ICIP
CIPI

Canadian Institute for Photonic Innovations (CIPI)

1999
2012

Final Report

RCE NCE

Content

Host University

UNIVERSITÉ LAVAL

The CIPI network began in 1999 with its first NCE phase by engaging Canadian researchers together with industry in a broad spectrum of initial research projects. In 2002, the CIPI research program was focused into three main thrusts organized around end applications: Materials and Devices, Information and Telecommunications, and Health, Environment and Security. Furthermore, a new program called Technology Exploitation and Networking (TEN) was created, with the objective of strengthening industry involvement and accelerating the exploitation of the newly developed technologies. At the same time, a student network in photonics, CIPI-S, was created, which has been an excellent vehicle for the students to organize training workshops and exchanges, complementing their technical training and improving their employment skills.

CIPI activities during its second funding phase, starting in 2005, were focused on the transfer of technology and knowhow to Canadian industry through three thrusts: Biophotonics, Frontier and Applied Photonics and Information and Telecommunications. In 2006, the CIPI Board created the Innovative Photonic Application program which involved an end-user company, a photonic company and academic researchers with the goal of solving specific problems of importance to the end-user community through the development of new photonic technologies.

The impact of CIPI is very significant. CIPI researchers involved in high intensity lasers prepared a CFI proposal which resulted in the creation of the Advanced Laser Light Source (ALLS), a laboratory with multiple femtosecond light sources at INRS-EMT in Varennes Quebec, which is now being used by Canadian researchers and the industry. The CIPI research projects also resulted in the creation of fourteen new companies of which 8 are still active, 138 patents and licenses, the generation 4000 scientific publications and 220 of the 515 students who left CIPI following their training were hired by the industry. In order to reach high school students, CIPI has created the Canadian photonic kit with 7 experiments demonstrating the applications of photonics. A total of 50 kits have been distributed all over Canada to kit keepers who organize visits at local schools.

The three research programs resulted in a very significant involvement of Canadian industry, facilitating the transfer of technology as well as the hiring of highly qualified personnel (HQP) trained in projects of interest to the industry. The yearly average contribution by the CIPI Affiliates grew from $1.4M at the beginning to $3,1M during the last phase of CIPI. An independent evaluation carried out by Dennis Rank and Associates in 2008 concluded that CIPI has had a marked impact on the photonics R&D landscape in Canada. Significant impact was made in the areas of support for excellence science, training of HQP, networking and collaboration among academic researchers, collaboration with industrial photonics producers, and generation of socio-economic benefit.

A second independent impact assessment of CIPI was completed by The Evidence Network in 2012 to evaluate the immediate and intermediate impact of CIPI on the industry. As immediate impact, more that 60% of the companies reported a significant or very significant impact of CIPI for knowledge, information or advice, and on access to research personnel, to equipment and to facilities. As intermediate impact of CIPI, 88% of the companies reported a positive impact on their degree of innovation, 77% reported a positive impact on their time to market, 72% on the ability to attract investment and 70% indicated an increase in their number of employees as well as research investment. Furthermore, the average intermediate impact for the companies that hired students was significantly greater than the impact on the ones that did not hire students. Overall, 82% of the companies were either satisfied or very satisfied with their interaction with CIPI. A total of 224 researchers from 36 Canadian universities were involved in collaboration projects with our 119 premier affiliate members.

An additional survey of companies involved in TEN and IPA projects concluded that 35% of them were expecting, within the next five years, combined revenues amounting to 60 times the total CIPI investment in these projects, demonstrating a very strong return on investment for these programs. Annex 1 provides examples of impact for some industries.

Following the sunset clause of NCE research networks, CIPI has ceased its research activities at the end of March 2012. However, the networking and collaboration in photonics between researchers, industry and Government organizations continued through the newly formed Canadian Photonic Industry Consortium resulting from the merger of CIPI with the Canadian Photonics Consortium. Therefore, the momentum created by CIPI to foster photonics in Canadian industry is maintained, demonstrating the strategic importance of photonics for generating wealth in Canada.

1. The CIPI Research Program

The Canadian Institute for Photonic Innovations, CIPI, was formed in 1999, in response to the Canadian photonics community's recognition that Canada needed to capitalize on the reputation its photonics researchers had built at the forefront of the field. Internationally, there was widespread recognition that photonics — the technology of light — offered opportunities for unprecedented advances in telecommunications, medicine, life sciences, manufacturing, environmental concerns and security applications. But despite their high international profile, Canada's photonics community was fragmented, with little collaboration and no coherent national vision to harness their individual strengths for the nation's greater benefit.

CIPI's accomplishments changed all that by establishing a vibrant and forward-looking network of efficient research teams; envisioning, creating and driving new directions in photonics innovations; training a whole new generation of photonics researchers; and articulating a long-term national photonics strategy for university research.

CIPI's major goals were:

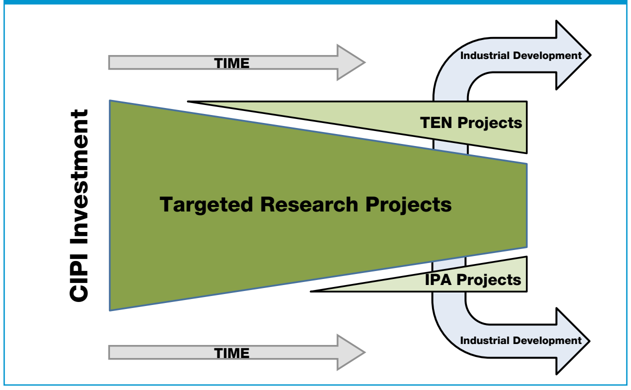
1. To increase networking between university researchers, industries and institutions;
2. To promote research excellence in universities;
3. To train highly qualified personnel (HQP) who could address the growing needs of photonics personnel in all sectors;
4. To accelerate the development of new applications outside the telecommunications sector; and
5. To develop effective mechanisms for transferring its research outcomes into innovation with socio-economic impact.

To achieve these goals, CIPI used three formal and complementary programs:

- The Research Program that targets both specific technologies and HQP training;
- The Technology Exploitation and Networking (TEN) Program that accelerates technology transfer, enhances networking and trains students; and
- The Innovative Photonic Applications (IPA) Program that exploits photonic technologies in end-user sectors.

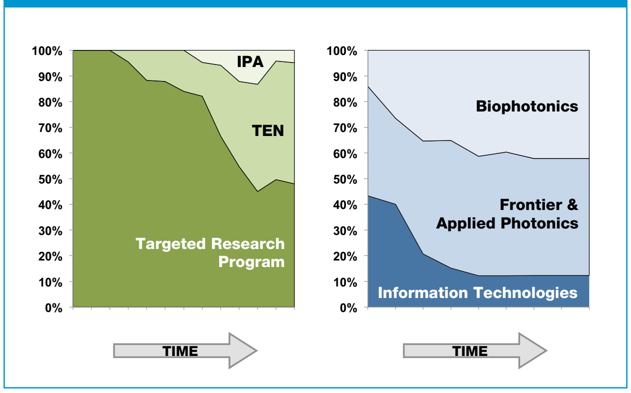
Figure 1 illustrates this logical progression of harmonized programs by depicting the chronology of and balance among funding allocations. The success of this triad demonstrated the sound and far-sighted stewardship provided by CIPI's management and governance teams. After the high-technology telecommunications bubble burst, many photonics companies refocused on applications for other potential markets. Similarly, CIPI re-directed its research towards biophotonics and other applications, as shown in Figure 2. The Left-hand panel illustrates the emphasis CIPI placed on research activities in the three programs. The Right-hand panel illustrates the proportions of CIPI's funding allocations for Information and Telecommunications, Frontier and Applied Science, and Biophotonics.

FIGURE 1. The CIPI Investment Model



When Industry Canada released its 2007 document Mobilizing Science and Technology to Canada's Advantage, CIPI had already developed a "Knowledge Advantage" through the excellence of its science; a "People Advantage" through its development of highly qualified personnel (HQP),

FIGURE 2. Evolution of CIPI Research Investment



and an “Entrepreneurial Advantage” through its knowledge-exchange and technology exploitation activities. In addition, CIPI exceeded Industry Canada’s advantage criteria by promoting collaboration through its networking and partnership activities.

CIPI maintained its research standards by assessing research projects annually. Projects that did not meet expectations were directed to correct their deficiencies or, where the initial goals appear unachievable, were terminated. Table 1 demonstrates the impact of CIPI demonstrating the growth of partnership, collaboration and technology transfer as well as the hiring of almost half of CIPI students by the industry.

Table 1 - Key Outcomes from the CIPI Research program

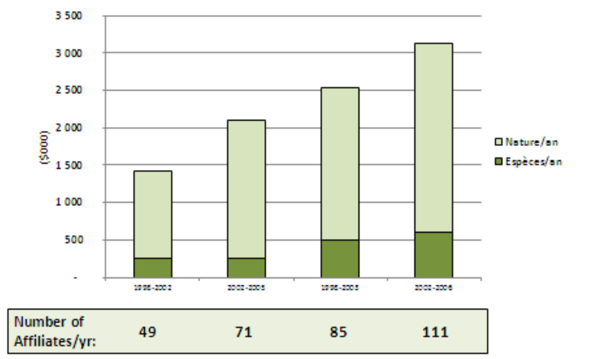
	First NCE Cycle		Second NCE Cycle	
	1998 - 2002	2002 - 2005	2005 - 2009	2009 - 2012
NCE Funding-Average per year	$ 3,262,000	$ 3,262,000	$ 4,243,000	$ 4,243,000
Affiliate Cash Contribution - Average per year	$ 246,000	$ 254,000	$ 495,000	$ 603,000
Affiliate Inkind Contribution - Average per year	$ 1,170,000	$ 1,851,000	$ 2,031,000	$ 2,523,000
Number of Partners - Average per year	49	71	85	111
Number of Industry - Average per year	22	32	49	71
Number of Patents/Licenses	10	15	43	70
Number of Spin-Offs	2	3	4	5
Number of students who completed their training	148	143	142	82
"% of trained students working in industry	59%	24%	44%	48%
Number of Researchers - Average per year	54	67	107	109
Number of Research Assistants and Post-Doctorate Fellows - Average per year	34	34	39	34
Number of Graduate Students Trained - Average per year	173	218	210	126
Number of Theses Completed	91	105	158	63
Number of Refereed Publications	514	749	1072	617
Number of Publications	783	1125	1292	765

2. Impact of CIPI

The networking of CIPI researchers involved in high intensity lasers resulted in a CFI proposal and the creation of the Advanced Laser Light Source (ALLS), a laboratory with multiple femtosecond light sources at INRS-EMT in Varennes, Quebec which is now used by Canadian researchers and industries. The CIPI research projects also resulted in the creation of fourteen new companies of which 8 are still active, 138 patents and licenses, the generation 4000 scientific publications and 220 of the 515 students who left CIPI following their training were hired by the industry.

The three research programs resulted in a very significant involvement of Canadian industry, facilitating the transfer of technology as well as the hiring of highly qualified personnel (HQP) trained in projects of interest to the industry. As indicated in Figure 3, the yearly average contribution by the CIPI Affiliates grew from $1.4M at the beginning to $3,1M during the last phase of CIPI.

FIGURE 3. Contribution by Afiliates



An independent evaluation carried out by Dennis Rank and Associates in 2008 concluded that CIPI has had a marked impact on the photonics R&D landscape in Canada. Significant impact was made in the areas of support for excellence science, training of HQP, networking and collaboration among academic researchers, collaboration with industrial photonics producers, and generation of socio-economic benefit. An additional survey in 2011 of companies involved in TEN and IPA projects concluded that 35% of them were expecting, within the next five years, combined revenues amounting to 60 times the total CIPI investment in these projects, demonstrating a very strong return on investment for these programs.

CIPI Spin-Offs witch are still active
Attodyne Laser
Cytognomix
Dicos (Now acquired by TeraXion)
ExOptx (Now called Fibrelase)
FiLaser
Inometrix
LaserAX
Moleculight

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As additional demonstration of impact, the Canadian Photonic Consortium conducted a survey of the Canadian photonic industry in 1998 with an update in 2012 and concluded that their revenues increased by an average annual compound growth rate of 7% and that their number of employees increased by 15% during the last cycle of CIPI.

The attached annex 1 provides some examples of CIPI impact on new products and services, sales and employment growth for the industries.

3. Excellence of the Research Program

The overall Network research program

Originally, CIPI's research program was distributed in 5 specific topics:

- Nanotechnology for photonics
- Engineering of Photonic Devices
- Photonics for Information Technology
- Ultra-fast Photonic Technology, and
- Precision Photonic Measurements

After validation in a number of end-user workshops for the photonics industry, the research program was structured in three thrusts: Biophotonics; Information and Telecom; and Frontier Photonics.

Biophotonics

The Biophotonics Thrust focused on improving the quality of future health care in Canada by advancing photonic tools in two main areas: diagnostic and therapeutic applications in medicine, and improved drug assessment. Projects included probing the state and health of individual cells (internally with nanometre probes, and externally by analysis of contents); improving on rapid assays of gene chips; developing advanced multimodal imaging techniques; and world-leading work on the next generation of photodynamic therapies based on two-photon excitation of activation agents.

Canadian companies such as **Astra Zeneca, Doric lenses, Elcan, Novadaq, Photon-Control, QLT, TeraXion and WDI** have been involved in these projects.

Frontier Photonics

Within the Frontier Photonics Thrust, research teams focused on a variety of applications designed for industrial and medical applications. This thrust was therefore naturally linked to the Biophotonics Thrust through its applications for medicine. The projects focused on advanced Canadian photonics technologies, such as femtosecond and high-power lasers; world-leading ultrashort light sources with pulse lengths of attoseconds; specialty glass and chalcogenide fibres and fibre-Bragg gratings; nanostructures for high-efficiency photonic devices (including advanced solar cells); and techniques for using structured and ultrashort laser pulses for high-performance laser micro-machining. CIPI has been instrumental in the installation of a new world-leading facility for atto-second imaging research called the Advanced Laser Light Source (ALLS), enabling all Canadian researchers to access these new technologies. Trust projects involved Canadian companies such as **Axis Photonics, Carmanah, CorActive Hightech, D-Tex, Dalsa, Doric Lens, Exfo, FiberTech optica, ITF Optical, Micralyne, MPBC, Nucryst, OE/Land, Opsens, OZ Optics, PhasOptx, Telops and TeraXion.**

Information and Telecommunications

This thrust, which focused on meeting the demands of Canadian information industries, involved the development of next-generation optical transceivers for fibre-to-the-home; optical packet switching leading towards high-speed all optical switching; quantum encryption of keys for totally secure information transmission; cost-effective integrated silicon photonics for sensing and information processing; and optical technology for data centres. A long-path demonstration of optical packet switching using a dark fibre has been developed between Quebec City and Montreal. CIPI researchers have enhanced the long wavelength response of silicon waveguide photodetectors, as well as silicon nanocrystal structures for silicon-based optical emitters. Among the Canadian companies involved in this work were **Bell, Enablence, Exfo, Group IV Semiconductors, Intel, Kotura, ITF optical, MPBC, Optenia, Optiwave Systems, Reflex Photonics, ST Microelectronics and TeraXion.**

4. Collaboration Among Researchers

Coherence and integration of multi-disciplinary research

During the second NCE funding cycle, the independent study of the impact of CIPI concluded that CIPI strongly supported excellence in various fields and that the number of CIPI acknowledged publications were significant while more than 20% have been published outside photonics or physics journals. Out of the total of 2,950 refereed publications by its researchers, 27% were by authors working in different research groups which also demonstrated the importance of networking and collaboration between the various universities.

The CIPI TEN Program to accelerate networking

Initiated in 2002, the Technology Exploitation and Networking program (TEN) is partly a networking mechanism and partly a mechanism for technology transfer. Three types of networking activities were financed:

- ➢ Exchange Program for Graduate Students
  - To encourage networking by students working with other university, industrial or government research groups
- ➢ Seminars, Conferences and Workshops
  - To encourage networking between students, researchers and affiliates
- ➢ National Facilities Access Grants
  - To encourage PDFs and Students to use and train at National Facilities

An average of 15 networking projects were supported every year by CIPI.

The Network's relationship with foreign organisations

CIPI researchers and their partners were also collaborators on international teams pursuing photonics investigations in such prestigious institutions such as Israel's Weizmann Institute, Germany's Max Planck Institute and the Japanese Science and Technology Institute. In addition to facilitating short term postings of Canadian students in foreign laboratories, CIPI has supported more than 50 international collaborative activities between its researchers and those from US, Europe and Asia, and entertained excellent relations with the US in biophotonics, with France in femtosecond lasers and with Germany in laser processing.

5. Partnerships with Industry and Government

Effective Research and Technology development links between academic institutions, federal and provincial agencies, and private-sector participants.

Networking has always been an important feature of CIPI's vision. With the multi-university and multi-disciplinary structure of its research projects, CIPI developed a culture of networking between researchers in Canadian universities, government and industry. This is demonstrated by a significant increase in collaboration and the fact that 27 percent of CIPI's publications are by authors from more than one research group. The significant increase in number of Affiliates involved in CIPI projects in a given year from 49 during the first years of CIPI to 111 during the last years of the CIPI network is also a strong indication of the improved networking between researchers, industries and institutions.

In addition to an active partnership with the Quebec Photonic Network and the Ontario Photonic Industry Network, CIPI had collaborative agreements with many federal and provincial partners such as CMC Microsystems, the Canadian Space Agency, NSERC, the Ontario Centers of Excellence, Nano-Québec, and FQRNT. These collaborations complemented the CIPI offering to the industry, thereby accelerating the use of technology and and the generation of wealth.

CIPI research program, were opened to all Canadian university photonic researchers with the objective of promoting the technology developed in Canadian universities and fostering knowledge exchange among all photonic stakeholders, thereby stimulating technology exploitation by industry through knowledge and technology transfer. Its networking aspect ensured that all suitably qualified groups could participate through its exchange programs for graduate students, support for seminars, conferences and workshops, and grants to access the National Facilities.

6. Knowledge Transfer and Exploitation

Although there were some knowledge transfer through its targeted research program, CIPI's strategy for knowledge exchange and technology exploitation was built into both CIPI's TEN Program and its IPA Program. These programs have laid a foundation for continued collaboration and networking within the Canadian photonics community. The collaboration and technology transfer components enabled to evolve technologies from the research program to the industry.

The Technology Exploitation and Networking (TEN) Program

Applicants to the TEN Program were faculty members in Canadian universities. The selection criteria varied, depending on the type of grant being requested:

Collaboration Grants

- To encourage the establishment of a significant collaboration with a company or institution aiming at resolving short-term problems in photonics;

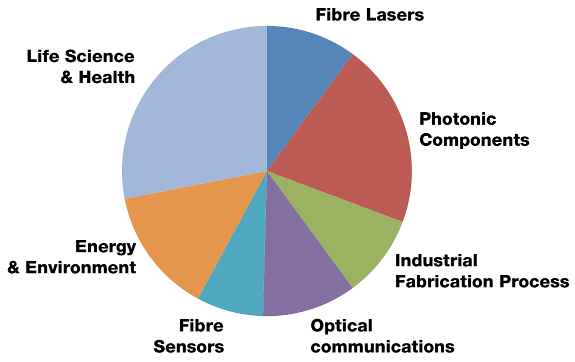
Technology Exploitation Grants

- To assist in the process of exploiting a technology or know-how developed in a Canadian university. It included early-stage activities (alpha prototypes, commercial evaluation) and late-stage activities (preparation of a business plan, mentoring, etc.)

The Innovative Photonic Application (IPA) Program

In 2006 CIPI launched a new program to help industry benefit from photonic solutions spun out of university laboratories across the country. The IPA Program brought together university researchers, technology implementers and end-users in targeted projects where advanced photonic technologies were put to use to solve specific end-user problems, thereby increasing their efficiency, productivity and profitability.

FIGURE 4. Distribution of TEN and IPA projects - by category



As discussed in Section 1, the distribution of research investments by program moved toward more collaboration and technology-transfer. Figure 4 presents the distribution of these projects by category. While 30% of the projects covered fibre lasers and photonic components, 70% were focusing on photonics applications. Life sciences and health projects covered 28% of the total, followed by energy and environment at 14%. Comments from CIPI Affiliates as well as the many repeats using the TEN and IPA programs demonstrated the value of these programs. Furthermore, many research projects have spun off specific applications through the TEN and IPA programs which enhanced their exploitation.

CIPI organized workshops for targeted industrial sectors to identify problem areas and educate end-user sectors on the possible benefits of using photonics. These workshops led to new projects for improving productivity and increasing end-users' competitiveness. They also facilitated the transfer of exploitable technologies to Canadian-based partner companies that stand to reap substantial financial benefits from successful outcomes. The IPA Program was designed to stimulate implementation of photonic technologies in all major industrial sectors in Canada: telecommunications, natural resources, manufacturing, food, agriculture, transportation and pharmaceuticals.

Technology and commercial Impact on the industrial partners

Annex 1 presents examples of new products, processes or services that have been or are being commercialized by Canadian firms and that will strengthen the Canadian industrial base, enhance productivity and contribute to long-term economic growth and social benefits.

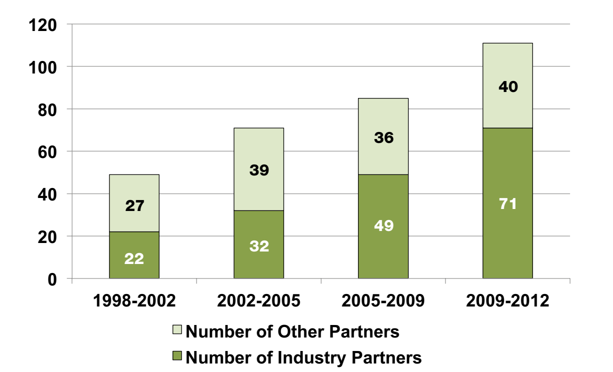
Management and protection of intellectual property resulting from network-funded research

Although intellectual property rights for CIPI projects resided in universities, CIPI has been active in facilitating the transfer of intellectual property through its research projects and by organizing topical technology-transfer workshops. During the last independent impact study of CIPI, 49% of the industry indicated a significant impact of the CIPI projects on their technology development and 22% indicated a significant impact on their access to intellectual property.

Collaboration with the private and public sectors in technology, market development and public policy development sector

As shown in Figure 5, the number of partners has grown significantly within the life of CIPI. Furthermore, CIPI was on the Board of the Canadian Photonics Consortium (CPC) and was very active within Canadian regional clusters such as the Quebec Photonic Network (QPN) and the Ontario Photonic Industry Network (OPIN). CPC represented Canadian companies, regional clusters, and research institutions active in optics and photonics. CPC's vision was to establish Canada as the place for business success in optics and photonics. In 2006, CIPI organized a meeting in Canada of the International Electro-technical Commission (IEC) on international standards for optical fibres, and met with CSA representatives on the same subject. A total of 150 participants from 18 countries were involved. One of the main outcomes was that 2 additional Canadian industries joined the Canadian IEC-TC86 Committee that defines the standards for optical fibre systems and their testing. CIPI has also been heavily involved in the development of the Canadian Photonics Strategy. CPC was therefore a natural organization for amalgamation with CIPI to create the Canadian Photonic Industry Consortium (CPIC) in 2012.

FIGURE 5. Number and Type of Partner - (annual average)



7. HQP and Attraction of Researchers

Development and retention of outstanding researchers in research areas and technologies critical to Canadian productivity, economic growth, public policy and quality of life

The high-technology bubble burst, the accompanying downsizing of many telecommunication companies and the subsequent new directions taken by photonic industries made it critical for CIPI to adapt the way it trained students to the new needs of industry. Within CIPI, the training of HQP was done through four different formats:

1) Student participation in the CIPI Research, TEN and IPA projects that involve the students' direct interaction with affiliates;
2) The regular and various workshops and courses organized by CIPI-S (the student network that CIPI created and funded, and that was managed by CIPI students);
3) Support for travel, networking and attending workshops; and
4) Networking during CIPI events such as CIPI's AGM and technical conferences.

A total of 2560 person-years of student training have been performed in addition to 490 person-years of Research Associates and Post-Doctorate Fellows.

CIPI member universities such as Laval and McMaster have established formal undergraduate and graduate photonics-oriented academic programs. In addition to the CEGEP programs at André-Laurendeau and La Pocatière, photonic technologist-training programs have also begun in institutions such as Niagara and Ottawa's Algonquin College.

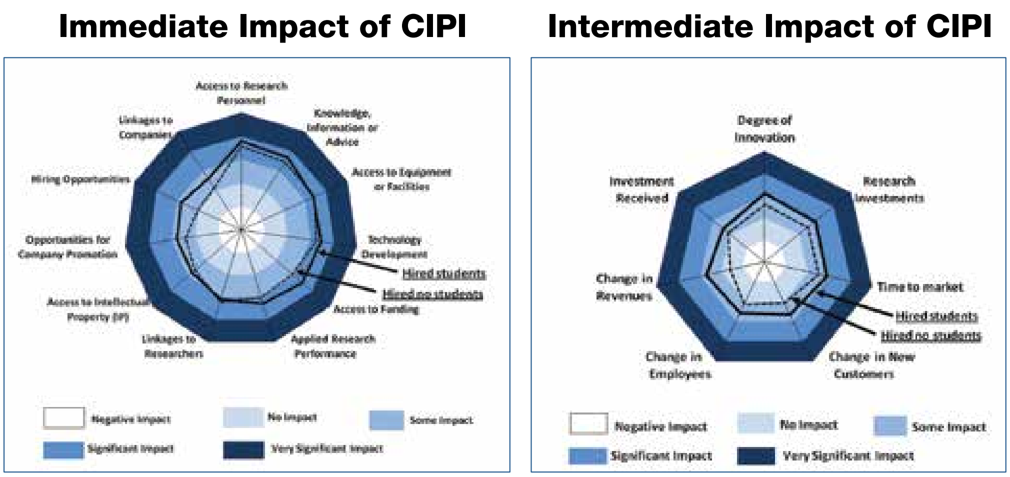
FIGURE 6.
Canadian Photonic KIT

In order to reach high school students which are in a critical time for deciding on their career, CIPI has created the Canadian photonic kit with 7 experiments demonstrating the applications of photonics. A total of 50 kits have been distributed all over Canada to kit keepers who are organizing visits at local schools. Reports from the Kit Keepers indicate strong interest and enthusiasm from the students.

Network training strategies that promote multi-disciplinary and multi-sectorial research approaches and encourage trainees to consider the economic, social and ethical implications of their work

On average, 220 students, research associates and Post-Doctoral Fellows were involved in CIPI's various projects every year. More than 55% of the overall budget that CIPI distributed to the universities was dedicated to HQP. Each year, the CIPI's student network (CIPI-S) organized workshops of high interest to photonics students. These workshops covered subjects such as the photonic software used by industry and research institutions; hands-on courses on photonic components; biophotonics; and nanotechnology. During the CIPI era, 43% of students leaving the network were hired by industry. The 2008 CIPI Impact Study demonstrated that appropriate training of HQP was one of CIPI's strongest features. The impact of hiring students has been demonstrated in the 2012 impact assessment as shown in Figure 7.

FIGURE 7. L'impact de l'ICIP sur l'industrie



Source: "An assessment of the impact of Canadian Institute for Photonic Innovations, March 26, 2012, by The Evidence Network"

8. Network Management

Network management structure and extent of involvement of the user sector

The structure of CIPI was unique among NCE networks. As a not-for-profit corporation, its governance was provided by a strong Board of Directors, a full-time President and CEO and a Scientific Director.

Key strategic direction was defined by the Board. The Board represented all photonics stakeholders: government, university, and industry. The Research Program Committee headed by the Scientific Director ensured quality and adequacy of the research projects, while the Technology Exploitation and Networking (TEN) and the Innovative Photonic Applications (IPA) committees ensure that projects are sound and correspond to real industrial needs. Funding allocation for the programs was decided by the Board and implemented by the CIPI management team. The Research Vision Committee, composed of international experts in photonics, were regularly reviewing the progress and direction of the research and technology transfer programs.

Business development was provided by the President and CEO, as well as by a network of Business Development Officers, each of whom were working out of one of five major cities: Montreal, Ottawa, Toronto, Edmonton or Vancouver. The Business Development Officers met with industry representatives to identify their needs, and with university researchers and University- Industry Liaison Officers to identify potential offerings. This structure has demonstrated its efficacy and efficiency.

A survey of students, researchers and affiliates demonstrated the critical importance — and success — of the CIPI network.

CIPI had a number of mechanisms for publicizing its successes:

1) The TEN and IPA Programs and the joint CIPI/CMC and CIPI/Nano-Quebec/ASC calls for proposals.
2) CIPI-S: the active student network and the call for student proposals for CIPI support to conferences and for the Scientific Popularization contest.
3) Numerous student-oriented and industry oriented workshops and conferences to publicize the Network's research findings, foster new relationships, and contribute to the dispersion of breaking advances among potential receptors in other fields and industries.
4) PHOTONS, a unique Canadian magazine aimed at all photonics stakeholders (students, researchers in other fields, and industry) that described research projects not only in technical language but in non-technical summaries that provide readers with the salient interest points of each project.
5) CIPI's and our partners and affiliates websites, plus the www.biophotonicsworld.org website which is still actively supported by the Center for Biophotonic Science and Technology (CBST) in California.

9. Conclusion

The mission of CIPI was to bring university researchers together with public sector and industrial partners in a network with state-of-the-art facilities in order to stimulate innovations in photonics, and promote their exploitation to generate wealth and enhance the quality of life for Canadians. Through its flagship programs — Research, TEN and IPA — CIPI has succeed, evolving into an efficient and effective network with improved networking, knowledge, and technology transfer. The Network has dramatically increased the transfer of technology to industry and end-users and carried out world leading research and training of HQP in strategic areas of importance to Canada that led to significant economic and social benefits. CIPI's governance and management structure ensured responsiveness to the continuing evolution of Canadian industries' needs focussing on strengthening the three Canadian advantages identified in Industry Canada's S&T strategy document, namely its "People Advantage, Knowledge Advantage and Entrepreneurial Advantage."

With a clear vision in place, CIPI has advanced the positive technological and social impact of photonics in Canada. It has developed a strong platform for continuing support of the strategically important photonic industrial and research community within Canada.

Although CIPI has ceased its NCE research activities at the end of March 2012, the networking and collaboration in photonics between researchers, industry and Government organizations continued through the newly formed Canadian Photonic Industry Consortium resulting from the merger of CIPI with the Canadian Photonics Consortium. Therefore, the momentum created by CIPI to foster photonics in Canadian industry is maintained, demonstrating the strategic importance of photonics for generating wealth in Canada.

ANNEXE 1 – Examples of CIPI impact on the photonic industry

Attodyne (Toronto, ON) - Ultra-fast fibre lasers for manufacturing

Projects	Description	Impact
IR Picosecond Lasers and Novel Ultrafast Laser technology (University of Toronto) and Ultrafast Lasers for ablation of Tissue (McGill University)	Development and improvement of pico-second lasers for medical and manufacturing applications	Spin-off; now offers 2 laser systems; Since 2011, hired 7 persons.

As the researchers at the University of Toronto performed various experiments, they aimed to explore optic techniques and the associated impact of light energy on water. This required a small but powerful laser that would emit strong pulses of light every trillionth of a second. The challenge: given extreme budget constraints, the team did not have the funds to purchase a costly laser 'off'-the-shelf'. In the absence of cost-effective technology, the photonics researchers built a laser that addressed their unique requirements. They constructed a device that is 10 times more powerful than the existing technology they initially assessed. Within a few weeks of working with the new laser, they realized this new technology could be applied in several industries – from manufacturing to energy, ICT and medicine. Following the release of their first product in early 2010, Attodyne is achieving success in these initial markets. They are currently selling the laser around the world, gaining strong traction for precision manufacturing and repair of LCD screens and solar cells.

Boreal Laser (Edmonton, AB) - Detection of Hazardous Gas

Projects	Description	Impact
Long Wavelength laser development, Quantum Cascade laser (University of Alberta)	Development of a solid state open path cascade laser for environment trace gas sensing applications	New product called GasFinderPT for Hydrogene Fluoride monitoring, cumulative sales to date of $200k, one additional employee

Unrefined fuels emit toxic gases such as hydrogen sulfide which can be detrimental to the environment and human health in high concentrations. Petroleum firms are forced to monitor such substances closely as a gas flare can bring operations to a halt, cost millions in lost revenues and jeopardize the well-being of their people. This issue is shared by aluminum smelters, oil refineries, chemical plants, gas production and processing facilities, brick and ceramics manufacturers, and agricultural emissions research firms.

With a focus on this challenge, Boreal Laser aimed to develop a novel laser that uses light to detect, monitor and measure hazardous gases, and provides the information required to enable rapid corrective action. The resulting optical technology improves the productivity and safety of the oil and gas sector.

CorActive Hightech (Quebec, QC) - Novel types of Optical Fibres

Projects	Description	Impact
Hybrid Microwires and non-linear Devices (McGill University), Bragg Filters in Multi-mode Fibers (Université Laval), Laser Induced Cooling (Polytechnique Montreal)	Production of optical micro-wires as non-linear devices and filters; Development of a process to write spectral filters on multi-modal optical fibres; Study to implement an optical cryo-cooler for solids.	Projects have contributed to the development of the laser platform called CoraLight and to the development of fibres for the laser marking market. Sales of few Millions dollars per year.

CorActive Hightech manufactures specialty optical fibers for applications in the industrial, telecom, defense, sensing, medical and scientific markets. They have collaborated successfully with Canadian University researchers which generated transfers of technology and filing of patents. They have developed optical components that generate broadband infrared light and enable fast optical signal processing from our chalcogenide glass optical fibers. This fibre has very unique properties that allow to transmit infrared light over long distances and build ultra-compact infrared light laser sources. It is anticipated these projects will cultivate new expertise in fabrication and packaging of optical components based on our optical fibers and will help to facilitate the creation of novel laser systems that open up new markets.

Cyrium (Ottawa, ON) - More efficient and Cost-Effective Solar Energy

Projects	Description	Impact
Anti-Reflection Coatings (Ottawa University); Fabrication of high Efficiency Solar cells (Université de Sherbrooke)	Development of Anti- reflection coatings for concentrated photovoltaics; Novel fabrication process for solar cells	Staff increased to >20 by 2010, 1^{st} Gen product general availability by Dec. 2009 Penetration of Asian market in 2011 2^{nd} Gen released by Dec. 2012

With increasing demand for renewable energy, the global market for solar cells and modules is forecast to reach $90 billion by year 2017. It is a lucrative opportunity that fuels innovators at Cyrium Technologies. This Ottawa-based firm is dedicated to the development of solar cells for use in concentrator photovoltaic (CPV) systems. This technology uses mirrors and lenses to concentrate sunlight hundreds of times onto the tiny, highly efficient solar cells. Using breakthrough nanotechnology, the company is developing cost effective, high efficiency solar power solutions. A key goal: to lower the cost of solar cell ownership and put this technology within the financial reach of the average consumer. CIPI projects enabled to explore a variety of different coatings and identify those with the potential to enhance the performance of our technology. The company has drawn on some of the outcomes of this initiative and incorporated them into the product development process.

Tex (Calgary, AB) - Detection of Harmful Bacteria such as Lysteria, E.Coli and Salmonella

Projects	Description	Impact
Continuous Monitoring of water Patogens (University of Calgary)	Development of an optical filter transform which is still a breakthrough in the industry.	Leveraging $1M in additional investment, 2 new patents, hired 5, growing to 16 in 2014, revenues of $1M in 2013, growing to $3M in 2014

In the food industry, safety is a top priority. As the food we enjoy moves from a producer to our table, it makes many stops along the way. It passes through many hands and facilities that enable processing, packaging, shipping and distribution. If food is not managed properly during each step of this process, it can become contaminated. The onset of harmful bacteria such as Lysteria, E. Coli and Salmonella in food stuffs prompts large-scale product recalls, lost yield and food disposal, and a wave of negative economic and social impact. More importantly, when contaminated food is ingested, it can lead to food poisoning, illness, and in severe cases, mortality. The food industry is continually seeking innovative ways to detect such bacteria and keep food safe. It is an issue that a Calgary-based start-up called D-TEX Inc. is addressing head-on by developing a novel real time imaging device to detect bacteria and other pathogens in food and water.

Genia Photonics (Montreal, QC) - Novel Laser Technology

Projects	Description	Impact
Programmable and Tunable Laser (Université Laval) and Coherent Raman Spectroscopy (Université Laval and NRC)	Development of novel types of lasers and of new pulse coding.	New types of lasers and Services now offered, sales growing by 400% in 2011 and 300% in 2012; employment grew from 2 in 2009 to 21 in 2012

Founded in 2009, Genia Photonics made a significant leap forward by capitalizing on the power of partnerships. The Quebec-based company specializes in two families of optical products: (1) High-speed picoseconds programmable fiber lasers – instruments that emit a targeted pulse of light every trillionth of a second, with adjustable features that are controlled by software.and (2) Spectroscopy measurement systems that assess the absorption and emission of light and other radiation by matter.These technologies target broad applications in sectors such as life sciences, industrial, and defense and security. Moreover, prospective users are emerging in fields such as environment, aerospace and telecommunications. Based on the design of their first laser, the company wrestled with technical challenges to develop its commercial product. The team aimed to extend the cavity of their first laser and improve its grating. Leveraging funding from CIPI, Genia Photonics launched collaborative R&D projects with Laval University and key suppliers. The outcomes of this project contributed to Genia Photonics' first commercial product and established the foundation for long-term R&D collaboration with Laval University.

LaserAX (Quebec, QC) - Novel Laser Cutting technology for soft material

Projects	Description	Impact
Laser Cutting system for soft tissues (Université Laval)	To develop a laser cutting system for production of hygiene products	Setting-up of LaserAX, a CIPI spin-off; Demonstration at an major industrial customer site; Development of a new platform for laser cutting in an industrial environment; Creation of 2 new jobs

Laser processing employs a high power laser to cut, weld or drill materials such as plastic, glass, ceramic and thin metals with dimensions from 1 micron to a few cm. Once sliced by the laser beam, the material melts, burns away, vaporizes, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. This technique is particularly useful for high precision cutting required by manufacturers in life sciences, automotive, aerospace, ship building, and textiles. A Laval-based research team believed they could offer manufacturing companies the right laser cutting solution for them. They quickly established a collaborative R&D project with a manufacturer and launched Laserax. The new entrepreneurs worked closely with the corporate partner, visiting a manufacturing plant and assessing current cutting machinery. They studied the properties of this material; assessed how it interacted with the laser; and manipulated the laser beam to achieve different types of cut. They also worked on its integration into production – a critical success factor for technology adoption. The team provided initial successful trials on the company production plant.

Moleculight (Toronto, ON) - Revolutionizing Wound Care at the Point-of-Care

Projects	Description	Impact
Optical imaging platform for real-time preclinical and clinical applications (Ontario Cancer Institute, University Health Network)	To develop a medical imaging device platform for clinical detection of applications in wound care management and image-guided surgery of cancer.	Company was spun out, prototype PRODIGI™ imaging device was successfully validated in over 100 patients in multiple hospitals, wound clinics and home care settings with results indicating significant benefit to patients and payers. MolecuLight's target launch of the first product in early 2015.

Early recognition of bacterial infection, identification of pathogenic microorganisms and assessment of pathogenic load would have an enormous impact on wound management. MolecuLight's disruptive solution to this urgent medical need is a handheld point-of-care optical imaging product called PRODIGI™ (Portable Real-time Optical Detection, Identification, and Guide for Interventions). PRODIGI™ allows physicians and wound care personnel to quickly, easily and safely visualize and objectively/quantifiably measure pathogenic bacterial load in chronic or acute wounds. It can be used to guide procedures (e.g. swabbing, biopsy and debridement), determine whether additional lab tests are required, track bacterial burden and the response to treatment over time, and objectively document treatment response. It provides the earliest detection of infection and evidence-based, point-of-care decision making to wound care for the very first time.

Clinical trials using the PRODIGI™ imaging device have been performed in several hospitals, wound clinics and home care settings. To date, PRODIGI™ has been clinically validated in over 100 patients with a variety of wounds (e.g. diabetic foot ulcers, pressure ulcers, and surgical wounds). Independent microbiology laboratory analysis has confirmed that the PRODIGI™ imaging device can instantly and accurately detect areas of bacterial burden, including dangerous bacterial biofilms that would otherwise be missed by traditional clinical diagnostic protocols. As a platform imaging technology, PRODIGITM is also being clinically evaluated for intraoperative fluorescence-based cancer surgery and clinical trials are now underway at the Princess Margaret Hospital in Toronto. At this point, Moleculight is focused on the wound care market and is actively evaluating institutional and multinational investment and strategic partnership opportunities, with a long term goal of launching the first medical product in 2015.

Early financial support and mentorship for the PRODIGITM R&D program from CIPI have had enabled accelerated prototype development as well as preclinical and clinical validation testing, which together have made a compelling investment story. CIPI's financial support was a critical early step in helping to improving this new imaging technology and get it one step close to clinical translation for improving the health of Canadians and enhancing the potential commercial success of the company.

OneLight (Vancouver, BC) - To Accelerate the Detection, Diagnosis and Treatment of Cancer

Projects	Description	Impact
Spectrally Programmable Light Engine and MEMS based hyperspectral imaging (UBC)	Development of an Hyperspectral videobronchoscopy system; Hyperspectral platform for analysis of neoplactic process	New patent; Annual sales of $500k; Currently seeking financing to implement new design

OneLight Corporation aim to dramatically improve the diagnosis and detection of diseases such as cancer. The firm is developing 'illumination' or light-based technology that will allow physicians to perform surgery with greater accuracy; enable the development of new, non-invasive endoscopic tests that scan tissue for disease; and improve the capability imaging for existing video endoscopy systems. With more than 15 million endoscope procedures performed on patients each year in the U.S. alone, there is significant demand for OneLight technology. To capitalize on this market opportunity, the firm employs leading scientists and highly creative approaches to R&D and this includes industry-academic research collaboration enabled by CIPI. Drawing on existing products, the researchers have developed an application that illuminates individual tissues one color at a time and then puts them together in a systematic way to create a single comprehensive picture. This digital light processor enables health care providers to gather new information about cancer markers, helping them to more accurately determine the type of cancer and how rapidly it is spreading. It could also be applied to drug discovery and development as it can illuminate multiple markers in several tissues simultaneously. This creates new opportunities to assess how a particular drug interacts with or alters the biology of a particular gene or marker.

Opalux (Toronto, ON) - Turning Nature's Canvas into Photonic Paint

Projects	Description	Impact
Photonic Crystals as Indicators (University of Toronto)	Development of photonic crystal materials for application in security and charge indicators	Work led to continued funding support of more than $1.5M to date with security division growing from 2 to 5 people in last 2 years

The opal is a brilliant gemstone that diffracts or spreads light, reflecting an array of different colors. These minerals display 'structural color' – color that is derived directly from the internal composition of the material as opposed to a conventional dye or pigment. These crystals permit select wavelengths of light to flow through, while reflecting others.. Opalux is commercialising a novel photonic color technology developed by innovators at the University of Toronto who produced photonic materials that create vivid, customized and controllable colors that could be applied to products in a host of industrial sectors. This includes energy, life sciences, finance, manufacturing, ICT, security and defence – just to name a few. By harnessing the unique characteristics of photonic crystals, they have invented a novel photonic colour technology. The collaboration project had an inestimable impact on Opalux's growth and market applications. A printing project is now in large-scale integration and testing trials, using rolls of more than 5km in length which are then cut and introduced in the material which is application specific.

PhasOptx (Montreal, QC) – Connecting fibers and bio-sensors

Projects	Description	Impact
Fiber Laser applications of SMA Optical Fiber Modulator, Development of a bio-sensors (Université Laval)	Development of a bio-sensor on an optical fibre and of a phase modulator based on a shape memory alloy component	Development of the Optimend™ platform; proof of concept for new market, Industrial Technology centre of 6000ft^2; plan 12 to 45 employees by 2014 and creation of a subsidiary called PhasOptx Telecom.

With the advent of new network configurations that bring fiber optic cable much closer to the consumer, PhasOptx initially focused on how to improve 'fiber-to-thehome' (FTTH) connectivity. About the size of a human hair, these fibers are thin glass pipes that enable the transmission of data over the Internet. When connected directly to a home or office with such fibres, more data can be transmitted at a faster rate. To fully enable this service, telecommunications providers required a host of new technologies. Combining their expertise in photonics and shape memory alloys, PhasOptx created a new optical connectivity component in a range of products. These compact and costeffective devices were designed to enable very high data throughput, and support the delivery of reliable and stable FTTH service. Furthermore the PhasOptx Telecom subsidiary has been created in 2013. The same device has been used to develop new applications of optical fibres such a biosensors.

TeraXion (Quebec, QC) - Innovating at speed of Light

Projects	Description	Impact
Optical frequency Standard as reference; Multi-Channel Tunable equalizer (Université Laval) Integrated Dual-Wavelength Source, Narrow Linewidth lasers, Vibration Monitoring (Ottawa university); Low-cost coupling (Université de Sherbrooke)	Development of a multi-channel chromatic dispersion equalizer for high bit-rate communications; Development of an optical source for microwave photonics and of ultra-narrow linewidth lasers; Fibre phase sensitive OTDR for vibration monitoring; Efficient low-cost coupling from an optical fibre to a submicron silicon waveguide	CIPI projects where TeraXion has been involved have greatly contributed to enhance our products portfolio and create new market opportunities. Today, tunable chromatic dispersion compensators are a 50M$ market and TeraXion has become the leader. Low-cost coupling to silicon waveguide is a key aspect of our future technology platform opening a new market opportunity of more than 300M$.

Optical communication is any form of telecommunication that uses light as the transmission medium. An optical communication system consists of a transmitter, which encodes a message into an optical signal, a channel, which carries the signal to its destination, and a receiver, which reproduces the message from the received optical signal. In high speed optical communications, very large volumes of data are transmitted across a technology-laden network that is comprised of hardware, software and communications protocols. Telecommunications providers consistently aim to increase the speed of this information as it travels from the sender to the receiver. The challenge: data is distorted along the way. This is further complicated as information travels at different speeds and distances over different channels, causing various levels of distortion. To ensure information is properly received, the network must compensate for this distortion as data is transmitted over the network. TeraXion, a designer and manufacturer of state-of-the-art optical components and modules for high-speed fiber-optic transmission networks, fiber lasers and optical sensing applications has a technology to deliver on this objective. Their technology manages one channel at a time very effectively but they wanted to address multiple channels. The collaborative research projects created the opportunity to improve the company's products and market positioning.

WDI, Wise Devices Inc. (Markham, ON) - Real Time Image Stabilization for Live Animal Imaging

Projects	Description	Impact
Live Animal Imaging Active Stabilization Unit (Université Laval)	Development of a new image stabilization for microscopes	Now offer a new product called Live Animal Stabilization Sensor (LASS); Expect sales of $75k in 2013 and $150k in 2014

Optical microscopy has become the tool of choice in biology because it offers cellular and subcellular resolution with molecular specificity. Optical microscopes have been used to provide great insights in biology, especially when used in combination with transgenic animals that express fluorescent proteins in specific cell populations or with novel imaging modalities that do not require any exogenous labelling. Contrary to imaging cell cultures or ex vivo tissues, imaging live animals provides systemic information about interactions between various cell populations or various components of the body. However, this wealth of information comes at a cost since even under very controlled conditions, there is always sample movement resulting from animal breathing or heartbeat. This results in image distortion and prevents one from following the fast activity of a given cell population. In many cases, it renders the experiments impossible to carry out. Wise Devices Inc (WDI) was founded in April 2005 and has developed the world's first tracking auto focus sensor – a system that would allow the microscope to be in focus even when it was in motion. Today, WDI develops test, inspection and repair systems for flat panel display (FPD) manufacturing, which are used by the consumer to increase yield, reduce material loss. WDI continues to innovate not only within the FPD industry but has expanded the use of its technology into new applications such as Semiconductor and Solar Panel test and repair, as well as into the Biomedical field. The research project resulted in the development of a new imaging capability for live animals.

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CIPI Premier Affiliate Partners 1999-2012

2G Robotics
ABB Bomem Inc.
APN Inc.
Attodyne
AXIS Photonique Inc.
Bell University Labs
Biophage Pharma
Boreal Laser Inc.
Bragg Photonics
Brightwell Technologies inc.
BTI Systems
C2C Link Corporation
Christie Digital
CMC Microsystems
Cone Tec Investigations Inc
COPL
CorActive High Tech
Corvis
CSE-Communications Security Establishment
Cyrium Tech.
Cytogenetic Inc
Cytognomix Inc
Dalsa
DiCOS Technologies inc.
DÔ Network
Doric Lenses
Dragonwave
DRDC Valcartier
D-Tex
ELCAN Optical Technologies
Eli-Lilly (Canada)
Enablence
EXFO Electro-Optical Engineering
Fiber-Tech Optica
Fox-Tek
Gamma-medica ideas Canada inc.
GDG Environment
Genia
Gestion Technocap
Group IV Semiconductor
Honeywell
Hycal Research Laboratories
Hydro-Québec – IREQ
iCore
IGNIS
IMRA
Innovation PEI
Innovision
INO
Inolume
Intel
ITF Labs
JDS Uniphase
Kotura
Laboratoires Quidd
LanXESS Inc.
LxSix Photonics
Magnor
Matcor Advanced Technologies
MDS
Micralyne
Monteco
NanoQuébec
Neoptix
Nortel Networks
NOVELIS INC.
NRC – IFCI
NRC - Industrial Materials Institute
NRC - Institute for Microstructural Sciences
Nucryst Pharmaceuticals
O/E Land
OAML
OCE - Ontario Centre of Excellence
Olympus Canada
OneLight Corp.
Opalux
Opsens
Osaki Electric Co. Ltd
Osemi Canada
P&P optica
Palladium7
PARTEQ
PhasOptx
Photon Etc.
Plasmionique
Prompt
Pronto Medical Technologies
PV Labs
QPS Photronics
Rabbit Holes Holding
Reflex Photonics (Canada)
SciMed Tech.
Siborg Systems
Sigma
SiXtron Advanced Technologies
SOCPRA
SolarPro
Spectalis

Suncor Energy
Telops
Telus
TeraXion
The Fox Group
Thermoptik
Tidal Photonics
Trans Canada Pipeline (TCPL)
T-Ray Science
Unisearch Associates Inc.
Univalor
Vacci-Vet Inc
ViRexx
Xceed Molecular
Xeos
Xogen Technologies Inc.
Xsencor Tech.
Zenastra

CIPI Network Partners 1999-2012

University of Alberta
Algonquin College
University of British Columbia
University of Calgary
Carleton University
Concordia University
Dalhousie University
ÉTS- École de technologie supérieure
University Health Network
INRS-EMT
Université Laval
University of Lethbridge
University of Manitoba
McGill University
McMaster University
Université de Montréal
Mount Allison University
U. du Québec en Outaouais
U. of New Brunswick
OCAD University
U. of Ontario Inst. of Technology
University of Ottawa
École Polytechnique de Montréal
Queen's University
Ryerson University
U. de Sherbrooke
U. of Prince Edward Island
University of Regina
Simon Fraser University
University of Toronto
Victoria University
University Of Waterloo
The University of Western Ontario
Wilfrid Laurier University
Windsor University
York University

Awards to CIPI Researchers 1999-2012

International Society for Optics and Photonics

SPIE Fellows

Bao, Xiaoyi
Dubowski, Jan J.
Lessard, Roger A.
Meunier, Michel
Morandotti, Roberto
Sheng, Yunlong

American Physical Society

APS Physics Fellows

Bandrauk, André D.
Corkum, Paul B.
Laflamme, Raymond
Steinberg, Aephraim M.

Canadian Academy of Engineering

CAE Fellows

Kashyap, Raman
Meunier, Michel
Plant, David V.
Wu, Ke

The Canadian Association of Physicists

CAP Medal for Lifetime Achievement in Physics

Chin, See L.
Corkum, Paul B.

CAP - INO Medal for Outstanding Achievement in Applied Photonics

Bao, Xiaoyi

CAP - Herzberg Medal

Steinberg, Aephraim M.
Hessels, Eric

Alexander von Humboldt Foundation

Humboldt Research Award

Bandrauk, André D.
Chin, See L.

Institute of Electrical and Electronics Engineers

IEEE Fellows

Cartledge, John
Darcie, Thomas E.
Jan Bock, Wojtek
Leon-Garcia, Alberto
Plant, David V.
Rusch, Leslie Ann
Yevick, David O.

Optical Society of America

OSA Fellows

Aitchison, Stewart J.
Campbell, Melanie
Cartledge, John
Chen, Lawrence R.
Chin, See Leang
Corkum, Paul B.
Darcie, Thomas E.
Herman, Peter R.
Kashyap, Raman
Lit, John
Meunier, Michel
Piché, Michel
Plant, David V.
Sheng, Yunlong
Steinberg, Aephraim M.
Stolow, Albert
Strickland, Donna T.
Vallée, Réal

Charles Hard Townes Award

Corkum, Paul B.

Natural Sciences and Engineering Research Council of Canada

NSERC John C. Polanyi Award

Bandrauk, André D.
Corkum, Paul B.

NSERC E.W.R. Steacie Memorial Fellowships

Berini, Pierre
Brabec, Thomas
Hessels, Eric
Jaeger, Wolfgang
Morandotti, Roberto
Steinberg, Aephraim M.

NSERC - Herzberg Gold Medal

Corkum, Paul B.
Polanyi, John C.
Scaiano ,Tito

Royal Society of Canada

McNeil Medal

Miller, Dwayne R. J.

Killam Research Fellow

Jessop, Paul
Kashyap, Raman
Kumacheva, Eugenia

Order of Canada

Bandrauk, André D.
Corkum, Paul B.