Getting Light to Work – photonics up-skilling for industry

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ABSTRACT

This paper provides an overview of an innovative approach to delivering photonics up-skilling for industry. The strong emphasis of the approach is on hands-on creativity whereby participants in the up-skilling process demonstrate novel applications of principles of photonics.

Keywords: Photonics, Up-skilling, Industry, Education, Training

1. INTRODUCTION

The work described within this paper has been undertaken within the Photonics Academy of Wales @ Bangor (PAWB). It is noted that the acronym PAWB is the Welsh-language word for 'everybody'. This accurately characterises the approach undertaken within PAWB to bring awareness and knowledge of photonics to the widest possible constituency. PAWB is a particular manifestation of the Photonics Academy for Wales which has undertaken several projects directed at enhancing the profile of photonics amongst students of all ages. An exemplar of such activity is the ' Magical Home' project (**M**aking **A** **G**lowing **I**mage **C**entred **A**round **L**ight) which engages primary school students in the design of futuristic homes which make the maximum design use of the capabilities of photo-voltaics. That project highlights an emphasis given within PAWB to imagination and creativity. Another central characteristic of PAWB activities is hands-on experiential learning. Such activity is illustrated in the Photonics Academy Summer School (PASS) at which high-school students are challenged to develop a novel photonic device of societal benefit. Participants in PASS are introduced to several characteristic features of light, and then are asked to devise, design and build a photonic device which exploits one of more of these defined properties of light.

The aim of the work described in the present paper is to extend the scope of such activities to meeting the needs of the photonics industry. In order to enthuse both experienced and novice employees, use is made of an innovative approach to delivering photonics up-skilling for industry. Strongly aligned with the PAWB philosophy, the clear emphasis of the approach is on hands-on creativity whereby participants in the up-skilling process demonstrate novel applications of principles of photonics.

The approach has been pioneered within the Photonics Academy of Wales @ Bangor (PAWB) and has benefited from support within two projects : UPSKILL - User-driven Photonics Skills Improvement via Life-long Learning (UPSKILL) and OPUS : Optics and Photonics Up-Skilling for industry. UPSKILL was completed in July 2012, whilst OPUS is in progress and will continue until June 2015. UPSKILL was part of a wider project concerned with on enhancing opportunities in Science, Technology, Engineering and Mathematics (STEM). The HE-STEM project was funded by the Higher Education Funding Councils of England and Wales – HEFCE and HEFCW respectively. OPUS is funded under a Work-Based Learning programme supported by the European Social Fund and the Welsh Government.

The paper describes exemplars of activity undertaken within both UPSKILL and OPUS and will specifically demonstrate means for enthusing participants to develop novel applications of photonics. Such creativity is underpinned by participants gaining familiarity with the fundamentals of photonics. The PAWB approach has been used successfully

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with a wide range of participants : from primary school students through to post-doctoral workers and experienced industrial engineers.

The paper details outcomes of the completed UPSKILL project and describes the work currently underway within OPUS. Within OPUS detailed work has been undertaken on novel course content which has been designed to meet requirements in industry. The OPUS aim may be summarised as 'Getting Light tO Work ' - GLOW.

The next section details the aims and outcomes of the completed UPSKILL project. Section 3 outlines plans for activity within OPUS and also exemplifies progress to date.

2. USER-DRIVEN PHOTONICS SKILLS IMPROVEMENT VIA LIFE-LONG LEARNING (UPSKILL)

2.1 Aims and Objectives

The principal aims of UPSKILL were to:

1) Define, in partnership with the Welsh Optoelectronics Forum , the SEMTA UK Sector Skills Council and the Photonics Academy for Wales, the Photonics skills training requirements of identified SMEs and micro-enterprises
2) Develop exemplar learning techniques and materials to meet these generic requirements.
3) Demonstrate and deliver these learning techniques and materials in the workplace.
4) Provide opportunities to enhance the sense of personal achievement, and significance for each individual within a Company as a direct consequence of their contributions to new design initiatives (which may well lead to highly innovative new applications within Photonics).

All those aims have been substantially achieved and specifically;

1) The complexity of photonics skills training requirements of industry has been established – the project has highlighted many opportunities for further development.
2) A learning technique and relevant learning materials have been successfully road-tested by means of the Photonics Academy Summer School (PASS) at Bangor ; an international summer school (EUSPEN) at Cambridge University and work-experience placements.
3) Participants from industry have engaged constructively with the learning technique and materials.
4) Participants consistently expressed astonishment that the learning technique enabled them to make creative contributions to photonics product design and application.

2.2 Background and Rationale

UPSKILL was conceived as a means for raising skills levels of employees in the Photonics industrial sector. The specific objective of UPSKILL was to provide work-based learning opportunities at Level 4 and above. It was intended to give particular emphasis to SMEs and micro-enterprises, which typically possess insufficient in-house training resources. It was observed that, in the North and West Wales Photonics cluster alone, of the order of 100 employees could benefit from the planned bespoke training. A second thrust of the project was to target people wishing to enter photonics based industries.
A key driver for the project was the complete absence of appropriate learning materials for the target market. Work within the project thus needed to define as precisely as possible the target market; develop appropriate learning materials and then demonstrate the effectiveness of the approach.

2.3 Definition of skills requirements

The first phase of the UPSKILL project was focussed on acquiring market intelligence on skills requirements within the photonics industrial sector. This work was undertaken in partnership with the Welsh Optoelectronics Forum (WOF) and

the Photonics Academy for Wales. Secondly advice was obtained from the relevant skills council SEMTA. Finally information was obtained from a small subset of photonics enterprises of their specific skills training requirements.

A specific part of the data used in this phase is contained in a report prepared for WOF in November 2007 on " Opto-Electronics Knowledge Transfer& Management Study " . One startling feature of the report is its revelation that the companies surveyed did not perceive a requirement for up-skilling their workforce. On the other hand those companies foresaw a need to recruit additional technical staff over the forthcoming 5 year period. The resolution of that paradox would appear to lie firstly with the short time horizon on which companies effected their human resource (HR) planning and secondly the apparent industrial perception that concerns about a lack of skilled workers was primarily a strategic responsibility of government. More positively, the companies involved saw both the FE and HE sectors as helpful partners for engaging with skills, training and product research and development. These observations offer a possible key to unlock apparent resistance by companies to providing up-skilling for their employees.

It may be expected that detailed market requirements will have changed since the above-cited WOF survey was completed . Thankfully there is some evidence that the attitudes of some employers have changed. Reference may be made to the activities – and indeed the very existence - of the north Wales STEM employers forum which seeks to ensure that the educational system is aware of industry requirements. It is pointed out that no like for like comparison is being made here since the membership of the STEM employers forum is not congruent with the set of companies who were surveyed by WOF. Nevertheless it is considered to be a positive development that employers are highlighting STEM requirements. Building on the expectations articulated by employers there has been collaborative HE/FE activity, again under the auspices of the Photonics Academy for Wales, to establish photonics work-based-learning opportunities. The data obtained from this activity was formed a key element of a submission of the project '*Optics and Photonics Up-Skilling for Industry (OPUS)*' for support under a European Structural Funds (ESF)-funded work-based learning project (managed by Glamorgan University). Discusion of that project is provided below.

This phase of activity demonstrated the complexity of the photonics skills requirements of industry.
The main conclusion drawn from this work was that an effective means for encouraging companies to augment the skills of their employees is to provide a hands-on educational and training experience wherein a new application of a basic optics principle is utilised. The carrot for employers would be that such an application would be available to add to the product portfolio of the company.

2.4 Learning Methodology – 'Road Testing'

The second phase of the project was focussed on identifying appropriate learning methodologies appropriate to the target industrial sector. The work of this phase was undertaken almost exclusively by the project officer Ray Davies. He devised all the learning materials and undertook or led all the activities described here.

The approach taken was to conduct training sessions wherein participants are appraised of several properties of light, and are then immediately challenged to use such light properties to meet a real requirement in the work place. The challenge included the need to develop and test a prototype Photonics device which can be utilised in a practical environment. This approach provides education and training which is as far removed as possible from traditional classroom methods, and hence was expected to stimulate the interest and imagination of the participants. This proved to be the case.

Before conducting such trials in a company environment, the opportunity was taken to 'road test' the approach using other target audiences. The additional challenge here was to apply the techniques to audiences with little or no background in Photonics. The target audiences in these cases were (i) postgraduate and post-doctoral researchers from a range of engineering disciplines, and then (ii) high-school and college students. The former audience was accessed via the European Society for Precision Engineering and Nanotechnology (EUSPEN) Team Challenge, held at the Institute for Manufacturing, Cambridge University, in July 2011. This participation followed from an invitation extended by Professor Paul Shore FREng, Cranfield University and was hosted by Professor Bill O'Neill, Cambridge University. The high-school student audience was encountered in the Photonics Academy Summer Schools (PASS) held at Bangor in August 2011 and 2012. An additional opportunity has been accepted for applying the same Photonics techniques in the hosting of work-experience students from Clongowes Wood College, County Kildare, Ireland, for two weeks in November 2011.

2.4.1 EUSPEN Team Challenge

EUSPEN brought together 27 post-graduate or post-doctoral researchers from 9 different EU countries. None of these researchers was specifically engaged with Photonics activity. The attendees were formed into teams of three, with no team having more than one member from any given country. Having introduced the attendees to relevant concepts of Photonics, the teams were challenged to devise and construct a photonics-based device which would enable a blind person safely to negotiate a flight of steps, by acquiring optically sensed information about the Rise, the Tread, or the Pitch of the steps. Prior to the EUSPEN Summer School, the Project Officer had constructed nine quarter scale model steps, formed in Acrylic, on which the completed devices, for use by a blind person, had to be demonstrated. The teams had 3 days in which to develop their team proposals for the required prototype design.

It has to be recorded that the initial reaction of many of the participants to this challenge was "to panic". The challenge took them outside their comfort zones, and they were concerned that they would, perhaps for the first time in their lives, fail to meet such a technical challenge. However, following the PAWB visual demonstrations of several Photonics concepts, the teams began to see, and realize, that they could achieve the aim.

The methodology for this EUSPEN Team Challenge was that all 27 participants were provided with a series of highly visual PAWB Photonics Demonstrations, all of which contained aspects of potential solutions within the innovative devices the Teams were about to create. The quite universal response at this stage of the three days was "How have we reached this stage in our scientific careers, without having seen such amazing Photonics equipment being used for such demonstrations ?" This specific approach seemed to demolish the initial feelings of "panic", and each of the nine Teams then set about their imaginative design work with an inspired enthusiasm, and ever increasing confidence, which was obvious to witness, and which certainly developed, during the ensuing three days.

This EUSPEN Challenge was sponsored by the three Companies of Heidenhain, Hexagon Metrology, and Renishaw UK, with a group of four European Judges assembling on the final Day to hear the Team Presentation, and to witness the demonstrations of the nine uniquely different working Prototype Designs which has been created during the three days.

The major outcome of this activity was the realisation, by the participants, that the learning methodology, which was used throughout the EUSPEN Team Challenge, allowed each participant rapidly to acquire Photonics knowledge, as well a working skills, both of which could be put to good use. Well over half of the participants interestingly reported back that they had acquired as much Photonics knowledge, and practical design know-how, in those three days that they would have anticipated would have taken several months to acquire in their own Universities. It is conjectured that the same realisation will be made by the target industrial participants, when UPSKILL moves into that phase of activity.

2.4.2 PASS

The second field test of the UPSKILL learning methodology was undertaken under the auspices of the Photonics Academy Summer Schools (PASS) l. Here, 20-25 high-school and college students volunteered to spend 4 weeks of their Summer vacation, undertaking a Photonics-based task. In this case the students worked individually, and each was challenged to conceive and build a novel Prototype Design device of societal benefit utilising Photonics principles. It is underscored that for PASS, there was no prescription by the Project Officer of the target device – the eventual prototype design outcomes were very much the product of each of the participant's individual imagination and ingenuity.

It may be mentioned that for PASS. there was a quite diverse age range of participants - the youngest being 15 and the oldest (a mature FE college student) being 28. Although the Summer Schools have been far from gender balanced there were several female participants. The work of the Project Officer was supported each time by three Mentors, one of whom was a female undergraduate student at Bangor University.

A similar initial learning methodology approach, as utilised for the EUSPEN Challenge, was adopted during each specific PASS, in that many Photonics concepts were demonstrated initially, prior to each student deciding on some Photonics concept of particular interest to them, and then investigating that concept in some detail. Instant Tutorials were a frequent occurrence during PASS, each Tutorial serving to extend the Photonics knowledge of the entire group whenever a particular piece of Photonics information became a useful bridge-link to a next step in one, or more, of the students' Prototype Designs.

Perhaps one of the most impressive outcomes from PASS was the shear extent of the width of the applications of the Photonics concepts which were incorporated into the 23 innovative prototype design outcomes. The evidence is clear that the 21st Century Technology of Photonics is both an enabling technology in its own right, and yet it is also enables high school and college students to demonstrate their individual initiative, imagination, ingenuity, as well as their potential to be highly innovative in their thinking.

The 23 PASS Prototype Design achievements each carry an acronym name, with the acronym describing the Photonics purpose, and achievement, of the Prototype Design.

CARLI	**C**omputationally **A**ssisted **R**anging **L**aser **I**nterface
LEVEL	**L**ight and **E**lectrons to **V**ery **E**ffectively **L**evel
CREST	**C**old **R**efrigerator **E**lectronic use for **S**olar **T**echnology
PCW	**P**hoton **C**ontrolled **W**rist
AUDIO	**AU**dio **D**ata **I**mparted **O**ptically
TORNADO	**T**urbine **O**scillations to **R**eveal **N**egotiated **A**ir to **D**ictate to **O**blivious
SPECIAL	**S**peckle **P**erforming **E**lectronic **C**alculations **I**nvolving **A** **L**aser
LAH	**L**aser **A**ctivated **H**arp
SCHEMA	**S**ensory **C**ommunication **H**elper and **E**xtremity **M**ovement **A**ssistant
BAILS	**B**reathing **A**larm **I**ncorporating **L**aser **S**peckle
LASER	**L**aser **A**ssisted **S**teering **E**lectronic **R**obot
LULLS	**L**aser **U**tilizing **L**iquid **L**evel **S**ensor
LOCK	**L**aser **O**perated **C**ombination **K**ey
PAL	**P**olaroid **A**utomated **L**evelling
LAG	Laser Activated Guitar
TEDI	**T**yre **E**lectronic **D**epth **I**ndicator
POSITION	**P**recise **O**ptical **S**ystem **I**n **T**racking the **I**ncident **O**bject's **N**avigation
LABHAT	**L**aser **A**ctivated **B**ook **H**older **A**nd **T**urner
SOLAR	**S**un **O**perated **L**aser **A**ctivated **R**otator

The student Prototype Design achievements, and the individual Presentations given by the students, which were highlighted in the School of Electronic Engineering of Bangor University during the Celebration Day, demonstrated just what is possible with this type of Photonics methodology.

One important feature of PASS was that the practical Laboratory involvements of the students were supported by a series of 56 Laser Photonics Tutorial Sheets, which the students received prior to the actual start of PASS. In addition, an Introductory Day was held in the School of Electronic Engineering, when the students were introduced to the feasibility of using Photonics concepts as the initial starting point for all of the above mentioned STEM related Prototype Designs

Following the PASS project work, a Presentation Day event was held in Bangor University, when all the participants explained to an audience of families, friends and other visitors, the outcome achievements from their Summer vacation PASS activities.

PASS was grateful to the St Asaph-based company Phoenix Optical Technologies for presenting a magnificent trophy which was awarded to the participant adjudged to have executed the best project. All participants received a certificate of their achievement from Bangor University and the Photonics Academy of Wales @ Bangor (PAWB) and a Photonics Academy logoed USB pen drive, provided with support from the Welsh Optoelectronics Forum (WOF), who also funded the refreshments for the participants and visitors. An invited adult audience of about 80 were present to hear the students' Presentations.

The conclusion of PASS reinforced that drawn from the EUSPEN Team Challenge. Given the opportunity to engage in hands-on activity, participants exhibit enthusiasm and imagination greatly in excess of that normally obtained in traditional learning modes. For PASS, an additional benefit was obtained by the Mentors, and notably the Bangor undergraduate student, who is now undertaking a final year project which emerged from ideas she obtained during her personal contributions to PASS.

It is noted that many photographs are available of the activity described above but are not included here due to the relevant costs of production.

3. OPTO-ELECTRONIC UPSKILLING FOR INDUSTRY (OPUS)

3.1 Aims and Objectives

The main aim of OPUS is to initiate the provision of innovatory work-based learning in optics and photonics in order to up-skill the photonics workforce. OPUS will focus on industry-based technicians and managers and will develop teaching materials which will be delivered, as required, at company premises or at the Photonics Academy for Wales @ Bangor (PAWB).

3.2 Context

The context for the Level 4 OPUS is defined by the pioneering activities of the Photonics Academy for Wales in establishing the Level 3 training in photonics under the DCELLS-funded ' Technicians in Optoelectronics Project ' (TOP). TOP delivered the very first Level 3 optoelectronics training within the UK and ipso facto within Wales. TOP thereby defined relevant National Occupation Standards (NOS) in photonics.

The objective of OPUS is to carry forward the innovatory aspects of TOP in order to provide the first Level 4 training in photonics. OPUS aims to set the standard for such training in Wales, across the UK and internationally.

TOP was prepared and delivered by Deeside College on behalf of the Photonics Academy for Wales. The Photonics Academy for Wales includes in its membership representatives of the photonics industry, government agencies and educational institutions. OPUS will be developed utilising educational resources at Bangor University and specifically those within the Photonics Academy of Wales @ Bangor (PAWB) in the School of Electronic Engineering. PAWB has engaged in a broad range of educational outreach and photonics skills training and notably the annual Photonics Academy Summer School (PASS). PAWB is currently delivering the HE-STEM project UPSKILL which is concerned with pedagogical research in methodologies for photonics learning in an industrial context.

Photonics research was a key component of the Bangor University, Electronic Engineering (EE) submission to the 2008 UK Research Assessment Exercise (RAE 2008). That submission achieved a Grade Point Average (GPA) of 2.95 - the second highest RAE 2008 Electronic Engineering GPA in the UK. As a direct consequence of that success, Bangor University has made a major investment in Electronic Engineering including the development of a new theme for research in ' Green' Electronics 6 new academic appointments at lecturer and senior lecturer levels have been made to advance that theme. Several of the new staff members have expertise in photonics technologies. One new appointee has a

particularly strong track record of educational outreach particularly with US-based female students of Puerto Rican extraction.

The combination of technical and educational expertise offered by Bangor creates a potent mixture and the ideal platform from which to launch the leading-edge teaching and learning activities which will be developed by OPUS.

3.3 Programme of Study

The specific work of OPUS will be structured around six initial modules which have been identified following industrial consultation. Modification or amplification of the provision will be effected to meet market demand.

Delivery of the modules will be arranged to optimise uptake by industry. On-site delivery will be effected where possible. Facilities within the School of Electronic Engineering and specifically within PAWB will be used for delivery where specialist laboratory resources are required or when company premises cannot offer suitable learning spaces. Under the HE-STEM UPSKILL project, PAWB is currently organising industrially-targeted photonics workshops. These are seen as one mechanism for expanding the take-up of OPUS modules. The key motif of OPUS provision is accessibility.

The modules, which are defined explicitly below, will be designed to be stand-alone so as to broaden access by allowing participants to freely choose points of entry into the training provided by OPUS. Participants will be enabled to pursue a part, or the whole, of the available teaching, and hence to achieve appropriate credit. Flexibility in delivery will allow as broad as possible spectrum of participants from the industrial sector.

Having established the efficacy of OPUS, effort will be directed at widening the geographical reach of the project. In this case it is anticipated that additional provision will be required to enable satisfaction of a more disparate demand engendered by a wider customer base. Bangor University is presently leading the HE-STEM project ‘CAMPUS’ which aims to delineate the capabilities of all HEIs in Wales for delivering work-based learning in photonics. Work on CAMPUS is described in an accompanying paper.

OPUS offers 6 inter-related modules:-

Principles of Photonics; Photonics Sources of Light; Photonics Instrumentation; Photonics Opto-mechanical Concepts; Photonics Design Opportunities; Photonics Technologies.

Further details of the contents of these modules is available from the authors.

3.4 Early Implementation.

Having received Bangor University validation of these Level 4 Courses, the Photonics Academy of Wales@ Bangor is now seeking opportunities to deploy its expertise via OPUS. The approach will be trialed with a number of groups in educational establishments during the summer of 2013. Thereafter OPUS will seek to meet the demands of the photonics industry in Wales and beyond. OPUS is scheduled to be active through to June 2015.