James Watt Institute *for* High Value Manufacturing

HERIOT WATT UNIVERSITY

TECHNICAL PROGRAMME

Photonics and Microsystems in High Value Manufacturing

23 April 2009

Postgraduate Centre, Heriot Watt University, Edinburgh

08.30	REGISTRATION & COFFEE
09.00	Welcome **Professor Denis Hall** (Heriot Watt University)
09.10	High value-added manufacture in the UK economy **Professor Anton Muscatelli** (Principal and Vice Chancellor, Heriot Watt University, Edinburgh)
09.25	High value manufacturing at the UK Technology Strategy Board **Dr. Neil Morgan** (High Value Manufacturing Team, Technology Strategy Board, Swindon UK)
09.50	**KEYNOTE I** Advanced solid state lasers: Status and perspectives **Professor Andreas Tünnermann** (Fraunhofer Institute for Applied Optics and Precision Engineering, Jena, Germany)
10.30	COFFEE BREAK
10.50	**KEYNOTE II** Potential and limits of optical 3D-sensors **Professor Gerd Häusler** (University of Erlangen-Nurenburg, Germany)
11.30	Optical metrology through scattering media for high value manufacturing **Dr. Wei Wang** (Heriot Watt University, Edinburgh)
11.50	Infrared technologies for manufacturing processes – seeing beyond the visible **Dr. Jonathan Shephard** (Heriot Watt University, Edinburgh)
12.10	New optical techniques for diode lasers in manufacturing applications **Ms. Natalia Trela** (Heriot Watt University, Edinburgh)
12.30	Poster 'Trailer' Session
13.00	LUNCH AND POSTER SESSION
14.00	**KEYNOTE III** MEMS – Boom after bust? **Professor Richard Syms** (Department of Electrical Engineering, Imperial College, London, UK)
14.40	Nano-mechanical sensors for health and environmental monitoring **Dr. W Shu** (Heriot Watt University, Edinburgh)
15.00	COFFEE BREAK
15.20	Post-CMOS MEMS: Driving the small revolution **Dr. David Flynn** (Heriot Watt University, Edinburgh)
15.40	Smart materials based micro-devices for manufacturing and biological applications **Dr. Richard Fu** (Heriot Watt University, Edinburgh)
16.00	Ultra precision manufacturing of high added value product **Dr. Xichun Luo** (Heriot Watt University, Edinburgh)
16.20	END

High Value-added Manufacture in the UK Economy

Professor Anton Muscatelli
Principal and Vice Chancellor,

Heriot Watt University, Riccarton, Edinburgh EH14 4AS UK

Abstract
The current economic crisis emphasises how advanced economies have to pursue economic growth strategies which are resilient to rapid declines in particular sectors (like financial services). The key to this is an economic strategy based on developing high-level (graduate and postgraduate skills) and fostering innovation.

A recent paper, produced by a panel of economists, commissioned by Universities Scotland, develops this argument. A number of important conclusions emerge:

For example, it concludes that public investment in general activities such as cutting business costs, personal taxation and improving transport are unlikely to result in economic growth unless very carefully targeted.

The paper also concludes that general understanding of the labour market is wrong. Scotland will need fewer mid-level skills and more high-level skills in the future. 'Vocational' initiatives such as expanding apprenticeships will not produce economic growth.

And it concludes that if we rely on an 'industry support strategy' which encourages and reinforces existing behaviour we will struggle to deal with the structural change we will see during recovery from recession. We need a strategy that encourages economic transformation and the development of new industries.

Professor Anton Muscatelli

Anton Muscatelli is Principal and Vice-Chancellor of Heriot-Watt University, Edinburgh, a post he has held since February 2007.

He is currently a special adviser on monetary policy to the House of Commons Treasury Select Committee. He has served on the Panel of Economic Advisors of the Secretary of State for Scotland (1998-2000), and has previously acted as consultant to the European Commission, the World Bank, and other organisations. In 2008 he was appointed to Chair an independent expert group on the future financing of devolution for the Calman Commission.

He is a member of the Council of the Royal Economic Society, a Fellow of the Royal Society of Edinburgh, and an Academician in the Learned Societies of the Social Sciences.

He was Chair of Universities' Scotland Research and Commercialisation Committee (2007-08), a member of the Scottish Funding Council's Research and KT Committee (2004-08) and led the SFC's Economic Development Action Group. He chairs the Strategy Board of the Scottish Research Partnership in Engineering, and since August 2008 he has been Convener of Universities Scotland, and Vice-President of Universities UK.

He was previously Vice-Principal (Strategy, Budgeting and Advancement) at the University of Glasgow between 2004-07 and Dean of the Faculty of Social Sciences at Glasgow University from 2000-04. Whilst at Glasgow University he was Daniel Jack Professor of Economics (1994-2007) and Professor of Economics (1992-94).

High Value Manufacturing at the Technology Strategy Board

Dr. Neil Morgan
High Value Manufacturing Team

Technology Strategy Board, Polaris House, North Star House
Swindon SN2 1UE UK
neil.morgan@tsb.gov.uk

Abstract
The Technology Strategy Board (TSB) has a vision to create wealth and enhance quality of life. Its role is to stimulate technology-enabled innovation in the areas which offer the greatest scope for achieving this through promoting, supporting and investing in technology R&D and commercialisation. It also advises Government on how to remove barriers to innovation and accelerate the exploitation of new technologies.

The Technology Strategy Board recognises that modern UK manufacturing is a complex global activity that must primarily compete on value rather then cost. This presentation will describe the strategy for High Value Manufacturing in detail and give an overview of the practical and operational aspects relevant to companies and university researchers.

Dr. Neil Morgan

Neil Morgan is currently Lead Technologist for Manufacturing at the Technology Strategy Board. Neil graduated from Cranfield University with an engineering doctorate degree and subsequently remained at Cranfield University as a lecturer at the campus within the Defence Academy of the United Kingdom in Oxfordshire. Subsequently Neil moved to the USA to work on the manufacture of medical devices with Johnson & Johnson in Fremont California. Neil is on the steering board of the Cranfield IMRC and the Industrial Liaison Forum at Brunel University.

In the summer of 2008 Neil was seconded from the Technology Strategy Board into the Department of Business, Enterprise and Regulatory Reform (BERR) in Westminster to work on the Government's Manufacturing Strategy.

Neil is also currently leading the 'Retrofit for the Future' project announced by the Prime Minister in January 2009 that concerns the retrofit of existing UK social housing stock to meet future $CO2$ targets.

Advanced solid state lasers: Status and perspectives

Professor Andreas Tünnermann

Friedrich Schiller University Jena, Institute of Applied Physics, Albert-Einstein-Str.15, D-07745 Jena, Germany

Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Strasse 7, D-07745 Jena, Germany Andreas. Tuennermann@iof.fraunhofer.de

Abstract

Solid-state lasers are attractive sources of coherent radiation for various scientific and industrial applications, leading to a substantial growth in photonics industry. A key driver of this development is the market segment laser materials processing with strong impact on several key economic fields. A prominent example can be found in the automotive industry, the welding of car bodies and cutting of stamped parts has improved both productivity and quality. In 2008, the world market sales volume of solid state lasers amounted to more than US $ 1.500 Mio.. However, the different fields of applications increasingly demand more powerful, efficient, and rugged lasers with higher beam quality. Hence, at present a new generation of laser systems with improved parameters have begun to dominate the market. Thin disc and fiber lasers have now entered the regime of multi-kilowatt of average output power with almost diffraction limited beam quality. Wall-plug efficiencies exceed 20% for systems with emission wavelength in the near infrared. In this contribution, novel developments in advanced solid-state lasers and their application in production technology are reviewed.

Professor Andreas Tünnermann

Andreas Tuennermann was born in Ahnsen, Germany, and received his diploma and Ph.D. degrees in physics from the University of Hannover in 1988 and 1992. His PhD work focused on nonlinear processes with emphasis on the interaction of high intensity laser sources with matter for the generation of short wavelengths lasers. In 1997 he received the habilitation for his work on ultrastable light sources for interferometric gravitational wave detectors.

From 1992-1997 he was head of the development department at the Laser Zentrum Hannover, and in 1994 became the national scientific coordinator for the development of solid state lasers within the LASER 2000 program. In 1998 he joined the Friedrich-Schiller-University in Jena, Germany as a Professor and Director of the Institute of Applied Physics, and in 2003 he became the Director of the Fraunhofer Institute of Applied Optics and Precision Engineering in Jena.

His main research interests include scientific and technical aspects associated with the tailoring of light. Research topics are the design and manufacturing of novel micro- and nanooptical photonic devices using high-end microlithography and its application for generation, amplification, steering and switching of light.

In particular, his work on high power diode pumped fiber and waveguide lasers is widely recognized, and has had a major impact on novel solid state laser technology developments. He is also responsible for pioneering work has in utilizing high power femtosecond lasers for materials processing, and in collaboration with coworkers, he demonstrated new prospects for a precise microstructure technology. Because of the rapid progress in this field, attention is switching to "real world" industrial applications of these lasers.

Professor Tuennermann is member of the German Physical Society, and the Optical Society of America. His research activities on applied quantum electronics have been awarded with the Roentgen-Award 1997, WLT-Award 1998, Otto-Schott-Award 2003, Leibinger Innovation Award 2004 and the Gottfried-Wilhelm-Leibniz-Award 2005.

Potential and Limits of Optical 3D-sensors

Professor Gerd Häusler

Institute of Optics, Information and Photonics,
University of Erlangen-Nuremberg, D 91058 Erlangen, Germany
haeusler@physik.uni-erlangen

Abstract

Optical 3D-sensors acquire the geometrical shape of surfaces. Shape data are invariant against shift, rotation, illumination, texture and soiling (two-dimensional intensity images are not). So, why don't we find 3D-sensors everywhere at inspection lines? We will discuss the potential, as well as the physical, information theoretical and technical limits of optical 3D-sensing, and we present some new sensors and new applications.

Professor Gerd Häusler

Gerd Häusler is currently extraordinary professor at the Institute of Optics, Information and Photonics (Max Planck Research Group), University of Erlangen. He is heading the group "Optical 3D-Metrology". Born in 1944, he studied physics at the Technical University of Berlin and received a Dr. Ing. for the "expansion of depth of field in microscopic imaging". In 1974 he became scientific assistant of Prof. Adolf Lohmann, at the former "Institute for Applied Optics" (University of Erlangen). For his habilitation thesis about nonlinear optical feedback systems (1980) he received with his student G. Ferrano the Rudolph Kingsley Medal of the SPIE. He had visiting research positions at IBM Sindelfingen, at the University of Munich, ENST Telecom Paris, RCA Labs Zurich and at RIKEN Institute Tokio, where he received the "eminent scientist award".

Gerd Häusler's interests are technical optics, information optics and optical metrology. He aims to explore the physical limits and information theoretical limits of optical 3D-sensors, and to develop sensors that reach these limits. He published more than 200 papers. Several of his inventions are widely used, among others Fourier domain oct ("spectral radar"), white light interferometry at rough surfaces ("coherence radar") and phase measuring deflectometry. In 2001 he founded with five of his students the company "3D-Shape GmbH", which develops and commercialises optical 3D-sensors.

Since 1996 he is a member of the board of directors of the German Society of Applied Optics.

MEMS – Boom after bust?

Professor Richard R A Syms

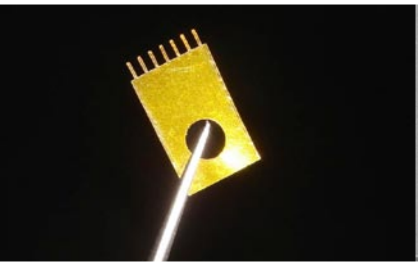
Department of Electrical and Electronic Engineering
Imperial College London, South Kensington Campus
London SW7 2AZ, UK
r.syms@imperial.ac.uk

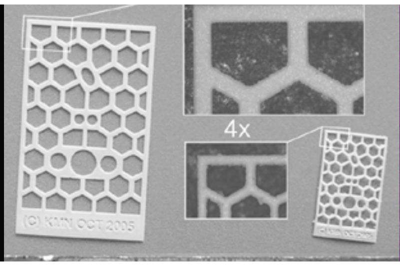
Abstract

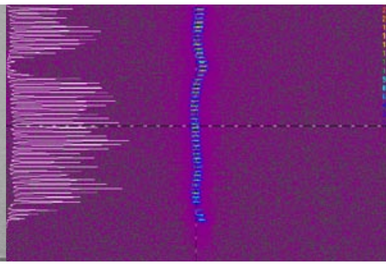
In this lecture we consider the status of MEMS and attempt to address the issues of the day. What are the successful applications, and what Darwinian factors have been at work? What is the importance of design? What differences have new production methods made and what is the role of a foundry? What were the effects of the technology crash and the impact of low-wage economies? How has the picture been been altered by the current economic climate? What are the new opportunities, given inescapable shifts such as the collapse of growth, climate change, energy shortages, fundamentalism and an ageing population?

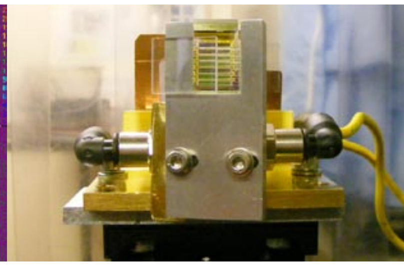
Professor Richard R A Syms

Richard R.A.Syms was born in Norfolk, VA, in 1958. He obtained a BA in Engineering Science in 1979 and a D.Phil. in 1982, both from Worcester College, Oxford. He has been Head of the Optical and Semiconductor Devices Group in the EEE Dept, Imperial College London, since 1992 and Professor of Microsystems Technology since 1996. He currently lectures on guided wave optics, electromagnetic theory and MEMS. He has published over 140 journal papers, 80 conference papers and two books on holography, integrated optics, laser and amplifier devices and microengineering. Most recently he has been developing electrical MEMS such as micro-connectors, RF probes for magnetic resonance imaging, and miniature quadrupole mass spectrometers, optical MEMS devices such variable optical attenuators and tunable lasers, and three-dimensional self-assembling micro-structures. He has consulted widely on guided wave optics and MEMS, and co-founded the MEMS spin-out Microsaic Systems in 2001. He currently acts as an Associate Editor for the Journal of Microelectromechanical Systems and for Metamaterials. He has served on many MEMS review panels, including for the EPSRC Microsystems Technology Integration Program, and the German, Canadian and Singaporean MEMS programs. He is a Fellow of the Royal Academy of Engineering, the Institute of Physics and the Institute of Electrical Engineers.









Optical Metrology through Scattering Media for High Value Manufacturing

Dr. Wei Wang
Mechanical Engineering, Heriot Watt University

Abstract

With the rapid development of high value manufacturing, the demands on new technologies for optical metrology with extremely high accuracy, performance and reliability are ever increasing. In this talk, I will introduce two optical metrology methods with its potential applications in high value manufacturing. The first approach is called Spatial Coherence Holography. Through synthesis of spatial coherence gate by monochromatic source, the depth-resolved image can be achieved for absolute measurement of objects with large discontinuous gaps. The second method is referred to as Electronic Speckle Polar-Interferometry. Due to the fact that some important material parameters, such as stress over a loaded sample, complex reflective index, and thickness of a thin film, can only be obtained from a polarized wave transmitted or reflected by a birefringent sample of interest, I will introduce a novel inteferometric polarimetry that is able to map a spatiotemporal change in the state of polarization and phase, and exploit it application to simultaneous full-field, non-contacting, 3D measurement of deformation measurement.

Infrared Technologies for Manufacturing Processes – Seeing Beyond the Visible

Dr. Jonathan Shephard
Mechanical Engineering, Heriot Watt University

Abstract

Using IR wavelengths has the potential to open up new applications in the field of manufacturing that are currently restricted by absorption and scattering in the visible. For example, the invention of a radically different design of fibre fabricated from novel (non-silica) glasses which has a hollow core, where the majority of power is guided, has the potential to push deep into the IR region. One such application is the possibility of achieving fibre delivery of high power CO2 lasers but, importantly, in single mode operation, something which is currently impossible with existing technologies.

An additional problem is that many component materials have restricted transmission or are highly scattering in the visible making non-contact, non-destructive optical inspection techniques of final parts impossible. However, by designing an imaging system based around infrared wavelengths (5 to 7 microns) we have shown it is possible to image even small micro-cracks deep within a ceramic component. This technique should offer a significant advantage in the quality control of "mass customised" ceramic parts.

New Optical Techniques for Diode Lasers in Manufacturing Applications

Ms. Natalia Trela
Physics, Heriot Watt University

Abstract
Diode lasers offer both high efficiency and low cost, features that are attractive for industrial applications, but currently they have insufficient brightness and pulse capability for most established manufacturing processes. We are developing new optical techniques to greatly increase brightness for direct diode use and enhance fibre laser pumping in pulsed applications, using our ability to directly laser-write arbitrary surfaces for beam shaping optics. An important development is our use of single-mode diode laser arrays, rather than the current industry standard of the lower beam quality, broad area emitters. High quality collimation and fast-axis correction with the direct-write optics have given low-loss wavelength locking with Volume Bragg Gratings (VBG), for brightness scaling by the dense spectral combining method. A multi-bar version has provided a high brightness pump for new fibre laser systems. The technique also has enabled new spatial beam combining methods, matching linear array beams into circular apertures.

Nanomechanical Sensors for Health and Environmental Monitoring

Dr. W Shu
Mechanical Engineering, Heriot Watt University

Abstract
Nanomechanical sensors based on cantilever devices have been investigated for wide applications related to health and environmental monitoring. Rapid and accurate identification of biomolecules, gases and chemical vapours have been demonstrated. In particular, nanomechanical cantilever biosensors capable of detecting DNA, proteins and cells are of great importance for applications in rapid disease diagnostics and drug screening. In this talk, our recent progress on manufacturing low cost nanomechanical cantilever sensors along with the potential applications for health and environmental monitoring will be discussed.

Post-CMOS MEMS - Driving the small revolution

Dr. David Flynn
Electrical and Computer Engineering, Heriot Watt University

Abstract
Emerging nano and micro technology devices as well as their integration present significant challenges and opportunities for future products within a myriad of applications. The transition of micro and nanotechnology from the laboratory to the point of application requires integration with the support circuitry. Integration of these technologies with established manufacturing methods is a key enabler to their exploitation. From a technical perspective it enables a higher degree of autonomy and functionality to the device. In business terms, integration enables the development of cost effective mass manufacture, stimulating technology transfer and commerce.

Presently, there are three common methods to integration, they are pre-CMOS, mixed flow CMOS and post-CMOS. This presentation will provide exemplars of commercialised Microsystems and the technologies used in their manufacture. The manufacturing challenges of integration will be highlighted and the means of resolving them, with a particular focus on the post-CMOS process.

Smart materials based microdevices for manufacturing and biological applications

Dr. Richard Fu
Mechanical Engineering, Heriot Watt University

Abstract
This talk will focus on my recent work on the microdevices based on the smart materials, whose properties will change in response to an external stimulation. First part of my talk will focus on shape memory polymer (SMP) and its nanocomposites. SMP has the capability of recovering their shape upon application of an external thermal or joule heating, light or even water. Nano-size fillers have been used to enhance the mechanical and shape memory recovery properties of SMP, which can be used for biological, assembly and disassembly applications. The second part of my talk will focus on recent work of piezoelectric materials based microfluidic system. The integration of surface acoustic wave device with electro-wetting technique can form novel lab-on-a-chip with functionalities of droplet generation, transportation, mixing and biosensing.

Ultra Precision Manufacturing of High added value product

Dr. Xichun Luo
Mechanical Engineering, Heriot Watt University

Abstract
This presentation highlights some key ultra precision manufacturing technologies, including diamond turning, diamond grinding, Focused Ion Beaming (FIB) machining and their applications. In the first part of this presentation, a new concept of a multifunctional machining centre is proposed in order to provide UK SME with affordable ultra precision machining facility. Diamond drilling and laser drilling of glass wafer for a new MEMS device is used as a case study to prove the concept of multi machining processes. The second part of this presentation is focused on the development of cost-effective production processes. The problems in the current ultra precision manufacturing processes are identified. Focused Ion beam machining that currently is carried out at Heriot-Watt University. Some FIB fabrication examples are used to show how simulation technique can be applied to develop new machining process.