EPSRC Centre for innovative manufacturing in ultra precision

Future Trends and Emerging Technologies

In Ultra Precision Engineering

2019 CONFERENCE

PROGRAMME

Future Trends and Emerging Technologies

In Ultra Precision Engineering

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WELCOME

It is with great pleasure that we welcome you to the sixth Ultra Precision Conference hosted by the 2018/19 MRes Ultra Precision Engineering student cohort.

Building on the success of previous conferences, the collaboration between Cranfield University, the University of Cambridge, and the University of Nottingham aims to increase the connectivity for experts in both academia and industry within the engineering sphere.

This year's theme, "Future Trends and Emerging Technologies", aims to disseminate novel and innovative research, in additive manufacturing, metrology, neural interfaces, and nano-characterisation to name a few. The academic and industrial delegates engaged in ultra precision research will meet to present their latest research findings and discuss their future needs. We hope that the outputs from this event will generate further knowledge and enable the development of new ideas within precision engineering.

We would like to offer our personal thanks to the speakers, exhibitors, and delegates for taking part and for making what we are sure will be a memorable and productive event.

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AGENDA

09:00	**Registration and Exhibitors**
10:00	**Welcome and Introduction**
10:10	**Dr Sebastian Pattinson** - *University of Cambridge* *Additive Manufacturing of Mechanically Tailored Mesh for Compliant Wearable and Implantable Devices*
10:40	**Dr Martin Tolley** - *Science & Technology Facilities Council* *Microtargetry – An Overview*
11:05	**Morning Break - Exhibitors and Posters**
11:20	**Kim Larsen** - *Oxford Instruments* *Nano-characterisation: Driving development and providing solutions for quality control*
11:50	**Dr Ian A. Robinson** - *National Physical Laboratory* *The Kibble Balance: using virtual power to measure mass in the revised SI*
12:20	**Dr Samanta Piano** - *University of Nottingham* *Towards super resolution surface metrology*
12:45	**Lunch - Laboratory Tours, Exhibitors, and Posters**
14:15	**Dr Joanna Skiba-Szymanska** - *Toshiba Research Europe* *Engineering Individual Photons*
14:45	**Prof Xichun Luo** - *University of Strathclyde* *Ultra Precision single point diamond turning of GaAs*
15:10	**Afternoon Break - Exhibitors and Posters**
15:25	**Dr Chris Proctor** - *University of Cambridge* *Engineering advanced neural interfaces*
15:55	**Prof Chris Sansom** - *University of Cranfield* *Precision Engineering for Concentrating Solar Power*
16:20	**Closing Remarks**
16:30	**Drinks and Posters**

SPEAKERS

Dr Sebastian Pattinson
University Lecturer, *University of Cambridge*

Dr Pattinson is a Lecturer in Manufacturing Processes, Systems and Organisations at the University of Cambridge. His research interests include additive manufacturing, material chemistry, computational design as well as learning how to produce new devices and materials whose structures are controlled from the nano- to the macro-scale for enhanced function.

He was formally a postdoctoral fellow in the Department of Mechanical Engineering at MIT.
He received his Ph.D. and Masters degrees in the Department of Materials Science & Metallurgy at the University of Cambridge. His awards include a US National Science Foundation postdoctoral fellowship; UK Engineering and Physical Sciences Research Council Doctoral Training Grant; MIT Translational Fellowship; and a (Google) X Moonshot Fellowship.

Additive Manufacturing of Mechanically Tailored Mesh for Compliant Wearable and Implantable Devices

Additive manufacturing (AM) of medical devices including orthopaedic implants and hearing aids is highly attractive because of AM's potential to match the complex form and mechanics of individual human bodies. Wearable and implantable tissue-support devices, such as ankle or knee braces, and hernia repair mesh, offer a new opportunity for AM to mimic tissue-like mechanics and improve patient quality of life. Here, we demonstrate how explicit programming of the toolpath in an extrusion AM process can enable new, flexible mesh materials with digitally tailored mechanical properties and geometry. Meshes are fabricated by extrusion of thermoplastics, optionally with continuous fibre reinforcement, using a continuous tool path that tailors the elasticity of unit cells of the mesh by incorporation of slack and modulation of filament-filament bonding. We show how the tensile mesh mechanics can be engineered to match the nonlinear response of muscle, incorporate printed mesh into an ankle brace with directionally specific stiffness, and present further concepts for tailoring the 3D geometry for medical applications.

Dr Martin Tolley

Target Fabrication Group Leader, *Science & Technology Facilities Council*

Dr Martin Tolley is the Target Fabrication Group Leader at the Science & Technology Facilities Council. Martin has held a permanent position in the Central Laser Facility since 2001 developing the group's capabilities across an integrated range of microfabrication techniques. His research interests include next generation targetry types and disruptive high repetition rate targetry solutions.

With a background in theoretical physics, biophysics and philosophy of science. He also ensures commercial access to the group’s extensive targetry capabilities via the spinout Scitech. All of his activities are underpinned by an exploration of the complex microscaling issues pervading microtargetry. Ultimately his strong sense of irony enables him to enjoy perfectly made microtargets being destroyed by high intensity lasers in billionths of a second.

Microtargetry – An Overview

Microtarget fabrication is the production of sub-cm targets built to few micron accuracies for use in High Power Laser experiments. Although the discipline is not well known it has been crucial during the last forty years for enabling experiments on matter under extreme conditions. A broad and complementary range of microtechnologies are deployed to make microtargets. Within a few years advances in diode pumped laser systems will require microtargets to be manufactured and positioned at much higher rates. The talk will review the current status of the field and indicate which technologies will need to be developed.

Kim Larsen

Senior Product Scientist, *Oxford Instruments*

Kim Larsen joined HKL Technology A/S in January 2004. The company was acquired by Oxford Instruments in the following year. Through his history at HKL Technology A/S and then Oxford Instruments, Kim has worked in several areas including Customer Support, Development and Marketing; always with a strong focus on Electron Backscatter Diffraction (EBSD).

Nano-characterisation: Driving development and providing solutions for quality control

The continual development of new technologies and processing methods requires corresponding improvements to quality control and characterisation techniques. The integration of energy dispersive spectrometry (EDS) and electron backscattered diffraction (EBSD) on a scanning electron microscope (SEM) are routine methods of material analysis. EDS offers chemical quantification and element spatial distribution in the form of quantitative analysis and X-ray mapping. EBSD enables microstructural characterization studying phase relationships, local misorientations and grain properties such as size, morphology and boundary characteristics. The benefits from developments in detector hardware means that these characterisation techniques provide solutions to support the implementation of new engineering technologies over a large range of length scales.

Dr Ian A. Robinson

Fellow, *National Physical Laboratory*

Dr Robinson is an NPL Fellow and, over the last 43 years, has pioneered the development of the Kibble balance, which underpins the redefinition of the kilogram. He has experience in making high precision measurements of voltage, resistance, velocity, mass and free-fall acceleration "g", often using custom-built, highly-isolated, low-noise instrumentation.

The Kibble Balance: using virtual power to measure mass in the revised SI

The recent revision of the SI has freed the world's measurement system of its last artefact: the International Prototype of the kilogram (IPK). However the world now needs to implement the new definition of the kilogram and take advantage of the freedom that the fixing of the numerical value of the Planck constant has provided. The talk will describe some of the history leading up to the redefinition of the kilogram and describe the operation and the future use of the Kibble balance which enables the implementation of the new definition of mass in the SI over a range of scales from kg to mg.

Dr Samanta Piano
Assistant Professor in Metrology, *University of Nottingham*

Dr Piano is an Assistant Professor in Metrology and deputy director of the Manufacturing Metrology team at the University of Nottingham (UoN). Her research interests concern the development of innovative and unconventional optical techniques and 3D probing systems for high-precision coordinate metrology to be used in industrial applications.

She is a former Marie Curie and UoN Advanced Research Fellow who has contributed to several forefront areas of experimental condensed matter physics, materials science, atomic and optical physics, metrology and nanotechnology.

Towards super resolution surface metrology

The ability to perform high precision measurements, sensing, and imaging at micro- and nano-scale underpins a plethora of applications in manufacturing industry, biomedical sciences, fundamental physics and information technology. Several techniques to scan and reconstruct complex features of three-dimensional inert or living samples have been developed in recent years, and the quest to enhance the signal-to-noise ratio and the acquisition rate in these setups is still very much open. The majority of optical imaging techniques utilise light sources, which are essentially modelled as classical, which means that the precision achievable in such setups is a priori limited by the so-called shot noise limit. On the other hand, it is well known that quantum features such as superposition and entanglement can give rise to an enhanced precision in metrology and imaging, allowing one to beat those limitations. The applications of quantum metrology to a wide range of technologies (e.g. communication, navigation, clocks) are currently being pursued as a priority in the UK and in Europe.

In this paper we investigate the localization of two incoherent point sources with arbitrary angular and axial separations in the paraxial approximation. By using quantum metrology techniques, we show that a simultaneous estimation of the two separations is achievable by a single quantum measurement, with a precision saturating the ultimate limit stemming from the quantum Cram´er-Rao bound. Such a precision is not degraded in the subwavelength regime, thus overcoming the traditional limitations of classical direct imaging derived from Rayleigh's criterion. Our results are qualitatively independent of the point spread function of the imaging system, and quantitatively illustrated in detail for the Gaussian instance. This analysis may have relevant applications in three-dimensional surface measurements.

C. Napoli, S. Piano, R. K. Leach, G. Adesso, T. Tufarelli, Phys. Rev. Lett. 122, 140505 (2019)

Dr Joanna Skiba-Szymanska
Senior Research Scientist, *Toshiba Research Europe*

Joanna is a Senior Research Scientist at Toshiba Research Europe working on development of novel quantum light sources for quantum communication applications.

Joanna received her B.Sc. and M.Sc. degree in Electronics Engineering and Optoelectronics from Wroclaw University of Technology in Poland. In 2008 she completed her PhD in Physics at The University of Sheffield where she was working on electron spin interactions in semiconductor quantum dots. Straight after she moved to Cambridge, where she has been working with Toshiba and collaborating with Semiconductor Physics Group at Cambridge University. Joanna's work is focused on engineering of semiconductor based devices that produce single and entangled photons that can be used for Quantum Key Distribution systems.

Engineering individual photons

Quantum communication systems rely on individual photons to carry encrypted information between the users. In order to make such communication possible we have to be able to generate photons with particular optical properties, i.e. photon energy, spin splitting, coherence time and intensity. For added functionality these photons can be generated in discrete semiconductor devices which allow us to determine how and when they are created. The talk will introduce you to the world of super fine semiconductor device engineering and the science behind it.

Prof Xichun Luo
Professor in Ultra Precision Engineering,
University of Strathclyde

Xichun Luo is a Professor in ultra precision manufacturing and technical director of Centre for Precision Manufacturing at the University of Strathclyde. He is an elected Fellow of the International Society for Nanomanufacturing, an Associate Editor for Proceedings of the IMechE Part C: Journal of Mechanical Engineering Science and Journal of Micromanufacturing, and an editorial board member for Nanomanufacturing and Metrology, Micromachines and International Journal of Extreme Manufacturing. He received the Institution of Mechanical Engineers (IMechE) Ludwig Mond Prize in 2015. He obtained his PhD at Harbin Institute of Technology (China).His research interests include ultra precision machining precision motion control, micromachining, and nanomanufacturing.

Ultra Precision single point diamond turning of GaAs

Due to its superb electronic and optical properties, GaAs is gaining widespread applications in digital logics circuits, optics for IR systems quantum dot and quantum photonics integrated circuits electronics, quantum emitters, to name a few. This talk will present results of preliminary study of ultra-precision single point diamond turning of GaAs in order to develop a cost-effective manufacturing process for commercialisation of these GaAs-enabled devices. The talk starts with a brief introduction of manufacturing challenges of GaAs due to its high brittleness and anisotropy properties. It then describes a nano-indentation experimental study in order to establish GaAs's fracture toughness and hardness in different crystal orientations. Molecular dynamics simulation is also performed to gain understanding of the material removal mechanism. A series of single point diamond turning experiment is carried out to study the anisotropy machinability of GaAs. Finally, nanosmooth machined surface finish is obtained in single point diamond turning of GaAs even along the hardest machining direction by using operation conditions determined form the theoretical critical depth of prediction model.

Dr Chris Proctor
Research Associate, *University of Cambridge*

Chris is a Borysiewicz Biomedical Sciences Fellow and Research Associate in the Engineering Department at the University of Cambridge. His research is focused on engineering devices and developing materials to enable a seamless connection between electronics and living tissue in order to address intractable disorders. Ongoing project themes include developing flexible implants for minimally invasive recording and stimulation as well as electrophoretic drug delivery for epilepsy and cancer.

Chris received a B.Sc. in Interdisciplinary Physics from the University of Michigan in 2008. Following two years as a general scientist at the U.S. Nuclear Regulatory Commission, he earned a Ph.D. in Materials from the University of California, Santa Barbara where he investigated loss mechanisms in organic photovoltaics (2015). Subsequently, Chris was awarded a postdoctoral fellowship from Whitaker International to develop implantable bioelectronic devices for treating neurological disorders at the Ecole des Mines de St Etienne.

Engineering advanced neural interfaces

Despite tremendous research efforts, treatment options for many neurological disorders are inadequate. Systemic drug treatments suffer from side effects and long-term habituation; electrical stimulation is unspecific; and the fluidic injection of drugs often displaces the very cells that are being targeted due to the local pressure increase. Thus, there exists a pressing need to develop novel treatment strategies that overcome these limitations. One such technology is the recently introduced drug delivery platform known as the microfluidic ion pump (µFIP). The µFIP is an implantable device that electrophoretically pumps ions (eg. neurotransmitters, drugs, etc) to the target tissue. In addition to spatial and temporal control, a distinctive feature of the µFIP is that it delivers just the ion and not the solvent and thus does not increase pressure at the outlet. This "dry" delivery is of paramount importance for neural interfacing as it enables an intimate interface between the drug delivery outlet and the target cells. Here we report recent advances in precise engineering to incorporate µFIPs into implantable devices for treating neurological disorders including both depth probes and cortical arrays with recording capabilities. The efficacy of the µFIP platform is demonstrated by stopping epileptic seizures in vivo. This is the first in vivo demonstration of an ion pump for treating a neurological disorder and offers a glimpse of what can be achieved by tailored engineering of the µFIP platform. We anticipate this work to be the starting point for new stimulation, recording and drug delivery paradigms in chronic neural implantation.

Prof Chris Sansom
Professor in Concentrating Solar Power Centre (CSP) and head of the Centre for Renewable Energy Systems, *Cranfield University*

Chris Sansom graduated in Physics from Liverpool University and studied for his PhD in Infrared detector technologies at Sussex University. He joined Cranfield University Precision Engineering Institute (PEI) in 2007 after over 20 years in industrial research labs with Plessey, GEC, Marconi, and Perkin Elmer. Within Cranfield PEI he was course director of the MSc in Ultra Precision Technologies and Knowledge Transfer Manager. He now leads the largest UK research team working solely on CSP and has recently been appointed head of renewable energy research at Cranfield.

Precision Engineering for Concentrating Solar Power

Prof Chris Sansom describes the application of tools and techniques from his precision engineering background to the development of concentrating solar power components and systems. These CSP power plants are playing an increasing role in the decarbonisation of utility-scale electrical power generation in locations with strong direct sunlight.

EXHIBITORS

Aerotech, for over 40 years, has specialised in design and manufacture of high-performance motion control and precision positioning systems. Aerotech provides local and international support for demanding applications in photonics, high vacuum, high-throughput production, semiconductor, aerospace and medical industries.
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This conference is organised and hosted by the 2018/19 MRes Ultra Precision Engineering cohort, the University of Cambridge, the University of Nottingham, and Cranfield University.

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