

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.

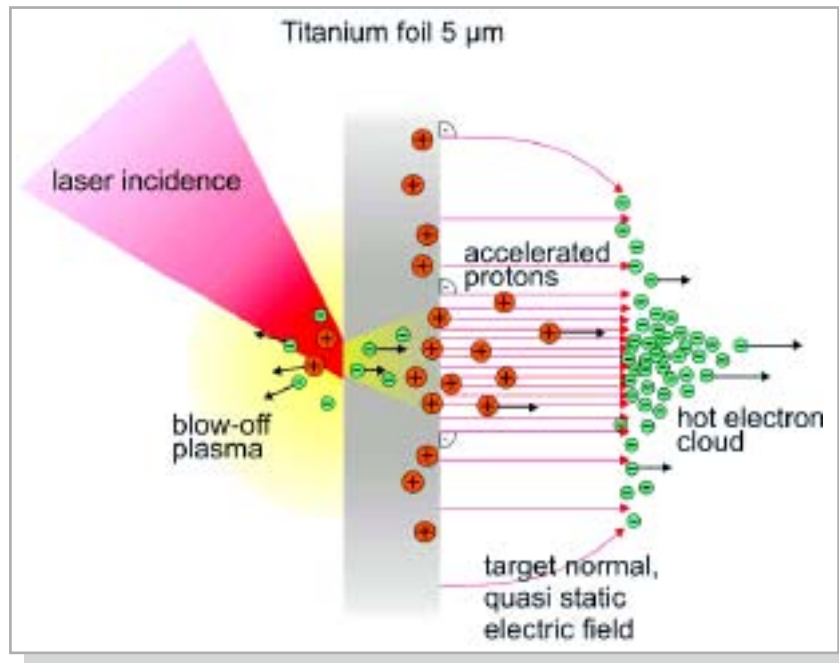
Information and communications

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 lithography 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 CO₂ 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%.

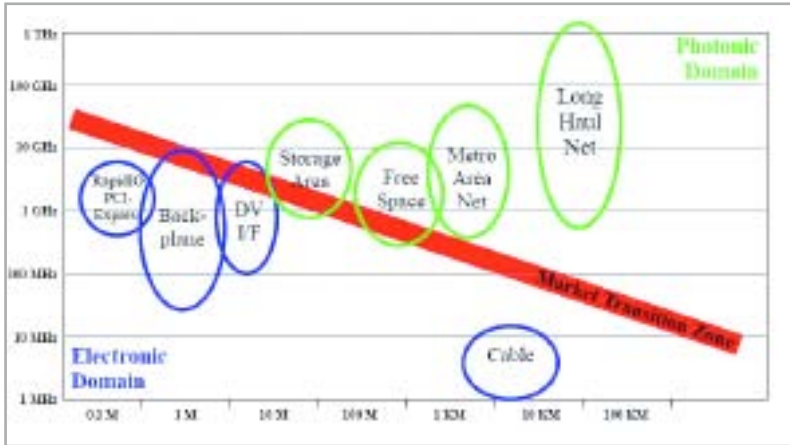
A key technology at the end of the information chain is visualisation. Future displays based on SSL components will offer exciting features in terms of resolution, colour, contrast, speed and compactness far beyond today’s possibilities. Slim liquid crystal displays (LCD) are everywhere in our daily 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

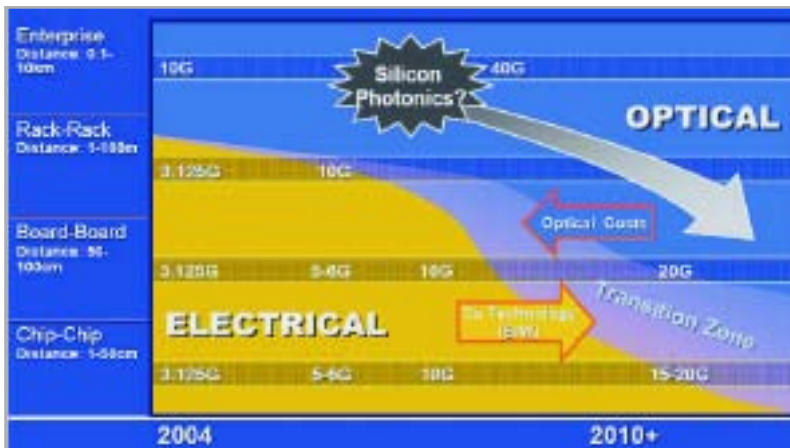
South Africa has an active community of engineers and scientists working in photonics and related fields. Various engineering departments are active in a wide range of fields such as fibre optics, optical signal processing, quantum communication and quantum cryptography systems. Various physics departments 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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