THE LIGHTHOUSE

Photonics & Optics in New Zealand

SECTOR DEVELOPMENT PLAN 2011

A Roadmap for Photonics in New Zealand

The Lighthouse Platform was established in 2009 with the aid of the FRST TRST B contract UOO0901, with the express aim of developing enhanced contact and engagement between industry and the University of Otago, the University of Auckland and Industrial Research Ltd., the three major research agencies in New Zealand working in the photonics sector. The project was funded by $125,000 from the TRST B contract, and co-funding of $71,708 from the three participant agencies.

The responsible authors of this report are the members of the Governance Board of the Lighthouse Platform: Prof Crispin Gardiner (representing the University of Otago), Prof John Harvey (representing the University of Auckland) and Dr Andrew Kay (representing Industrial Research Ltd.) Others who participated in the production of the report were Dr Margaret Tompkins, Dr Ruth Appleby, Phil Shepherd, Rachel Prendergast and Catherine Andrews.

Please visit our website lighthouseplatform.org.nz *to obtain further information about the Lighthouse Platform, copies of this report and further information about photonics.*

Executive Summary

The global photonics sector is growing at a sustained and impressive pace. Global sales of laser systems, display panels, optical diagnostic systems and other photonics enabled technologies have already generated a multi trillion dollar sector. While the 20th century is considered the *age of electronics*, the 21st century will be known as the *photonics century*. The significance of photonics was acknowledged recently by the European Commission as “one of five key enabling technologies for future prosperity with the potential to address the grand challenges of our time.”

- New Zealanders benefit from advances in photonics innovation on a daily basis, from mobile devices, to DVD players, to accessing the World Wide Web. However, the photonics sector is still at an early stage of development and its potential as an enabler of innovation will not be realised by consumers, industry or governments until much later this century.

  Northern Hemisphere countries have recognised this potential and are mounting impressive research programmes to establish leadership positions. Tight coupling of industry and photonics research communities is a common characteristic across all of these programmes.

- In New Zealand, we are at an earlier stage of development. However, with our vibrant, coordinated photonics research community, we can move forward at a quicker pace. The key to New Zealand’s success in the photonics century will be the effective collaboration between industry and the research community. That is the purpose of the Lighthouse Platform.

  In its first year of existence, the Lighthouse Platform has engaged actively and successfully with industry. Nineteen companies attended Lighthouse events and workshops across the major cities. A Sector Engagement Group was established with senior representation from Fisher and Paykel Healthcare, as well as from the investment company Pacific Channel.

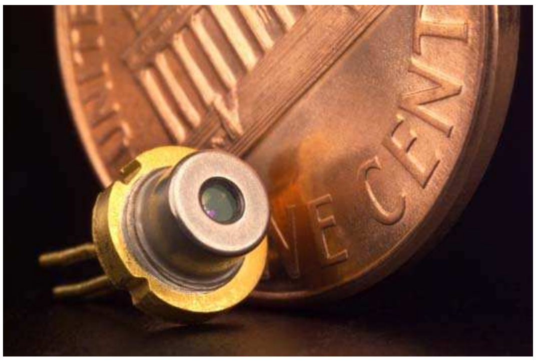
  This engagement provided the Lighthouse with direct exposure to the needs of industry that can be addressed through photonics innovation. It also demonstrated the collective capability and collaborative spirit that exists across the New Zealand photonics research community.

- For example, the Lighthouse has established the *Optical Communications Working Group* (OCWG), to support the government’s Ultra-Fast Broadband (UFB) initiative. The OCWG promotes the broadband-related capabilities that exist across New Zealand universities and has engaged with the leading UFB contenders as well as Crown Fibre Holdings.

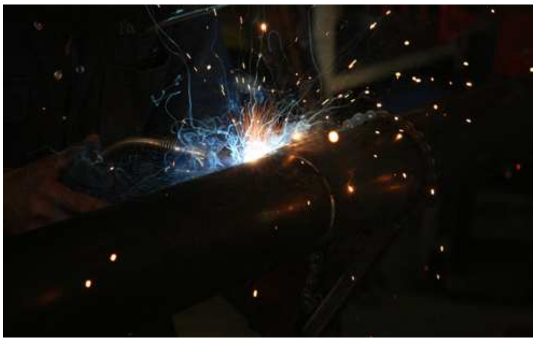
Photonics and Laser Enabled Technologies Play a Key Role in the US Economy

Manufacturing	**$1 Trillion**
Aircraft and car manufacturing	$500 Billion
Cutting Drilling Welding	$5 Billion
CO_2 & Fibre Lasers	$1.3 Billion
BioTech & Healthcare	**$2.5 Trillion**
Blood Testing Gene Sequencing Eye surgery	$20 Billion
Diagnostic and Surgical	$1.5 Billion
Solid State & Excimer Lasers	$400 Million
Telecoms e-Commerce & IT	**$4 Trillion**
Internet Computers Music Movies	$200 Billion
Information Routing and Storage	$25 Billion
Diode and Fibre Lasers	$3.2 Billion

Laser and photonics sectors in the United States
www.laserfest.org/lasers/baer-schlachter.pdf



A diode laser, such as is used in telecommunications, gas sensing and research laboratories.
en.wikipedia.org/wiki/Laser_diode



Laser cutting in the *Stainless Steel Factory*, in Tauranga, which offers a laser cutting service from design through to finished product using predominantly stainless steel, aluminium and mild steel.
www.lasercut.co.nz/The-Stainless-Factory

The *OmniGuide Inc.* flexible CO2 laser for neurosurgery allows neurosurgeons to perform precise dissection, cutting, debulking, and microvascular coagulation using a hand-held, no-touch instrument, that is portable and flexible.
medgadget.com/archives/2008/09/the_beampath_neuro_system_first_flexible_co2_laser_scalpel.html

- Another major potential application of photonic technologies is in the development of new manufacturing systems utilising high power laser systems. These systems are not limited to large scale cutting and welding applications, which are well known, but can be used to drill microscopically small holes and cut microscopically narrow trenches in virtually any material, leading to a whole new field of *micromachining*. The Lighthouse is acting as the major interface between industry and the new two million dollar femtosecond laser micromachining facility—the *Photon Factory*—at the University of Auckland.

  There are numerous other examples of the potential for photonics research to assist industry. Companies which can benefit include some of New Zealand's leading primary produce exporters (through improved photonic sensing systems), bioengineering companies, security system producers and environmental monitoring companies. A particularly important growth area is in the field now known as *biophotonics*, which is generating hundreds and perhaps thousands of new startup companies worldwide each year, driven by the need for new monitoring, sensing and diagnostic systems for medicine.

- Another important example is within the New Zealand defence sector. Photonics is becoming increasingly important in defence systems as national security forces upgrade surveillance systems and seek to develop new means of countering increasingly sophisticated weapons systems, many of which are photonically enabled (such as heat seeking missiles and laser guided bombs). The Lighthouse has had discussions with the Defence Technology Agency (DTA) in Devonport on ways in which the facilities at the University of Auckland can be used by DTA, who need access to a widely tuneable light source operating in the infrared region of the spectrum. We anticipate that this engagement will develop significantly in the future.

- Sector engagement is a fundamental tenet of the Lighthouse Platform. The Lighthouse will extend its successful engagement model into new these sectors over the next 24 months.

Whether the reason is to support New Zealand exporters, technology companies, defence interests and researchers, or simply to claim a stake in a significant global opportunity, further development of the photonics sector through the Lighthouse Platform is of *national* significance.

Contents

1 Photonics

The science of optics, which concentrated on optical instruments, such as microscopes and telescopes, was revolutionised by the invention of the laser in the 1960s. The laser empowered optical technologies to take on a role similar to that of electronics. Nowadays the term *Photonics* embraces all of those technologies which are based on the use of light, and in particular those that use lasers.[1]

Whereas the 20th Century was the *Electronics Century*, the 21st century will be the Photonics Century. The significance of Photonics was acknowledged recently by the European Commission as *"one of five key enabling technologies for future prosperity with the potential to address the grand challenges of our time."* [2]

Photonics enabled technologies support the following important areas of development

1. ***Optical communications,*** most notably fibre-optic telecommunications networks
2. ***Sophisticated very high precision optical instrumentation,*** including microscopes, telescopes and a wide range of sensing instruments.
3. ***Laser welding, cutting and micromachining*** provides welding with minimal heating and distortion, very precise cutting and the ability to manufacture extremely complex structures, even at microscopic scales.
4. ***Biophotonics,*** including diagnostic, therapeutic and other medical applications.
5. ***Basic research into the properties of light and matter***
6. ***Inexpensive optical technologies,*** such as the laser in a DVD player, arising as spinoffs from research or advanced applications of photonics.
7. ***Classical optics,*** as known before the laser, but benefitting from the rise of photonics, as well as new sources of light such as LEDs.

A typical New Zealander uses photonics every day in a variety of contexts; every barcode reader, every CD and DVD player, and almost every use of the internet or cellphone involves the use of lasers and other photonic components as an essential part of their functioning.

Photonics Drives the Internet and the World Wide Web

20th Century
Electrons through copper wires

Vintage telephone exchange and equipment

Electrons carry information through copper wires over 1000s of km with moderate bandwidth

100 characters per sec (1970s)
100,000 characters per sec (1990s)

Time to transmit a single typed page: seconds

21st Century
Laser light through fibre optics

Telecommunications laser transducer

High-bandwidth communication using infrared lasers and fibre optics to guide the light.

100 billion characters per sec (2010)
A million times faster than copper wire

Time to transmit a single typed page: 10s of nanoseconds

[1] A fascinating and easily understood outline of the history and the industrial and scientific importance of lasers today can be obtained from www.laserfest.org/lasers/baer-schlachter.pdf

[2] See, for example, www.photonics21.org

2 The Photonics Sector

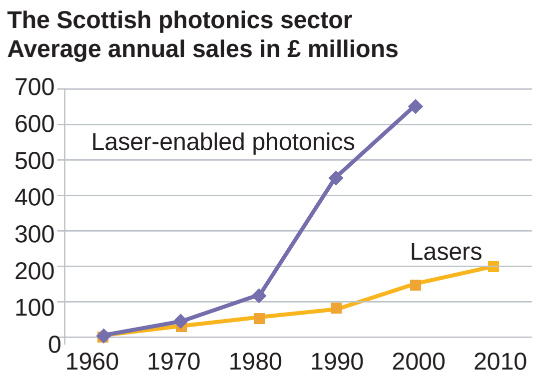
2.1 Global Photonics Industry Developments

The global market demand for photonics-enabled technology is on a sustained growth trajectory, growing from US$500 billion in sales in 2006 to several trillion in 2010.[3] Some interesting observations are revealed when examining specific regions and countries.

A good example is Canada, which has realised growth in line with that experienced globally. Canada is considered a leader in photonics development, generating roughly US$4 billion annually and employing approximately 20,000 people across 370 companies, the majority of which are SMEs. The workforce is highly skilled, with 40 percent involved in research and development. Of the photonic goods produced in Canada, 85% are for export.[4]

In 2009, the European Commission designated photonics as one of five key enabling technologies for future prosperity—in 2010, the European photonics industry is expected to employ 1.5 million people, building US$300 billion worth of products.[5]

A more relevant example for New Zealand is Scotland. The Scottish photonics industry consists of approximately 85 companies, including multinationals (e.g. SELEX GALILEO, Thales Optronics and Raytheon), large indigenous companies (e.g. Optos), as well as Small and Medium Enterprises (SMEs). The combined annual sales of these companies in 2007 totalled approximately £750 million (NZ$1.6 billion), employing in excess of 4,000 professional staff. There are currently 12 Scottish Universities with at least one department engaged in optoelectronics research and there are over 400 researchers engaged in optoelectronics research.[6]



The contribution of lasers and photonics to the Scottish economy. The manufacture of lasers, while very significant, is overshadowed by *laser-enabled photonics*, the manufacture of devices based on lasers.
phys.strath.ac.uk/laser/pdf/Laser50.pdf

2.2 The New Zealand Photonics Sector

As in the rest of the world, photonic technologies in New Zealand are utilised in a range of industries, services and consumer devices. In addition there is a vibrant research culture, located in the universities and in Industrial Research Ltd. However, when compared with Northern Hemisphere countries, the New Zealand photonics sector is at an early stage of development—to ensure we are a net producer

[3] Global Optoelectronics Industry Market Report and Forecast, Optoelectronics Industry Development Association, Washington DC, 2007, www.oida.org/store/221

[4] Illuminating a World of Opportunity, A Survey by the Canadian Photonics Consortium, Photonics in Canada, January 2009, www.ontariophotonics.com

[5] Photonics for the 21st Century, Consolidated European Photonics Research Initiative, Association of German Engineers, 2005, www.eurom.org/index.php?option=com_content&task=view&id=30&Itemid=32

[6] The Scottish Optoelectronics Association website optoelectronics.org.uk/about-soa/key-facts

of photonics innovation, rather than a net consumer, it needs to develop quickly.

The New Zealand photonics sector includes industry, government entities and the research community. Industry participants include companies involved in high technology manufacturing, information and communications technology (ICT) as well as sensing and measurement. Photonics technology supports New Zealand companies in the primary sector through the development of innovative instrumentation to support productivity and processing gains. The sector also includes Government entities that depend upon photonics technology, such as the Ministry of Defence, NZ Defence Force, NZ Transportation Agency, NZ Customs and Crown Fibre Holdings.

Importantly, the New Zealand photonics sector includes a research community of scientists, engineers and students, united by their passion for laser and optical technologies.

Key to the successful development of the New Zealand photonics sector is the linking together of industry and government entities to the research community. This will ensure they develop their expertise in applying optical and laser technologies to solving important industry challenges. The creation of these linkages is a fundamental tenet of the Lighthouse Platform.

The characteristics and interrelationship between the various entities of the photonics sector can be illustrated from a value chain perspective, as shown in Fig. 1, which links the various entities in the photonics sector value chain and the flow of innovation from the research community, through the value chain to the ultimate end users. The components of the value chain can be summarised as:

- ***Materials and Signalling*** : Developed by the research community, materials and signalling are the core photonics technologies which drive all downstream sector activities.
- ***Devices and Components*** : Derived from materials and signalling technology, specialist small to medium sized enterprises develop specialist photonics devices and components, often for use as a part of a larger manufactured product.
- ***Manufacturing*** : Consisting of one or several embedded photonics components, these products are typically made by large equipment manufacturers.
- ***Global Distribution*** : Global Distributors (and these are often also manufacturers) have established channels to market for photonics-enabled products, and include foreign multinationals with a presence in New Zealand.
- ***End User*** : Typically large companies and government entities, End Users are consumers of manufactured photonics products, often without realising it.

As the New Zealand photonics industry is at an early stage of development the value chain is yet to take full shape. Some companies are stepping up their investment in photonics and others will do so in the medium term. Examples of New Zealand and multi-nationals that will ultimately fit into the value chain are also listed in Fig. 1.

Located in Dunedin, *Allan's Sheet Metal and Engineering Services* offer a Laser cutting service which combines high speed with accuracy and precision. Ideal for producing thousands of manufactured standard items or a one off precision cut, the results are the same, clean fast and accurate, which all adds up to cost effectiveness.
www.allans.co.nz/Plant-Equipment/Laser-Cutting/

Located in Manukau City, *Laser Welding Ltd* offers a Nd:Yag Laser microwelding service for the repair and modification of plastic injection moulds, machine components, small metal parts, and assembly welding of small machine, medical etc., components.
laserwelding.co.nz

It is important to note that while the entities listed in the Global Distribution and End User categories form a critical part of sector value chain, many are unaware of their increasing reliance upon photonics innovation. An important goal of the Lighthouse Platform over the next two years is to engage with these entities, listen to their related challenges and inform them of the potential for photonics to address their needs.

2.2.1 Realising the Photonics Opportunity for New Zealand

To realise the opportunity requires the various participants to work to build an awareness of themselves as belonging to this sector, and to have clear understanding of :

1. The needs and capabilities of the sector members, namely
    - Universities and other research institutions
    - Small to medium sized enterprises (SMEs)
    - Large companies
    - Multinationals
    - End users of photonics technology
2. The flow of ideas and information from one sector member to another, and in particular from research to development and then to production.
3. The flow of skilled personnel, often coming out of the Universities, into research, development and ultimately into management

Ideally, sector growth is fed by the innovation developed by researchers, and by the stimulation which manufacturers and other end users of photonic technologies can provide to the researchers though close interaction and collaboration.

This is the global situation, but within New Zealand—a small remote and independent part of the global economy—we see only some parts of the value chain shown shown in Fig. 1, most of which takes place elsewhere. Thus multinationals rarely source their research locally, and all manufacturers are willing to develop intellectual property from anywhere, if this makes commercial sense.

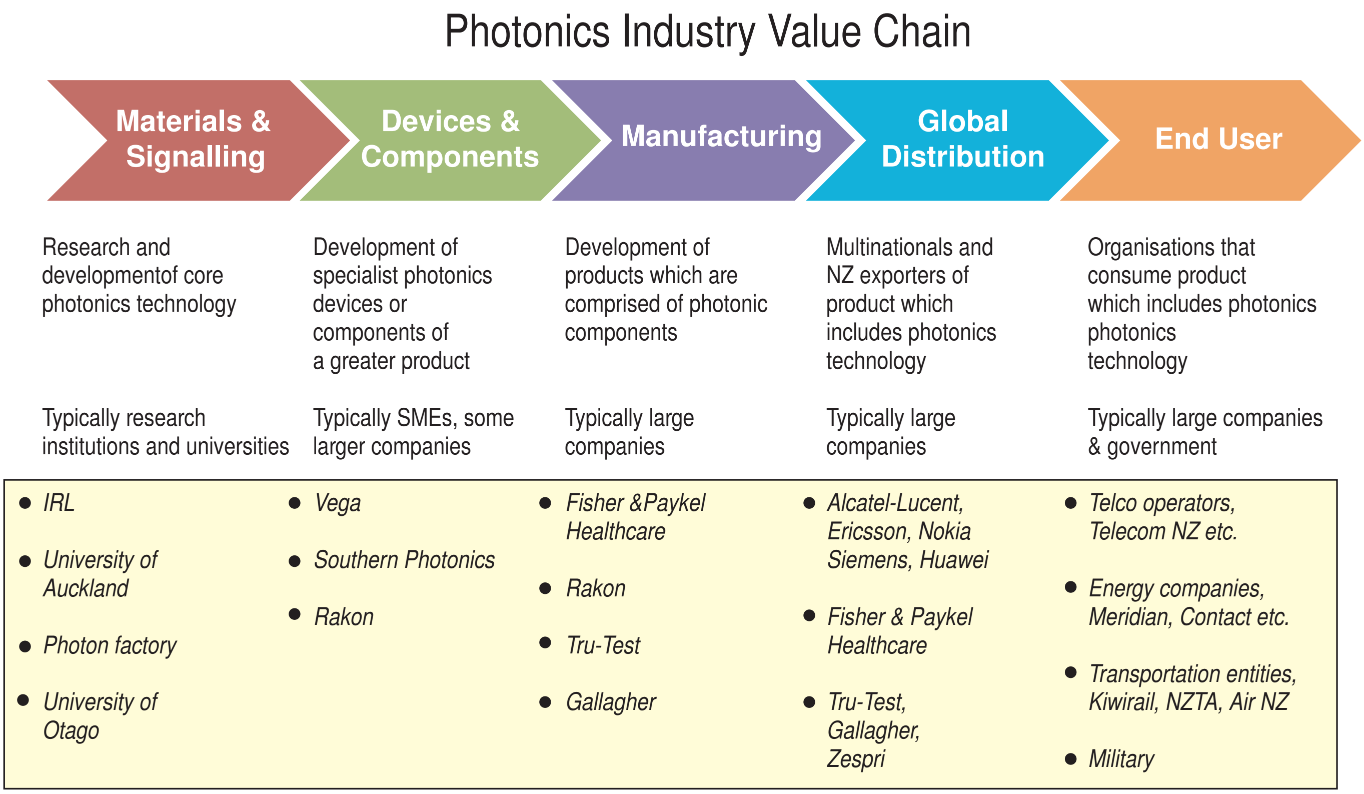
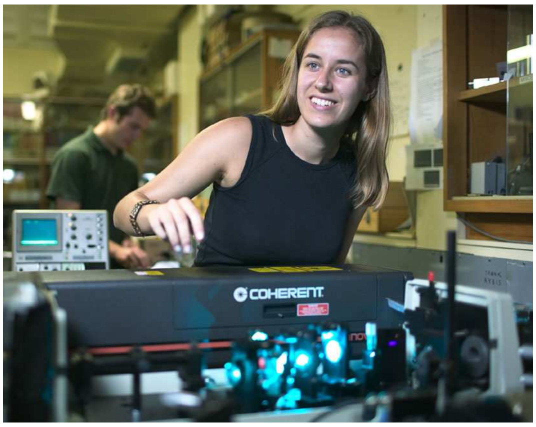


Figure 1: The Photonics value chain: This figure summarises the various entities in the global Photonics Sector value chain and the flow of innovation development from the research community to end users.

In the lower box are some New Zealand examples of the various kinds of entity, which include some of New Zealand's leading exporters, such as Fisher and Paykel Healthcare, Rakon, Zespri, Fonterra, Gallagher and Tru-Test.



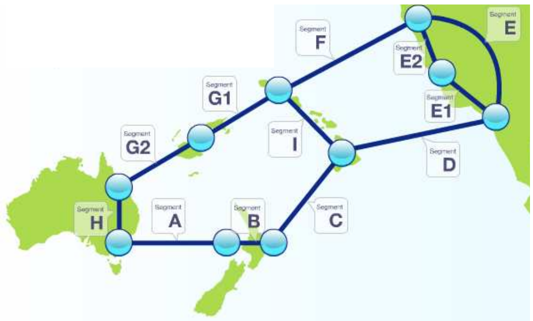
Photonics research laboratory in the physics department of Auckland University

3 Photonics in New Zealand Research and Industry

There are considerable resources of human capital and equipment in the research institutions, and the research includes a wide range of programmes, extending from "blue sky" research to directly applicable research projects. The Universities conduct research as part of their educational role. Basic research forms a significant part of their effort, and the photonics based research programmes in the University of Otago and the University of Auckland are large and have high international standing.

On the other hand, there is very little photonics based research that does not have a goal rooted in the idea of ultimate applicability, and the laboratory skills related to lasers, electronics, computer control and computer modelling are highly relevant to high-tech industry. Most of photonic research in New Zealand universities can be thus viewed as targeted basic research.

In the sections below, several areas where photonic technologies are poised to have a substantial impact (or are already dominant) are discussed together with their connection to local industry and research groups. For each area, the existing research efforts in the Universities and at Industrial Research Ltd. and their actual and potential linkages to industry are discussed.



The *Southern Cross Cable Network* provides fast, secure bandwidth from Australia, New Zealand and Hawaii the USA. The network includes 28,900km of submarine cable incorporating around 500 optical repeaters (placed every 40-70km to boost signals), and 1,600km of terrestrial cable. Cables in the network contain six optical fibres between Sydney and Hawaii, and eight fibres between Hawaii and the US West Coast.
www.southerncrosscables.com

3.1 Communications Technologies

3.1.1 New Zealand Participation

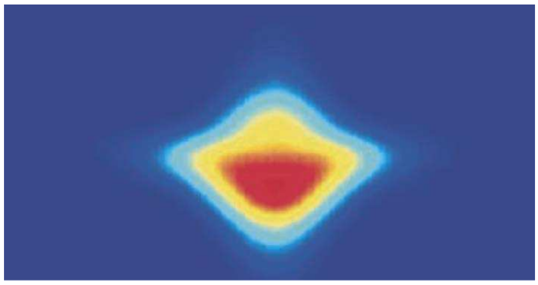
The importance of optical communications technologies has been brought into prominence recently with the plan of the current Government to provide high speed fibre optic telecommunications links to business, farms, and the homes of 75% of the population within 10 years. This ambitious plan will require significant investment in infrastructure, much of which can only be supplied by overseas companies, but there is still a significant opportunity for New Zealand companies to participate in this rollout, and through their participation, leverage their own products and services to generate new export opportunities.

3.1.2 New Zealand Photonics Research in Communications

New Zealand has a strong research group in optical communications technologies at the University of Auckland and through its allied spinoff company Southern Photonics Ltd. Since 1996 Industrial Research Ltd., the University of Auckland and the University of Otago have undertaken a joint research programme on the development of organic nonlinear optical materials as the enabling technology for next generation devices for telecommunications (and other applications). This has led to the development of further research programmes looking at the development of a range of new photonic materials. These additional programmes include VUW and Massey University as research partners.

The thrust of these programmes is the development of a range of materials through which light can be controlled via the application of, for example, an external electric field. The types of materials now being developed include nonlinear optical polymers, glass ceramics, quantum dots, advanced glasses and nanoparticles. The overall aim of this research is to use these materials to develop prototype all-optical switches and modulators, all-optical wavelength converters and all-optical signal regenerators. Consequently the goal is to develop key components for networks based on dense wavelength division multiplexing (i.e. optical communications).

Frequency resolved optical grating pulse analyser for optical signals manufactured in Auckland by *Southern Photonics Ltd.*



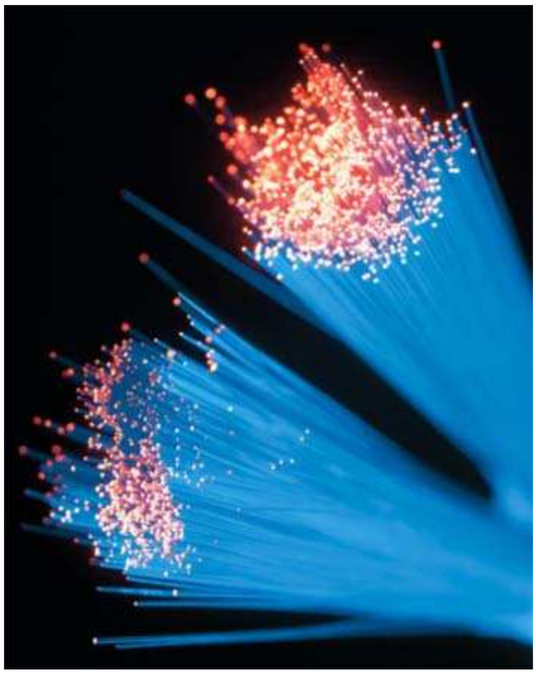
Spectrogram produce by frequency resolved optical grating pulse analyser.
`southernphotonics.com`

3.1.3 New Zealand Manufacturing for Communications Photonics

1. Southern Photonics makes test and measurement equipment for other research workers in the area of very high speed optical communications (40 Gigabit per second and beyond). Increasingly the company is moving into the area of supplying other photonics based instrumentation that is less specialised and has a larger market base.

   This company grew from a research team at the University of Auckland, working in the area of nonlinear fibre optics on what was originally a programme of basic research. Southern Photonics was formed in 2001 to commercialise technologies developed in the early 1990s. In this connection it is important to be realistic about the development of new companies and their potential to contribute to the local economy. Whilst their impact may ultimately be large, it is often more than ten years after the original research was done before a spinoff company can grow to a substantial size.

2. Other companies in New Zealand are engaged in optical communications as suppliers or distributors of photonic systems for communications, but their role is mainly at the delivery end of the supply chain. It is important to note however, that Tyco for example has more than 120 employees in Christchurch alone and they are engaged in the manufacture of optical fibre cables locally (although the optical fibres themselves are drawn overseas). Several other local companies are involved in the supply and maintenance of optical communications systems,



Optical fibres use laser light to transmit information a million times faster than copper wires.
`www.broadbandsuppliers.co.uk/uk-isp/how-fast-is-fiber-optic/`

The Siemens In-situ Laser Gas Analyzer LDS 6 Monitors HF in Real-time. A basic focus in the Aluminium production industry is the high energy consumption. Design and process improvements have progressively reduced energy consumption, but have also strengthen the demand for HF control in the flue gas filter and the exhaust gas to protect workers and ambient air quality.
www.sea.siemens.com/us/internet-dms/ia/AppliedAutomation/AppliedAutomation/docs_ap/cs_LDS6_Alum_en.pdf

In Germany *Hail-Tech GmbH* manufactures the Lasertec 80 precision cutting and welding machine, which is used for the manufacture of devices from stock as thin as 0.01mm, and materials such as alloyed and unalloyed steel, light metals, noble metals, diamond, nickel and cobalt alloys, ceramics, semiconductors and composites. The illustration shows the manufacture of a medical stent for alleviating blocked arteries
www.hail-tec.com/content/aktuelles/praezisionslasermaschine.php

as optical fibres gradually displace copper based communications systems.

3.2 Sensing Technologies

3.2.1 New Zealand Participation

Sensing technologies are very important to New Zealand, not only as a possible export industry of high value specialised manufacturing, but also as a vital component of the primary industries, enabling the monitoring of quality and compliance with environmental and other standards. Whilst there are a large number of competing products and sensors based on other technologies, photonic sensing has become established in a number of areas over the last decade as the system of choice. Although photonic sensing costs more than other technologies to install, it may have advantages in terms of longevity of the sensor, stability, reliability and other factors, which outweigh the increased costs. In this respect photonic sensing technologies are an ideal area of focus for New Zealand researchers and companies, in that there are a huge number of niche applications for sensing of gases, environmental parameters, pressure, strain, dissolved chemical species etc. A few examples of photonic sensors relevant to New Zealand include:

1. Refractometers for measuring the sugar content of fruit.
2. Optical fibre temperature gauges for monitoring the temperature of pot lines at an aluminium smelter,
3. Optical fibre strain gauges for measuring the deflection of superyacht structures,
4. Optical gas sensors for determining the concentration of molecular species in cool stores.

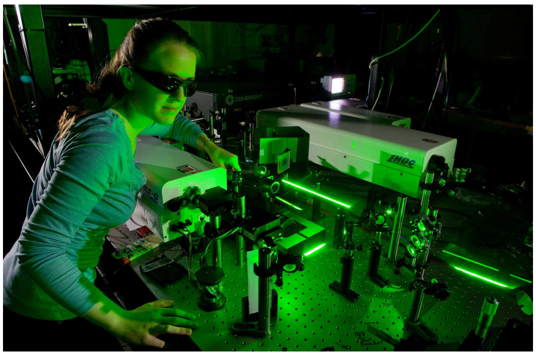
3.2.2 New Zealand Photonics Research in Sensing Technologies

Research at the the University of Otago on the development of ultra-stable swept frequency lasers has led to the development of Photonic Innovations Ltd., a spinoff company formed to manufacture portable optical gas sensors. These sensors can be used to measure the concentrations of various gas species; the particular gas targeted being determined by the frequency of the laser used. Competing technologies include semiconductor gas sensors, which are well established in the market, but which can only monitor a restricted range of gases. New Zealand already has a company manufacturing semiconductor gas sensors in Auckland, and further collaboration between optical and semiconductor gas sensor manufacturers could lead to synergistic developments of economic value.

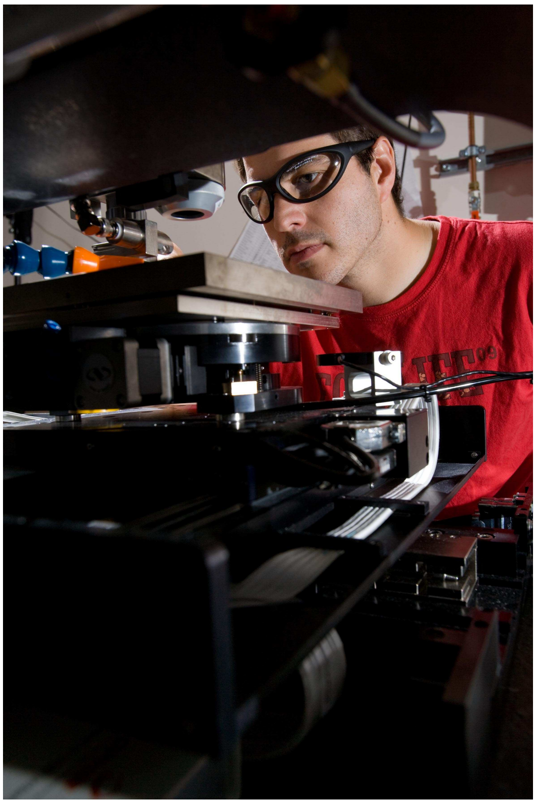
Research at the the University of Auckland and at Southern Photonics Ltd. into optical fibre based strain gauges and their applications

has been undertaken since 2005, in collaboration with Korean researchers and a manufacturer of strain gauge sensor systems. Opportunities have been pursued for application of these technologies with Meridian Energy (Wind Turbine monitoring) and Opus Ltd. (Lower Hutt). Southern Photonics Ltd. has now developed a prototype high speed interrogation system for monitoring strain changes at kilohertz rates using optical fibre sensing elements, while other new applications are being investigated under a collaboration with Industrial Research Ltd., which funds a research fellowship and a PhD scholarship in this area.

Industrial Research Ltd. has a research programme in photonic sensing, which has a goal of developing new photonic sensing devices. This work builds on their materials expertise, and aims to develop new strain and temperature sensors for applications in temperature ranges: less than 100°C, up to 600°C, and up to 1000°C. It is anticipated that this work will also lead to highly sensitive sensors for non-destructive testing for applications such as infrastructure monitoring (e.g. bridges, furnaces), agriculture (e.g. ethylene monitoring in ripening fruit) and chemical detection. This programme is linked to Southern Photonics Ltd. and to Photonic Innovations Ltd., and new applications for the technologies will find a ready route to market through existing collaborations with industry. This area is potentially a fruitful one for the export of photonics systems and devices.



Femtosecond lasers in the Photon Factory are used to monitor molecules harvesting the energy from light.
photonfactory.auckland.ac.nz



Laser micromachining is performed at the cutting edge with the high-tech equipment in the Photon Factory. Here, the lasers are being used to create tailored features as small as a few hundred nanometers for the solar energy harvesting industry in New Zealand.
photonfactory.auckland.ac.nz

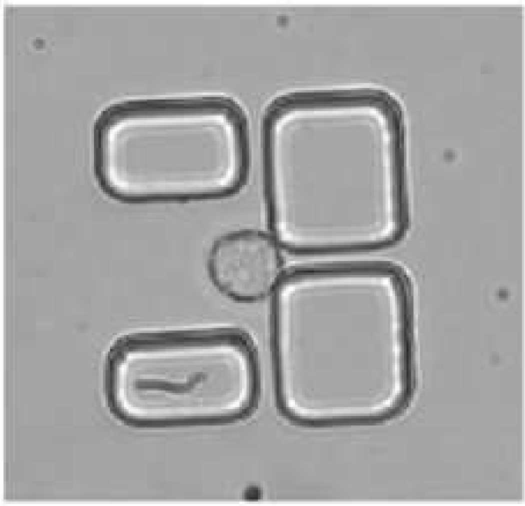
3.3 Industrial Processing

Worldwide uptake of photonic technologies for industrial applications is widespread and increasing rapidly. In this area New Zealand lags behind other industrialised economies, but this is to be expected when much of the uptake has been driven by heavy industry with huge investment budgets. Examples include laser welding systems for car assembly plants, surface modification of large metal sheets (for example Aluminium cladding sheets for buildings), and laser cutting tools.

3.3.1 New Zealand Participation

A newly developed application for high power pulsed laser systems enables photonic materials processing on the microscopic scale. Such systems use laser ablation to enable the manufacture of microscopic structures that cannot be made in any other way. This involves the use of very short duration, high peak-power laser pulses, to remove material without heating the surrounding material. This is an expensive technology, but one suitable for devices that have high value and small size, such as small stents for insertion in blood vessels.

> ***The Photon Factory,*** a $2 million joint facility of the Physics and Chemistry Departments of the University of Auckland commissioned in 2010, now provides this technology in New Zealand. At its simplest this laser micromachining facility can drill very



A single cell trap constructed in the Photon Factory as part of a microfluidic device for biomedical research. The bead trapped in the device is about 10 microns in diameter.
photonfactory.auckland.ac.nz

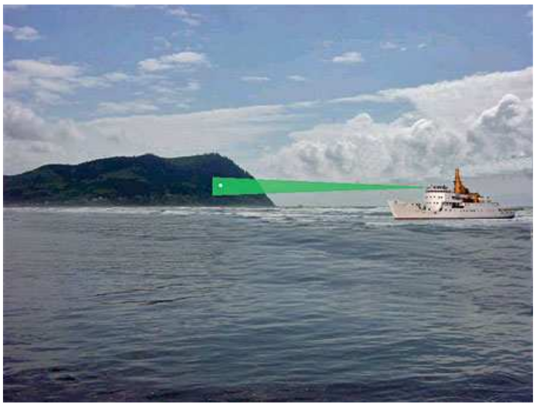
small holes and cut narrow trenches in virtually any material. In addition, since the beam handling equipment is computer controlled, quite complicated structures can be engineered. It is also possible to write structures inside a solid material by using a tightly focused beam.

The commissioning of this laser micromachining system has opened up new opportunities for industrial collaboration in the development of new devices. Whilst it may be economic in some cases for industries to purchase their own micromachining platforms, it is essential to make extensive use of a shared facility in the early stages to prove the economic viability of the proposed processes. The uptake of this technology is expected to be rapid, and to be a variety of industries—a substantial number of partners in New Zealand industry have already been identified. The Photon Factory has the dedicated website photonfactory.auckland.ac.nz

3.3.2 New Zealand Research in Industrial Processing

The facilities available in the Photon Factory are being utilised in two collaborative research projects linking the Auckland team with Industrial Research Ltd. The projects involve new applications for terahertz (THz) wave systems including the manufacture of THz wave optical components, and the machining of polymer optical waveguides for new optical sensor technologies.

New applications for the laser micromachining facility are also being investigated in a number of cross disciplinary research projects involving the Faculty of Engineering and other Science Faculty Departments. In addition, various New Zealand companies are now starting to use the facility in an exploratory way to assess its potential.



The Canadian *Gated Laser Retro-Reflection Scanner Surveillance System* detects almost all optical devices observing its platform, from binoculars to weapon sights and optical seeker heads. It instantaneously provides a very precise zoomed image of the detected device, as well as its position.
www.valcartier.drdc-rddc.gc.ca/sciences/glares-ft-fs-eng.asp

3.4 Security and Defence Technologies

Worldwide investment in photonic technologies for defence systems is enormous. This investment is not just in well known systems such as laser guided bombs and heat seeking missiles, but also in less obvious defensive systems such as, night vision glasses, or detectors that scan the surrounding countryside for specular (mirror like) reflections indicating the presence of glass (in binoculars for example) or similar reflecting inorganic materials.

Other important security related photonic technologies include laser anti-intrusion systems and infrared motion detectors. These detector systems are available at low cost through large scale manufacture elsewhere and are now a mature technology.

3.4.1 New Zealand Participation

New Zealand maintains the Defence Technology Agency (DTA) in Devonport which conducts research into photonic technologies and has a significant number of staff working in the area. They work closely with DSTO in Australia which has a much larger team working in photonic and optoelectronic technologies. At least two companies work directly in this area and liaise closely with DTA.

3.4.2 New Zealand Research in Security and Defence Technologies

Whilst there are currently no significant research programmes at the Universities of Auckland or Otago or at Industrial Research Ltd. in photonic technologies for defence systems, the University of Auckland has for several years been discussing possible collaborations with DTA in this area. This has included a team of project students working at DTA using a valuable high speed infrared camera. There are also discussions of the use of the photon factory as a widely tuneable source of infrared radiation to assist with developing counter measures against new threats to New Zealand defence personnel. New Zealand is also undertaking research into terahertz (THz) imaging and sensing and this a technology that will form a significant part of future security screening systems. For example THz technology will complement X-ray systems for airport bagging screening and has the significant advantage of being able to specifically identify a given substance such as a drug or explosive. Furthermore THz radiation is non-ionising (unlike X-rays) and is therefore safe. The current research involves Industrial Research Ltd., the University of Auckland, the University of Otago and Massey University, and involves the development of cost effective THz sources, high sensitivity detectors and systems components such as low loss lenses.

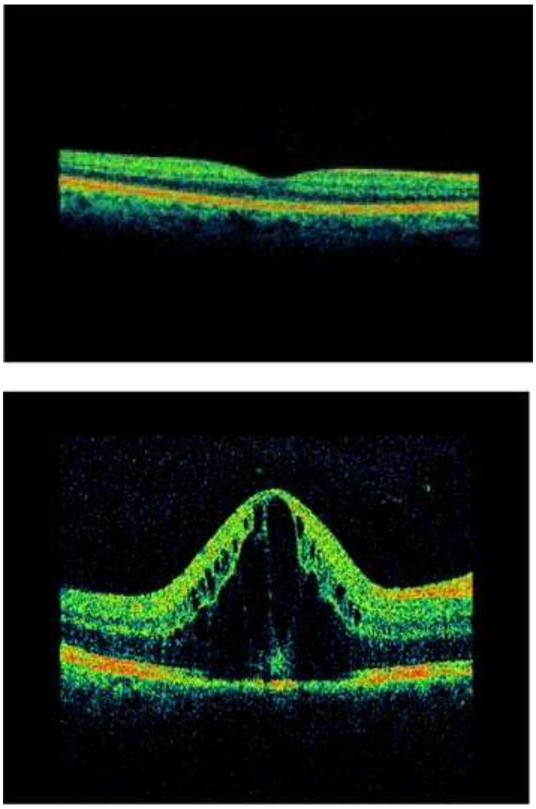
Photodynamic therapy avoids the scarring associated with surgical removal of the tumour and the need for an in-patient hospital stay. This treatment involves; (i) the application of a pharmaceutical to the skin, (ii) absorption of the pharmaceutical into the skin and then subsequent conversion of the drug to an active photosensitiser, (iii) followed by controlled exposure of laser or LED light, which induces a photoactive reaction which activates the drug and destroys the skin cancer cells. `www.ambicarehealth.com/medical-products/ambulight-pdt/overview/`

3.5 Biophotonics Technologies

Biophotonics is one of the fastest growing areas of photonics, with global investment increasing at a remarkable rate, driven by the medical devices market. The overall investment in biological technologies in general is also growing rapidly. Researchers in the biological sciences, both worldwide and in New Zealand, make extensive use of photonic technologies in expensive instruments imported for research teams, often without knowing (or needing to know) of the underlying technology which enables the measurements being made.

There is a growing realisation amongst photonics researchers of the market potential for new technologies in this space. The opportunity for the development of commercial biophotonic systems and devices is very significant, and countries around the world have recognised this by their investment in this area. Investment by other countries does not undermine the opportunities for New Zealand researchers however, as the range of applications and the number of small niche opportunities is vast.

Fisher and Paykel Healthcare offer a broad range of heated humidification products and systems for use during the treatment of respiratory conditions by ventilation or oxygen therapy. From birth, humidified therapies provide continuous respiratory care to restore natural balance. The result is optimal care and a family of solutions that nurture life. `www.fphcare.com/rsc/infant-care.html`



In these optimal coherence tomography (OCT) images the different colours represent the different retinal layers. The upper image shows a healthy eye, with a dip at the centre of the macula. In the lower image the retina is thickened—swollen by fluid which should not be there.

www.liv.ac.uk/researchintelligence/issue37/diabeticretinopathy.htm

3.5.1 New Zealand Participation

Research teams at the Universities of Auckland and Otago have substantially increased their research efforts in Biophotonics through new staff appointments, although funding for research is still difficult to obtain. There are however, opportunities not only in the commercialisation of new devices but also in increased collaborative efforts with industry. The case of Fisher and Paykel Healthcare is illustrative. As New Zealand's most successful medical devices company, Fisher and Paykel Healthcare has a long history of interaction with the University of Auckland in the development of an optical respiratory humidity meter. This device can read out the humidity of air being breathed into and out of the lungs by a patient using a respiratory humidifier. As the leading world manufacturer of these humidifiers, the availability of this photonic measurement system has given them a substantial edge on competitors.

3.5.2 New Zealand Research in Biophotonics

Biophotonics covers a large and diverse range of systems and devices used in New Zealand Research institutes. These include conventional optical microscopes and confocal microscopes utilising a range of nonlinear optical phenomena. Research is also conducted on systems for extending the resolution of optical microscopes below the wavelength limit normally associated with optical microscopy, on various fibre optic probe systems for invasive and non invasive characterisation of tissue, and on *optical coherence tomography* (OCT) imaging. Much of this research is cross-disciplinary involving the Medical schools and Physiology Departments of the Universities of Otago and Auckland.

Researchers in the Physics Department of the the University of Auckland have recently made an important advance in this area, by developing a new all-fibre dispersion compensation system for use in OCT systems, for which a US patent is pending. OCT is now widely used in opthalmology and increasingly in other diagnostic medical procedures. The OCT market is dominated by major international instrument suppliers, but there are opportunities for researchers to gain returns from new advances by teaming with international companies in the medical area, as well as by exploiting niche areas with new instruments.

3.6 Conventional Optical Technologies

3.6.1 New Zealand Participation

New Zealand has a long history of participation in geometrical and physical optics, which developed mainly in the forerunner of Industrial Research Ltd., the Physics and Engineering Laboratory of the former DSIR. This has resulted in a number of successful commercial enterprises including:

1. ***Vega Industries Ltd.*** designs and builds specialised signal lights for safe movement by sea, air and land. Some of the most challenging waterways in the world are marked by PEL Sector Lights made by Vega. Nowadays, more people and products are transported around the globe by sea, air and land, ships are larger and ports are competing to host them. Squeezing larger ships into existing channels requires better signal lights to help pilots to guide the ships safely.

2. ***KiwiStar Optics*** is a world leader in the development and manufacturing of large, precision optics, and operates as a part of Industrial Research Ltd. They produce optical systems used for applications in astronomy, instrumentation, defence and surveillance.

   KiwiStar are experts in designing optics and performing systems integration for extremely complex optical systems up to 1.8 metres in diameter, providing a unique total system integration package with the ability to design and manufacture the mechanical housing for the optics, and the assembly and precision alignment of the optical system. They have extensive experience in developing, manufacturing, and installing systems for a wide range of environments and applications.

A solar-powered *Vega Lighthouse* system.
www.vega.co.nz/assets/gallery/lighthouses/preview.jpg

The large aperture (620mm) precision navigation becon installed at Deigo Garcia US Naval Base in the Indian Ocean. KiwiStar manufactured the optical components. Image courtsey of *Vega Visual Signals*.
www.kiwistar.com/?q=gallery

In addition, research institutes regularly receive enquiries from industry about assistance with ray tracing and geometrical optics problems. The demand for these services is increasing worldwide and several New Zealand companies (e.g. Vega Industries Ltd, 3i Innovation Ltd, Ampelite (NZ) Ltd) are involved in this resurgence of optical technologies. The demand for these designs is driven by the development of new optical sources which are now supplanting conventional tungsten filament lamps in a wide range of applications. The design of reflectors, lenses and waveguides which are optimised for use with Light Emitting Diode (LED) sources for example, can be challenging.

Examples of successful engagement with industries include the design of new LED based road studs for illuminating lanes on roads, and the design of new roofing panels for a leading supplier of these systems to optimise the heat rejection and light gain in warehouses.

3.6.2 New Zealand Research in Conventional Optics

Whilst there is some ongoing research in the development of interferometers and other free space optical systems within the research

community, most of the research work in Universities and CRIs involves the development of new photonics devices and systems, since the science behind conventional ray tracing and geometrical optics is well understood. The Universities have, nevertheless, an important role in producing graduates who have the necessary background and skills to use the very sophisticated software packages which are now available. These packages are available from a number of suppliers to support the worldwide demand for conventional ray tracing calculations.

4 The Lighthouse Platform

Lighthouse at the entrance to Otago Harbour

The *Lighthouse Platform* was formed to promote the development of New Zealand's photonics sector by providing a national collaboration platform with a structured engagement programme to link researchers, industry and government agencies. The Lighthouse Platform is modelled on successful photonics platforms in other countries, particularly Europe, North America and North Asia. In all instances, these successful platforms have established strong and enduring links between business, research and government partners.

4.1 The Lighthouse "Value Proposition"

The Lighthouse Platform aims to raise the profile and competitiveness of the New Zealand photonics sector by

1. Building a network of companies, researchers, government and international platforms and/or companies,
2. Providing resources to industry, e.g. market analysis and help with funding applications,
3. Enabling the commercialisation of government-funded research,
4. Retaining skilled graduates in New Zealand, and
5. Providing routes to technical advice and specialised resources.

4.2 Sector Development Activities

Lighthouse "Meet and Greet", March 9, 2010.

Lighthouse activities and achievements aligned with the Lighthouse Value Proposition, were held from July 2009 to June 2010 were as follows.

4.2.1 *Lighthouse Events and Contact with Industry, Government and Researchers*

The Lighthouse held three "Meet and Greet" events in Wellington, Auckland and Christchurch. A total of 81 people attended these events, including staff from companies, industry groups, government organisations, university management and researchers from CRIs and universities. Each event included a presentation about the Lighthouse Platform and research posters. Guests from 19 companies, 2 industry groups and 2 investment companies attended.

The Lighthouse has a total of 157 companies, investors and industry associations on its contact list. This list has been steadily expanding since the launch of the Lighthouse Platform. Contact is managed through e-mails, mail-outs, LinkedIn, industry bodies such as NZICT, and the dedicated website www.lighthouseplatform.org.nz

4.2.2 Lighthouse Optical Communications Working Group

This group submitted a proposal to the Ministry of Economic Development and Crown Fibre Holdings to be a potential supplier of services, tools, and expert advice for broadband rollout in New Zealand. A similar application has recently been lodged in Australia through the National Broadband Network project by Harmonic Ltd. and Southern Photonics Ltd.

The Optical Communications Working Group has made presentations to the Ministry of Economic Development, Crown Fibre Holdings, the potential local fibre companies, Citylink, Telecom/Chorus and Vector, as well as technology partners Ericsson and Downer, submitting two commercial proposals and providing a platform for the commercialisation of New Zealand investment in innovation across Universities. The Government's Ultra Fast Broadband plan is an important economic initiative and the New Zealand tools and capabilities promoted by the Optical Communications Working Group will be required to ensure its success.

4.2.3 New Working Groups for Establishment

New working groups with a similar purpose to the optical communications working group will be established in the following fields:

1. ***Laser Materials Processing*** : Auckland University has a dedicated facility, *The Photon Factory* (see Sect. 3.3.1), which offers opportunities for industry to access state-of-the-art laser facilities with a wide range of machining capability.

2. ***Sensing*** : New commercialisation opportunities exist for optical sensing technologies in the transportation, construction, energy and primary sectors.

4.2.4 Establishment of the Sector Engagement Group

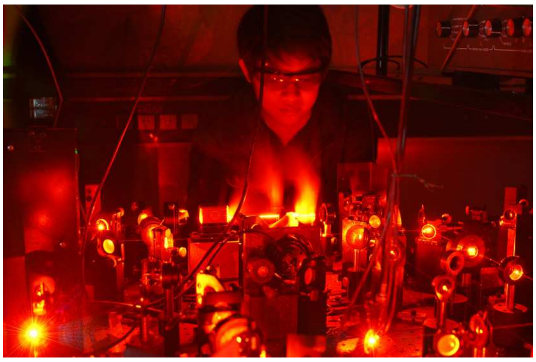
The Sector Engagement Group was set up initially with a membership from the scientists and business development managers from each partner in the Lighthouse, but with an aim to identify and appoint suitable representatives from business. As a result of the policy of engagement with business, we have now appointed the following business representatives, all of whom have a strong commercial interest in the development of New Zealand's photonics sector:

1. ***Matthew Laws***, Product Development Manager with Fisher and Paykel Healthcare. He formerly worked at Navman and other high-tech companies and has technology transfer and product development expertise.
2. ***Mitali Purohit***, Associate with Pacific Channel, a venture development and investment company (biotechnology and engineering products). Through this company she is COO for Breathe Easy Ltd.
3. ***Tony Price***, founder and principal of Procam Associates Ltd, which provides consultancy services to the high technology sector (e.g. business development, management of R&D and IP).
4. ***John Hamilton,*** Sector Manager—Specialised Manufacturing and SMEs, Canterbury Development Corp (CDC), which is the business development arm of the Christchurch City Council. He also leads the Hi-Tech Launch Programme.

5 Sector Development Plan

As a result of the activities undertaken by the Lighthouse up to the current time, we now have developed a preliminary map of the Photonics Sector. In particular:

1. We have identified a significant number of businesses in which photonics plays an important role. Even so, we know this task is not complete, since we are continuing to discover more such businesses.
2. As a result of the programme of engagement with industry and business, we are well on the way to establishing what the role of research organisations is in respect of industry.
3. We have raised the profile of the *Photonics Sector*, but are aware that the general understanding of the concept of *photonics* is not good.
4. The *Photonics Sector Engagement Group* which has now been formed is in a position participate in the ongoing development of the *Sector Development Plan*, as formulated in this document, in conjunction with New Zealand industry and the research organisations.
5. The definitive formulation of the Sector Development Plan—in a form generally accepted by the industry and research organisations—is now the principal task of the Lighthouse Platform.



An ultra stable laser system being developed in the University of Otago for long-range detection of ultrasound, ultimately to be used for testing materials for structural defects.

5.1 Capability Development within the Research Organisations

The capability development phase of the Photonics Sector has been under way for at least 40 years as a result of photonics-based research and educational programmes in the Universities and Industrial Research Ltd. This development has been significantly supported by funding from not only FRST, but also from the Marsden Fund. There has not so far been significant direct financial support from industry. It is therefore not surprising that the research programmes on the whole are not directly linked to commercial outcomes. All of the FRST funded photonics programmes currently being undertaken within the University of Otago, the University of Auckland and Industrial Research Ltd. are most correctly viewed as *targeted basic research*. Some have more obvious immediate goals, while others have goals based on quantum information theory, which offers potential for enormous

strides in power and speed of ICT. While research funded by the Marsden Fund is categorised as “untargeted”, in practice much of it is well aligned with many components of the FRST funded research, particularly those related to quantum information.

5.1.1 Current Research Programmes in Photonics

The current capability of the research organisations is based on the FRST funded programmes of research listed in Fig. 2. The scientific content of the programmes in each institution is as follows:

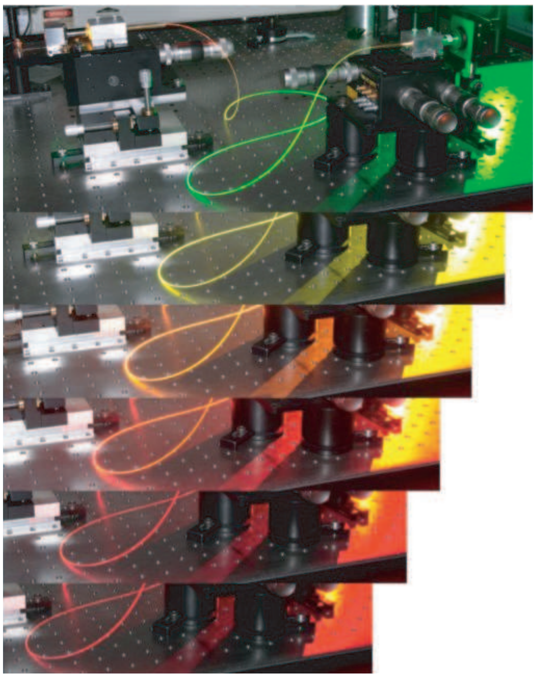
1. ***The University of Otago.*** The *Jack Dodd Centre* in the University of Otago operates an extensive research program covering both the experimental and theoretical aspects of Ultra-Cold Atoms and Photonics. The programme is a mixture of basic research and targeted research. There are four very well equipped laboratories, with advanced equipment with a value of at least $4,000,000. The theoretical programme both underpins the experimental programmes and does independent research in the field of Ultra-Cold Atoms.

2. ***The University of Auckland.*** Although the University of Auckland does not hold a contract from FRST, it is heavily involved in both experimental and theoretical research in photonics and quantum optics, much of it funded through subcontracts as detailed in Fig. 2. In addition, the University of Auckland has recently made a substantial capital investment (nearly $2,000,000) in developing the first laser micromachining facility in New Zealand. This facility (known as the Photon Factory, see Sect. 3.3.1), is already proving to be of great value to New Zealand industry as well as providing a unique national facility for research into ultrafast phenomena in Chemistry and Physics. It also provides a source of tunable infrared light urgently needed by the Defense Technology Agency (DTA) for research into photonics based defense systems.

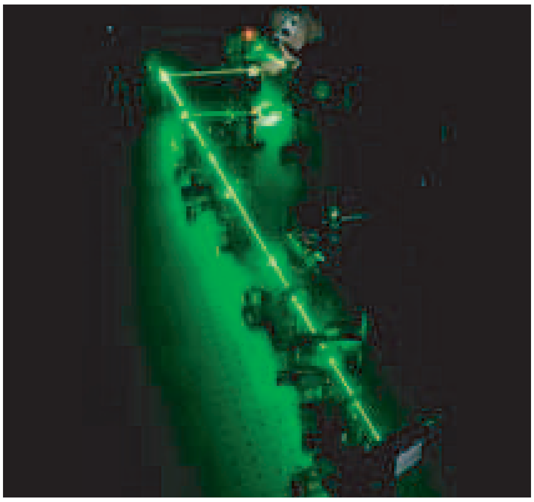
3. ***Industrial Research Ltd.*** Research focuses on four projects, optical signal processing, integrated optical devices, photonic imaging and sensing, nanostructures and composites for radiation detection and imaging.

   Much of the research is done (under subcontracting arrangements) with research partners, namely the University of Otago, the University of Auckland, Victoria University of Wellington, Massey University, as well as Quest Reliability and GNS Science. A significant feature of the research actually within Industrial Research Ltd. itself is concerned with the development of optically active organic materials, with a view to incorporating them into novel all-optical processing devices. A key challenge is to prepare materials with the requisite temporal, photochemical and thermal stabilities.

4. ***Southern Photonics Ltd.*** is a world-leader in optical pulse diagnostic equipment, delivering integrated end-to-end equipment for characterising short pulses used in high speed op-



Researchers at Auckland have created a tunable source of visible light from a a fibre made of pure silica glass. Such a source operates in a wavelength gap where no tunable lasers currently exist, and which can address significant potential applications in the biomedical field. The illustration is a montage of pictures, showing the same device operating at wavelengths ranging from green to red.

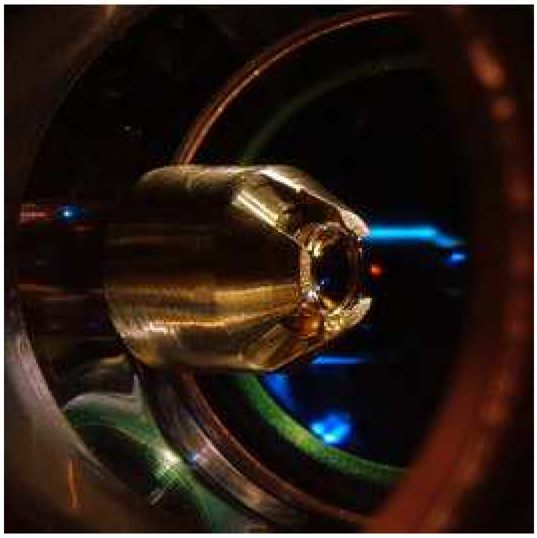


A system in Industrial Research Ltd. measuring the photostability of host-guest films containing amorphous polycarbonate and an organic chromophore using a 5W diode-pumped solid state frequency laser.
www.irl.cri.nz/our-research/advanced-materials/photonics-research

Organization and Contract	Partners	Title	Annual Funding	Total funding / years
Southern Photonics NERF SPHT0801	University of Auckland Kiriama Ltd (Sydney)	Applications of nonlinear fibre optics	$1,370,667	**$5,482,667** 1-Oct-08 to 30-Sep-12
University of Otago NERF UOOX0703	Southern Photonics Photonic Innovations	Quantum Technologies	$1,726,489	**$6,905,955** 1-Oct-07 to 30-Sep-11
Industrial Research Ltd. NERF C08X0702	University of Auckland University of Otago	ICT/Communications Photonics objectives only	$625,000	**$3,750,000** 1-Oct-07 to 30-Sep-13
Industrial Research Ltd. NERF C08X0704	Victoria University	Integrated optical devices	$900,000	**$3,600,000** 1-Oct-07 to 30-Sep-11
Industrial Research Ltd. NERF C08X0807	University of Auckland Southern Photonics Massey University Quest	Photonic Imaging and Sensing	$994,000	**$5,964,000** 1-Oct-08 to 30-Sep-14
University of Otago TRST UOX0901	University of Auckland Industrial Res Ltd	The Lighthouse	$125,000	**$125,000** 1-Oct-09 to 30-Jun-10
Totals			**$5,741,156** ***Per annum***	**$25,827,622** ***Grand total***

Figure 2: Foundation Funded Contracts in Photonics. Funding figures include GST

tical communications systems. In conjunction with the University of Auckland, Southern Photonics Ltd. operates FRST funded research projects on fibre optics, in particular on microstructured plastic fibres, ultra-high repetition rate pulsed Raman lasers, nonlinear effects in photonic crystal fibres, nonlinear propagation in optical fibres, and nonlinear optics.



University of Otago physicists are the first in the world to consistently isolate and capture a single atom, which can be seen in the upper picture. The lower picture shows the atom trapping apparatus, which uses laser light focused with a high quality but inexpensive lens. (This kind of lens is mass produced, for focusing the laser in a DVD player.) A cloud of about 50,000 atoms shows as an orange dot in front of the lens, and it is from this cloud that atoms can be isolated one at a time.

The ability to manipulate individual atoms has the potential for the construction of ultrafast quantum computers—the computers of the future.

5.1.2 The Relationship between Research Organisations and Industry

In the case of universities, the primary functions are education in the widest sense, and research. At the advanced level, education takes place through the medium of research projects. The role of Universities as industrial developers and commercialisers is less well-defined, and there are significant barriers to university researchers in taking up commercial activities.

In the case of Industrial Research Ltd., the current review of the CRIs as a result of the CRI Task Force makes the position less apparent. The CRI task force has made it clear that CRIs must develop strong links with business and with universities, but does not see CRIs as being commercialisers of research, rather it recommends that

> The Government identify technology transfer as a core responsibility for all CRIs and require CRIs to develop, invest in and manage intellectual property with the intent of moving that intellectual property from their balance sheet into the private sector as soon as possible.

Only a small proportion of the research noted in Sect. 5.1.1 has any direct relationship to product development for industry—the main outputs have been scientific papers and capability development.

5.1.3 The Emerging Photonics Sector

There are very considerable resources of expertise, human capital and equipment available within the research teams within the University of Otago, the University of Auckland and Industrial Research Ltd., associated with their programmes of targeted basic research. This research is a valuable resource, and it is now time, especially in the light of new methods of science funding, to build on this resource and expand the research effort to include projects related to industry. It would be expected that industry would provide input into the the design of such research programmes, which would promote the generation of research outputs of increased value to the local economy.

However, this must be done in a way consistent with the core purposes of the research institutions, and should not be seen as supplanting successful programmes of basic research, in some of which New Zealand is world leading.

It is not the role of any of the publicly funded research institutions to become product development laboratories for industry. Industry

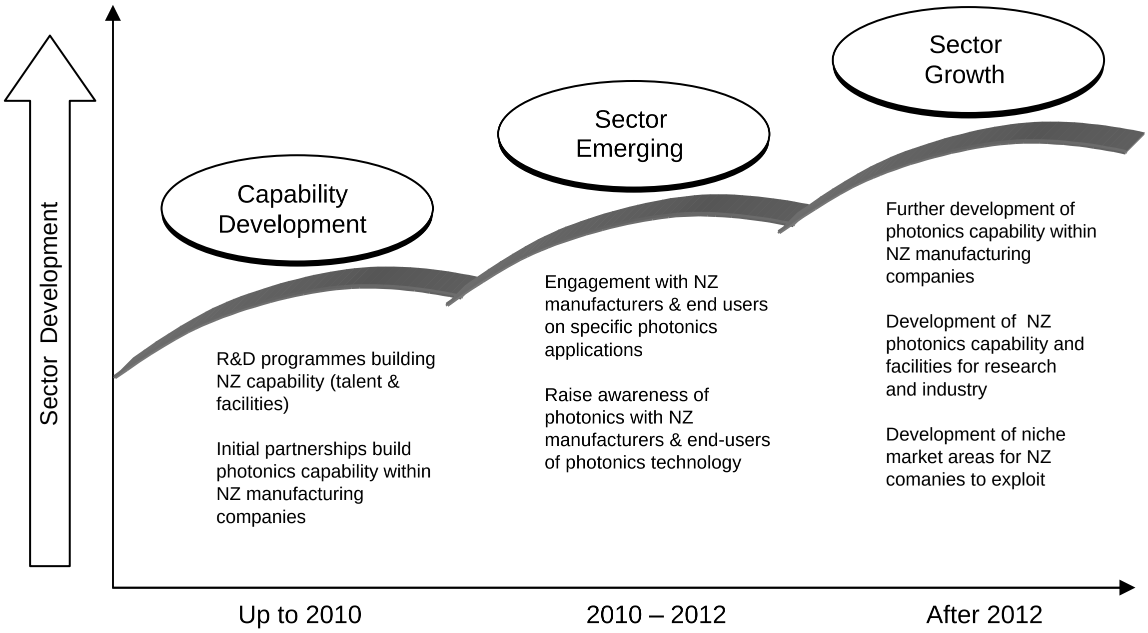


Figure 3: The development of the New Zealand Photonics Sector

tends to want to do this kind of research "in house", thus preserving trade secrets—this often provides more effective protection than patenting.

Rather, the aim must be to engender a mature photonics sector, in which all aspects including basic research, applied research, development of applications, industrial development and manufacture are in contact with each other and benefit either directly or indirectly from the expertise and involvement of the others.

A conceptual view of the development of the photonics sector is given in Fig. 3

Photonic solutions involving lasers are becoming a significant technology in the dairy industry, for example: Laser light can be used to monitor pasture growth and for measurement of milkfat and protein in in-line milk sensor systems; Laser levelling can give a precise even fall from the headrace to the lower end of a paddock, increasing productivity; In the new Edendale dryer, opened recently in Southland, laser-guided vehicles and robots stack bag after bag of the finished product; In plant breeding programmes laser-assisted seed selection is described as being much more efficient than planting lots of plants and walking the rows.
www.dairyexporter.co.nz

5.2 Lighthouse Activities for Development of the Photonics Sector

In the next 18–24 months the Lighthouse will begin to leverage this existing capability in order to support the emerging photonics sector. The activities of the past year have revealed that photonics and optics are indeed quite widely used in industry, but that there is little awareness of the existence of photonics as a well developed technology with broad application to a modern high-tech industry.

Rather, most companies see their optical or photonic devices as one-off or minor components. One objective of the near future will be to increase New Zealand manufacturers' understanding of the potential of photonics solutions in advanced manufacturing processes, and that of embedded photonics technology in high-tech products. A detailed list of activities is shown in Fig. 4

	Objectives	Key Activities	Operational Priorities
1.1	Build a knowledge base of Photonics Sector in NZ	Photonics technology knowledge transfer to industry	Develop a Communication Plan that includes media articles to increase photonics knowledge and build a community of interest in NZ.
1.2	Build a knowledge base of Photonics Sector in NZ: Companies	Engage with companies involved in photonics in NZ and build knowledge of their activities/ products.	Create a Photonics Sector Industry Listing with details of companies and technologies, and make available on Lighthouse website.
1.3	Build a relevant knowledge base for the Photonics Sector in NZ: Research Areas	Provide a framework in which research institutions/companies can interact effectively with each other and with the photonics industry.	UOO, UOA and IRL in conjunction with relevant Crown agencies develop a ***National Photonics Platform.*** This would co-ordinate photonics research programmes and provide improved consulting and research services to industry on the basis of more flexible research funding. It should also have a specific allocation of funding to directly support industry engagement
2.1	Enhance economic outcomes in the Photonics Sector: Build and maintain photonics technology skills base in NZ	Research, Tertiary Education and Industry to work together to build and maintain a pool of highly skilled workers in NZ	The Platform should, in conjunction with industry, develop a *Photonics Capability Plan* to outline the opportunities and gaps in photonics technical skills, and to identify ways of retaining skilled workers in NZ.
2.2	Enhance economic outcomes in the Photonics Sector: Identify new opportunities	Establish relationships with companies wishing to expand the their production or use of high technology products Provide services for identifying funding and appropriate collaborators to develop new opportunities. Engage with industry on commercialisation of outputs from government-funded research	a) Identify opportunities for photonics solutions and provide access to photonics capability that will support initial feasibility work b) Provide access to state of the art equipment and facilities c) Maintain flexibility in Investigator-led research programmes such that the research programmes build capability that is relevant to respond to New Zealand Company interests d) Be able to rapidly respond to industry needs and trends due to flexible a funding system
2.3	Enhance economic outcomes in the Photonics Sector Identify niche market areas to develop	Identify key areas where New Zealand could develop niche photonics expertise and have a substantial impact on the New Zealand economy.	The National Platform should bring together industry, government and researchers to develop a long-term plan to identify and develop niche market areas with high value.

Figure 4: Lighthouse activities for the New Zealand Photonics Sector development

Glossary of Acronyms

CRI	Crown Research Institute
DTA	Defence Technology Agency
DSTO	Defence Science and Technology Organisation (Australia)
ICT	Information and communications technology
LED	Light emitting diode
NZICT	New Zealand Information and Communication Technologies Group Inc.
OCWG	Optical Communications Working Group
SME	Small to medium enterprise
THz	TeraHertz = $1,000,000,000,000\,\mathrm{Hz}$
OCT	Optical coherence tomography
UFB	Ultra-Fast Broadband