

# Industry-Based Projects in Photonics Technician Education

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## ABSTRACT

Students in photonics technology associate degree programs have two short years to prepare for employment as technicians. Recognizing that there is little in the traditional lecture/lab format of instruction that allows students to practice real-world project planning, time management and technical problem-solving skills, the authors have collaborated to provide students with authentic “real-world” industry problems in a final one or two semester capstone course. In this paper we present several student projects, describe barriers to successful project completion and strategies to improve outcomes.

**Keywords:** Capstone project, photonics education, community college, technician, inquiry, college-industry partnership, problem solving, critical thinking

## 1. INTRODUCTION

According to a 2009 survey conducted on behalf of the American Association of Colleges and Universities (AACU)<sup>1</sup>, employers “are most supportive of practices that demonstrate; a) students’ acquisition of both depth of knowledge in their major and broad skills, b) students’ ability to apply their college learning in real-world settings, and c) their ability to conduct research and develop evidence-based analysis”. The vast majority (79%) of employers believe that colleges should put greater emphasis on learning outcomes that include “the ability to apply knowledge and skills to real-world settings through internships or other hands-on experiences”.

Finding internships can be problematic, however, especially during difficult economic times when employers are unable to offer paid short-term employment to students. Community college students are often non-traditional, that is, older students responsible for household and family expenses, so a semester-long unpaid internship is unrealistic for most students. In this environment we have developed relationships with local industry that provide support for senior capstone projects that can be completed as part of a students’ regular course of study in the final semester (or two semesters) of their academic program. This real-world emphasis on student projects has been lauded as a great way to “bridge the gap” between theory and practice, providing students with a unique opportunity to gain valuable real-world experience while at the same time providing employers the opportunity to vet potential future employees. Another benefit to colleges is that the companies typically provide the components, equipment, mentorship, and resources that otherwise would be difficult or impossible to replicate in the classroom.

## 2. SPRINGFIELD TECHNICAL COMMUNITY COLLEGE (SPRINGFIELD, MA)

The Laser Electro-Optics Technology (LEOT) associate degree program at Springfield Technical Community College (STCC) includes a two-semester senior capstone project course sequence; Senior Project Research (LEOT 365 - fall semester) and Senior Projects (LEOT 465 - spring semester). LEOT 365 is a 2-credit fall semester course (1 hour lecture/3 hour lab) in which students research potential capstone project ideas, and develop and present a detailed project proposal that will guide their work in the spring semester LEOT 465 course (4 credits – 1 hour lecture/6 hour lab). Students in the LEOT 365 course investigate key aspects of project development including in-depth research on their project topic, project management, development of design specs and Gantt charts, identifying required resources, prototype development, and testing requirements. At the end of the spring semester, students submit a final written project report, and present their results in both an oral PowerPoint presentation to faculty and students, and in a poster

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board session to the LEOT industrial advisory board, which is also open to the general campus community, local high schools and businesses.

Over the past several years, great effort has been made to identify and recruit potential industrial sponsors from local laser and optics companies for student projects. Companies that have been active sponsors of STCC's student capstone projects have included Prima Laser in Springfield, MA, IPG Photonics in Oxford, MA, Nufern Inc. in East Granby, CT, RSL Fiber Systems in East Hartford, CT, JDS Uniphase in Bloomfield, CT, and others.

During the fall and spring semesters, students are required to attend weekly "Monday morning" status meetings with their class in which they report out on their accomplishments from the prior week and set goals for the upcoming week. Depending on the availability of the industry mentor, students also meet either weekly or bi-weekly at the company site to discuss progress on their projects, and in many cases, actually work on their projects in the company's labs when specialized equipment is needed – a win-win situation.

### ***2.1 Sponsored Capstone Project: Developing a fiber optic tail light system for Volvo trucks in Brazil***

In September 2011, RSL Fiber Systems of East Hartford, CT approached the LEOT program at STCC with a potential student capstone project in collaboration with Volvo Trucks in Brazil. The goal of the project was to design and produce a working prototype of a fiber optic tail light system capable of delivering light from remotely located LEDs to the exterior tail lights on a Volvo truck via fiber optic cable. The system was to be designed to be retrofitted to existing Volvo truck tail light fixtures and produce the same light output as a conventional tail light.

The rationale for the project stems from the fact that traditional incandescent tail lights are fragile, susceptible to moisture and other environmental conditions and have a relatively short lifespan. Light Emitting Diodes (LEDs), on the other hand, are more durable and energy efficient, and are fast becoming a replacement for conventional light bulbs in automotive applications. While much more robust, the LED is still susceptible to moisture and other exposure problems. For example, a boat trailer must still have its tail lights disconnected to avoid short circuits when launching a boat into the water. The same issue is prevalent in trucks designed to operate in rugged environments where water and other environmental factors may compromise tail light (and headlight) operation. In this project, the LEDs and their circuits would be placed into a waterproof, shockproof enclosure and remotely located in the cab of the truck and the light would be delivered safely to the tail lights via fiber optic cable.

RSL Fiber Systems of East Hartford, CT is known for developing sophisticated remote lighting systems on a large scale for naval ships as well as commercial remote lighting applications. To help expand their business into the consumer market, the results of this project will help RSLF demonstrate the application of their technology in Volvo Trucks in Brazil, which would like to integrate such a lighting system into their Concept Truck due for 2013.



Figure 1 – (Left) Prototype LED enclosure. (Right) High powered LED mounted for x-y positioning.

Over the course of two semesters, an STCC LEOT student worked closely with RSLF's technical staff and counterparts from Volvo Trucks in Brazil via bi-weekly conference calls and site visits to RSL Fiber Systems to establish the design criteria and brainstorm possible solutions. Of the key issues to be addressed were the selection of appropriate LEDs

capable of providing sufficient light output needed to overcome fiber optic coupling losses, experimenting with different types of optical fiber (i.e., solid core versus fiber bundles; glass versus plastic, etc.) to determine the most cost effective delivery method, and measuring the luminous output of the system to ensure that is comparable to traditional incandescent bulb tail lights. After several months of research, evaluation and prototype testing, the student was able to successfully demonstrate a viable fiber optic tail light system to RSL Fiber Systems and Volvo Trucks in a final poster board presentation at the LEOT program's industrial annual advisory board meeting.



Figure 2 - (Left) Light output for bulb (left) versus LED (right). (Right) Visibility of bulb (left) versus LED (right) at 30 ft.

### 2.2 Sponsored Capstone Project: Building a fiber laser demonstration unit

Over the past decade, fiber lasers have emerged as a new and cutting edge alternative to traditional CO<sub>2</sub> gas lasers and solid state Nd:YAG lasers in a multitude of industrial, commercial, and medical applications. One of the challenges this growth presents to technician education programs is the specialized laboratory equipment and components needed to properly train students with the knowledge and skills needed to be productive in the fiber laser field. With this in mind, Nufern, Inc. in East Granby, CT, a leading manufacturer of fiber lasers and long-time employer of STCC LEOT graduates “stepped up to the plate” to provide STCC LEOT students with the equipment, components, resources, funding and mentoring needed to build an actual working 5-Watt Ytterbium-doped fiber laser (1064 nm wavelength) for use in the STCC LEOT laboratories.

Over two years (2010-2011 and 2011-2012 academic years) several teams of STCC LEOT students worked with engineers and scientists at Nufern to develop working fiber laser demonstration units with the potential for being marketed as a “fiber laser education kit.” Nufern provided all of the discrete components required to construct the laser including pump lasers, active fiber, Bragg gratings, couplers, housing and power supply. Over the two-semester senior project course sequence, students visited Nufern’s plant on a bi-weekly basis to receive mentoring from engineers and scientists, and were provided specialized on-the-job training in component handling, fiber winding and splicing, and specific testing procedures used by Nufern in the manufacturing of their lasers. The completed and functional laser is shown in Figure 3.



Figure 3 –(Right) Fiber laser gain medium and pump lasers (Left) Ytterbium-doped fiber laser demonstration unit.

During the 2011-2012 academic year, Nufern sponsored another capstone project involving the design and construction of an automated fiber laser final test unit. The fiber laser test unit was designed using a commercial thick gauge steel tool box to ensure laser safety, and modified to accommodate test equipment, wiring, and interlock hardware. The test unit is capable of measuring laser output power and wavelength automatically and logging using data using LabView in the final test stage of Nufern's fiber laser manufacturing line. This specialized training and technical support has resulted in LEOT graduates with the real-world knowledge and skills desperately needed by Nufern and other companies – skills that would be difficult or impossible to teach in the classroom.



Figure 4 – (Left) Unit under test. (Right) Ophir StarLab software interfaced with LabView for measuring laser

### 3. THREE RIVERS COMMUNITY COLLEGE (NORWICH, CT)

The Laser and Fiber Optic Technology (LFOT) associate degree program at Three Rivers Community College (TRCC) has required a capstone project in the final semester of study for many years.<sup>2</sup> In Spring 2012, the time devoted to the project course increased from 3 to 5 hours per week and the “Interdisciplinary Capstone Design” course became a requirement for students in the Electrical Engineering Technology (EET) and Manufacturing Engineering Technology (MfgET) as well as LFOT. Working in interdisciplinary teams, students are required to develop a project management plan, including design specifications, budget and Gantt charts and, over the semester, to produce a prototype subject to testing. Weekly written status reports and conferences with the instructor are used to reinforce time management, identify potential problems and keep projects on track. At the end of the semester, students submit a final written project report and present their results in a poster board session to the LFOT Industry Advisory Committee and other students in the LFOT program.

In the first years of the project requirement, students created their own projects from equipment in the LFOT laboratories, for example, a project to develop a machine vision system to count quarters in an array of coins on a rotating platform. Since there is no college or departmental funding to support projects, the TRCC SPIE Student Chapter pledged up to \$50 per person each year for supplies. In some cases, a project would not require any funding and students were free to share funds with peers if they so desired. Lack of funding prohibited some projects from being completed or even attempted, but it also forced students to be creative, substituting inexpensive and “found” items where possible.

One advantage of an industry-supported project is the financial backing that often goes with it. Mentoring by industry professionals is an even more valuable benefit, and the desire to please someone who may influence future job prospects is powerful. We will describe three of the industry- supported projects completed by TRCC students: the first completed on campus with industry oversight, the second carried out at the company location and a third project that was not a success for several reasons and so may serve as an example of what not to do.

#### 3.1 On-Campus Sponsored Design Competition: Solar Tracker

In 2010, one of the authors (G. Tomasi, President and CTO, RSL Fiber Systems) contacted TRCC with a proposal for a student competition to design and build a solar tracker/collector that would transmit sunlight into an optical fiber. The design was to use inexpensive off-the-shelf parts and be completed in one semester. Each competing college (two took

up the challenge) would receive \$1000 for project expenses and the winning design would receive a cash prize for the department.

A team of four LFOT students began working on the project with a visit to RSL Fiber Systems, meeting with the engineer who would oversee the project. A recent college graduate, he acted as mentor to the students throughout the semester. The students quickly decided to build a Fresnel lens-based system with further focusing provided by a small convex lens. As always, the most difficult task was designing and building the mechanical support system. The team planned a large open cube of perforated angle iron mounted on a base so that it was free to rotate in one dimension, however the actual construction of the frame was problematic. Fortunately, a student from the Manufacturing Engineering Technology program offered to weld the frame for them in her home shop. (See Figure 5.) A pair of sensors on either side of a small piece of wood was mounted on one side of the top of the frame; this arrangement was used to track the motion of the sun. A small motor moved the entire assembly slightly toward the west when the eastern sensor fell in the shade of the piece of wood.

Once the major pieces were ordered and assembly had begun, the students realized they did not have the specifications for the fiber that was to receive the light. The RSLF engineer suggested they contact OFS in Avon, CT for samples of suitable fiber. In retrospect it would have been better for students to have a fiber “target” to design for right from the beginning; nonetheless their final design transmitted sufficient light that they were deemed winners of the competition. (It helped that the other college team did not complete the project.) The prize was a \$2000 award to the LFOT program, a “small fortune” that was used to purchase hand tools for the senior project lab and provide supplies for two more years of senior projects.



Figure 5 - (left) the completed solar tracker/collector. (right) close-up of lens, fiber collimator and output from the end of the fiber. Not visible is an IR filter located above the lens.

In the following two years, additional students were able to completely redesign and build the solar tracker/collector, thanks to the RLS Fiber Systems prize money. The same RSLF engineer served as mentor in both 2011 and 2012. The 2011 team of three students decided to try a mirror-based Cassegrain-type system rather than use a Fresnel lens. Using FRED software, available to the college through under the Photon Engineering’s University Gratis program, one member of the team developed the optical design while the others worked on redesigning the electronics and mechanical support. The group was beset with problems including a primary mirror that did not match published specifications and several weeks of rainy weather that prevented testing the optical system. The biggest problem was spending far too much time (over) designing and not leaving enough time to build a prototype.

In 2012, the capstone project class was very small since it had not yet become a graduation requirement for students in the Electrical and Manufacturing Engineering Technologies; only one student took on the challenge of working with RSL Fiber Systems on the project. The student who redesigned and prototyped the solar tracker/collector was working full time as the manager of a fast food restaurant and at the same time he was taking a course overload. Yet, he still managed to build a lightweight, inexpensive mirror system that combined the best features of the two previous designs. Having the optical fiber on hand at the beginning of the project greatly simplified the process since he was able to incorporate its characteristics in the design, which he created using FRED software. He also removed the heavy sensor-and-wood tracking module, replacing it with two sensors located just below the rim on opposite sides of the parabolic primary mirror. As the sun moves and one sensor is in shadow, the assembly rotates until the irradiance on both sensors is equalized. Unfortunately a week of cloudy and rainy days at the end of the semester prevented the final testing of the device with RSL Fibersystem’s instrumentation, which was planned for the day of the LFOT Industry Advisory

Committee meeting. Nonetheless, discovering what appears to be a similar design in a newspaper article on fiber lighting of a proposed underground New York City park was an exciting clue that the student was on the right track.<sup>3</sup>



Figure 6 – Revised version of the solar tracker/collector using a lightweight Cassegrain mirror system. Left: Mirror assembly with motor to the left. Right: Light sensors are mounted below the rim of the mirror on opposite sides.

### 3.2 Off-campus project: Study of Super Polished Surfaces

As an adjunct faculty at TRCC, co-author F. Tinker (President, Aperture Optical Sciences) hired a TRCC student as a part-time intern and recognized an opportunity that would allow the student to complete a meaningful capstone project. With the assistance of AOS, the student and a friend submitted a capstone project proposal to create surface roughness masters of silicon carbide (SiC) brought to a super polished finish (roughness measurement  $\leq 2 \text{ \AA}$ ). In order to complete the project, the students needed to understand what is meant by surface roughness, how roughness data is collected and analyzed, and the process for achieving a super polished finish.

The work was completely overseen by an AOS engineer at the company site. Students provided weekly progress reports to the instructor that were orders of magnitude more professional and informative than those submitted by students working in college labs. It was clear that they took their position as researchers seriously and that they were being closely mentored to produce professional work. The final report produced by the students was a comprehensive binder including the applicable ISO 10110-8 standard, a document on Fundamentals of Scanning White Light Interferometry and Microscopy for NewView (ZYGO), documentation defining surface parameters, data and graphs for the masters they polished and measured, and a final report that could be used as a tutorial in other courses.

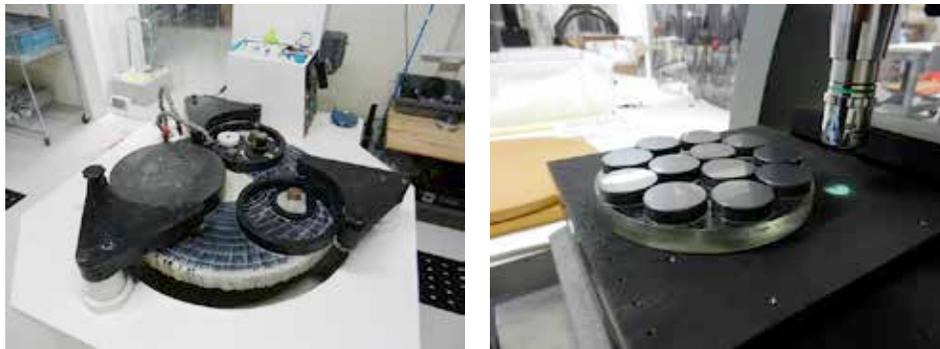


Figure 7- (Left) Roughness masters polishing on a 36 inch planetary polishing machine. (Right) Masters readied for measuring on a NewView white light scanning profilometer.

Although the students did not reach the goal of super polished finish by the end of the semester project (their sample measured just over  $5 \text{ \AA}$ ) the project was a success because of the deep understanding and skills developed – in-demand skills such as polishing and measurement techniques that the college is simply not equipped to teach. According to the

final report, “While our project was not completed to the degree we were hoping, we were extremely successful in developing a wealth of knowledge... as well as be(ing) trained in many aspects of polishing and roughness testing.”



Figure 8 – Student working with Zygo MetroPro software and white light profilometer.

### ***3.3 How not to do a sponsored project***

In the late spring of 2011, TRCC was contacted through a third party by an entrepreneur (who will not be identified) looking for assistance with a project to purify ship bilge water using fiber-delivered ultraviolet light. Three students were interested in participating; two were Navy veterans and one had significant fiber optic experience. Since the project was to begin in the summer after the academic year had ended, the students were encouraged to meet with the project director on their own and report back to the instructor on the work’s suitability as a capstone project. All three were non-traditional students with considerable technical experience in various fields.

After the initial June meeting, the students reported that their contact was in a hurry to complete the project. Since the college is not open at night in the summer and the students worked at their jobs during the day, summer collaboration was difficult. Also, the faculty member overseeing the project was only occasionally available due to other summer commitments, and the college would not allow students to enter the lab without a faculty member present. Oversight by a faculty member was further complicated by the secrecy surrounding the project; the students had signed a non-disclosure agreement and were reluctant to ask for direction for fear of violating the agreement.

Despite frequent emails from the contact requesting updates, students were able to accomplish little in the summer besides researching various approaches to the problem of bilge water purification. The contact began dangling tantalizing hints about filing for an SBIR and forming a corporation that would hire multiple TRCC graduates and local veterans. The students may have found this prospect encouraging even though at least one of the Navy veterans on the team was skeptical that the new approach would be adopted over current technology.

According to the students’ formal proposal presented in September, they would “construct plans and a prototype of a light delivery mechanism to send ... ultraviolet light into bilge systems to break down cellular/molecular matter in bilges and piping capable of being used in sea going vessels.” The students would design and build a prototype at one UV wavelength and provide suggestions for extending the system to multiple specific UV wavelengths. The contact provided the students with a list of suggested UV sources and sent one of them a personal check for \$500 to cover expenses. Not only was the amount insufficient to complete the project as required, but sending funds directly to a student also removed college oversight of the budget. This proved to be a point of contention after the semester completed.

The instructor made contacts with several industry experts, principally in the fiber optic lighting industry, and encouraged the students to seek their guidance and advice. Since the students had signed a non-disclosure agreement, discussion of specifics was impossible, if, in fact, the students really understood the specifics since the contact spoke mainly in generalities. Nonetheless, by mid October, the students had gathered enough information to believe that “the physics of what we are trying to do won’t work”. At that point, they began to feel the pressure to complete the project course with a passing grade, so they informed the contact that due to budget and instrumentation constraints they would

do a proof of concept with visible light for his approval. The project was completed and presented in December, at which point one of the three students graduated. The student who received the support check returned the balance through a cashier's check. Two months later, the contact claimed not to have received the check so it was reissued and sent by registered mail.

The contact requested a meeting the following semester to determine how the project could continue to go forward with TRCC students. Only one of the remaining students had any interest, so he and the faculty advisor met with the entrepreneur. It was clear from this meeting that the gentleman was not expert in fiber optic sources, coupling or properties and his focus seemed to have shifted to tunable UV sources. We tried to make it clear that the work (as we understood it from his vague presentation) was beyond the scope of our college labs and our students' knowledge and skills, yet he persisted in asking for updates throughout the spring semester. The remaining student sent a "final report" suggesting some technologies that might be applicable but noting it was difficult to be sure when the parameters of the project were so ill defined.

#### **4. RECOMMENDATIONS FOR SUCCESSFUL PROJECTS**

Industry-supported capstone projects have proven to be invaluable for providing real-world experience to students without causing disruptions or delays to their academic progress. In order to maximize the likelihood of a successful project we recommend that:

- Project objectives and requirements (including time expectations) must be clear to both students and industry mentor.
- Any funding or materials should be given directly to the college and not to the student.
- Require clear and complete written records of all project work. Records need to be kept in a signed, dated notebook.
- Ensure that any issues of proprietary information are worked out before the project begins.
- As part of project management, students should create a timeline for completion, and revisit this frequently with the instructor/industry mentor throughout the course of the project.
- Constantly remind students that time is valuable, so use it wisely.
- Deadlines are to be strictly adhered to. The real world doesn't want to hear excuses about why something was not completed on time.

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