NEWSLETTER
OCTOBER 2015
ISSUE NO. 1

PHOQUS

IN THIS ISSUE:

Welcome to the first PHOQUS Newsletter!

Despite the acknowledged importance of Multi-disciplinary Research, progress in training of the next generation of young scientists at the interface between Life and Physical Sciences has been limited so far. There is an urgent need for more effective integration between these two sectors of science research, in order to advance our knowledge and understanding of complex processes in living organisms, linking events from the molecular to the tissue and organism scale and their translation into new diagnostic capabilities required to assess effects of novel developed drugs and applications in medicine.

The PHOQUS programme will develop state-of-the-art photonic technologies that will enable development of new imaging tools for the Life Sciences, necessary to make significant advances in the understanding of a range of outstanding biomedical problems from the molecular and cellular to the tissue and organ level scales.

Specific aims of PHOQUS are to

- train a new generation of exceptional scientists in the life and physical sciences, without the historic barriers that have existed between these disciplines;
- develop new photonics tools that will feed into the design and development of smaller, more cost effective instruments;
- use these new tools to investigate the cellular and molecular dynamics which drive the process of cell division;
- use newly developed imaging techniques to investigate the role of cell behaviours during embryonic development and disease.

In this first newsletter you will hear more about the PHOQUS Programme and the initial training events, meet some of the PHOQUS fellows and find out what they have been doing since they joined the project.

MARIE CURIE ACTIONS

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 608133

UNIVERSITY OF DUNDEE

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What is PHOQUS?

PHOQUS (**PHOtonic tools for Quantitative imaging in Cells and tissUeS**) has been awarded funding of €3.8 million from the EU's FP7 Marie Curie Innovative Doctoral Programme to train 13 early stage researchers (the "fellows") as interdisciplinary scientists at the interface between Physics/Photonics, Medicine and Life Sciences. The fellows will be based at the University of Dundee in Scotland where they will have access to world-class expertise in life and medical sciences, surgical and image interventional technologies, nanomedicine and photonics. They will also have access to academic and commercial expertise and training for key aspects of the programme provided by academic and industrial and partners from across Europe.

The PHOQUS fellows will work as a cohort, developing an identity as interdisciplinary researchers. PHOQUS aims to develop scientists with the correct mind-set to discover and address the big problems in biology/medicine and physics from an early stage in their research careers.

PHOQUS officially started on 1st November 2013 and the Kick Off meeting was held on 26th November. The main focus of the Kick Off was to agree the recruitment strategy, discuss the initial training events and elect the members of the Recruitment and Training Supervisory Board and Steering Committee.

All 13 early stage researchers have now been recruited with the final fellow joining in September 2014. The fellows have interdisciplinary backgrounds with a wide range of experience including Physics, Photonics, Biotechnology, Biomedical Engineering and Molecular Biology.

Associated Partners

Aston University
Universität Bern
Coherent
The University of Edinburgh
University of Oxford
Goethe Universität Frankfurt am Main
University of Leicester
M Squared
moor instruments – innovation in microvascular assessment
nuomedis®
In Supremæ Dignitatis 1343
Photometrics
Tampere University of Technology
Eberhard Karls Universität Tübingen
Teravil
Zeiss – We make it visible.

FULL INFORMATION ON ALL ASSOCIATED PARTNERS CAN BE FOUND ON THE PHOQUS WEB SITE.

The Training Programme

PHOQUS offers a wide variety training events, from generic transferable skills training courses provided by the University of Dundee to in-depth technical skills training provided by the Scottish Universities Physics Association (SUPA). In addition, PHOQUS will develop a number of new training events

PHOQUS FELLOWS
AT THE MICROSCOPY AND IMAGING WORKSHOP

tailored to the specific needs of the programme, including workshops, Summer Schools and academic “Super Seminars” delivered by the PHOQUS Supervisors.

The training programme kicked-off in August 2014 with a 2 week workshop on Microscopy and Imaging organised by Dr Sam Swift. The workshop consisted of a mixture of lectures and “hands-on” practical sessions delivered by academic staff at the University of Dundee, and **Zeiss** and **Photometrics**, two of the PHOQUS industrial partners. During the workshop, the fellows also worked together to build a microscope.

In September 2014, PHOQUS co-sponsored a meeting in the area of Biophotonics. This covered all aspects of the topic from the development of new optical sources to the development and application of new microscopy techniques. Invited speakers included Prof Paola Borri (Cardiff University), Prof Jamie Hobbs (University of Sheffield), Prof Gail McConnell (University of Strathclyde), Dr Jonny Taylor (University of Glasgow) and Dr Chris Leburn (Chromacity).

The first PHOQUS Summer School was held in Edinburgh last month. This was a 3 day event attended by the PHOQUS fellows, their PhD Supervisors and some of the Associated Partners. The program included presentations and posters by the fellows and invited talks from some of the PHOQUS Supervisors and Academic Partners including Martin Booth (**University of Oxford**), Robert Henderson (**University of Edinburgh**), Sergey Piletsky (**University of Leicester**), Erik Schäffer (**Universität Tübingen**), Ernst Stelzer (**Goethe Universität Frankfurt am Main**), Martin Frenz (**Universität Bern**) and Vittoria Raffa (**University of Pisa**).

SPEAKERS AND ATTENDEES
AT THE FIRST PHOQUS SUMMER SCHOOL

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MEET THE FELLOWS...

Piotr Zdankowski (PHOQUS fellow no. 5)

My name is Piotr Zdankowski and I come from Warsaw, Poland. I studied at the Warsaw University of Technology (WUT) Faculty of Mechatronics where I obtained my engineer's and masters engineer degree in Photonics Engineering. My main area of expertise was holography and holographic displays. After I obtained my masters degree in December 2013, I initially started PhD studies at the WUT. However, I thought I would like to try something new and fresh, challenge myself a bit more and get out of my comfort zone. Soon after I found an advertisement for the PHOQUS project and applied for it. A few months later I was in Dundee starting my new career in the field of microscopy and biophotonics. My research project is titled "Super-resolution analysis of the human mitotic spindle" and its main objective is to successfully design and build a stimulated emission depletion (STED) microscope and use it to image mitotic cells and their very fine and small structures such as kinetochores. Classical, diffraction limited microscopes are not suitable to resolve these structures properly, hence the necessity of using super-resolution to image them. In order to get more experience in the field of super-resolution microscopy, I spent 5 months on secondment at the Centre for Neural Circuits and Behaviour of the University of Oxford where I learned how to utilise adaptive optics in the microscope and how to correct aberrations to get images looking even crisper. Now I'm back in Dundee where I'm helping setting up the new PaLS (Physics and Life Sciences) Lab. I have started building my microscope and hopefully I'll be able to get it working in the near future.

Alessandra Cecchini (PHOQUS fellow no. 4)

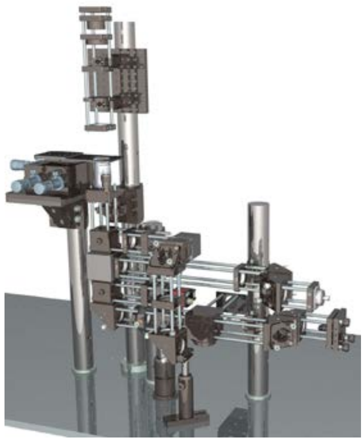
I am Alessandra Cecchini and come from Florence, Italy. I got my Bachelor's degree in Medical and Diagnostic Biotechnology at the University of Florence and my Master's degree in Industrial and Molecular Biotechnology at the University of Pisa, Italy. During my academic career I mainly focused on Biotechnology, Biochemistry, Biophysics and Nanomedicine. I won a six-month internship at the University of Excellence and Advanced Studies Scuola Normale Superiore, Italy, during which I worked on the effect of the topography of bionanomaterials on dopaminergic neurons. I realised that my dream was to keep working in the field of scientific research, possibly abroad, and particularly in a multidisciplinary environment, such as Biophysics or Nanomedicine.

I joined the PHOQUS programme in May 2014 to work on the development of quantum dot-based polymeric nanoparticles able to recognise human vascular endothelial growth factor (hVEGF) in vitro and in vivo. Recently I spent 2 months at the Biotechnology lab at the University of Leicester, UK and I am currently on secondment to the University of Pisa, Italy to carry out in vivo experiments in Zebrafish.

Thomas Rabl (PHOQUS fellow no. 13)

My name is Thomas Rabl and I am from Tirol, Austria. I attended a mechanical and electrical engineering high school in preparation for my academic career. My bachelors and master's degree in physics from the Leopold Franzens University in Innsbruck was appointed in 2013. Thin film development and applied physics where my specialisations. During my studies and the year after my degree, I worked at D. Swarovski KG. in Wattens in a department that combined physical testing, chemical testing and microscopy. I was able to perform the laboratory work for my master thesis in cooperation with D. Swarovski KG. on the design and manufacturing of a measurement device. This thesis was at the interface of engineering and physics as well as on the interface of academia and industry.

With my interest gradually expanding towards biology and chemistry I was searching for a PhD that would satisfy my thirst for knowledge. After initial considerations I decided to look for programs all over Europe. Luckily a friend pointed me towards the PHOQUS project that was, by far, the most interesting program I came across. And finally on 11th of August 2014 my journey within PHOQUS began.



Within PHOQUS my project is to develop and build a Raman spectroscopy system that is able to assess quantitatively intracellular drug concentrations. To achieve this task, I not only have to build and design the spectrometry system, but perform sample preparation as well as cell culturing specifically for my purposes. As support, I was assigned a supervisor in Biology and a supervisor in Physics. Moreover, I have amazing people around me, within and outside of the PHOQUS project who are always there to help.

Beyond the experience directly related to my project, personal experiences within the PHOQUS cohort and with scientists all around the world are the most important achievements during my first year in Dundee.

As an interdisciplinary researcher I now stand again in between, this time in between physics and biology. My hopes for the future are that my colleagues and I are able to build bridges between Biologists and Physicists in the University of Dundee and our future work places.

Full information on all PHOQUS fellows can be found on the PHOQUS web site.

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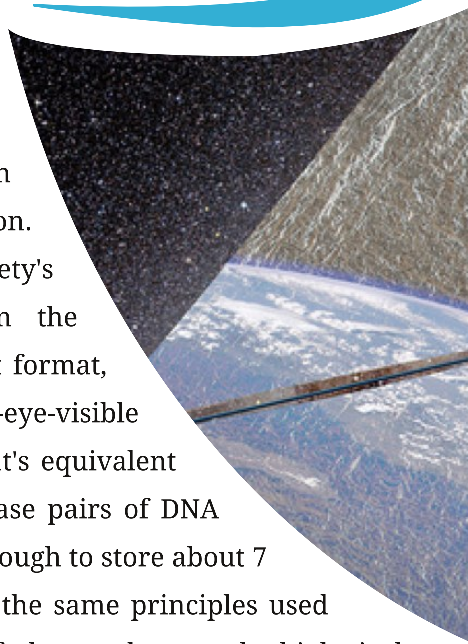
To Space and Back With Biophotonics



Carl Sagan inspired a wave of minds young and old to curiosity, scepticism and enquiry throughout his career. He was among the first to see the value of escaping the ivory tower and encouraging scientific literacy in a public audience, and in 1976 Carl Sagan went on the Johnny Carson show to describe the concept of solar sailing, a bizarre idea that dares to propel a spacecraft on a current of light. The strangeness defies intuition until the realisation of a simple photonic quirk of nature: photons of light, despite having zero invariant mass, possess momentum.

I'll invoke the most famous equation in the world to convince my readers. Energy is equivalent to mass multiplied by the square of the speed of light (E = mc2). One can verify from experience that light has energy: we can feel our skin temperature increase in sunlight. Thanks to Einstein, we know that it therefore must have inertial mass, and thus momentum, as well. This is why light is effected by gravity (allowing us to observe the mysterious influence of dark matter in the universe), and why a spacecraft can conceivably push itself along by reflecting photons. The latest effort to bring this science fiction closer to engineering practicality was the launch of LightSail-A by Carl Sagan's own Planetary Society. The craft tested sail deployment mechanisms, and subsequent versions of the craft will test solar sailing as a means of increasing orbital speed, and thus improve the practicality of light-based sail propulsion.

The reader may be beginning to wonder what all this whimsical sailing has to do with biology. We have briefly discussed a fundamental concept in photonics, the momentum of light, but we're missing at least one prefix to bring us back to focus. A solar sail craft must have an enormous wingspan to eke out an appreciable acceleration. The Planetary Society's LightSail-A, based on the shoebox-sized CubeSat format, unfurled to a naked-eye-visible 32 square meters. That's equivalent to almost 24 billion base pairs of DNA in a straight line, or enough to store about 7 human genomes. Can the same principles used to propel a spacecraft be used to study biological molecules a billion times as small?

The same physics apply, although we sometimes have to treat them slightly differently, at a scale of billions and billions, where we would like to send spacecraft, down to a scale of billionths and billionths where we find proteins. It is not typically necessary to brace ourselves against a strong gust of sunshine at the macroscopic human scale, we have more pressing forces to worry about. However, at the level of proteins and cells the magnitude of forces driving the essential activities of life is within the range of forces we can impart by redirecting a bit of laser light. This is the point at which we add a 'bio' prefix to make 'biophotonics', the study of life with light and vice-versa.

Several PHOQUS projects are built on the practice of redirecting light momentum to impart and measure minuscule forces to biological material, a group of techniques grouped under the term “optical tweezers.” Typically we use micron-scale plastic beads to act like tiny lenses, redirecting light and receiving a corresponding push. By tracking the position of the bead when it is influenced by fluidic or biomolecular forces, we can precisely infer or deliver the forces involved in fundamental processes.

LightSail-A
Picture by Planetary Society

Tissues and some cell activities have conventionally been just above the strength of forces we can influence and measure with optical tweezers, especially as, for biological materials, at some point increasing laser power will cook the sample. PHOQUS fellow **Valentina Ferro** develops anti-reflection coatings and high refractive index microbeads to overcome this historical hurtle. High strength microbeads are expected to enable experiments in tissue dynamics and cell motility previously unavailable to the advantages of optical tweezers.

My own work aims to directly measure the momentum change of light affected by microbeads to study protein conformation and activity associated with cell division. Genetics and molecular biology have provided a high-level blueprint of the parts involved, and my enquiry with optical tweezers aims to derive an engineer's mechanistic understanding of one simple protein piece of the biomolecular machine.

Many of the techniques are heavily influenced by space science, or alternatively, many of the techniques employed by scientists studying space are borrowed from biophotonics. Microscopy and telescopy have advanced together from a beginning in hand-wrought brass and glass to the modern application of computation, deformable mirrors, and liquid crystals. The adaptive optics I use to arbitrarily control optical tweezers are descended from systems first employed to counteract atmospheric turbulence in ground-based astronomy. It is unsurprising that a cohort of PHOQUS fellows are closely involved in collaborative outreach at the Mills Observatory in Dundee, highlighting seeing-based scientific enquiry in a project titled “Outer Space/Inner Space” (Or “Inner Space/Outer Space”, as fits your inclination). Looking inward or outward, the same fundamental technologies are enabling our enquiries.

Article by Q. Tyrell Davis (PHOQUS fellow no. 6)

SPIM-FLIM-FLAMMING!

Investigating cellular nuclear dynamics using single photons

The human body is an amazingly complex system with numerous different networks working together to create one functioning object, you! You are a number of organ systems, consisting of individual organs functioning in unison. These individual organs are made up of different tissues which themselves are composed of individual cells-the basic biological unit that provides structure and function to all living beings. But these individual cells are composed of minute objects, organelles, macromolecules, molecules and even down to single atoms.

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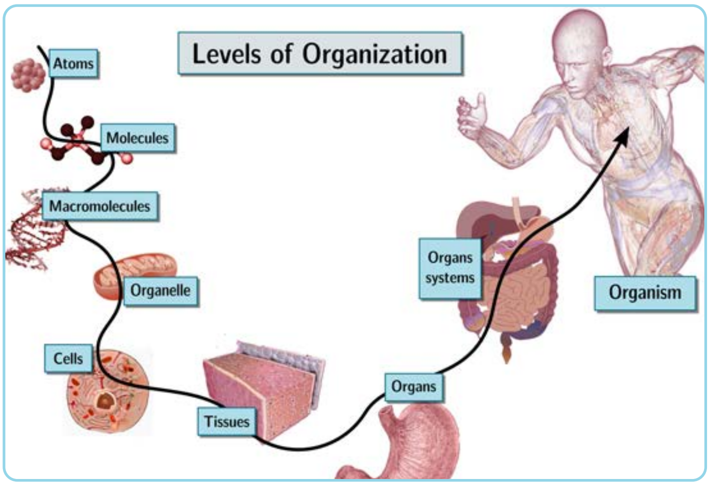


Proteins are one of these essential sub-cellular macromolecules, which are building blocks of the human body. They control all biological systems in a cell. Many proteins act independently, though the vast majority interact with others for proper biological activity. Characterisation of these protein-protein interactions is critical to understand protein function and ultimately, the biology of the cell.

And so we ask the question ‘How do we learn about these interactions?’. A number of microscopy methods have been developed to allow investigation of these interactions. They have achieved much but we always want to get more information faster, over a longer period, using less light. To achieve this we need to create new ways to look at cells using both prior knowledge and implementing new technologies.

Such is the aim of this particular PHOQUS project. Using already established microscopy modalities and existing expertise in Dundee and combining them to create new novel modalities, is one way to achieve our desired goals. By combining lightsheet microscopy and fluorescent lifetime imaging microscopy it’s possible to create a new multimodal system using and combining the benefits of both means.

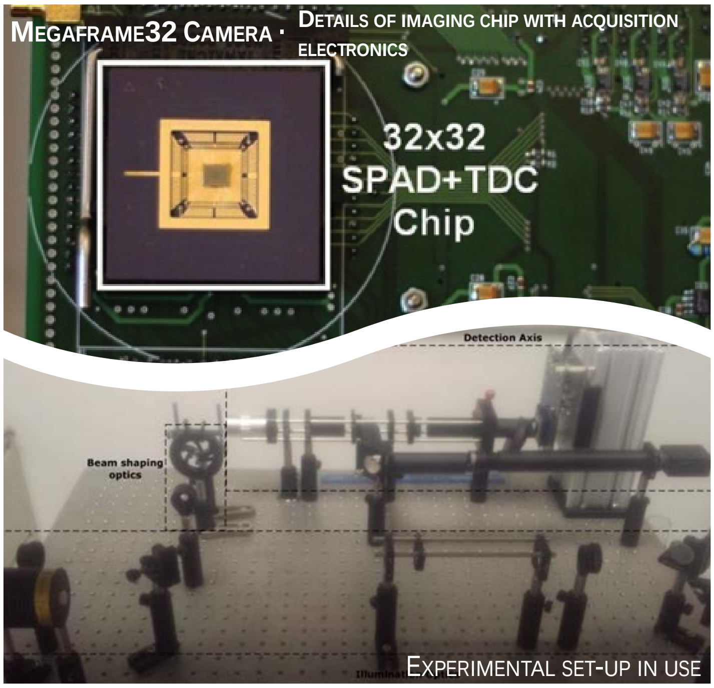
What drives this research then? A mutual interest and collaboration between scientists from a number of backgrounds within the University of Dundee.

What is the key to success with regard to this research going forward? Expanding this collaboration to include new partners outside the University of Dundee bringing in new technology to allow this research to include the newest state-of-the-art in its field.

In particular, for this project we work closely with the **University of Edinburgh**, who have shared a new camera called the Megaframe32, a camera capable of recording single photons and using the time of arrival of each photon to extract a plethora of information about these desired interactions.

To date this has been implemented in the Biophotonics Research labs based in Ninewells Hospital at the University of Dundee. Preliminary characterisation of the system is underway, with imaging of fixed samples having been performed on both plant and human cells. Future work will progress to three-dimensional, with the potential for four-dimensional (3D+time) data acquisition of living cells.

ARTICLE BY DANIEL O'BRIEN (PHOQUS FELLOW NO. 7)



ILLUMINATION SOURCE AND OPTICS, BEAM SHAPING OPTICS TO CREATE A LIGHTSHEET, DETECTION AXIS INCLUDING OBJECTIVE AND APPROPRIATE IMAGING LENSES TO IMAGE ONTO THE MEGAFRAME32 AND COALIGNMENT CAMERA.

PHOQUS fellows are reaching out

"Somewhere, something incredible is waiting to be known." (Carl Sagan)

… and all it takes is for someone to show it to the world.

Pursuing a career in research involves more than working in a lab or sitting behind a computer all day, it also involves disseminating results and promoting the research. Within the scientific community, communicating research happens through the publication of papers and participation at conferences, but it is equally important to engage to the general public through outreach activities. Therefore, the fellows have started up and participated in a number outreach and public engagement projects, to promote PHOQUS, Marie Cure Actions and scientific research in general.

Here are a few things to keep an eye on!

MCAA Scotland Chapter

The PHOQUS fellows have succeeded in procuring funding from the Marie Curie Alumni Association (MCAA), to set up the MCAA Scotland Chapter. The Chapter will organize activities until May 2016, mainly focusing on creating networking opportunities, participating in public engagement and promoting Marie Cure Actions, with the purpose of stimulating the birth of new exciting projects in the future. The Chapter already has more than 20 members from seven different Scottish universities. The first order of business will be the organisation of a Chapter Opening Night, giving the members the opportunity to get to know each other and discuss future events. Events will include a seminar series will be organised on the topic of "Science of Sci-Fi movies," exploring the reality and feasibility of science and technology that appears in science fiction popular culture, and hopefully proving that some these nerd's dreams have the potential to become reality.

Follow @MCAA_Scotland on twitter.

Outer Space Inner Space (OSIS)

Have you seen a picture of a cell and though that it looked like a far away galaxy? Or noticed that certain patterns and structures seem to reappear at every size dimension? The OSIS project makes the link between the macroscopic world of outer space and the microscopic world as viewed through a microscope. The project brings together enthusiasts from PHOQUS, the College of Life Sciences, the School of Computing, the School of Physics and Mathematics, and the Mills Observatory (Leisure and Culture Dundee with Dundee City Council), who will turn the Mills Observatory seminar room into a platform for multimodal and immersive engagement. This will include a room-filling presentation screen to show images of the macro and micro cosmos, and space for workshops and exhibitions. It aims to reach Observatory visitors of all ages and abilities, and will feature human-computing interfaces, ensuring that all audiences can experience and interact with the presentations. Within this framework, the PHOQUS ESRs have been awarded funding from SUPA (the Scottish Universities Physics Alliance) to organise activities for the International Year of Light. So far they have trailed their ex- hibition during two open days at the Mills Observatory, with great success. The aim is to teach the general public about the principles of optics, and how this can be used to look at both things that are

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very far away as things that are very small. Activities include building a telescope from scratch and imaging everyday objects through a PDMS drip lens. Follow @OSISDundee on twitter.

Still want more?

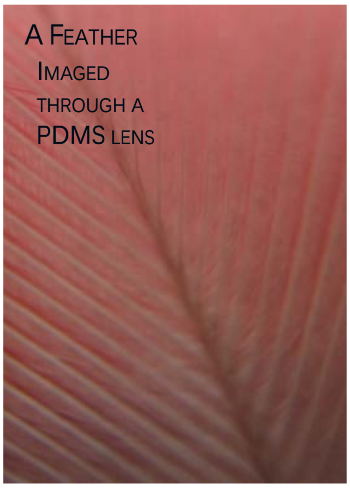
That's not all, several fellows routinely write about their experiences and thoughts of being a researcher on personal blogs (easy to find through the PHOQUS website). Next to that, and to prove that scientists can be funny too, some of the fellows participated in a Bright Club event. One explained how she plans to change the world by playing with lasers, while another student sang songs about science and lab safety. And as if that wasn't enough, a short promo video was made, showing a few fellows answering the question: **"what is PHOQUS?"**, in case there was still confusion on that matter.

It will be difficult to not know about PHOQUS with all this engagement going around. Follow @phoqus_fp7 on twitter to know more about upcoming research activities or go to www.phoqus.eu for more information.

Article by Valerie Bentivegna (PHOQUS fellow no.10)

Valerie Bentivegna (ESR 10)
Explaing Microscopy with the help of PDMS lenses

A Leaf Imaged through a PDMS lens



A Feather Imaged through a PDMS lens

Valentina Ferro (ESR 3)
Showing how to build a telescope

For comments and suggestions, email us at PHOQUS@dundee.ac.uk

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University of Dundee

Newletter Design by Valentina Ferro (PHOQUS fellow no. 3)