ScienceScope

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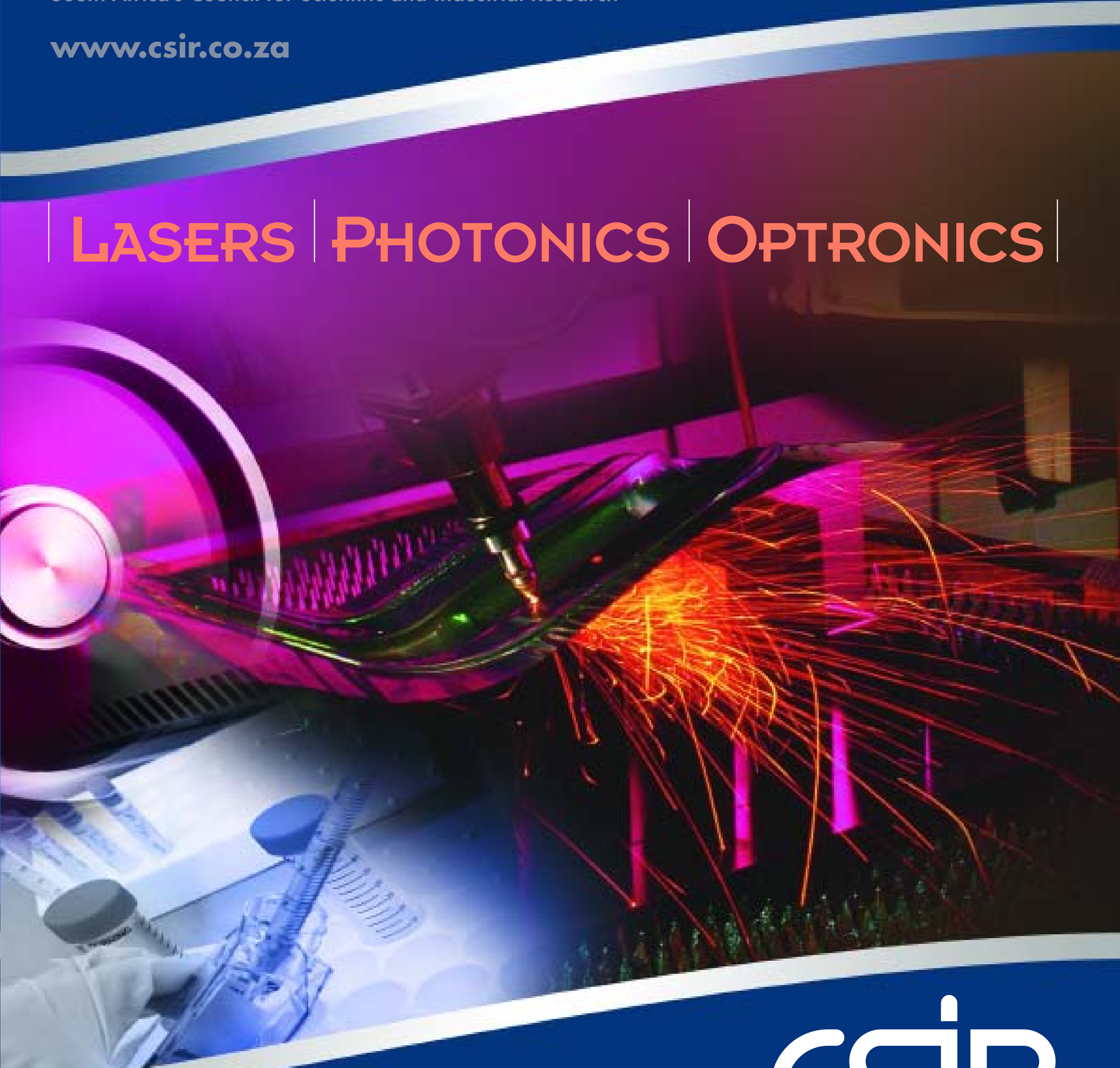
Lasers | Photonics | Optronics



CSIR

our future through science

Volume 1 Number 3 June 2006

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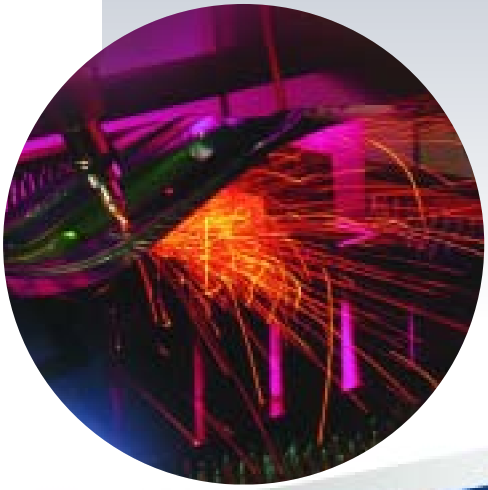

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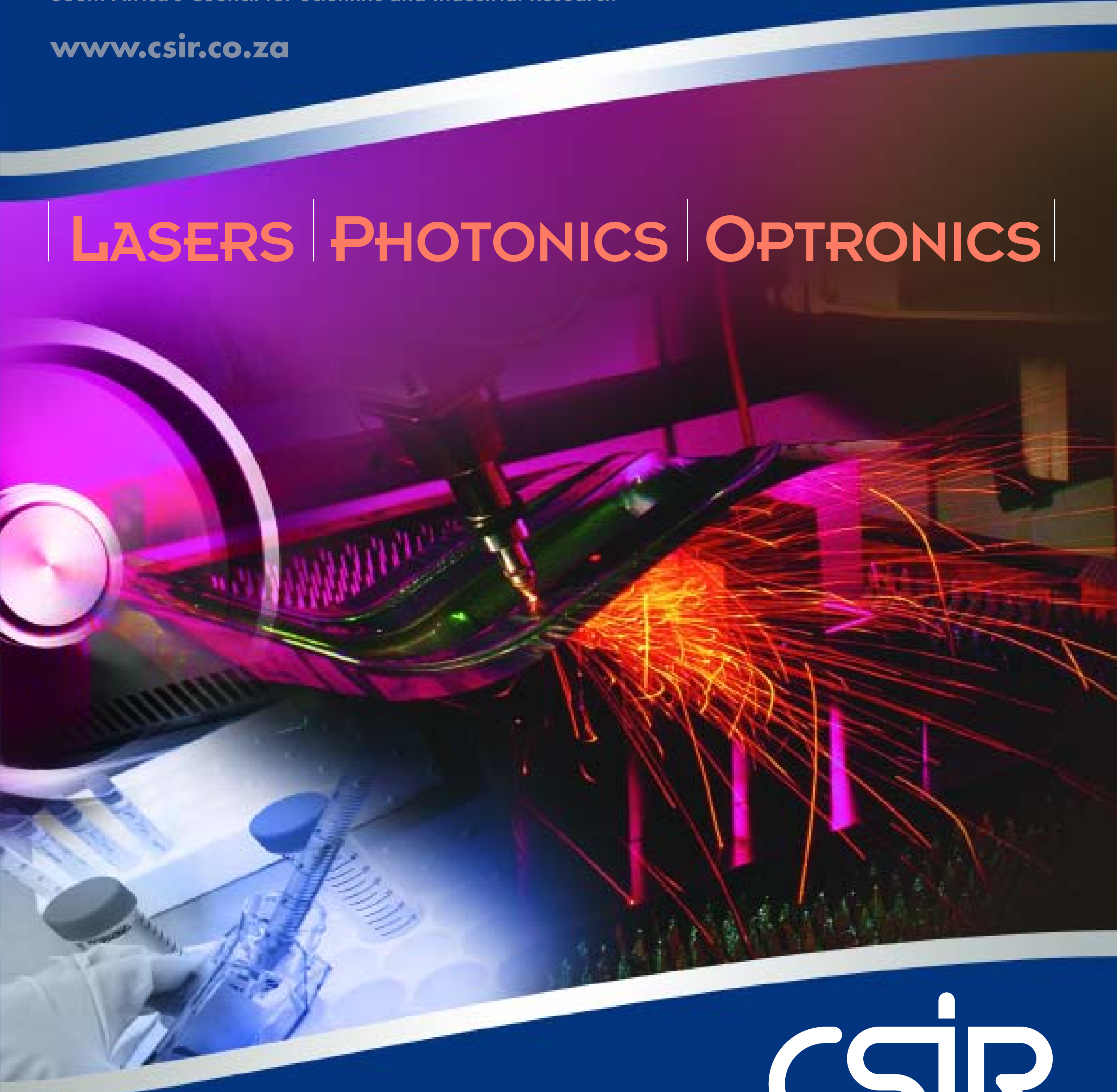

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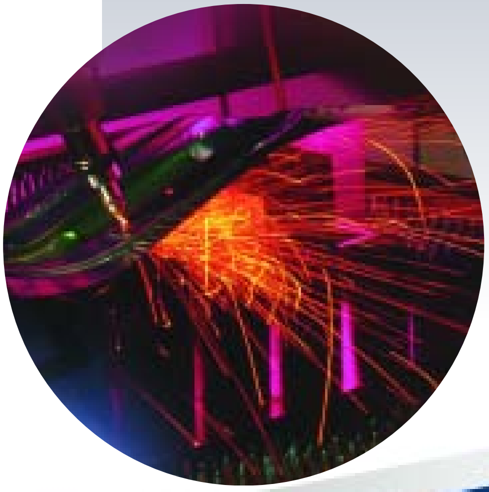

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CSIR
our future through science

Stimulating research in laser science and technology

The CSIR National Laser Centre strives to provide laser technologies and solutions that are relevant to the needs of South Africa.

As such, it is an imperative for our sustainability that our activities are aligned with developments within the public and private sectors as well as the academic environment. Therefore, we need to understand the value that we can add to our stakeholders in these sectors. Government for example, has a number of technology intensive programmes and initiatives, which can benefit from the involvement of the CSIR.

In my previous position as a researcher at Sasol, I made use of lasers in particle size analyses, for example. However, joining the CSIR has given me the opportunity to understand some of the fundamental aspects of these applications. Currently, the main link between the CSIR National Laser Centre and the private sector is in the application of lasers for materials processing. There are a number of opportunities within the chemical industry that we have not yet explored. These cover both basic research, such as using fast lasers to understand chemical reaction mechanisms, laser-induced chemistry to tailor and understand the selectivity of reactions, as well as more practical applications in on-line monitoring of chemical processes.

If one looks at materials characterisation within the chemical industry, success in the future will depend significantly on the ability to monitor chemical processes *in situ*. In catalysis, for example, where the drive is on improving the selectivity and not activity, one would like to understand the nature of the active centre. This can be done only with the catalyst in its active form, i.e. using *in situ* spectroscopic or microscopic techniques. Hence, we need to develop innovative laser-based diagnostic techniques that can address this technological challenge.

In the past, the CSIR National Laser Centre has been very successful in its quest to stimulate research in laser science at higher education institutions. The outputs in terms of students trained and scientific publications have been very impressive. Going forward, we need to develop strategies and models that will attract participation of industrial partners in the human capital development agenda. This will fast track the introduction of laser technology in industry, ensure that research activities are focused on relevant industrial scientific problems and that graduates in laser science are employable in the private sector. One of the possible spin-offs of this approach is an increase in the number of students who take up laser science as a career.

– Dr Thulani Dlamini: CSIR National Laser Centre

Introducing Dr Thulani Dlamini: CSIR National Laser Centre Manager

Dr Thulani Dlamini was appointed as the manager of the CSIR National Laser Centre in October last year. "This was a major change in my career, having spent a number of years in the petrochemical industry," he says. "I am keen to take up new challenges and see this as an opportunity to venture into a new area of science and at the same time bring new ideas into the Centre."

Dlamini holds a PhD in heterogeneous catalysis from the University of the Witwatersrand and an MBL from Unisa. Prior to his appointment at the CSIR, he spent eight years at Sasol, where his last position was that of Chief Scientist, responsible for materials characterisation.

2

Developing novel laser sources

Where did it all start?

In the past 46 years, the laser has developed from a "solution looking for a problem" to the foundation of the photonics revolution. Nowadays, lasers have applications in almost all areas of modern society. The Laser Physics and Technology Group at the CSIR National Laser Centre contributes to the world-wide research effort to improve current laser systems even further and to develop new lasers for tomorrow's demands.

Laser research in South Africa began in the early 1970s at the CSIR at the then National Physical Research Laboratory with the design and construction of the first solid-state laser in Africa, a ruby laser. Other lasers followed, including gas lasers ranging from "ultra-miniature" N2 lasers to large high-energy CO_2 lasers. During the late 1970s and 1980s, laser research focused on military applications, mainly range finding. This technology was later commercialised by Eloptro (now Denel Optronics).

In the mid 1980s, a large laser research group was formed at the then Atomic Energy Corporation (AEC), now the National Energy Corporation of South Africa, for laser-based isotope separation. New priorities following the 1994 elections meant reduced support for laser research both at the CSIR and the AEC. However, in 2000, the National Laser Centre was formed as an independent national centre, incorporating researchers from both the CSIR and the former AEC laser groups. In 2003, the National Laser Centre became part of the CSIR.

Current laser research

Currently, CSIR research into novel laser sources concentrates on robust and efficient pulsed lasers. The main areas of research are:

Mid-infrared (MIR) laser sources

A number of applications in industry, medicine and defence require laser sources, which operate in the mid-infrared wavelength region of 2 to 4 μm. CSIR research focuses on improved laser sources for the 2 μm region and on "non-linear" wavelength conversion to longer wavelengths.

Robust ultra-short pulse lasers

Lasers that emit pulses of a few pico-seconds (ps, 10^{-12}s) in length and have a relatively high energy per pulse are very effective in a number of applications. The largest market for these lasers is in materials processing for micro-machining applications, since ultra-short pulse lasers are able to machine much finer structures than conventional lasers. Current commercial ultra-short pulse laser systems are very complex and therefore expensive and not very reliable. In addition, many applications require more average power than current commercial systems can deliver. CSIR research in this area concentrates on novel concepts for robust high-power operation of these lasers. Another application that requires a similar typeof laser is lunar laser ranging (LLR). The CSIR is involved in an LLR project,where the aim is to measure the distance to the moon within a few millimetres in accuracy using a novel ultra-short pulse laser.

Electronic control of lasers

Electronic feedback control has the potential to substantially enhance the stability and performance of lasers. In collaboration with academia, CSIR electronic engineers and laser physicists perform joint research on novel control concepts for lasers. These will enable the group to develop new lasers with improved performance. The synchronisation of pulsed lasers with external systems with high accuracy is also under investigation.

Dr Christoph Bollig

Construction of novel diode-pumped solid-state lasers at the CSIR laser sources laboratory

The basics of laser physics

Introduction

The laser is a light source that exhibits unique properties. Since the first demonstration of a ruby laser by Maiman in 1960, there has been a phenomenal development in the field of lasers. Lasers dominate our modern world in a variety of forms ranging from tiny diode lasers in all CD and DVD players to large industrial lasers, used extensively for cutting and welding, e.g. in automobile manufacturing. In fact, lasers are used in thousands of applications in every section of modern society, including consumer electronics, information and communications technology, entertainment, science and industry, the medical field and defence. The laser triggered the photonics revolution and is the foundation of modern photonics.

Modern laser research involves fundamental laser physics, creative development of novel laser concepts and advanced experimental work and diagnosis. All this can lead to the development of new lasers, which will fulfil the requirements of current and future demands in science and industry.

Unique properties of lasers

Lasers range in size from tiny diode lasers to large systems the size of a football field. All of these have three basic properties in common, which separate lasers from ordinary light sources:

- **Monochromaticity:** conventional light sources emit light consisting of a broad range of wavelengths (i.e. colours); a laser, on the other hand, emits only a very narrow range of wavelengths.
- **Directionality:** conventional light sources, like a light bulb, emit light in all directions, while lasers can emit light which spreads ("diverges") only very little with distance. However, all laser beams eventually diverge as they move through space.
- **Coherence:** Some consider coherence to be the most fundamental property of laser light, i.e. where all parts of the electromagnetic waves are in phase.

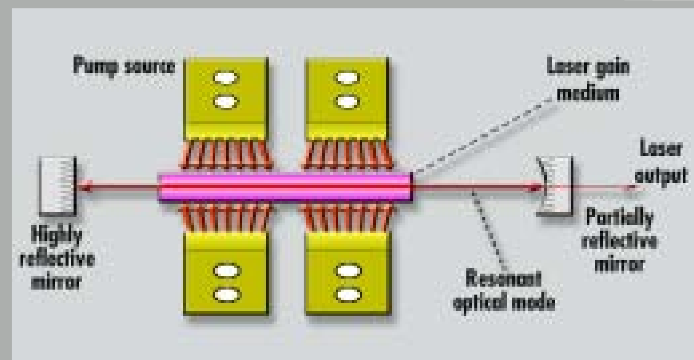
Principles of laser operation

The word "laser" is an acronym for light amplification by stimulated emission of radiation. It is worth noting that the term "light" refers to a wide spectrum of wavelengths from soft x-ray, through ultraviolet (UV) and visible to far infrared (IR).

The two most important basic principles for laser science are the quantum nature of light and a process called stimulated emission (both accredited to Einstein). The quantum nature of light refers to light quantised into discrete energy portions, nowadays called photons.

Basic components of a laser

A laser basically consists of three parts: a resonant optical cavity called the optical resonator, a laser gain medium (also called active laser medium) and a pump source to excite the particles in the gain medium as follows:



The optical resonator consists of at least two mirrors between which the light bounces up and down resonantly. In most cases, one or more mirrors are curved, so that a resonant optical mode forms. This mode defines the laser beam. Modern dielectric mirrors used in lasers typically have a reflectivity of up to 99.9%. However, one of the end mirrors is usually only partially reflective, so that a portion of the light is transmitted. This mirror is called the output coupler. The transmitted part forms the laser output.

In order to operate, the laser requires a gain medium in the resonator, which amplifies light and thus compensates for the loss through the output coupler. Lasers are typically classified by the type of gain medium they employ (gas laser, solid-state laser, dye laser, semiconductor laser, etc.). The stimulated emission process takes place in the gain medium. The gain medium amplifies light of any direction. However, only the light which bounces up and down between the resonator mirrors is amplified many times and therefore reaches a high intensity. In a continuous wave (CW) laser, the gain in the laser gain medium and the loss from the output coupler plus other losses are in equilibrium. The fact that the photon energy has to match a given energy transition makes the laser monochromatic. Since the amplification process maintains the phase and direction of the light, the laser output is directional and coherent.

The active particles in the laser gain medium need to be in a state of inversion for the laser to operate. To reach this state requires some pumping process, which lifts them into the required energy state. Typical pumping processes are electrical current in a gas or semiconductor laser or optical pumping in a solid-state or dye laser. Optical pumping is typically achieved either by flash lamps or by another laser.

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Laser activity at CSIR to provide industry with edge

Seeking global competitiveness through laser technology

Since the invention of the laser in 1960, laser technology has had a profound impact on virtually all spheres of modern life. Because of its spectacular successes over a broad range of applications, laser technology was soon identified as an enabler and a key technology to global competitiveness. This realisation led to the implementation of government-sponsored R&D programmes in laser technology in practically every industrialised country around the world. In fields as diverse as telecommunications, medicine and entertainment, laser technology opened up new frontiers. Manufacturing proved to be no exception. In each of the basic disciplines of cutting, joining, milling and drilling, laser technology introduced significant advantages as well as new possibilities.

At the heart of the competitive advantage that laser technology offers over conventional manufacturing techniques lies exceptional precision and control. To illustrate this point it should be mentioned that the beam from a standard industrial laser source of 4 kW power can readily be focused onto a spot size as small as 0.2 mm in diameter. This gives rise to a power density of over 10 million W/cm^2, enough to overcome the thermal properties of all known engineering materials resulting in melting and vaporisation. The advantages of a laser-based manufacturing process can be wide and varied depending on the particular application, but more often than not it includes a combination of high levels of productivity and quality.

In 2000, the CSIR National Laser Centre embarked on a programme aimed at introducing the competitive advantages of advanced laser materials processing to the South African manufacturing industry. Laser-based manufacturing processes that were specifically targeted are:

- Deep penetration welding
- Surface modification (cladding, hardening, alloying and cleaning)
- Laser milling
- 3D profile cutting of sheet metal.

The first objective was to establish a capacity for the practical demonstration and application of these processes. This required the establishment of infrastructure in the form of appropriate equipment as well as human capital development (HCD). The HCD process was fast tracked through a technology transfer agreement between the CSIR National Laser Centre and the Fraunhofer Institut für Laser Technik in Aachen, Germany. The infrastructure currently includes:

- Trumpf TLC 1005 Lasercell: five-axis gantry robot equipped with 5 kW CO_2 laser for deep penetration welding of ferrous metals and 3D cutting
- High-power Nd:YAG facility: eight-axis articulated arm robot equipped with 4.4 kW Nd:YAG laser for deep penetration welding of light metals, laser cladding and transformation hardening
- Deckel Maho Gildemaister: system for deep precision-laser engraving.

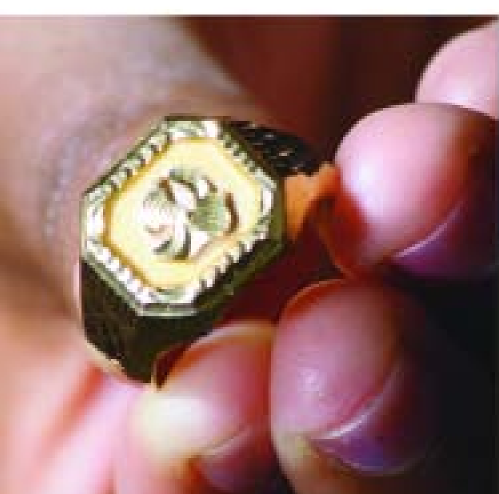
As the respective capabilities gain in maturity, the emphasis is shifting from demonstration and application to a focus on R&D.

Laser cladding research

Laser cladding is a surface engineering process where a defocused laser beam produces a shallow melt pool of the order of 1 to 4 mm in diameter on the surface of a metallic work piece. If metallic powder is injected into the melt pool, a metallurgically-bonded layer is formed on the surface of the substrate which is characterised by very low heat input, very low dilution and low levels of imperfections such as porosity, cracks and bonding defects.

Amongst the current research topics, a CSIR study is being conducted into the microstructure of laser cladded martensitic stainless steel and the effect of ceramic reinforcement on material properties. Due to the low heat input and consequential high cooling rates associated with laser cladding, solidification is a non-equilibrium process to which standard phase diagrams do not apply. The presence of retained austenite and its dependence on chemical composition and cooling rate will be under investigation. Ceramic reinforcement of the cladded layer through the addition of Al_2O_3, ZrO_2 and TiO_2 particles to the martensitic stainless steel powder as well as the *in situ* synthesising of Si_3N_4, TiN, Mo_2Si and TiB_2 will also be investigated. The introduction of the ceramic particles has the added potential of modifying the thermal coefficient of expansion of the layer, and hence improves the resistance to thermal fatigue.

The CSIR's surface modification group is undertaking work on a novel method of incorporating carbon nanotubes (CNT) into ferrous and non-ferrous surfaces. The main aim of this project is to lay the foundation for a new generation of metallic surfaces utilising the novel properties of carbon nanotubes. The idea of CNT-metal reinforcement is borrowed from the concept of composite materials where a composite describes a material made up of two or more phases, i.e. matrix and reinforcement. If the reinforcement is to improve the strength of a given matrix, it must be stronger and stiffer than the matrix. Metals are strong, tough and ductile but not stiff. Experimental measurements indicate that CNTs are very stiff and strong; this means Young's modulus of (~ 1 TPa) and tensile strength of (~ 20 -100 GPa).



The possible transfer of the CNT properties to host matrix materials is a major subject of research. Major challenges posed by CNTs as reinforcements are dispersion in the matrix for establishing good interface bonding between the tubes and the surrounding matrix. Despite these hurdles, CNT-reinforced composites have been successfully fabricated.

Laser milling research

Laser milling (or ablation as it is also known) is the process of selectively removing material from the surface of an object with a laser. The high power density associated with the focused laser beam removes the materials through vaporisation. The laser has a small spot size, typically 30µm, and can be very accurately positioned, resulting in features that are machined to a high tolerance. Since the process is thermal rather than mechanical, hard materials such as ceramics and hardened steel do not pose a problem to this process. The group currently has an Nd:YAG laser at its disposal to perform this work (wavelength 1 064 nm, nominal power 15 W, pulse width 250 ns).

The process has numerous advantages, including direct machining of a work piece from the CAD model, decreased production times for intricate parts, reproducibility, low or no tooling costs, machining of near vertical walls, and the machining of hard and brittle materials such as ceramics.

Typical industrial applications include prototype mould and model making, engraving and embossing, punch machining, jewellery prototyping, tool making inserts and electrodes.

A number of materials can be ablated, including steels, ceramics, aluminium, tungsten carbide, graphite, brass, copper and silicon carbide. More unusual materials, such as rhenium and molybdenum, have also been successfully ablated.

The laser ablation equipment is also being used to determine the effects of various lasers and other user inputs to the quality of the machined surface. This includes the effects of laser power and frequency, the scan speed of the laser beam, and the distance between laser tracks. In addition, it is envisaged that the effects of ambient conditions will also be pursued.

The CSIR uses laser ablation to produce tooling for the production of bipolar plates, direct prototyping of bipolar plates, and for the introduction of micro features into the plates.

The CSIR is also involved in laser ablation of photovoltaic panels in close cooperation with the University of Johannesburg (UJ). Experiments were undertaken to determine the correct parameters for laser scribing of lines onto the panels. Numerous panels have been scribed and tested, and the technology developed by the UJ has recently entered into a commercialisation phase.

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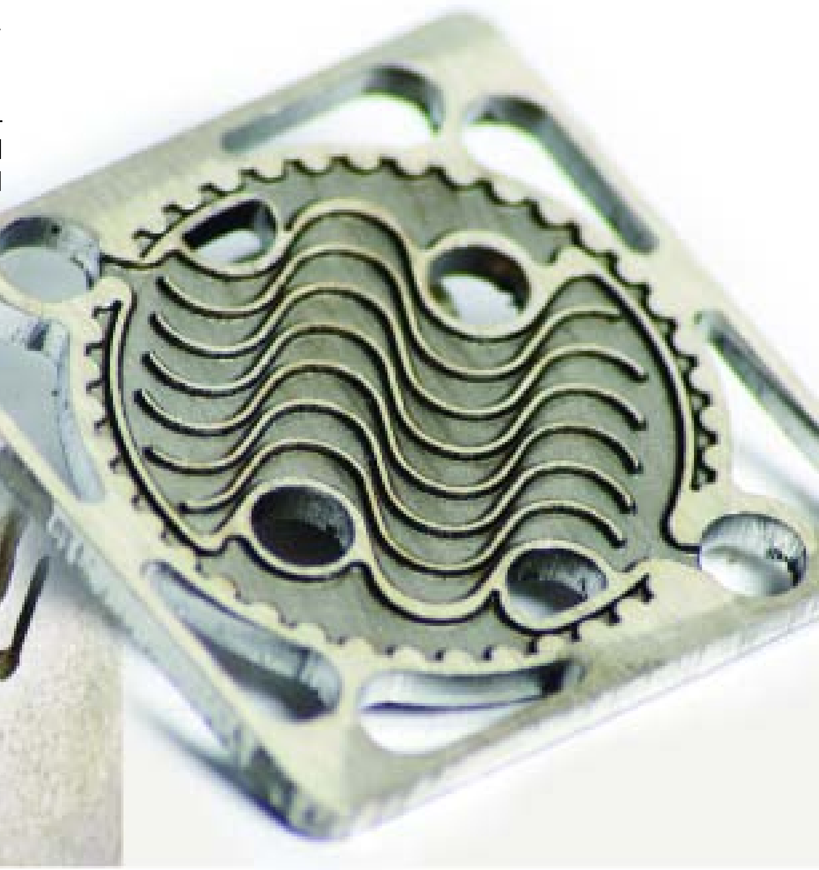

Promoting skills development and public awareness of laser science

Dr Paul Motalane

Dr Andrew Forbes

Introduction

South Africa is experiencing a dire shortage of skilled people in science, engineering and technology (SET) disciplines. The CSIR National Laser Centre has put measures in place to contribute to research capacity building in SET, as winning nations have clearly been those who have invested significantly in R&D. Singapore, for example, spends 2.1% of its GDP on R&D, while the figure for Japan is 3.1%. The Minister of Science and Technology, Mr Mosibudi Mangena, emphasised in Parliament in May 2006 that South Africa intends to increase funding support for R&D from the current 0.81% of gross domestic product (GDP).

To this end, the CSIR National Laser Centre is involved in a variety of activities to ensure that South Africa and Africa in general, benefit socially and economically from laser technology. These activities encompass carrying out cutting-edge research in laser physics and applications at its laboratories; building new lasers for specialised uses; processing materials using lasers; and raising laser science awareness in the community. An important activity involves transfer of laser technology to industry to introduce new ways of doing business more effectively and efficiently.

The CSIR also supports an extensive laser research programme that takes place at laboratories of various tertiary education institutions (TEIs) in South Africa, and at the CSIR. This research programme, carried out mostly at TEIs' premises, is referred to as the Rental Pool Programme (RPP).

A key emphasis of the RPP is the rejuvenation of the ageing laser science expertise of South Africa by developing and empowering the youth in laser research.

Initiatives of the group include:

- Various student opportunities
- Research support under the RPP
- Research and mentorship support under the CSIR user facility
- Research collaboration across Africa through the African Laser Centre
- PULSE (public awareness programme).

Student opportunities

In order to ensure that a sustainable corps of laser expertise is nourished and maintained, young researchers are trained in laser technology. Opportunities available to students are:

- **Vacation work** – A selected number of graduate students in SET gain valuable experience working during their summer vacation at the CSIR National Laser Centre laboratories
- **Internships** – This is a year-long internship programme whereby graduates in the SET fields gain experience and mentoring in laser-related science while employed at the CSIR under contract
- **Studentships** – MSc and PhD students may apply for studentships, which entail research work on CSIR projects at CSIR research facilities while registered at a local university.

Four students from TEIs get to grips with laser technology at the CSIR during their summer holidays

Rental pool

With administrative and financial support from the National Research Foundation (NRF), the CSIR runs an access grant scheme that makes unique laser equipment and diagnostics available to South African researchers in laser-related fields. The scheme provides TEIs in South Africa with access to lasers, diagnostic equipment and technical support to enable them to conduct research. The equipment is rented out to TEIs for specific approved research projects under the CSIR's RPP. While the name of the scheme suggests that the equipment and services are rented, there is no cost to the individual TEI participating. The CSIR and the NRF source funding for all associated costs on behalf of participating TEIs.

The RPP is becoming popular with TEIs as evidenced by a steady growth since its inception. The first review panel for the research projects approved eight projects in 2000, which grew to 11 in 2001. This year the number of supported project has peaked at 19. The process is highly competitive, with roughly only half of the applications being successful.

The focus areas of RPP research projects are determined by the TEIs themselves and the CSIR strives to encourage as diverse a laser research portfolio as possible. The research straddles disciplines such as physics, engineering, chemistry, health and environmental science. Lasers thus not only stimulate light, but also our natural curiosity!

User Facility

The CSIR National Laser Centre has in-house research laboratories that are referred to as the User Facility. These highly equipped laboratories are used by CSIR researchers to conduct research in multi-disciplinary fields such as nanotechnology, spectroscopy and laser beams.

The User Facility also provides cutting-edge equipment to researchers based at TEIs to use on a shared basis. In this way, experienced and inexperienced researchers are able to use state-of-the-art, expensive research equipment, which would otherwise not be available to each individual TEI.

New users are mentored through the process of starting laser related research and are assisted with writing grant applications. The facility thus provides the opportunity to gain experience on laser systems, while collaborating with CSIR scientists. Some of the TEIs that benefit from the facility this year include the Nelson Mandela Metropolitan University, the Tshwane University of Technology, the universities of Pretoria, KwaZulu-Natal, the Witwatersrand and Zimbabwe.

Public understanding

The CSIR National Laser Centre runs a public awareness campaign that has a characteristic acronym "PULSE" – Public Understanding of Laser Science and Engineering. Through the PULSE programme, the CSIR communicates its laser activities to the general public and also creates a broader community awareness of the economic and social benefits of SET. The centre participates in SET exhibitions and has an area earmarked for the CSIR at the SCI-Bono Discovery Centre in Johannesburg, Scie-Enza Science Centre at the University of Pretoria and at the University of Zululand Science Centre. The CSIR also participates in all important national SET festivals. PULSE undertakes regular outreach activities to a number of schools per year with a conscious effort to target previously disadvantaged schools. Over 10 000 school learners are reached annually.

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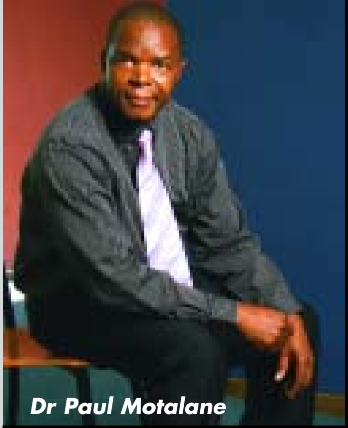
Dr Paul Motalane

Lasers for Africa

Creating nodes of excellence in laser technology throughout Africa has the potential to develop much-needed research capacity, infrastructure, technology transfer and application, which will ultimately contribute to the prosperity of the continent.

With this in mind, the African Laser Centre (ALC) was launched in November 2003 as a fledgling programme within the CSIR National Laser Centre. The ALC is aimed at encouraging laser science and optics-related research collaboration between African researchers, and facilitating researcher and student exchanges between African institutes.

The mission statement that was accepted by the ALC members is to "enable African nations to collaborate with each other and internationally play a major role in utilising light to advance science and technology, thereby contributing to the advancement of the economies, their global competitiveness, education and welfare of their people. This cooperation will take place in the spirit of New Partnership for Africa's Development (NEPAD) and the African Union".

The ALC is a virtual centre of excellence, which consists of nodes of research institutes all over the African continent. Membership is open to all research institutes in Africa that are actively involved in laser-related science and technology through R&D, education or training. Currently the ALC comprises 19 members from South Africa, Algeria, Cameroon, Ghana, Kenya, Lesotho, Senegal, Tunisia, Zambia and Zimbabwe with membership for organisations in Egypt, Ethiopia and Namibia to be confirmed in the near future.

The organisation is currently guided by a Board of Directors, with representation from South Africa, Senegal, Tunisia, Ghana as well as a member from the United States. The ALC will establish an office in Pretoria, with an Executive Director responsible for business development, sourcing funds, etc.

The ALC is an official NEPAD flagship programme. In this regard, Africa's S&T consolidated plan of action makes specific reference to investing significantly towards strengthening the ALC in the future. Currently the ALC is funded mainly by the Department of Science and Technology and the CSIR National Laser Centre. Thus, a major challenge is to obtain financial support from countries that have institutes which are members of the ALC. This will be one of the main drives of the ALC in the near future.

The CSIR also provides a management function for the various programmes of the ALC, including sourcing the required funding for its operations, and the organisation is involved as a collaborator in a number of ALC-funded projects.

The business plan of the ALC identified a number of programmes that will be pursued by the centre in the quest to achieve its objectives. These programmes include research, education, awards and special recognition, equipment and research infrastructure, technology transfer and financial development. Currently, the main focus of the ALC has been on capacity development through education and research.

There is no doubt that laser technology can play a significant role in improving the quality of life of the African people. It is therefore important to ensure that research outputs funded under the ALC address Africa's socio-economic problems. To this end, some of the projects currently funded by the centre are investigating issues such as cheap solar cells for the manufacture of heating and lighting devices and understanding the fundamental causes of plant stress, which is an important phenomenon in agriculture.

Some of the ALC highlights for the 2004/2005 financial year include the following:

- ALC members attended and presented papers at the South African Institute of Physics annual conference held in Bloemfontein, July 2004
- Research collaboration between eight South African institutions and other African countries was supported by the CSIR through the ALC
- The first ALC course was offered to technicians from African institutes at the University of Stellenbosch in February 2005
- The first lecture series took place at the University of Zimbabwe during April 2005 and at the University of Ethiopia in December 2005
- The US-Africa Advanced Studies Institute presented a successful workshop in November 2005 on photon interactions with atoms and molecules, attended by more than 90 participants
- In 2006, nine new peer-reviewed project proposals were accepted for funding.

Further information is available at
www.africanlasercentre.org

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A bright future in photonics

Introduction

Photonics is the science and technology of generating and controlling photons – particles of light. Photonic devices usually operate in the visible and near infrared region of the electromagnetic spectrum, often at frequencies in the order of hundreds of terahertz (1 terahertz = 1 012 Hz). The holy grail of the photonics community is to make the photon the electron of the future, i.e. "electronics" based on photonics. The applications of photonics cover many disciplines, with the single aim of harnessing the photon in fields such as optics, materials science, electrical engineering, nanotechnology, physics and chemistry. The 20th century is often called the century of the electron because of the technological breakthroughs enabled by the electron. It is likely that the 21st century will be known as the century of the photon.

As can be seen in the table below, the potential monetary impact of the photonics industry on the European economy is $250 billion. If one keeps in mind that the European photonics industry is less than 1/3 of the world photonics industry, the expected impact of photonics on the world economy in 2010 will approach one trillion dollars!

THE POTENTIAL OF PHOTONICS FOR THE EUROPEAN INDUSTRY

	Number of EU jobs	Monetary value of products (billion $)	Number of patents
Estimate for 2003	500 000	60	15 000
Estimate for 2005	1.5 million	250	45 000

Photonics in science

The science of photonics is a very wide and diverse field, and covers topics such as:

- Creating and studying Bose-Einstein condensates
- Developing devices for detecting gravitational waves
- Studying ultra-short phenomena
- Studying and creating extreme conditions
- Studying biological processes driven by photons
- Studying chemical reaction mechanisms
- Spectroscopy
- Laser particle accelerators.

Photonics in technology

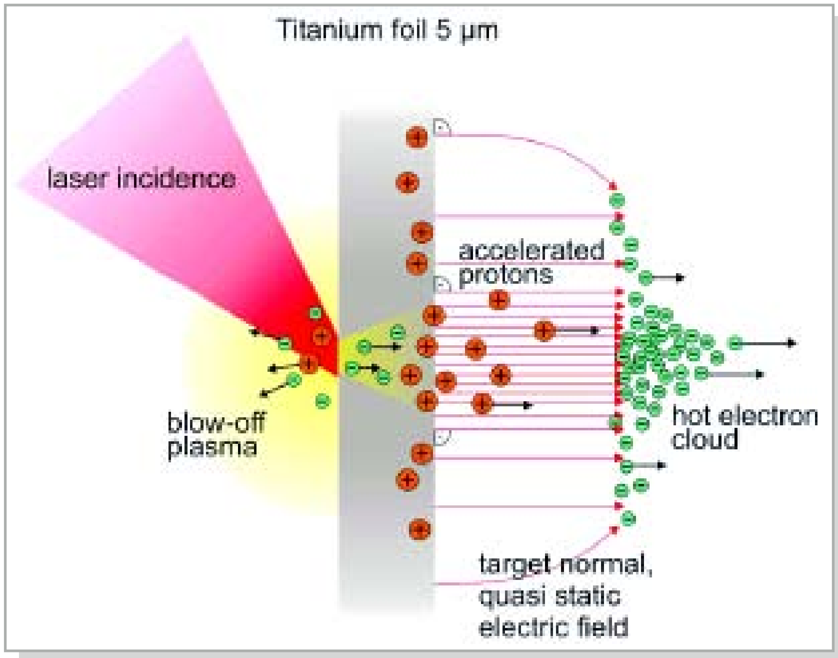
The application of photonics in technology is as diverse as that in science. The impact of photonics technology in our daily lives is immense. Photonics technology enables the processing, storage, transport and visualisation of huge masses of data. In manufacturing, laser light is used as a fast and precise tool for cutting, welding and scribing. Laser manufacturing is used for objects as large as huge ocean-going tankers to tiny nano structures. Innovative lighting systems create convenient surroundings and save energy. If light-emitting diodes were introduced aggressively today, they would save at least two billion barrels of oil per year by 2010!

Lasers and photonic devices are used daily in health care. Optical devices are used to do diagnosis and laser systems are used to correct a patient's vision. Photonic systems are also key to the micro-cosmos of life in biotechnology, pharmaceuticals and genetics. For example, photonic tools are capable of not only manipulating molecules but also living cells without causing harm to them. Photonics will significantly contribute to making life-saving drugs. Since the applications of photonics in industry are so diverse, the impact of two particular applications will be discussed.

Information and communications

Photonics has become the driving force for information and communications. The small nano structures of computer chips are fabricated by means of optical lithography. The feature size on these lithography masks is limited by the wavelength of light. The requirement for smaller featured sizes is the primary driving force for developing deep-ultraviolet laser sources. Current lithography systems are using 193 nm ArF Excimer laser sources. It is expected that the next generation of lithography systems would require an operating wavelength as short as 14 nm, in the extreme-UV. Many millions of dollars are currently being spent to develop extreme-UV lithograpy lasers.

Silicon-based photonics is an area of active research, driven primarily by the existing manufacturing base. Extending the existing silicon manufacturing base into the photonics domain could have tremendous benefits. An important driver for this technology is the intrinsic distance x bandwidth limitations of electronic communication links. Photonic links are typically utilised once these electronic limitations have been encountered. It is clear that more industries will switch to photonics in the near future.



Lighting and displays

Solid-state light sources are the most efficient sources of coloured light in the entire visible spectrum. Solid-state lighting (SSL) offers the most elegant method of directly converting electrical energy into visible light. SSL, consisting of inorganic and organic light-emitting diodes, has the potential to replace conventional light sources. It allows freedom of shape and full flexibility with regard to colour and brightness. This could result in so-called "healthy light". This will improve workplace safety, human mood and the wellbeing of people.

Considerable energy savings can be realised by replacing existing less efficient white light sources with solid-state light sources. For example, this would translate to savings in Europe by 2015 of 40 000 MW electrical peak power supply or an equivalent of two billion barrels of oil and 50 million tons of CO_2 per year. It is estimated that, if all current lighting sources are replaced by SSL, by 2025 SSL could reduce the global amount of electricity for lighting by at least 55%.

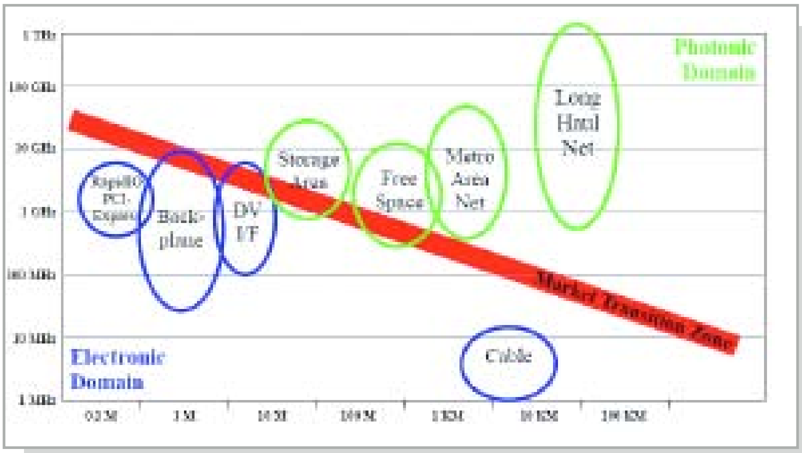
A key technology at the end of the information chain is visualisation. Future displays based on SSL components will offer exciting features in terms of resolution, colour, contrast, speed and compactness far beyond today's possibilities. Slim liquid crystal displays (LCD) are everywhere in our daily lives and are based on SSL source technology. An LCD screen backlit with a multitude of tiny red, green and blue LEDs can achieve colour quality in terms of brilliance and colour that has not been feasible until now. Screens like this will claim their share of the future large flat-screen televisions.

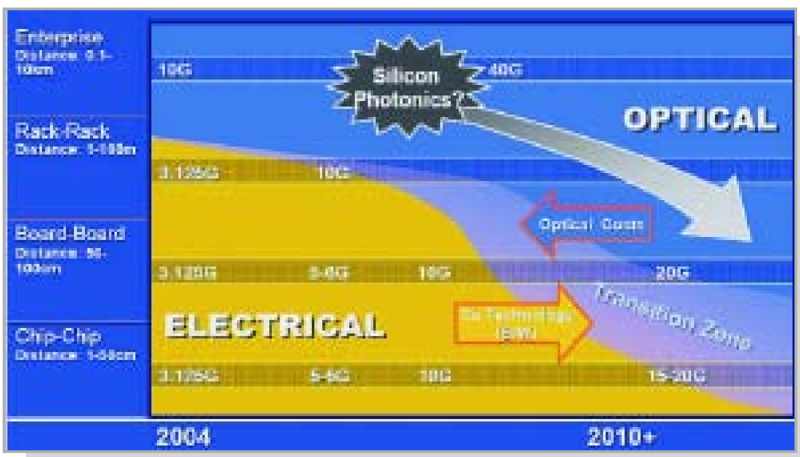
Photonics in South Africa

South Africa has an active community of engineers and scientists working in photonics and related fields. Various engineering departments are active in a wide range of fields such as fibre optics, optical signal processing, quantum communication and quantum cryptography systems. Various physics departments are also active on the scientific side of photonics. In particular, groups are active in ultra-short pulse lasers, laser physics and photonic materials.

The photonics industry in South Africa is relatively small, but a few companies are competing very well on the international stage. For example, South African-developed laser range finders and laser target illuminators are able to compete with the best in the world. Lasers manufactured by a South African company are used by many aerospace companies to perform non-destructive testing of composite aircraft components.

Various groups at the CSIR are active in photonics. In particular the CSIR National Laser Centre is active in laser development, biophotonics and laser materials processing. The Centre is an active player in the national ultra-short high-intensity initiative that aims to establish a petawatt class laser system in South Africa. CSIR Defence, Peace, Safety and Security is active in various areas of optronics such as directed infrared counter measure (DIRCM) systems based on lasers developed at the CSIR National Laser Centre. The CSIR has identified photonics as an emerging research area and it is expected that in the near future the organisation's activities in this very exciting field will increase.





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Conclusion

Photonics is an emerging area of both science and technology. As the world moves to "faster" and "smaller", so the domain of photonics will come into its own. From a photonics point of view, the future is so bright we need shades!

References

[1] Photonics for the 21st Century, a consolidated European Photonics Research Initiative

[2] Figure courtesy of Dr H Schwoerer, Institute for Quantum Optics, Friedrich Schiller University, Jena Germany, presentation at iThemba Labs in April 2006

[3] Figure courtesy of "Communications Technology Roadmap", The Microphotonics Centre at MIT, 2005

[4] Figure courtesy of Intel: www:intel.com

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BioBed holds great promise for medical break-throughs

Although biophotonics is already an established field of research internationally, it is still in its infancy in South Africa.

During the past few years, the biophotonics community in our country has grown considerably due to the links forged between the CSIR National Laser Centre's Biophotonics Group and the universities of Rhodes (Chemistry Department), Johannesburg (Health Sciences Department) and Stellenbosch (Department of Physiological Sciences).

Some of the activities currently carried out by the CSIR and its collaborators include:

- **Development and evaluation of drugs for photodynamic therapy (PDT) cancer treatment:** The results of this initiative could have a significant impact on the quality of life of cancer patients since PDT has fewer side effects than normal chemotherapy and less scarring occurs. At present PDT is not an approved treatment modality for cancer in South Africa. The project, driven by Prof Tebello Nyokong from Rhodes University, aims to establish PDT in the country and to develop drugs customised to the South African environment and its communities.

- **Light enhanced wound healing (LEWH), especially for diabetic patients:** Untreated diabetic ulcers can lead to limb amputation. With this in mind, the CSIR initiated a project with the University of Johannesburg to investigate the use of laser treatment to heal wounds. Good progress has been made so far.

- **Passive sorting of stem cell types using optical tweezers:** This project is being implemented in cooperation with the Physics Department of the University of St Andrews.

- **Studies on the impact of skin tone on medical laser applications:** A 3D model of human skin will be used to test the penetration of different laser wavelengths through skin. The results will be used to refine different laser treatment modalities.

The CSIR is also in the process of establishing a generic technology platform for further advanced R&D in laser applications and other optically-based methods for purposes of medical diagnostics and therapy. The first step in this process will be to set up a biomedical optics test bed (BioBed) facility for preclinical trial testing of novel experimental medical optics applications.

The main advantage of this BioBed facility is that it will allow for biomedical optics application tests in an *in vitro* experimental biological model as close to the final *in vivo* application as possible. Realistic extreme testing and risk analysis of new applications can be performed without any potential hazards to patients, as opposed to actual clinical trials. This will enable better, faster and more cost-effective planning of the required clinical trials and, in addition, will provide a firmer basis for ethical approval of such trials.

In order for the BioBed framework to become a reality, a biological cell culture laboratory has recently been established and closely integrated with an adjacent optical laboratory at the CSIR National Laser Centre. This set of dedicated laboratories constitutes a biophotonics research facility that is unique on the continent. Furthermore, the BioBed facility has enabled the CSIR to attract international attention and establish research collaboration with four European institutes, which are world leaders in their respective fields. All four of these institutes have committed to work towards a joint proposal and consortium for the 7th European Framework programme (FP7).

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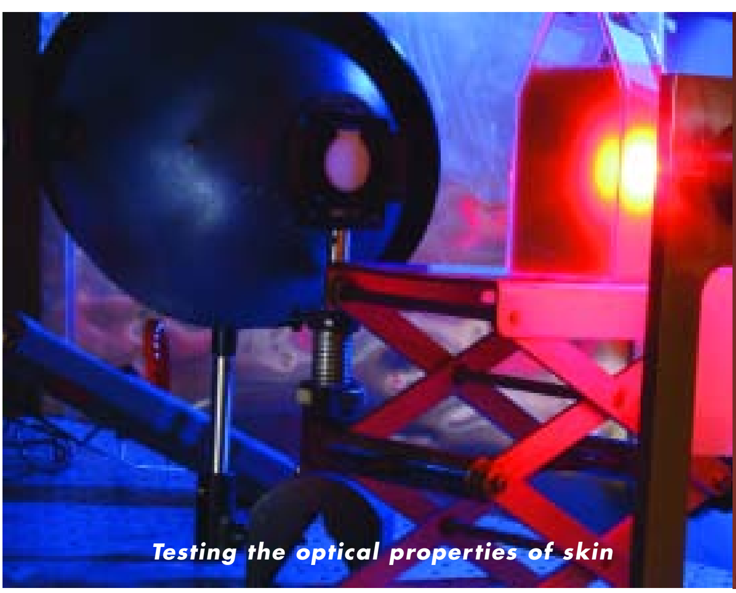
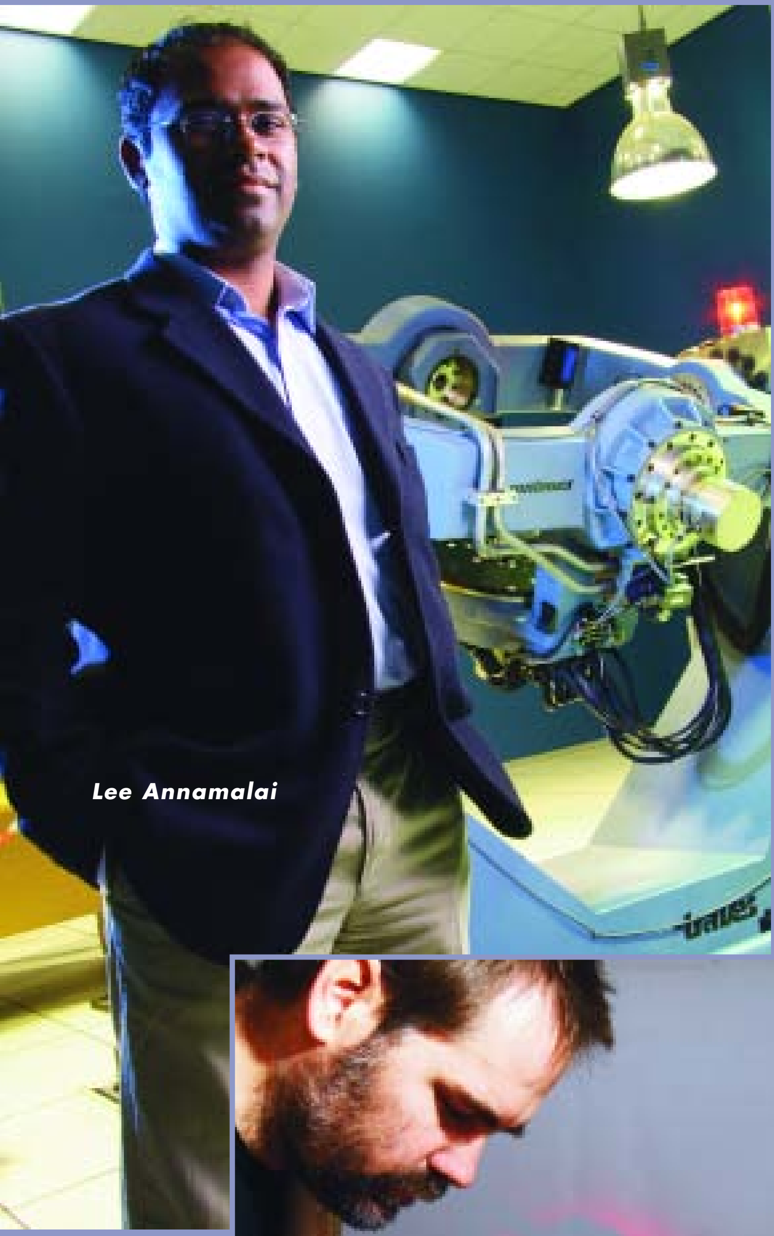

Testing the optical properties of skin


Aletta Karsten


Jan Dam

Advanced sensing systems with optronics



Lee Annamalai

Optronics – the field encompassing the study, design and development of sensors incorporating optics, mechanics and electronics – is a multi-disciplinary field that has been within the CSIR for a large part of its 60-year history. In recent years, optronics has been contributing significantly to the economic growth and techno-logical advancement of emerging knowledge-intensive countries. Application areas such as lasers, opto-electronic devices, novel optical design and manufacturing, infrared imaging, visual displays and fibre optics have all been contributing to industry growth in the billions of dollars.

Innovation in optronics

Optical research within the CSIR has a long and proud history that has seen the development of advanced optical devices, the introduction and growth of lasers and the growth of advanced unique new sensors incorporating optics and electronics.

The optical competences in the CSIR are located within four main groups:

- the sensors group at CSIR Materials Science and Manufacturing, with advanced developments such as the CoroCAM having a major impact both locally and internationally
- the fibre optic measurement team within the CSIR National Metrology Laboratory, with the first femtosecond laser in South Africa
- the CSIR National Laser Centre, which houses the largest unique laser capability in the country
- the Optronic Sensor Systems competence area within CSIR Defence, Peace, Safety and Security, with a focus on defence applications – sensor development in this latter area has spanned demonstrators for hyperspectral imaging, day and night long-range surveillance, optical telescopes for micro-satellites and flight tested infra-red active countermeasure systems.

Photonics has been identified as one of the CSIR emerging research areas, which will bring about the generation of new concepts that would take these strong competencies into the future.

The CSIR groups have maintained their technological leadership in optronics, with the diversification enabling each group to focus on particular areas and grow in depth and quality of R&D. There are some key examples, which are explored in other articles within this publication, exploring the advances in the field. With the current CSIR drive towards research outputs, we can expect to see more of the novel work currently applied practically, to be published widely and hence draw more international attention to the strong competencies within the organisation. There is little doubt that in this area the local capability is on par with many leading international players, with some skills actually being applied to international customer requirements.

The CSIR optronic capability has progressed substantially in the applied research area, and research thinking from other areas has become integrated into the optronics field.

Topics such as modelling and simulation are playing a strong role in predicting performance and hence driving the development of optimised solutions. Modelling also enables evaluation of the suitability of theoretical concepts to practical implementations prior to any expensive purchases. The use of modelling optical systems and their interactions with the environment has been used in defence applications to a large degree, where these techniques improve the protection of aircraft against optical threats.

Another application area that started growing in significance within the CSIR is the use of optical sensors data for remote sensing. Optical satellite sensor data are used in remote sensing applications to create early warning indicators of fires, approaching adverse weather conditions, and even the presence of fish in certain regions of the ocean.

There is a clear indication that the optronics capabilities in the CSIR have grown in the systems hierarchy over the years, from component level expertise to larger systems capabilities integrating other technologies, and involving advanced modelling and simulation concepts, derived from the deep understanding of the physical phenomena.

Although a growth in the systems hierarchy has been observed, there has been a move away from the advances in component technologies, which are attracting major research interest internationally. These component technologies reside within the field referred to as photonics, and is the study and application of electronic devices that interact with light. These devices are electrical to optical or optical to electrical transducers and are based on the quantum mechanical effects of light in semiconductor or other materials, sometimes in the presence of electric fields. This gives rise to new components such as photodiodes, organic light-emmiting diodes, photomultipliers, integrated optical circuit elements and new types of optical fibres.

Amidst all these technology advances, the CSIR is starting a process of re-orientation to stimulate new research activities in the field. Photonics has been identified as one of the CSIR's emerging research areas, which will bring about the generation of new concepts that would take these strong competences into the future. The shared vision at present is one of reinvigorating and stimulating a local industry, which would exploit the advances in technology and make them available to the demand that exists globally. In order to do this, growth in capabilities is needed, which can result only from coordinated participation between tertiary education institutions, industries and institutes. There is indeed a clear and encompassing role to be played by all participants towards achieving this vision.

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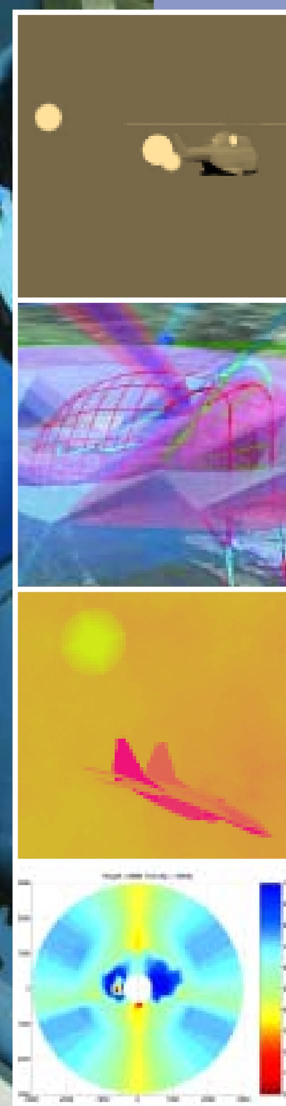
Getting to grips with optronic systems



Nelis Willers, JP Delport, Nelia Lombard and Suja Joseph of the optronics competency area

Computer-based modelling and simulation play a key role in understanding and exploiting optronic systems for safety and security. It is an essential component of research in the diverse field of optronics.

Optronics is a multi-disciplinary science, rooted in physics and electronics, but touching on environmental, atmospheric, earth observation, and human cognitive sciences and several engineering disciplines. An optronic system achieves its goal through the utilisation of electromagnetic energy in any or all of its "optical" forms, ultraviolet, visible, or infrared energy. Optronics can be considered the domain where light, optics, electronics and the human meet. Frequently the human eye and cognitive processes form part of this system. Optronic applications include advanced research support, medical, industrial, consumer and military applications.

The Optronics Competency Area in CSIR Defence, Peace, Safety and Security performs directed R&D and builds technology demonstrators in the fields of optical design, long-range surveillance, earth observation, imaging using TV and thermal cameras, image processing, fibre optics, camouflage, the evaluation and optimisation of military systems and protection of military personnel and equipment against observation and hostile missiles.

The multi-disciplinary nature of optronics results in a many-faceted problem space, often with interdependencies between seemingly unrelated phenomena. Modelling and simulation play a key role in handling the complexities of the problem space, thereby providing a tool to facilitate and enhance understanding. Modelling and simulation also provide the means to experiment with system elements and explore optronics phenomena. Such experimentation typically covers the problem domain beyond physically-observed behaviour, exploring new applications, testing new designs or evaluating a system's behaviour under large numbers of yet untested input conditions.

Optical radiometry, the scientific analysis of optical radiation energy propagation, is central to the description of optronics phenomena and systems. Radiometry employs physics and mathematics-based methods supported by measurements using highly sophisticated equipment.

Modelling is the process of building an understanding of the behaviour of phenomena in a system. In the optronics domain this understanding is captured in terms of data, radiometric properties and dynamic behaviour. This understanding is typically captured in detailed computer models that can be "exercised" to recreate the required behaviour in a "software laboratory".

The modelling process entails:

- compilation of a physics-based model of the radiometric phenomenon
- compilation of a three-dimensional geometric model
- execution of carefully-planned measurement observations
- numerical analysis to match the physical reality and the observations
- implementation of physics theory and measured data in a software-based computer model.

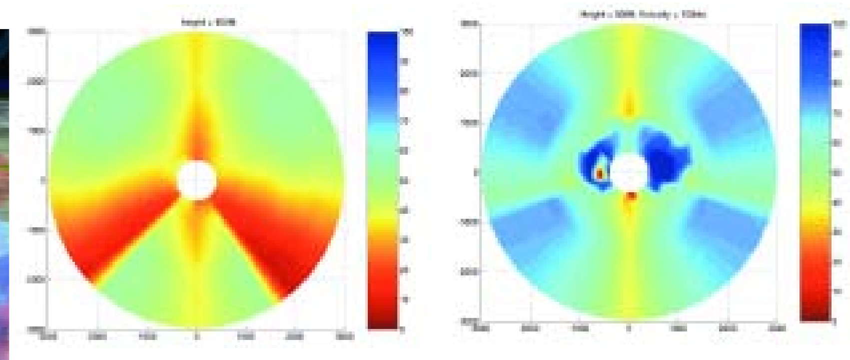
This model is constantly upgraded and improved with new information.

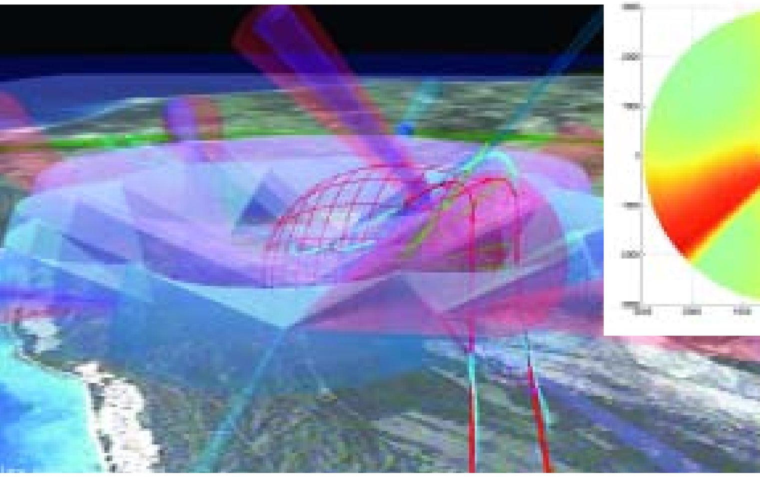
Optronics is a multi-disciplinary science, rooted in physics and electronics, but touching on environmental, atmospheric, earth observation, and human cognitive sciences and several engineering disciplines.

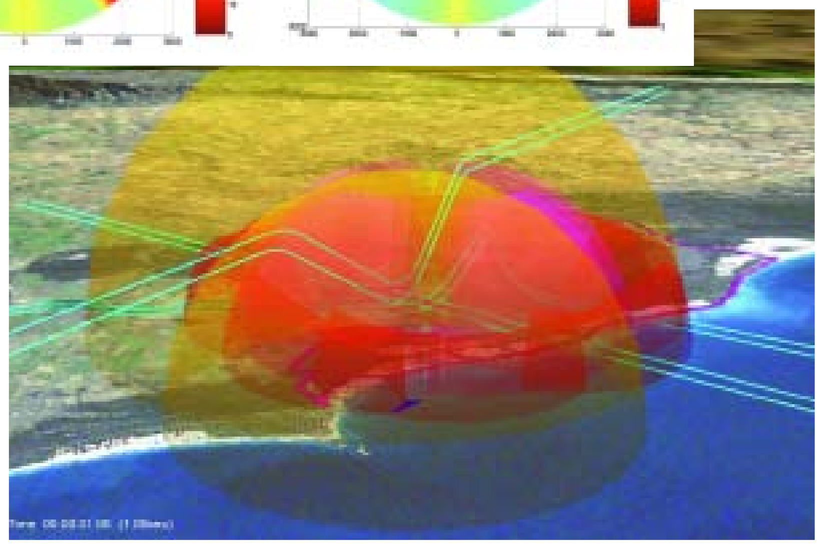
Simulation is the process of exercising these models and studying the models' behaviour. This is done in an appropriate computer environment, called a computer simulator. Hardware-in-the-loop simulator (HILS) simulations are also often used, integrating real equipment with the computer simulators. Computer simulations in optronics cover a wide range of levels of abstraction (from low-level physical models, to intermediate behavioural models, to high-level system emergent behaviour models), depending on the nature of the problem under investigation.

The core to the CSIR simulation ability is a suite of image simulation and visualisation systems. Three image simulation and visualisation systems are currently in active development and use. Ongoing research leads to continual improvements of

Polar plots of aircraft vulnerability to shoulder-launched missile attack







Right and far left above: The Cyclops visualisation tool rendering the battle handling complexities of the Ground-Based Air Defence System (GBADS)

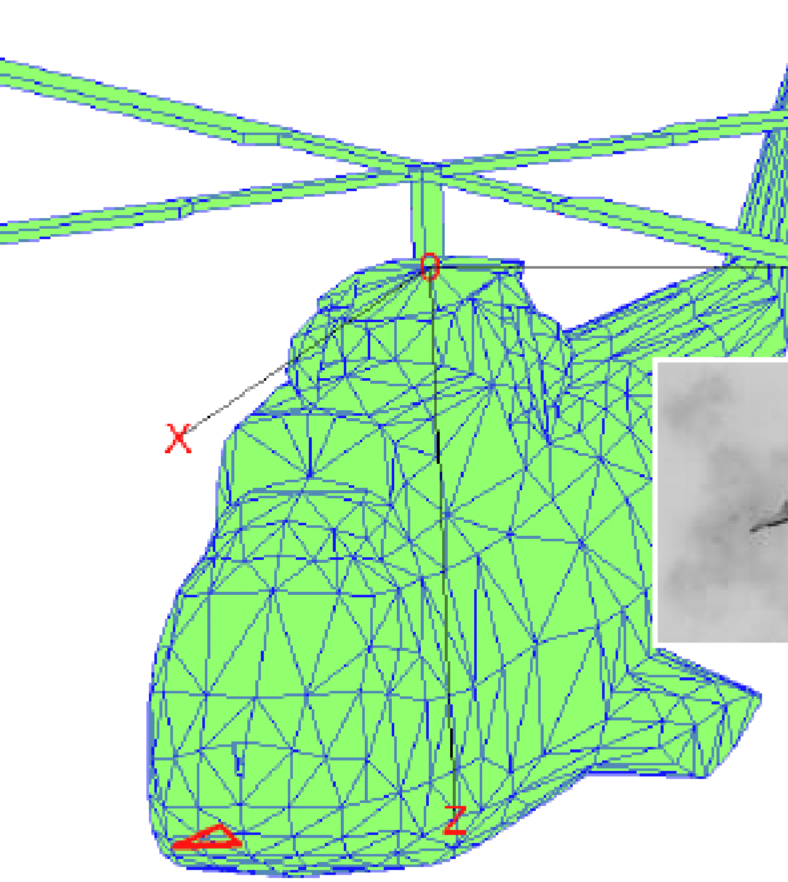
these simulation tools. These simulation systems, as powerful as they are, require considerable computation power, and are run on the group's Linux computer cluster.

The Countermeasure Simulation (CmSim) and the Optronic Scene Simulation (OSSIM) systems build synthetic environments that create images of yet unseen worlds and conditions, providing scientists and engineers with images suitable for radiometry research and image processing algorithm development. The systems create models of possible real-world scenes, complete with terrain, trees, buildings, roads and other objects. Such models are routinely used in games and computer graphics, but the unique CmSim and OSSIM contribution is the use of physics-based renderings equations. These rendering equations account for both reflected sunlight (e.g. normal human vision) as well as thermally self-emitted radiation (e.g. infrared heat radiation), path radiance and sky radiance, all at the same time. The rendering equations are based on rigorous physics principles, in order to provide accurate scene signature predictions.

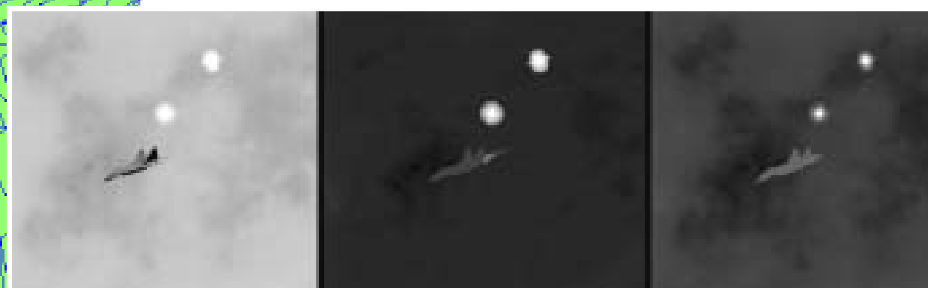
The innovative OSSIM simulator, developed jointly with Denel Dynamics, creates any number of images in different spectral bands in the spectral range from 250 nm to 25 μm. At shorter wavelengths, the reflected sunlight dominates the signature, while at longer wavelengths the signature of ambient temperature objects consists mostly of thermal self-emittance. In the 3–5 μm spectral band, the signature from objects in the terrain constitutes equal flux from the sun and thermal self-emission. OSSIM provides the capability to calculate these complex-source signatures with ease and accuracy. It is also now possible to accurately predict signatures and scene images in the critical periods around sunrise and sunset. This capability allows further research into the temperature cross-over phenomenon, where some objects appear invisible under transient conditions. Atmospheric optical radiation propagation and path radiance, for user-specified atmospheric conditions, are calculated with the acclaimed US-developed MODTRAN code and integrated into the simulation to render scenes true to the atmospheric conditions that could be encountered in the real world.

CmSim, executing in real-time, provides the ability to integrate with external systems in HILS simulations. In such a simulation, a real missile guidance unit is mounted on a gimballed rate table, providing the guidance unit with appropriate real-world angular and linear rates and accelerations. CmSim creates the appropriate target signals, as would be created by the missile as if it viewed a target aircraft. These computer simulated signals are injected into the missile guidance unit and the missile's response to these signals is used to create the new simulation signal. Repeating this process, the missile "flies" towards the target. The CSIR HILS testing is a very powerful capability serving the South African National Defence Force's (SANDF) needs.

The SANDF regularly undertakes peace missions throughout Africa as part of UN-sanctioned multi-national forces, often with limited deployment support. Since adversarial forces might on occasion attack SANDF aircraft, suitable means must be developed to minimise the risk of aircraft loss. The CmSim simulation



Modelling the three-dimensional wire frame and radiometric properties of a South African Air Force (SAAF) Oryx helicopter



The multi-spectral signature of an aircraft and counter-measure flares in three spectral bands on the left near infrared, in the middle 3-5 μm mid-wave infrared and on the right 8-12 μm long-wave infrared

was used to provide a countermeasure flare solution to decoy missiles away from the South African Air Force (SAAF) helicopters.

The nature of optronics simulation requires close liaison with stakeholders and experts in other, often unrelated, scientific disciplines. Close ties are maintained with laboratories abroad, partners and local industry and clients. The CSIR's optronics team employs modelling and simulation to serve clients' needs.

Typical applications include:

- development of aircraft self-protection systems
- prediction of optronic system performance
- design and optimisation of optronic systems
- HILS
- investigation of atmospheric or environmental effects on system behaviour
- providing infrastructure for image processing research.

A perpetual issue in surveillance is range prediction: "How far can I see the target?". Sophisticated simulation techniques provide details of the detection, recognition and identification ranges for user-defined objects. These simulations employ models of the human cognitive faculties, based on laboratory experiments and field trials.

The simulation environments provide test-beds for research into advanced sensor concepts, radiometry and physics-based image rendering, system level effects of optical energy propagation through real-world atmospheres, the effect of scene clutter on human cognitive processes and similar directed research issues.

A less obvious benefit of the simulation environments is that of knowledge management. The simulation and its associated models serve as a repository for all information obtained from measurements, and as a source environment for new research and technology development. The simulation environment is a living knowledge repository, supporting sustained institutional growth in expertise and knowledge, enabling the execution of new work hitherto not possible.

Modelling and simulation provide a unique blend of tools, techniques and ready knowledge, supporting R&D of optronics solutions to the national industry, the SANDF and international clients. This modelling and simulation foundation supports the development of sustainable business and human capital development to the benefit of the CSIR and its stakeholders.

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Alwyn Smit

Protecting aircraft with infrared counter-measures

Successful development and demonstration of a technology demonstrator

The infrared (IR) heat-seeking missile has brought down nearly all aircraft shot down in the last 15 years. One of the most lethal threats is the shoulder-launched surface-to-air IR missile, which is deployed all over the world (including Africa, where South Africa is involved in peace-keeping missions) – and it is available to all types of outlaw organisations.

The terror threat to civil aviation has also been widely acknowledged since the September 11th terror attack. Closer to home, recent news articles on the two South African pilots killed when their cargo plane was shot down by a surface-to-air missile (SAM) in the DRC, has brought these threats closer to South African interests. The South African military acquisition programme includes the new Airbus A400 transport aircraft to replace the ageing Hercules C130 fleet. These "slow" flying aircraft are very vulnerable to missile attacks during peace-keeping enforcement missions in hostile environments and need some form of effective protection.

Countermeasure flares, the common form of countermeasure against IR SAMs, will soon become ineffective against newer two-colour and imaging missiles. These newer generation missiles are already a threat to aircraft operating in mid-Africa. Until now, there has been no proven defence against the modern threats; however laser-based Directed Infrared Countermeasure (DIRCM) systems defeated the newer generation IR SAM threats very successfully at the US Army's White Sands Missile Range on several occasions during concept tests since June 1998. It is recognised that DIRCM technology and systems are strategically and commercially sensitive and therefore subjected to severe export constraints. The modulation techniques and active laser unit are, for instance, not available on the international market. The local development of such technology is thus crucial for the continued protection of military and commercial aircraft in the African context.

CSIR Defence, Peace, Safety and Security has, in conjunction with the CSIR National Laser Centre and a European partner, developed a technology demonstrator that successfully demonstrated some of the key "soft kill" (low power jamming) DIRCM technologies during field trials in February 2006.

The South African contribution to the technology project was fully supported and funded by the Department of Defence and managed by Armscor. The missiles used as simulated threats were provided by the South African Air Force (SAAF) as part of the Infrared Mobile Laboratory (IRML), a mobile research laboratory used to support the field trials. Ground testing was done at Zwartkops Air Force Base with flight tests conducted on a SAAF helicopter at the SAAF Test Flight Development Centre (TFDC) and the Overberg Test Range (OTB).

The demonstration proved that the technology exists within the respective institutes to produce a DIRCM system, although there is still room for improvements to optimise system performance, reduce physical size and weight as well as increase reliability. The CSIR laser technology used is leading edge, but reliability, size and specific functionality must be improved. Intimate knowledge on jamming of IR seekers as demonstrated by the CSIR was evident in the field trial successes.

The pointing system technology performed very well, but size and weight need to be reduced. The IR tracking technology performed reasonably well, but further improvements need to be made for tracking in high clutter environments. The IR missile warning technology used was not sufficiently mature, yet provided good threat designation. All these technologies were contributed by a European partner.

The stage has been set for new research in technology areas from lasers to image processing and optical design and testing, to push the envelope on operational effectiveness of this innovation.

The UV missile warning technology, originally from the CSIR, and transferred to Saab Avitronics in the early 1990's provided satisfactory alarms even though it was not optimised for DIRCM use. CSIR system and aircraft integration capabilities were demonstrated successfully.

The stage has been set for new research in technology areas from lasers to image processing and optical design and testing, to push the envelope on operational effectiveness of this innovation. New concepts to be explored in laser design will provide higher powers, better efficiency and reduced size.

Image processing to accurately track the threats in background clutter and ensure that multiple threats can be countered is a prime area that requires significant research. Robust algorithms, and novel detector and signal processing techniques will need to be developed to meet these demanding requirements.

Opto-mechanical design that will be able to perform at the high response times needs to counter a threat travelling at 600 m/s and will require a step improvement in current capabilities.

The cooperation over the project's lifetime (10 years since concept inception) has strengthened international ties, and created a profound global respect for the engineers and scientists involved in this development.

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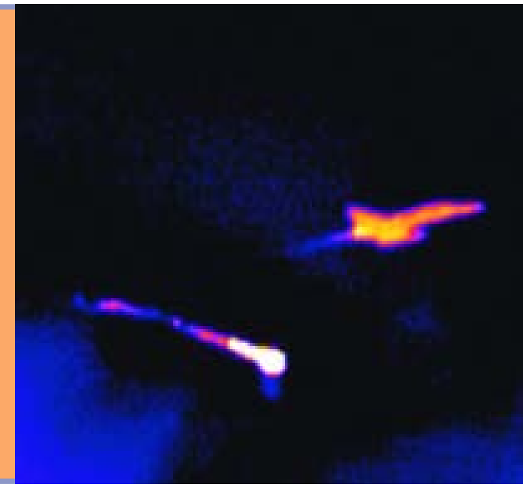
A holistic approach to platform protection of SANDF assets



"You don't know what you don't know, and you don't know until you measure it," is a typical belief held amongst most electronic warfare specialists. Measurements during field tests, camps and training sessions are considered the best method of optimising aircraft operating procedures against threats. This would inevitably result in the deployment of aircraft and personnel together with the dispensing of various countermeasures in order to evaluate effectiveness.

In the African scenario, slow-moving airborne platforms such as transport aircraft have in recent years come up against a wide variety of threats, including several generations of man-portable surface-to-air missile systems (MANPADS or SAMS). With South Africa's role in the African Union (AU) and New Partnership for Africa's Development (NEPAD), it is widely accepted that support for UN-sanctioned missions such as regional peacekeeping efforts, election support and the rendering of medical assistance, or the supply of food to isolated areas will become normal day-to-day events for our military personnel and assets.

The CSIR, in its role as a defence research and evaluation institute under research funding from the Department of Defence, was tasked with finding solutions for the protection of South African Air Force aircraft against infrared (IR) guided threats.

The first concerns, given the above scenarios, relate to the verified effectiveness of traditional countermeasures and doctrines against IR SAMS, given that 80% of all transport aircraft were brought down by the man-portable shoulder launched variants in all recent conflicts.

For purposes of objectively evaluating the vulnerability of aircraft to the threats, a series of steps must be taken, ranging from measuring the aircraft and environment, developing a detailed understanding of the threats (involving them in operational testing) and measuring the countermeasures and the doctrines in which they were employed.

With the introduction of IR thermal radiometers, it was possible to perform measurements and analytical calculations of aircraft signatures, flares and backgrounds, and predict the signature versus flare inten-sity to determine a J/S ratio (the ratio of countermeasure energy to aircraft signature energy).

The key question, however, revolved around how the threats could be included in a safe manner into the field exercises as the ultimate would be to test the effectiveness of flares against the actual missile threats.

This requirement led to the CSIR developing a process for aircraft self-protection that involved missile instrumentation exercises and the development of an IR mobile laboratory (IRML) that would bring the threats in a controlled manner to the field test and evaluation exercises.

The IRML (a South African Air Force asset) is a containerised field laboratory that integrates IR radiometers, instrumented missile systems and high-fidelity data-capture systems upgraded and optimised at the CSIR over many years, and has proven invaluable in the field evaluation of aircraft IR self-protection. These systems working in unison provide a skilled person with the necessary data to evaluate the survivability of the aircraft with its self-protection suite and doctrine, and to make suggestions on improvements.

With the confidence in the simulation system, and the fidelity of the environments, new opportunities arose for the capability.

However, the teams involved in this area of research realised there was the potential for major value addition. Large amounts of data were being gathered during these field trials and captured in the forms of reports, pictures, figures and data tables. With the growth in simulation concepts and software rendering techniques, a new way of capturing the valuable data being collected came to light – in the form of models – and a closed loop approach of measurements, analysis and simulation was defined.

The process of instrumenting the missile systems for integration into the IRML presented the opportunity to capture the essence of their operation in mo-dels. Measurements of aircraft provide valuable data as to the nature of their IR signatures and the contributors to these signatures, and could thus also be mo-delled. Due to the fact that these models were generated from actual IR measurements in the field and the laboratories, they are classified as being "real or high-fidelity models" operating at the signal level.

The next challenging step involved using the environment measured data and understanding of radiometry to create a synthetic world, radiometrically accurate in its physical representation. Software engineers, borrowing from work performed in computer graphics and gaming, created a virtual 3D IR world where the models could interact, thus providing a level of testing, simulating and evaluating that presented a cost saving and equipment lifetime saving that could not be matched.

The suite of simulation tools developed by the electronic warfare engineers and scientists opened up new areas of research in the areas of simulation, 3D computer image rendering, atmospheric physics and radiometry, computer systems and architecture in order to meet the requirements of the models and the desire to ensure that reality was accurately represented.

A model creation and verification process was developed and fine-tuned using tools and methods derived from the original measurement techniques. The move to digital networks enabled more data to be collected to validate model behaviour until confidence in its execution was achieved.

Detailed test points could now be simulated prior to field tests to predict behaviour of the aircraft and threats. Various countermeasure techniques that would require intensive flight clearance could be checked for effectiveness before involving any actual operational equipment or operators. Doctrines could be fine-tuned and developed in a safe risk-free environment. Flight trials became more that just trial-and-error exercises, but rewarding exercises, as just the most promising options could now be evaluated.

Part of the CSIR's technical advisory role to the South African National Defence Force (SANDF) is to assist in setting up specifications. By understanding the missile threat, the basic requirements for effective countermeasure performance specifications could be defined. Now, however, fine nuances in the threat operation and behaviour could be investigated more thoroughly. It became possible to identify in detail the reasons why certain countermeasure types and doctrines were ineffective. The simulation capability, together with the test and evaluation tools, enables the CSIR to objectively examine products and to comment on their suitability or adaptability for the South African environment.

With the confidence in the simulation system, and the fidelity of the environments, new opportunities arose for the capability. This involved real-time hardware-in-the-loop simulation using flight motion simulators to better characterise missile flight dynamics. The need to perform these simulations led to the requirement for wind-tunnel measurements performed at the CSIR's high-speed tunnel and the development of higher fidelity models, to better capture the threat behaviour.

More importantly, deviations in behaviour between the models and real systems were captured and analysed to improve the fidelity of the models or the rendered environment.

The models have become knowledge repositories that grow with the data gathered, while skills and understanding of the subject of IR electronic warfare have developed considerably through the closed loop measurement, simulation and analysis process.

The CSIR team, with this innovation in creating an integrated capability, is a leading IR electronic warfare centre, providing repeatable results taking all parameters into consideration to provide evaluation options in a systematic and traceable manner such that solutions to a very important problem can be found.

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Camouflage technology that deceives the eye

Camouflage is not about being "invisible". On the contrary, it's all about blending with the environment. Sometimes a potential target goes by undetected because observers see (and believe) what is presented to them for observation. In the extreme case, as with the army's Special Forces, these operators blend in so well with the environment that, even with intense searching, an observer is unable to detect them. Another example is that of a white aircraft, parked close to a chicken broiler, with only the telltale shape changed using the floor-mats, which remained undetected by reconnaissance aircraft (both these examples have been experienced by CSIR staff involved in camouflage activities).

Technology in the surveillance environment has improved in leaps and bounds, especially during the past few years of information technology and sensor development. It is not only the human eye that needs to be defeated, but also sophisticated sensors searching in the near-infrared (NIR), thermal and radar wavelengths. In the worst case, camouflage offers a few extra seconds – an additional edge over the opposing force. This is where "signature management" becomes important: can the enemy hear your vehicle from miles away, providing them with ample time to plan an ambush? Will they be able to smell the toothpaste you used this morning, once they are a few feet away from you?

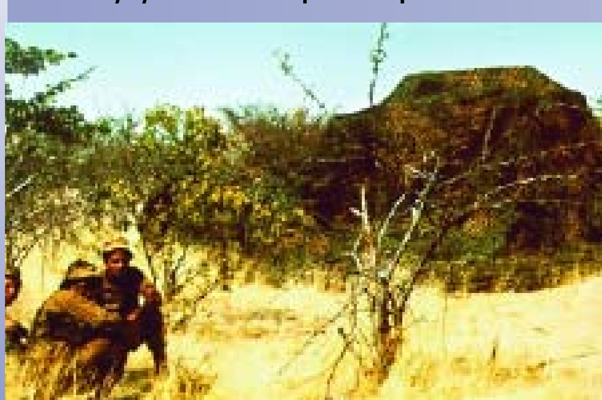
Quantitative measurement

The CSIR has recently expanded its modelling and simulation as well as test and evaluation capabilities. During the past few years, a huge amount of data about the South African environment (in the visual and NIR wavelengths particularly), has been accumulated. The data were analysed and a computer code was written to transform the data into a usable format. With this format, it was possible to predict "average colours" for specific environments. These colours were then printed onto fabric, using the current camouflage pattern of the South African National Defence Force (SANDF).

Digital photographs were taken of the uniforms in the field as depicted on pg 27, and the colours of the uniforms were compared to the colours in the rest of the scene. This comparison allows for a quantitative measure of the colours on the uniform in relation to the rest of the scene. In this particular scene, the colours in the brown uniform matched 30% of the environment's colours, while the percentage for the green uniform was 21%.

1978

Camouflage technology was established at the CSIR in 1978. Upon request from the SA Army, the CSIR developed a vehicle camouflage net (shown below), based on the technology available at that stage. A camouflage pattern for the G5 artillery system was developed and implemented.



1980s

With the help of industry, high-technology paints that are still been used today were developed to camouflage vehicles in the visible as well as the near-infrared part of the spectrum. The first vehicles to be painted with these paints were the Ystervark anti-aircraft gun and the Ratel.

Psychophysical evaluation

Most recently, psychophysical evaluations have been undertaken, where people evaluated the uniforms in the environment. Surprisingly, the green uniform performed better than the brown uniform, although the green uniform does not match the observed colour mix of the background as well as the brown uniform. Extensive evaluations will be performed over the next few months. The aim would be to refine the evaluation methods, and try to define the relationship between the numerical and psychophysical methods.

Two of the uniforms evaluated

Aerial evaluation

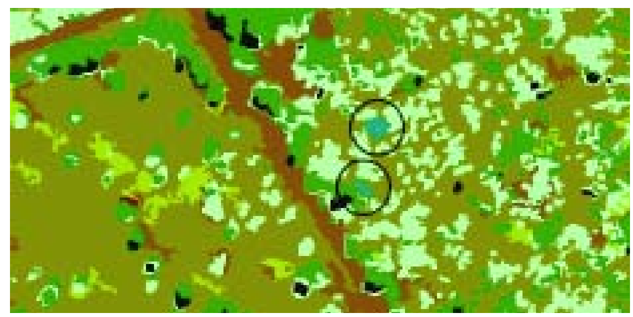
An aerial evaluation of various types of equipment in different stages of camouflage also took place. The aim was to demonstrate the effectiveness of the colours used on vehicles, as well as the effectiveness of camouflage nets used. It also demonstrated the capability and usefulness of modern software and image processing techniques. Of all the vehicles, one of each was deployed without any nets, in order to establish a baseline. The rest of the vehicles were deployed with nets as camouflage. The nets were standard SANDF issue, as well as various experimental nets developed by the CSIR. These nets were developed for rapid deployment, enabling the user to cover the vehicle in less than two minutes, and then remove the net again in less than a minute.

Image analysis techniques

Four different image analysis techniques were used to analyse the imagery, ranging from basic to sophisticated. The principle component analysis (PCA) method uses the different components/bands of the image – the red/green/blue (RGB) in this case. Each of these bands is inspected for anomalies, thereby increasing the probability of target detection. The success rate of detecting camouflaged objects with PCA was 67%.

The unsupervised classification technique involves allowing the software to classify the image in a pre-defined number of classes. One of the drawbacks of this technique is that it has considerable difficulties dealing with the rich information content of high-resolution data. This produces inconsistent classification results and the software has difficulty in extracting the objects of interest. The success rate of detecting camouflaged objects, using this method, was 40%.

The third analysis technique, supervised classification, comprises selection of areas with known properties as training samples from the so-called "calibration site", where nets and panels, having the reflectance properties of the targets, were displayed. The software used the training data and performed an inter-comparison with the rest of the image, which contained the camouflaged objects. Supervised classification had a 63% success rate of detecting camouflaged objects.



Object-based classification

The last image analysis technique applied to the imagery was object-based classification. Pre-defined rules for classifying objects in the image are set up. This can be the shape, size and texture. This close relationship between real-world objects and image objects vastly improves the detection probability. The 100% detection success rate of camouflaged targets was the best of all techniques used.

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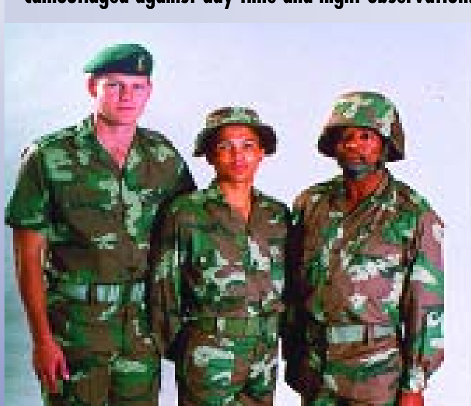
Early 1990s

The current SANDF camouflage uniform was developed with new technology between 1990 and1994, first issued in 1995. It has a visual and near-infrared pattern, enabling the soldier to be camouflaged against day time and night observation.

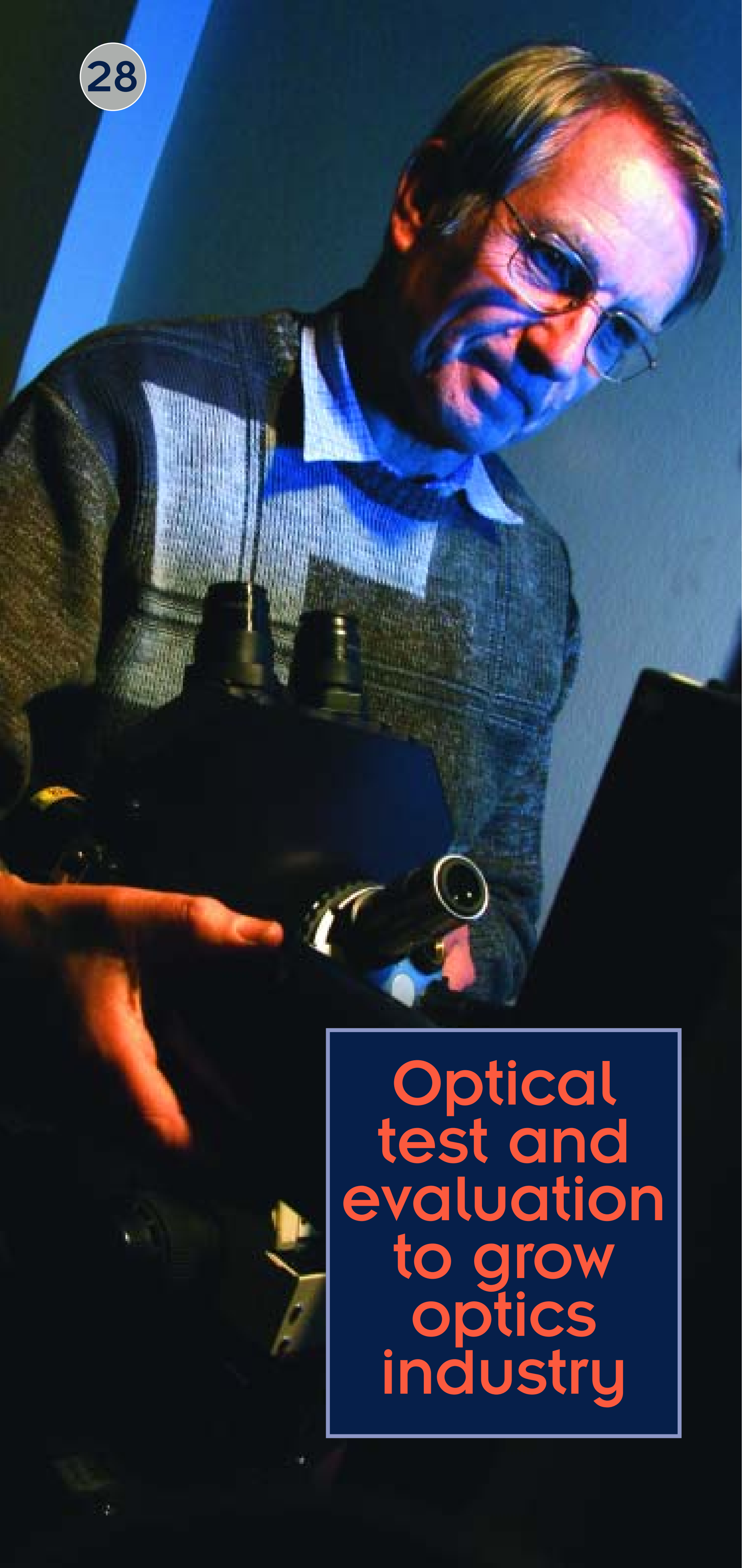


Late 1990s

Rapid deployable nets (deployment within 90 seconds) for vehicles were developed, to offer protection in the visual, near-infrared and thermal wavelengths, as well as the pattern for the Agusta light utility helicopter, procured under the most recent arms deal.

2000+

Different uniforms were tested in the field, on desktop with computer algorithms, and subjected to psychophysical and aerial evaluations to establish the effectiveness of the camouflage colours.

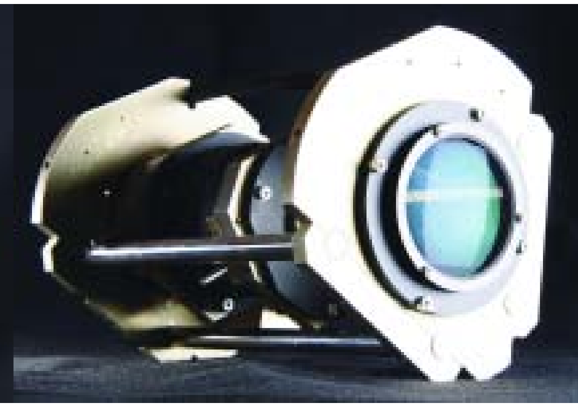


Optical test and evaluation to grow optics industry

Modern optical design dates back to the pioneering work of Fraunhofer, Abbe and Zeiss in the 1800s. A thorough mathematical base was developed followed by the development of optical coating techniques in the early 1930s (and the production of anti-reflection coatings on optical surfaces). This latter development is of significant importance as it opened up the possibility for the optical designer to use a multitude of elements in a single optical system. Thereafter, the electronic computer became commercially available and since the 1950s, many software design programs have been developed.

All of these and many other developments, especially in the fields of optical detectors, have led to an enormous growth in the optics industry. Much of this growth was supported by military requirements, specifically to obtain image information on enemy actions before and during a battle situation and to determine the effectiveness of an attack on enemy positions.

Furthermore, this information had to be obtained during the day and at night. Complicating aspects in this regard are the dawn and dusk periods, fog, rain, and atmospheric scintillations. Many different electro-optical sensor systems followed from the requirements of day/night and all weather operability. Electro-optical sensors are also deployed from a number of different platforms ranging from maritime submersed, (sea) surface, land, air and space environments.



The challenge to select the best sensor for a specific deployment has therefore become a complex task. Once a selection has been made, a further issue is to determine whether a supplier has indeed delivered a sensor to the contractually-agreed specifications. Over time, the owner of such a system would also like to know what ageing takes place and to what extent the unit is still performing with regard to the original specifications. Users might also want to know how they should operate optimally and apply their equipment.

In order to achieve all of the above, an electro-optical test and evaluation laboratory is an absolute basic requirement. However, people with the necessary skills form the most important part of such a test and evaluation capability.

In the beginning of the 1950s, the CSIR started its own optical laboratory originally to support the physicists. During the 1960s and 1970s, it grew to an optical engineering group that is now capable of designing, building and testing complex optical systems such as day and night vision long-distance surveillance systems.

The optical test and evaluation laboratory consists of several integrated test benches that incorporate operators into the optical evaluation procedures, as discussed below.

Night vision testing

Night vision goggles or stand-alone equipment can be tested for resolution performance under simulated night conditions.

These tests provide:

- a baseline performance value, measured under controlled and repeatable conditions, for a specific sensor unit
- an indication of the expected performance of the equipment in real-life situations under different light level conditions.

Resolution test bench

This bench is used for resolution testing of day cameras, while the total system modulation transfer function can also be determined. These results can be used to indicate a system's performance, similar to the night vision tests.

The object or target used in the resolution tests is the USAF three-bar target, which consists of a large number of black and white bars. In a resolution test, the smallest set of bars is determined, which is still resolvable as bars, and not a single black square to the eye. The tests are done using a sample of people with normal eyesight.

To confirm the validity of the testing procedures and processes, this facility as well as the night vision test facility is accredited by the South African National Accreditation System (SANAS) to the 17025 International Organisation for Standardisation (ISO) standard.

Modulation transfer function (MTF) test bench

The system and lens MTF can be measured on this bench. The significance of this capability is the fact that one can isolate the performance of a single lens or lens group from the rest of the optical system.

The target used on the MTF tests bench is a pinhole or an optical slit that is re-imaged at the image plane of the system from which its performance can be calculated. Again, this capability enabled the CSIR to test the performance of a lens versus specifications.

Thermal sensor test bench

In a similar way to the tests described thus far, minimum resolvable temperature difference (MRTD) tests for thermal cameras can be done on this bench. The object used in these tests is a four-bar target, consisting of a large number of slits in a metal plate evaluated against a black body. In MRTD testing, the smallest temperature difference is determined as well as the smallest slit, which is still resolvable as a slit and not a single black square to the eye. These evaluation tests are performed using a sample of operators.

With this suite of tests, the performance of a thermal sensor can be determined and compared with the relevant specifications for the sensor.

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Preshon Jeebodh

As our sense of vision is the most advanced of the senses, it plays a central role in our perception of our surroundings. While vision is limited to the visual band of the electromagnetic spectrum, imaging can be performed in almost the entire spectrum by the use of specifically designed sensors. Some familiar examples are x-rays, radar and ultrasound. It is therefore not surprising that image processing plays a role in many different application areas.

GOING FURTHER THAN THE EYE CAN SEE

The term image processing refers to the manipulation of an image. There are two broad categories into which processing algorithms can be divided. These are methods where input and output are an image, and methods where the input is an image, but the output is a measurement of a particular para-meter.

The CSIR's image-processing focus is on surveillance applications. The surveillance function involves the detection, recognition and identification of a target from as far away as possible. The user or operator of such a system would typically be a dismounted soldier; the amount of equipment a soldier can carry is limited. This requirement severely constrains the weight, size and the electrical power available. With this in mind, the Hurricane project was conceived.

Hurricane is primarily a technology demonstrator, which enables and supports surveillance missions in terms of technology. Its purpose is to develop a better understanding of surveillance with a specific emphasis on the role of image processing. The secondary objective of Hurricane is to develop an image-processing platform for testing surveillance related image-processing algorithms. Such a platform must support real-time image processing with multiple interface options and must be embedded in nature.

While there is a large body of information on image-processing algorithms, it is aimed at machine vision and medical applications. These applications of image processing differ significantly from that of surveillance, the first major difference being the environment in which machine vision or medical systems operate. The environment is controlled in terms of lighting and movement. Secondly, a target in a surveillance scenario would typically not be cooperative. This means that targets may use techniques such as camouflage and management of their electromagnetic signatures to avoid being detected.

With recent developments in the field of programmable gate array (FPGA) technology, the performance-to-price ratio of image-processing hardware is now very attractive. This represents a significant opportunity to explore new processing architectures and algorithms. Thus the Hurricane image-processing platform is based around FPGA technology.

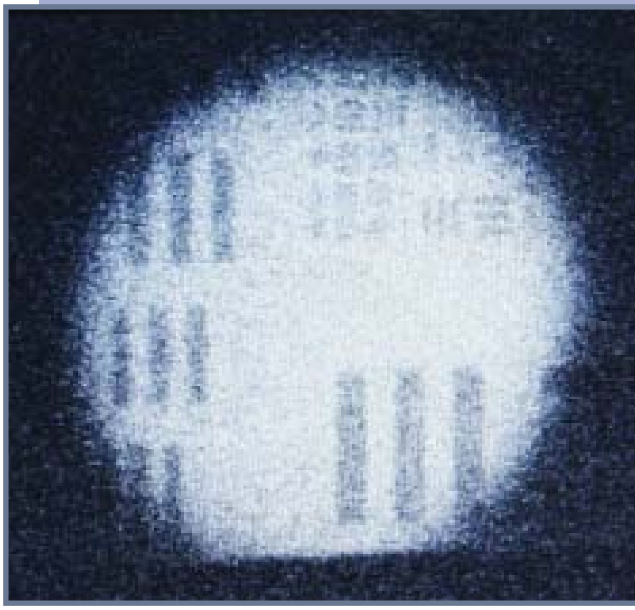
The concept architecture was developed and analysed for suitability at the CSIR, while a leading South African electronics company, PARSEC, constructed the final platform.

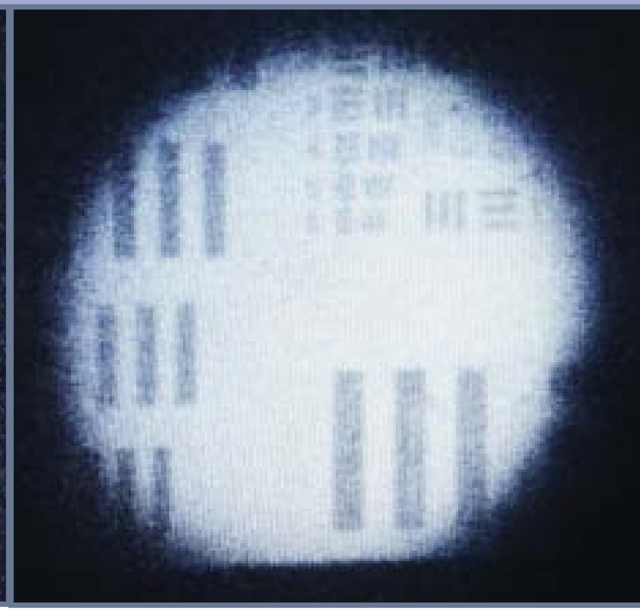
With recent developments in the field of programmable gate array (FPGA) technology, the performance-to-price ratio of image-processing hardware is now very attractive. This represents a significant opportunity to explore new processing architectures and algorithms.

Internally, the Hurricane uses a generic pipelined architecture, which enables the image-processing card to make full use of the available processing time. Lowering the clock frequency also has the benefit of lowering the power consumption. This architecture has the added benefit of simplifying the specification and development for algorithms. The system currently uses 10-bit processing, but the number of bits is expandable. The system is also not limited in terms of resolution.

The Hurricane image-processing card (IPC) is capable of running multiple algorithms simultaneously while being lean on power usage. It has been designed to be free from the shackles of legacy video formats like CCIR, which were developed in the 1940s and 1950s for the purpose of television broadcast. This is accomplished by providing two digital video inputs based on the industry standard Cameralink specification. Legacy video signals can still be used via a converter module that digitises the analogue video and then formats and streams the video to the image-processing card. By moving to a digital format the obvious benefit is the increased resolution. Newer cameras now offer resolution in the mega-pixel range compared to the analogue video standards such as CCIR, which provides a resolution of less than half a mega-pixel. Additionally, there is increased signal-to-noise ratio as well as more immunity to noise.

Within the context of surveillance systems, image processing can be used to reduce operator workload, aid operator interpretation of video, reduce transmission bandwidth requirements, improve target detection probability and range and overcome technological limitations. However, these objectives should not compromise the ability to search for or track a target. The potential cause of trouble here is the processing bottleneck. Algorithms must be both computational efficient (a property of the algorithm) and implementation efficient (a property of the software or hardware).





A number of algorithms have been implemented on the image-processing card. These are:

- An automatic contrast enhance
- Zoom
- Gaussian noise reduction
- Speckle noise reduction
- Motion detection.

The contrast enhanced algorithm is able to assist the operator by performing two functions. It matches an image to the display, which means that an image that does not make full use of the display capabilities, is enhanced so that it does. The algorithm is based on a linear contrast stretch. This technique does not distort the contrast information contained in an image whereas a technique such as the histogram equalisation might. The algorithm allows for the automatic setting of the contrast. This reduces the operator's workload as the operator would not have to manually adjust the contrast when lighting conditions change or the operator is using the system to view targets in a shadowed region moving into an area of bright sunlight.

A typical surveillance mission may include watching a specific target 24 hours a day, over a few days. Even a skilled, trained soldier would find fatigue setting in. A side-effect is a lapse of concentration and possibly missed activities in the scene of interest. The motion detection algorithm is useful in that respect. If a change in the scene occurs, the system has the ability to alert the operator by setting an alarm or possibly automatically triggering video recording.

Noise reduction algorithms aim to improve the signal-to-noise ratio of the video signal. There are two noise reduction algorithms currently implemented. These are the Gaussian noise and the speckle noise reduction.

Gaussian noise is observed during dawn and dusk periods where light levels are low and the camera gain is high. Gaussian noise reduction for surveillance is performed by temporal filtering of the images. Any form of spatial averaging is to be avoided since this reduces the resolution.

Speckle noise occurs with image intensifiers that are used for night vision. Free electrons that are amplified in the tube cause small, momentary bright spots in the image. The algorithm described here simply limits the rate of change of the displayed image and will be referred to as a temporal rate filter. Other rank filters, such as the median filter, are not considered because they are not as effective. These algorithms are typically used for so-called salt-and-pepper noise. However, the bright spots extend over several pixels and thus easily corrupt the output of a typical three-by-three median filter. Increasing the size of the filter dramatically increases computational load and reduces resolution.

The screenshots above are an example of the speckle noise reduction algorithm. The image above left shows a scene under starlight conditions. The bright spots of noise are clearly visible and the image is severely degraded. The second image pictured above right has also been taken under starlight conditions, but includes active image processing. A noticeable improvement can be seen. These scenes make use of new generation digital CCDs integrated with the Hurricane image-processing Card.

The Hurricane is a pilot project in the field of image processing. During earlier phases of the project, system engineering aspects were examined and mathematical models of the algorithms developed. The image processing card was designed, built and firmware written for the algorithms. Although future developments include further algorithms, the main area of attention is to evaluate the performance of the system in field trails.

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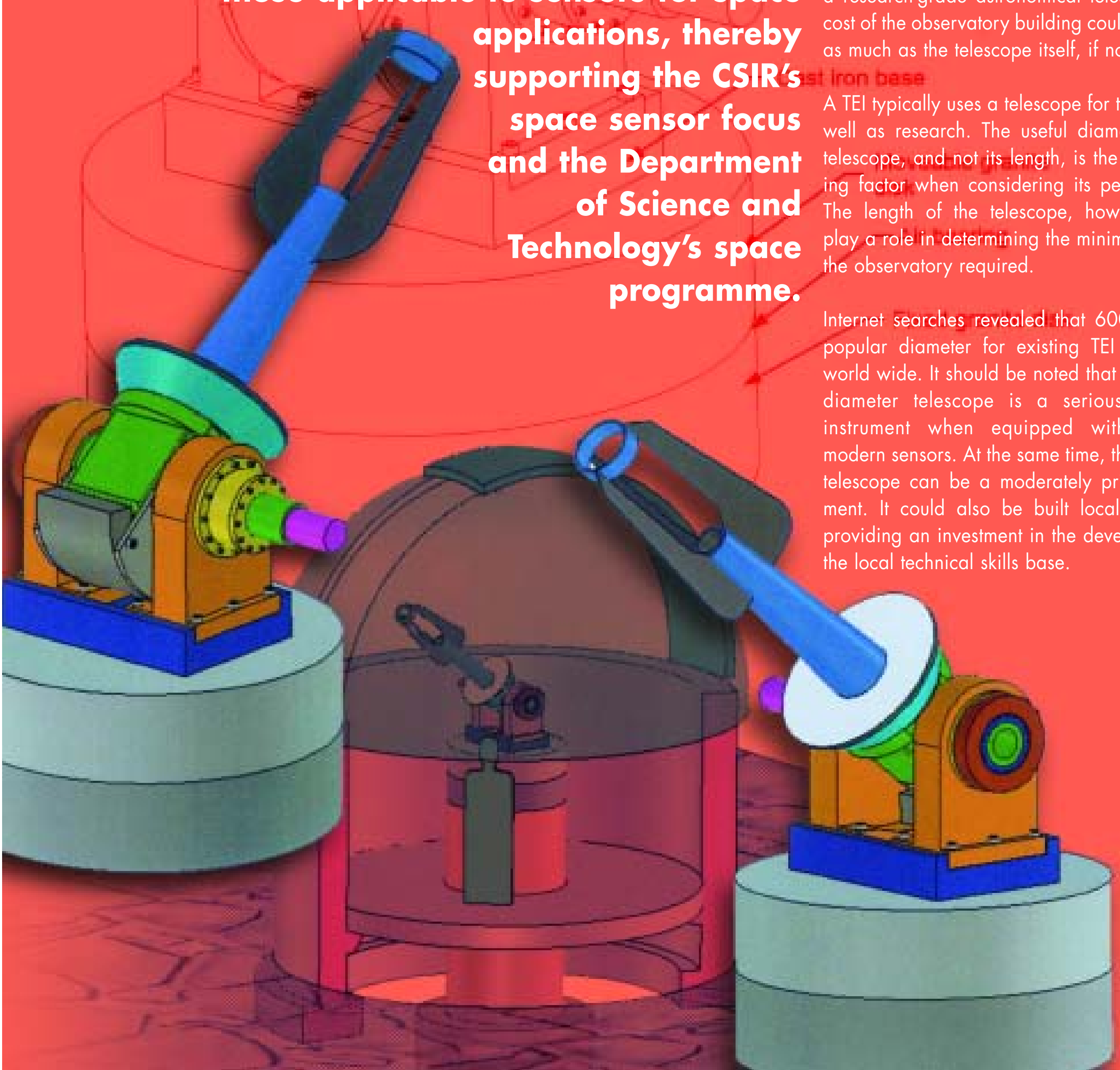
Keeping an eye on the sky

The concept design of a suitable, affordable telescope to be used by tertiary education institutions (TEIs) has recently been completed by the CSIR with Klee Optical Systems as part of a project on the study of large optics. The telescope concept makes use of design principles relating to a land-based telescope that are similar to those applicable to sensors for space applications, thereby supporting the CSIR's space sensor focus and the Department of Science and Technology's space programme.



Particular attention was paid to the size of the telescope. It had to make a meaningful contribution to the science of astronomy, while still be affordable and simple to operate within a TEI. The diameter was subsequently limited to 600 mm, with the telescope's overall size being such that it can be housed in an observatory 4 m in diameter.

Telescope concept design

Affordability of an observatory

It is an expensive undertaking for a TEI to build a research-grade astronomical telescope. The cost of the observatory building could easily be as much as the telescope itself, if not more.

A TEI typically uses a telescope for teaching as well as research. The useful diameter of the telescope, and not its length, is the main limiting factor when considering its performance. The length of the telescope, however, does play a role in determining the minimum size of the observatory required.

Internet searches revealed that 600 mm is a popular diameter for existing TEI telescopes world wide. It should be noted that a 600 mm diameter telescope is a serious research instrument when equipped with suitable modern sensors. At the same time, the 600 mm telescope can be a moderately priced instrument. It could also be built locally, thereby providing an investment in the development of the local technical skills base.

Notes on the telescope

A telescope is basically a device used to view distant astronomical bodies (the moon, planets or stars). To an observer in South Africa, astronomical bodies circumvent the southern celestial pole once every 24 hours.

Land-based telescopes vary in size from small portable hobby telescopes to large telescopes housed in observatories, such as the Southern African Large Telescope (SALT) at Sutherland. In between these extremes are telescopes (or astronomical observatories) aimed at a level of research typically done at TEIs. For larger non-portable telescopes, the term astronomical observatory refers to the telescope along with the building which houses it.

Telescopes are classified according to the optical design and the type of mount used. Some of the common optical designs (lens layout and shape) include Refractor, Newtonian, classical Cassegrain, Ritchey-Chretien and all-spherical. The two most common mounts are the alt-azimuth mount and the equatorial mount. Any optical design can be used in combination with any mount. Each of the optical designs and mounts has their advantages and disadvantages.

Small portable hobby telescopes tend to only have an eyepiece, while larger telescopes make use of CCDs to capture the image electronically.

The operating costs of the astronomical observatory should be considered in detail during the design phase. These costs include building maintenance, telescope maintenance, repairs and staff overheads. If the operating costs are minimised, the amount of research undertaken can be maximised within a given operating budget.

Optical considerations and design

There are a variety of telescope designs to choose from, depending on the required performance. In order to simplify the manufacturing and testing of the telescope's optical components, the telescope designs were restricted to those containing only spherical optical components (components whose active surfaces have constant radius).

Two optical designs were presented, each with its own advantages and disadvantages. The Telemacro design was developed by HW Klee some 20 years ago at the CSIR, while the relay telescope was inspired by a Buchroeder design published more than 30 years ago. It is also suitable for long focal length optical systems deployed on earth orbiting satellites, since it can be designed to be practically free from stray light.

Telescope mechanics

The term "telescope mechanics" applies to those mechanics that support the primary mirror and the secondary optics. The telescope mechanics, together with the optical components, form the telescope proper. The Meinel configuration was proposed. The secondary mirror is supported by a tubular cell, which in turn is supported by three vanes that are attached to the so-called Meinel stalk. The mirror rear is supported via an integral flange of the Meinel stalk. The stalk is hollow and serves as a standard lens barrel that accommodates the required optical components.

Telescope mounting

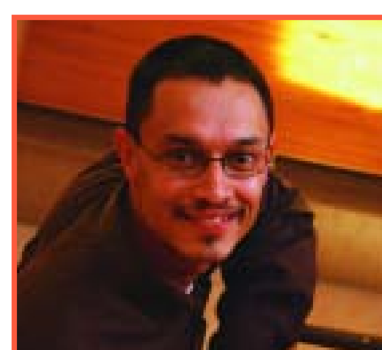
The mount proposed is an alt-azimuth type. The main advantage of this mount over an equatorial mount is that the rotating masses do not pose changing bending moments on the mechanics (unbalanced loads). Equatorial mounts have the advantage that their motion is easier to control, but with today's computers, this advantage is negligible.

The proposed azimuth bearing design is greatly increased in diameter and designed to operate as an air bearing. The oversized diameter allows for space where any required instruments can be mounted.

Direct-coupled torque motors were proposed. They have numerous advantages over the more traditional synchronous motors with precision gearboxes.

Conclusion

The results of this project indicate that a sizable astronomical telescope could be designed and constructed locally with a high degree of confidence. A lecturer and small party of students could be housed in a 4 m diameter observatory and could make use of the system to perform precision astronomical observations. The realisation of this concept has the potential to open up new avenues for networks of excellence in astronomy. The southern hemisphere is largely devoid of high-quality telescopes that can cover the skies only visible from this part of the globe. Having a network of such telescopes available to international astronomy researchers will greatly facilitate global observation of the night skies, and contribute to South African participation in this field.



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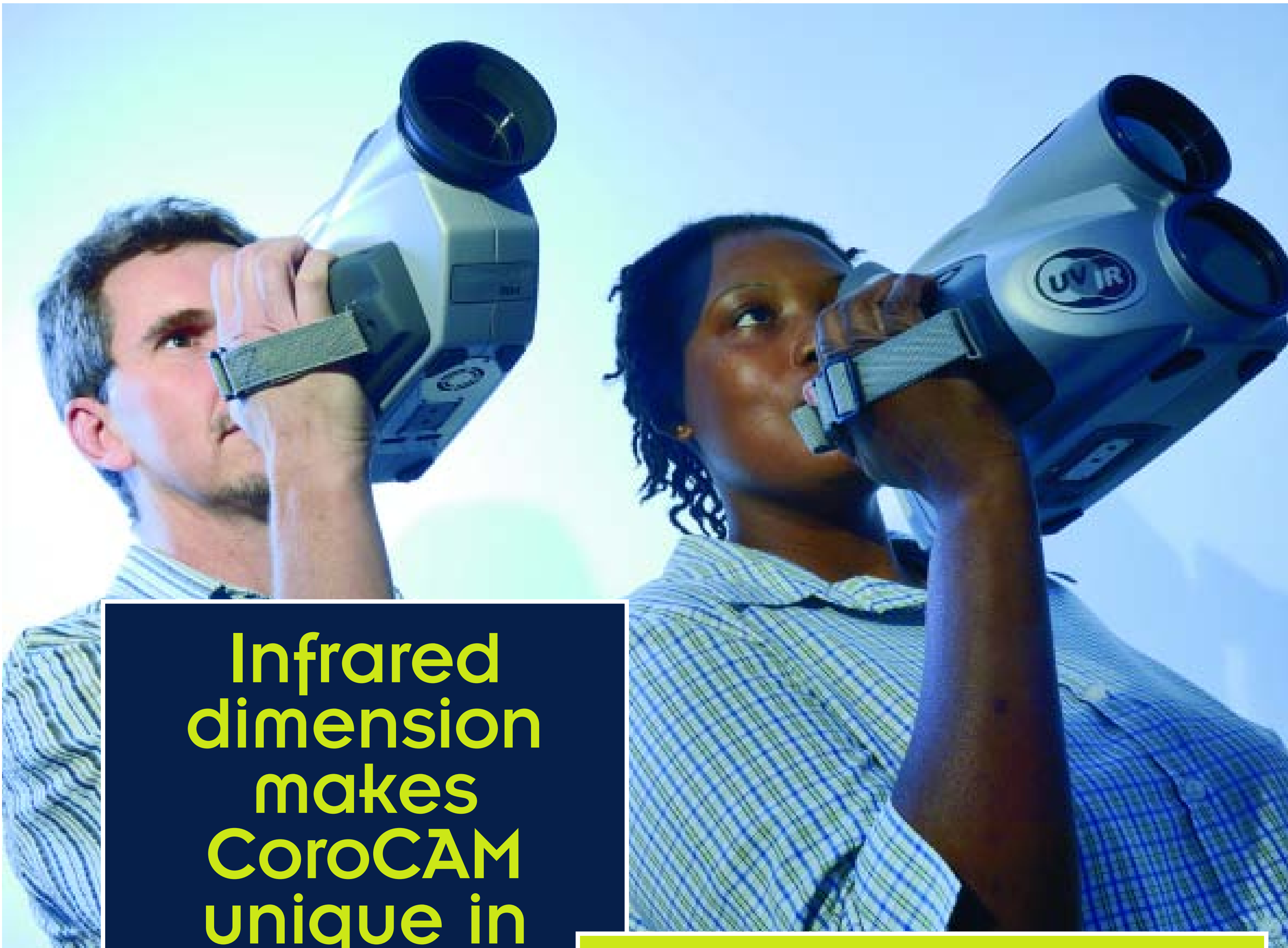


Infrared dimension makes CoroCAM unique in the world

The CoroCAM range of ultraviolet (UV) imaging cameras, developed by the CSIR in collaboration with Eskom Research in South Africa, has identified UV corona activities and surface discharges on high-voltage electrical equipment for more than 10 years. More than 100 units have been sold world-wide, proving the soundness and longevity of the original designs.

The CoroCAM 504 and Multi-Spectral Imaging Cameras

CoroCAM provides video images of the UV discharges that indicate high-voltage equipment problems on systems from 11 kV all the way up to 765 kV. The CoroCAM range covers operation at night (CoroCAM I), during the day (CoroCAM 504) and from the air (gimbal-mounted AirCAM).

The instruments are based on electro-optic technology, including the lens system, optical filter elements, ultra-sensitive light converter and the advanced image-processing algorithms, all of which have been researched, developed and adapted by the CSIR over a period of many years. Extensive research collaboration has taken place with sub-critical component suppliers in order to reach the highest levels of performance. Various electrical research institutes have participated in the optimisation of the instruments.

The CoroCAM I night camera uses a straightforward image intensifier with a monochrome CCIR camera to display the visual image of the object being inspected together with the UV corona discharge present on the object. Specific wavelength filters can be used to make the corona discharge clearer depending on the amount of background light that is present. The image is seen in a viewfinder and can be output as a PAL or NTSC video signal for recording and analysis.

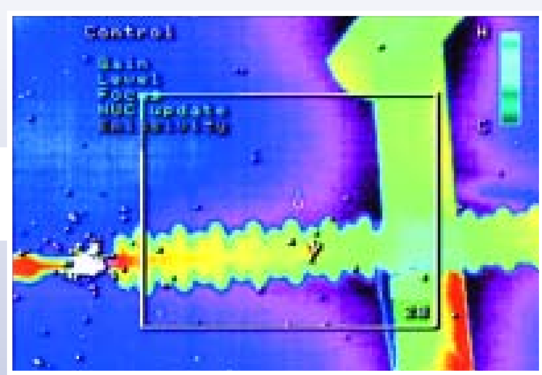
The recent release of the CoroCAM 504 model, replacing the first daylight model CoroCAM IV+, brings to the market the most user-friendly and efficient system ever, giving solar-blind daylight UV detection, image-processing and storage in a lightweight handheld unit the size of a standard video camera. The unit is a fully integrated system containing its own rechargeable power source as well as a data storage system on-board so that it can be transported in a small rigid case ready for immediate deployment and usage upon arrival at an inspection site.

The daylight camera operates by taking the incoming light and splitting it into two paths. One path passes the light through a standard video camera, which records the images of the objects being inspected (the background image). The video camera used in the 504 has an electrically operated removable filter, which increases its light sensitivity from approximately 3 lux down to 0,1 lux, allowing this model to be used in much darker conditions than was previously possible. This therefore extends its operational window far into the dawn and dusk hours instead of just during sunlight conditions.

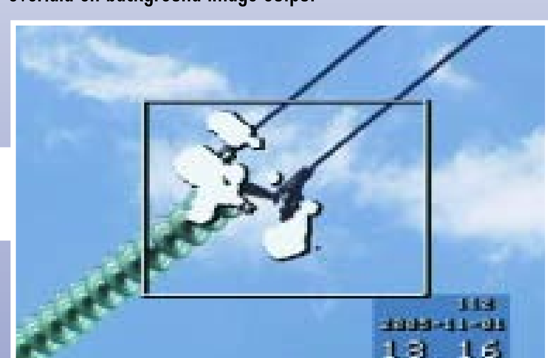
The second path takes its light through a 240-280 nm wavelength solar-blind filter, which eliminates all light except that of man-made UV corona discharges. Solar UV radiation occurs above a 280 nm wavelength; thus this filter blocks out the solar light so that the system can be used in full sunlight conditions, where otherwise the solar UV radiation would completely swamp any man-made sources. However, the magnitude of the UV discharges in the 240-280 nm wavelength is extremely small thus requiring a very sensitive ICCD detector coupled to an image intensifier to image it. In order to extend usage of the camera into the non-sunlight hours, the solar-blind filter has a patented mechanism enabling it to be removed from the UV light path. The filter removal is selected on the camera operating menu and allows the detector and image intensifier to see the full band of UV light from 240 to 400 nm, hugely increasing the camera's UV corona sensitivity in low-light conditions. The UV signal from the ICCD detector is digitised and passed through a complex image-processing package, which allows the user, via a menu system in the camera, to carry out a variety of operations on the image to provide the clearest output image. This image is then overlaid on the background image to give the user the final output with respect to UV corona dis-

Multi-Spectral

Multi-Spectral Imager in use with typical discharge overlay on infrared image output



CoroCAM 504 in use with typical UV discharge overlaid on background image output



CoroCAM 504

charges on the electrical equipment being inspected. This output can be recorded on a number of formats using one or more of the variety of output methods on the camera. These include standard video and audio channels, "S-video", USB and RS232 as well as an on-board flashcard storage for still images.

Additional optional features for the system, which will also add to its user-friendliness, include a GPS unit, allowing precise recording of the location of the UV corona discharges, and a laser pointer, aligned to the main axis of the camera enabling the user to "illuminate" the object being inspected to confirm that it is the correct one.

High-voltage electrical problems can manifest themselves in two ways, either by UV corona discharges or by heat generation, which is detected via infrared (IR) thermography. The two technologies are complementary as some faults exhibit only UV, some only IR and others exhibit both. Until now, it has been necessary to have two separate systems to detect all possible faults.

The imminent release of the multi-spectral imaging system (MultiCAM) will add an infrared dimension to complete the product range. This system is based on technology that allows the user to simultaneously record information from three different spectra – IR, UV and the visible spectrum. It is completely unique since it is the only such system on the world market.

As it is based on the CoroCAM 504 UV system, the UV and visible background channels work in exactly the same way, with the addition of an uncooled microbolometer IR detector for the IR channel. The output images can be IR only, UV overlaid on IR or UV overlaid on the background object, providing huge flexibility relating to the ways in which the information can be used.

All outputs are in the form of .mpeg video or .jpg still images allowing them to be easily incorporated into standard report writing data packages.

Customers are typically electrical utilities, industrial end-users and service providers to industry; systems have also been purchased by the US Navy. The CSIR uses a network of international distributors to facilitate the sales and service of CoroCAM instruments, which now covers some 30 countries on five continents.

Further information is available at **www.corocam.co.za**

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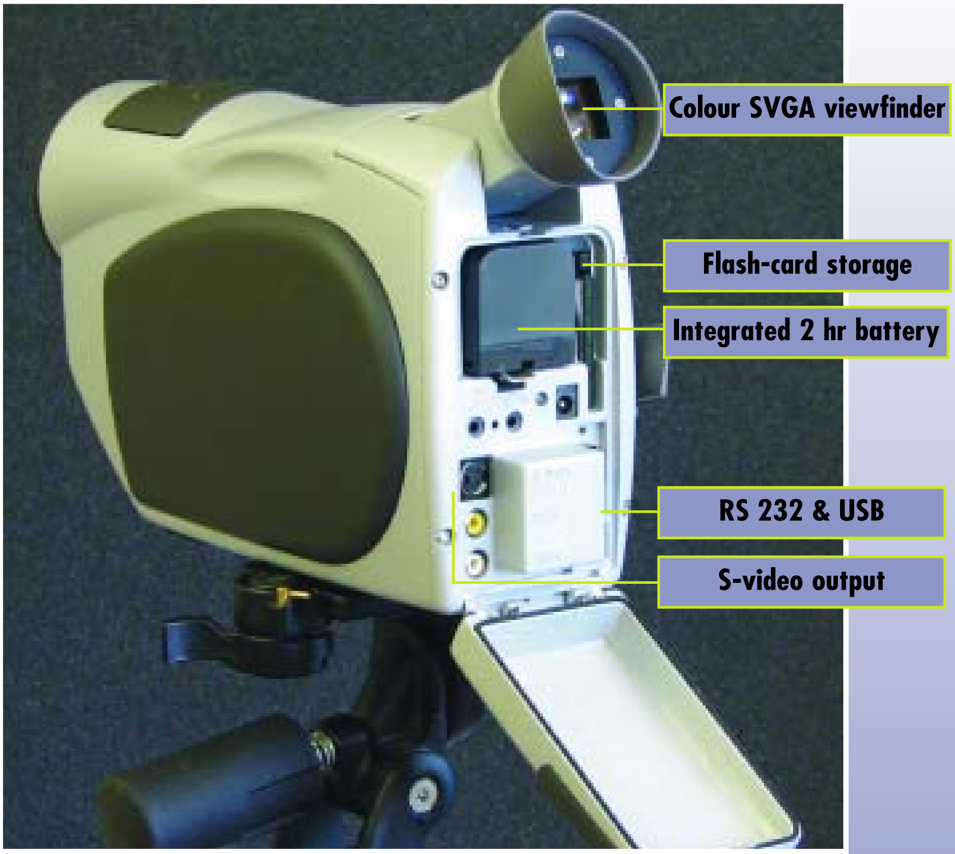
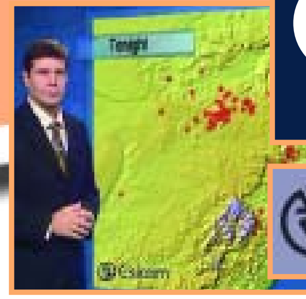


CoroCAM 504 features neatly packaged inside the rear cover



SA public gets fire updates on TV

The South African public saw a world first on television when the SABC became the first public broadcaster to televise active fire maps as part of its weather reports on 7 June 2006 at 19:30. The fire map, developed jointly by the CSIR and power utility Eskom Holdings, showed active fires throughout South Africa as detected by satellites over the preceding 12 hours on the broadcast date.

"This is a prime example of a private-public sector partnership, using the power of science and technology outcomes, to the benefit of the public. Through the CSIR's research expertise, and its application for Eskom, people will get a better understanding of the extent and threat of fires in South Africa," comments Dr Sibusiso Sibisi, CSIR President and CEO.

The fire map is one of the outcomes of the Advanced Fire Information System (AFIS), a joint project between the CSIR and Eskom.

AFIS is a satellite-based fire information tool that delivers locations of active fires in near-real time over southern Africa. The CSIR's expertise in remote sensing, in collaboration with the University of Maryland in the USA, NASA and Eskom, has resulted in the development of a unique fire detection system. The application of remote sensing coupled with cell phone technology for alert messaging (or SMSs) is the first of its kind in the world.

The system allows Eskom management to respond quickly to fires under transmission lines, which could reduce damage and power supply disruptions. "We are proud to have implemented this technology in Eskom," says Hein Vosloo, Servitude Specialist – Transmission Division. "As AFIS is a new system, we are still experimenting and improving the system." He notes that not all fires are detected by the system, as size and duration do play a role.

The SABC fire map comes at the time when South Africa is in its fire season between May and October (in the northern parts of the country). Information for the map is delivered free of charge to the SABC by the CSIR and Eskom.

Each dot on the fire map shows an active fire varying in size from 200 m to 1 000 m. Active fires are detected using data from the Moderate Resolution Image Spectro radiometer (MODIS) sensor on NASA's Aqua and Terra satellites.

Sub-Saharan Africa has the highest frequency of fires in the world. While wildfire is a natural phenomenon, people are responsible for most fires, sometimes with devastating consequences for humans, animals (wild and livestock), vegetation and infrastructure.

Countrywide, fire protection associations are being established in terms of the National Veld and Forest Fire Act (Act 101 of 1998). It is also planned to include them in the SMS service to mobilise fire fighters at the earliest possible time

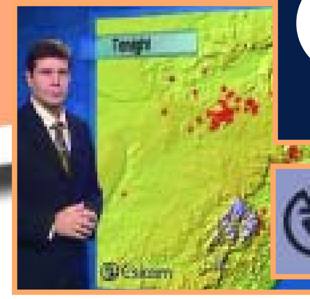
For more information on AFIS, visit **www.wamis. co.za/ afis/afis.htm**, or send an email to **afisinfo@csir.co.za** or **Afis@eskom.co.za**

Launch of Meraka Institute's Soweto office

Free/libre and open source (FLOSS) activities in Soweto have received a boost with the launch of an office focusing on FLOSS and its applications by the Minister of Science and Technology, Mr Mosibudi Mangena. The Meraka Institute, managed by the CSIR, has set up an office at the NICRO Community Centre in Soweto to support and grow current FLOSS activities as well as other information and communications technology (ICT) endeavours.

FLOSS refers to computer software and the availability of its source code under a licence, which allows one to study, change and improve its design.

The Soweto office was launched in May 2006. The programme included an opening address by CSIR President and CEO,



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Commenting on the new office, interim Director of the Meraka Institute, Llew Jones, states, "This initiative is in line with the institute's vision of meeting socio-economic challenges through ICT, people and applications. We are particularly pleased to open this office one year after the launch of the Meraka Institute in Pretoria".

Meraka's Soweto office is a fully integrated part of its Open Source Centre. Dr Ntsika Msimang, OpenProject leader of the Open Source Centre, is responsible for interactions with KOSS and with other interested parties from the community.

Msimang comments, "The enthusiasm and talent of the KOSS group have transformed the Soweto office into a vibrant centre of learning and innovation. I am confident that providing FLOSS to people with such talent will have a multitude of spin-offs, including development of different technologies within communities, where it is needed most".

The major objective of the Meraka Institute is to facilitate national economic and social development through human capital development and needs-based research and innovation, leading to products and services based on ICT. Its various initiatives cover application innovations, such as the National Accessibility Portal, the Digital Doorway and Wireless Africa projects, and technology research such as Human Language Technology, as well as the management of specialised ICT infrastructure projects such as the Centre for High Performance Computing. FLOSS underpins the work of the Meraka Institute.

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CSIR secures funding for SPOT 5 imagery

The Earth Observation Service Centre (EOSC) of the CSIR Satellite Applications Centre has been providing remote sensing products and applications to its customers for over 25 years. Recently, a breakthrough in negotiations with multi-departments to fund the SPOT 5 sensor under an open access model for government and for users beyond South Africa's national boundaries, promises huge benefits for the user community.

The CSIR Satellite Applications Centre is well aware of the growth in the demand for remote sensing applications from low resolution to very high-resolution imagery geo-processed to ortho-rectified level. The content of the Spatial Data Infrastructure Act 54 of 2003 provides a well-established guideline for the centre to ensure that spatial data owned by government is not duplicated in its procurement process.

The centre has a clear position in this regard and has implemented an aggressive strategy to ensure that remote sensing imagery is provided to government at the lowest possible prices and that datasets procured under a multi-government licence are distributed at no cost to multi-departments for optimised utilisations of remote sensing imagery within government. The sensors available under a multi-government licence agreement include:

- Landsat 5 & 7
- Quickbird
- MODIS
- Spot 2, 4 and 5
- Ikonos
- NOAA.

The prime deliverable to government from SPOT 5 will be the first 2.5 m natural colour seamless mosaic over South Africa. The dataset will be tiled in 30′ x 30′ and will be fully processed by the end of March 2007. It is foreseen that this coverage will be repeated on an annual basis, with the assurance of at least two repeats of coverage per three-year cycle.

The direct receiving capability of SPOT 5 at the CSIR Satellite Applications Centre will be fully operational as from August 2006; its advanced geo-processing system will ensure the automation of ortho-rectified multi-sensor imagery in October 2006. The agreed SPOT 5 contract with SPOT Image carries a reduced price for the private sector, thereby achieving affordability and value for money.

As part of the CSIR, the Satellite Applications Centre was established in 1961 and has participated in space science and technology ever since. The centre's involvement in remote sensing as well as the managing of a large remote sensing archive and the processing and distribution of the imagery, is one of its core functions. The centre is recognised as a national key point and was also recommended as the prime facility to receive and distribute remote sensing imagery within the South African Earth Observation Strategy (SAEOS) for and on behalf of government.

The centre maintains a large archive of imagery, which is updated on a daily basis with new acquisitions. The earth resources information, supplied by the EOSC, provides valuable input to decision-makers in areas such as food security, ocean resources, water management, disaster management and mitigation, agriculture, housing development, utilities and infrastructure planning, mine rehabilitation, national safety and security, and others.

The CSIR Satellite Applications Centre aims to provide an advanced remote sensing service to its stakeholders and, through continuous improvement of its sensor portfolio and geo-processing supply chain, world-class product delivery.

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Local tourism to benefit from e-business survey

A collaborative initiative between South African and European researchers and the South African Department of Communications has tested whether an internationally-applied e-business survey (EBS) methodology could be used successfully in a developing economy such as South Africa. Research partners include the CSIR and Trigrammic in South Africa, TNO in the Netherlands, and the Free University of Brussels in Belgium.

The aim of EBS is to inform industrialists and policy-makers about how changes are occurring in business practice and about how much these changes mean in terms of economic performance (productivity, compe-titiveness, employment and innovation). According to TNO's Pascal Verhoest, who developed the survey metho-dology, EBS uses qualitative indicators and quantitative estimations to measure the impacts of actual and emerging e-business practices.

"One of the reasons that studies such as these are needed in South Africa is the lack of understanding of the role of information and communications technologies (ICTs) in leveraging specific industries (particularly SMMEs)," explains Tina James of Trigrammic. "In addition, there are no common indicators for e-business practices – these are needed by a number of government departments to support improved decision-making on the diffusion and uptake of ICTs."

The pilot study took place between May and August 2005 and focused on South African SMMEs in the tourism industry, more specifically Gauteng-based tour operators, with particular emphasis on emerging operators. The results of the study were substantive and showed that the adapted OECD methodology could be used successfully, although there were some interviewer difficulties relating to the complexity and technicality of the questionnaire.

CSIR researcher, Mario Marais, points out that the findings of the pilot study should not be generalised to the tourism industry or to other industries. "Sector differences are important in understanding the potential effects and benefits of ICT usage, and sector studies show contrasting outcomes per sector and per industry," he says.

The research team emphasises that, despite the limited scope of the pilot, the report would be of immediate value to the South African tourism industry and government departments having to make decisions on the application of ICTs to this sector.

The pilot study would have to be expanded to include additional components of the tourism value chain in order to understand more fully what industry-specific and environmental factors would be most beneficial at a certain stage in its evolution. Innovation policies and industry strategies, which mobilise scarce resources to stimulate ICT usage, will be most effective if they take these factors into account.

"This study shows that despite significant advances in mobile technology, broadband internet is required for an industry such as tourism to compete internationally," Verhoest comments. "A significant amount of work remains to be done in this regard."

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Vishnu Pillay to take up Vice-Presidency at Gold Fields

As from 1 July 2006, Vishnu Pillay – CSIR Group Executive: Institutional Planning and Operations – joined Gold Fields as Vice-President: Head of Operations for Driefontein Consolidated.

Pillay joined the CSIR as Director of CSIR Mining Technology in 2004, where he played an instrumental role in securing future mining research and saw to the design and implementation of a new collaborative research model, which was embraced by the platinum industry.

Not only did he make a valuable contribution to the CSIR's mining research component, but he also played a pivotal role in the reconfiguration of the organisation. CSIR President and CEO, Dr Sibusiso Sibisi, commented, "Vishnu's astute leadership of the Beyond 60 transformation team that designed the new CSIR ensured that the implementation took place smoothly and successfully. I look back with pride at our accomplishments over the past few months and would like to acknowledge Vishnu's insight and tenacity in tackling a difficult task and successfully taking the CSIR to a level where it is well positioned to deliver on its mandate."

Khungeka Njobe appointed as CSIR Group Executive

Khungeka Njobe, former Executive Director of CSIR Natural Resources and the Environment, was appointed as CSIR Group Executive: R&D Outcomes and Strategic Human Capital Development in May 2006. The appointment follows the departure of Dr Phil Mjwara who recently joined the Department of Science and Technology as Director-General.

Njobe joined the CSIR in 2003 as Director of the then CSIR Environmentek. In 2005, she became Executive Director of the newly-constituted unit for research and development into Natural Resources and the Environment, which combines the domains of mining, forestry, pollution and waste, water, resource-based sustainable development and ecosystems.

Her management career includes the positions of Sector Coordinator at the then Department of Arts, Culture, Science and Technology and Directorship within the Department of Environmental Affairs and Tourism, Directorate on Biodiversity Management. Before joining the CSIR, Njobe held the position of Director of the National Botanical Institute where she was responsible, amongst other duties, for the establishment of a new Directorate on Biodiversity Policy and Planning as well as several new programmes with concomitant funding requirements and stakeholder relationships.

Her qualifications include an MSc in Zoology and Mastering Technology Enterprises (MTE) – a management development programme from the Institute for Management Development, Lausanne, Switzerland. Njobe has been active on many committees and task teams. She is Chairperson of the National Environmental Advisory Forum and has been a member of the South African Reference Group on Women in Science and Technology.

THE CSIR'S OPERATING UNITS AND NATIONAL RESEARCH CENTRES

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  Durban (031) 261-8161
- **CSIR Built Environment**
  Pretoria (012) 841-2034
- **CSIR Defence, Peace, Safety and Security**
  Pretoria (012) 841-2780
- **CSIR Materials Science and Manufacturing**
  Pretoria (012) 841-2411
  Port Elizabeth (041) 508-3200
  Johannesburg (011) 482-1300
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