ILLUMINATING A WORLD OF OPPORTUNITY

CPC

PHOTONICS IN CANADA

A SURVEY BY THE CANADIAN PHOTONICS CONSORTIUM | JANUARY 2009

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EXECUTIVE SUMMARY

Photonics is a $710 billion global industry that impacts every sector of the economy and the daily life of every Canadian. Yet despite its pervasiveness, this "science of light" has a relatively low profile among our leaders and decision makers.

Canada has approximately 370 photonics companies that employ some 20,000 people and collectively generate close to $4.5 billion annually – approximately 85% from exports. Most of these companies are subsystem- or system-level integrators of photonics components.

The nation's core photonics producer sector is firmly rooted in small and medium enterprises (SMEs) and startups with revenues in the $1 million–$10 million range and up to 50 employees (although there are a handful of larger companies or divisions). These companies range from developers and component manufacturers (e.g., of lasers, fibre optics) to complete photonics-based instruments (cameras, projectors, scanning microscopes).

The industry has migrated away from the telecommunications sector with which it was strongly associated during the high-tech "bubble" of 2000: with the exception of the consumer market, it now addresses most industry sectors. Automobile and aerospace companies, for example, make extensive use of photonics. Canada invests strongly in – and excels at – photonics R&D. However, the research is often untargeted, and translation of the outcomes into commercial success could be improved.

But while Canada creates world-class photonics physicists at the PhD level, a shortage of photonics technicians and application engineers hampers the industry's growth. Most engineers graduating from Canadian universities have little exposure to photonics, impeding the industry's ability to adopt photonics solutions in all sectors. Yet photonics has great potential to be a significant engine for national economic growth.

Given greater public and industry awareness, and greater focus on potential key applications in such sectors as energy and the environment (each with a strong domestic demand for photonics solutions), Canada is well positioned to leverage its expertise by creating companies with global opportunities.

Observers have begun predicting that, while the late 20th century was the age of electronics, the early 21st century will belong to photonics. And yet, despite its ubiquity in a vast array of consumer products, ask most of the beneficiaries if they have ever heard of photonics and how it impacts their lives, and they will probably struggle to answer.

DID YOU KNOW?

Photonics is a $710 billion global industry that impacts every sector of the economy and the daily life of every Canadian.

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CANADA'S PHOTONICS INDUSTRY

PHOTONICS IN CANADA TODAY

Photonics is a $710 billion global industry that impacts every sector of the economy and the daily life of every Canadian. Canada was an early player in photonics and has established a global presence in both research and commercialization.

THE NUMBERS

Today, Canada has approximately 370 photonics companies that employ some 20,000 people and collectively generate close to $4.5 billion annually – approximately 85% from exports. The United States is the dominant market, accounting for 50% of revenues. Europe accounts for about a quarter of all sales. A handful of companies gain their revenues from Asia.

Canada's photonics industry is dominated by small companies. Nearly three-quarters have revenues below $10 million, and close to a quarter have revenues below $1 million (or are pre-revenue). Eighty-five per cent of the 370 companies employ fewer than 100 employees in total; 30% have fewer than 10 employees; while only 7% of companies or divisions have more than 250 employees.

The industry is less dependent on the telecommunications sector with which it was strongly associated during the high-tech "bubble" of 2000. Only 20% of companies now address this sector, though there are a number of successful post-bubble companies that are making an international name. Canadian photonics companies create products and solutions for almost every industry sector: health care and life sciences; energy; environment; security and defence; and industrial processing and monitoring.

The Canadian photonics workforce is highly educated and contains a high proportion of professionals. Roughly 40% of the workforce (over 8,000 employees nationwide) is engaged in industrial photonics research and development. This is due to two factors: first, startup companies typically have a predominance of R&D staff; and second, several large companies maintain R&D facilities in Canada but manufacture elsewhere. Nevertheless, the proportion engaged in manufacturing (33%) is high for the technology sector, implying that many companies still prefer to produce their products in Canada rather than transfer their assembly operations offshore. Furthermore, Canada's role in the value chain remains significant, in large part due to our expertise in system integration.

Though Canada has a strong R&D competence in materials and devices, it has few large indigenous suppliers of photonics devices, with the exception of detectors. Indeed, only a quarter of Canadian companies address this level in the food chain. Canada's strength is its ability to integrate photonics devices and technologies, no matter where they come from, to provide value-add solutions such as networking equipment, optical test equipment, manufacturing inspection equipment, gas analyzers, and solid-state lighting assemblies.

REGIONAL BREAKDOWN

Both Ontario and Quebec have well-established photonics industries that represent the entire food chain with a mix of large companies, startups and SMEs. While there is a continuing strong focus on traditional photonics markets such as defence and telecom, key emerging markets include sensing (Quebec) and life sciences (Ontario). Ontario dominates the country in both revenues (66%) and employees (50%), primarily due to a handful of large companies such as DALSA and ELCAN.

In Western Canada, the economic activity in photonics is more diverse. There are few large companies, no major government facilities specializing in photonics, fewer university groups, and little formal networking of photonics interests. In these provinces, much of the activity takes place in SMEs or startups. Clusters of activity are emerging in the Edmonton (oil and gas exploration) and Vancouver areas (lighting). NRC's newly established National Institute of Nanotechnology (NINT) in Edmonton is a potential source of new companies: NINT already has two photonics startups in its incubator unit. A current proposal to establish a fusion facility in Alberta would create a significant cluster of expertise in high-power lasers. With appropriate nurturing, strong photonics clusters could be created around both Edmonton and Vancouver to address two areas of strategic importance to Canada: energy and the environment.

THE USER SECTOR

The contribution of photonics to Canada's GDP far exceeds the $4.5 billion in revenues contributed by the companies surveyed for this report. Photonics is used in some way in virtually every sector of the economy. For example:

- An estimated 1,000 high-power lasers are used in Canada for cutting and welding in a myriad of applications. The auto industry in Southern Ontario uses lasers on virtually every assembly line. Several companies in Winnipeg use lasers to assemble buses.

- Numerous laser "job shops" cut metals, plastics and fabrics. In the Prairies alone, this survey identified 25 such companies, many of which are engaged in cutting complex structures for use in the oil and gas industry.

- Photonics is extensively used in the food processing industry. In Newfoundland, the fishing industry uses optical techniques to size and shape fish fillets, and a local company provides the hardware.

- The aerospace industry uses lasers extensively to cut and align pieceparts and to provide advanced control and lighting systems in aircraft.

- The forestry and paper industry uses photonics for sizing of logs, disease detection and process control.

OPPORTUNITY FOR GROWTH

Major Canadian wealth-creating industries – such as aerospace, automotive, forestry, and oil and gas suppliers – are increasing users of photonics and understand that if they are to stay competitive, they must embrace photonics techniques wherever they offer advantages in capability, speed, cost, safety and energy savings. This creates a major opportunity for Canada's photonics producers to provide solutions for strong domestic industries and exploit them globally. But to do so effectively requires better engagement between photonics users and domestic producers; increased training of photonics technicians; and better sharing of knowledge and information between the various sectors.

JUST A FEW CANADIAN PHOTONICS FIRSTS

- The solid-state laser range finder
- The TEA CO_2 laser and laser marking
- Fibre Bragg grating
- Charge-coupled devices (CCDs)
- Open-heart surgery using an excimer laser
- Photodynamic drug therapy for cancer treatment
- Commercial 10 Gbit/s optical transport
- The first laser radar (LIDAR) system on the surface of Mars

PHOTONICS COMPANIES IN CANADA

	COMPANIES	EMPLOYEES	REVENUES
Quebec	104	4,750	$600M
Ontario	117	10,200	$3.0B
Prairies	95	2,990	$330M
B.C.	50	2,010	$430M
Atlantic	8	310	$36M
TOTAL	374	20,260	$4.4B

DEFENCE AND SECURITY

PHOTONICS FOR A SAFER WORLD

Infrared night vision systems. Biometric signatures. Laser-guided weaponry. This isn't just the stuff of a best-selling spy novel: today, cutting-edge innovation in photonics is driving a global $30 billion defence and security market that's predicted to keep growing.

The security and defence industry has traditionally been an early adopter of leading-edge photonics technology and has often driven the development of technologies that are now in common usage elsewhere. Compact high-power solid-state lasers are revolutionizing offensive and defensive capabilities. Lightweight fibre-optic gyroscopes are found in missiles and aircraft. Handheld optical devices can "sniff" hazardous agents at levels below toxic thresholds.

Since September 11, 2001, national and even local security has taken on an unprecedented urgency: the agencies responsible for our protection are increasingly looking to the world of photonics to keep all aspects of our lives safe, from our neighbourhoods to public transit systems and meeting places.

Using optical techniques to monitor for hazardous substances or detect perimeter intrusion isn't science fiction anymore; it's almost commonplace today.

SECURING CANADA'S POSITION

Canada has a strong history in the development of laser and electro-optic technologies for defence and security systems, thanks to a strong commitment to research by organizations such as Defence Research and Development Canada. We gave the world charge-coupled detectors, solid-state laser range finders and the TEA CO_2 laser. Several Canadian companies are global players in the sector, while at the same time international defence companies have invested in Canada for our research and development capabilities.

In addition to our research capabilities, Canada has a natural advantage. We share a common security perimeter and enjoy a trading bloc with the world's largest user of defence technologies, accounting for 60% of the worldwide market. As a result, small Canadian technology companies are able to participate in major projects with our U.S. partners and NATO through agreements with DND (Department of National Defence) and Defence Research and Development Canada.

We have built leadership in key technologies that are applicable to defence and security, including communications technologies, remote imaging, visualization, simulation and remote sensing. One of the global leaders in digital imaging for defence applications is a Canadian company with revenues of over $16 million, while another Canadian firm is a major supplier of custom optics to U.S. and global military integrators and defence platforms.

Canada's expertise at photonics integration is also in demand for defence systems, and a number of smaller companies are enjoying niche opportunities in the sector by integrating Canadian technologies.

Canada's prowess in defence photonics is claiming a more peaceful presence in space too. The digital imaging systems on the International Space Station that probe deep into space are Canadian, as is the Light Detection and Ranging (LIDAR) system that found water on Mars.

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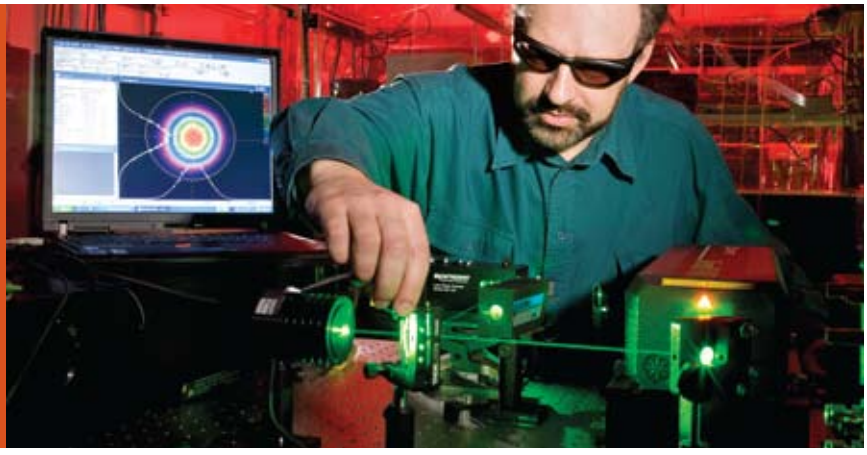

HEALTH AND MEDICAL

PHOTONICS: LIGHTING THE WAY TO A HEALTHIER WORLD

One of the most exciting areas in which photonics plays an ever-increasing role and brings together innovation, commercial opportunity and human good is health care. From the diagnosis and treatment of disease to new cosmetic procedures that improve our quality of life, photonics-based technology is key to supporting today's physicians and surgeons in delivering patient care.

As our global population increases and ages, so grows the opportunity for photonics to make real differences in real lives. Around the world, millions of people have already benefited from laser surgeries that reduce bleeding and speed recovery. For nearly a decade now, laser-based eye surgery has been used to correct vision, and laser-based dentistry is removing the fear and pain of traditional high-speed drills. Advanced imaging techniques applied in the field of genomics are used today in diagnosing disease faster and saving lives.

Within the span of the next generation, we'll be able to monitor our health at home and send information directly to our doctors by combining the power of photonics with the Internet. Perhaps most inspiring is how photonics is helping treat dangerous cancers more effectively and with less trauma through photodynamic therapies that use light-activated drugs to attack malignant cells.

The impact that photonics is having on health care creates a huge commercial opportunity. Estimates place the potential global cost savings of photonics technologies in health care at over $400 billion per year. That in turn translates into a robust market for photonics devices: the Optoelectronics Industry Development Association puts the current worldwide market for medical lasers alone at over $600 million.

CANADA'S HEALTHY OPPORTUNITY

Canada has a history of innovation in health care. In the early '90s, we pioneered the development and commercialization of drugs for photodynamic therapy to treat cancer. Today, Canada is poised to enter a vigorous global health care photonics market with a strong portfolio of new and innovative technologies and applications. Over the past 10 years, Canada has invested considerable money and resources in scientific and academic research, providing a wealth of opportunities. Canada's challenge will be to effectively commercialize these technologies.

With Canada's geography, we have naturally developed core expertise in telecommunications and telemedicine. Now combined with photonics, that expertise is helping lead the world in technologies that can capture and move medical data over long distances quickly, and perform analytical and surgical procedures remotely to improve efficiency and enhance patient care.

We are at the forefront of optical coherence tomography (OCT), a non-invasive and high-resolution way to image tissue. Already used for ophthalmology, OCT promises to be highly valuable for cardiology and cancer treatments. Estimates place the global market for OCT by 2012 at $800 million.

Fluorescence tissue scanning, which looks for genetic biomarkers to detect disease, is another area where Canada has a significant lead. The U.S. market alone for Canadian fluorescence technologies, expected to be a major tool for diagnosing and treating cancers, today includes over 1,000 pathology clinics.

Just these examples illustrate the incredible potential for Canada to capture value from our investment in photo-medical research. Our cluster approach to research enables us to build a critical mass. The prestigious University Health Network, which brings together the resources of three major teaching hospitals in Ontario, conducts revolutionary research into innovative medical technologies, and sets the bar for investment in future medical breakthroughs. Canada is at the forefront of using photonics to create a healthier world.

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Canada is the leader in optical coherence tomography, which promises to be an $800 million global market by 2012.

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REMOTE SENSING AND MEASUREMENT

OPTIMIZING OIL AND GAS EXTRACTION AND DELIVERY

Photonics is the perfect technology for imaging, sensing and measuring in harsh environments such as those common in the oil and gas industry. Photonics can measure physical parameters such as temperature and strain, detect and quantify gases and chemicals, image and send data over long distances. Photonics furthermore requires no electrical signal at the point of measurement, making it very well suited to remote or explosive environments such as oil wells.

The global market for optical measurement and sensing technologies was over $500 million in 2007 and is expected to double by 2010. Applications in the energy sector, including oil and gas, account for over 50% of this value. This plays to a core Canadian strength, and as a result Canada has numerous companies, many based in the West, making exciting advances and commercializing technology in the energy sector. For example, one Montreal company is using fibre-optic sensors to measure temperatures and pressure in the Alberta tar sands. Another is using the technology to remotely monitor corrosion and leakage in pipelines. Numerous companies use laser machining to cut the complex shapes of down-well tubes.

Canadian companies have developed technologies for remote detection and measurement of many hazardous gases. Compact laser-based detection systems can be flown several hundred metres above a gas pipeline to look for leaks. Other companies have developed photonics tools for airborne digital terrain mapping, water depth measurement and water quality assessment.

With a growing energy and environment market, a strong resource-based economy, and government regulations driving monitoring requirements, Canada is well positioned to be a global leader in using photonics for the real-time sensing and measurement of remote environments and facilities.

DID YOU KNOW?

A laser-based device can measure gas concentrations at the top of a chimney from a distance of several hundred metres, or be flown several hundred metres above a pipeline to detect leaks.

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MANUFACTURING

MAKING A WORLD OF GOODS

Lasers are used in some way to manufacture many of the goods produced in the world today, and they play a variety of critical roles – from cutting and welding to heat treatment and marking, and even to measure and monitor manufacturing processes and quality. In fact, the global market for laser-based manufacturing systems is valued at nearly $10 billion worldwide.

Lasers drive bottom-line business results and enable mass customization. Solid-state lasers and fibre lasers reduce complexity, improve waste heat management and slash processing times.

The applications are almost endless. For example, the ability to place indelible information such as human- or machine-read codes has been a major breakthrough for the manufacturing of everything from semiconductors to automobiles to iPods, as it enables manufacturers to effectively track each product throughout the manufacturing lifecycle. Other examples of lasers in action include how laser positioning and welding is a feature of many modern car production lines, and how even the lumber industry uses computer-aided laser measurement to maximize the output from each log.

Canada is primarily an end-user of photonics sources for manufacturing. Approximately 1,000 cutting machines are installed in Canada in manufacturing companies and job shops. While most are in Ontario and Quebec, there are more than 100 in other provinces, used in job shops supplying parts to diverse industries including agricultural machinery and oil and gas.

MEASURING UP

Photonics is also used extensively for measurement and in-process monitoring in industries as diverse as semiconductors, forestry, postal and food. The total market was $12 billion in 2007. Machine vision – and the CCD or CMOS optical sensor that drives it – is an integral part of automation and alone has a global market of $6.7 billion.

Canada maintains a strong position in this technology and is a world leader in several segments of the market. One of the most high-profile Canadian success stories from this market is the high-resolution CCD imagers used in the NASA Mars Exploration Rovers – manufactured in Canada.

Other manufacturing applications include bar-code scanning, fibre-optic and other sensors for both distributed and point measurement of various parameters, patterning, 3D shape acquisition, and 3D prototyping using stereo-lithography.

Although product identification (laser marking) was pioneered in Canada in the 1970s, many other industrial applications were developed by foreign suppliers. Canadian manufacturers must maintain a close watch on developments that can impact their competitiveness and productivity. Currently, the foreign suppliers of this technology are not seen as part of the photonics community. To best serve the needs of industry, both end use and component/subsystem, their involvement is needed.

The U.K., for example, has been proactive in ensuring that manufacturers have access to current laser technology information. In the early 1990s, TWI (a leading institute in welding technology) managed a program called “Make it with Lasers” to encourage knowledge exchange. All the industrial laser manufacturers (local and foreign) lent their support to workshops for various industry sectors. These activities were augmented by AILU (Association of Industrial Laser Users). The end result: a portal was set up with detailed information for non-photonics designers to continue learning: **www.designforlasermanufacture.com**.

CONSUMER

WORKING AND PLAYING WITH PHOTONICS

Photonics is rapidly changing the way we work and play. In our homes, traditional cathode-ray TVs and computer displays are disappearing in a wave of flat high-definition plasma and liquid-crystal screens. We now capture our memories with digital cameras built into cell phones and watch movies in the car on overhead flat-panel displays (FPDs) while we read email on the remarkably clear screens on our PDAs. At home we can now use innovative blue lasers to watch a high-definition movie stored on a single DVD disc that holds four times the amount of data that a conventional DVD can.

These nifty consumer devices, in fact, make up 40% of the total global revenue generated by photonics-enabled devices – and the market is growing at 20% per year with no sign of slowing down. Displays alone are a $100 billion business.

For example, over one billion cell phones were sold last year, and every single one of them was equipped with a flat-panel display screen. The demand for solid-state sensors for the digital cameras in cell phones produced over $4 billion in revenue in 2007. And in that same year, the number of flat-screen TVs surpassed the number of cathode TVs for the first time.

PLAYING TO OUR STRENGTHS

In business, wisdom comes in knowing when and where to compete. Like so many consumer goods, the photonics devices that we all enjoy at work and at home are manufactured in Asia, partly to ensure that they remain affordable. As a result, outside of Asia, few countries in the world have a significant manufacturing presence in the consumer market.

Canada has been successful at identifying several niches within the consumer market where we can have a presence. Several Canadian companies provide sub-assemblies and test-and-measure solutions to consumer goods makers, and in fact, one Canadian company is the world's leading supplier of equipment used in manufacturing FPDs.

Our ability to take advantage of the massive global consumer market today is still limited. However, in the future, Canada's research and development investments may help create the next generation of consumer products.

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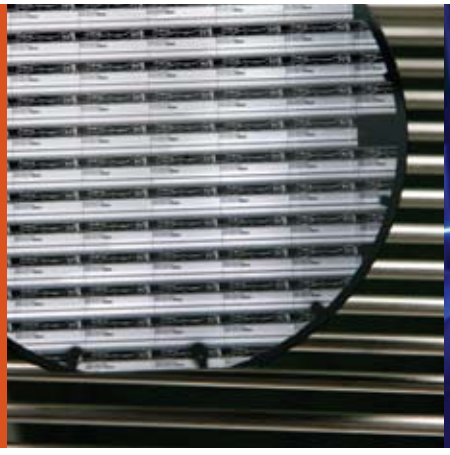

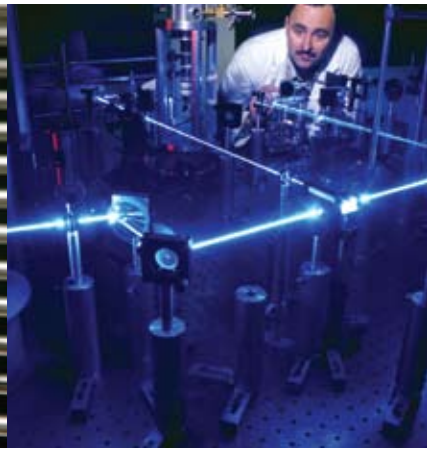

COMMUNICATIONS

COMMUNICATING AT THE SPEED OF LIGHT

The rapid advance of consumer-driven photonics devices is creating a voracious appetite for bandwidth. At home, at work, on the go – we want our YouTube, Facebook, movies, pictures and music when we want them, where we are and right now. The demands of business, medicine, defence and government are also generating vast amounts of digital content. In fact, the more bandwidth we build out, the faster we find ways to use it.

In response, carriers around the world are upgrading infrastructure to feed the growing beast we've created, raising backbone network data rates from 10 to 40 Gb/s and even 100 Gb/s. Cable companies are transitioning to hybrid-fibre and coaxial copper, and telcos are installing fibre to the consumer's front door. At the same time, wireless companies are installing fibre in their backbone networks to ensure that we can continue downloading photos and videos to our wireless devices.

Not surprisingly, the global revenue number for optical networking equipment sales for the last quarter of 2007 achieved a healthy $4.4 billion, with a growth rate of over 20% annually. And the action further down the value chain is heating up. At $4 billion in revenue annually and a growth rate of over 18%, the component and module market is continually pushing innovation to reduce the cost of building and operating optical networks and bringing fibre closer to the consumer.

Yet despite this activity, many companies are struggling to find ways to make profits. Major North American and European optical equipment makers, including Canada's own Nortel, are facing fierce competition from Asia's Huawei. For component makers, the situation is worse. As many as 20 companies share 80% of a very cost-competitive market, and most are turning to Asia to reduce costs. But even then, without massive industry consolidation, they will have a hard fight to become profitable.

KEEPING LEADERSHIP

At the height of the explosive growth of the Internet and telecommunications sector, Canada too was at its height as an optical communications gorilla. Companies like Nortel and JDS Uniphase were market dominators in 2000, and in the same year optical telecommunications startups in Ottawa alone attracted $500 million in investment.

After the dot-com bubble burst, Canada emerged in a strong position, smaller but still a very significant presence. Canada continues to boast over 50 companies supplying the optical communications sector, several of them industry leaders.

It's a Canadian company that solved the problem of undersea switching of optical cables and continues today to lead that niche market. It's a Canadian company that is winning global carrier and enterprise customers for its flexible network management equipment. And an Ottawa-based company has raised over $75 million and is winning contracts in the competitive Asian market for integrated subsystems that are critical to extending fibre to the home. Yet another Canadian company is looking even further ahead with single-chip solutions that will reduce costs further.

As always, it's research and development where Canada shines. Along with private sector labs, the National Research Council and the Communications Research Centre have spawned an intellectual and engineering base in Ottawa and elsewhere in Canada that will be the foundation of a strong sector for years to come. That's why major global players continue to locate their labs here. And that foundation will help Canada take advantage of a number of exciting opportunities, such as the continued low cost of deploying fibre, our expertise in providing broadband to remote areas, and our ability to retain our top talent. Canada will continue to drive the future of optical communications.

Even today, many people still wrongly associate photonics with only the communications sector.

Canada boasts over 50 companies supplying the optical communications sector.

Canada's private sector labs, the National Research Council and the Communications Research Centre have spawned an intellectual and engineering base in Canada that will be the foundation of a strong sector for years to come.

GREEN ENERGY

ALTERNATIVE ENERGIES

Around the world, increasingly green-minded governments, businesses and consumers are looking for ways to significantly reduce energy consumption and CO_2 emissions. As opinions and policies change about energy as a consumable resource, photonics is becoming a powerful tool in helping create a greener world.

LIGHTING THE WAY TO A GREENER, SAFER WORLD

With about 20% of the world's electrical energy used just for lighting, the need to use photonics, the science of light, to fight climate change is compelling. The U.S. Department of Energy is targeting a 50% reduction in energy use for lighting by 2025, a goal that will see savings of $12 billion and 6.5 million metric tons of carbon per year.

Worldwide, the market for lamps alone exceeds $20 billion per year and represents an enormous market for new, less polluting lighting technologies.

Today's fluorescent bulbs are a partial solution to the energy-inefficient incandescent light bulb but suffer from problematic end-of-life issues. In the near future we will see these replaced with photonic innovations like high-brightness light-emitting diodes (HB-LEDs) and organic light-emitting diodes (OLEDs). HB-LEDs are already cutting the energy needs of high-impact lighting used in signage, architecture and security. The current market for such devices is over $5 billion annually. OLEDs offer a sheet-like flexible lighting source that will have numerous novel lighting and display opportunities.

Low-weight, low-energy innovations are perfect for lighting on the move. Modern trucks and cars now use HB-LEDs in rear and brake lights and headlights; in just a few short years, almost all truck and cars on the road with be equipped with LEDs both outside and inside. The change will happen fast – today, LEDs make up 60% of automobile high-level rear lights and almost 20% of rear and turn lights. As we drive down the road, we encounter photonics again, as traffic signals today are increasingly equipped with LEDs. In the air, planes use HB-LEDs for cabin lighting to take advantage of lower power consumption and the ability to change the cabin "mood" during a flight.

CANADA: THE POWER OF VALUE-ADD

Despite the large investments made by other countries such as the United States, Taiwan and Germany in LED technologies, Canada has a role to play. Several Canadian universities have built world-class expertise in developing custom LEDs, and the Canadian Photonics Fabrication Centre has the equipment needed to produce custom LEDs from epitaxy wafers. An Ottawa-based company has attracted significant investment as it develops new sources based on light emission in silicon.

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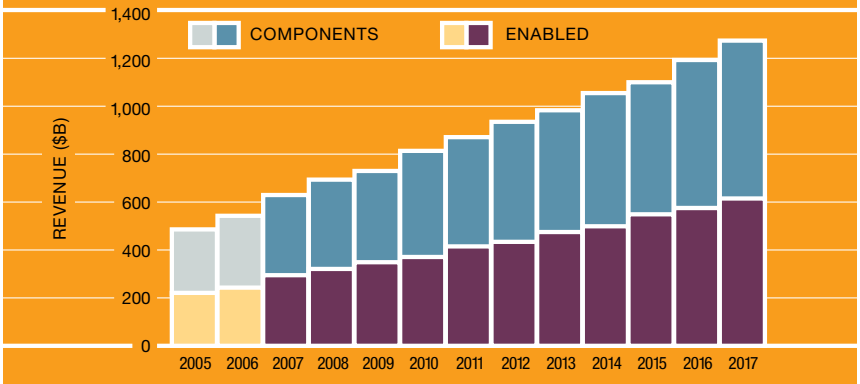
GLOBAL PHOTONICS COMPONENTS AND PRODUCTS MARKET



(from the Optoelectronics Industry Development Association)

But it is Canada's strength as a system integrator where we really add value. Canadian companies are developing LED-based lighting solutions for specific applications such as parking lot and street lighting, remote off-grid lighting, advertising needs and show lighting. A Vancouver-based company combines LED lighting with solar power to be a world leader in the supply of stand-alone lighting solutions for marine, defence and recreational applications. A startup in Edmonton is developing office lighting systems based on HB-LEDs. One of the world's largest lighting companies, Philips, has recognized Canada's capabilities and has already acquired two Canadian companies as it builds a vertically integrated value chain.

CONVERTING SUNLIGHT TO USABLE ENERGY

The sun is the ultimate clean, renewable energy source, and photovoltaics, the direct conversion of solar power into electricity, provides an exciting market opportunity for clean energy. Globally, the photovoltaics market was worth $15 billion in 2007, with a 25% annual growth rate. Venture capitalists are lining up and have already invested over $500 million in companies developing new technologies and techniques for harnessing the power of the sun. Not coincidentally, Japan and Europe lead in the photovoltaics market and boast governments that have the strongest incentives and laws to encourage consumers to adopt green energy generation alternatives.

CANADA'S ROLE

One of the challenges to developing a mass photovoltaics market is Canada's gain: the need for silicon.

Current photovoltaics use silicon solar cells. Used extensively in semiconductors as well, silicon is in demand, with over 50% of silicon used today for solar cells. This is creating supply shortages and consequent price pressures. One of Canada's great strengths – the mining and processing of raw materials – is being applied to the production of solar-grade silicon. At least two Canadian companies have processes that offer an economic advantage; one is already winning major contracts from solar cell producers. Another venture-backed company has developed a process to reduce cost and increase safety during solar cell manufacture.

Silicon solar cells are also relatively inefficient. This has stimulated Canadian companies and universities to look at alternatives. Already an Ottawa-based startup has demonstrated world-beating efficiencies in gallium arsenide nano-structures. Others are working on polymers and nanotechnologies.

Canada's strength in system integration is being used to build total solar power solutions for on- and off-grid applications. An Ottawa-based company has developed a tracking system that maximizes electrical conversion from solar cell arrays and combines it with solar water heating. Its systems are installed at several public buildings and a major supermarket. A Vancouver-based company is operating a solar array on Prince Edward Island.

Further in the future, the Laser Fusion Project, which is being discussed for Alberta, would see Canada take a leading position in renewable energy and would help build a significant photonics strength in Western Canada.

Canadian companies are developing LED-based lighting solutions for specific applications such as parking lot and street lighting, remote off-grid lighting, advertising needs and show lighting.

Globally, the photovoltaics market was worth $15 billion in 2007, with a 25% annual growth rate.

Venture capitalists are lining up behind photovoltaics and have already invested over $500 million in companies developing new technologies and techniques for harnessing the power of the sun.

RESEARCH INFRASTRUCTURE

CANADIAN PHOTONICS RESEARCH AND DEVELOPMENT INITIATIVES

Canada has a long history of investment in photonics and hosts a number of internationally acclaimed institutions. A focus on the commercialization of technology has spawned many successful photonics companies.

GOVERNMENT RESEARCH FACILITIES

National Research Council (NRC)

NRC is a national organization with over 4,000 employees, 19 institutes and a budget of over $750 million. An estimated $50 million of this is related to the development or application of photonics technologies, much of it spent at the Institute for Microstructural Sciences (IMS) in Ottawa, which conducts world-renowned research in optical materials and devices. The institute has been responsible for world-leading publications and patents and has spun off a number of photonics companies. Several are located within NRC's Industry Partnership Facility (NRC-IPF), an incubator unit for startup companies.

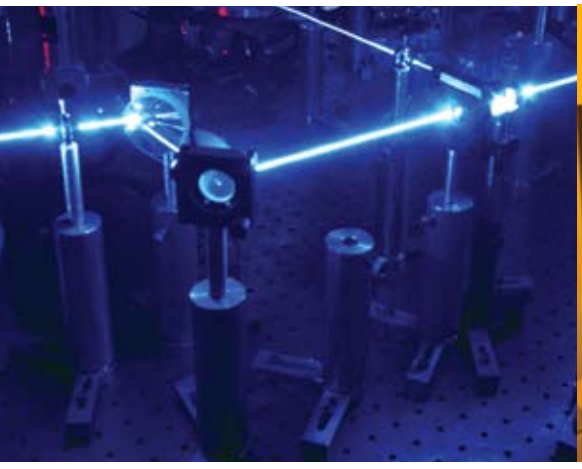
The Steacie Institute for Molecular Sciences (SIMS) in Ottawa has a world-class team looking at femto-second and atto-second laser pulses and their interaction with matter.

In 2001, NRC established the National Institute for Nanotechnology (NINT) on the campus of the University of Alberta in Edmonton. There is a strong photonics capability within the institute. The Innovation Centre at NINT contains 15 laboratory and office spaces for rent by startups. Several small photonics companies are operating out of this facility.

To drive commercialization, NRC administers the Industrial Research Assistance Program (IRAP), under which Canadian companies with fewer than 500 employees can receive up to 50% support for research and development up to $500,000. IRAP supports several hundred companies annually with a budget of close to $100 million. Photonics companies received $3.5 million through IRAP in 2007.

Canadian Photonics Fabrication Centre (CPFC)

CPFC is a state-of-the-art photonics fabrication facility that opened in 2005 with a $30 million grant from the federal government and $13 million from the Ontario government. CPFC bridges the gap between innovation and product commercialization, assisting SMEs in bringing new products to market. The centre is staffed by professionals with many years of industrial experience and provides opto-electronics foundry services accessible through standard foundry-type agreements. Since its inception, CPFC has been a clear success in stimulating the transfer of technology and "de-risking" investment for its clients. In early 2008, the centre received a further $22.3 million in funding from the federal government.



INO

Founded in 1988, INO is the largest optics research centre in Canada, and one of the most prominent in North America. INO works closely with companies in all sectors to develop innovative custom solutions using optic and photonics technologies by offering services from design to prototyping to small-volume production. It currently employs 210 technical staff, with plans to double in size by 2011. Based in Quebec City, INO receives funding from the federal and Quebec governments, with commitments of more than $80 million over the next five years. INO has been extremely successful in generating and transferring intellectual property, with a portfolio of close to 100 patents, 20 spinoff companies and over 30 technology transfers.

Canadian Light Source (CLS)

Based at the University of Saskatchewan in Saskatoon, CLS is a synchrotron-based source of high-intensity closely focused X-ray, UV and infrared radiation. Established in 2004, CLS's mission is to keep Canada at the front of synchrotron radiation and provide a research tool into the structure and property of materials.

Advanced Laser Light Source (ALLS)

ALLS is a joint venture between Canada, France, Austria, Sweden, Germany, Italy, Greece and Japan located at the Institut national de la recherche scientifique in Varennes, Quebec. As one of only two such facilities in the world, ALLS is a femto-second laser source that enables the observation of materials and tissues on a molecular timescale. The Canadian Foundation for Innovation provided $21 million to the facility in 2004.

Defence Research and Development Canada (DRDC)

DRDC, an agency of the Department of National Defence (DND), responds to the scientific and technological needs of the Canadian Forces, DND, and Canada as a whole. Approximately one-third of its scientific program is directed at the general area of optronics, of which photonics is an integral part. DRDC has a strong expertise in lasers, and was responsible for the development of the TEA CO_2 laser in the late 1960s. Today it is a leader in remote sensing, LIDAR systems, airborne and space surveillance systems, EO/IR active and passive missile seekers, active and passive imaging, and data exploitation such as hyperspectral image analysis.

ACADEMIC PHOTONICS RESEARCH IN CANADA

Over 20 universities have discrete photonics groups or centres at the PhD level. Many are internationally renowned.

Several national organizations support this effort, including:

- The Natural Sciences and Engineering Research Council (NSERC) provides research grants in photonics and optics totalling $18 million annually and funds over 30 Canada Research Chairs in photonics-related topics.
- The Canadian Institutes of Health Research (CIHR) invests over $5 million in photonics-based health care research.
- With an annual budget of approximately $4 million, and industry leverage of another $1 million to $2 million, CIPI (Canadian Institute for Photonic Innovations) brings together researchers and public sector and industrial partners in a national network for photonics research. CIPI funds 15 research projects at 20 universities, involving 90 researchers and 300 graduate students. Fifteen projects are supported under the Technology Exchange and Networking program (TEN) and the IPA program (Innovative Photonic Applications). Almost two-thirds of the funds for these projects come from industry partners as cash and in-kind contributions.

- CMC Microsystems was launched in 1984 as a government, university and industry joint venture to develop and deliver a national research infrastructure to enable researchers and developers to design, manufacture and test microsystems concepts for future applications in many industrial sectors. CMC supports projects in over 40 universities. Photonics is a core pillar of CMC's program, and the organization works closely with the Canadian Photonics Fabrication Centre (CPFC) to provide foundry services for university researchers.
- The Ontario government has been an active funder of photonics research since the 1989 formation of the Ontario Laser and Lightwave Research Centre, one of the original Ontario Centres of Excellence. Now the Centre for Photonics of Ontario Centres of Excellence (OCE), it manages a typical investment of about $3 million annually, which is more than doubled by contributions from industry. OCE places a strong emphasis on technology transfer by collaborative R&D between universities and companies. Several successful Ontario-based photonics companies owe their existence to early support from OCE.
- In Quebec, the Fonds québécois de la recherche sur la nature et les technologies (FQRNT) contributes about $2 million annually to university research in photonics and nanotechnologies.

Canada spends about $140 million annually of federal and provincial government money on photonics-related research with a focus on commercialization initiatives. Beneficiaries include universities and government laboratories, with some support for individual company R&D.

MAJOR PUBLIC SOURCES OF FUNDING FOR PHOTONICS RESEARCH IN CANADA

INSTITUTION	ANNUAL PHOTONICS-RELATED FUNDING ($M)
National Research Council (NRC)	50
Defence Research and Development Canada (DRDC)	20
Natural Sciences and Engineering Research Council (NSERC)	18
Institut national d'optique (INO)	15
Canadian Light Source (CLS)	14
Canadian Institutes of Health Research (CIHR)	5.5
Canadian Institute for Photonic Innovations (CIPI)	4
Industrial Research Assistance Program (IRAP)	3.5
Ontario Centres of Excellence (OCE)	3
Fonds québécois de la recherche sur la nature et les technologies (FQRNT)	2
CMC Microsystems	1
TOTAL	**136**

EDUCATION AND TRAINING

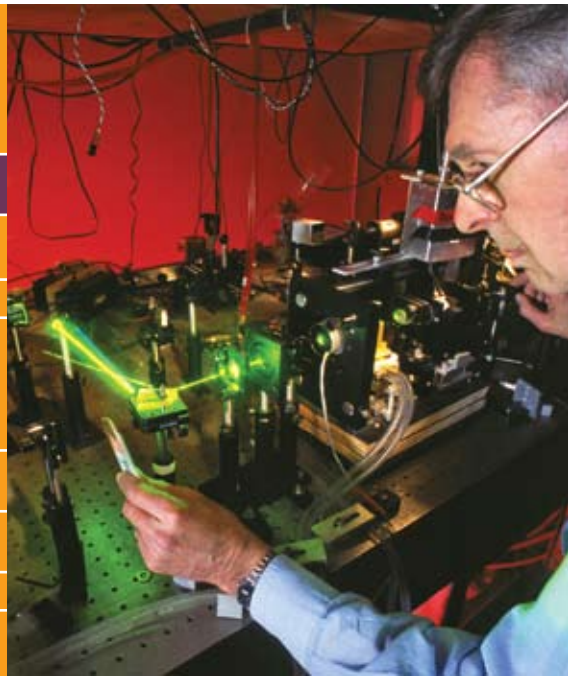
EDUCATION AND TRAINING

Through its investment in research, Canada generates a large number of highly qualified photonics and optical scientists. Like many countries, however, we need to increase training at the graduate and technician level. Many universities offer some training at the bachelor's and master's level through electives within engineering and physics courses. Six offer a specialization in optics or photonics.

The lack of trained photonics engineers and technicians is an issue that is not unique to Canada. In 2001, Ontario Centres of Excellence (OCE) helped establish the Ontario Photonics Education and Training Association (OPETA) to promote photonics education and awareness and to co-ordinate activities between the universities and colleges in the province. OPETA has been successful in attracting photonics professionals to contribute to courses and in persuading companies to donate equipment to colleges. OPETA helped launch undergraduate and diploma programs at two colleges in the province.

UNIVERSITY AND COLLEGE PHOTONICS PROGRAMS IN CANADA

INSTITUTION	COURSE	LENGTH (YEARS)	QUALIFICATION
Algonquin College	Photonics	3 4	Diploma Bachelor's
Laval University	Biophotonics	2	Master's
Niagara College + Brock College	Photonics Engineering Technician Photonics Engineering Technologist Graduate Certificate in Lasers	2 3 1	Diploma Diploma Bachelor's
McMaster University	Applied Engineering (Photonics)	4	Bachelor's
University of Waterloo	Education for Photonics Professionals	2+	Certificate
Wilfrid Laurier University	Photonics	4	Bachelor's



CONCLUSIONS AND RECOMMENDATIONS

Photonics offers a rapidly emerging toolbox of technologies that are pervading all aspects of society and impacting all of Canada's core industrial sectors.

Canada has an established photonics sector that contributes to the global capability base and increasingly adds value by integrating globally available technologies with system and user applications. The sector has a number of globally competitive strengths; by focusing on key opportunities, it can play an even bigger role in the Canadian economy.

The core of Canada's photonics producer sector is firmly rooted in SMEs and startups with revenues in the $1 million–$10 million range and – at most – 50 employees. These small companies are often underfunded, and are frequently disadvantaged when facing their U.S. competitors, who have access to the Small Business Innovation Research (SBIR) program.

In Ontario and Quebec, where clusters have been encouraged, the distribution of economic activity about this core SME mass shows a balance indicative of healthy growth potential (i.e., a strong startup base, together with migration of SMEs into larger entities). In other parts of the country, where clusters do not exist, this distribution of economic activity is more scattered, and the comparative size of photonics-related activity is significantly diminished.

Canadian photonics is already a multibillion-dollar enterprise with a high contribution to exports. However, Canada's photonics export growth lags behind that of market demand, suggesting that we may be losing ground to our international peers. There are some unique opportunities – such as in the energy and environment sectors – where there is a strong domestic demand for photonics solutions that can be leveraged to create companies with global opportunities.

Canada excels in photonics at the R&D level. However, with the exception of NRC, CPFC, INO and a few universities, our success in converting this into economic activity to the fullest extent is limited, indicating a potential weakness in our business infrastructure.

While Canada creates good photonics physicists at the PhD level, we are not producing enough photonics technicians and applications engineers. The average engineer graduating from a Canadian university has insufficient exposure to photonics, which is a barrier to companies that wish to put photonics in subsystem- and system-level products.

Photonics has great potential to be a significant engine for national economic growth. However, at the strategic level, it is not yet truly recognized as an industrial sector. This limits its visibility at the highest levels of business and government, which may not be in the best national interest. Photonics sits firmly on the global stage. To be successful, Canada's photonics community must have a global perspective, both in expanding its international presence, and in ensuring that Canada's own domestic environment remains open to – and benefits from – the fullest participation of foreign photonics practitioners and centres of excellence.

RECOMMENDATIONS

1. Engage the User Community

The photonics producer community should engage more strongly with the user community to develop solutions that provide leadership to key Canadian industries and potential export opportunities. (The Innovative Photonics Application [IPA] program introduced by CIPI could be a suitable model.) Representatives of the key economic sectors should have a voice in bodies such as the Canadian Photonics Consortium (CPC). Canada should also encourage foreign manufacturers of laser systems used in manufacturing to participate in the photonics community in Canada. This will ensure that our manufacturers and suppliers have an informed view of photonics capabilities, open up opportunities for local system integrators, and apply our process knowledge more effectively.

2. Facilitate Knowledge Exchange

A common theme emerging from the workshops and interviews used to compile this study was a thirst for information about photonics and its applications. We recommend setting up information portals, similar to those of the U.K. Knowledge Transfer Networks (KTNs), in strategic application areas of photonics, such as solar energy. CPC, regional photonics clusters, and organizations such as CIPI should consider becoming the delivery vehicle for such information gateways.

3. Improve Education and Awareness

The level of photonics education and awareness in Canada is inadequate for meeting the future demands of photonics users. We recommend that CPC launch a photonics awareness initiative to attract students to train in the subject and overcome the lingering negativity from the collapse of the telecom bubble. Photonics should become a core part of all undergraduate engineering courses, and there should be an increase in the number of photonics technician courses at colleges (similar to those offered in Ontario). Educators and communicators should be engaged to popularize the photonics world around us to the general public.

4. Increase Commercialization of Canadian Technology

Despite the high investment in photonics R&D, technology flow and transfer between the academic and industrial sectors is inadequate. (This is a phenomenon that is not unique to the photonics sector.) We recommend establishing inter-agency programs that use alternative models for financing and managing technology transfer, and that encourage stronger participation and leadership from industrial partners. One proven model is that used by the Seventh Framework in the European Union. We also recommend that other agencies consider direct funding of small companies, much as the SBIR program does in the United States.

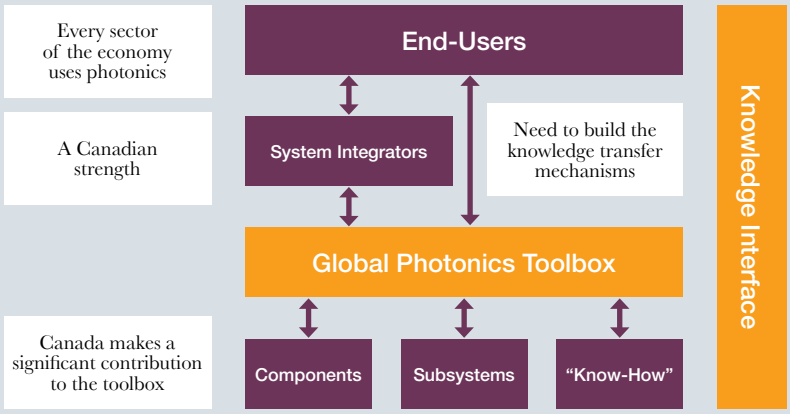
5. Focus R&D on Strategic Sectors

Countries that have deliberately focused investment in key areas of photonics (such as Germany and the United Kingdom) have been remarkably successful in building globally competitive industries and attracting inward investment. Canada's investment in photonics is broad-brush and relatively unfocused. We recommend establishing a photonics strategy group that includes industry and academics. Their role: to focus the investment on a few key sectors that are judged to be of global significance in the next 10 years and where Canada has the photonics skills to make a difference.

6. Expand the Cluster Model

Experience in Ontario and Quebec has demonstrated that the presence of strong cluster activity encourages the incubation and development of a balanced distribution of photonics companies. There are a growing number of photonics producers and users in Western Canada, but they are very loosely organized and lack the benefits of the strong clusters found in Ontario and Quebec. CPC should work with provincial and regional governments to catalyze the formation of clusters in Alberta and British Columbia.

THE PHOTONICS TOOLBOX



Canadian photonics is already a multibillion-dollar enterprise with a high contribution to exports.

Photonics has great potential to be a significant engine for national economic growth.

COMPANY PROFILES

BOREAL LASER

www.boreal-laser.com

Since April 1993, Boreal Laser has concentrated on the development of laser-based gas detectors featuring the use of telecommunications diode lasers, fibre optics, photodetectors and related technology. Boreal Laser's offering, the GasFinder, has grown into a family of high-precision industrial monitoring solutions for any scale of operation. Laser-based gas detectors are now being used in a wide variety of applications for process and quality monitoring, and safety and environmental compliance. The Boreal GasFinder is used in more than 35 countries worldwide, with customers selecting the technology based on the fact that photonics solutions are more reliable and less expensive than alternative technologies. Boreal Laser is based in Spruce Grove, Alberta, and is privately held.

BTI SYSTEMS

www.btisystems.com

BTI Systems designs and develops packet optical systems for the seamless transportation of data, voice and video services over fibre networks. The company is built on a solid foundation of visionary leadership, a world-class engineering team, and a commitment to delivering cutting-edge, environmentally friendly intelligent networking solutions. Founded in 2000, BTI has established business in the U.S., Europe and Asia with key strategic partnerships serving hundreds of service providers and enterprise customers. BTI's vision is to continuing pushing the boundaries of intelligent edge networking for next-generation high-definition video networks, 4G wireless backhaul, and Ethernet services to deliver high-return, profitable service solutions. Ottawa-based BTI is privately held and venture capital funded.

CARMANAH TECHNOLOGIES CORPORATION

www.carmanah.com

Carmanah Technologies Corporation designs and manufactures solar-powered LED lights and solar-electric power systems. Carmanah, one of the most trusted names in solar technology, has earned a reputation for delivering strong and effective products for industrial applications worldwide. The company's range of products includes solar-powered beacons for marine, aviation and defence applications; solar-powered area lighting for recreational, commercial and industrial applications; stand-alone solar-electric power systems for mobile, roadway and remote applications; and large-scale photovoltaics power systems (grid-tie and off-grid) for commercial, industrial and institutional applications. Industry proven to perform reliably in some of the world's harshest environments, Carmanah's solar-powered LED lights and power systems provide a versatile, dependable and cost-effective energy alternative. The company is based in Victoria and is publicly traded with common shares on the Toronto (CMH) and Frankfurt stock exchanges (QCX).

DALSA

www.dalsa.com

DALSA was founded in 1980 by imaging pioneer Dr. Savvas Chamberlain, a former professor in electrical engineering at the University of Waterloo with a focus on charge-coupled device (CCD) image sensors. Since its inception, DALSA has grown into an industry leader in digital imaging and semiconductor technology, with more than 1,000 employees worldwide and revenues of more than $180 million. The company's products are vital components in equipment for the manufacturing sector, including semiconductor foundries, automated systems for manufacturing electronic equipment and boards, digital X-ray equipment, DNA-based laboratory test equipment, and many other industrial applications. Headquartered in Waterloo, Ontario, DALSA has research and development and manufacturing operations in Canada, the U.S., and the Netherlands, as well as offices in North America, Germany, Japan and China, which support an international distribution channel serving more than 40 countries. The company is publicly traded on the Toronto Stock Exchange (DSA).

EXFO

www.exfo.com

Founded in 1985, EXFO is a leading provider of test and monitoring solutions for network service providers and equipment manufacturers in the global telecommunications industry. The company's Telecom Division offers a wide range of innovative solutions extending across the full technology lifecycle – from design to technology deployment and service assurance – and covering all layers on a network infrastructure to enable triple-play services and next-generation, converged IP networking. The Life Sciences and Industrial Division offers solutions in medical device and opto-electronics assembly, fluorescence microscopy and other life science sectors. The Quebec City-based company is publicly traded on NASDAQ (EXFO) and the Toronto Stock Exchange (EXF).

IRIDIAN SPECTRAL TECHNOLOGIES

www.iridian.ca

Iridian provides optical solutions for customers using its highly advanced proprietary thin film filter technology. The company manufactures a wide range of high-quality, competitively priced telecommunications, spectroscopy, laser and biomedical filters, as well as large-diameter (>150 mm) optics custom thin filters for other applications. Iridian was founded in 1998 and continues to invest in ongoing research and development to deliver high-value, advanced technology purchased by customers worldwide. The company's proprietary design and deposition process control software, experienced design staff, and highly automated optical characterization and filter processing technology ensure that the company has a competitive advantage in the cost-effective manufacture of high-performance and consistently high-quality thin film optical components. Iridian is based in Ottawa and is privately held.

MPB COMMUNICATIONS INC.

www.mpbc.ca

Founded in 1977, MPB is one of Canada's early champions of photonics excellence. The company played a key role, in the development of the Undersea Branching Multiplexer, in the multinational effort that resulted in the world's first undersea fibre-optic communications systems in 1987. Since that time, MPB has continued to be one of the leading companies in this market space, and has also built a reputation in the development and supply of complete, repeaterless optical communications links using Super Raman amplification. MPB's focus on photonics excellence and a deep knowledge of fibre laser has led the company into the medical and industrial (micro-machining) sectors. The company does business on a global basis, exporting 95% of its products and systems. MPB is based in Montreal.

OPTECH

www.optech.ca

Optech Incorporated was founded in 1974 by Dr. Allan Carswell as a spinoff from his research in the Physics Department of York University to develop commercial systems based on LIDAR technology. The company has grown to be the world leader in the development, manufacture and support of advanced laser-based survey instruments. The company is based in Vaughan, Ontario, and has over 200 employees in Canada. Optech's U.S. subsidiary provides LIDAR instrumentation for airborne terrestrial mapping, airborne laser bathymetry, 3D laser imaging, industrial process control, and a variety of space-qualified orbital and planetary applications. Optech, in collaboration with MDA Space Systems, has provided the first LIDAR on the surface of Mars as part of the meteorological station MET developed by the Canadian Space Agency for NASA's 2007 Mars mission, Phoenix. The company is privately held.

SERVO-ROBOT INC.

www.servorobot.com

Servo-Robot Inc. (SRI) has established itself as a global leader in high-performance 3D laser vision systems and laser cameras for welding, robotic and automatic manufacturing. The company was founded in 1983, and since then has pioneered unique and novel laser-based industrial robotics solutions. Based in Saint-Bruno, Quebec, the privately held company exports its solutions globally and has established subsidiaries in Japan, the U.S., Korea and China. With more than 100 employees, Servo-Robot serves the automotive, aerospace, shipbuilding, rail construction and energy sectors.

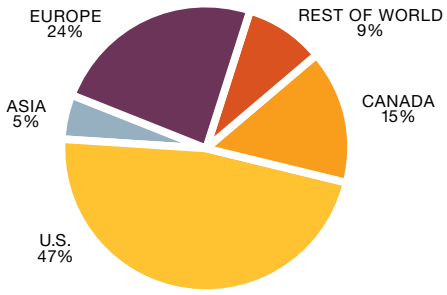
WEGU-DEVICE INC.

www.wegudevice.com

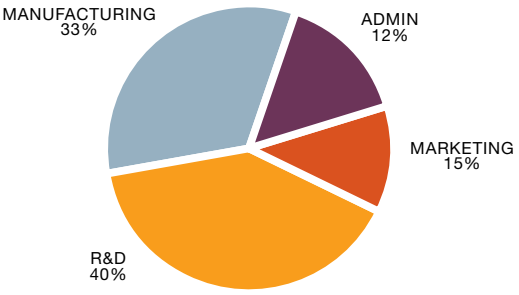
Wegu-Device Inc. (WDI) was founded in 2005 when a production equipment company closed its Canadian operations. The company's established development team formed WDI and worked together to develop a digital, laser-based autofocus sensor required by LCD makers. Since its founding, the company has built itself an international reputation in providing solution for the LCD market and is expanding its offering to the semiconductor, biotech, solar panels and automated optical inspection markets. At customer request, WDI offers a wide range of industrial microscopes and sensors that are used worldwide. The company is focused on developing unique, leading-edge components for large, fast-growing industries and on partnering with knowledgeable agents and OEM partners. The company is headquartered in Toronto and is privately held.

CANADA'S PHOTONICS INDUSTRY AT A GLANCE

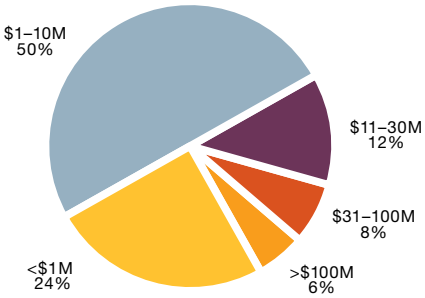
DISTRIBUTION OF SALES FOR PHOTONICS COMPANIES IN CANADA



DISTRIBUTION OF EMPLOYEES BY FUNCTION

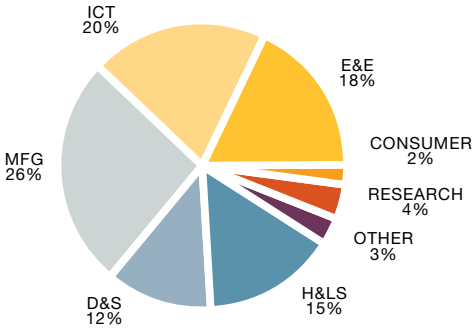


DISTRIBUTION OF COMPANIES BY REVENUE

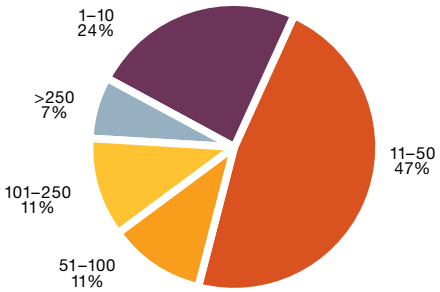


BREAKDOWN OF MARKETS SERVED

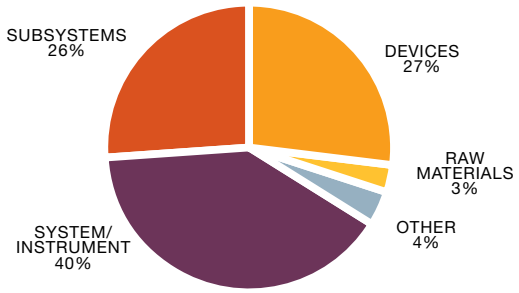
(NOTE: SOME COMPANIES ADDRESS MORE THAN ONE SECTOR)



SIZE OF PHOTONICS COMPANIES BY NUMBER OF EMPLOYEES



DISTRIBUTION OF COMPANIES BY END PRODUCT



PHOTONICS COMPANIES IN CANADA

	COMPANIES	EMPLOYEES	REVENUES
Quebec	104	4,750	$600M
Ontario	117	10,200	$3.0B
Prairies	95	2,990	$330M
B.C.	50	2,010	$430M
Atlantic	8	310	$36M
TOTAL	**374**	**20,260**	**$4.4B**