.00 | |  | | Project Students | | 0 |  | | | |  |  | | |
| Exceptional items | 0 | |  | | Technician | | 36 |  | | | |  |  | | |
| Equipment | 77,793.3 | |  | | Other | | 5.4 |  | | |  | |  | | |
| Large Capital | 0 | |  | | Visiting Fellows | | 12 |  | | | |  |  | | |
| PCTF | 0 | |  | | **Total** | | 89.4 |  | | | |  |  | | |
| **Sub-total** | 292,831 | |  | |  | |  |  | | | |  |  | | |
| Indirect Costs | 91,895.00 | |  | |  | |  |  | | | |  |  | | |
| **Total** | 384,726.00 | |  | |  | |  |  | | | |  |  | | |
|  | | | | | | | | | | | | | | |

**Start date and Duration**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| a. Proposed start date | | |  | b. Duration of the grant (months) | | |  |
|  | 2022/09/01 |  | | | 36 |  | |
|  | | | | | | | |

Research Councils/MoD Joint Research Grant scheme (JGS)

If MoD/Dstl have indicated that they are prepared to provide support for this proposal if successful, please indicate the percentage level of this support and MoD/Dstl contact name.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Percentage level of support | | |  | Name of MoD/Dstl contact | |  |
|  | % |  | |  |  | | |
|  | | | | | | |

Public Communication Training Funds (PCTF)

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| Do you wish to apply for Public Communication Training Funds? YES  NO |
|  |

Objectives

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| * Build the multicell atomic quantum memory (MAQM) experimental set-up with optical tweezers array trap. * Achieve the current state-of-the-art memory lifetime of 1 ms. * Surpass the current state-of-the-art lifetime by 2 - 3 order of magnitude, i.e., 0.1 – 1 second of memory lifetime. * Participate in R&D with M2Lasers industrial partner, investigating scalable solutions of MAQM for potential commercialisation. * Organise international outreach workshops on quantum hardware with Chinese collaborators. |  |

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Summary

Quantum information technologies, promise unparallel computational speeds and quantum communication protocols guarantee unbreakable encryption with respect to their current market-dominant classical counterparts. A key component in realising quantum communication systems is the quantum memory or “qRAM”. Analogous to classical RAM, “qRAM” is responsible for the retrieval of quantum states to be read at a later time. However, inherent quantum mechanical effects such as atomic free expansion make it difficult to distribute entanglement over long distances and for a useful amount of time.

Herein, we propose an experiment to realise a quantum repeater node based on multicell atomic quantum memory (MAQM) as demonstrated by Li et al. (2021), a co-author of this proposal and contributor, however by utilising optical tweezers to trap and manipulate atomic ensembles instead of magneto-optical traps (MOTs). Optical tweezers arrays, which use highly focused laser beams on microscopic atomic ensembles are promising candidates in increasing the memory lifetime of the memory cells by mitigating the atomic free expansion of the ensembles. Thus, demonstrating longer lifetime per memory cell, entanglement between nodes is maintained for longer times. This will constitute an important step towards goals such as the quantum internet and scalable quantum computing components.

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Beneficiaries

* This research is aligned with the UK’s £ 150 million investment portfolio in novel quantum technologies.
* Maintain as a nation a leading role in academia and remain at the forefront in the global race for useful quantum computing.
* Promote ground-breaking international collaboration.
* The realisation of a long-lived quantum memory cell, *i.e.,* order of magnitude greater of milliseconds, marks an important step towards long distance quantum networks, and controlled production of entangled states at the interaction of light and matter.
* Quantum communication is of transformational importance for the underlying infrastructure in many sectors like finance, business, and government.
* Collaboration with local industrial stakeholders carries potential impact on the Scottish job market for the long run.

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Staff

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | **Starting** |  | **EFFORT ON PROJECT** | | |  | **London** |  |  |
| **Name and grade** | | **point on spine** | **Increment date** | **Appointment date** | **Duration of appointment** | **% of Full time** | **Basic starting salary £** | **allowance Y/N** | **Gross annual salary £** | **Total cost on grant £** |
| RESEARCH STAFF | |  |  |  |  |  |  |  |  |  |
| i) Existing Staff | |  |  |  |  |  |  |  |  |  |
| ii) New Appointées | |  |  |  |  |  |  |  |  |  |
| C. Iakovou | | 25 | 2023/09/01 | 2022/09/01 | 36 months | 100 % | 29,614.00 | N  N | 38,966.00 | 120,528.00 |
|  | |  |  |  |  |  |  |  |  |  |
| iii) Project Students | |  |  |  |  |  |  |  |  |  |
| TECHNICAL STAFF | |  |  |  |  |  |  |  |  |  |
| D. Weber | | 19 | 2023/09/01 | 2022/09/01 | 36 months | 30 % | 24,871.00 | N | 33,537.00 | 30,183.00 |
| OTHER STAFF | |  |  |  |  |  |  |  |  |  |
| M. Smith | | 10 | 2023/09/01 | 2022/09/01 | 36 months | 15 % | 19,623.00 | N | 26,062.00 | 11,728.05 |
|  | |  |  |  |  | % |  |  |  |  |
| VISITING FELLOWS | |  |  |  |  |  |  |  |  |  |
| N. Hempler | |  |  | 2024/01/02 | 12 months | 100 % | 53,348.00 |  | 71,173.00 | 21,351.90 |
|  | **Total £** | | | | | | | | | 183,790.00 |

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Visiting Fellows

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| **Details** | **Nominated Fellow** |
| Title/Initials | Dr. N |
| Surname | Hempler |
| Post held | General Manager |
| Home Organisation | M Squared Lasers |
| Division or Department | Quantum Research and Systems |
| Country | Scotland, United Kingdom |
| Telephone | 07135546645 |
| Fax | None |
| E-mail | n.hempler@m2lasers.com |

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| --- | --- | --- | --- |
|  | **Financial Details of Nominated Fellow** | | |
|  | a. Will Fellow be supporting dependants? | YES  NO | |
|  |  | |  |
|  | b. What annual salary would host organisation pay staff of the Fellow's status? | | 71,173 £ | |
|  |  | |  |
|  | c. If salary contribution required from EPSRC, state: | |  |
|  |  | |  |
|  | (i) percentage of normal salary being received from any other source | | 70 % | |
|  |  | |  |
|  | (ii) normal salary if less than given above | |  | |

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Travel and Subsistence

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| **Destination and purpose** | **Total £** | | |
| IEEE International Conference on Quantum Computing and Engineering, Singapore 2024 | 4,500.00 | | |
| Workshop in Advances in Quantum Hardware (WAQC23), Glasgow 2024 (as organisers) | 5,000.00 | | |
| Workshop in Advances in Quantum Hardware (WAQC23), Beijing 2025 (as organisers) | 8,000.00 | | |
|  |  | | |
| **Total £** | 17,500.00 | | |
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Consumables

|  |  |  |  |
| --- | --- | --- | --- |
| **Specify** | **Total £** | | |
| Laboratory electricity consumption of 7000kWh per annum (20.772p per kWh) + daily standing charge | 5,200.00 | | |
| 4g Rubidium @ 99.9% purity + FedEx Rate – Goodfellow Cambridge Ltd. | 848.00 | | |
| 2 Desktop Towers + Peripherals | 3,500.00 | | |
| Electronic Components, cables, and micro-controllers | 500.00 | | |
| Publication costs | 3,700.00 | | |
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| **Total £** | 13,748.00 | | |
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| Exceptional Items | |  |

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| **Specify** | **Total £** | | |
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| **Total £** |  | | |
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Equipment (single items under £100,000)

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| --- | --- | --- | --- | --- | --- | --- |
| **Description of items and country of manufacture** | **Basic price £** | **Import duty £** | **VAT £** | **Total £** | | |
| Single Photon Detector (6 in total), UK | 3,566.28 (x1) | 0 | 713.2 (x1) | 25,675 (x6) | | |
| Zero-Order Half-Wave Plate (8 in total), UK | 355.22 (x1) | 0 | 71.04 (x1) | 3,410.1 (x8) | | |
| Mounted Achromatic Quarter-Wave Plate (8 in total), UK | 666.75 (x1) | 0 | 133.4 (x1) | 6,400.8 (x8) | | |
| 2x2 Multimode Coupler 50:50 Split (4 in total), UK | 255.88 (x1) | 0 | 51.2 (x1) | 1,228.2 (x4) | | |
| Mounted Polarizing Beam splitter (2 in total), UK | 253.72 (x1) | 0 | 50.7 (x1) | 608.9 (x2) | | |
| EO Phase Modulators (7 in total), UK | 2,025.00 (x1) | 0 | 405.00 (x1) | 17,010 (x7) | | |
| Thorlabs Optical Table (1 in total), UK | 7,599.00 (x1) | 0 | 1,519.8 (x1) | 9,118.8 (x1) | | |
| 100x Mitutoyo Plan NIR Microscope Objective (2 in total), UK | 4,441.25 (x1) | 0 | 888.3 (x1) | 10,659 (x2) | | |
| Mirrors and lenses, UK | 2053.00 | 0 | 410.6 | 2463.6 | | |
| Colour Camera CCD (1 in total) | 1,015.75 | 0 | 203.2 | 1,218.9 (x1) | | |
|  |  |  | **Total £** | 77,793.3 | | |
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Large Capital (single items £100,000 and over)

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| **Description of items and country of manufacture** | **Basic price £** | **Import duty £** | **VAT £** | **Total £** | | |
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|  |  |  | **Total £** |  | | |
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Services and HPC

Give details of any proposed usage of EPSRC-supported services required together with the cost that will be incurred. Please complete a separate service form if necessary.

|  |  |  |  |  |  |
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| **Service** | **Instrument(s)** | **Units** | **Cost £** | | |
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|  |  |  |  | | |
|  | **Total** |  |  | | |
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Other Support

Give details of any support sought or received from any source for this or related research in the past three years (minimum £10,000).

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| --- | --- | --- | --- |
| **Source** | **Brief title of research proposal** | **Amount sought £** | **Amount awarded £** |
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Collaboration

Please give details of collaborators and their contributions to the research. These contributions should be in addition to resources identified in pages 3 to 5. If there are more than two collaborating bodies, please continue on a separate sheet.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Details** | **Collaborator 1** | | | | | **Collaborator 2** | | | |
| Name of contact | Dr. Chang Li | | | | |  | | | |
| Name of collaborating body | Beijing Normal University | | | | |  | | | |
| Address of collaborating body | 19 Xinjiekou Wai St., HaiDian District 100875, Beijing, People's Republic of China | | | | |  | | | |
| Telephone | +123456789 | | | | |  | | | |
| Fax | None | | | | |  | | | |
| E-mail | c-l15@mails.tsinghua.edu.cn | | | | |  | | | |
| Type of organisation | Academic Institution - SME | | | | |  | | | |
| Number of employees | 0 | | | | |  | | | |
| Main business area and SIC code if applicable | N/A | | | | |  | | | |
| **Direct contribution to project** | **Description** | | | | **Value £** | **Description** | **Value £** | | |
| a. cash |  | | | |  |  |  | | |
| b. equipment/materials | 3-year loan of M Squared’s Solstis EMM from Tsinghua University. | | | | 28,800 |  |  | | |
| c. secondment of staff | Three-year Stay at Strathclyde. Annual contribution to salary of 50% at spinal point 32 | | | | 74, 459 |  |  | | |
| d. other |  | | | |  |  |  | | |
| **Sub-Total** |  | | | | 103,259 |  |  | | |
| **Indirect contribution to project** | |  | | |  |  |  | | |
| a. use of facilities/equipment |  | | | |  |  |  | | |
| b. staff time |  | | | |  |  |  | | |
| c. other |  | | | |  |  |  | | |
| **Sub-Total** |  | | | |  |  |  | | |
| **Total Contribution** |  | | | |  |  |  | | |
|  |  | |  | **Total Value (including contributions from additional collaborators)** | | | 103,259 | | |
|  | | | | | | | |  |

Declaration

In completing this research proposal, we confirm that:

a. we have read the funding guide;  
 b. if a grant is offered we will accept the EPSRC Terms and Conditions;  
 c. we have not entered into any obligations which may conflict with these.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Signatures | Name in BLOCK CAPITALS | Date |
| Principal Investigator | Prof. Kata Benedek | KATA BENEDEK | 2022 / 01 / 07 |
| Coinvestigator(s) | Dr. Christoforos Iakovou  Dr. Lewis Russell | CHRISTOFOROS IAKOVOU       LEWIS RUSSELL | 2022 / 01 / 07   2022 / 01 / 07 |
| Head of Department | Prof. Stefan Kuhr | STEFAN KUHR | 2022 / 01 / 07 |
| Administrative Authority (Position held) |  |  |  |

2 OTHER INFORMATION

This information will NOT be circulated to referees or panels.

|  |
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Referees

Please give details of three expert referees whom the EPSRC may approach for assessment of this research proposal.

|  |  |
| --- | --- |
| Referee 1 |  |
| Name | Dr. Daniel Oi |
| Position held | Senior Lecturer |
| Organisation | Computational Nonlinear & Quantum Optics Group, University of Strathclyde |
| Address | JA 7.12, Department of Physics, University of Strathclyde, 107 Rottenrow, Glasgow, G4 0NG, U.K |
| E-Mail | daniel.oi@strath.ac.uk |
| Referee 2 |  |
| Name | Dr. Thomas Jennewein |
| Position held | Associate Professor |
| Organisation | Institute for Quantum Computing, University of Waterloo |
| Address | Mike & Ophelia Lazaridis Quantum-Nano Centre, QNC 3317 |
| E-Mail | thomas.jennewein@uwaterloo.ca |
| Referee 3 |  |
| Name | Dr. Immanuel Bloch |
| Position held | Professor for experimental physics |
| Organisation | Faculty of Physics, Ludwig-Maximilians University (LMU) |
| Address | Schellingstrasse 4 / 1. & 2. Stock, 80799 Munich |
| E-Mail | immanuel.bloch@physik.uni-muenchen.de |
|  | |

Personal Information

The EPSRC aims to encourage equal opportunities. If you are willing to do so, please provide information on your own and your colleagues’ age, sex and ethnic origin. We will NOT use this information in the assessment of this research proposal, but only for internal and statistical purposes.

**Please give details for each investigator below. Continue on a separate page if necessary.**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Principal Investigator** | **Co-investigator 1** | **Co-investigator 2** |
| Date of birth | 1981/06/04 | 1985/06/24 | 1993/11/28 |
| Sex | Female | Male | Male |
| Ethnic origin (see below) | White | White | White |

Ethnic origins

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **White** | **Black-African** | **Black-Caribbean** | **Black-Other** | **Indian** |
| **Pakistani** | **Bangladeshi** | **Chinese** | **Other** |  |