NATIONAL SCIENCE AND TECHNOLOGY FORUM (NSTF)
In partnership with the
COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)
and the
DEPARTMENT OF SCIENCE AND TECHNOLOGY (DST)

LIGHT-BASED TECHNOLOGIES INNOVATION FORUM
14-15 MARCH 2016
EMPERORS PALACE CONFERENCE CENTRE, KEMPTON PARK, GAUTENG

TABLE OF CONTENTS

DAY 1: CHAIRMAN: DR NDUMISOCINGO (CSIR)

WELCOME AND PURPOSE OF THE MEETING (MS JANSIE NIEHAUS (NSTF) AND DR NDUMISOCINGO (CSIR))

Ms Niehaus and Dr Cingo welcomed attendees to the discussion forum.

The theme of the forum followed that of the 2015 International Year of Light and Light-based Technologies (IYL 2015) proclaimed by the United Nations. The discussion forum was a collaborative effort between the CSIR's National Laser Centre (NLC) and the NSTF, funded by the Department of Science and Technology (DST).

The IYL 2015 was a global initiative to raise awareness of the role of optical technologies in promoting sustainable development and providing solutions to challenges in the areas of energy, education, agriculture, food security, communications, health and others. The current event was one in a series supported by the DST in celebration of the IYL 2015. The aim of the event was to bring together society, industry, the research community, higher education and government to discuss the opportunities presented by photonics focussing in particular on the opportunities within three main areas of application: solar renewable energy, additive manufacturing (AM) and fibre optics (or optical) communications. The objectives of the event were to:

- Raise awareness of how optical technologies provide sustainable development and solutions to national challenges, particularly through application in the three main areas
- Explore opportunities presented by optical technologies in these areas
- Determine the steps to be taken by various stakeholders to enhance and exploit opportunities within South Africa.

The anticipated outcomes of the event were:

- To raise awareness of the key advances in optical technologies as applied in many spheres of society
- To raise awareness of the key sources of funding for activities ranging from research and development to commercialisation of optical technologies
- To enhance knowledge of national strategies (approved or under development) in support of activities in photonics for the enhancement and exploitation of identified opportunities
- To identify specific actions to be shared with relevant stakeholders ranging from industry to education and research as well as government in order to facilitate the realisation of opportunities discussed and presented during the course of this forum.

The programme included breakaway sessions during the afternoon of Day 1 and panel discussions on Day 2 would address points raised during the breakaway sessions and identify concrete actions to be taken forward.

GENERAL TALK ON LIGHT AND ITS ADVANCES (PROF. MALIK MAAZA, UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANISATION (UNESCO) UNIVERSITY OF SOUTH AFRICA (UNISA)/ITHEMBA LABS AFRICA CHAIR IN NANOSCIENCES AND NANOTECHNOLOGY)

The African Laser Centre, a virtual facility that was established as an extension of the NLC in 1999, had achieved much with minimal funds and was exemplary in terms of excellence in Science and Technology (S&T) in Africa.

Prof. Maaza shared the journey of light through history and the role of light in everyday life. Optics and electromagnetism are driven by perception. Light is not merely the visible part of solar emission but includes the broader photonics spectrum. The eye has a specific configuration and is proof of the power of light. Further proof of the power of light is the process of photosynthesis, which is extremely effective in CO_2 reduction.

Ibn al-Haytham, an Iranian scientist from the 11th century AD, is prominent among the masters, ambassadors and pioneers of optics through the ages and is recognised at the father of optics as he adequately described the propagation of light.

Time is defined according to light. It was unfortunate that Africa did not have a high precision atomic clock and European and American time was used for purposes of Global Positioning Systems (GPS) in Africa. This should be addressed by the DST, the NLC and the African Laser Centre.

Optics and light helped explain the nature of any living species through the discovery of gene sequencing and detect gravitational waves, and formed the basis of a wide range of familiar technology, such as barcode scanners, cellular phones, computer and TV screens, telecommunication, sensor technology, and laser and microscopes for medical purposes.

Photonics refers to the development of technologies based around the application, manipulation and use of light. The photonics industry represents a million dollar market, with core photonics components and materials producing revenue of 156 billion USD from 2750 companies (mostly in Europe) and creating 700,000 jobs. Photonics is used in the following areas of production:

- Communications and optical storage
- Materials processing and lithography
- Medical and aesthetic
- Instrumentation and sensors
- Scientific research and military
- Entertainment and displays.

South Africa has contributed substantially to the world in terms of the science of photonics and light, and this country has the expertise (particularly in terms of laser) and the potential to build a strong photonics industry.

ADVANCED MANUFACTURING TECHNOLOGY ROADMAP PROJECT: PHOTONICS (DR FRANCOIS PRINSLOO, CSIRNLC, KEY CO-ORDINATOR: PHOTONICS ROADMAP AND TASK TEAM LEADER: DST'S ADVANCED MANUFACTURING TECHNOLOGY ROADMAP PROJECT (AMTRP))

The photonics roadmapping exercise, commissioned by the DST, aimed to guide the DST's Research and Development (R&D) programme and seek alignment with industry priorities, bridging the gap between research and commercialisation and taking cognisance of the triple challenge of poverty, inequality and unemployment. The exercise was preceded by the Photonics Initiative of South Africa (PISA) and the National Strategy for Photonics, which laid the foundation for photonics in this country particularly within the research community. Photonics spans a wide spectrum of industries within three main areas: Core photonics components and materials, photonics products and photonics enabled products. Photonics was one of the six key enabling technologies defined by the European Union (EU) and the photonics market was expected to grow to 615 billion Euros by 2020.

A series of workshops and surveys with participation from 50 organisations and 100 attendees from industry, science councils and higher education institutions (HEIs) began in April 2015. The roadmapping process looked at trends and drivers of photonics, and identified applications and technologies and a knowledge base to develop the applications, as well as the resources and enablers required to drive that process, bringing these together with the current status to develop a vision for the future of photonics in South Africa.

In South Africa more than R2 billion of revenue is generated from photonics related activities, the sector employs approximately1870 people in Science, Engineering and Technology, the infrastructure is worth about R2.5 billion and the R&D spend in photonics is in the area of R285 million. There is an abundance of opportunities for growth in the area of photonics in this country.

The four most important areas where photonics could make a significant contribution as far as advanced photonics manufacturing was concerned were identified in the roadmapping exercise. These are:

- Systems, sensors and sources
- Renewable energy
- Industrial manufacturing
- Life Sciences and Health.

Although lighting and displays and Information and Communication Technologies (ICT) were also identified as important sectors, South Africa is currently dependent on imports and little work was being done to develop products and technologies in this country. In addition, technology transfer into industry remained problematic in these areas. Emerging technologies is another important sector of photonics where market penetration and skills development are problematic.

Major enablers and resources for photonics were identified in the roadmapping exercise.

The draft Photonics Roadmap will be presented to the DST in March 2016. Further inputs to the draft document are welcomed. The roadmap was a living document that will adapt to changes over time and be updated regularly.

PHOTONICS PROTOTYPING FACILITY (PPF) (DR ANGELA DUDLEY, CSIRNLC)

The PPF is funded by the DST and the CSIR and open to the broader photonics community. The facility was established in recognition of photonics as a key economic driver and the extensive growth in the photonics industry globally.

South Africa currently has a miniscule impact on the global photonics industry. Factors contributing to this included: limited collaboration between HEIs and industry, a lack of automation in manufacturing processes and of manufacturing capabilities, domination by imports, low local content, a lack of uptake of South African technology and minimum Research, Development and Innovation (RDI) in the country.

The purpose of the PPF is to facilitate the development of prototypes which result in products that satisfied a market need associated to photonics-based technologies and devices. Problems leading to a lack of prototype development within South Africa include the lack of skilled manpower and cohesion of resources that were needed to industrialise technologies, the lack of infrastructure and facilities for developing technologies to a market-ready state, and lengthy timeframes to take products to market. To address these problems, the PPF aims to create new enterprises and a skilled workforce in terms of product development in photonics, stimulate global exports aligned to the photonics industry and improve industry competitiveness by shortening time to market. These actions will lead to increased revenue and the replacement of imported technologies with locally manufactured technologies.

The PPF as a national facility for photonics prototype development will bridge the gap between research and commercialisation by assisting technology participants (HEIs, science councils, industry, entrepreneurs) through an optimal and iterative process closely aligned with the market to develop prototypes and bring them to a state of market readiness. The PPF provides the necessary infrastructure and equipment, technical skills (including an intern programme) and business development and funding networks to realise this, leading to the licensing of new technologies to industry or the formation of small, medium and micro-sized enterprises (SMMEs).

The PPF's location within the CSIR allows for cohesion across multiple expertise and access to pockets of excellence. The governance structure and assessment criteria follow the CSIR framework, with a manager responsible for the day-to-day operational management of the facility. Advisory bodies include a steering committee and a project selection panel that provide strategic direction and ensure alignment with industry needs. Flagship programmes assist in streamlining the business model as well as the cost and revenue structures of the facility.

A call for proposals will be sent out once the committee selection and appointment processes are finalised in May 2016. The steering committee has the final say on the projects featured within the facility and the approved projects will commence early in 2017. Screening criteria focussed on the clear application to industry and commercial relevance, and proof of concept has to be demonstrated. The PPF's activity will be integrated into the photonics roadmapping initiative.

The PPF could be contacted for further information, discussions or to arrange a tour of the facility.

FIBRE OPTIC COMMUNICATION: THE ULTIMATE SPEED LIMIT FOR BROADBAND INTERNET (DR SANDILENGCOBO, CSIR)

Fibre optics is the technology of sending coded information in a beam of light through glass tubing. The technology was developed in 1950 for use in endoscopes for medical purposes. The use of this technology to transmit telephone calls at the speed of light was discovered in the 1960s. A fibre optic cable is made up of incredibly thin strands of glass or plastic known as optic fibres. One cable carries about 144 strands of optic fibres, is less than one tenth of the thickness of a human hair and carries about 25000 telephone calls.

Optical fibres carry light signals in modes describing the wavelength, the shape of the light beam and the path followed by the light down the fibre. A single mode fibre has a very thin core and the light does not bounce of the edge but travels straight. Cable TV, internet and telephone signals are carried through this mode. Multi-mode fibre is slightly thicker and is able to carry a multiple of laser beams. Fibre optic cable can carry information over hundreds of kilometres using entirely light based technology.

American Standard Code for Information Interchange (ASCII) represents text in computer language (binary code), which is sent through optical fibre by using a transmitter and at the receiving end, the binary code translated through an electrical signal. This occurs at the speed of light. Internet broadband speed is increased by increasing the capacity of the fibre optic cables.

Three components are necessary in order to achieve the ultimate speed limit for broadband internet: the terminal bandwidth capacity of optical fibre, the ability to route packets of data at ultra-high speed and economics. The theoretical limit of data transmission for optical fibre is known as the Shannon Limit and is the maximum rate at which the signal can be sent over an optical fibre with zero error. In 1998, the widely accepted upper theoretical limit for the industry standard of single mode optical fibre was about 400 gigabits per second and the practical limit was about 100 gigabits, with about 40 channels each at about 2.5 gigabits. Today, there is single threaded transmission in enterprise grade equipment and deployment is in multiple channels of 100 gigabits. The current limit is thought to be about 500 terrabits. In 2014, Alcatel NET reported the fastest ever broadband speed of 1.4 terrabits per second, which is enough to send 44 uncompressed high definition films a second over existing broadband fibre cables covering a distance of 410 kilometres.

The intended contribution of the CSIR towards increasing internet broadband speed was through the transmission of binary codes in bits. Each binary code would be assigned a certain value and sent to a digital laser source, which would distinguish the electrical current and allocate a different shape when coupled to a fibre. The data should be able to be received through a fibre and the same value assigned back and sent through. This new way of thinking implies that instead of sending information in bits, it is reprocessed before being sent through a fibre in bit format. This would automatically increase the bandwidth, possibly by more than a factor of seven.

The ultimate speed for broadband internet was still uncertain.

LIGHTING THE FUTURE: FOCUSING ON LUMINESCENTNANOMATERIALS AND THEIR APPLICATION (DR MARTIN NTWAEABORWA)

Phosphors are chemical materials that emit light when exposed to high energy particles such as photons, electrons or x-rays. Dr Ntwaeaborwa's research is based on nanoscience and nanotechnology in the preparation and application of phosphors, creating new and different types of phosphors that are chemically stable in order to improve light emissions or the output of phosphors, which could lead to more cost effective, better performing and durable light emitting devices.

The physical appearance of phosphors is in the form of powder or thin film, made up of microscopic particles. Different types of light can be generated by exciting the powder with electrons or photons. The size of the particles can be increased or decreased to change the colour depending on the application. When particle sizes become smaller, the height and energy difference between energy levels increases.

Methods of preparing phosphors include one pot synthesis, sol-gel method (SiO_2) and combustion. Characterisation of phosphors looks at the broadening or narrowing of the peaks and the shape and size of particles.

Applications of phosphors include:
- Light emitting devices, such as fluorescent bulbs, where phosphor transforms ultraviolet light into visible light. Light produced depends on the composition of the phosphor.
- Light Emitting Diodes (LEDs), which are traditionally used as indicators in different devices. Red, green and blue phosphors are used together to obtain white light. Phosphors are used as sources of light in LEDs in TV and computer screens, for example.
- Solar cell technology: Phosphors are prepared for use in conventional silicon and organic photovoltaic (PV) cells. Research was being done towards improving photon absorption in silicon as well as organic solar cells, which would improve power conversion efficiency.
- Phototherapy lamps used in the treatment of various skin diseases and cancers. Research was being done to improve the efficiency of the narrow band phosphor to avoid sunburn during treatment.

The research has been able to demonstrate that luminescence intensity of phosphors can be increased considerably by energy transfer from encapsulated nanoparticles to luminescent centres. By selecting a suitable host it is possible to produce phosphors that are chemically stable with 'non-degradable' luminescence intensity. Single host phosphors that emit white light have been produced.

Potential socio-economic benefits of the new and different types of phosphors created include low cost lighting, rural electrification, reduced cost of electricity and improved quality of life.

TECHNOLOGY COMMERCIALISATION (MS NONTOMBIMARULE, DEPARTMENT OF TRADE AND INDUSTRY (DTI))

The innovation value chain is made up of three phases: the concept phase, the development phase and the commercialisation phase. Specific commercialisation related activities and stakeholders play a role in each phase of the value chain. Most R&D-led innovation does not come from a direct demand or market pull and products of R&D tend to take a long time to reach the market. Industry partnerships and SMME development are only considered at a late stage in the value chain, in a high-risk space, creating a gap in the value chain, referred to as the 'innovation chasm'.

In 2014, the DTI brought together all the stakeholders in the National System of Innovation (NSI) to discuss ways to bridge the innovation chasm. The discussions led to the development of the National Technology Commercialisation Strategy, which is implemented by all NSI stakeholders.

The DTI's programme for incubation in technology commercialisation offers assistance with product development, target markets, venture assessment and Intellectual Property (IP) evaluation. DTI programmes that take the commercialisation process beyond incubation are the Technology and Human Resources for Industry Programme (THRIP), the Support Programme for Industrial Innovation (SPII), Technology Venture Capital (TVC) and the Incubation Support Programme (ISP).

The DTI proposed the establishment of a Technology Commercialisation Incentive with activity gates including prototype development, testing and validation, product development and small scale manufacturing. Techno-Industrial Clusters are linked to the Regional Industrial Development Strategy, geared towards high-tech (and therefore appropriate to the photonics industry), and used as a tool for sectoral growth and creating new technology-based industries. Specialised Industrial Facilities are geared towards low-tech and technological infrastructure programmes. Multi-stakeholder programmes include

Science Parks, Centres of Competence, Centres of Excellence, Special Economic Zones, Incubators, FabLabs, Accelerators and Tech Stations.

WRAP-UP OF THE MORNING'S PROCEEDINGS (DR NDUMISACINGO)

Dr Cingo highlighted the following from the morning's presentations:

- Prof. Maaza presented an overview of photonics globally and highlighted the potential available for the local photonics industry.
- Dr Prinsloo's presentation on the Photonics Roadmap highlighted the four potential areas that would be pursued (Systems, Sensors and Sources, Renewable Energy (particularly South African grown PV panels), Industrial Manufacturing and Life Sciences and Health) and the opportunities to grow the Lighting and Displays, ICT and Emerging Technologies photonics sectors in this country.
- Dr Ntwaeaborwa presented the work he is doing in creating new and different types of phosphors that are chemically stable in order to improve light emissions or the output of phosphors, which could lead to more cost effective, better performing and durable light emitting devices. The research done has potential to be taken further.
- Dr Dudley presented the PPF, a facility that serves the photonics community and bridges the innovation chasm with a focus on translating research into the commercialisation space and the opportunities in this regard.
- Dr Ngcobo spoke about the ultimate speed limit for broadband internet. The potential of ICT photonics sector should be considered for inclusion in the Photonics Roadmap as an area that should be pursued with vigour.
- Ms Marule presented the DTI's programmes that address the innovation gap, and the commercialisation phase of the innovation value chain. She defined the innovation value chain and identified problems particularly those related to commercialisation of R&D. Areas for further interaction with the DTI regarding various photonics related programmes (PPF, Photonic Roadmap) were identified.

DAY 2: CHAIRMAN: DR NDUMISOCINGO (CSIR)

EMERGING PHOTONICS RESEARCH AT UNIVERSITIES IN SOUTH AFRICA (PROF. ANDREW FORBES, UNIVERSITY OF WITWATERSRAND (WITS))

South Africa started to make lasers very soon after the laser was invented. Twenty years ago, two main groups were doing good work in uranium enrichment using very big lasers and high power lasers for applied projects. The programmes were amalgamated to form the NLC, pooling resources and expertise in the country. In 2004, considerable photonics material research was being done in the country. The CSIR and military companies, as well as several spin-out companies were making lasers. Fibre optics, particularly for sensors, was put on the map by the University of Johannesburg, which produced most of the graduates currently actively involved in this area of photonics. Fibre optics communication programmes at Nelson Mandela Metropolitan University (NMMU) mainly involve polarisation. New and emerging research fields in technologies such as femtosecond science, quantum photography, nanotechnology and biophotonics have begun to come to the fore.

The establishment of Research Chairs and Centres of Excellence around the country have ensured that certain centres have become very well known in various fields of photonics. The NLC played a strong role as a national facility providing opportunities for people to learn and experience a photonics laboratory and work with the experts. The NLC's equipment rental pool programme has been very successful. Today, South Africa has a very vibrant photonics community that has grown over the years. Given the success of growing photonics in South Africa, the NLC has been requested by government to mimic local programmes across Africa. The African Laser Centre has been established and supports various education and research programmes in Africa, but faces immense challenges.

Prof. Forbes started a research group at the CSIR in 2004 and introduced the concept of using digital holograms to create structured lights. He currently heads up the Structured Light Laboratory at Wits that works on digital holography, which is exploited for a range of applications. The laboratory was looking at how to mimic quantum transport, novel lasers, and how to pack information into light. A paper released recently was on a laser that generates shapes of laser beams to go through a particular fibre. Practical demonstrations of this technology would be done over the coming months.

The IYL 2015 presented an opportunity to promote photonics and light in general. This is the century of the photon and the photonics industry is growing rapidly. About ten years ago, at the start of the PISA, it there were good initiatives in government to move towards a knowledge economy. Although photonics research may be doing very well and a handful of people were doing pioneering work, this country does not have a photonics industry and does not have the capacity to compete internationally. The good research being done is not being taken forward. This remained a challenge. The photonics community needed to work together to resolve this problem and PISA needed to be revived.

BIOPHOTONICS (DR PATIENCE MTHUNZI-KUFA, CSIR)

Dr Mthunzi-Kufa's presentation showcased what is being done and the future work of the Biophotonics Programme at the NLC.

Biophotonics is a combination of biology and photonics and a multi-disciplinary field that uses photonics to study biological entities. Areas of application include: Life Sciences, Medicine, Agriculture and Environmental Sciences. The NLC focussed on the medical application of biophotonics through specific techniques, such as:

- Optical tweezing (moving nanometer and micrometer sized entities or materials)
- Optical guiding (moving particles within a sample)
- Optical sorting (sorting diseased cells from healthy cells, for example)
- Beam shaping and spatial light modulator technology (used to probe diseased cells at a genetic level, for example)
- Optical transfection (using different modes to give cells DNA that they do not already possess, changing those cells).

PANEL DISCUSSIONS

Additive Manufacturing (Panel: Mr Hardus Greyling (CSIR, NLC), Dr Mpho Madisha (University of Pretoria (UP)), and Dr Manfred Johannes (CSIR))

Mr Hardus Greyling

The AM Roadmap was approved by the DST in November 2015. AM, specifically the implementation of support programmes for additive manufacturing, is one of the national programmes within the NLC. About 50% of the AM technologies use light either in the mounting or the creation of an object or in terms of curing polymers for AM. Light plays an important role in process control.

According to the Wohlers Report, the global market for AM in terms of service and products was about 2.4 billion USD at the end of 2014 and has shown significant growth since 1993. Although there is huge potential for AM, the size of this market is miniscule compared to the conventional manufacturing technologies market. The main market applications include consumer and product electronics, and industrial and business machines. The fastest growing markets are in the aerospace and dental and medical sectors. The percentage of the total AM market globally that is used for final part production has grown from 3.9% in 2003 to nearly 42%.This excludes the metal market, which is still fairly small. The potential of this technology should be realised in all markets and there is a wide scope for new process technology development.

The focus areas for the AM industry through structured programmes over the next 10 years are:

- Medical and aerospace industry (complex, customised designs using exotic materials)
- AM for impact in the traditional manufacturing sectors (not to replace, but to significantly enhance conventional manufacturing)

- New AM material and technologies (local mineral resources and developing concepts in technologies that support AM)
- SMME development and support (removing barriers in order for AM to be adopted by industry)

The activities within the focus areas are supported by crosscutting initiatives with regard to skills development and education.

Dr Mpho Madisha

A focus area for AM in the country should cater for low-end AM that uses machines of between 50W to 100W.Customisation presents the opportunity for the low-end application to use AM in popular and novel ways, such as toy- and figurine-making. The skills set required could be a barrier to the use of AM, particularly in terms of the low-end application. People should not only be consumers of 3D printer materials but also be involved in the production of these products. Modelling and engineering skills are essential.

Dr Manfred Johannes

Dr Johannes is involved in non-destructive testing (NDT) of components that are made for engineering applications. Anything manufactured for the aircraft industry has to be qualified and certified. NDT requires that specific steps must be taken and be developed in parallel to the manufacturing process. This was a barrier to AM. A substantial investment would have to be made in this area in order for in-line inspections to be available. A further problem was the lack of material science. AM, NDT and material science all need considerable investment in order to be successful. The DTI should invest in this important area and scale of production should be a consideration.

Questions/comments

Ms Paruna, Institute of Inventors and Innovators: 1) In terms of the Fourth Industrial Revolution technologies, it was said at Davos that AM will not create jobs but will create democratisation of manufacturing. The DTI does not seem to be prepared for the competition from global forces.**2)** It is important for our innovators to be able to do prototyping of their inventions. Would it be possible to enter into collaborations with innovators? **3)** What about IP issues?

Response, Dr Johannes: 1) I do not agree with the view that AM will not create jobs. There is no upper level and novel ways will always be found. The capabilities youngsters have in working with technology are astounding. I have no fear for the future. This should be seen as an opportunity rather than a threat.
Even if we are not competitive, it is important to understand what is good and not to purchase bad quality products, such as the solar panels used in low-cost housing, which had to be replaced after five years because of wrong materials and the lack of basic design knowledge. Human capital development is crucial if this country is going to make the right choices and buy cleverly.**2)** Inventors are welcome to call me if an invention requires inspection.

Response, Mr Greyling: 1) It is necessary to strategically consider the areas to focus on and make the right choices made in terms of competitive advantage.AM, specifically aerospace and medical applications, is not linked only to new technology but also to the mineral resources available in this country. These need to be exploited. There are several programmes running parallel to AM initiatives looking at the use of titanium metal, which would make the technology globally competitive.
2) In terms of supporting innovators and inventors, there is a thriving makerspace movement in South Africa. A number of institutes and service bureaus, particularly the Vaal University of Technology and the Central University of Technology, have excellent facilities to support inventors and entrepreneurs to realise their designs. **3)** In terms of IP, clauses related to NIPMO and the IPR Act is applicable if government funding is used. When technology development at the CSIR is funded by a source other than government, the IP belongs to the inventor of the technology.

Response, Dr Madisha: 1) My opinion is that support into the makerspace was very critical in addressing job creation. Currently, makerspaces are limited and need to be promoted and supported particularly in communities where there is high unemployment. This would encourage more people to develop skills in AM, but it is not necessary to be skilled, or a qualified engineer to be part of a makerspace. A makerspace is an informal set-up where AM hobbyists and entrepreneurs gather on a regular basis and make tools and machines available for others who are interested in designing and creating models or making 3D printers to experiment with AM. Makerspaces present opportunities to develop entrepreneurs who set up their own SMMEs and contribute to the economy, and create a significant number of new jobs. In the future, AM will support the change in the supply chain of products and goods and eventually replace centralised manufacturing.

Mr James van der Walt, Ugesi Gold Renewable Energy: It tends to take a long time to certify new technology. Products from AM will be totally outdated by the time they are certified. How can this problem be overcome?

Response, Dr Johannes: Currently, a process is engineered and designed, then inspected to see if it qualifies. It will be necessary to start with qualification in parallel to technology development. This is difficult to do.

Response, Mr Greyling: 1) From an engineering perspective it is important to manage this process and go into lockdown of a particular design. The hype around AM needs to be managed. As part of the AM Roadmap, we have to rollout programmes of science and engineering communication. Clever ways need to be found to communicate the message about AM without causing hype because there are challenges too. Anyone who would like to participate in these programmes can contact me.

Unknown person: What is being done about the lack of skills in AM and what are the plans to equip people to use AM?

Response, Dr Madisha: AM must deliberately be included in the curriculum at university level. At UP, AM is included at the project level where students work in teams to make designs. They have access to the makerspace on campus. This is the best way to inculcate the skills needed for AM. The engineering field focusses solely on Computer-Aided Design (CAD), but some of the models created are more suited to Fine Arts. We also need to look at makerspaces and involve those who are not necessarily in a formal education institution. A lot of skills come out of the informal AM space. More of this needs to be encouraged.

Response, Mr Greyling: In the AM Roadmap, the makerspace is seen as part of the SMME development process. It is necessary to have technology development that drives AM from a high-end perspective, with the right mechanisms in place to support how this is pulled into industry.

Dr Cingo: **1)** The choice of focus areas in the AM Roadmap is good. However, plans to use titanium are still in the development stage and there is risk as to whether it will eventually work. Are there efforts to de-risk this process? If the processes do not work, would it be an advantage if we have to import titanium powders to support the industry that have been developed? **2)** To what extent is the DTI involved in and supporting the roadmap?

Response, Mr Greyling: 1) The question regarding titanium and local mineral reserves raises an important point. The AM community does not have control over this aspect but there are plans in place with regard to de-risking the material problem. All the work being done in the current research programmes makes use of commercial titanium materials and we have plans to get additional support equipment to assist with powder manufacture. It would be a big win for South Africa if the South African design for the commercial process to produce titanium works. **2)** A core team was driving the AM Roadmap and people from the AM group at DTI participated at this level. Presentations have been made to the DTI and the department is fully aware of the programme. DTI has a particular role to play in breaking down barriers for entry to industry.

The way forward

Dr Madisha: People at the lower-end of AM and in the makerspace should receive support as entrepreneurs. More makerspaces are needed, particularly in the context of some of this country's challenges. A deliberate effort needs to be made to place makerspaces in townships and rural areas, and where they are easily accessible. This will stimulate entrepreneurship.

Dr Johannes: As one of the few people in South Africa appointed in the fulltime research position in NDT, I believe we need to get positions for interns who can start doing NDT research. Research Chairs in NDT are essential in order to do NDT-related research.

Mr Greyling: There is a bright future for AM. However, industry-led research is essential for AM to succeed. The community is constantly reaching out to industry to guide the research. I support the view that we need to invest in entrepreneurs and SMMEs and this is why the makerspaces are so important. Discussions about how to get additional funding into this environment were necessary. South Africa has a very vibrant AM community that is growing faster than the AM products and services market. The AM industry association, Rapid Product Development Association of South Africa (RAPDASA) holds annual conferences, with more than 250 people participating in 2015, most of them from industry.

Solar Energy (Panel: Dr Kittessa Roro (CSIR), Prof. Malik Maaza (UNISA/iThemba Labs), Dr Mmantsae Diale (UP), Mr Dominic Milazi (CSIR))

Prof. Maaza

The Minister of Trade and Industry recently inaugurated a R5 billion concentrated solar power (CSP) power plant with a capacity of 50MW in Bokpoort. This is the largest Saudi Arabian investment in South Africa and was part of the government's Integrated Resource Plan (IRP) 2010-2030 and its strategy to support renewable energy. Several other solar plants are operational in the country but the bulk of them are PV, which is an area of solar energy production dominated by the Chinese. South Africa should focus on niche areas in CSP technology in terms of photonics.

Dr Diale

During the breakaway session:

- Dr Roro spoke about:
  - Electricity from sunlight and gave an overview of PV growth in South Africa
  - PV as the main supplier of electricity globally
  - Solar power in South Africa was 52% cheaper than in Europe
- Mr Milazi spoke about:
  - Unlocking the potential of renewable energy in South Africa.
  - Fragmentation of the photonics landscape and the need for better coordination of activities within the photonics community.
  - The importance of interaction between scientists and policy-makers.
  - Placing more focus on patenting research and commercialisation of products of R&D.
  - The possibility of renewable energy and independence from the grid resulting in the loss of revenue for municipalities and Eskom.
  - France's plans to have 40% of renewable energy by 2030.
- Dr Diale spoke about:
  - The role of PV and artificial photosynthesis in producing off the grid electricity
  - Nanoparticles and semi-conductors in solar energy and electricity production
- Mr van der Walt, an entrepreneur, spoke about micro-utilities and the green economy, providing schools and rural communities with electricity, and the market for small generation capacity.

The solution to South Africa's energy problems, particularly in the rural areas, is integrated, renewable energy from solar.

Dr Roro

South Africa has a competitive advantage in terms of its solar resource and needed to start making use of this energy form to address the country's energy challenge. By 2015, PV contributed about 1% to the electricity mix. PV technology is proven and tested. Nonetheless, some performance and reliability issues need to be addressed to ensure investor confidence. The performance of the modules (components of atypical solar energy system) must be monitored, specifically their performance in the South African environment. It was essential to undertake the scientific measurement of the performance of PV in the local environment in order to produce credible data and enhance the understanding of the technology.

Mr Milazi

Solar and wind energy have strong potential, but the wheels of policy in government turn very slowly. The initiative to bring renewables onto the grid started in 2003 with the Energy Whitepaper, and many years later large investments have been made in the renewable energy sector. The decisions taken about renewable energy are very important and once they are made and the process is set in motion it becomes difficult to change the course. Currently, the costs of solar PV and wind energy are dropping, causing shifts in national energy mixes across the world and forcing energy utilities to review their business models. The innovations of scientists were being considered in the discussion on how solar PV can fit into the energy landscape in terms of municipal electricity supply. Policy can only work within the confines of what is physically possible. Scientists dictate what is physically possible with their innovations.

Questions/Comments

Ms Paruma: Has any work been done on storage of solar energy? The NSI is polarised and we do not communicate with each other. The DTI has been approached to fund an innovation that maximises solar power through a spatial algorithm. More details are available about this project.

Response, Dr Roro: Storage is a different business case. PV without storage makes PV expensive, but still worthwhile in rural areas. This would be very helpful and would open up research questions. I have been involved in this over the past four years, monitoring performance of the CSIR's first PV plant. The energy output was being lost on cloudy days.

Dr Diale: The technology to store energy through batteries is already being used.

Dr Monnamme Tlotleng, CSIR: We put up water treatment plants using solar pumps to provide water in rural areas. Solar energy has an impact on socio-economy. Municipalities that do not need to be on the Eskom grid should be forced to use solar energy. This is where impact can be measured.

Dr Cingo: Dr Prinsloo pointed out that instead of importing PV there is potential for this country to export PV. Other opportunities were presented in the AM sector and through the research on luminescent nanomaterials done at the University of Free State. Has consideration been given to how these opportunities could be pursued?

Response, Prof. Maaza: These opportunities do exist. There is an expectation that the PV sector of photonics would be the second most important after the lighting and displays sector, and that there would be a high demand for silicon ingots.

Response, Dr Diale: The silicon that is needed to make solar devices is not expensive and not as pure as the silicon needed for other technologies. Photonics technologies would feed into various sectors. Before considering exporting photonics technology, it is necessary to use the existing technologies and put them together in novel ways.

Response, Dr Roro: Solar technology can be divided into upstream (material research) and downstream (designing installations). There are already metallurgical grid silicon manufacturing factories in South Africa. The DST has identified that this material can be purified for solar grid. There are current efforts to address the challenges in this regard. NMMU is developing innovative technology to purify silicon. The CSIR Energy Centre is aware that this material research is highly capital intensive and requires investment and many years of hard core research as a gateway to solar energy research. The centre's work focussed on performance and reliability assessment in South African conditions, and it wants to position itself to assist the growing PV industry by giving scientific advice in system design and optimisation as well as assisting South African module manufacturers.

Response, Prof. Maaza: PV is well established globally and South Africa will not be able to compete. However, there is massive potential for R&D in CSP. The solar component (CSP innovation and human capital development) has to be part of platforms such as PISA and RAPDASA. It is necessary to identify niche areas for CSP and to bring together the solar research community and the various initiatives in this country.

Mr van der Walt: There needs to be collaboration between the DST, the DTI, the Department of Energy and the Department of Higher Education and Training in order to promote solar energy.

Response, Mr Milazi: Two obstacles to local manufacturing are:

- People localise their actual businesses and need business cases to do this. If they do not have line of sight on their pipeline of projects, they will not do business in this country. The research and innovation process is a competitive bidding process, with very little certainty to justify localising. A company such as Siemens produces their turbines locally because they can supply into the formidable coal power plant industry in this country. This is not the case for smaller companies.
- Although local manufacturing is supported, the technologies need to be bankable. When a project is being developed and is proposed to the DST, it must be financed by a bank and the bank has to be assured of the revenue over the next 20 years.

Fibre Optics and Communication (Panel: Prof. Andrew Forbes (Wits), Dr Lorinda Wu (CSIR), and Dr Sandile Ngcobo (CSIR))

Dr Ngcobo

- Dr Hay of Neotel, a company that provides fibre optics communication in South Africa gave a presentation on broadband fibre. He indicated that the current built capacity in terms of bandwidth is high but the demand is low. About 10 000 kms of fibre optic cables have been laid, connecting cities throughout the country and mainly intended for business. Fibre-to-home would require substantial funding. Most of the fibres laid are imported.
- There are many opportunities to distribute data to homes, particularly in terms of SMME development and job creation. This is where the focus should be. The question is whether the current research activities happening in this space address job creation and whether the fibre-to-home problem could be addressed by moving to digital decoding (used in TVs).
- Some of the challenges experienced in increasing bandwidth for transmit high volumes of data will be addressed through the SKA.
- Fibre optics and communication should be included in the Photonics Roadmap
- The CSIR developed 2-micron fibre lasers that have potential to go to the market, but capacity and products are needed in the fibre optics sector. There was good potential within this area to create spin-out and there was a need for more market driven research.
- In terms of communication, the focus should be on technology to do encoding and decoding of information on long fibres and fibres-to-home.

Dr Wu

One of the main issues for researchers who work in the fibre optics space is that many of the tools and technologies present in South Africa are imported, even though there are scientists and engineers in this country who are able to work in this space and develop products, which would benefit this country's economy. Building capacity remained a problem and should be addressed. She was working on 2-micron fibre lasers at the NLC. Lasers in general are extremely useful in numerous applications.

Prof. Forbes

The fibre optics programme should be more holistic as many aspects have to be addressed in order to spin-out technology. Very few people are working in this area yet problems have to be resolved. The work being done in respect of tools to multiplex and de-multiplex and studying cross-talk in fibres is not enough to start a company. It is necessary to have people to look at integrated sources and the interface to the data. There is a joint venture between IBM and Wits to look at the 'Big Data problem' common to the SKA and to CERN (the European Organisation for Nuclear Research). Problems of getting data through fibre and through electronics must be solved simultaneously. It would help to solve these problems if the technologies and the people working on them were brought together. One of the motivating factors could be the duplication of technology (such as making fibres) could be implemented in the SKA, for example. If people with skills are produced, companies would be developed. A combination of different people at different levels in the value chain is needed. Bridges between the levels in the value chain could be built and created.

Questions/Comments

Dr Diale: What is the role of the community, particularly the academic community, in assisting policy-makers and government to understand the work being done in this sector?

Response, Dr Ngcobo: The NLC assists the DST in terms of keeping them up to date on developments in lasers, and runs outreach programmes.

Dr Madisha: We have minds that can develop technology but we see technology being imported into this country. The lack of capacity seems to be an ongoing problem. At some point, research leaders will have to use their problem-solving skills to address this problem and take responsibility to convince policy-makers to understand the consequences of the lack of capacity.

Dr Ngcobo: I believe we should be doing market-driven research. This might help address the capacity issue.

Prof. Forbes: The problem is not hard to solve. However, we all work as individuals and carry the risk and the reward as individuals. Like other scientists, I have to report to some funding body every year, but it is not possible to make substantial progress, or start a company in the space of one year. To overcome this, I produce articles and so on, as this is the road of the highest return and the lowest risk. If I was in a community that worked together and the timeframe was longer than one year, and I could share in other people's rewards, then I would be prepared to take more risk. If everybody worked like that, we could overcome the address the problem. The main issue is the division of the community, which means that there is never enough critical mass to take something all the way through without stopping everything else. The problem will be addressed very quickly if the community is brought together.

Dr Johannes: What role does IP play in not getting research done? A department at Cambridge University released all its patents making them available to the market and so much work has come in since doing this. Researchers do not make money out of patents. If there is broader involvement in the IP, there will be synergy instead of division.

Response, Prof. Forbes: A patent is a future liability for universities, but they do not carry the liability and do not take this seriously.

Dr Cingo: About two years ago, the CSIR made its patents (that it was not actively pursuing but still owns) available to entrepreneurs. The patents can be viewed on the web portal. We need to see something coming out of the ideas we generate and research we do. What is the alternative to IP? How do you prevent other people duplicating the work that you have already done? Part of managing IP is to keep the know-how in-house. There is a need to exercise caution in what can and should be done with IP that comes from public funds.

Ms Paruna: IP management is crucial. There is a lack of IP managers in this country to manage, analyse and commercialise technology. It is not necessary to avoid IP.

WRAP-UP AND WAY FORWARD (DR CINGO)

Dr Cingo posed a question to the forum about what steps should be taken to bring together the photonic community and provide a platform for stakeholder engagement.

Prof. Forbes indicated that some form of PISA should be revisited and must incorporate the entire photonics community to give photonics a good voice. This would have to be done as soon as possible (during this year). If photonics is seen as enabling technology (across all disciplines) then a body is needed that will sit with each discipline and be part of their discussions and their strategies. The players in the fibre optics and communication arena are known, but there are a lot of people in the physics community and in engineering involved in photonics. They should be brought together in a separate event. Flagship projects that everyone could contribute to and share in the success. There should be one voice to government to explain that we are a community and have critical mass to do something useful. This can be done.

Prof. Maaza concurred with this proposal, reiterating the need for a revival of PISA in some form. He emphasised the multi-disciplinary and enabling nature of photonics, and the need to be as inclusive as possible.

Dr Cingo emphasised the importance of the Photonic Roadmap at a national level and that the intention was not to create a parallel body but rather to have an active body that fills the gap that has been identified and drives the interests of the entire photonics community.

The following actions were proposed:

- In respect of reviving PISA:
    - The DST should be asked to give a presentation on the status of PISA and to indicate what must be done to resurrect it and what happened to the original strategy, which would have to be reworked to be more inclusive. Active members of the PISA steering committee could assist this process. An encompassing approach is needed.
    - The DST's Science Forum at the end of the year should be used for a parallel meeting for all those interested in reviving PISA. An initial engagement could be arranged prior to this.
- In order to ensure the inclusion of the fibre optics and communications sector as one of the focus areas of the Photonic Roadmap, it would be necessary to make representation based on the activities, interest and potential opportunities in this area from players in industry, science councils and HEIs. This should be done between now and the time that the Roadmap is revisited. (Dr Prinsloo's indication that a decision to include fibre optics and communications in the Roadmap at a later stage would have to come from the community, and supported by the proposed new representative body was noted.)

Dr Cingo highlighted the following points raised in discussion forum:

- Concrete opportunities for the export of PV have been identified. It is necessary to consider other technologies that could be put on a platform of this nature. The work that has been done by Prof. Ntwaeaborwa on light emitting material could potentially form a part of this platform.
- A world-class PV facility has been set up at the CSIR and is performing part of the value chain of PV in the country.
- Photonics are positioned to make a major contribution to all renewables. However, the photonics community appeared to be fragmented when it comes to solar renewables. Prof. Maaza mentioned that the South African Photovoltaic Industry Association (SAPVIA) could play a role in bringing together the community.

- The PPF provides infrastructure for phototyping technology. Calls would be made to the community to submit ideas for prototyping that would be taken to the next level.
- The DTI's technology commercialisation strategy attracted interest from the photonics community, and the Techno-Industrial Clusters for specialised industries presented potential for the photonics community. Cluster development was an aspect of the Regional Industrial Development Strategy that could be supported by the photonics community.
- Very little of the bandwidth available was being used currently. The question is where does innovation come in to fibre optics and the space around projects such as the SKA, which, once fully operational will transfer volumes of data that will possibly saturate all available bandwidth. New ways of increasing bandwidth will have to be found.
- The choice of focus areas in the AM Roadmap is good. There is concern that plans to use titanium are still in the development stage and there is a risk if these plans do not come to fruition.
- Skills training is a new area that requires a parallel shift in terms of how people are trained to take advantage of what is offered by AM.
- There is a need to provide internships for NDT to do in-line testing for monitoring as AM takes place. NDT is a critical element in ensuring that AM components qualify particularly aerospace components.
- There was almost no industry base or education programme in NDT. Investment in NDT at the appropriate scale was necessary. It was suggested that there should be a Research Chair in NDT.
- It is the responsibility of scientists to convince policy-makers to grow and use the capacity in the country to develop photonics technologies instead of importing these technologies.
- Micro-utilities can be used to provide off-the-grid electricity, particularly in rural areas.
- Efforts should be made to bring the photonics community together.
- Solar energy must be part of the Photonics Roadmap and PISA.

CLOSING

Dr Cingo thanked everyone for participating in the discussion forum and remarked on the usefulness of the diversity of people attending the event and the engagement.

Ms Niehaus thanked all attendees, presenters and panel members for their contributions to the discussions, the coordination committee responsible for the programme content, Dr Cingo for chairing the event, the DST's Multilateral Cooperation Unit for funding the event in terms of their support for the IYL 2015, and UNISA for providing conference bags.

ANNEXURE A: ACRONYMS

AM	Additive manufacturing
AMTRP	Advanced Manufacturing Technology Roadmap Project
CAD	Computer-Aided Design
CSIR	Council for Scientific and Industrial Research
CSP	concentrated solar power
DST	Department of Science and Technology
DTI	Department of Trade and Industry
EU	European Union
GPS	Global Positioning Systems
HEI	Higher education institution
ICT	Information and Communication Technologies
IP	Intellectual Property
IRP	Integrated Resource Plan
ISP	Incubation Support Programme
LED	Light Emitting Diode
NDT	non-destructive testing
NLC	National Laser Centre
NMMU	Nelson Mandela Metropolitan University
NSI	National System of Innovation
NSTF	National Science and Technology Forum
PISA	Photonics Initiative of South Africa
PPF	Photonics Prototyping Facility
PV	photovoltaic
R&D	Research and Development
RAPDASA	Rapid Product Development Association of South Africa
RDI	Research, Development and Innovation
S&T	Science and Technology
SAPVIA	South African Photovoltaic Industry Association
SMME	small, medium and micro-sized enterprise
SPII	Support Programme for Industrial Innovation
THRIP	Technology and Human Resources for Industry Programme
TVC	Technology Venture Capital
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISA	University of South Africa
UP	University of Pretoria

ANNEXURE B: ATTENDANCE

Name	Organisation
Mr Petrus Britz	Agricultural Research Council
Mr Nkwakwa Komane	Bakone Ba-maanakane Community Development Trust
Mr Paul Vermeulen	City Power, JHB
Dr Monnamme Tlotleng	CSIR
Dr Kittessa Roro	CSIR
Prof Sisa Pityana	CSIR
Dr Ndumiso Cingo	CSIR
Dr Sandile Ngcobo	CSIR
Dr Francois Prinsloo	CSIR
Dr Lorinda Wu	CSIR
Mr Hardus Greyling	CSIR
Dr Patience Mthunzi-Kufa	CSIR
Dr Manfred Johannes	CSIR
Dr Angela Dudley	CSIR
Mr Dominic Milazi	CSIR
Mrs Lindiwe Gama	DST
Ms Nontombi Marule	DTI
Miss Nirvashnie Bagirathi	Exxaro
Mr Pranay Devchand	Gauteng Department of Education
Ms Raluca Paruna	Institute of Inventors and Innovators
Mr Archie Corfield	Mintek
Mr Tshimangadzo Masikhwa	Mintek
Mr Daniel Mogale	Mitumi Projects CC
Ms Ntombifuthi Nkosi	Moipone Academy Science Centre
Mr Thato Setladi	Moipone Academy Science Centre
Mr Joseph Taetsane	Moipone Academy Science Centre
Mr Kagiso Nkadimeng	Moipone Academy Science Centre
Ms Jansie Niehaus	NSTF
Dr Angus Hay	Neotel
Mr Ntembeko Njovane	Non-Proliferation Council
Mr Fannie Matumba	Programme for Technological Careers (PROTEC)
Mr Vhudzisani Mulaudzi	SABS Design Institute
Mr Menzi Mahlobo	Systemdex (Pty) Ltd
Dr Patricia Popoola	TUT
Prof Sunday O. Ojo	TUT
Miss Mapule De Gama	TUT
Mr Caleb Hlebela	TUT
Mr Junius Ngoepe	TUT
Mr Hlaluku Wisani Mkasi	TUT
Mr Neo Papi	TUT
Miss Angelica Nkuna	TUT
Mr Sizwezakhe Masemola	TUT
Mr Makeke Rufus	TUT
Mr Telo Moloi	TUT
Mr Adam Selolo	TUT
Miss KgomotsoToka	TUT
Dr Diethelm Schmidt	TUT
Mr Kopano Motubatse	TUT
Mr Thabo Maesela	TUT
Mr Raymond Segoboge Mohlamonyane	TUT
Mr Timothy Sithole	TUT

Mr Poeletso Seloane	TUT
Mr Armand Aime Eroko Zintchem	TUT
Miss Samantha Komape	TUT
Miss Mokgadi Nomsa Mokgalaka	TUT
Mr Leonard Mosesi	TUT
Miss Makwena Kgafe	TUT
Miss Boithelo Pule	TUT
Mr Joshua Bila	TUT
Mr James van der Walt	Ugesi Gold Renewable Energy
Prof Martin Ntwaeaborwa	University of Free State
Mr Farouk Varachia	University of Johannesburg (UJ)
Mrs N. Tshiongo-Makgwe	UJ
Mutu Erinosho	UJ
Stephen Akinlabi	UJ
Lerato Raganya	UJ
Mashila Motadi	UJ
Prof. Esther Akinlabi	UJ
Dr Madindwa Mashinini	UJ
Dr Mpho Madisha	UP
Dr Mmantsae Diale	UP
Dr Sadanandam Gullapelli	UNISA
Dr Lingfeng Zhang	UNISA
Prof Malik Maaza	UNISA
Prof Andrew Forbes	Wits