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The Integrated Knowledge Centre: A Partnership between UK Higher Education and the Engineering Industry

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Abstract: We discuss the creation of an Integrated Knowledge Centre, a unique collaboration betweenacademia and industry, which is delivering to UK industry 'disruptive' technologies based on ultraprecision engineering. The partners include Cranfield University, the University of Cambridge, University College London, and the OpTIC Technium. This paper concentrates on the development of Knowledge Transfer systems and the successful implementation of processes for the delivery of postgraduate taught courses, short courses for industry, and distance learning packages. In order to retain competitive advantage, UK precision engineering industry requires a regular supply of technically proficient and organizationally prepared graduates. This paper explains the approach taken by Cranfield University and its partners to increase the size of the pool of postgraduate precision engineers and to enhance the skills of industrially based engineers. The approach involves the design of a multilevel system, which draws on increased connectivity between the University, UK Engineering companies, and the student. The main vehicle for providing the technical training is the postgraduate Masters degree in "Ultra Precision Technologies". We explain how this course has been designed for broad appeal, whilst incorporating world class technical teaching and an external focus on the needs of participating companies.

Keywords: Knowledge Transfer, Engineering, Postgraduate, UK Higher Education

Introduction

An Integrated Knowledge Centre (IKC) has been created to deliver disruptive technologies based on ultra precision engineering to UK industry. The IKC is a unique collaboration between academia and industry, and is known by the acronym of UPS^2 (Ultra Precision and Structured Surfaces). The UPS^2 partners include Cranfield University, the University of Cambridge, University College London, and the OpTIC Technium. This paper decribes the various outputs of UPS^2 including the Knowledge Transfer activites, particularly the postgraduate Masters degree in "Ultra Precision Technologies".

Context and background

The "Large Optics Manufacturing Study or LOMS" report of October 2003 stated that

"The UK had specific pockets of relevant leading edge manufacturing technology but it was not joined-up in order to offer an internationally credible process chain for large scale ultra precision surfaces".

"LOMS" also clearly stated that

“In the near future there will be a major shortage in the capacity to supply large scale optics, mirrors and windows”

The inevitable conclusion followed, that

“The UK is not a player in this growing market”.

However, despite the pressure from global competition the UK precision engineering industry was continuing to thrive, and was potentially a key enabling force in a range of modern technology rich applications. These included space, aerospace, optics, optoelectronics, machine tools, energy generation (both nuclear fusion and alternative renewable sources), sensors, displays, and medical. In this arena products can range from prosthetic joints through wind turbines to mirror segments for space and ground-based telescopes. The common need for all of these applications is a highly skilled pool of precision engineers.

Patnerships between academic institutions and manufacturing industry have been developed in many fields, including engineering (Kettunen, 2006). The Ultra Precision and Structured Surfaces IKC (UPS^2) was initiated in January 2007 through an EPSRC “pilot” call. IKCs are intended to develop new approaches to support UK industry through a wide range of industry-facing technology transfer and innovation initiatives. The industry sectors planned to benefit from the creation of the IKC represent over £75 billion annual business in the UK and account for a major percentage of UK export trade. A key feature of an IKC is that they focus on wealth creation activities and that they should become self supporting beyond the initial 5 year EPSRC funding period. UPS^2 is located at the OpTIC Technium amongst the companies forming the significant North Wales opto-electronics business cluster. OpTIC is itself a dedicated knowledge transfer and business incubator centre and is therefore an ideal location for establishing an industry-facing knowledge transfer and innovation initiative on behalf of EPSRC.

Success therefore will be gauged by the creation of a self-funding UK Centre of Excellence housed at the Technium OpTIC. It must have world class research facilities with a vibrant research and IP portfolio, supporting the introduction of new UK products. It must operate innovative technology transfer initiatives which support the competitiveness of the UK companies. In international terms the IKC will be recognized as the leading Centre of Excellence for the development of value adding surface technologies, components and high value products. Furthermore, it will support engagement of UK industry into large scale science programmes that demand ultra precision technologies. It is important to emphasise the depth of the interactions between the academic partners and the participating companies. The knowledge transfer activities are of particular interest in the context of this paper, but there are opportunities for a partner to link through facilities, equipment, and R&D as well.

IKC structure and management

The structure of the IKC in Ultra Precision and Structured Surfaces is shown in Figure 1.

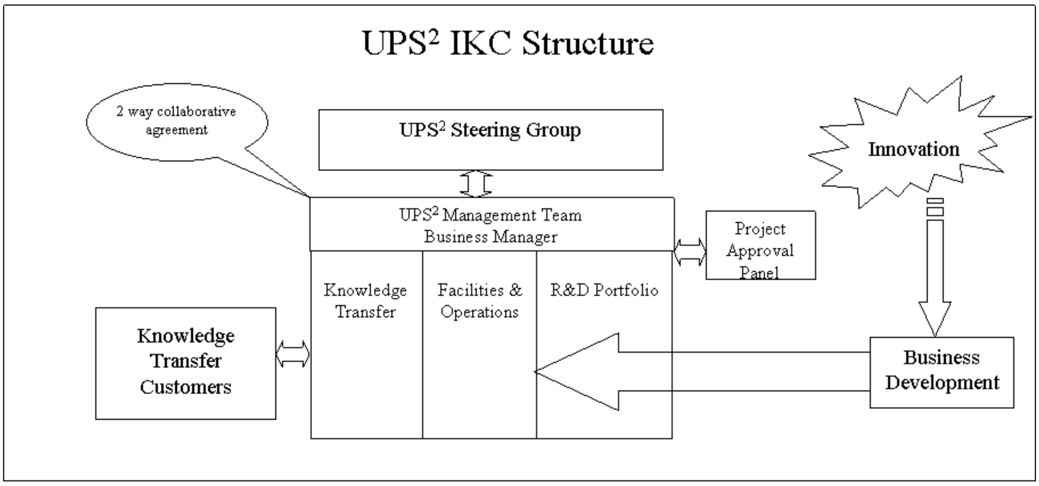

Figure 1. Structure of the UK IKC in Ultra Precision and Structured Surfaces

The Steering Group is the top level guidance body for the IKC. It represents the interests of EPSRC, the Welsh Assembly Government (WAG) and UK industry - providing advice to help the UPS^2 Management team realise its mission. There are presently thirteen members of the Steering Group as shown in Table 1. Industrial members who work at the highest levels within relevant UK companies have been invited to join. These companies operate in market sectors dependent on UPS^2 enabling technologies.

Mr Chris Price	Chairman
Prof Paul Shore	IKC Director
Mr Sean Amos	IKC Business Manager
Mrs Janice Burnie	Welsh Assembly Government
Dr Rebecca Steliaros	EPSRC
Mr Andrew Jones	Cranfield University
Dr David Walker	University College, London
Dr Bill O'Neil	University of Cambridge

Mr Dave Rimmer	Optropreneurs Ltd
Dr Peter MacKay	Gooch and Housego Ltd
Dr Gareth Williams	Airbus Ltd
Mr Dave Price	Qioptiq Ltd
Dr David Purl!	Surrey Satellite Technology Ltd

Table 1: UPS2 IKC Steering Group

The Steering Group normally meets twice per year. Its remit is to review progress of the IKC against objectives and deliverables and then to observe, comment and advise on the direction setting of the UPS^2. The IKC Business Manager reports into the Steering Group with financial support from the IKC Finance Manager, Andrew Jones. The Steering Group will approve and comment on yearly IKC reports provided to EPSRC and WAG. Occasionally Steering Group members may be requested to provide independent advice on proposed large scale activities. Steering Group members are invited to join by the Steering Group Chair.

UPS^2 IKC is led by IKC Business Manager, Sean Amos, who operates a Management Team which includes: the IKC Finance Manager, Andrew Jones; the IKC Knowledge Transfer Manager, Dr Chris Sansom; the IKC investigators and key representatives from OpTIC. Monthly meetings of this team are held by video conference to allow members to attend from any site, ensuring information is shared across the collaborating team.

Day to day activities are now devolved to 3 sub-committees. These individually cover: Knowledge Transfer, Facilities and Operations and the R&D Programme. The sub-committees report into the monthly Management Team meetings.

A comprehensive non disclosure agreement has been agreed and signed off by all UPS^2 partners. A collaboration agreement has been negotiated between the parties, which includes the treatment of IP generated.

Facilties and Operations

The role of the Facilities and Operations (FO) sub-committee within the organisation of UPS^2 was identified in the UPS^2 IKC proposal. Its remit is essentially two-fold. First it is to drive the development of unique facilities and capabilities within UPS^2 both centrally at OpTIC and at the complementary centres of excellence within the partnering universities. These facilities are uniquely equipped to support the growth of the two associated programmes in Knowledge Transfer and Research and Development. The second part of the remit is to foster the creation of new business, utilising and developing new intellectual property. These twin objectives are central to the achievement of UPS^2's longevity; the activity will be self-supporting within the timescale of the funding period both through exploitation of the developed IP and through commercial activities, many of which will be centred upon progressive use of its distinctive technologies and facilities.

Ultra Precision Surfaces Laboratory (OpTIC)

The Ultra Precision Surfaces laboratory (Figure 2) has been substantially augmented. The last calendar year has seen the complete installation of the environmental control system, the installation of a 10 tonne gantry crane and the installation and commissioning of the large optics manufacturing machines: the 2m capacity Cranfield “BoX” (Big Optics) grinder to join the previously-installed large optics Zeeko polisher. The layout of the laboratory was also revised to ensure it represents the leading edge of large optics manufacturing capability.

Figure 2: UPS2 Laboratory at OpTIC

The existing metrology capability has been extended for large optics with the installation of the NPL Swing-arm Profilometer. This means that the UPS^2 IKC now includes facilities permitting the creation and measurement of large (metre-scale) optics of the highest quality using the most economic techniques. Metrology capability will be extended into the nanometric accuracy regime with the establishment of the metrology tower to be sited within the laboratory. The vibration-isolated and highly-damped tower, which supports interferometry and other non-contact static metrology techniques, is at an advanced stage of design. These new comprehensive manufacturing and measurement facilities permit UPS^2 to bid for international scale large optics programmes.

Surface Structuring Laboratory (OpTIC)

Plans have been put in place for the imminent completion of a new Surface Structuring (SS) laboratory adjacent to the existing UPS lab.The purpose of the

SS laboratory will be initially to provide world class diamond machining facilities for structured surface replication master generation in support of advanced UPS^2 IKC projects. To this end, a uniquely capable large capacity drum diamond turning machine has being procured.

This facility, which was a central commitment in the IKC proposal, will allow UPS^2 to serve the burgeoning optical films sector, which is central to 10's of billions of dollars of business worldwide in displays, lighting, renewable energy and security markets. Manufacturing supply to this sector is underrepresented in the UK; the establishment of the SS lab will allow UPS^2 IKC to deploy its extensive existing and developing expertise in this area to address this imbalance.

Loxham Precision Engineering Laboratory (Cranfield)

The new Loxham Precision Engineering Laboratory has been established at Cranfield through University funds. The Laboratory (see Figure 3) which opened officially in December 2007, consolidated much of Cranfield's precision engineering activity into one purpose-built area and with the University's existing Ultra Precision Machining Laboratory, and cemented Cranfield's UK pre-eminence in the field, operating at world class.

Figure 3 : Loxham Precision Engineering Laboratory at Cranfield

The facilities of the new laboratory, which has a precision controlled environment, distributed chilled water and air supply, and special seismically isolated precision machine areas, are available to the UPS^2 IKC's operation. The facilities include advanced 5-axis CNC micromachining, precision diamond turning, 4-axis diamond grinding, advanced plasma machining and a comprehensive suite of surface metrology instruments.

The principal addition to the facilities since January 2007 has been in large scale co-ordinate metrology. With the acquisition of the Leitz 3m x 2m x lm capacity PM^{-}MF Co-ordinate Measuring Machine (CMM), Cranfield has now established the UK's highest accuracy large scale co-ordinate metrology capability. The CMM is pivotal, with its established contact-based metrology, to measurement of large optics carriers and alignment fixtures and is therefore integral to UPS^2 IKC's large optics manufacturing capability.

Centre of Industrial Photonics (Cambridge)

The Cambridge facilities at the Centre of Industrial Photonics (CIP) have been recently upgraded to include technologies that will provide a wider range of micro laser machining capabilities. These include new laser source technologies and a range of high resolution and high speed laser scanning systems for wide area processing.

Diagnostic and analysis capabilities include a new dual beam FIB/SEM stage with recent addition of EDX and EBSD analysis suite. The CIP is now fully-equipped to develop advanced micromachining and surface structuring processes and applications.

Optical Sciences Laboratory (University College London)

The establishment by University College London (UCL) and Cranfield University of the National Facility for Ultra Precision Surfaces at the Technium OpTIC in North Wales in 2004 offered the prospect, now achieved, of surpassing the existing grinding and polishing capability at UCL. The emphasis of work on-campus is now consolidated in active and adaptive optics and applications such as X-ray systems.

As part of this development, newly-refurbished office space was also created for the entire astrophysics group. This enabled the Optical Science Laboratory on-campus staff to be integrated within these new astrophysics facilities, enhancing the contact between the astronomers using instrumentation and the optical science staff and students working on instrumentation. In the era of the forthcoming next generation of Extremely Large Telescopes, this close contact is expected to pay dividends.

A summary of major equipment available to the UPS^2 IKC, and its current location, is contained in Table 2 below.

Capability	**Equipment**	**Location**
Ultra precision large optics grinding facility -rapid low-damage grinding to 2 metre	BoX ultra-precision grinding and measuring machine	OpTIC
Large optics free-abrasive machining: CNC polishing, fluid-jet and hybrid abrasive	Zeeko IRP 1200 7 axis CNC polishing machine, and smaller scale machines	OpTIC
Co-ordinate metrology	3m x 2m x lm volume contact and non-contact co-ordinate metrology to order-micron uncertainty	Cranfield

Plasma machining	CNC plasma machining to 300mm capacity	Cranfield
Surface form and texture metrology	Swing-Arm Profilometer and range of interferometry/stylus based instruments including	OpTIC
Laser Micro Machining	Range of laser sources and scanners with Fibre Laser to 200W	Cambridge
Diagnostics	FIB/SEM and white light interferometric microscope	Cambridge
	Full suite of FIB/SEM, TEM, SPM, XRD, XPS, AES etc.	Cranfield
Ultra precision diamond turning and	5 diamond turning machines to 1.6 metre capacity - 3 diamond grinding machines to 300mm capacity	Cranfield
Precision creep-feed/HEDG and superabrasive turning	5-axis and 4-axis machines	Cranfield
Contact and non-contact surface metrology	Full suite of interferometers for texture and form analysis (5 instruments) - range of stylus based instruments for form and texture (3 instruments)	Cranfield

Table 2: Overview of relevant facilities available to UPS^2

Research and Development (R&D)

The remit of the Research and Development Programme sub-committee is to establish and manage a near-market R&D project portfolio. This portfolio is managed through a 'stage gate' review process. Emphasis is placed on the wealth creation and sustainability aspects of UPS^2. The R&D sub-committee will achieve self-supporting status for the UPS^2 R&D operations through enabling IKC business income, securing share holding, licences, and other IP revenue.

The UPS^2 collaborative project portfolio was announced in August 2007 and initial projects commenced throughout 2008. Each month a project approval panel sits to review written proposals. Those successful are reviewed by a short interview to agree deliverables, stage gates and IP handling. Each project approval panel comprises at least 3 of the 4 UPS^2 partners.

Knowledge Transfer “Systems description”

The lack of any formal connection between Higher Education and business has been well documented (Yasin *et al*, 2000). This situation persisted throughout the latter half of the last century, and can be modelled as a set of closed systems. The two primary systems of interest are the business (industrial engineering employer) system and the teaching and learning system (postgraduate level Masters in the context of this paper). These, with the main sub-systems and process elements of

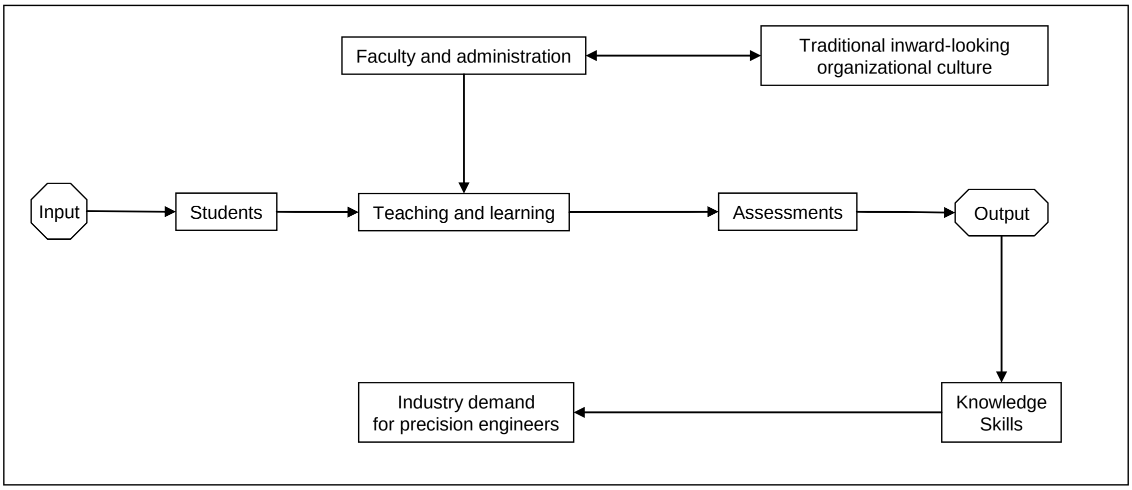

Figure 4 : Traditional teaching showing the elements of a closed system (after Yasin *et al.* , 2000).

interest are shown in Figure 4. The systems show little connectivity and exhibit no effective feed forward or feedback control mechanism. Course design and development occur as a top-down implementation of HE establishment strategy, embedded within an inward-facing culture. The end-customers (industrial employers) are the recipients of an output that they have little opportunity to influence. The teaching staff, students, and employers are alienated in this arrangement. The HE institution may find it hard to attract high quality students as the employability of the postgraduates that emerge from the teaching and learning processes is likely to a matter of good fortune. UK students are likely to emerge from their first degree with financial debts, owing to increasing undergraduate fees and lower grants. Faced with increased choice of postgraduate opportunities, a Masters degree is not a choice to be taken lightly. In this buyers market, the HE institution must adjust its processes to ensure much closer alignment with the needs of today's engineering students and the business environment that demands their knowledge, skills, experience, and emotional intelligence.

This implies the adoption of an open systems approach. The system must include a high level of integration between the system's components, in particular a partnership between the HE institution and the employer. Figure 5 shows an open systems model (Sansom and Shore, 2008) which is

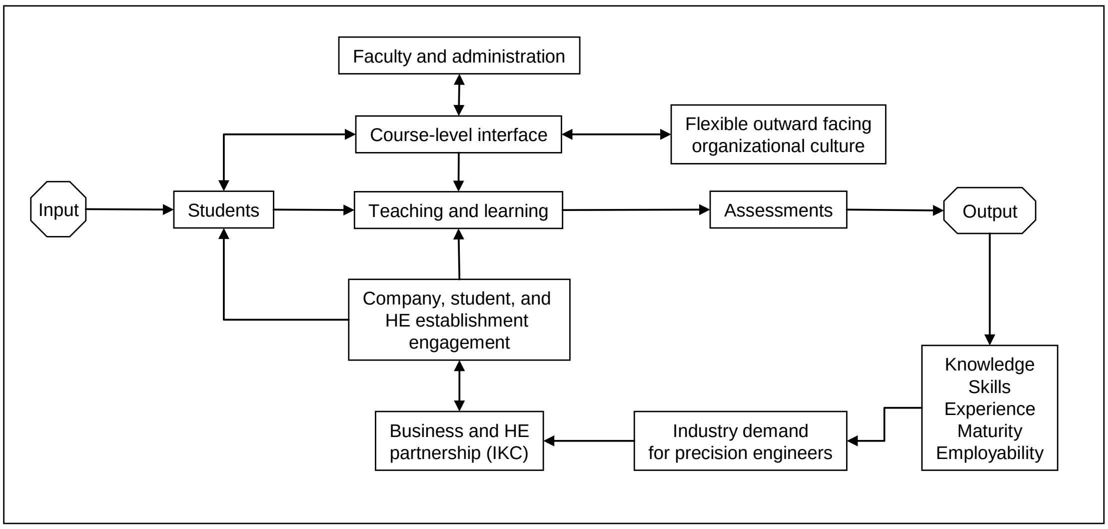

Figure 5: Open systems model emphasizing company-student engagement

based on the work of (Yasin *et al*, 2000), but extended to meet the special requirements of UK precision engineering clients. In particular, there is a need for greater engagement between students and employers at all stages in the recruitment and learning processes. This is met by the inclusion of an intermediate shell of sub-processes which provide a proactive link between individual students and company representatives. These are described as the “Course level interface” and “Company, student, and HE establishment engagement” sub-systems in Figure 5, and are the domain of a dedicated HE academic or professional.

In this model the student is pulled into the teaching and learning sub-system by these “shell” processes which act in addition to the existing HE marketing and promotional activities. Interaction with potential employers takes place prior to course registration, and as part of the recruitment process. This link becomes stronger as the Masters course progresses, with Company placements and sponsorships available to the most able students. Each participating Company becomes a key stakeholder in the overall system, with interest in student recruitment, the course content, project work, and assessment criteria. The shell processes are intended to collect and process the outputs from the student and company experiences in order to enhance both the teaching process and the design of the overall system.

The MSc in “Ultra Precision Technologies”

The MSc in “Ultra Precision Technologies” is divided into three components:-

(i) A taught component, given as a series of one-week modules and including lectures, tutorials, case studies, laboratory demonstrations, workshops and exercises as appropriate. These are summarised in Table 3.

Precision engineering – ‘principles and state of the art concepts’
Metrology and optical testing
Managing innovation and new product development
Computer-aided engineering for ultra precision
Optical design and fabrication
Surface engineering and coatings
Modern optical technologies
Laser micromachining and surface structuring

Table 3: Taught modules – MSc in “Ultra Precision Technologies”

(ii) A group project, in which groups of between 4 - 10 students work as a team on a multi-disciplinary problem of industrial relevance. The project has a strong practical bias, preferably with a hardware output, and can attract commercial sponsorship. In addition to practising precision engineering skills the students also have the opportunity to experience project management and team working, two important qualities on the path to achieving enhanced employability.

(iii) An individual research project of industrial relevance, culminating in an MSc thesis. These projects involve company placements and can be sponsored by industrial partners. Thus, this provides another bridge between acadamia and engineering companies, and opportunities for knowledge transfer. We should not underestimate the challenge for a new engineer entering the world of industrial manufacturing. Hurdles exist to complicate the transition from Higher Education into the workplace, which has been discussed by many authors including (Heinz, 1999), (Arnold and Mackenzie Davey, 1992) and (Holden and Hamblett, 2007). By undertaking a Masters level project in a company, the student practices their newly acquired technical skills (building on the learning from taught modules) – but also have to adapt to working within teams and groups which stretch their interpersonal skills and motivations. The Individual project in-company placement programme provides a “safe” and controlled environment within which the student can experiment in order to optimize their effectiveness in a precision engineering role. However the expectations of the course team are more ambitious than this, and the student is challenged to exhibit originality in their research and excellence in their project management and presentation style. This is clearly in evidence from the fact that three students emerged from the first year of the course to progress directly into PhD research projects within the Cranfield University Precision Engineering Centre.

For full-time students, the three components are weighted for assessment purposes as follows:

Lecture courses (40%), Group project (20%), Individual project (40%).

Teaching and learning styles

The taught modules vary in style from traditional lectures for subject based learning, through experiential learning, to practical sessions with an emphasis on problem based learning. Examples of problem based learning can be found throughout sections of the “Managing innovation and new product development” module, whilst experiential learning predominates in the “Computer-aided engineering for ultra precision” module. It is the difference in presentation and teaching styles that is designed to address the need for different learning styles, in an attempt to reduce gender bias and increase appeal to mid-career change applicants. As discussed by Rae (2005), entrepreneurial learning can aid the mid-career change applicant (MCE) by facilitating a successful transition from a role that utilises existing skills and expertise to a new role in a field that utilises newly learned skills and expertise. In making the transition to Precision Engineering, an MCE may not have the same recollection of basic science and engineering knowledge as a new graduate (Blackburn and Mackintosh, 1999). This can be addressed during the Induction week, and in tutorials during the taught modules. Group Project work presents both opportunities and issues for the MCE. Care is needed to ensure that the MCE is not cast as an outsider within a team of new graduates. Rather, the MCE should be given the opportunity to use their experience of problem solving and common-sense solutions to the good of the team. This can be a fine balance, and a skilled project facilitator may be needed at key decision points within the duration of the project.

Conclusions

In order to retain competitive advantage in precision engineering the UK engineering industry was required to integrate islands of excellence to form a world class and internationally recognised partnership. This partnership, funded in part by both EPSRC and the Welsh Assembly Government, was created under the banner of an Integrated Knowledge Centre or IKC. This IKC in Ultra Precision Structured Surfaces (or UPS^2) includes the UK academic institutions of Cranfield University, the University of Cambridge, and University College London; plus the OpTIC technium in North Wales. This paper has outlined the background to the IKC in UPS^2, and has described the structure and organization of its main systems and processes.

Particular attention has been paid to the Knowledge Transfer sub-system and to the flagship Masters level course in “Ultra Precision Technologies”. The results of our inaugural recruitment process, which took place between July and September 2007, produced 10 students who registered on the full-time MSc in “Ultra Precision Technologies”. Eight of these were “Home” students, with one “EU” and one “Overseas”, as defined by the UK Higher Education regulations. Despite the small sample size the achievement of 80% “Home” students is extremely encouraging, since the percentage of “Home” students on postgraduate courses (excepting PhD and the Postgraduate Certificate of Education) at all UK HE institutions is 34% (HESA, 2005/6). Equally promising is the statistic that 30% of the October 2007 cohort were female, which compares favourably with the 8.5% women who study mechanical engineering at UK Higher Education level. This statistic includes both undergraduate and postgraduate students, but excludes PhD and Postgraduate Certificate of Education students (Setwomanstats, 2004/2005).

The companies that participated in the first year of the MSc course, in the sense that they agreed to the placing of students within their organizations, covered a range of applications. They included Airbus UK, Gooch & Housego, PJ Coatings, OpTIC, Qioptiq, PV Crystalox Solar, Perkin Elmer, and Microsharp. Most of these had previous involvement with UPS^2 and some were sited near to UPS^2 headquarters at OpTIC amongst the North Wales opto-electronics business cluster. For this reason it was decided to locate four students in North Wales, to better serve the industrial clients in that region.

Looking forward to the second cohort and beyond, the challenge is to repeat the successes of the first year as well as expanding the numbers of both students and companies. The IKC is also keen to globalize its operations, including its knowledge transfer activities. The MSc in Ultra Precision Technologies has already attracted interest from Italy and India.

The participating companies are expected to grow in number over time, further strengthening the links to the IKC, and taking opportunities to increase the effectiveness of the course to industry. In the future, we can expect the gap between supply and demand for these strategically vital skills to be narrowed.

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