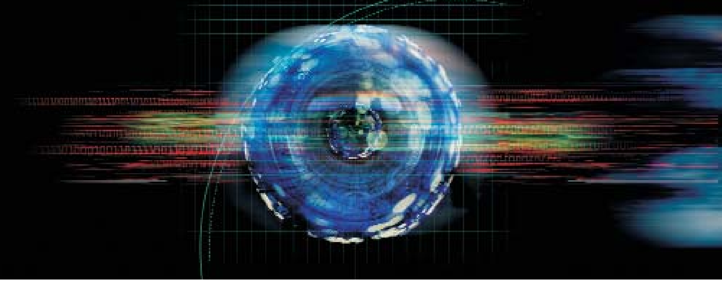

Electronics and Photonics

The application of electronic and photonic technologies can enhance the performance of a wide range of products across markets as diverse as transport, security, communications, healthcare and energy.

UK CAPABILITY

The UK has few indigenous industry heavyweights in this sector. However, we do have many smaller but world-class companies in developing areas like optoelectronics and electronic design. These companies are often powerhouses for creativity and exploitation of our world-class science base in photonics and electronics. In addition, a range of inward investors have R&D and manufacturing bases in the UK.

Globalisation has had a big impact on the industry in the UK. It has led to the offshoring of commodity electronics manufacturing, with a need for UK industry to move up the value chain. This means placing more emphasis on intellectual property-rich technology and design.

GLOBAL MARKET OPPORTUNITY

Worldwide, electronics applications are burgeoning – electronics are performance enhancers, at the heart of most modern products and typically represent over 20% of the cost. Though the market is very cyclical, it has grown consistently and now exceeds £700 billion worldwide.

- In **computing and communications,** electronics and photonics continue to facilitate faster, more versatile and lower cost systems.
- **Security** is a priority – a safer world requires advances in sensing and imaging technologies.

- **Healthcare** is a key area for electronics and photonics applications, such as medical imaging and photodynamic therapy.
- The massive improvements in car safety, emissions and fuel economy are largely due to the incorporation of electronic systems, and this **transport** demand will increase.
- **Environmentally,** electronic and photonic technologies will provide solutions to climate and pollution monitoring. Also, substantial energy savings can be achieved through the development of solid-state lighting.

PRIORITIES FOR ACTION

Based on the potential for industrial exploitation and UK research excellence, the themes below are priorities for the Technology Strategy over the next three years. The Electronics Innovation and Growth Team, the Photonics Strategy Group, and Foresight identified these as areas of great opportunity:

- Organic/plastic electronics and displays, an emerging field that is poised to disrupt the world of electronic circuits and flat panel displays, with an ultimate market opportunity of over £50 billion. The UK's university departments are doing world leading research, while UK companies have leading positions in early products and a dedicated Plastic Electronic Technology Centre is being developed.
- Photonics, lasers and lighting. The UK has a strong position in this growing field, with a number of significant global players and a world-class science base. The technology strategy will help the exploitation of new opportunities in this £90 billion market.
- Sensors and imaging. The UK has a broad and strong academic base with a range of centres of excellence and businesses with leading activities on sensor systems, materials and image analysis, which we will support to develop this market.
- Electronics design and systems. While the UK is not a major player in the £100 billion market for semiconductors, it boasts great strengths in electronics systems design. We have Europe's largest independent electronics design industry as well as centres such the Institute for System Level Integration in Scotland.

An embryonic field of great interest is disruptive nanoelectronics. This area is of longer term industrial exploitation potential and supported through EPSRC's programmes.

The European Commission is developing a number of European Technology Platforms in this area, such as Photonics21 and ARTEMIS. We need to ensure that UK industry is well placed to exploit opportunities within Framework Programme 7.

To maintain understanding of developments elsewhere there is potential for a number of Global Watch Missions in electronics and photonics which will be complemented by UK Trade & Investment activities.

DTI maintains the UK measurement infrastructure, headed by the National Physical Laboratory. In a fast moving area of technology, it is important that R&D programmes in electronics and photonics are tasked to advance measurement knowledge to support the exploitation of future developments in these areas.

USER APPLICATIONS

Meeting the needs of users is critical for the UK to stay in the race in this sector. We plan to utilise findings from research to ensure that electronics and photonics developments are 'market-led' and adopt a holistic approach to ensure ideas are adopted and brought to market as swiftly as possible. Recently established Knowledge Transfer Networks on displays and lighting, sensors, and soon-to-be formed photonics, imaging and electronics will also exploit relevant technologies in the UK to increase applications and market ownership.

TECHNOLOGY PRIORITIES

ORGANIC ELECTRONICS AND DISPLAYS

Introduction

Organic electronics is an emerging field that is poised to disrupt the world of electronic circuits and display technologies. The term is used to encompass the area of semiconducting organic molecules, including polymers. The great advantage of semiconducting polymeric materials is that they can be printed directly onto large substrates without the need for the very expensive vacuum deposition equipment used for fabricating silicon semiconductors. Polymers can also be produced that emit light and form the basis for polymer light emitting diode displays which have the potential to be much lower cost and more energy efficient than liquid crystal displays.

Organic electronics will initially penetrate markets with simple, low-end products (such as backlights for displays in hand-held devices) but as the technology matures and improves in performance, will move rapidly up the value chain to address high performance, high value markets. It is important to note that the technology is complementary to conventional silicon-based electronics but allows the prospect of developing flexible circuitry for use in areas like flexible displays (sometimes referred to as e-paper), electronic RFID labels, intelligent packaging, bio-sensors, disposable electronics and intelligent textiles.

Organic light-emitting diode displays (OLEDs) are brighter, faster, lighter (in weight) and potentially more power efficient and lower cost than liquid crystal displays (LCDs). Apart from offering exciting possibilities for new ultra-thin, flexible and transparent displays, this technology also has potential applications in solar panels and imaging.

UK capability to develop and exploit the technology

The UK has an exceptionally strong academic base in this field, with 5-star university departments such as the Cambridge Cavendish laboratory and Imperial College and Southampton having world class activities. The EPSRC has taken a key lead in supporting university research in this area, for example via the recent award of a £3 million grant to the Cavendish for research into molecular and polymeric semiconductors.
Patent analysis indicates that organic electronics is a ‘hotspot’ in innovation activity in the UK, with research effort to date concentrated on the basic enabling materials and processing technologies. Within the National Measurement Programme, the National Physical Laboratory (NPL) is actively progressing the metrology and measurement potential of the technology through scientific groupings. NPL is also developing measurements (composition, photonic and charge transport) for nanoscale organic layers (see Annex 1).

The UK is also very well placed to exploit this technology, and is already host to many parts of the developing industrial value chain, with home-grown businesses like Plastic Logic and Cambridge Display Technology and Xaar having leading positions in developing and marketing early products. The UK lead in this field is also encouraging inward investment with companies like Epson, Kodak and Merck having established UK R&D centres in this field.

Working in partnership with the DTI, One North East is planning to develop a Plastic Electronics Technology Centre at Sedgefield which will develop relevant manufacturing technologies.

It is anticipated that within the EU Framework 7 programme (from 2007) there will be an active programme covering organic electronics.

The size of the global market opportunity

The worldwide market for plastic electronics and displays is estimated to reach $5 billion by the end of this decade and $10 billion by 2014. Given the UK’s current position at the forefront of academic and industrial research activity in this area, there is a realistic prospect of the UK capturing up to 30% of this market by 2014. Technology analysts such as GartnerGroup have estimated that there is an opportunity for new markets that could ultimately be worth over $100 billion, although this is a highly speculative figure.

Recognising this opportunity, companies in other countries, particularly in Asia, have significant activities in this field supported though government programmes. To maintain understanding of developments elsewhere there is potential for Global Watch missions to Japan and the US. To encourage investment and partnering UKTI missions to China, India and Brazil should be considered.

Potential for impact and timescale

It is clear that the UK has a significant R&D base in organic electronics. The major wave of innovation that started in the 1990s has been commercialised with varying degrees of success since then. Markets for organic electronics are expected to be large over a 10 to 20 year timescale, and there is a strong prima facie case for supporting the development of UK technology in this area in which the UK could be a significant player. An investment by the Technology Programme will make a real difference in putting the UK industry in a leading position in the exploitation of this disruptive technology area.

The technologies have now reached a state of maturity in which they can be developed to address the needs of specific products and markets. Support should therefore be directed to product and process innovation, especially in the field of display, RFID and lighting applications.

PHOTONICS, LASERS AND LIGHTING

Introduction

The market for systems dependent on photonic technologies is already worth over £100 billion, and predicted to rise three-fold or more over the next 10 years as such systems become even more pervasive. Historically, innovation in photonics and lasers was driven by the telecommunications and defence market with a few applications in consumer electronic products like CDs and DVDs. More recently photonics has diversified and moved into wider areas of consumer electronics, ICT, medicine and lighting.

Photonic technologies in the form of lasers are providing a range of invaluable tools for precision engineering, inspection, marking and lithography. The increasing performance levels of semiconductor lasers and other forms of solid-state lasers is continue to open up new markets for high-performance, high-efficiency, low cost products, many of which were previously only accessible to large, ‘conventional’ gas laser systems.

Photonics technologies associated with high power and efficiency LEDs are closely aligned to semiconductor laser technology and are creating a range of applications, particularly in energy efficient lighting. There is increasing pressure to improve the efficacy of light sources as iIt is estimated that at least 20% of the world’s electricity production is consumed by lighting. In addition, many existing light sources contain toxic materials like mercury;, a material that will be phased out by increasingly stringent environmental legislation. There are, therefore, pressing needs to develop more efficient light sources and large area lighting panels, possibly, employingpossibly employing organic semiconductors. As the cost of high brightness LEDs declines, their deployment will increase.

Photonics is playing an increasingly important role in healthcare, where techniques such as laser surgery and photodynamic therapy are already important. New developments like terahertz technologies are expected to have a major impact, and many of the recent approaches to genomics, proteomics, pharmaceutical screening and biomedical diagnoses also rely critically on photonic technologies. Lasers have become essential as part of the capillary electrophoresis systems used for DNA sequencing.

Other applications of optics to biotechnology range from sophisticated systems using ‘DNA chips’ to simpler systems using transmission probes. Minimally invasive and robot-assisted surgery is only possible using miniaturised solid-state cameras for endoscopic imaging (‘pill camera’) and solid-state illumination.

Photonics is also key to the next generation of broadband communications systems. The backbone of the Internet is optical, and scaling with advances in lasers and switching technologies. The major challenges though will be in developing cost effective components and architectures that will support the hundred-fold growth of bandwidth to the user that the market is likely to demand within the next decade.

UK capacity to develop and exploit the technology

The UK has a long-standing reputation for world-class laser research, including groups at the Clarendon Laboratory, Heriot-Watt, Imperial, Southampton and St Andrews. Industrial activity in the UK in lasers is mainly concentrated in small companies that address specialist markets, many of which originally can be traced back to university spin-outs;: companies like Oxford Lasers, Rofin-Sinar, Powerlase, Elforlight, Cascade, Mesophotonics and Southampton Photonics.

The UK also has significant industrial and academic activity in many parts of the medical/biophotonics supply chain. World-class science and research activities exist in University groups like St Andrews, University College London, Strathclyde's Centre for Biophotonics, Imperial College and Aston. Industrial activities range from large inward investors such as GE Healthcare to small companies such as Teraview, Spectrolab and Evanesco that provide specialist components, systems and services to the medical sector. EPSRC recognises the importance of biophotonics and have has engaged the UK's academic community in a series of relevant projects as a precursor to possibly establishing a more formal, managed programme.

Historically the UK has been very strong in the field of optical communications. This sector was badly hit following the downturn in telecomms markets in the early 2000s but has since recovered somewhat and the UK has the potential to compete strongly in the reviving market. Examples are Bookham who have been leading the consolidation in the optical components space and IQE which is the leading global player in the manufacture of compound semiconductor wafers

In addition, the UK has particular strengths in LED light unit design, fabrication and system concepts, and a strong position in organic LED technology which could provide a longer term opportunity. NPL is actively progressing the metrology and measurement potential of lighting and LED technology and areas such as fluorescence characterisation through scientific groupings. They are developing measurements (composition, photonic and charge transport) for nanaoscale and micro systems. Greater involvement in “technical and quality standards” was recommended by a UK roadmap.

NPL is actively progressing the metrology and measurement requirements of photonics, lighting and laser technology. The laboratory's work covers areas such as bio-healthcare characterisation (bio-photonics) and the measurement of data rates in optical networks. NPL is developing measurements (composition, photonic and charge transport) for nanoscale and micro systems.

The size of the global market opportunity

The worldwide market for photonics components and enabled products in 2004 was worth more than $230 billion. Market forecasts estimate that the total photonics market value will expand to over $500 billion by 2015 with an average annual growth rate of between 10 and 15%. Within this the largest share was displays and components with other applications showing longer term potential.

One market report indicates that the market for high brightness LEDs is projected to grow from $4 billion in 2005 to over $7 billion in 2009. Beyond that, the market is likely to grow to more than $20 billion as LEDs progressively replace conventional lamps. Typical applications have included traffic signals, large outdoor single-colour and full-colour signs, automotive exterior and interior lighting, and LCD display backlighting. As a result of technical progress in compound semiconductor materials such as InGaAlP and InGaN, which has led to increased efficiency, and lower cost, LEDs have also begun to address a number of lighting applications such as architectural lighting and illumination for signage.

Another market of great potential is medical equipment and biophotonics, though market forecasts that span the whole spectrum are difficult to access. butHowever, as an example to illustrate its potential size, NEXUS predicts that the world market for bio-medical microsystems will exceed $10 billion by 2006. Other estimates from the Foresight EEMS project give an indication that the UK could capture between up to $5 billion of the market for integrated lab-on-chip systems. Such systems provide a platform technology for a number of multi-diagnostic applications including diabetes treatment, health monitoring, drug targeting and cancer detection.

There is potential for Global Watch Missions to several locations including Taiwan and Korea. To encourage investment and partnering, UKTI missions to China should be considered.

Potential for impact and timescale

Photonics, lasers and lighting form a rapidly developing area where the UK has a significant technology and market base. Photonics R&D is highly interdisciplinary, involving electronic engineers, physicists, chemists, life scientists, software engineers and human factors specialists. An investment by the Technology Strategy would make a real difference in putting the UK industry in a leading position in the exploitation of these technologies. It would catalyse projects which bring together players in the supply chain, from materials suppliers to end-users.

The UK has a significant R&D base in the area of photonics and lasers related research. Markets for products deriving from these underpinning technologies are expected to grow significantly over the next 10-20 years, and there is a very strong case for supporting the development of UK technology. It is an area where UK industries have much to contribute and potentially much to gain. On the subject of lighting, a recent market transformation report sponsored by Defra identified that around 20% of the UK's total energy usage was currently consumed by lighting and there is a pressing need to improve the luminous efficiency of light sources. Government support at this stage could provide a timely stimulation to industry and the research base to address an area with the prospect of substantial commercial and environmental benefit. This is a rapidly developing area in a state of great flux. An investment by the Technology Programme will make a real difference in putting the UK industry in a leading position in the exploitation of these technologies.

On the subject of lighting, a recent Market Transformation report sponsored by Defra identified that around 20% of the UK's total energy usage was currently consumed by lighting and there is a pressing need to improve the luminous efficiency of light sources. Government support at this stage could provide a timely stimulation to industry and the research base to address an area with the prospect of substantial commercial and environmental benefit.

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Within Europe the Photonics21 Technology Platform was recently launched by the Commission which illustrates the importance of this area. Support for this field within the Technology Programme would help UK industry to fully exploit this field within Framework 7.

SENSORS AND IMAGING

Introduction

Sensors and Imaging systems provide the basis for many of the detection tools in medical, security, industrial and engineering applications. Novel sensor technologies often derive from areas initially investigated for other applications.

Recent examples include fibre optic accelerometers and hydrophones and the use of silicon ICs as imaging and sensing elements. Furthermore, many sensor markets, such as automotives are cost sensitive and conservative so the historic rate of acceptance of innovation has been slow.

Key activities in the UK that have been prioritised in recent years have included:

- 'Lab-on-a-chip' – development of advanced chemical and bioparticle analysers on silicon chips using microfluidic or electro-kinetic manipulation techniques and biosensor techniques.
- Detectors – increasing specificity, development of very large arrays of detectors and strategies to integrate rapidly different kinds of information from multi-modal detector arrays.
- Image processing and image analysis – including machine vision and image processing, medical imaging and image recognition.
- Sensor and control systems – sensor materials, transducer technology control systems engineering and non-linear control and learning engineering systems.
- Sensor robustness – development of robust sensors specific to widespread uses in extreme conditions for monitoring chemicals and physical parameters in the environment (e.g. polluting gases, liquids and particles).
- Miniaturisation – developing micro- and nano-sensors with very low power demands for applications such as implantation in medical monitoring.

Imaging research encompasses both generic research on the development of image capture technologies through to the processing and analysis of the captured images.

Imaging systems will find applications a variety of sectors including:

- Medical imaging – a particular UK strength.
- Business applications such as text and signature recognition.
- Machine vision for manufacturing and NDT techniques.
- Transport.
- Pattern/feature recognition and surveillance (crime prevention and detection).

UK capability to develop and exploit the technology

Sensors research is very broad-based and the research and industrial communities is relatively fragmented, partly because sensors research is focused either on the basis of sensor technology or its application.

Key enabling sensor technologies include sensor data fusion, systems integration to turn transducers into functional units and the development of novel sensor materials. UK centres of research excellence include Oxford, Southampton, Heriot-Watt, Loughborough, Warwick, Manchester and Leeds.

Applications of imaging are numerous and varied and the generation of new image analysis algorithms often takes place in parallel with the development of the application. Major UK centres of academic activity in image analysis include UCL, Surrey, Oxford, Heriot-Watt, Edinburgh and Manchester.

The UK has been particularly active in the field of image processing/capacitive sensor combinations for fingerprint and other biometric identification applications.

UK control systems research has a high international profile, and there is considerable potential for the integration of improved control systems in engineering applications. Much of the academic focus to date has been on control systems theory, and a key issue is to develop an effective system integration approach. Major centres of activity include Leicester, ICSTM, Cambridge, Manchester and Glasgow.

There are well over a dozen UK medium-sized industrial companies (industrial and domestic sensors) and numerous SMEs in the UK supplying and supporting sensor and imaging systems.

The size of the global market opportunity

Markets are very broad and diverse, and given that application areas range from familiar mass-production automotive sensors to astronomical instruments for spacecraft, a global figure is hard to estimate.

A report from 2004 forecast that US demand for sensors, $9.5 billion in 2003, will grow 8% annually, driven by sales of more advanced types used in motor vehicles, consumer electronics and information technology. Products such as proximity and positioning sensors, complementary metal-oxide silicon (CMOS) imaging sensors, and micro-electromechanical systems (MEMS-based) sensors will predominate. Another report estimated the global CMOS imaging sensors market would increase from $2.4 billion in 2004 to $5.6 billion by 2008.

Sensors for use in homeland security, particularly in the US, are receiving massive funding and the market will exhibit rapid development during forthcoming years. In the longer term, nanosensors, i.e. sensors based on nanotechnology, offer strong prospects and several have already been commercialised. Global markets for nanosensors are expected to rise to $2.7 billion by 2007. Overall, the sensor market is in a highly dynamic state and offers strong prospects for companies with access to advanced technology.

Within the UK, the MoD estimates that it spends a considerable percentage (maybe as much as 26%) of its procurement budget on sensors and sensor systems of one sort or another. There could be significant benefit to UK-based industries by aligning industrially focused R&D activities to applications that have dual-use applications.

EPSRC is supporting a wide range projects with sensors, imaging and instrumentation content under the Basic Technology Programme. A recent study of gas sensors research in the UK showed that there were 47 groups at 34 universities active in the field, of which a good proportion were collaborating with industry.

The 2003 Foresight Sensor Task Force indicates that at least 60% of the sensors manufactured in the UK are exported, resulting in a positive balance of trade running at 10-20% of annual sales. This ranks the UK in fourth position, behind the USA, Japan and Germany. Within the UK over 3,000 companies are engaged in sensor technology, employing around 80,000 people. The UK is well placed to capture up to 25% of the world market for security imaging technologies within the next five to 10 years.

Global Watch Missions have supported a visit to the USA in 2005 to evaluate the UK strengths in wireless sensor networks (WSN) and WSN have been tipped as a topic within the future FP7 programme.

Potential for impact and timescale

Sensors and imaging technology drives a broad range of applications from systems incorporating instruments and sensors for research to embedded industrial sub-systems and components. Thus these technologies underpin, for example, instrumentation, control and automation and many other applications for sensors.

Sensors are at the beginning of a complex supply chain involving detection, measurement and control in end-user applications. The value added down the chain can be one or two orders of magnitude greater at each stage. By providing the essential first step in meeting a functional requirement, sensors have high value in both economic and intellectual terms.

The combination of sensors and imaging with electronics systems requires generic skills in which the UK is rich and software, electronics and systems considerations are significant challenges in many applications. The UK has historically been successful in commercialising nationally funded research in the field of sensors and measurement. But while within the UK there are islands of achievement, overall, the sensors and measurement industry in the UK does not appear to be growing as fast as the global market.

Since the advanced research activity stimulated in the last few years by Foresight is expected to emerge in the commercial domain in 2015, complementary support for and encouragement of related applied research and product development would be particularly timely now.

ELECTRONICS DESIGN AND EMBEDDED SYSTEMS

Introduction

Electronics Systems design involves the design of electronic products and their constituent electronic component parts such as semiconductors. It also covers aspects of the design process including issues such as manufacturability and testability as well as the base functionality. The semiconductor chip, usually but not invariably silicon, is typically the key to electronic products and usually the most complex part to design.

Electronic design is a significant UK industrial strength, indeed, it is frequently claimed that the UK has 40% of Europe's independent electronics design houses. The Electronics Innovation and Growth Team (EIGT) recognised Electronic Design Automation (EDA) as an important area for the UK. Successful electronics design underpins all electronic equipment, including wired and wireless telecommunications, computing, instrumentation and control and medical electronics, plus 'non-electronics' sectors that increasingly depend on electronics, such as automotive and aerospace.

While the UK is still one of the largest players in the area of electronics design outside of the US, there are increasing threats to the UK systems design industry from relatively low wage cost economies (India, China) and from countries that see design as a strategic addition to existing industries like semiconductor manufacturing (Taiwan, France).

The electronic design function could best be supported by stimulating the development and use of system-level design tools for systems, semi-custom devices like field-programmable gate arrays (FPGAs) and application specific integrated circuits (ASICs).

The Electronic System Level (ESL) design field focuses on optimising the design of systems, rather than that of individual components. The aim of ESL is to provide a means of specifying and optimising a design at a high level prior to hardware/software partitioning with those portions selected for implementation in hardware subsequently being synthesised efficiently and automatically into a lower-level description that can be used directly to create a chip.

ESL design aims to enable complex products to be designed more quickly, with lower risk and at a lower design cost than is attainable with conventional design paradigms. It seeks to enable system and software designers without traditional hardware design backgrounds to implement directly digital hardware designs in silicon.

The UK capacity to develop and exploit the technology

The UK is home to development teams of major multinational players like Cadence, has a sound and diverse academic ESL design sector (Oxford, Bristol, Southampton, Cambridge, Edinburgh and ISLI, for example) and a plethora of smaller players – many of them academic spin-outs.

A key UK strength is the range of design activities. This includes OEMs and semiconductor companies with in-house design teams: Philips Semiconductor and STM have large teams in UK. There are the so-called 'fabless semiconductor' companies that undertake all of the product design but sub-contract the manufacture: world-leading examples are Wolfson Microelectronics and Cambridge Silicon Radio. There are the 'chipless' semiconductor companies that licence design building blocks (or intellectual property, IP): an example is ARM Ltd, the world-leader in microprocessor core IP. Many of the world's CAD tool suppliers have development facilities in UK: examples are Mentor Graphics, Cadence and Zuken. There are also centres of excellence such as the Alba centre, dedicated to systems on chip technology. There are also strong industry associations which are actively addressing how to address the future needs of the UK's electronics design community and plans to create an Electronics Knowledge Transfer Network.

In Scotland participants in the FPGA High Performance Computing Alliance (FHPCA), made up of top academics, Scottish Enterprise, Scottish SMEs (Alpha Data Parallel Systems, Algotronix and Nallatech for example) and global computing experts intend to work together to build supercomputers which are capable of processing one trillion instructions per second.

The size of the global market opportunity

The world market for electronic equipment already exceeds $1 trillion and, following the industry's worst ever downturn, is now forecast to grow at some 8% in financial terms for the foreseeable future. Design accounts for a significant and growing proportion of this market as systems increase in complexity. Semiconductors accounts for some $140 billion world-wide and is forecast to grow at around 15% pa reflecting a continued rise in semiconductor content of the equipment.

The market for wireless communications, highly dependant on the ability to design complex silicon-based electronics, is growing rapidly. Examples include mobile personal communications, with systems such as 3G and Bluetooth now evolving and future developments under way. The electronics content of an automobile now averages some 25% of its production costs and this figure is expected to rise to 40% by 2010 due to the application of more sophisticated controls in engine management, drive train, ABS brakes, steering, tyre pressure monitoring and many other functions.

To encourage investment and partnering UKTI missions to China and Taiwan should be considered.

Potential for impact and timescale

Based on the foregoing, the following are considered priorities areas:

- CAD tool design, and design methodologies involving topics such as formal methods, verification (incl simulation), high level design, design for manufacture, design for test, auto-routing (of layout)
- Novel circuit architectures, including self-organising systems, self-repairing systems, massive parallelism
- Circuit techniques such as asynchronous design
- Tools to enable distributed design (using e-grid infrastructure)

Electronics design projects are supported by EPSRC but these tend to be application or discipline specific. Around 20 UK universities have had involvement in these projects. Research projects with high electronics design content, are important as 'electronics' becomes a greater proportion of the cost of a product.

Electronic design technology can often be transferred to civil and military applications and MoD is a major developer and user of electronic design within its procurement requirements for defence systems.

The importance of maintaining and strengthening activities in the high value-added area of electronics design has been recognised by the industries and Member States of the European Union. Building on a base of industry-led initiatives like MEDEA+ and ITEA the European electronics industries are working under the aegis of a European Technology Platform called ARTEMIS to ensure the importance of this are is fully recognised and supported. A complementary UK focus on this increasingly important area would help to ensure that our UK industrial and academic base is maintained at a sufficient level to compete with and work alongside their European counterparts.

ANNEX 1: ELECTRONICS AND PHOTONICS MEASUREMENT STANDARDS ISSUES THAT MAY LIMIT DEVELOPMENT/ EXPLOITATION

Organic electronics and displays

- Characterisation of optical and electrical properties of polymer materials are key to improving the efficiency of organic electronic devices; measurements include electronic transport, refractive index and loss.
- Organic electronic device operation is strongly dependent on the material properties of organic multi-layer structures, creating three dimensional electrical, optical and material measurement challenges.
- Understanding polymer lifetime is essential for greater deployment and requires further measurement of diffusion rates, interfacial mixing, changes with device operation, variation between deposition methods and processing conditions.
- Displays utilising polymer technology offer curved and flexible panels creating new measurement challenges for luminous output and operation under difficult ambient conditions.

Electronic design

- Circuit manufacture from concept to production is increasingly dependent upon simulation and modelling tools, placing a significant reliance on greater model verification and validation through traceable measurement.
- Next generation integrated circuits will require new architectures with higher packing densities, increases in operating frequency and optical or nano-electronic solutions. Effective design will require improved measurement data for the physical structures and electro-optical properties of fabrication materials, complemented by new methods to characterise embedded node operation, cross-talk, interconnect coupling efficiency, packaging effects and top-level device performance.
- The effects of temperature, new lead free solders, new substrate materials and flip chip-techniques will lead to complex cross-related lifetime and performance issues which require greater measurement data for effective design.
- Mixed signal chips incorporating electrical, optical and biological sections will require new approaches to measurement.

Photonic technologies

- Understanding and identifying contrast mechanisms in bio-healthcare imaging requires new approaches and measurement information in the optical and electromagnetic parts of the spectrum.
- Higher data rates in communication systems will place demands on conventional time and frequency domain measurement techniques for optical-electrical conversions and potentially all optical networks.
- Measurement of laser power, beam profile, pulse length and shape are key for effective deployment from mechanical machining to healthcare therapy and diagnostics.
- Distributed optical sensor systems relying on the existing optical backbone, require new approaches to measurement and calibration for successful duplex integration and quality of service. (Examples exist in transport management and telematics.)

Sensing and imaging technologies

- Imaging standards are required for the characterisation of biological systems from a few-cells to the whole body, in conjunction with regulatory groups such as MHRA, HSE and potentially the FDA.
- End to end capture, display, storage and reproduction of images in 'true' colour, offers significant challenges, particularly if data compression is used.
- Muilti-modal imaging and diagnostics presents new challenges in data interpretation, display and verification.
- Three-dimensional displays for medical diagnosis, machine visions and security offer challenges in validating contrast, colour and geometry under difficult ambient lighting conditions. Human factors require verification for user perception, usability, visual comfort and methods of specification for the technology all require addressing.
- Virtual reality systems as constructional tools require analytical techniques to verify user interaction and usability, but also simulation accuracy.
- Display aging and reductions in image contrast will have safety critical effects on healthcare diagnosis and long term records, reliable methods for characterising aging is essential.

Solid state lighting

- The measurement of radiance, illuminance, (spectral) goniometric and spatially resolved outputs from new solid-state systems for compliance with safety and specification standards.
- Increases in efficiency and reliability of current solid-state lighting and next generation combined photo-voltaic/solid-state devices can be achieved through measurement.
- Techniques are not fully developed for traceability of all solid-state lighting parameters and further work is required to compete effectively with foreign suppliers and support sub-component.
- Work to establish common internationally agreed standard test methods for some of above also a potential barrier, still some debate regarding the use of CIE or IEC based regulations (lamp or laser) the former is likely to be adopted.
- Eye and health safety critical measurements require new approaches to deal with the source size, spectral content and intensities of solid-state lighting.