ANNUAL EVALUATION REPORT
LASER-TEC
YEAR 7, JUNE 2019 - JUNE 2020

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PART I

INTRODUCTION

LASER-TEC is the National Science Foundation Advanced Technological Education Center of Excellence in Lasers and Fiber Optics (the Center). It is an association of community and state colleges, universities, high schools and technical centers, trade associations, and laser and fiber-optic (LFO) companies. LASER-TEC started its operation in September 2013 based at Indian River State College in Florida, with the following principal partners: Central Carolina Community College (North Carolina), Tri-County Technical College (South Carolina), and CREOL (the College of Optics and Photonics at the University of Central Florida).

The mission of LASER-TEC is to develop a sustainable pipeline of qualified laser and fiber optics technicians to meet industry needs in the United States. To accomplish this mission, the following goals were set:

1. Increase and strengthen LFO academic programs to meet the industry demand
2. Create and offer LFO professional development programs for secondary school teachers, college faculty, and incumbent workers
3. Develop LFO curriculum materials for secondary schools, colleges, and industry
4. Develop, promote, and deliver outreach and awareness programs to secondary STEM teachers, advisors, counselors, administrators, and the general public
5. Develop strategies and materials for recruiting and retaining underrepresented groups and to promote diversity in LFO programs

This report evaluates the progress, accomplishments, and challenges in achieving these goals in year 7, the last year, of LASER-TEC operation.

The evaluation results presented are based on multiple data points provided by the Center, evaluations and surveys developed by the evaluator and the Center's management, and also includes the feedback gathered from a variety of stakeholders.

Part II of this report describes the evaluation model and methodology used for this project. The evaluation team started working with LASER-TEC during the proposal development period and created the current evaluation plan. The evaluation plan is graphically represented in the logic model presented on page 4 of this report. Continuous formative evaluations have been done during the five years of operation. Part III lists the recommendations for changes or improvements. Part IV of this report presents the conclusions of the evaluation team.

PART II

EVALUATION METHODOLOGY

A mixed evaluation methodology was used to assess and analyze the goals and their outcomes of this project. The following four questions were asked to facilitate the evaluation process:

- What was proposed to be done?
- How was it planned?
- Is it being done as planned?
- Is the program successful?

The four-level Kirkpatrick and Kirkpatrick method was used to evaluate results and outcomes of the second goal, which focused on teachers' professional development. The following questions were asked:

1) To what degree are K-12 teachers, counselors, and administrators satisfied with the content and quality of LFO seminars and the center services? (Reaction Level)
2) To what degree did K-12 teachers, counselors, and administrators understand the need to incorporate LFO modules in life sciences classes and career counseling? (Learning Level)
3) To what degree are K-12 teachers, counselors, and administrators incorporating LFO modules in life sciences classes and career counseling? (Behavior Level)
4) How many new LFO courses, modules, lessons, and career guidance sessions have been added in K-12 schools, and how many students have attended? (Results Level)

At the beginning of the project, the PI met with the evaluator on multiple occasions and outlined the goals, objectives, and tasks of the Center. An evaluation plan was drafted that includes the collection of data for a continuous formative evaluation during each year of the project and a summative evaluation at the end of each year of the project. Feedback from the formative evaluations was provided to the management team on a regular basis so that corrective actions are taken immediately for effective management. The evaluator was responsible for creating the evaluation instruments, scripts for telephone interviews, and other evaluation tools. The Center's staff disseminated and collected the evaluation results from participants and presented them to the evaluator for analysis and report preparation.

This report represents the formal summative evaluation for year 7 of LASER-TEC operation.

LASER-TEC LOGIC MODEL

RESOURCES	ACTIVITIES	OUTPUTS	SHORT-TERM OUTCOMES	LONG-TERM OUTCOMES	IMPACT
In order to accomplish our set of activities, we will need the following:	In order to address our problem or asset, we will accomplish the following activities:	We expect that once accomplished, these activities will produce the following evidence or service delivery:	We expect that if accomplished, these activities will lead to the following changes in 1-3 years:	We expect that if accomplished, these activities will lead to the following changes in 4-6 years:	We expect that if accomplished, these activities will lead to the following changes in 7-10 years:
Funding from NSF.	Find industry needs in LFO technicians and training.	A list of training programs. A list of training strategies. A list of priorities and timelines for training.	Familiarity with industry needs in the number of required technicians. Familiarity with training needs of the industry.	Quicker responses to industry training needs.	Make US economy more responsive, efficient, and competitive in the global market.
Support from IRSC in infrastructure, offices, computer services, telecommunications, etc.	Establish specialty LFO training labs at each principal partner college.	A number and type of specialized LFO training programs at partner colleges.	A number of technicians trained at each college.	Industry satisfaction to demand in skilled workforce.	Increase the number of well-paid technicians. Strengthen industry by meeting workforce requirements. Strengthen the US economy.
Support from the industry in providing needed information on technician skills and needs.	Create training programs in colleges located close to industry.	A list of LFO training programs at colleges close to industry.	Increase the number of competent technicians available to the industry.	Further reduction in the gap between supply and demand for technicians.	Balance the supply and demand for technicians.
Endorsement from professional societies like SPIE, OSA, and IEEE.	Create a dynamic IAB to establish the direction of the Center.	Growing membership numbers in the IAB. A list of future directions.	Create courses and training needed by industry.	Reduce the response time in the creation of new courses and training	Strengthen and make US economy more competitive.
An action plan for year-to-year operations.	Provide outreach to K-12 teachers, counselors, and administrators.	A number of outreach programs for educators. A number of outreach participants.	Increase number of students studying LFO or related subjects.	Further increase the number of students that study LFO or related subjects.	Strengthen US economy and increase prosperity of graduates with LFO degrees.
Competent Center staff.	Recruit more veterans and minorities.	A number of veterans, minorities, and women in the industry.	Increase the standard of living of veterans and minority graduates.	Further increase the standard of living of veterans and minority graduates.	Strengthen US economy and increase prosperity for veterans and minorities.

PART III

EVALUATION FINDINGS

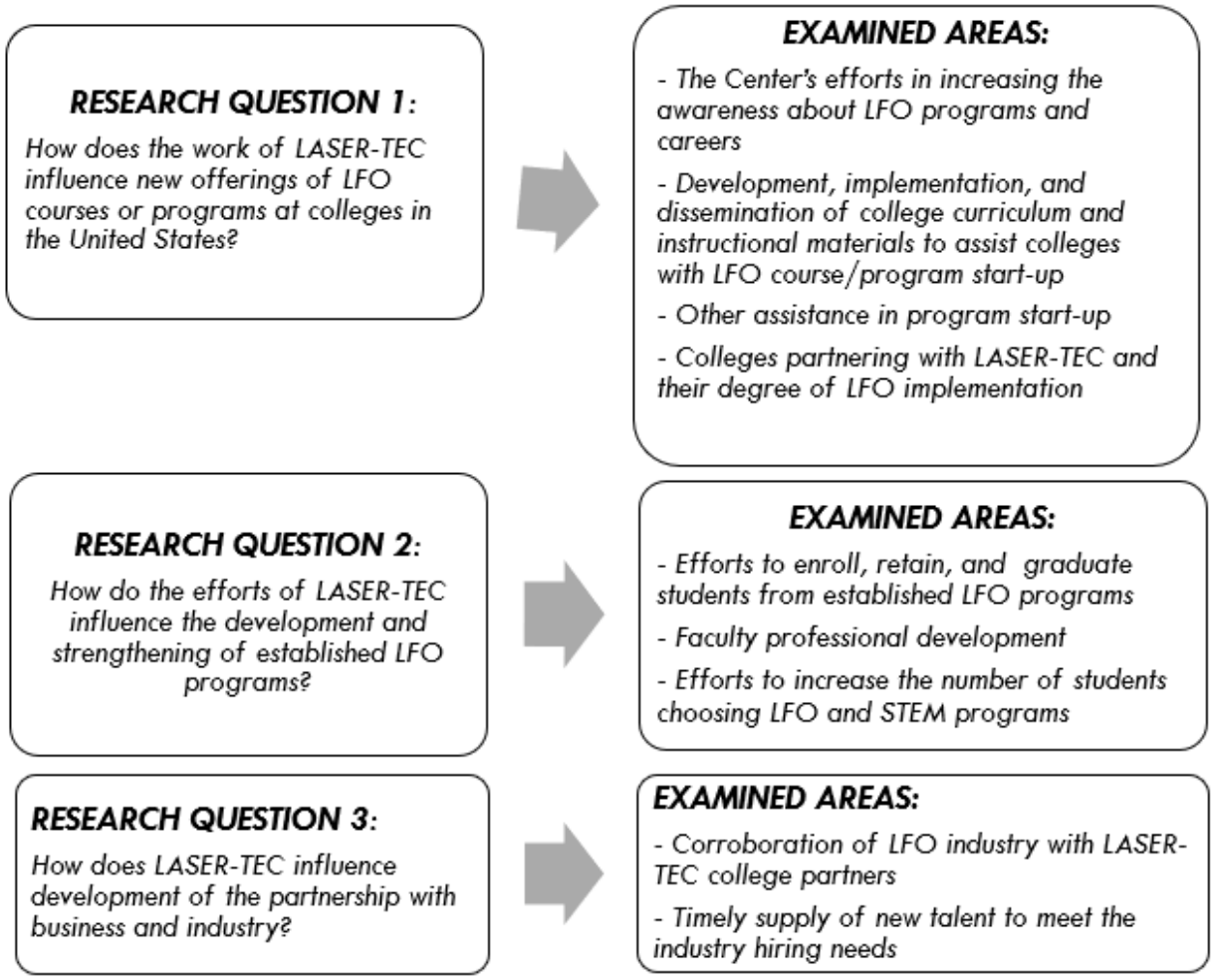
This is the last year before the Center for Laser and Fiber Optics Education, LASER-TEC, transitions to a Resource Center in September 2020. After seven years of work, LASER-TEC is transitioning from an active NSF ATE Center to a Resource Center until August 2023.

This report evaluates the Center's initiatives during the period of June 2019- June 2020, notable for many challenges and changes. During this time the evaluator observed the Center's swift responses to many external influencing factors in order to better assist photonics educational and industry communities.

Among multiple tasks and projects, the Center has focused its work around the following major areas:

- Plan and prepare for the transition to become a Resource Center
- Operate a larger national college network as the results of merging of the existing Optics and Photonics College Network (OPCN) with the LASER-TEC college network
- Respond to the COVID-19 pandemic and provide colleges with necessary tools and resources to continue offering photonics technical education.

I. LASER-TEC COLLEGES OFFERING LASER, PHOTONICS, FIBER OPTICS, AND OPTICS (GOAL 1)



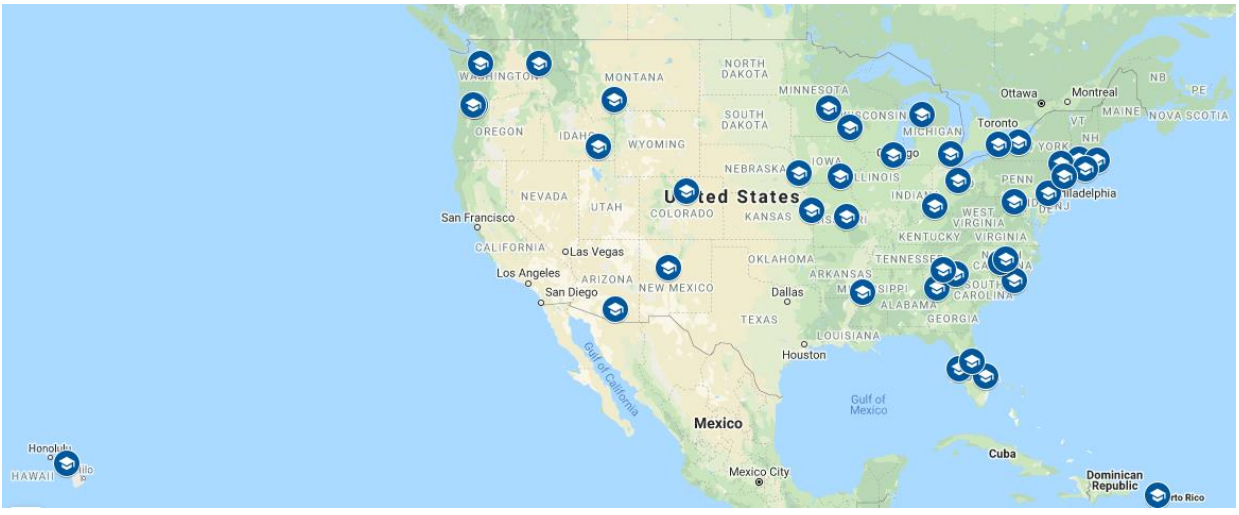
OVERVIEW

In September 2019, LASER-TEC began to operate the Optics and Photonics College Network, previously organized and managed by OP-TEC. As the result of merging of the two college networks (LASER-TEC and OP-TEC networks), the current LASER-TEC network consists of 41 institutions nationwide, see Table 1. LASER-TEC has published detailed information about the OPCN colleges on their website: https://www.laser-tec.org/opcn.html . With just a few exceptions, all colleges withing the network offer either a full program, a specialization, or a course in lasers, photonics, or optics. In addition, the Center monitors the progress of program planning and development at 24 other colleges as shown on Figure 1.

TABLE 1. LASER-TEC COLLEGE NETWORK 2019-2020

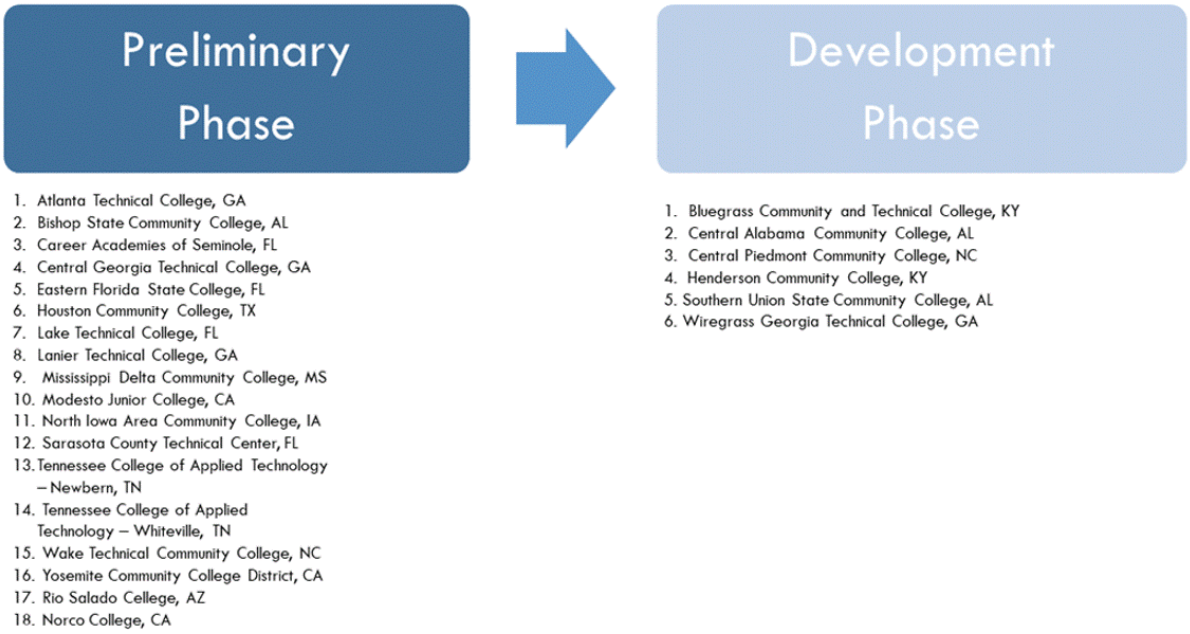
1. Anoka Ramsey Community College/Anoka Technical College
2. Atlanta Technical College
3. Blue Ridge Community and Technical College
4. Camden County College
5. Cape Fear Community College
6. Central Carolina Community College
7. Central New Mexico Community College
8. Cincinnati State Technical and Community College
9. Clackamas Community College
10. College of Lake County
11. Front Range Community College
12. Gallatin College
13. Hillsborough Community College
14. Idaho State University
15. Indian Hills Community College
16. Indian River State College
17. Iowa Western Community College
18. Johnson County Community College
19. Lake Washington Institute of Technology
20. Maui Community College
21. Mississippi Delta Community College
22. Monroe Community College
23. Niagara College
24. North Central State College
25. Northwestern Michigan College
26. Oregon Institute of Technology
27. Pima Community College
28. Puerto Rico Photonics Institute
29. Southeast Technical / Minnesota State College
30. Spokane Community College
31. Springfield Technical Community College
32. State Technical College of Missouri
33. Stonehill College
34. SUNY Ulster Community College
35. Three Rivers Community College
36. Tri-County Technical College
37. Valencia College
38. Wake Technical Community College
39. Wayne County Community College
40. Westchester Community College
41. Young Harris College

FIGURE 1. STATE DESTRIBUTION OF THE COLLEGE NETWORK



To track the advancement of colleges within the network, the evaluator and the Center's management team developed a three-phase classification system which includes preliminary, development, and implementation phases. In 2019-2020, six colleges are in the development phase, and eighteen colleges in the preliminary phase.

FIGURE 2. COLLEGES EVALUATING OR PLANNING PHOTONICS OFFERINGS



The baseline survey tool that will identify the stages of photonics integration, student enrollment and placement has been developed. However, the Evaluator and the Center's management are planning to identify the best time period to launch and conduct the survey to ensure maximum response level that might be affected by the colleges' operation during the spread of COVID-19.

NETWORK PROGRESS, 2019-2020

During 2019-2020, Young Harris College, GA, has completed the approval process for the infusion of fundamentals of optics and photonics into the physics class. The first class is scheduled to be offered in the Fall 2020.

Wayne County Community College is pursuing the launch of Photonics and Laser Technology course. LASER-TEC curriculum and educational kits will be used to support the course.

During 2019-2020, two colleges expressed their interest and initiated preliminary discussion about starting an LFO program- Rio Salado College in Arizona and Norco College in California.

A relatively slow rate of college photonics programs advancements can be explained by a brief "active" time withing this reporting period, when colleges were proactive in moving forward with their new programs before shifting to a remote/online mode of operation which happened amid COVID-19 and ceased the majority of colleges' activities.

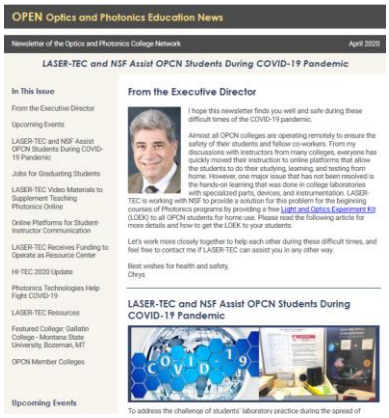
LASER-TEC'S SUPPORT OF COLLEGE NETWORK (GOAL 1, GOAL 2, GOAL 3)

During this evaluation period, the Center has supported the colleges with enhanced college-industry relationships, curriculum materials, student outreach, student career preparation, and student job placement.

1. NEWSLETTER

LASER-TEC has employed multiple platforms to support continuous communication with faculty, administrators, teachers, and the Industry Advisory Board, National Visiting Committee, members of

the NSF ATE community, and other stakeholders. In September 2019, the Center started publishing monthly electronic newsletters which are sent out each time to nearly 2,000 recipients that include members of the stakeholder groups listed above. This is a new initiative of the Center and appears to be successful, well-planned and properly executed.


OPEN Optics and Photonics Education News

Newsletter of the Optics and Photonics College Network — April 2020

LASER-TEC and NSF Assist OPCN Students During COVID-19 Pandemic

In This Issue

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Photonics Technologies Help Fight COVID-19

LASER-TEC Resources

Featured College: Gallatin College - Montana State University, Bozeman, MT

OPCN Member Colleges

Upcoming Events

From the Executive Director

I hope this newsletter finds you well and safe during these difficult times of the COVID-19 pandemic.

Almost all OPCN colleges are operating remotely to ensure the safety of their students and fellow co-workers. From my discussions with instructors from many colleges, everyone has quickly moved their instruction to online platforms that allow the students to do their studying, learning, and testing from home. However, one major issue that has not been resolved is the hands-on learning that was done in college laboratories with specialized parts, devices, and instrumentation. LASER-TEC is working with NSF to provide a solution for this problem for the beginning courses of Photonics programs by providing a free Light and Optics Experiment Kit (LOEK) to all OPCN students for home use. Please read the following article for more details and how to get the LOEK to your students.

Let's work more closely together to help each other during these difficult times, and feel free to contact me if LASER-TEC can assist you in any other way.

Best wishes for health and safety,

Chrys

LASER-TEC and NSF Assist OPCN Students During COVID-19 Pandemic

To address the challenge of students' laboratory practice during the spread of

The newsletter content is developed and scheduled around general operational cycles of colleges and industry. This ensures that LASER-TEC partners receive only relevant and helpful information in a timely manner. For example, the Center reminds LFO faculty about availability of text and lab books, modules, and other pedagogical resources in summer and winter months as faculty plan and prepare their Fall and Spring classes. The photonics industry is encouraged to contact colleges to host informational and hiring sessions in October and April as new wave of LFO graduates emerges in December and May. The Center has published special editions of the newsletter to facilitate student career preparedness and job placement as well as to sustain critical communication during the spread of COVID-19. By the time of this report writing, the Center has published 9 issues of the newsletter, which are available to view on their website: https://www.laser-tec.org/newsletter-archive .

The Center and the Evaluator closely monitor the data and statistical reports provided by the publishing platform-Constant Contact to ensure efficiency and fine-tuning of this effort. The average LASER-TEC newsletter opening rate (measures the percentage of emails opened out of all of those sent) is 26.3%, which exceeds the reported overall average industry rate at 20%. The click-through rate (the number of people who clicked on a link within an email against the unique number of opens) peeked at 45% which is substantially higher than the average industry rate of 7% . Small "unsubscribe" and "bounce" rates indicates that the Center provides helpful content to its well-targeted groups. Examples of the recipients' feedback include: "This is really excellent!", "Nice work on the letter", "Helpful". The Evaluator recommends the Center to continue publishing the newsletter as an effective and a direct way of communication and material dissemination.

2. FEATURING OPCN COLLEGES IN PHOTONICS SPECTRA MAGAZINE

In partnership with Photonics Spectra, LASER-TEC has initiated a project that increases awareness and expands the collaborative platform between OPCN colleges and the photonics industry. Beginning January 2020, one OPCN college is featured in the monthly B2B magazine that reaches more than 100,000 photonics industrial subscribers.

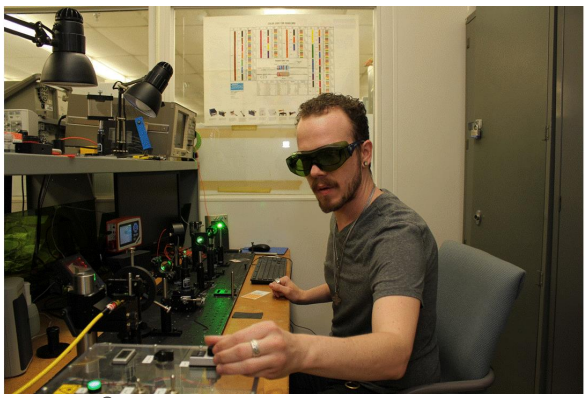


FIGURE 3. A STUDENT OF SPRINGFIELD TECHNICAL COMMUNITY COLLEGE IS MEASURING LASER BEAM CHARACTERISTICS

The publications enable colleges to reach out to local, regional, and national photonics employers and showcase their academic programs, specializations, laboratory facilities, as well as graduates' skillsets and knowledge. For the industry, this is a valuable source of information about availability of qualified technical workforce. The colleges provide direct contact information to streamline communication process between the two parties.

By the time of this report writing, Photonics Spectra has featured 5 colleges:

- Indian River State College (click here to view)
- Central Carolina Community College (click here to view)
- Indian Hills Community College (click here to view)
- Niagara College (click here to view) , and
- Stonehill College, MA (click here to view)

Another seven colleges are scheduled to be published in the magazine until January 2021 (the order might change slightly):

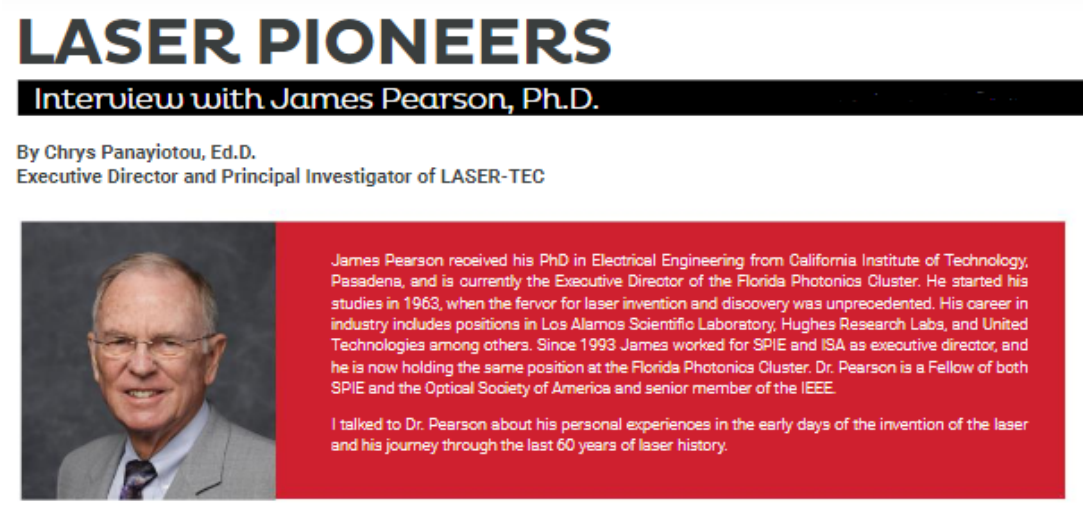
June	Gallatin College, MT
July	Springfield Technical Community College, MA
August	State Technical College of Missouri, MI
September	Hillsborough Community College, FL
October	Front Range Community College, CO
November	Spokane Community College, WA
December	Monroe Community College, NY

Photonics Spectra has committed to continue publishing LASER-TEC's college profiles in 2021. The Center is currently working on developing submission packages from other OPCN colleges for 2021.

The Evaluator and the Center's Management are currently working on developing the evaluation tool to measure the results and outcomes of this initiative.

3. OTHER NATIONAL PUBLICATIONS TO SUPPORT PHOTONICS TECHNICAL EDUCATION

This year, LASER-TEC has continued to actively pursue increasing special groups' and general public's awareness on various photonics-related topics through partnering with national publishers. In addition to collaboration with Photonics Spectra described in the previous section, LASER-TEC has published a series of articles in other two national publishers, the Laser Institute of America (LIA) and BioPhotonics.


LASER PIONEERS

Interview with James Pearson, Ph.D.

By Chrys Panayiotou, Ed.D.
Executive Director and Principal Investigator of LASER-TEC

James Pearson received his PhD in Electrical Engineering from California Institute of Technology, Pasadena, and is currently the Executive Director of the Florida Photonics Cluster. He started his studies in 1963, when the fervor for laser invention and discovery was unprecedented. His career in industry includes positions in Los Alamos Scientific Laboratory, Hughes Research Labs, and United Technologies among others. Since 1993 James worked for SPIE and ISA as executive director, and he is now holding the same position at the Florida Photonics Cluster. Dr. Pearson is a Fellow of both SPIE and the Optical Society of America and senior member of the IEEE.

I talked to Dr. Pearson about his personal experiences in the early days of the invention of the laser and his journey through the last 60 years of laser history.

Initiated last year, the "Laser Pioneers" series is published in the LIA-Today e-magazine and features interviews with people who worked and contributed in the early years of the laser industry. This series is intendent to capture the history of the laser technology development through the eyes of forefront scientists and engineers. The Center has encouraged to share these publications with current and potential LFO students to provoke their curiosity about the history of the rapid laser technology advancement, learn about the nature of discovery and technological progress.

During 2019-2020, the Center has published two additional interviews, Dr. James Pearson (click here to view p.30) and Dan Hull (click here to view p.25)

The Principal Investigator has received positive feedback and numerous comments about the value of these interviews and articles.

LASER-TEC has also discussed the current state of the photonics technical workforce, challenges and progress in Biopinon published by BioPhotonics magazine in its May/June 2020 issue. Click here to access the article. The article was well-received. One of the readers feedbacks was: "is a very strong piece, and will highlights something that has likely been in the back of the readers' minds, and just maybe it could alert someone in a position to offer suggestions to local institutions, as well."

4. STUDENT SUPPORT SERVICES

LASER-TEC has continued offering student services and resources during 2019-2020 evaluation period.

With the joint assistance from the National Science Foundation and professional photonics societies, LASER-TEC supported and facilitated students' participation at three conferences: the 26th National ATE Principal Investigators Conference in Washington, DC October 23-25, 2019, PCB Carolina is an Electronics Trade Show and Technical Conference, Raleigh, NC November 13, 2019 and Photonics West, San Francisco, February 4-6, 2020.

While in San Francisco, IRSC and CCCC faculty and students visited the National Ignition Facility at Lawrence Livermore National Labs. In addition, during 2019-2020, students from IRSC visited L3Harris Technologies facility in Palm Bay, FL and students from CCCC visited Synoptics and UNCC Photonics Research Center. Student field trips are an important learning component in photonics education as they provide a rare opportunity to view first-hand many new and exciting photonics technology demonstrations. Students were also able to discuss employment opportunities with photonics companies actively conducting candidate searches.

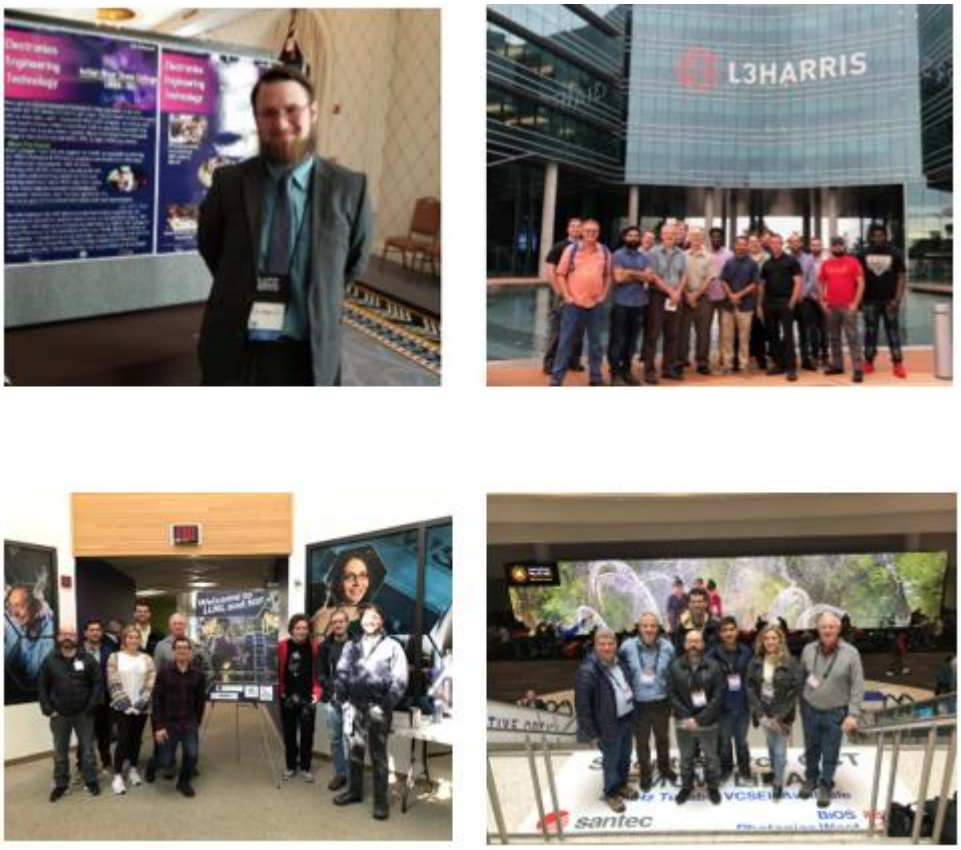


FIGURE 4. LASER-TEC STUDENTS ATTENDING CONFERENCES AND TOURING PHOTONICS COMPANIES IN 2019-2020

Similar to the previous years, the Center has hosted the Career Preparedness and Job Search workshop for photonics and laser technology students at two colleges: Indian River State College and Central Carolina Community College. This workshop is embedded into the photonics classes as a required project and students were assigned to develop their resumes and prepare a full job application package for an existing vacancy. The students indicated that they had found the workshop useful. One of the students shared, "This was an incredibly helpful and inspiring event that (we) will utilize for life".

FIGURE 5. CAREER PREPAREDNESS WORKSHOP AT IRSC

The Center has collected, organized and published multiple career resources on its website to make it available for students at all OPCN colleges. The information about availability of these resources was disseminated through the Center's monthly newsletter and social media. Students' career resources can be found here: https://www.laser-tec.org/career-resources.html

To extend the assistance in the job application process to all network institutions, the Center now offers the Career Preparation and Job Search workshop using online platforms. The colleges can learn more about this workshop and request a session on the Center's website: https://www.laser-tec.org/career-preparedness-workshops.html. The workshop description and topics are listed below.

This workshop helps students and graduates to:

- Connect what they learned in their photonics program to what an employer needs
- Understand what to expect when searching for employment
- Focus on areas that need to be improved
- Gain confidence

The workshop includes the following topics:

- Transferable skills: from college to photonics employment
- Job searching strategies: general and specific for photonics technicians
- Resume and cover letter: dos and don'ts. Examples
- Application process: stages and best approaches
- Interview preparation & technical Interviews: what do you need to know
- Professional follow-up

Although due to limited timing, no online session has been requested, the concept was highly supported by OPCN faculty members. "Love the idea of a career preparedness workshop", "Will include it in our Fall schedule", were some of the comments from the group.

5. THE CENTER'S RESPONSE TO THE PANDEMIC COVID-19 (GOAL 1, GOAL 2, GOAL 3)

By April 2020, almost all OPCN colleges have transferred to a remote operation to ensure the safety of their students and fellow co-workers due to the spread of the COVID-19 pandemic. The Principal Investigator had multiple discussions with instructors from many colleges and quickly learned that they all had one common challenge – there were no solutions for the hands-on practice that was done in college laboratories with specialized parts, devices, and instrumentation. Currently, LASER-TEC is working with NSF ATE program to provide a free Light and Optics Experiment Kit (LOEK) to all OPCN students for home use. The kits are mailed directly to students' home addresses; for classes starting in the Fall 2020, which are very likely to be conducted in an online or hybrid format, many faculty preferred the kits to be shipped to the colleges.

To provide financial support for this project, the Center has applied and received a supplemental award from the NSF ATE Program.

This kit supports the majority of experiments in the textbook Fundamentals of Light and Lasers and will allow students to complete laboratories in beginner Photonics courses from the safety of their homes. The detailed information about the upgraded Light and Optics Experiment Kit is provided in section V of this document.

The Center will also be working on developing videos which will guide students through the experiments supported by the kit. These videos will be available on LASER-TEC's YouTube channel.

The progress and information about the project and video uploads are communicated through newsletter (click here to view) , emails, website and social media (click here to view):

By the time of this report writing, LASER-TEC has received and fulfilled requests for the kits from 11 colleges. Total of 116 kits were mailed by the end of May 2020.

TABLE 2. NUMBER OF KITS SHIPPED TO COLLEGES BY MAY 26, 2020

Iowa West Community College	**6**	**Indian Hills Community College**	**1**
Spokane Community College	**8**	**Hillsborough Community College**	**25**
Puerto Rico Photonics Institute	**5**	**Northwestern Community College**	**13**
State Technical College of Missouri	**23**	**Young Harris College**	**6**
Pasadena City College	**27**	**Monroe Community College**	**1**
Niagara College	**1**		

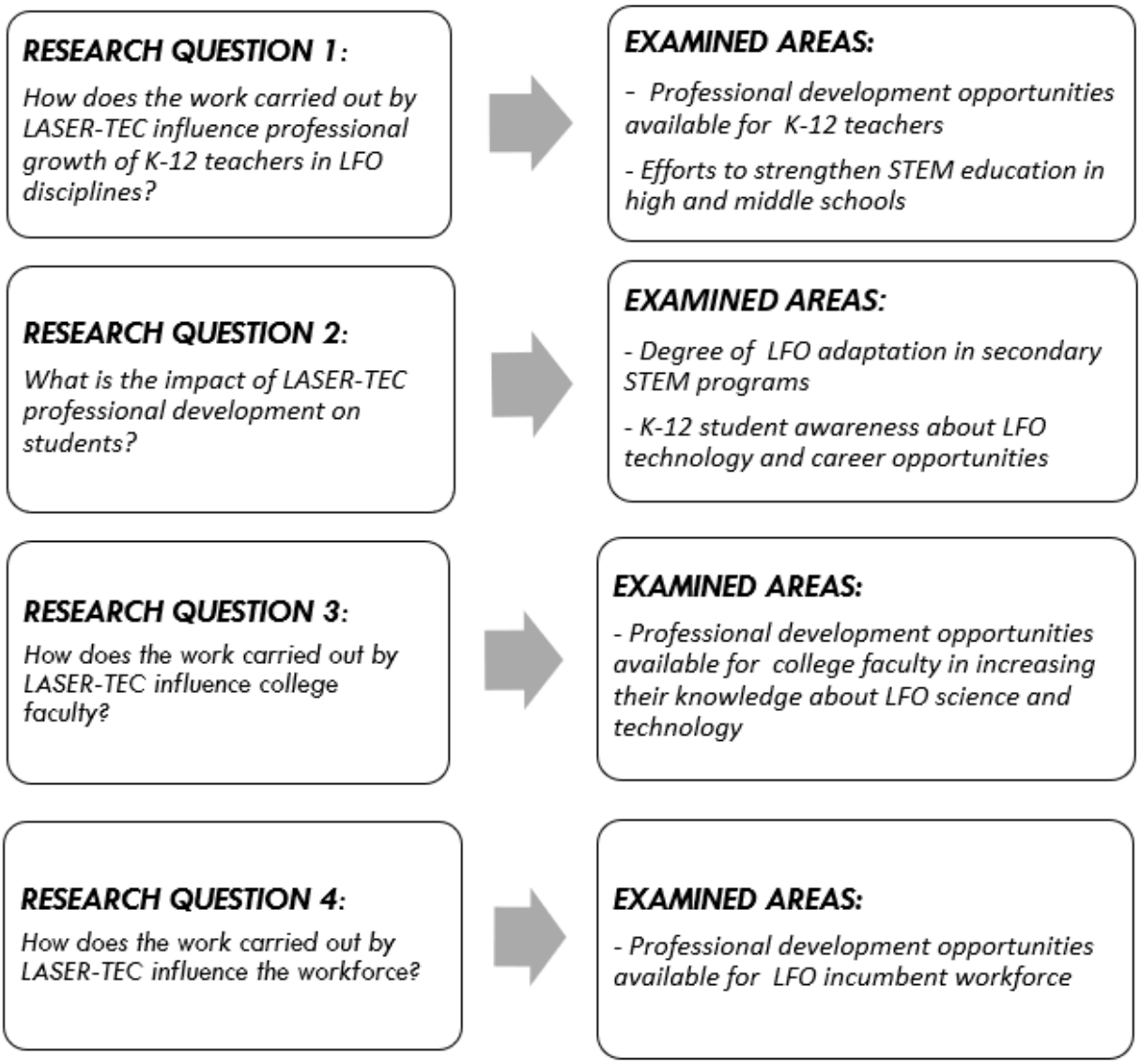
The Evaluator would like to commend the Center's agility and fast response to this need. The Center's personnel worked around the clock to ensure the sufficient inventory for 400 kits, timely assembly, and rapid shipment of kits to students.

The Center has since received positive comments and feedback from the OPCN faculty and students:

- "It has been a unique and fun experience, and I like doing the labs. Being under quarantine, I have been able to experiment with the laser and the other components. It has been a cool opportunity." Luis Morales, student of Photonics Institute of Puerto Rico, Engineering Technology in Photonics & Lasers at Universidad (town of Aibonito, Puerto Rico)
- "I am extremely grateful with LASER-TEC for the Experiment Kit. I have been able to do the labs safely in the comfort of my home. And, very importantly, the experiments are very interesting. "Hernan Molina, student of Photonics Institute of Puerto Rico, Engineering Technology in Photonics & Lasers at Universidad (town of Dorado, Puerto Rico)
- "This semester I am the instructor of the Fundamentals of Light and Lasers course, part of our Associate Degree in Engineering Technology in Photonics & Lasers at Universidad Ana G Mendez, Cupey campus. Quarantine in Puerto Rico due to the COVID-19 pandemic started March 15. We had only done three of our labs, in a course where we usually do 10-11 labs. The Light & Optics Experiment Kit by Laser-Tec afforded my students the opportunity to continue with our labs in a safe way, maintaining social distancing. Moreover, students have been able to play with them at home (what better way to learn?). By the end of the semester we will have done experiments 4, 6, 12, 13, 19, 20 and 21. As academic director of the Puerto Rico Photonics Institute, I am very grateful to Laser-Tec for this material." Dr. Andres Diaz (town of Manati, Puerto Rico).
- "When we were notified that we would not be allowed on Campus for Spring quarter and we would have to teach our classes online I had no idea how I would be able to give my students the equivalent of hands-on learning with videos and simulations. Fortunately, LASER-TEC and the NSF came to the rescue. Each of my students were given a LASER-TEC Light & Optics Experiment Kit, delivered to their home. Since then they have done experiments on the Laser Safety, the Law of Reflection, the Law of Refraction, Finding the Speed of Light in an Acrylic Block, Total Internal Reflection, Laser Beam Steering, and Optical Filters. We will be back on Campus doing labs in small groups starting next week. Without these kits we would have so

much to make up I am not sure we would get it done before the end of the quarter. Thank you, LASER-TEC and NSF." Judy Irvin, Spokane Community College.
This is an ongoing project and would most likely extend to the Fall 2020.

II. LASER-TEC PROFESSIONAL DEVELOPMENT PROGRAMS (GOAL 2)



During this evaluation period, LASER-TEC has hosted professional development opportunities for K-12 teachers, college faculty, and incumbent workers. The delivery format included a day-long workshops at conferences and 8-week long hybrid courses.

BLENDED COURSES:

In January 2020, LASER-TEC launched the Laser-Photonics Technologies series of blended courses as part of the effort to increase the production of photonics technicians in the United States to meet industry demand. The goals of this project are:

- Provide education to future photonics technicians of all ages and backgrounds and prepare them for the challenges of the 21st century in the field of lasers-photonics.
- Provide professional development to instructors from around the country who want to learn and add laser-photonics content to their existing programs, or create new courses and programs.
- Provide opportunity for industry to update their incumbent workers in an efficient and cost-effective way.
- Raise awareness in the community in general about the importance of the field of photonics and light enabled technologies and applications for future technological advancements in the 21st century.

The five-course series consist of the following courses:

Course 1. INTRODUCTION TO PHOTONICS
Course 2. GEOMETRICAL AND PHYSICAL OPTICS
Course 3. FUNDAMENTALS OF FIBER OPTICS
Course 4. LASER SYSTEMS AND APPLICATIONS
Course 5. INTRODUCTION TO SPECTROSCOPY

For all courses, theoretical overview is facilitated online by a LASER-TEC faculty using the Blackboard Learning Management System, the practical sessions are hosted at a LASER-TEC college. More information about this professional development project, the course descriptions, and schedules can be found on LASER-TEC website: https://www.laser-tec.org/courses.html

The pilot course's cohort of 6 attendees included a high school science teacher, Electronics Engineering faculty and 4 incumbent engineers and technicians from Edmund Optics, Jenoptics Optical Systems, and Shipwrite companies. The first course of the series was launched on January 22 and ended with the hands-on session at Indian River State College on March 16, 2020. The attendees found the course very helpful.

Here are the full-length (unedited) reviews from the attendees:

- "Having a laser laboratory and courses so readily accessible for educators is an amazing opportunity. Photonics is an important part of many careers and becoming a part of everyday life. Being knowledgeable about photonics makes me able to open my students up to possibilities they may not have ever considered"
- "This course gives good broad baseline knowledge of photonics and laser safety. As such, it is a necessary building block for more advanced classes. For a company working with lasers, this course gives a new employee the basic understanding of the equipment and safety requirements. Rather than teaching the employees in the company, here they know that nothing is left out, the teaching is done by a quality teacher, and there is independent prove of training to show the employees are qualified for the work with photonics equipment. The theory section being offered fully online gives the flexibility necessary even if the company is in a different town or even state. But the most beneficial part for me is the practical part of the course. My company will be new to using lasers and this course gives me the hands-on perspective that the textbooks and video lectures alone lack. I'm looking forward to the more advanced courses that follow."

The Center's management and the course faculty evaluated the need and feasibility of offering the rest of the course's series during the times of social/physical distancing enforced during the spread of COVID-19. After multiple discussions with the photonics industry managers, instructors and teachers, the Center made a decision to postpone the courses until a later date. It was found that majority of photonics companies were able to sustain and even increase the workload of their technical personnel

and would rather have a short-term training options versus the 8-week commitment. Faculty and teachers across the country had to shift their courses completely online and had limited or no time for professional development.

SHORT-TERM WORKSHOPS

The Center hosted its traditional Laser and Fiber Optics Workshop at the North Carolina Career technical Education Conference in Greensborough, NC in July 2019. The Center hosted 3 sessions of the workshop, and a total of 30 CTE teachers participated. The Center has been improving the content of this workshop and tuning it up to the needs of educators since it began its operation in 2013. It is a hands-on professional development workshop that utilizes components and tools provided in the LASER-TEC's Light and Optics Exploration Kit. The Kit includes the Teachers' guide that is linked to Next Generation Science Standards.

FIGURE 4. LASERS & FIBER OPTICS WORKSHOP AT NCCTE CONFERENCE

In partnership with Corning Optical Communications, LASER-TEC conducted a full-day training "Fiber Optics for Beginners" during the High Impact Technology Exchange Conference on July 26 2019 in Saint Louis, MI. Fourteen faculty members from 12 colleges participated.

FIGURE 5. FIBER OPTICS FOR BEGINNERS. WORKSHOP AT HI-TEC 2019

The "Fiber Optics for Beginners" workshop is intended for instructors who want to learn more about the practical aspects of fiber optics so they can create and/or enhance courses with the latest technologies impacting the termination, connecting, and testing of fiber optic networks. In addition to learning about the theory of fiber operation, participants terminate a single mode fiber with the Corning Unicam system, create and test fusion splices, and use an OTDR for signal tracing and troubleshooting. Fiber to the home, passive optical networks, and distributed antenna systems (DAS) are also covered.

The post-workshop evaluation indicated that the training had an excellent content, relevance, and quality. Here is the summary of the results is provided in table 2:

TABLE 3. EVALUATION RESULTS. FIBER OPTICS FOR BEGINNERS. JULY 26, 2019

Content	**Excellent 14**	**Good 2**	**Fair**	**Poor**
Relevance of topic	**Excellent 15**	**Good 1**	**Fair**	**Poor**
Quality of workshop	**Excellent 14**	**Good 2**	**Fair**	**Poor**
Speakers	**Excellent 8**	**Good 1**	**Fair 2**	**Poor**
Were expectations met?	**Excellent 4**	**Good 2**	**Fair**	**Poor**

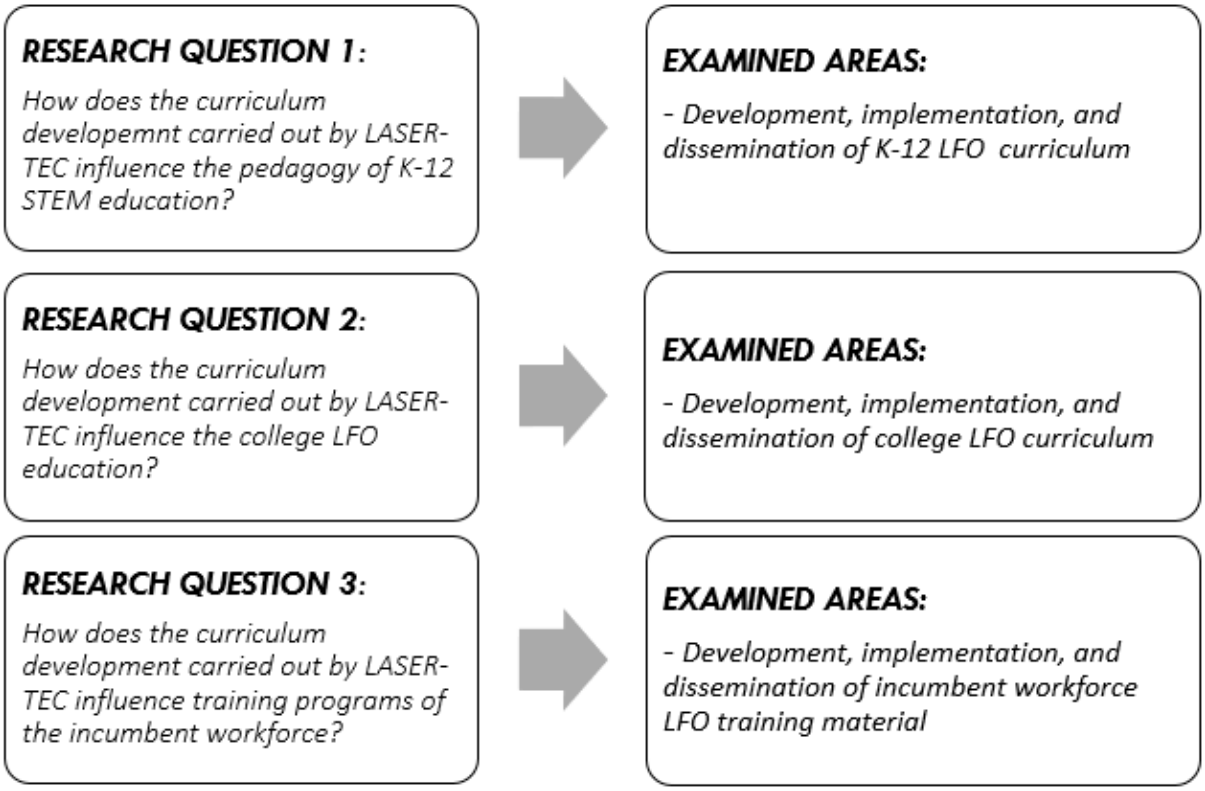
The workshop was very sought after by educators and reached its maximum registration capacity very quickly. To provide opportunities for more faculty to attend this hands-in industry-lead workshop, the Center had planned another session for HI-TEC 2020 in July. However, its face-to-face format has recently been cancelled.

Through multiple discussions with OPCN faculty, the Center has learned about the need for training in laser safety for educational institutions. To respond to this need, LASER-TEC had scheduled to conduct the "Laser Safety Officer" work group training during HI-TEC 2020 in partnership with KENTEK.

During this workshop, KENTEK and LASER-TEC clarify the ANSI standard governing laser safety, legal issues and liabilities of colleges that use lasers in their labs. Laser safety officer training, how to create standard operating procedures for students using these labs, and hazard calculations are be among the topics covered.

Due to the conference cancellation, the Center will evaluate alternative ways of offering this workshop for members of OPCN.

III. CURRICULUM AND INSTRUCTIONAL RESOURCES (GOAL 3)



OVERVIEW

As LASER-TEC transitions to the Resource Center in 2021, its staff did an extended work in systemizing existing materials and creating a digital library of resources on the website. In 2019, LASER-TEC has also migrated OP-TEC's materials on the www.laser-tec.org. The instruction-related materials can be views on www.laser-tec.org, the "Resources" tab. Starting 2020, the Center also

serves as an "request" platform for the Indian Hills Community College Photonics Kit: https://www.laser-tec.org/indian-hills-community-college-photonics-kit.html

Currently, the following curriculum materials are available from LASER-TEC:

Textbooks: Fiber Optics for Technologists, Fundamentals of Light and Lasers 3rd edition, Laser Systems and Applications 2nd edition, Integrated Photonics, Essential Mathematics for Engineering Technicians, Mathematics for Photonics Education Supplemental Text

Lab Manuals: Light and Optics Exploration Lesson Plans (instructor and student editions), Light and Optics Experiment Book (instructor and student editions), Introduction to Lasers and Optics-Student Guide, Photonics Lab Manual for High Schools.

Lab Kits: Light and Optics Exploration Kit, Light and Optics Experiment Kit, Laser-Enabled Security System Kit, Green Laser Pointer with IR Filter, the Indian Hills Community College Photonics Kit.

Modules: Enhanced Spectroscopy, Light Emitting Diodes, Thermoelectric Device Measurement Lab, Solid-State Laser Crystal Manufacturing, Field Service Engineering, and High Energy Pulsed Solid-State Laser Design and Testing.

The Center hosts and distributes the following OP-TEC-developed modules:

Photonics Enabled Technologies Modules: Manufacturing
- Laser Material Removal: Drilling, Cutting, and Marking
- Laser Welding and Surface Treatment
- Lasers in Testing and Measurement: Alignment, Profiling, and Position Sensing
- Lasers in Testing and Measurement: Interferometric and Nondestructive Testing

Photonics Enabled Technologies Modules: Forensic Science and Homeland Security
- Imaging System Performance for Homeland Security
- Infrared Systems for Homeland Security
- Lasers in Forensic Science and Homeland Security

Photonics Enabled Technologies Modules: Environmental Monitoring
- Basics of Spectroscopy
- Spectroscopy and Pollution Monitoring
- Spectroscopy and Remote Sensing

Photonics Enabled Technologies Modules: Optoelectronic
- Photonics in Nanotechnology
- Photonics in Nanotechnology Measurement: A study of Atomic Force Microscopy
- Photonics Principles in Photovoltaic Cell Technology

Photonics Enabled Technologies Modules: Biomedicine
- Diagnostic Applications of Lasers
- Lasers in Medicine and Surgery
- Therapeutic Applications of Lasers

Precision Optics Series
- Quality Assurance of Precision Optics
- Metrology of Optical Systems

Many of OP-TEC's modules were developed in the early 2000 and need to be updated with the new technology and science. The Center projects to complete this work by the end of 2023.

An additional four modules are currently under development: Semiconductor Lasers, LiDAR Technology, Power Meter Measurements, and Optical Coherence Tomography (OCT) Technology.

K-12 Outreach and Educational kits: Arduino I: Visible Light Spectrum Kit, Arduino II: Wireless Technologies Kit, Arduino III: Game Programming Kit, Electronics Maker Kit.

Educational Videos: Fiber Optics for Technologists Video Series, Instructions for the Laser-Enabled Security System, Projects with Arduino.

Educational posters: Diode Lasers, Fiber Lasers, Helium –Neon Lasers, Nd:YAG Lasers, Laser Safety.

LASER-TEC continues to successfully leverage existing resources. The Center is collaborating with the leading publishing agencies (Laser Focus World, Laser Institute of America etc.) and photonics companies (Newport, Corning, etc.) in transforming available license-free materials into pedagogical packages. These modules are developed by subject matter experts with extensive field experience and offer comprehensive content on various LFO topics. To ease their implementation into the existing photonics curriculum, LASER-TEC is developing necessary faculty resources: learning objectives, test banks, answer keys, student self-assessment, power point slides, bibliography, etc.

LASER-TEC disseminates curriculum materials through a) Its monthly newsletters; b) workshops and seminars conducted throughout the year; c) conference presentations, and other communication platforms. The supporting materials are available for download on the LASER-TEC website.

LIGHT AND OPTICS EXPERIMENT KIT

This year, the Center has focused its attention on improving the Light and Optics Experiment Kit. It is worth mentioning, that the Experiment Kit was developed as the result of feedback collected after the Center had released the Light and Optics Exploration Kit. The "Exploration" kit was originally developed to support the workshop for K-12 high and middle school STEM teachers. It is a cost-effective, inclusive, and easy-to-restock educational tool appreciatively received by teachers. Its major goal is to introduce teachers and students to the fundamentals of optics and photonics through simple demonstration of various phenomena. Readers can learn more about the Exploration Kit by visiting the webpage: https://www.laser-tec.org/exploration-kit.html

Later, it was identified that there is a great need for a similar, cost-effective kit for Advanced Placement STEM and college-level students to be able to conduct experiments with measurements and calculations. Industry-graded tools and components are often cost-prohibitive for schools and colleges especially in the beginning of their photonics program development.

The Center has demonstrated creativity and ingenuity to include the experimental and qualitative investigation of photonics without increasing the cost of the kit. Below are some of the examples of the solutions provided by the Center.

1. Polarizers/ analyzers required for the investigation of light polarization, critical in the study of photonics, can easily exceed $200 per unit. Instead, the Center has developed the polarization wheel, shown in Figure 8. After multiple improvements and alignment of the "wheel", it was brought to the point when the Malus experiment showed consistent results; The cost of this polarizer-analyzer system (excluding the cost of labor) is about one US dollar.

FIGURE 6. POLARIZATION WHEEL FOR LOEK

2. Similarly, light diffraction slits and pinholes are the fundamental tools in photonics and if acquired from an optics store can add up in the cost. Using CO2 laser engraver, the Center supplied the Experiment kit with both slits and pinholes for a fraction of one dollar. See Figure 9.
3. The Center had to improve the stand used for light sources in the kit to minimize utilization of the college's wood-shop services and reduce the unit's size to fit it into the existing packaging. The stand's mold was printed using the IRSC's 3-D printer, then eight of these units were used to create a rubber-silicon plastic casting that can be reused multiple times. In the next step, casting material Snoot Cast 320 was used to create the objects. The big advantage of this resin material is that has ultra-low viscosity, works with detailed molds, cures under room temperature withing an hour. The cost of the final product (not including labor) is just a little bit over 1 dollar. See Figure 10.
4. With the current supply-chain interruptions, caused by COVID-19, LASER-TEC had to come up with a replacement for a green laser pointer used as a source for almost all experiments. The new and improved laser assembly uses a red laser diode, vinyl water tubing, ¼" ID, 3/8" OD; both laser head and jack are pressure fit and it takes less than 5 min to put together. The Center is currently testing the assembly to conform its integration to the kit without any adjustments. See Figure 11.

FIGURE 7. VERTICAL DIFFRACTION SLIT FOR LOEK

FIGURE 8. LIGHT SOURCE STAND FOR LOEK

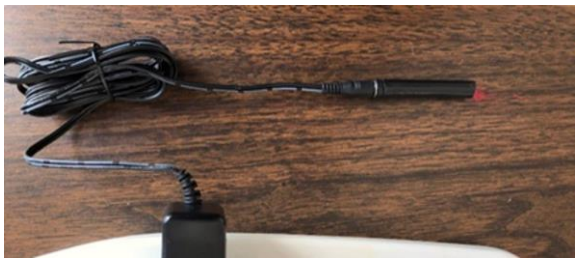


FIGURE 11. RED LASER DIODE ASSEMBLY FOR LOEK

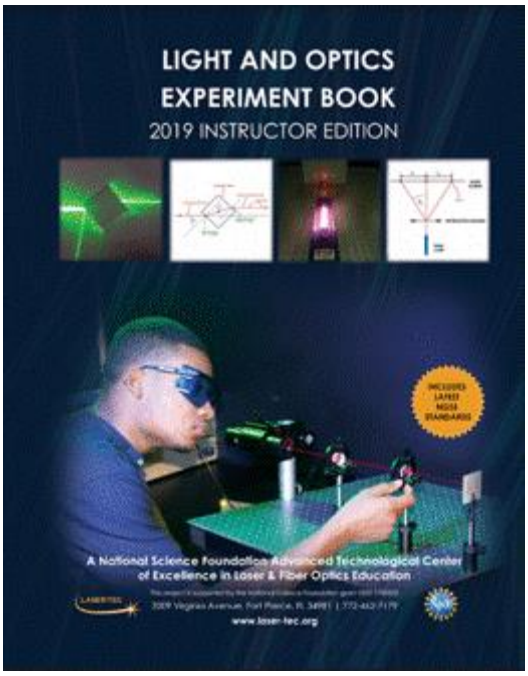
The following experiments are included into the Experiment Manual:

1. Laser Safety
2. Care and Cleaning or High-Grade Optical Components
3. The Law of Reflection
4. The Law of Refraction
5. Finding the Speed of Light in an Acrylic Block
6. Total Internal Reflection

7. Laser Beam Steering with Right Angle Prism
8. Optical Filters
9. Diffuse and Specular Reflections,
10. Optical Photometer Use and Stability
11. Measuring Laser Beam Diameter and Divergence
12. Measuring the Focal Length of Bi-Convex Lens
13. Measuring the Focal Length of a Bi-Concave Lens
14. Measuring the Focal Length of a Fresnel Lens
15. Beam-Expanding Collimators
16. Optical Alignment Techniques
17. Determining Laser Wavelength Using Grating
18. The Spectrum of White Light
19. Interference and Diffraction Through a Pinhole
20. Interference and Diffraction Through a Slit
21. Measuring Diameter of Human Hair Using Diffraction
22. Polarization of Light
23. Semiconductor Laser Diode Basics

The Light and Optics Experiment Kit support 18 of these experiments.

FIGURE 12. LIGHT AND OPTICS EXPERIMENT KIT



In previous years, LASER-TEC had developed the Experiment Book for students, which included the 23 experiment listed above. In 2019, the Center published the new and updated edition of the Book as well as the Instructor Edition that includes solutions, instructional notes, and student assessment keys.

During this evaluation period, the Experiment Book has been peer-reviewed by OPCN faculty. As the Center is distributing the Experiment Kit to OPCN students and faculty to sustain the hands-on learning during the spread of COVID-19, it is collecting students' and faculty feedback to improve both the kit and the experiment book. The feedback form is available on the Center's website: https://www.laser-tec.org/experiment-kit.html

IV. OUTREACH (GOAL 4, GOAL 5)

RESEARCH QUESTION 1:

How does the work carried out by LASER-TEC influence awereness of teachers, students, and general public about LFO?

EXAMINED AREAS:

- Development and implementation of LFO outreach programs

RESEARCH QUESTION 2:

How does the work carried out by LASER-TEC influence the diversity of LFO student pipeline

EXAMINED AREAS:

- Development and implementation of outreach and retention programs designed for culturally/ethnically diverse groups

-Development and implementation of outreach programs that increase the number of women in LFO

-Development and implementation of outreach and retention programs for active military personnel and veterans

During this 2019-2020 evaluation period, LASER-TEC continued reaching out to K-12 students, teachers, counselors, advisors, members of general public, and other groups in exploration of the field of photonics.

The broad spectrum of the outreach programs included year-around students bootcamps, field trips, laboratory visits, remote video sessions, science fairs, short-term workshops, school visits, laser shows, student chapters activities, and others.

Some of the highlighted LASER-TEC's events and programs are described in the following paragraphs.

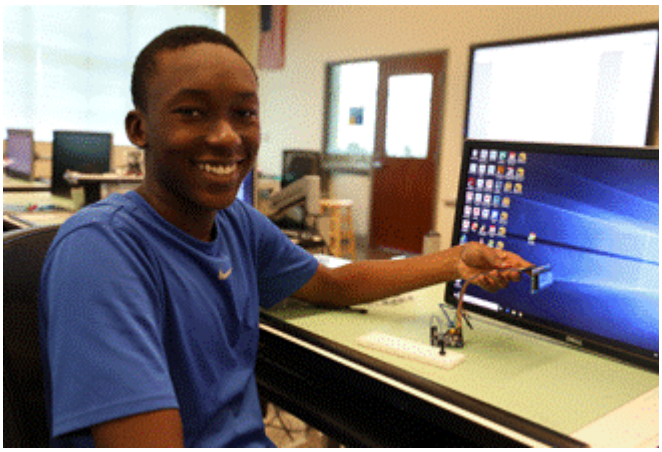


FIGURE 13. HIGH SCHOOL STUDENT ATTENDS LASER-TEC ARDUINO CAMP

The series of six-week-long bootcamps are offered by the Center to middle and high school students throughout the academic year. The camps are designed to engage students in hands-on learning and facilitate growth of skills and knowledge to interest students in STEM and photonics to help them prepare for college programs. During 2019-2020, LASER-TEC has continued offering the series of its 4 camps, Arduino 1, Arduino 2, Arduino 3, and Electronics Maker. Each Arduino bootcamp is focused on

exploration of optics, lights, lasers, and enabling technologies such as electronics and telecommunications. The Center has developed educational kits to support each of these camps. At the end of each camp, camp completers keep the kit to continue their learning process at home. More detailed information about each camp can be found on www.laser-tec "Bootcamps".

At the beginning of this year, LASER-TEC made a decision to diversity its outreach programs and offer two bootcamps geared for the adult community. With the planned launch date in late April, the Center had to postpone this offering until a later date due to the COVID-19 outbreak..

Central Carolina Community College has continued its successful collaboration with the local high schools. The LASER-TEC Co-PI and the lead instructor of the CCCC Laser Technology Program, Gary Beasley, has engaged students in planning, developing, and conducting various laser-themed activities for the local community and schools. This year, among other outreach programs, CCCC Laser Technology Program hosted the Science Fair. The Exploration Kits were provided for high school teams to develop a laser-themed experiment each demonstrating a property of light. Six teams from two different high schools participated in the event. The event was attended by over 100 high school students, parents, and family members from the public, which helped to create awareness about the CCCC laser program, LASER-TEC, and opportunities in the laser and fiber optics industries.

FIGURE 14. JACK BRITT HIGH SCHOOL STUDENTS PARTICIPATED IN CCCC LASER SCIENCE FAIR

IRSC SPIE Student Chapter collaborated with SPIE and the Prismatic Magic LLC to conduct laser shows at three local high schools. Students organized total of five sessions.

The Center has continued its efforts to engage groups that have been historically underrepresented and underserved in the STEM and photonics fields. Both LASER-TEC's principal colleges, Indian River State College and Central Carolina Community College, have established synergistic and successful partnerships with the colleges' Minority Affairs divisions leading programs such as TRiO, Upward Bound, Upward Bound Math and Science, College Reach-Out Program, Education Talent Search, Summer Residential Program, Bridge Program.

In 2019, LASER-TEC kicked off the extended "Tech-Like a Girl" Program for high school girls attending local PACE Center of Treasure Coast for Girls. This center is an alternative to traditional schools and geared for girls who feel they don't fit into a standard high school environment. The Center has hosted 2 out of 5 planned sessions before the schools' closure due to the COVID-19 pandemic. Each 2 hour session was conducted at the IRSC Photonics Lab and was integrated in the Center's science curriculum.

FIGURE 15. TECH LIKE A GIRL STUDENTS 2020

To finalize, The Center's conducted good recruitment strategies and facilitated partnerships with local, state, and national organizations supporting underrepresented groups, veterans, unemployed, or underemployed has facilitated the expansion of

diversity in the LFO workforce pipeline. For example, 45% of the Indian River State College photonics cohort of 91 students and 28% of the 267 students enrolled across all LASER- TEC programs during 2018-2019 are from populations historically underrepresented in STEM fields. In 2019 the number of female students in LASER-TEC colleges tripled to 30. Enrollment by veterans nearly quadrupled increasing from eight in 2013 to 31 in 2019. The most recent data will be collected through the survey of all OPCN colleges. The survey is developed and ready to be launched. The Center and the Evaluator are working on identifying the best window for conducting the survey for higher response rate.

V. LASER-TEC TRIP TO GERMANY

In the fall 2019, a LASER-TEC delegation visited several photonics companies in Germany, the country that holds the world's leader position in laser and optics technologies for quite a long time. Germany is also known for its very successful system of preparing its technical workforce through apprenticeships and close collaboration between education and industry. Its vocational education and training system, also known as the dual training system, is highly recognized worldwide due to its combination of theory and training embedded in a real-life work environment.

The delegation included Dr. Chrys Panayiotou, Gary Beasley, and Dr. Mo Hasanovic. The two-week trip was sponsored by additional grant-based funding from the NSF ATE program. While in Germany, LASER-TEC delegation visited the following organizations: Jenoptik, Laser Components, Trumpf Lasers, EOS, Max Plank School of Photonics, Fraunhofer Institute of Laser Technology, and the Federal Institute for Vocational Education and Training.

The main goals of this visit were to learn more about the technical workforce programs in Germany, visit technical education institutions and talk with educators, visit the laser industry and learn about their established programs that sustain their workforce needs.

The trip was very insightful and thought-provoking. After learning more about the German technical workforce development programs, the team summarized approaches that can be explored by the U.S. educational system to build a sustainable pipeline of qualified workforce:

- Increase industry internship opportunities
    - One to two days a week, or
    - Two to three weeks per semester
    - Involve industry partners selection of student candidates for interns
- Obtain more current industry equipment for hands-on training
    - Test Fixtures/Test Components
    - Used/prototype products
- Develop strategy for more industry involvement with labs being more directly related to what students will see in industry
- Add more designated application/research lab areas

LASER-TEC had presented the lessons learned from this trip at the ATE PI conference, 2019. Another presentation was scheduled for HI-TEC 2020, which, as mentioned before, was cancelled with possibility of asynchronous life stream sessions. The Center will develop a full report which will be shared with the Center's main stakeholders- colleges, schools, and industry clusters.

FIGURE 16. JENA TRAINING CENTER WHICH WAS ESTABLISHED BY THREE COMPANIES: SCHOTT, CARL ZEISS, AND JENOPTIK

FIGURE 17. TRUMPF TRAINING CENTER. POST-DUAL TRAINING SYSTEM

FIGURE 18. LASER-TEC DELEGATION VISITING TRUMPF

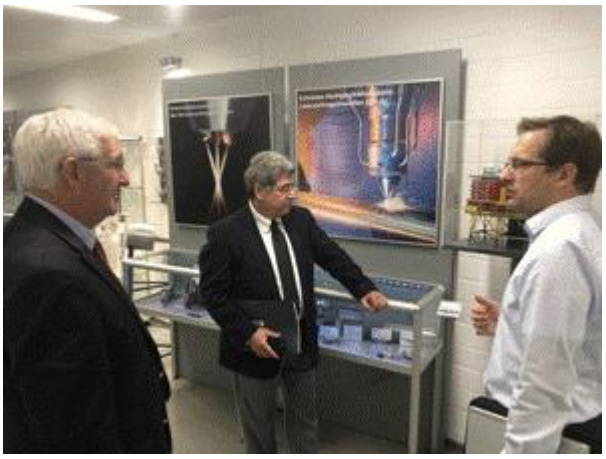


FIGURE 19. LEARNING ABOUT ADDITIVE MANUFACTURING USING LASERS AT FRAUNHOFER INSTITUTE FOR LASER TECHNOLOGY

VI. LASER-TEC AS A RESOURCE CENTER

LASER-TEC begun its operation in August 2013. In 2017 it received the second NSF ATE funding to continue its work as an ATE Center until 2020. This year, LASER-TEC has been awarded a $1.6 million grant from the National Science Foundation Advanced Technological Education Program to continue its operation as a Resource Center during the next three years.

As a Resource Center, LASER-TEC will update and maintain educational services and materials, and provide open access to these resources for secondary, post-secondary, and industry educational and training programs.

The Resource Center's mission will be to update, maintain, and provide open access for a broad range of services and materials to secondary, post-secondary, and industry educational and training

programs with the intention of continuing expansion in the robust laser, optics, photonics, and fiber optics technical workforce. The Resource Center's goals include:

- developing a comprehensive, high-performing, and responsive website to house and distribute all LOPFO educational products;
- enhancing all curricular materials with updated technical content and high-impact pedagogical strategies;
- creating tailored content and professional development events for teachers, college instructors, counselors, advisors, administrators, incumbent industry members, and other communities;
- informing K-12 and college educators about the availability of these LOPFO resources; and
- connecting industries that need LOPFO technicians and colleges that offer LOPFO programs.

The grant will facilitate the development of new modules in the areas of Raman Spectroscopy, LiDAR, High Power Diode Lasers, Femto Second Lasers, Disk Lasers, and other LOPFO technologies, in cooperation with industry partners. LASER-TEC will also continue its efforts in supporting historically underserved and underrepresented groups to increase diversity in this technological field.

VII. LASER-TEC'S IMPACT

During this evaluation period, LASER-TEC's activities had the following impact:

GOAL1

- Increased number of colleges that are aware of photonics education
- Increased number of colleges developing photonics courses and programs
- Increased number of colleges offering photonics courses and programs
- Increased output of graduates from southeast colleges
- Reduced the supply/demand gap for photonics technicians in the southeast

GOAL 2

- Increased infusion of photonics into K-12 STEM disciplines as the result of:
    - increased number of teachers attending LASER-TEC workshops
    - diversified content of the workshops
- Availability of LASER-TEC support with the content integration
- Growth and sustainability of academic photonics programs anchored by continuous faculty professional development
- Incumbent workforce knowledgeable and skilled in the latest advancements of photonics technology

GOAL 3:

- Increased infusion of photonics into K-12 STEM disciplines
- LASER-TEC kits create an affordable way to teach photonics in K-12 schools and colleges
- Increased infusion of photonics curriculum into college programs and industry training programs
- New modules are being developed
- LASER-TEC resources support fast track and affordable training of photonics workforce

GOAL 4:

- Increased number of students interested in photonics
- Increased number of teachers, advisors, and counselors who are aware about academic and professional career pathways to the photonics field

- LASER-TEC boot-camps and workshops provide a long-term photonics engagement platform for middle school and high school students to prepare for college

GOAL 5:

- Multifaceted engagement and recruitment programs launched by LASER-TEC
- Increased number of women in LASER-TEC programs
- Expanded cultural diversity in LASER-TEC programs
- Increased number of veterans in LASER-TEC programs

PART IV

RECOMMENDATIONS

- Continue developing new and updating existing photonics educational materials.
- Standardize all LASER-TEC curriculum.
- Continue efforts in assisting colleges with photonics materials and resources.
- Continue offering mentoring to colleges integrating photonics into their program offerings.
- Ensure strong communication and collaboration among OPCN colleges.
- Focus on professional development initiatives for educators and industry.

PART V

CONCLUSIONS

Despite obstacles presented due to the spread of COVID-19 during the 2019-2020 evaluation period, LASER-TEC has delivered significant outcomes for goals identified in the logic model, which are provided on page 4 of this report. The evaluator regards these deliverables as having been attained. The Center's implementation of these goals is outlined below.

During the 2019-2020 evaluation period, LASER-TEC has increased assistance to its growing network of colleges offering photonics programs, courses, or modules. The current network of LASER-TEC colleges advanced to 41 colleges with active photonics offerings and 24 colleges that are at different stages of the planning phase. The Center has maintained regular communication and collaboration among the members of the network.

LASER-TEC has provided the colleges with necessary resources to adjust to the new educational format due to national "stay-at home" orders and continued support of quality hands-on photonics education. During the last couple of months, the Center has assembled and mailed 116 Light and Optics Experiment Kits to 11 colleges in 10 states. This assistance has been identified as significant by the participating colleges.

The Center has offered professional development in lasers, photonics, optics, and fiber optics for educators and the industry professionals in multiple formats, consisting of both online courses and

face-to-face workshops at colleges and conferences. The post event evaluations indicate that the Center has developed and conducted relevant and quality professional development.

The Center made a significant effort in locating, systemizing, and publishing curricula and educational materials on their website. The evaluator notes that the Center recognized limitations of the current website in streamlining access to the materials. However, as the Center transitions to the Resource Center, it will develop a new website using available platforms that offer necessary solutions.

Public outreach and student engagement have remained central to the major goals of the Center in 2019-2020. LASER-TEC has offered both long- and short-term events such as camps, workshops, lab visits, industry visits to schools, laser shows and more. LASER-TEC has continued its efforts in reaching out to populations that were historically underrepresented in photonics and other STEM fields.

In summary, LASER-TEC remains to be focused and agile in its approaches to fulfill its mission to build and sustain the laser and fiber optics workforce.

Collaboration