# Job Description

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| **Job title** | Research Associate |
| **Department/School** | Physics |
| **Job family** | Education and Research |
| **Grade** | 7 |
| **Reporting to** | Prof D Skryabin |
| **Responsible for** | Numerical modelling of nonlinear effects in whispering gallery microresonators, scientific manuscript and project report writing |
| **Location** | University of Bath premises |

| **Background and context** |
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| We are looking for a Research Associate to carry out computational work on the modelling of frequency comb generation, solitons and other nonlinear optical effects in various types of microresonators. Postholder is expected to have strong background in theoretical nonlinear photonics, computational methods, nonlinear physics and scientific report writting.<br><br>Project abstract and general context |

## Abstract

This project aims to develop a comprehensive theory of the solitons associated with the frequency comb generation in micro-ring resonators. We propose to develop a theory of bright and dark, scalar and vector comb solitons, of their interaction with linear waves and between themselves. Our models will describe materials with the Kerr and second-order nonlinearities and include lasing and polaritonic effects. We will also study generation of the secondary combs and comb locking mechanisms and pay a particular attention to the resonators when the periodic boundary conditions have a profound impact on the solitonic and other regimes of comb generation.


## Context

Optical frequency combs provide highly accurate frequency rulers for the metrology and spectroscopy applications and enable researchers to further study nonlinear and quantum nature of light matter interaction in structured environment, which is the primary reason why pioneers in this research area have been awarded with the Nobel Prize in 2005.

One of the current trends in the area of comb generation is to move from large laser systems to small micro-resonator based comb schemes. A typical device is a millimeter radius ring resonator, made of, e.g., a semiconductor or glass, and a laser beam coupled to it. This simple setup is capable to transform a single spectral line of the pump laser beam into many thousands of new frequencies called - frequency comb. The frequency spacing between the comb lines, the comb width and a particular frequency range it covers are important parameters, which researchers try to control. We are not aiming here to perfection existing or explore novel applications of combs, but rather plan to study fundamental physical aspects of comb generation. A particular area of our interests is to enrich knowledge about dynamics and instabilities, which happen in small optical systems. In order to achieve this we outline a set of new problems and approaches relevant for micro-ring combs and also propose new theoretical models relevant for ongoing experiments.

While research in nano- and micro-photonic devices is currently blossoming, micro-rings and the comb generation in them stand out from the crowd. This is because the number of modes involved in comb generation is very large, so that one clearly deals with a very complex dynamics, which is sure to provide research results significantly extending our knowledge of basic physics. At the same time, this is a small system where its finite size and unavoidable spatial periodicity of light structures circulating along the ring are very important. This combination creates a new context for such fundamental research topics as solitons and instabilities. Indeed, the above where studied in most details in systems where approximation of the infinite size was rightfully believed to be good enough to capture the important physics. However, new effects in micro-rings are expected to be related to the small device size allowing to control small, but finite frequency separation between the comb lines.

Solitons are pulses of light, which natural tendency to broaden with propagation is arrested by the power dependent, i.e., nonlinear, properties of the material they propagate in. Spectrum of solitons is routinely and most often absolutely correctly assumed to be continuous. Solitons, have also been recently observed in micro-rings and associated with comb formation. However, their spectrum there is discrete, since they never isolated pulses, but a periodic sequence. As preliminary research done by PI and collaborators indicate, this discreteness changes significantly the soliton stability and their interaction with cavity modes opens up novel routes for frequency conversion. Research into comb solitons is currently going through its initial stage and existing results are to the large degree reducing the problem to what has been known for solitons with continuous spectrum, in particular, in optical fibers and fiber loops. New comb solitons and frequency conversion physics will be studied by us in the context of the already established, so-called Lugiato-Lefever, model and also extended beyond it by including cases of other nonlinear light matter interactions. In particular, we will study combs due to quadratic nonlinearities, competing cubic and quadratic nonlinearities and combs in lasing and polaritonic systems.

## Job purpose

To provide subject-specific research expertise and undertake specific research work to a Principal Investigator for a specified project. The job will require developing of numerical and analytical models of comb generation and and other nonlinear in optical resonators and their arrays

## Main duties and responsibilities

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| | Responsible to the PI/CI for (as appropriate to discipline): |
| **1** | Conduct individual and/or collaborative research projects. Take a lead in the design and execution of the project. Collect and analyse existing data related to the project using qualitative and quantitative techniques. |

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| **2** | Writing up results of research and contributing to publishing of results in high-quality peer-reviewed academic literature. |
| **3** | Project management: e.g. timetabling and meeting project milestones; participating in regular discussions with collaborative partners. Liaise with key stakeholders/industrial partners and conduct focus groups. |
| **4** | Disseminating results of project as appropriate to the discipline e.g. by presentations at conferences. |
| **5** | Participate regularly in group meetings and prepare and deliver presentations to project team, internal and external stakeholders or funders. |
| **6** | Assist with the supervision of graduate students and undergraduate project students and the assessment of student knowledge. |
| **7** | Continually update knowledge and understanding in field or specialism to inform research activity. |
| **8** | Identify sources of funding and provide assistance with preparing bids to funding bodies contribute to securing of funds for research. |
| **9** | Develop research objectives and proposals for own or joint research, with assistance of a mentor if required. |
| **10** | Disseminate knowledge of research advances to inform departmental teaching effort. |

Person Specification

| Criteria | Essential | Desirable |
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| **Qualifications** | | |
| A PhD degree in subject area of direct relevance for the project, or an equivalent professional qualification and significant relevant experience where applicable. | √ | |
| **Experience/Knowledge** | | |
| Post doctoral experience | | √ |
| Demonstrated significant depth and breadth of specialist knowledge in at least two of the following: nonlinear optical effects in microcavities, photonics in two-dimensional periodic potentials; optical solitons | √ | |
| Demonstrated awareness of latest developments in the field of research and in research design | √ | |
| Demonstrated potential to publish in high quality, peer reviewed journals | √ | |
| **Skills** | | |
| Ability to prepare research proposals, to conduct individual research work and to disseminate results | √ | |
| Ability to organise and prioritise own workload | √ | |
| Ability to write research reports and to effectively disseminate outcomes | √ | |
| Excellent oral, interpersonal and written communication skills | √ | |
| Proficiency in numerical techniques (as appropriate to discipline) | √ | |
| Proficiency in IT skills (as appropriate to discipline) | √ | |
| **Attributes** | | |
| Commitment to working within professional and ethical codes of conduct | √ | |
| Innovation and developing creative solutions | | √ |
| Enthusiasm and self-motivation. | √ | |
| Organisation – able to plan and deliver work to meet required deadlines | √ | |

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| Tenacity – working to achieve own and team objectives and to overcome obstacles | √ | |
| Ability to be an effective team worker | | √ |