

Institution: Queen's University Belfast		
Unit of Assessment: 9		
Title of case study: LIGHT! OUTREACH! ACTION!: Exploiting light-based research to enhance public knowledge and change perceptions		
Period when the underpinning research was undertaken: 2000–2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	Role(s) (e.g. job title):	Period(s) employed by submitting HEI:
Dr. M. Yeung	Lecturer in Laser Physics	2015-present
Prof. B. Dromey	Professor of Laser Physics	2009-present
Prof. A. Fitzsimmons	Professor of Astrophysics	1988-present
Dr. M. Schwamb	Lecturer in Astrophysics	2019-present
Prof. S. Smartt	Professor of Astrophysics	2004-present
Period when the claimed impact occurred: 2010 – 2020		
Is this case study continued from a case study submitted in 2014? N		
1. Summary of the impact		
<p>Physicists at Queen's University Belfast use their research programmes for a range of outreach and educational activities in Northern Ireland, as an integral part of the annual Northern Ireland Science Festival (NISF). By explaining the nature of light, its applications in modern technology and how we use it in scientific research, we target, and demonstrably impact, a wide audience. Our interactive 'Lasers Live' exhibit is engaged by tens of thousands in normal years. Random sample surveying reveals new learning in over 70% of participants (with >90% confidence). Another key outcome of these surveys is that over 80% of all age groups would see more events like Lasers Live. This has had direct impact on decision making by National Museums NI for current and future science installations. Physics teachers and schoolchildren report appreciation of educational support through this programme.</p>		
2. Underpinning research		
<p>Outreach and promotion of physics to school pupils and the general public is performed by staff in all our Research Centres. The bulk of public outreach in the REF assessment period involved researchers and results from the Centre for Plasma Physics (CPP) and the Astrophysics Research Centre (ARC). Together, these research centres use the nature of light and its applications in technology and science to encourage appreciation, interest and engagement in STEM.</p> <p>An engaged team of people focus on delivering this programme to a wide range of audiences. This includes local schools, to the general population in Northern Ireland and even worldwide viewers. In CPP, Prof. B. Dromey developed our Lasers Live programme in 2015 and continues to oversee its management under the auspices of his EPSRC grants (EP/L02327X/1 (2014), EP/P016960/1 (2017), EP/P010059/1 (2017)). Dr. M. Yeung runs and organises this event and collects the key indicators of impact given in Fig 1. This has had a direct impact in how National Museums NI plan and conduct events. Members of the ARC (Prof. Fitzsimmons (NI Science Festival, Irish Astronomical Association, BBC Documentaries, School Teacher Curriculum Support), Dr. M. Schwamb (Planet 4 Citizen Science, BBC Documentaries) and Prof. S. Smartt (SmarttScience, Irish Astronomical Association)) all engage in activities focused on growing public awareness of our place in the universe.</p> <p>Since 2015, CPP has operated the "Lasers Live" outreach event to showcase its research in high power lasers and promote the public's knowledge of light-based technologies. At the core of this underpinning research is the world-class TARANIS laser facility based in the School of Mathematics and Physics [R1]. The majority of CPP researchers work in fields based around using such lasers to generate secondary radiation sources with unique properties such as ultrashort pulse ion beams and coherent X-rays. For example, [R2] use proton sources generated by the TARANIS laser to perform time-resolved measurements of ion-induced damage in matter on timescales that cannot be reached with other sources. The "Lasers Live" event arose as an</p>		

opportunity to raise awareness of this facility and our research and to inspire an interest in light-based science and technology beyond just high-power lasers, driven by CPP-led expertise.

At the same time, ARC has engaged in a programme of outreach activities based around their core research areas of Solar Physics, Solar-System studies, Exoplanet research and Transient science (supernovae and gravitational wave sources), all of which received significant STFC/Royal Society/ERC funding during the REF assessment period. High-visibility research featuring in our outreach activities include the first kilonova identified as a source of gravitational waves [R3]. As the first (and currently only) gravitational wave source with a detected electromagnetic signature, GW170817 gave the first direct evidence of the origin of heavy elements via neutron star collisions (<https://www.bbc.co.uk/news/science-environment-41640256>). Another highlight was the study of the first interstellar object discovered passing through our Solar system, 1I/Oumuamua [R4]. Rapid investigation revealed a surface similar to inert comets and the possibility of ice being maintained under a crust, possibly developed in interstellar space (<https://www.bbc.co.uk/news/science-environment-42397398>).

A recent broadening of research effort into citizen science by the appointment of new staff is continuing via an established Zooniverse project on Martian weather systems [R5]. This project uses imaging of polar geyser deposits by the NASA Mars Reconnaissance Orbiter to measure wind patterns and climate variations near the South Pole of Mars. This is currently leading to an upcoming project on exoplanets using Transiting Exoplanet Survey Satellite (TESS)/ Next Generation Transit Survey (NGTS) data. The recent first light images from the world's largest Solar telescope used cameras led by ARC (<https://www.bbc.co.uk/news/uk-northern-ireland-51308335>).

3. References to the research

[R1] Dzelzainis, T., ... **Dromey, B.**,*et al.*, (2010), "The TARANIS laser: A multi-Terawatt system for laser-plasma investigations." *Lasers and Particle Beams*, 28, 451.

<https://doi.org/10.1017/S0263034610000467>

[R2] **Dromey, B.**, *et al.*, (2016), "Picosecond metrology of laser-driven proton bursts..", *Nature Communications*, 7, 10642. <https://doi.org/10.1038/ncomms10642>

[R3] **Smartt, S.**, *et al.*, (2017), "A kilonova as the electromagnetic counterpart to a gravitational-wave source.", *Nature*, 551, 75. <https://doi.org/10.1038/nature24303>

[R4] **Fitzsimmons, A.**, *et al.*, (2018), "Spectroscopy and thermal modelling of the first interstellar object 1I/2017 U1 'Oumuamua.", *Nature Astronomy*, 2, 133. <https://doi.org/10.1038/s41550-017-0361-4>

[R5] **Aye, K.**, *et al.*, (2019), "Planet Four: Probing springtime winds on Mars by mapping the southern polar CO2 jet deposits.", *Icarus*, 319, 558. <https://doi.org/10.1016/j.icarus.2018.08.018>

4. Details of the impact

LIGHT! OUTREACH! ACTION! is a multifaceted outreach programme focused on light-based science and technology developed in QUB to grow awareness of how we make the brightest sources of light on Earth to how we study the brightest sources of light in the Universe.

Informing decision making in National Museums NI and NISF

The centrepiece of the annual LIGHT! OUTREACH! ACTION! agenda is the interactive Lasers Live exhibit. This was created and is managed by CPP physicists and its overarching aim is to entice all ages groups (Fig 1) to engage with Physics-based knowledge transfer via an interactive display, staffed by enthusiastic PhD students. Additionally, it raises awareness in NI of the cutting-edge light-based research taking place within their local universities. Drawing inspiration from UNESCO's International Year of Light, in its first year (2015) Lasers Live became a focal point of the Ulster Museum's involvement with the NISF, reaching over 12,000 members of the public, including many school groups. Yearly events have seen an explosive growth in visitor numbers during the annual NISF, reaching >30,000 in 2019. For 2020, numbers were lower due to growing concerns about Covid19 in late February. Our presence has been central to this growth, as outlined by the National Museums NI Head of Curatorial: "*Lasers Live has become a roaring success in its own right contributing to a remarkable year-on-year increase in visitor numbers to the museum as shown below.*" [S1].

The interest generated by Lasers Live influenced the Museum to install additional science exhibits (Fig 1, question d), *"The clear appetite among the public for more science exhibits as demonstrated by Lasers Live was part of the case for making the Elements exhibit a permanent feature in the museum"* [S1]. It has also played a central role in the success of the NISF, directly assisting the establishment of one of largest science festivals in the UK as highlighted by the Festival's Director: *"This is an annual highlight of our programme, with the interactive displays and public participation giving us our largest footfall of any single event."* [S2] The previous experience of QUB Physics staff led to an invitation to join the founding Board of NISF in 2014 *"...due to his experience in public engagement and outreach. He was instrumental in obtaining funding from the local University sector for the NISF, and continues to assist us in guiding the festival each year."* [S2]. Combined, this evidence demonstrates how the physics light-based outreach agenda has successfully provided direct input into the decision-making process for Museums NI and NISF.

Evidence of enhanced learning opportunities through engagement

As part of Lasers Live, large scale random sample surveys to determine the before and after impact of our events were conducted throughout 2017, 2018 and 2019. These data are summarised in Fig 1 as taken from a random sample of 1229 participants (demographics, evidencing reach and scope of our events, are shown in the pie charts). Random samples were taken in writing, on iPads (Survey Monkey) and by direct presenter-participant engagement. The samples show increased engagement amongst the 12-17 year old age group and the over 65s. Otherwise, we record near uniform engagement across the 18-64 year age bracket. This indicates that the results of our survey (columns) are an accurate % representation of the general impact of Lasers Live and not skewed by any one demographic. In the 3 questions relating to learning outcomes (a-c), we record a consistent >70% confirmation of increasing knowledge. Furthermore, d) reveals >80% desired for more events of this nature. This granularity in our data has directly impacted how National Museums NI decide on installations i.e. 'Elements' exhibit in quote from [S1] above. When it is considered that these random samples are taken from > 80,000 visitors over 3 years we can have high confidence that these results are an accurate representation of the overall interaction for Lasers Live.

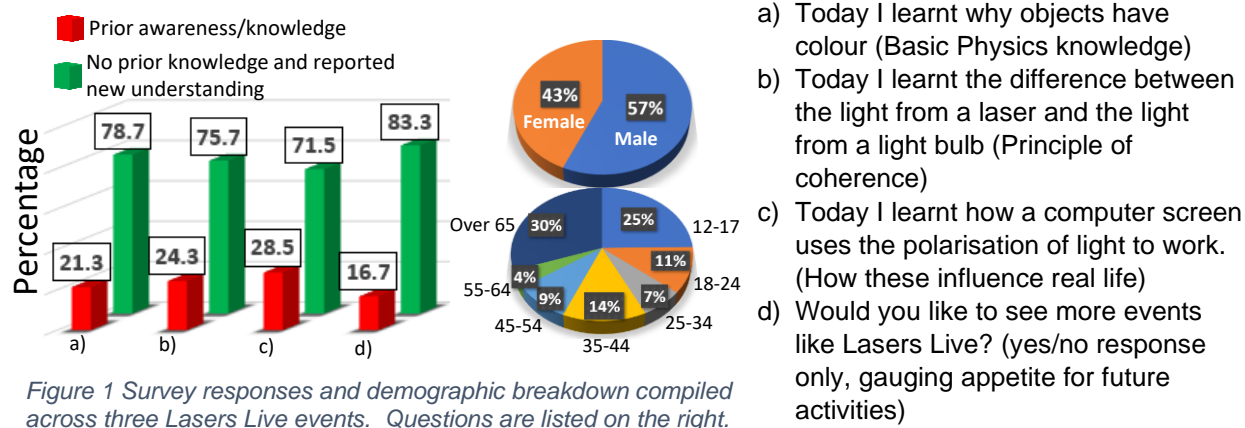


Figure 1 Survey responses and demographic breakdown compiled across three Lasers Live events. Questions are listed on the right.

Breaking down these data along the lines of associated comments reveals that the core impacts of Lasers Live achieved through this engagement were:

- **Challenging understanding:** "How does a plasma ball actually work?" ([S3], pg7); "It was brilliant because was learned [SIC] how electrons go through your hand and lights up the stick" ([S3], pg5).
- **Changing perceptions:** "I was apprehensive about physics because it never kept my attention. The presenters explained the material in a relatable way and with experiments so it was fun. Thank you" ([S3], pg14); "I learnt something new. Kind of cool" ([S3], pg26).
- **Inspiring novel thinking** "you could explain how colour reflects from one wall to another?" ([S3], pg8).
- **Engaging the next generation:** "...the children of Queens childcare services loved it" ([S3], pg9); "Excellent at catching children's attention! And keeping it we had to drag them away!" ([S3], pg12).

In a mark of its success, this activity has branched out to other events around Belfast, with both Lasers Live and astrophysics exhibitions being very popular at events such as Late Lab (2016, 2017, 2019), Science Uncovered (2016, 2017) and W5 Late (2018), designed to attract the difficult-to-reach demographic of 18-35 year olds [S1, Fig 1]. Members of ARC accelerated this expansion by hosting public lectures, Sun/Moon watches, and Astronomy Question Time panels. Indeed, the reach of Lasers Live has been extended outside Northern Ireland, with appearances at the Cavan-Monaghan Science Festival (2017, 2018) and Dublin Maker (2018, 2019).

A recent development has been the operation of citizen science projects on Martian geology and weather using the Zooniverse platform. Version 1 of "Planet Four" reached over 30,000 members of the general public (Aye et al. 2019). Version 2.0 launched in March 2020, with the two separate projects engaging approximately 24,000 and 12,000 people respectively in 65 countries. This is one of our activities to engage with a wide age group; *"You gave an old lady hope and that I was still capable of using my brain and doing something worthwhile."* [S4].

Staff are highly visible in promoting scientific understanding and their research in the media. Invitations occur due to the staff being valued as clear communicators of their science. "The Conversation" articles on Laser Physics and Planetary Science have been read 863,000 times and 460,000 times respectively. ARC staff featured in BBC Horizon programmes and other documentaries and have been interviewed in the BBC series "The Sky At Night" at least once per year [S5]. ARC research has influenced the subjects chosen for those programmes. Indeed, the February 2018 episode of this BBC2/4 show was entirely based at QUB, due to their work on 'Oumuamua (i.e. Fitzsimmons et al. 2018), *"You'll see from the viewing figures below that this programme reached an especially large audience and generated some particularly positive feedback."* [S5].

Educational impact

Since 2013, there has been a 28% decrease in the number of NI students taking Physics 'A'-levels, a reflection of the more general decline in NI students taking STEM A-Levels over the 2004-2014 period (NI Assembly Research and Information Service Research Paper NIAS 620-15) [S6]. Through our outreach efforts we have counteracted this trend and maintained the number of students entering undergraduate Physics degrees, by promoting physics to school pupils and supporting local teachers on new syllabus content in astrophysics. *"Your workshop plus the materials you gave us made a clear difference in delivering this to our students"* [S7].

In May 2014, ARC staff hosted the STFC "Seeing the Universe Exhibition" and 3 associated public lectures, visited by hundreds of members of the general public plus 9 school parties of 160 pupils during the week. ARC also host the bi-monthly meetings of the largest amateur astronomy society in Northern Ireland [S8].

During the Covid-19 lockdown in Spring 2020, ARC staff hosted an online learning platform for teachers and parents called 'SmarttScience', providing space science resources and a series of 6 linked lessons aimed at students 8 - 12 years old with associated teaching material (<https://www.smarttscience.com/>). One teacher reported *"This was a really fun lesson that the pupils very much enjoyed. The material aligns with the Key Stage 2 curriculum and the topic of 'Our place in the universe', which is very helpful."* [S9]. An online 'Experience Physics from Home' event organised by CPP staff was attended by 140 16-17 year-olds, with feedback including *"Before school and work experience were cancelled, I struggled to find any work experience opportunities pertaining to aspiring physics students. So, this opportunity coming up is like a God send."* [S10].

5. Sources to corroborate the impact (indicative maximum of 10 references)

[S1] Letter from the National Museums NI Head of Curatorial, Ulster Museum

[S2] Letter from the Festival's Director, Northern Ireland Science Festival

[S3] Lasers Live Survey data

[S4] Planet 4 Citizen Science Feedback

- [S5] Letter from the Series Producer of The Sky at Night, BBC Documentary Evidence
- [S6] NI Physics A-Level/Undergraduate degree statistics.
- [S7] School teacher curriculum support letter
- [S8] Letter from the President of Irish Astronomical Association
- [S9] SmarttScience Feedback
- [S10] Personal Statements from 'Experience Physics from Home' in 2020