V.

Evolution of a Photonics Education Program

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Abstract
The Photonics Technology program at Niagara College was first launched in 2001. Since that time, in an attempt to meet the joint needs of industry and students, Niagara has developed the technology program into a cluster of four programs related to photonic technology. Niagara is also building relationships with universities to deliver photonic course material to physics undergrad students using Niagara College Photonics facilities and faculty to create an undergraduate specialization in lasers.
This paper will review the development of the photonics cluster at Niagara College and present the current state of its evolution.

1. INTRODUCTION
As a result of the proliferation of photonic technology in virtually every sector of industry, many companies find themselves without the necessary optical and electro-optical expertise. In 2001 the Ontario Photonics Education and Training project (PET) established completely new Photonics Engineering Technician (2 years) and Photonics Engineering Technologist (3 years) programs at Niagara and Algonquin Colleges. With the conclusion of the 2007 winter term, Niagara College will have educated 3 cohorts of Photonic Engineering Technologists, and 4 cohorts of Photonics Engineering Technicians. Since the initial launch of these two programs both colleges have expanded their offerings in photonic education. This growing demand for photonic professionals is what fueled the creation of the original two Photonic programs. With the initial graduating class has come acceptance of Photonic Technicians and Technologists by industry. With acceptance has come greater demand for more professionals trained in the discipline of photonics. To this end Algonquin and Niagara Colleges have introduced a 4-year Bachelor of Applied Technology or BAT in Photonics, and Niagara College a 1-year Advanced Lasers Graduate Certificate. Although graduates are being readily hired by industry, recruitment of students into these new and often misunderstood programs has proven to be a substantial challenge.

2. PHOTONICS PROGRAMS

2.1 Introduction
In this section the individual photonic programs at Niagara will be reviewed. Changes in the program curriculum since inception will be described, and the reasons for those changes discussed.

2.2 Photonics Engineering Technology

The Photonics Engineering Technology program as launched in 2001 ran for 3 consecutive intakes from Fall 2001 until Fall 2003. In Fall 2004, Niagara College suspended intake of the Technology program in an attempt to bolster numbers for the new 4-year Bachelor of Applied Technology (Photonics) program. The removal of the 3-year program created a gap in the college's ability to retain students within the Photonics cluster. Students who had difficulty coping with the rigor of the BAT (Photonics) had only the option to transfer to the 2-year technician program if they were to remain in Photonics despite being better suited to a 3-year technology program. The lack of a 3-year program could be a contributing factor in poor retention rates in keeping BAT students within the Photonics cluster.

In 2006 changes were proposed and accepted to modify the curriculum of the Photonics Technology program. The Photonics Technology program is currently accepting an intake for the Fall 2007 term under the new model and is expected to run.

The adopted program model provides laddering of the Technician curriculum directly into that of the Technology program. Under the new model both the Technology and Technician programs share a common first year. Second year is also common with the exception of math courses. The new program model is shown in Table 1. This model provides students with several opportunities for movement within the photonics cluster. For struggling technologists it provides an exit point after two years which will provide the student with a Technician diploma. It also provides easy lateral movement for Technicians who after one or two years in the system decide to complete the third year and graduate with a Technologist diploma. When combined with courses designed to provide bridging from Technology to BAT, this model provides a complete pathway from Technician to BAT and in an attempt to maximize retention it provides a reverse pathway from BAT to Technician.

Some of the changes in curriculum address the recommendation made in the paper **Technician and technologist photonics teaching: An Ontario success story Jay Yatulis et. all.** In order to improve the students electronics manufacturing skill set a new course has been introduced. Manufacturing Technology for Photonics is a 3-hour per week course delivered in term 2. As an introductory course in manufacturing technology it exposes students to through–hole and surface mount soldering, epoxies, and printed circuit board fabrication. This will allow more advanced manufacturing technologies to be explored in the preexisting Manufacturing Photonics Components, and Photonics Manufacturing Systems courses.

When combining the Technology and Technician streams it was necessary to replace the Technologist version of Light and Lasers Principles with the Technician version. In order to improve the rigor of the Technologist's light and laser theory, the addition of the Advanced Laser Theory (3 credits) course in term 5 was made.

Another improvement made to the curriculum was to modify the Photonics Research Project so that it spans terms 5 and 6 (originally term 6 only). This will allow an improved treatment of the project, enable students to generate more reasonable timelines, and hopefully provide longer more meaningful contacts with industry partners. The first term will be used to develop the project and finalize details on what is to be accomplished. Any materials for fabricated parts of a design would be ordered at this time. The second term will be used to perform and complete any testing. A comprehensive paper will be prepared for the conclusion of this course

2.3 Photonics Engineering Technician

The Photonics Engineering Technician program has gone through several iterations since its initial launch in Fall 2001. Students of the first cohort were enrolled into the same core courses as Technologist students. In many cases the difficulty of the technologist courses was above the ability of students enrolled at the Technician level. This resulted in the creation of modified courses to provide an improved academic fit within the Technician program. The introductory manufacturing course described in 2.2 was introduced into the program for the Fall 2006 cohort. As discussed in 2.2 the current version of the Technician program is once again common with the Technologist program. In the new model Technician level courses are delivered to both streams, and additional theory is introduced in year 3 of the Technologist program to maintain the academic rigor of that program.

Photonic Engineering Technician

Crs. No.	Course Name	Hrs.
LEVEL 1		
CTEC1544	Computer Programming & Applications	60
ENGL1133	College English	45
MATH1131	Mathematics I for Technology	60
PHYS1108	Optics & Waves	105
TECH1244	Health & Safety for Technology	45
TECH1271	Future Trends in Advanced Technology	45
LEVEL 2		
ELNC1220	Electrical Principles for Photonics	75
MATH1231	Mathematics II for Technology	60
MMFG1279	Manufacturing Technology for Photonics	45
PHTN1220	Optic/Optical Fibre Principles	90
PHYS1220	Kinematics & Dynamics	75
LEVEL 3		
CTEC1330	Data & Telecommunications	60
ELNC1320	Electronic Principles for Photonics	90
MATH1299	Statistics for Technicians	30
PHTN1300	Principles of Light Sources and Lasers	75
PHTN1334	Fibre Optics Communication	75
GenEd	General Education Elective	45
LEVEL 4		
ELNC1430	Digital Technology	60
PHTN1400	Principles of Laser Systems	75
PHTN1431	Manufacturing Photonics Components	75
PHTN1432	Vacuum & Thin Film Coating Applications	60
GenEd	General Education Elective	45

Photonic Engineering Technology

Crs. No.	Course Name	Hrs.
LEVEL 1		
CTEC1544	Computer Programming & Applications	60
ENGL1133	College English	45
MATH1131	Mathematics I for Technology	60
PHYS1108	Optics & Waves	105
TECH1244	Health & Safety for Technology	45
TECH1271	Future Trends in Advanced Technology	45
LEVEL 2		
ELNC1220	Electrical Principles for Photonics	75
MATH1231	Mathematics II for Technology	60
MMFG1279	Manufacturing Technology for Photonics	45
PHTN1220	Optic/Optical Fibre Principles	90
PHYS1220	Kinematics & Dynamics	75
LEVEL 3		
CTEC1330	Data & Telecommunications	60
ELNC1320	Electronic Principles for Photonics	90
MATH1331	Mathematics III for Technology	45
PHTN1300	Principles of Light Sources and Lasers	75
PHTN1334	Fibre Optics Communication	75
GenEd	General Education Elective	45
LEVEL 4		
ELNC1430	Digital Technology	60
PHTN1400	Principles of Laser Systems	75
PHTN1431	Manufacturing Photonics Components	75
PHTN1432	Vacuum & Thin Film Coating Applications	60
GenEd	General Education Elective	45
MATH1431	Mathematics IV for Technology	45
LEVEL 5		
ENGL1430	Technical Communications	45
MATH1637	Statistics	45
PHTN1500	Advanced Laser Theory	45
PHTN1530	Advanced Optical Systems	75
PHTN1531	Opto-Electronic Devices	60
PHTN1533	Photonics Research Project I	30
PHYS1630	Heat Transfer	60
LEVEL 6		
ELEC1532	Industrial Controls - PLC	75
PHTN1630	Photonics Manufacturing Systems	75
PHTN1631	Imaging/Image Processing	60
PHTN1632	Laser/Matter Interaction	75
PHTN1633	Photonics Research Project II	45

Table 1 Photonics Technician and Technology Programs of Instruction

2.4 Bachelor of Applied Technology (Photonics)

The Bachelor of Applied Technology (Photonics) or BAT was launched in Fall 2004. The 4-year BAT program is designed to provide industry with photonic undergraduates who possess the theoretical background comparable to that of a university undergraduate science degree and also to provide an individual with hands-on technical skills comparable to that of a Technologist. The graduate of this program is industry ready, requiring minimal on-the-job training.

The curriculum of the BAT program is unique in that it is modeled after a top down approach to learning. As shown in Table 2, students of the BAT program are exposed to applications of photonics immediately in term one. Unlike a traditional university degree which begins with minimal exposure to the discipline of choice, instead focusing solely on the fundamentals, the BAT degree immerses the students in lab based activities exposing them to advanced applications and concepts immediately. Initially these concepts are treated from a perspective not requiring an understanding of the underlying principles. As the program progresses more of these principles behind the concepts are revealed until the student is left with a complete understanding of both fundamentals and advanced concept. The advantage of this model is that it engages the student into the material from day one. Attrition is often the result of students losing interest in the material, or failing to understand how the fundamentals being studied relate to the applications that may have drawn the student into the program in the first place.

The BAT program received a second intake of students in Fall 2005, but the intakes for Fall 2006 and 2007 have been suspended due to recruitment difficulties. Although the college's industry partners have expressed interest in the graduates of this program, the challenges of recruiting university level students to take a degree at a college has proven problematic. Science and technology teachers at the secondary school level have proven to be invaluable allies in correcting the misconception that a college BAT degree is somehow less valuable than a university Bachelor's degree.

LEVEL 1		
Crs. No.	**Course Name**	**Hrs.**
BATP9101	Occupational Health and Safety and Ethics	45
BATP9102	Optics and Waves	75
BATP9103	Trends in Photonics	45
BMAT9104	Calculus I	60
BPRO9105	Programming I	45
BSCI9106	General Chemistry	45
LEVEL 2		
BATP9201	Optics/Optical Fibre Principles	75
BELN9202	Electro-technology	75
BMAT9203	Calculus II	60
BPRO9204	Programming II	45
BSCI9205	Kinematics and Dynamics	60
LEVEL 3		
BATP9301	Fundamentals of Light Sources	75
BATP9302	Interfacing	60
BATP9303	Optics/Optical Fibre Devices	60
BELN9304	Semiconductors and Logic	60
BMAT9305	Linear Algebra	45
CPLN9061	Career Planning and Development	
	Liberal Studies Elective	45
LEVEL 4		
BATP9401	Laser Systems	75
BATP9402	Manufacturing Photonics Components	60
BATP9404	Telecommunications	60
BCOM9403	Technical Communications	45
BMAT9405	Differential Equations	45
BMAT9406	Statistics	45
LEVEL 5	**Co-op**	
COOP9402	Co-op Work Placement I	

LEVEL 6		
Course Name	**Course Name**	**Hrs.**
BATP9501	Advanced Optical Systems	75
BATP9502	Control Systems	60
BATP9503	Photonics Manufacturing Systems	75
BATP9504	Thin Film and Vacuum Systems	75
	Liberal Studies Elective	45
LEVEL 7	**Co-op**	
COOP	Co-op Work Placement II	
LEVEL 8		
BATP9601	Image/Signal Processing	60
BATP9602	Opto-Electronic Devices	75
BMAT9603	Advanced Calculus	45
BMGT9604	Business Principles	60
BSCI9605	Electro-Magnetic Theory	45
	Liberal Studies Elective	45
LEVEL 9	**Co-op**	
COOP	Co-op Work Placement III	
LEVEL 10		
BATP9701	Advanced Optical Theory	45
BATP9702	Photonics Research Project	60
BATP9703	Thermodynamics and Heat Transfer	45
BSCI9704	Materials Science	60
BSCI9705	Quantum Physics	45
	Liberal Studies Elective	45
LEVEL 11		
BATP9801	Advanced Research Project	60
BATP9802	Bio/Medical Photonics	60
BOPS9803	Operations Management	60
BSCI9804	Solid State Physics	45
	Liberal Studies Elective	45

Table 2 Bachelor of Applied Technology (Photonics) Program of Instruction

2.5 Advanced Lasers Graduate Certificate

The Advanced Lasers Graduate Certificate is a one year program providing an amalgam of courses running in the BAT and Technology programs. The program received approval from Niagara College to run its first intake for Fall 2007. This intake was later suspended as a result of low application numbers (public marketing for the program did not receive approval until February 2007). The college will be marketing for a Fall 2008 intake.

The Advanced Lasers program was designed to accomplish two tasks;

1. Provide skilled and theoretical laser training to those with a technical or engineering background
2. To economize the BAT (Photonics) program.

The program provides students with the expertise to work at an advanced operator or design level and is open to any student with a science or technology diploma and/or degree, including electronics, mechanical and electrical engineering technology graduates. The applied & practical skills acquired in this program are required for direct entry into industry which should be of particular interest to students of university physics programs which are classical in nature. The program provides hands-on experience in the areas of laser operation, maintenance, reprocessing and design. With the exception of business principles, every course in this program features a major laboratory component.

The Advanced Lasers program was originally designed to leverage off of preexisting courses from the BAT and Technology programs, using students of the Advanced Lasers program to help offset the effect of attrition of students. This was seen to provide improved economy of the BAT program and year 3 of the Technologists program, while at the same time providing a useful service to industry, and engineering professionals. Since the design phase of the program much has changed. The program has necessarily morphed into one that can be delivered independent of the other photonics programs. In order to recruit the additional students required to allow the Advanced Lasers program to run independently Niagara has created a partnership with Brock University.

An articulation agreement between the Brock University Bachelor of Science Honours Degree in Physics and the Niagara College Advanced Lasers Graduate Certificate program has been created. The Senate of Brock University has approved the establishment of a concentration in Applied Optics and Laser Technology within its current honours Bachelor of Science program. This agreement is designed to enable students to complete concurrently an honours degree in Physics from Brock University and a graduate certificate in Advanced Lasers from Niagara College. The current structure of the Advanced Lasers Graduate Certificate as accepted by both Niagara College and Brock is provided in Table 3.

LEVEL 1		
Crs. No.	**Course Name**	**Hrs.**
BATP9301	Fundamentals of Light Sources	75
BATP9303	Optics/Optical Fibre Devices	60
PHTN1530	Advanced Optical Systems	75
PHTN1531	Opto-Electronic Devices	60

LEVEL 2		
Crs. No.	**Course Name**	**Cr.**
BATP9401	Laser Systems	75
BMGT9604	Business Principles	60
MMFG9101	Laser Maintenance and Manufacturing Technology	60
PHTN1432	Vacuum and Thin Film Coating Applications	60
PHTN1632	Laser Matter Interaction	75

Table 3 Advanced Lasers Graduate Certificate Program of Instruction

2.6 Additional Academic Options

Niagara College currently offers additional academic options to students of the Photonics programs. Given the similarities in program curriculum between photonics and other technology programs, select Photonics graduates have been provided with a one year advanced standing in Niagara College's Electronics, and Electrical Technician programs. The completed dual diploma has proven to be extremely popular with employers looking for employees with a broad base of experience.

In partnership with the Hoseo University of Korea, Niagara College is piloting a hybrid English as a Second Language (ESL) and Photonics Technology program. This project will bring select students who have completed their second year in the Bachelor of Science at Hoseo University to Niagara College for eight weeks of training. The first six weeks provides traditional ESL training to be followed by two weeks of hands-on training to develop skills in the field of display technology. Niagara College expects to host the first 20 students of this program in July of 2007.

3. RECRUITMENT

The challenges and successes of recruiting for the photonics programs at Niagara College have been explored[1].

In a move to improve recruitment of students the Technology Division has hired an individual with a science background to work part time as a Program Liaison Officer. This individual is responsible for recruiting activities within the division, with special focus on the photonics program cluster. Internally the Program Liaison Officer organizes events, tours, and provides support to Niagara College's recruitment department. The most effective recruitment technique at Niagara College's disposal continues[1] to be on site tours of the lab facilities by high school students. New recruitment activities have included attendance at popular cultures events such as science fiction exhibitions. The success of recruiting at these events has been mixed, but has resulted in exposure of the program not just at the event, but also by television, print, and Internet media present at the event.

4. FACILITIES

The photonic facilities at Niagara College have previously been described in great detail[1]. Since that time numerous upgrades and improvements have been realized, the most notable as described below;

a. New laser machining lab:
    i. Laser Marker
    ii. Laser Welder
    iii. Laser (Micro)Machining Centre

b. New Class 4 laser lab
c. Dedicated research lab space
    i. 100W CO_2 laser
    ii. Pyrocam (10.6um laser profilometer)
    iii. Infrared camera system
d. Scanning Electron Microscope
e. Lesker 3 target sputtering thin-film deposition system
f. Two new aerospace grade laser projectors

Additional equipment to be donated to Niagara College, but as yet unrealized includes a computer controlled polisher capable of polishing high-end aspheric lens.

Improvements to facilities and equipment are primarily the result of excellent relations with industry. Employed graduates frequently donate equipment and materials to the college. This shows the good will of our partners, but also demonstrates industries realization that the college is training the next generation of photonic professionals. By training students with equipment donated by industry the college is providing industry with employees who require significantly less on the job training, saving time and money.

5. RESEARCH

The introduction of photonics curriculum at the college level occurred at approximately the same time that the province of Ontario began to encourage applied research at College institutions. Given Niagara College's unique collection of photonic facilities and faculty it has become involved in several applied research projects.

Current projects funded by the Ontario InnovationTrust;

a. Laser Applications in the Greenhouse Industry
b. Use of Photonic Technologies to Control Disease Spread in Greenhouse Production

Niagara College is in the process of submitting other proposals that would include research into the areas of display technology and laser induced breakdown spectroscopy.

The applied research projects are designed to help local industry and garner attention for the college and the program. Funded research has resulted in dedicated lab space and new equipment that can be used for both the intended research and as learning tools during scheduled classes. The most important aim of the projects is to involve students in collaborative relationships with industry. Past projects have resulted in employment opportunities for students who have worked with industry on these projects. The research crosses disciplines, and helps to demonstrate to students the importance of breadth of knowledge.

6. RECOMMENDATIONS

6.1 Co-Operative Learning

Providing Co-operative learning opportunities for BAT students was initially challenging. This was deemed to be primarily a result of industry's inexperience with a photonics undergraduate degree program, and as a secondary concern most members of industry are seeking eight month placements, where as the BAT program only offers 4 month placement opportunities. As of the end of March 2007, BAT co-op placements are progressing slowly although at an improved rate over the same time in 2006.

Co-ops have been an immensely successful and important component of other Technology programs at Niagara College. They provide on the job training, and industrial experience of the kind that is not reproducible in a class environment. It also provides employers the opportunity to try out students at little risk or cost to themselves and many times results in permanent full-time employment of the student upon graduation.

Co-operative learning is currently missing from the curriculum of the Photonics Technology program. Given the success of co-operative learning in other programs and consultation with members of industry, it is recommended that the Photonics Technology program be aligned with the other existing Technologist programs to include one four month co-op, and one eight month co-op.

6.2 Facilities

Optical lens and mirror manufacturers in Ontario have begun to employ graduates of the Photonics programs. Unfortunately the college facilities do not currently include any optical lens manufacturing or polishing equipment on which to train students. One industrial partner has made motions to provide Niagara College with a donation of a lens polisher, and proposed the loan of two others. This will still leave the college with a requirement for equipment for the generation and grinding of lenses and mirrors.

6.3 Articulations

Unofficial articulation agreements between Photonics, Electronics, and Electrical programs need to be formalized and expanded. This agreement will allow a student who has completed Photonics at the Technician or Technologist level direct entrance into year 2 of the Electronics or Electrical program. This agreement already exists in principle, and has been used by several students successfully. Formalizing the agreements will allow them to be used as recruitment tools, and hopefully make the Photonics program more appealing to those with interests outside of the Photonics discipline. Other possible articulations into Computer Technology and from Mechanical Technology are being considered.

7. SUMMARY

Photonics curriculum at the college level is still a relatively new introduction and is in a continual state of self-improvement. With the assistance of industry partners, graduates, and the students currently in the system, Niagara College is endeavouring to create curriculum that will meet the needs of all parties. Given the continued demand for photonic professionals that has been communicated to the college by industry it is assured that the college photonic programs will enjoy long life in one form or another. As the general populace better understands the term "photonics", and photonic professionals become more ingrained within the fabric of local industry, recruiting pressures will begin to ease. With continual interest by partners to collaborate on applied photonics research, Niagara College is assured exposure not only locally, but internationally. Continual research and donations by members of industry also ensure that students will be training in modern facilities for many years to come.

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REFERENCES

1. Technician and technologist photonics teaching: An Ontario success story Jay Yatulis et. all

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Back To Index