# The Light Express Roadshow: a Case Study in a Successful Secondary School's Photonics Outreach Activity

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## ABSTRACT

The schools outreach programme of the School of Physics and Astronomy at the University of Southampton has reached over six thousand school children during the last five years. The outreach programme centres on a traveling 'Light Express Roadshow'; a laser light show and photonics lecture provided free to schools throughout the South East of England. This paper explores the technical and educational issues associated with providing a successful outreach activity to inspire and encourage a new generation of physicists.

**Keywords:** photonics education, University of Southampton, School of Physics and Astronomy, schools outreach

## 1. INTRODUCTION

This paper discusses the benefits and challenges associated with using a professional laser light show to promote physics and photonics to school children. It is argued that the benefits of providing a traveling Photonics Roadshow free to schools in the South East region – as part of on ongoing outreach programme by the School of Physics and Astronomy at the University of Southampton – outweigh the challenges associated with this innovative project. Lastly the strengths and weaknesses of the project are evaluated from all the different perspectives of those participating.

## 2. BACKGROUND AND PROGRAMME

The United Kingdom has suffered recently from a sharp decline in the number of students choosing to study physics at university. This decline is potentially disastrous for the country as it will affect the UK's long-term ability to be among the world leaders in applied technology. In an interview with BBC News reporters[1], Lord May, president of the Royal Society, said:

> "We are still facing a crisis in physics, maths and chemistry... Entries in physics have decreased by 35.2% since 1991, while those in maths and chemistry had fallen by 21.5% and 12.6%."

The School of Physics and Astronomy at the University of Southampton (one of the top three physics departments in the United Kingdom according to the on-line Guardian Unlimited Newspaper on-line[2]) is trying to increase the numbers of students studying physics with a comprehensive marketing strategy which now includes the use of a traveling laser light show with a spectacular photonics lecture.

The Light Express Roadshow was set up in 2000 with the intention of raising awareness of the emerging photonics industry. The University of Southampton conducts a huge amount of leading-edge research in this field and has established several high-profile spin-out companies as a result. The University of Southampton's research into optical fibres from the mid-1960's onwards has been key to the emergence of modern communications technology, and the University's Optoelectronics Research Centre is still a world-leader in this field.

The Light Express Roadshow aims to explain to students how photonics is used in telecommunications to provide the underlying technology of the internet. The show includes a lecture which is informal, informative

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and fun to watch. The lecture uses spectacular demonstrations and utilizes lasers and optics which schools and colleges would otherwise not have access to.

The Light Express Roadshow lecture has a two-tiered presentation and is based on the UK's National Curriculum for Physics at either the General Certificate of Secondary Education (GCSE) level or Advanced (A-) level. British students normally take GCSE exams when they are 16 years old and students wishing to go to university – or obtain better paid jobs – continue their education and take A-level exams. The Light Express Roadshow not only aims to inspire students' interest in science and photonics, but also to raise awareness of available careers in science and to promote the University of Southampton itself. Schools which do not have a strong tradition of students pursuing science, or applying to the University have been specifically targeted for performances.

Almost 100 Light Express presentations have been given over the last five years. These presentations have included schools visits, Light Express days at the University, a trip to the prestigious Royal Albert Hall in London for the British Association Science Day in 2001, and a performance in a church and laser light show against the medieval monument in Southampton's city centre. Approximately six thousand members of the public, teachers and school children have seen the Light Express Roadshow perform. All shows are provided free to the audience and venue.

## 3. TECHNICAL EQUIPMENT AND DEMONSTRATIONS

The Light Express Roadshow relies on a one watt mixed argon/krypton ion gas laser, an eight channel polychromatic acousto-optic modulator, Cambridge 6800 HP scanning mirrors and Pangolin laser lightshow software The school or college hall serving as the Light Express venue is hazed – or fogged – to make the laser beams visible. Overhead beam shows are used – similar to those in nightclubs – to catch the audiences' attention, and a popular soundtrack is played along with the laser show. This is usually the first time that a GCSE audience has seen a laser light show and as a result there is often a sense of great excitement in the darkened hall. It is quite common for the GCSE students to sing along to the soundtrack during the laser show.

During the photonics lecture accompanying the beam show the optics in the laser light show system are set using adjustable mirrors for several different demonstrations. These demonstrations are designed to illustrate the main differences between lasers and other light sources. The demonstrations concentrate on the directionality, spectral purity and coherence of laser light and relate to the uses of lasers and fibre optics in the telecommunications industry.

Total Internal Reflection (TIR) is demonstrated using a large water tank of approximately one metre in length and the laser. A full watt of laser power travels upwards through the tank and reflects down off the surface of the water. The beam path is adjusted using a large front surface mirror to show refraction, partial reflection, and then total internal reflection of the laser beam in the water. A PowerPoint slide which illustrates the angle at which water can no longer escape the tank of water and is reflected back downwards by the surface of the water, accompanies the demonstration.

Lord Tyndall's (or Colladon's) experiment – demonstrated in 1870 to the Royal Society – is used to show students how light can be guided around a corner. The experiment shows the laser beam reflecting inside a path of water flowing from a jar with a small nozzle at its base. This demonstration relates to fibre optics and how light can be guided around a bend in the fibre due to total internal reflection.

Strips of diffraction grating are supplied to the audience to view the differences between the continuous spectrum smear observed from the white light emitted by a candle in comparison to the discrete seven wavelengths from the Argon/Krypton laser. The effects of diffraction and interference are also explained. Sometimes the audience is encouraged to make their own 'diffraction grating' with a strand of their own hair.

The laser beam is then expanded with a lens to allow the audience to observe laser speckle. This demonstration illustrates coherence. The audience is invited to 'test their own eyesight' – by observing the movement of the speckle pattern as they move their heads – to determine whether they are near- or far-sighted.

Finally, the laser beam is launched into an optical fibre that has been hung up around the school hall – causing the whole fibre to glow spectacularly. Students observe the pattern of coloured laser light emerging from the end of the fibre and watch how the light can be attenuated by bending the fibre optic.

The A-level version of the show also demonstrates a Michelson interferometer and Young's double slits experiment. The interferometer is used to demonstrate coherence and how changes in laser beam path lengths between the two arms of the split beam can be detected with great accuracy. Young's double slits experiment is covered in the A-level syllabus and acts as a review for students. Both of these demonstrations are filmed with a video camera and the image displayed above the laser system.

At the end of the show students are encouraged to approach the stage – where the equipment is set up – to have a closer look at the fibre, the laser and the optics used. The post-graduate students demonstrate how the laser beam is reflected around the breadboard and optics and draw students' attention to the fibre launch stage and the fibre optic itself. The laser power is turned down to a relatively safe power of less than 5 mW for this.

### 3.1. Staffing the Light Express Roadshow

The Roadshow relies on post-graduate student helpers, physics lecturers at the University of Southampton, and a Light Express coordinator. The Light Express Roadshow is run by a small team of post graduate student demonstrators who set-up and operate the laser for the shows and carry out 'behind the scenes' maintenance of the equipment. The PhD students also design show content, programme the laser shows, design fliers and update the website content. The Physics lecture element of the Roadshow is often delivered by a lecturer from the School of Physics and Astronomy.

The Light Express Roadshow is run by a coordinator who organizes the school visits. The coordinator works for the Light Express Roadshow on a part-time basis for the duration of the School year – approximately nine months of the year, acting as the main point of contact between the school or college venues and the School of Physics and Astronomy with regard to show bookings. The coordinator is also responsible for the maintenance of the Light Express website[3], the production of advertising material and programmes for the audience and most importantly, the safety of the audience and demonstrators during the school visit.

The coordinator visits school or college venues prior to the Roadshow performance to check the suitability of the venue. The coordinator verifies that the School or College hall ceiling is high enough to ensure that the laser beams will travel high over the students' heads in accordance with Health and safety legal requirements.[4] The coordinator also ensures that venue staff know to turn off any smoke detectors for the performance. Other aspects of a pre-performance school or college visit include checking that there will be parking available close to the performance area, and determining how to ensure the safe handling and installation of the heavy equipment used with the Light Express Roadshow. It is the coordinator's task to provide a written safety risk assessment for each performance.

Another reason for visiting venues before a performance is to ensure that the school or college has a suitable power supply. The Light Express Roadshow laser uses a 32A single phase power supply. This particular laser was purchased because many school and college halls or theatres have stage lighting which use the same power supply. Many Physics teachers are unfamiliar with their school's or college's hall or theatre equipment so it is vital for a visit to ascertain whether the venue has the power supply required.

## 4. BENEFITS TO TEACHERS AND YOUNG STUDENTS

> "We will welcome you any time at Cantell, so please contact me if you have any more exciting projects." Mrs. Sally Rowe, Cantell, Maths and Computing College.

The above quotation from a letter thanking the Light Express team is typical of the responses of teachers to the Roadshow. The Light Express currently has a long waiting list of schools wanting visits. Over 100 schools have contacted the University of Southampton requesting visits by the Roadshow and every school visited has requested a return visit.

There are numerous benefits for the schools who request a performance from the Light Express Roadshow. The Roadshow lecture and demonstrations are designed to cover National Curriculum physics topics such as; characteristics of waves, the electromagnetic spectrum and telecommunications technology, using equipment that the school teacher will not otherwise have access to. The Light Express Roadshow demonstrations and lecture supports the teacher's curriculum and is therefore a valuable teaching tool.

The Roadshow lecture concentrates on the following areas that teachers have to cover in their Science curriculum: Characteristics of waves: reflection, refraction and diffraction of waves, including light and sound as examples of transverse and longitudinal waves. The meaning of frequency, wavelength and amplitude of a wave is also covered with the quantitative relationship between the speed, frequency and wavelength of a wave that waves transfer energy without transferring matter. The lecture covers the contents of the electromagnetic spectrum. Also included are some ways in which microwaves, infrared and ultraviolet waves are used and the potential dangers of these. Telecommunications topics need to be covered including; how information can be transmitted along optical fibres and that radio waves, microwaves, infrared and visible light carry information over large and small distances. The Light Express Roadshow lecture also informs students about global transmission via satellites, and about ways in which reflection, refraction and diffraction affect communication.

The performance-like atmosphere is another benefit to teachers and their students. Students always appreciate variety in their learning. The Light Express requires a darkened and fogged room – which causes great excitement – a real change to a students' normal classroom environment. The Light Express is designed to appeal visually and auditorily to hold the attention of students with different learning styles. The students are always impressed by the performance – with the overhead laser shows, the engaging science and the power of the laser we demonstrate.

Below is a write-up from Daniel Jenkins, a Year 9 pupil at Bishop Luffa School in Chichester, reflecting on the experience of seeing a Light Express Roadshow performance at his school for his school magazine.

> "No sooner had I got over the excitement of being given a *free* holographic pencil, I was plunged into an exciting display of strobing images projected by lasers. With the 'Mission Impossible' music... they certainly made a good first impression, the entire hall – transfixed... Now they had us right where they wanted us. An excellent presentation demonstrating practical uses of Lasers... [we were] totally in awe of the Photonics department at Southampton University and keen to learn more."

The Light Express Roadshow also introduces teachers and students to 'cutting edge' research topics and researchers in physics and photonics, providing them with a valuable resource.

### 4.1. Challenging Stereotypes and Providing Role Models

In the BBC News article entitled 'Media studies overtakes Physics', quoted above Lord May – president of the Royal Society explained: 'More than three quarters of this year's A-level physics candidates were male.'

The Light Express Roadshow aims to challenge and address a number of stereotypes about physics and physicists, which are partly responsible for the low numbers of female and minority students considering physics as a subject for study or career path to follow. The Light Express Roadshow involves female physics students to undermine the stereotype that only boys study physics. Female researchers are particularly encouraged to take part in helping on the Light Express Roadshow to act as role models for the younger students.

There is also a general view amongst the public that physicists are white-haired and lack social skills or are 'geeky' or 'nerdy'. As a consequence the show is made as entertaining as possible. It is hoped that by using popular music, fog and blow torches (to light candles) in the Light Express Roadshow – and involving post graduate students – the school pupils will see that research scientists can be young and dynamic.

When students have a clear understanding of what they can do with their knowledge in the future their motivation to work hard in their studies increases. There is a general lack of understanding among young students about the many career opportunities open them if they study physics. The Light Express Roadshow lecture attempts to raise awareness of the wide range of careers available to physics graduates. The Roadshow also emphasizes how familiar technologies such as mobile phones, cable TV, CD and DVD players and the internet rely on physics research.

## 5. BENEFITS TO THE UNIVERSITY

The University of Southampton benefits from running the Light Express Roadshow in a number of ways. Firstly, the Roadshow raises the profile of the University locally, nationally and internationally. Locally – through the schools visited with the local publicity the performances generate. Nationally – via our Schools Outreach Magazine, which reports on Light Express activities and is sent to 2,000 schools and colleges throughout the UK and internationally through papers such as this and our supporting website. It can be argued that this positive publicity works in a number of different ways to attract students – both to Physics and to the University of Southampton as a whole.

The Light Express performance helps to foster on-going relationships between school and college teachers and members of staff at the University. Having members of University academic staff visit local schools also keeps staff in contact with school populations – reminding them where their students come from.

Improvements in our Marketing and Recruitment programme as a whole have led to an almost doubling of applicants between 2004 and 2005.

Secondly the University's students benefit from taking part in the Roadshow, learning a number of transferable job skills during their involvement. Student demonstrators take part in explaining the physics behind the laser demonstrations during and after the lecture. A smooth dialogue transfer between speaker and demonstrator is needed and the explanation must be given clearly and pitched at the right level for the audience. This lecturing practice develops valuable communications skills.

Team work skills are vital for the success of a Light Express show and the safety everyone involved. Light Express setups are always pressurised due to time constraints. Each team member must constantly be alert and acutely aware of what the other team members are doing, particularly during set up when the laser light show and demonstrations are being aligned. The team members need to give each other safety instructions and to help each other carry and install the equipment together.

The team working, problem solving and communication skills learned and developed in the Light Express Roadshow are all transferable with regard to a demonstrator's future career. The Light Express Roadshow gives postgraduate students valuable experiences especially if the demonstrator is interested in becoming a science educator. The Roadshow also gives post-graduate demonstrators experience of working in a school environment. The post-graduate students gain familiarity with the security precautions and general procedures involved with visiting schools and working with young students. The demonstrators are also introduced to a number of different independent and government maintained school environments.

The postgraduate Light Express Roadshow demonstrators prove themselves to be outstanding workers – they need to be reliable in terms of their time management (often needing to work very early and late hours). The demonstrators are often required to solve technical problems which test their technical and logistical problem solving skills to the limit. It is not unusual for host schools and colleges to recognize the exceptional qualities of the demonstrators and to show interest in offering team members a job. There is a national shortage of Physics teachers in the UK, most Physics teachers do not have a Physics degree – or even Physics A-Level. The Roadshow team demonstrates ability to communicate to young students and an enthusiasm for their subject which the schools and colleges value highly.

### 5.1. Postgraduate Students

Working with the Light Express Roadshow is also beneficial to the postgraduate student demonstrators. The most obvious and immediate being that demonstrators are paid well for the hours they work during Light Express shows which provides a welcome source of extra income.

Working with the Roadshow fosters a sense of improved self-esteem and enthusiasm for their subject. Dr. James Gates – a former Light Express Roadshow postgraduate helper said:

> "Light Express gives me the opportunity to use a large laser just for 'fun' rather than for research purposes. The equipment was initially built by a number of postgraduate students in their spare time. Much of the equipment was donated from the physics department research groups."

The more Light Express setups and shows a demonstrator takes part in, the more experienced he/she becomes with handling the equipment and dealing with the problems that inevitably occur.

> "Even with almost 100 shows under our belts problems can still occur; in the past we have managed to evacuate a whole school, trip a school building's mains power and blow several fuses. Despite these minor set backs the show has always been a success."

The combination of excellent team working, communication and trained troubleshooting skills means that not a single Light Express Roadshow has ever had to be cancelled due to technical problems. This is a record that the Light Express Roadshow team is very proud of and one which they hope to maintain for the future.

## 6. CHALLENGES

### 6.1. Safety

Light Express uses a Class IV laser, so ensuring the safety of the team and the audience is of paramount importance. Every effort is taken to ensure that the Roadshow meets or exceeds the safety standards described in 'The Radiation Safety of Lasers used for Display Purposes, HS (G) 95.'4

Approximately three hours are required to set up the equipment in school halls before the show to ensure that the audience is safe and that legal safety requirements are adhered to. A thorough Risk Assessment is provided for each show. A Risk Assessment – required by schools and the University administration – includes the formal documentation of all the potentially dangerous elements of an activity and illustrates how these factors are going to be mitigated. Post-graduate helpers and participating academic staff members have all been laser safety trained in the School of Physics and Astronomy's laser safety programme. The Light Express coordinator was trained in the Fundamentals of Laser Safety, by the Laser Institute of America.

The risk factors associated with operating and watching the Light Express Roadshow include: laser hazards to eyes, electrical hazards, mechanical hazards – tripping/falling and manual handling hazards, driving hazards and hazards to equipment. It is generally thought to be the student demonstrators who are most at risk during the set up of the show.

The demonstrations are designed so that it is not possible for an equipment failure to expose any person to the laser beam, either directly or via a specular reflection during the show. The laser projector is enclosed by black screens, which block stray beams. Members of the public are excluded from the hazardous area between the projector and the projection surface, by hazard tape and laser warning signs. In the event of a scanning mirror failure, the aperture set by the screens around the projector blocks the laser beam before it can drop below the minimum legal height above the audience. The show does not involve scanning the audience.

A beam dump blocks the laser beam between demonstrations; while the beam is blocked, pre-aligned, hinged mirrors are flipped up and down to select different paths. All stray beams are terminated in beam dumps.

At each venue, the setting up procedure involves meticulous scrutiny of the projection surfaces for specular objects, such as light fittings and gantries, switches and internal windows. The laser projection area can be selected using the light show software to avoid the above hazards. However if this is not possible, it is necessary to either cover the hazard or modify the projection zone.

A shutter in the projector head controlled by the computer keyboard 'Esc' key can block the external beam within a few milliseconds. Whenever the shutter is open, a member of the Light Express team is stationed by the computer, able to switch the beam off instantly in the event of a problem. Another team member is responsible for monitoring the safety of the audience and hitting an interlock stop button during the performance to block the beam if required.

Setting up the laser to ensure that the audience members are safe is slightly more hazardous for the demonstrators as they work to prepare the school hall for the performance. A detailed standard operating procedure has been written to ensure that the demonstrators avoid all hazards, including eye hazards. The beam power during alignment procedures is kept at a minimum and index cards used to ensure that the beam is traced along its intended path and controlled at all times. The Light Express coordinator has purchased laser safety glasses

to attenuate the Argon/Krypton laser beam which was controversial as the glasses were approved by USA safety standards, but did not have any British Safety Organization approval. However, safety glasses are worn by the coordinator and demonstrators to be used to safeguard their eyes – as a last resort – during alignment.

The electrical hazards inherent in the Light Express system are mainly due to the laser power supply. The laser draws about 30A of current and has high voltages on the tube in the laser head; The Light Express team can face problems with the host school/college electrical system.

Some of the equipment used in the Roadshow is heavy and awkward. The laser is estimated at a weight of approximately 75 kg and therefore requires three people to lift it safely. The laser is usually placed on tables on stage at performance venues. The design of school and college halls often requires the lifting of the equipment up steps and onto stages. The chiller for the laser is also heavy and awkward to hold and requires two people to lift it. The equipment also needs to be pushed up and down ramps – on and off the van – carefully to prevent injury. Sack trucks, and carts have been purchased to ensure that the least amount of lifting is done to move the equipment. The Light Express coordinator and all of the student demonstrators have received manual handling training to ensure that they know how to handle heavy equipment with a minimal risk of injury to themselves or others.

Moving around an unfamiliar venue in low light conditions under the stress of a performance involves a significant risk of tripping, especially over cables. Taping down any cables which might prove hazardous is therefore a key item on the standard operating procedure.

The laser is robust, designed for turnkey operation on and off with no special precautions to protect the tube. The scanning mirrors are extremely delicate, and are only handled or adjusted by qualified personnel. Everyone involved with the show should be aware that the University insurance schedule specifically excludes leaving the equipment overnight in the van, unless the van is in a locked garage or compound. The equipment is frequently subject to knocks and jolts so regular safety testing – approximately once every three months – is undertaken by the School of Physics and Astronomy's safety technicians. The equipment requires constant maintenance and repair.

### 6.2. Equipment Maintenance and Updating

At the heart of the Light Express is the 1W Argon-Krypton mixed gas laser, this was bought second-hand in 2000 – as an already ageing piece of apparatus – to run the laser shows and demonstrations. Over the last five years, wear and tear from regular use at schools and open days has begun to show in the increasing amount of maintenance time required to keep the laser working optimally. The main concern is the falling output power and the weakness of some of the colours (the blues and purples in particular). A large amount of time is spent adjusting the laser cavity, acousto-optic modulator, drivers and software to keep the laser shows at maximum brightness whilst maintaining the correct colours and colours balance.

The Light Express Roadshow team is currently looking to replace the gas laser with a diode pumped solid state (DPSS) red, green and blue system. This system has many advantages over gas lasers which would bring a tremendous benefit to both the Light Express Roadshow team and host venues. The key advantages would be the reduction in show setup time, much more relaxed power requirements and reduced maintenance.

As a DPSS system is essentially a light-weight, desktop system, the large amount of equipment currently supporting the gas laser could be removed. The decrease in the amount of equipment could relate to two large trolley loads of equipment. One large trolley is currently necessary to support the laser water cooling system and pipes alone. DPSS systems are air-cooled using fans; and a second trolley for the laser power supply and transformer would also be removed – as a DPSS system requires only a 13 amp plug socket.

Less equipment means less time needed to setup a show and the hire of a smaller van. Less equipment to transport would ease the pressure on schools and colleges to keep their main hall free for the entire day while the equipment is set up and taken down. It is estimated that with the reduced equipment and maintenance needed for each show, setup time could be reduced by over an hour and the take-down reduced to just an hour. For schools that use their main halls for assemblies, lunches and after school activities, this is very important. For the School of Physics and Astronomy the decreased time spent in schools relates to either less costs in demonstrators' wages – or an increase in the number of schools targeted.

Reducing the power requirements from a single phase 32A supply to a normal wall plug socket is advantageous both in terms of safety and school power resources. With a DPSS system there is no longer the risk of dealing with incompatible power supplies or fusing the school power switchboard when turning on the laser. The majority of pre-visits to schools to check for suitable power supplies would no longer be necessary.

### 6.3. Funding

The Light Express Roadshow was initially funded with a grant from the South East England Opto-electronics Skills (SEOS) Delivery Plan Project grant to raise awareness of the Photonics industry. The SEOS project was itself funded in turn by the Government's South East England Development Agency (SEEDA) The SEOS Project grant purchased a one-watt Argon Krypton laser and professional laser light show software. Much of the supporting equipment for the show was 'cobbled together' by postgraduate students with a passion for communicating their research work.

To help combat the low aspirations of students in the South East Region the Government funded the University of Southampton's 'Widening Participation: AimHigher' scheme. AimHigher encompasses a wide range of activities to engage and motivate students and young people aged 13-30 from all backgrounds, who have the potential to enter higher education but are under-achieving, undecided or lacking in confidence. The programme particularly focuses on young people from disadvantaged social and economic backgrounds, ethnic minority communities and the disabled. The University of Southampton awarded its School of Physics and Astronomy an 'Action on Access' grant to reach out to inner-city, middle school pupils from disadvantaged backgrounds as part of a Widening Participation: Aim Higher initiative.

The objective for the year-long project – to give 20 performances in local schools – was met and the Roadshow was deemed a great success. To further build on that success, the School of Physics and Astronomy chose to fund the Roadshow for marketing and recruitment purposes. The School of Physics and Astronomy pays for a part-time Light Express Co-coordinator who also works doing schools outreach work for the School of Engineering Sciences at the University.

The Roadshow has also received financial support from other University Schools – the Optoelectronics Research Centre (ORC) and the School of Electronics and Computer Science (ECS), the Institute of Physics (IoP) and the Particle Physics and Astronomy Research Council (PPARC).

However, it is difficult to evaluate the success of the project now that it has been funded as a marketing and recruitment tool. There is currently very little quantitative data available to suggest that the Light Express Roadshow can specifically raise the number of students who choose to study physics at the University of Southampton in particular. The students targeted by the Light Express Roadshow have been aged 15-16 years, so it will take at least three to four years to assess the impact of the project. Although the Light Express Roadshow is a unique outreach activity valued by secondary schools, it is more difficult to evaluate its success under these new funding conditions.

### 6.4. Pressure

Two Light Express shows, at a school over an hour's drive away from the University, can result in a 15 hour work day. The Light Express Roadshow takes approximately three hours to set up at a school or college. Despite many improvements to the laser equipment and optics over the years, there are always a host of small problems to solve, usually with regard to optical alignment of the laser beam or because of missing or broken equipment. However, there is invariably one technical problem that takes time and lateral thinking by all the team members to solve. These problems may be either mechanical, optical, electrical, thermal, software or logistical – and need to be solved within a limited amount of time. Problems have included power supply outlets not working, or earth leak trip switches tripping due to the large current required to charge the laser transformer capacitors, laser overheating, no staging on arrival, insufficient time for set up due to school organization, difficult venues – making maneuvering heavy equipment difficult and finally, school fire alarms being set off. Almost all parts of the Light Express Roadshow equipment have broken down in some way, from the audio and amplifier system to the laser refusing to work. In the past the laser cavity has had to be adjusted just before a show, and demonstrations re-aligned 'on the fly'. The above problems can be highly stressful for the coordinator and demonstrators causing great anxiety. The audience applause at the end of the show provides a welcome relief indicating another successful performance.

## 7. EVALUATING THE SUCCESS OF THE LIGHT EXPRESS ROADSHOW

The Light Express Roadshow is popular, flexible, and long-lasting. The Roadshow is a unique tool for both schools outreach work to promote science – in particular physics and photonics – and acts as a superb marketing and recruitment vehicle for the School of Physics and Astronomy. The Roadshow performs to visiting students in-house on University Open days and during the University of Southampton's National Science Week's 'Family Day'. The Roadshow works to combat the negative stereotyping of science and scientists, while raising awareness of current research and technology.

Going forwards there are a number of opportunities arising from developing the Light Express Roadshow. The School of Physics and Astronomy offers post-performance visits to the University where schools and colleges are invited to take part in hands-on activities that demonstrate different optics principles. These activities include 'lasers and jelly' demonstrations which show reflection, refraction, total internal reflection and interference by varying the angle and direction at which a low power laser beam is shone at blocks of jelly. There are also demonstrations to show polarization and liquid crystal technology. The University now offers holography workshops for students. The scope of the Roadshow has recently been enlarged creating the 'Light Fantastic' – a Roadshow based on particle physics.

Weaknesses in the Light Express Roadshow project include the uncertainty of continued funding. The Light Express Roadshow is currently funded by School of Physics and Astronomy under the auspices of Marketing and Recruitment. However, this is a long-term project; most of the students that we target are 'GCSE' students, aged 15-16 years. This means that we will not be able to ascertain whether they have seen the Light Express show – and whether it inspired them to study physics – until they reach University in three years time. As a result there is currently very little numerical data to support our work.

Cost of new equipment; An ailing laser – with the falling of numbers of students studying physics comes the lowering of funding to Physics departments across the country. The University of Southampton's School of Physics and Astronomy is no different. Although the price of DPSS systems are now relatively cheap – it is estimated that to replace the ailing Light Express Roadshow laser with a DPSS system of equal brightness, we would need a power of just 200 mW for each diode. As the cost of the blue diodes continues to fall, it is becoming an increasingly attractive option to sell on our gas laser and purchase a diode system for better and brighter Light Express.

The threat of discontinuing the Roadshow would be a threat to the study of science in general. The reduction in the number of schools outreach projects aimed at young students may lead to a failure to feed the pipeline to Universities and in turn, industry. It is essential to encourage minorities and women into Physics to increase the shrinking pool of students choosing to study physics. This has a long-term threat to the UK's ability to continue world leading technologies

The Light Express Roadshow is sheer hard work. Despite the hours demonstrators are paid for the shows, they are not paid for the many hours that are spent maintaining, tweaking, adjusting and fixing the equipment. Almost an equal amount of time can be spent repairing the equipment as it can be performing the shows. The busier periods of the Light Express Roadshow can involve several shows in a single week. This puts an enormous strain on a demonstrator with regards to the time he/she should be spending doing their own PhD research work and the time needed for the Light Express Roadshow. It is not unusual for supervisors to complain that their students are spending too much time involved in pursuits other than research.

## 8. CONCLUSION

The above paper argues that while it is difficult to prove that the Light Express Roadshow is a successful marketing and recruitment tool for the University – in terms of student numbers – the project's strengths and benefits as a physics and photonics outreach activity outweigh any of its weaknesses. While the benefits of the Light Express Roadshow are almost intangible quantitatively they are strongly felt by both audience and participants. It is hoped that the inspiring nature of the Roadshow – both for audience and participants – has a long-lasting and positive impact, ensuring a healthy future for physics and photonics in the UK.

"Ultimately when the lights go out, the music starts and the laser show begins, you see the children fall silent in awe, then cheer and applaud, the sense of achievement and satisfaction can be overwhelming." Sunil Patel, Light Express Roadshow demonstrator.

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