Photonics in South Africa

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A growing research and development sector is a sign of a healthy economy. South Africa hopes that a focus on photonics technologies will help drive the country's socio–economic development.

The development of science, engineering and technology (SET) has been identified as one of the key elements for the long-term sustainability and competitiveness of the South African economy. As such, the South African government has set a target to increase expenditure on R&D by both the private and public sectors to 1% of the country's gross domestic product by 2008 and to 2% by 2018. The country's commitment to SET is evident from the various initiatives that have been implemented by the South African Government, such as the International Centre for Genetic Engineering and Biotechnology, the bid to host the Square Kilometer Array, construction of the Karoo Array Telescope and investment in infrastructure for high-performance computing, nanotechnology, astronomy and space science[1].

NLC

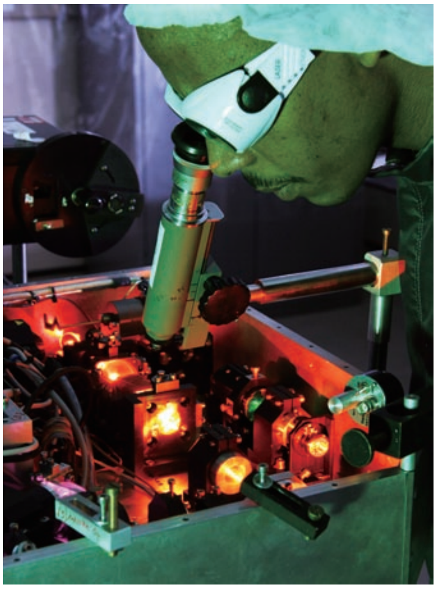
Figure 1 Philemon Mjwara (left), the Director General of the DST, during a visit to the research labs of the NLC. Thulani Dlamini (right), the director of the NLC, is showing him a high-power Nd:YLF laser developed at the centre. The DST strongly supports photonics research in South Africa.

South Africa was an early adopter of laser technology, introducing the first laser to the National Physical Laboratory at the Council for Scientific and Industrial Research in the early 1970s, quickly followed by a laser programme at the University of Natal (now University of KwaZulu-Natal) that led to important developments in optical systems[2]. However, lasers in South Africa only gained significance in the 1980s, with the start of a large laser programme in molecular laser isotope separation (MLIS) — an alternative to the ubiquitous centrifuge technology for uranium enrichment. This required a substantial investment in laser and photonics technology in terms of infrastructure and equipment, as well as in competency; it is estimated that several hundred million Rands (tens of millions of US dollars) were spent on the programme. Although South Africa is often lauded for voluntarily halting all of its nuclear-enrichment programmes, the termination in 1997 of the MLIS programme, with over 300 trained scientists and technicians and an estimated $3 million worth of laser and photonics equipment, placed the photonics community in South Africa in a quandary. Clearly an impasse had been reached and a policy to establish better relations with the then Department of Arts, Culture, Science and Technology was required. The outcome was the National Laser Centre (NLC), with an envisaged focus on partnerships with industry and academic institutions for the advancement of laser research and technology adoption in South Africa. In 2000, the NLC (Fig. 1) was formally launched under a trust supported by the Department of Science and Technology (DST). In 2003, the NLC changed status from an independently funded trust to a research centre within the CSIR. With 67 members of staff and an annual budget of $6 million, the NLC is the largest photonics centre in Africa. It performs research and development in a wide range of areas, such as laser materials processing, solid-state laser development, atmospheric remote sensing, mathematical optics, femtosecond-laser applications and biophotonics. Many of these research activities are performed in close collaboration with South African and international university research groups.

A key focus area for South African industry is advanced manufacturing. The NLC plays the role of advisor and research test bed for the implementation of lasers in the country's manufacturing industries with its main focus on machining — for example, the cutting, welding and cladding of various materials. Current research includes developing techniques to laser process light metals (aluminium, for example) and advanced laser cladding — work undertaken by the NLC as a partner in the European Union sixth framework programme, FANTASIA. Another very active applied research area at the NLC is the study of solid-state laser resonators[3] and the associated development of diode-pumped solid-state lasers (Fig. 2), with a focus on high-power systems in the ultrashort-pulse (mode-locked) and mid-infrared domains. One potential application is the use of such systems in lunar and satellite laser ranging, where South Africa hopes to combine an existing space geodesy programme with short-pulse lasers to become a world leader in the field.

The South African government has identified biotechnology as a research focus area[4], and so, not surprisingly, there is a move to promote the use of lasers in biology, chemistry and the life sciences[5]. The NLC has established a state-of-the-art femtosecond-laser facility for the study of complex systems, and several groups in the country contribute to biophotonics research through NLC-driven initiatives. There are active research programmes in light–tissue interactions, wound healing and photodynamic therapy, where already several advances have been made[6] by researchers at Rhodes University, the University of Johannesburg and the NLC. The contributions to the field by Tebello Nyokong at Rhodes University were recently recognized when she was awarded a research chair — one of only four linked to photonics.

The NLC also runs a number of community-based programmes, the most notable of which is the Rental Pool programme. The Rental Pool supports photonics research in South Africa through equipment loans as well as scientific and technical support. It is often overlooked that South Africa is still a country with a very young democracy and that during the apartheid times there were separate universities for the different ethnic groups with huge differences in funding and quality. This necessitates a 'grassroots' approach to advancing photonics research in the country. The Rental Pool launch in 2000 was the boost the community was waiting for, making it possible for any university in South Africa to consider photonics research regardless of lack of experience and equipment. This has seen lasers and photonics adopted across many disciplines whereas previously it was predominantly the domain of physicists. There has been a concomitant increase in publication output and student involvement in photonics research, with Rental-Pool-supported research alone contributing over 100 scientific papers and roughly 160 students in training at the various institutes[7]. This accounts for nearly 90% of South Africa's total photonics research, an indication of the small size of the community as a whole. However, the photonics community has grown substantially since the inception of the NLC, and is now the third largest community in the South African Institute of Physics. It is set to grow larger still: the research chair programme[8,9] of the DST, aimed at attracting talent to South Africa, has announced four new research chairs related to photonics: photonics, ultrafast and ultra-intense laser science (Heinrich Schwoerer, University of Stellenbosch); quantum information processing and communication (Francesco Petruccione, University of KwaZulu-Natal); medicinal chemistry and nanotechnology (Tebello Nyokong, Rhodes University); and nanophotonics (Reinhardt Botha, Nelson Mandela Metropolitan University).



NLC

Figure 2 A scientist at the NLC aligning a solid-state laser system.

The ultrafast and ultra-intense laser science research chair brings additional expertise and funding to the Laser Research Institute of the University of Stellenbosch, the largest photonics research group outside the NLC. Although traditionally they have focused on high-resolution spectroscopy (especially in the vacuum-UV region at wavelengths below 200 nm), new research areas include fibre and solid-state laser development, and femtosecond lasers and their applications, and they have already produced some important work[10].

The new research chair at the Nelson Mandela Metropolitan University in nanophotonics continues South Africa's long history in materials science. And they are not alone in this research area: many of South Africa's top research institutions have some involvement in this field (Fig. 3). Notable among these is the University of Witwatersrand, which has many years of experience in diamond research, where scientists are now turning their attention to diamond for photonic devices. There is an active community in South Africa studying the potential of diamond as a single-photon source for applications in quantum cryptography. The group at the University of KwaZulu-Natal, under Francesco Petruccione, hopes to exploit the properties of diamond to produce novel quantum communication systems. The group has the backing of the national government, through funding, and also the local government, through a joint agreement to turn the municipality of the city of Durban into the first municipal network to use quantum-encrypted communications protocols.

A strong culture of scientific excellence in photonics has been established in South Africa. This is highlighted by the fact that South Africa is the most successful Third Country participant in the EU framework programme[11]. In the sixth framework programme, there were 60 projects that had South African participation, with two of these in laser-related research. Despite this very active research community, South Africa has been slow to convert research ideas into spin-off companies. There are only four local photonics companies: two that specialize in niche laser systems, namely Scientific Development and Integration (SDI), which produces CO_2 laser systems, and Zeiss Optronics (formerly Denel Optronics), which focuses on defence applications; one that concentrates on the manufacturing of optical elements and coatings (Optocon); and CBI Electrical Telecom Cables, which supplies fibre-optic cables. Although the photonics industry in South Africa is still small, there is hope that it will follow the trend seen in the research community and grow significantly over the coming years.

Recently, the DST took a decision to invest in the development of a national strategy for photonics under the banner

Figure 3 The main research centres in photonics are concentrated around Johannesburg (University of the Witwatersrand, University of Johannesburg), Pretoria (NLC), Durban (University of KwaZulu-Natal), Stellenbosch (University of Stellenbosch), Port Elizabeth (Nelson Mandela Metropolitan University) and Grahamstown (Rhodes University)[13].

of the Photonics Initiative of South Africa (PISA). This is based on a need to create a co-ordinated approach to research, development and innovation in the country. The long-term objectives of PISA are: (1) to stimulate R&D in photonics at higher-education institutes, national research labs, and industry; (2) to develop human capital for a skills-based economy in photonics; (3) to create an enabling environment for the incubation and formation of local photonics industries; and (4) to position South Africa as a significant player in the field of photonics worldwide. PISA follows shortly after the implementation of the National Nanotechnology Strategy, which received funding of $24 million to be spent over three years[12]. It is expected that the funding level for PISA will be significantly more than this, giving photonics a further boost.

South Africa, as the most developed country in Africa, has taken the lead in ensuring that Africa participates in shaping the future of photonics. A number of initiatives have been established to foster collaboration between researchers on the African continent. In the field of photonics, the African Laser Centre (ALC) has had a significant impact in terms of human-capital development and providing access to research infrastructure by linking researchers from all over the continent. This centre was initiated by the NLC, but has since received continent-wide acclaim, with participation by more than 20 member institutions from across the continent. The ALC is endorsed by the New Partnership for Africa's Development. Other continent-wide networks, such as the African Laser, Atomic, Molecular and Optical Sciences Network, have helped develop scientific cooperation in photonics in Africa and have ensured that the level of photonics research is elevated through various training events and conferences.

The increased expenditure in R&D, research infrastructure and human-capital development signals a positive future for South Africa's SET. The recent developments in photonics will certainly position South Africa in the forefront of the field, especially in selected niche areas where the country has a comparative advantage. Despite this there are still a number of challenges that need to be overcome, one of which is the ability to commercialize technologies emanating from government-funded research.

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