TSTC Waco’s Photonics Summer Institutes for High School Science and Technology Teachers

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Dan Hull, OP-TEC

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TSTC WACO’S PHOTONICS SUMMER INSTITUTES
FOR HIGH SCHOOL SCIENCE AND TECHNOLOGY TEACHERS

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Abstract: OP-TEC: The National Center for Optics and Photonics Education—funded through the National Science Foundation’s Advanced Technological Education (ATE) program—is pooling the expertise and resources of schools (especially two-year postsecondary), businesses, and professional associations in supporting the implementation of photonics programs and elective courses (including teacher professional development) in high schools and colleges with the aim of creating a secondary-to-postsecondary “pipeline” of highly qualified and strongly motivated students. By empowering community colleges to meet the urgent need for technicians in optics and photonics, OP-TEC will play a significant role in maintaining our country’s economic competitiveness and military preparedness, and ensuring that highly rewarding jobs will be retained for American citizens.

What is the problem?
Most colleges with photonics technician programs need larger enrollments of qualified, successful students. These students should be familiar with the field, interested in technician careers in photonics, and math-ready (proficient in high school algebra, geometry, and trigonometry).

The most promising source of students is recent high school students. Colleges need successful strategies that will enable them to recruit more students by “building the high school pipeline.”

To whom is this monograph addressed?
This monograph is addressed to postsecondary educators and administrators at colleges that offer or are planning to offer courses and/or programs in photonics technology.

What is the purpose of the monograph?
The purpose of this monograph is to describe a successful program that TSTC Waco has developed and to provide information about how the program can be replicated.

Introduction
The primary reason TSTC Waco established its Photonics Summer Institute program was to increase its enrollment by building a successful and sustainable secondary-to-postsecondary “pipeline” of students. High enrollments in college technical education programs do not just happen. Student recruitment is hard work that requires persistence over the long haul and commitment on the part of high school and college administrators, faculty members, college
recruiters, and high school counselors. In other words, significant planning and viable partnerships between and among all the players are required for lasting success.

Two-year colleges have employed a variety of methods in their efforts to increase enrollment in their technical programs. One method that has been used successfully by TSTC Waco’s Laser Electro/Optics Technology (LEOT) program is the summer institute model, which is described in detail in this monograph.

The process described has evolved over the past three years and has been improved with each institute. The gradual improvement in results demonstrates that college faculty members and administrators must develop a patient attitude and be willing to invest time and effort in the beginning and be prepared to wait for the fruits of their labor to be fulfilled over time. Since students in the secondary system tend to make their career choices around the ninth grade, the TSTC Waco Photonics Summer Institutes are geared toward middle and early high school students. Consequently, it is hoped that the success achieved thus far is only the beginning of a promising trend that may achieve dramatic results over the next few years.

Background

The Laser Electro/Optics Technology (LEOT) program at TSTC Waco was the first of its kind in the U.S., dating back forty years. As early as 1980, enrollment in the program exceeded 130 students. Over the years, more than $5 million in lab equipment has been acquired or donated for use in the program’s many hands-on activities. Graduates from the program are employed throughout the country by R&D labs; original equipment manufacturers (OEM); government and private defense, aerospace, and energy organizations; manufacturing and materials processing facilities; and telecommunication and medical equipment companies. Some of the program’s graduates have continued their education at higher levels (some earning doctorates) and others have founded and operated their own companies.

Today, TSTC Waco offers two photonics-related AAS degree programs:

1. Laser Electro-Optics Technology (LEOT) is a 72-hour AAS program comprising eight courses (36 hours) in optics, electro-optics, laser fundamentals, and laser systems and applications. Graduates of the LEOT program are qualified to work as R&D technicians in energy, defense, and aerospace and as field service techs for laser equipment and laser systems OEM companies.

2. Nanotechnology is also a 72-hour LEOT program with a specialization in nanotechnology that gives students access to advanced, industry-standard equipment in lasers and optics, vacuum systems, semiconductor development equipment, and electronic support systems.

TSTC Waco is also planning to offer in the near future a one-year Laser Lab Technician certificate as an “early college” program.

Graduates of TSTC Waco’s photonics-related programs always get good jobs. In fact, there are usually not nearly enough graduates to fill the jobs available.

TSTC Waco currently has 65 students in its photonics-related programs. Last year the programs graduated and placed only 15 completers. To meet the demands of the photonics employers that rely on TSTC Waco, the programs must increase their enrollment and help more of their students earn marketable credentials.
Recruiting students into TSTC Waco’s photonics-related programs is particularly difficult. TSTC Waco is a statewide institution, which means that it must recruit its students from all across Texas (a very large state). Most community colleges have much more limited service areas. For them, student recruitment requires only that they maintain a “local presence” and build partnerships with nearby high schools. Most TSTC students travel to the campus from other regions of the state to become full-time students in residence. To do this, the students must know, in advance, why they are enrolling in TSTC Waco and must have clear career expectations—what is required of them and what they hope to gain in the workplace. Students don’t just move to Waco, enroll at TSTC, and wait a few semesters to decide on their majors.

The success of TSTC Waco’s photonics-related programs in recruiting students depends on the programs’ ability to maintain statewide visibility and to earn the respect of high school science and technology teachers and guidance counselors. Experience has shown that the best way to enhance the programs’ reputation with educators is to invite them to the campus to participate in hands-on activities similar to those experienced by full-time students. Weeklong summer institutes for teachers and counselors have proven to be a smart strategy for accomplishing the programs’ recruiting goals.

Strengthening the Photonics Pipeline through High School STEM Academies

In nearly every state of our country, there are intense, well-funded initiatives to create STEM academies in high schools. (The acronym “STEM” refers to the science, technology, engineering, and mathematics cluster of career and technical education.) STEM academies are typically four-year, secondary-level smaller learning communities whose curricula and teachers focus on the career exploration and foundational courses necessary for smooth transition from high school into postsecondary engineering and engineering technology programs. Students choose to enter STEM academies at the beginning of the ninth grade. The curriculum of a STEM academy contains all the courses needed to graduate from high school and enter postsecondary education, but many of the math and science courses are taught in the context of engineering and engineering technology careers. In addition, elective courses in the “engineering/technology core” are provided to familiarize students with engineering fields and enable them to acquire foundational knowledge pertaining to careers in those fields. Students who enter STEM academies are not “tracked” out of options. If they decide not to continue in engineering (or related technology fields) after high school, they can transition to other majors without being academically penalized or losing credits. But for those who do continue their postsecondary studies in engineering fields, their high school programs of study will have provided them with proficiency in the required mathematics and science areas, thus ensuring that they can master courses pertaining to any number of technical fields, including photonics. Their STEM academy programs may also enable them to complete—and receive postsecondary credit for—a broad spectrum of technology courses.

Since STEM academy students make their choices at the beginning of the ninth grade, photonics should be one of the technologies introduced to eighth graders as a way of attracting them into STEM academies. Photonics (or lasers) is one of the most attractive fields in the STEM cluster.

Another important feature of many STEM academies is that students are encouraged to participate in internships with technology-focused employers during the summer after the eleventh grade. These internships reinforce employability skills and motivate students to continue their career-related studies after high school graduation.
A cautionary note: If STEM academies are to do their part in strengthening the pipeline for AAS programs such as those offered at TSTC Waco, they must remain open to a broad range of students. Colleges should strongly encourage their affiliated high school STEM academies to keep enrollment open to the top 70 percent of student achievers. A frequent mistake of STEM academies, after a few years of successful operation, is to “cream the crop” by restricting enrollment to the top 15–20 percent. When this happens, the academies become pipelines only for baccalaureate programs—not for AAS programs. The engineering technician shortage in our country is as great as, if not greater than, the engineering shortage. A recent OP-TEC study found that 2100 new photonics technicians are needed in 2009. The two-year colleges in our country are currently producing fewer than 300 photonics technicians a year. This represents a critical gap between “supply and demand” that threatens our national security and economic growth. High school graduates in the “middle 50%” are the main source for our future students. We believe they are capable but underachieving because they are predominantly “applied learners” and do not respond well to traditional, abstract teaching of math and science.

Purposes and Goals of TSTC Waco’s Photonics Summer Institutes

For the past two summers (2007, 2008), TSTC Waco has hosted weeklong Photonics Summer Institutes. The institutes were held during the first and second years of the NSF OP-TEC grant. The institutes’ training and awareness events were supported with funds provided by the grant. As other colleges explore how they might replicate the program, they should keep in mind the purposes and goals of the TSTC Waco institutes.

Purposes of the Institutes

1. Introduce photonics (lasers and optics) and show topics that can be infused into science and technology courses
2. Provide “hands-on” experiences and best practices to interest teachers in photonics
3. Familiarize teachers with optics and laser equipment and safety; show them how they can acquire equipment and set up labs at their respective high schools at minimal cost
4. Display laser and optics graphics and informational materials and provide information on how to acquire copies
5. Provide information about careers in photonics; provide copies of high-quality SPIE promotional DVDs so that teachers can play them for their students
6. Discuss postsecondary educational programs in photonics
7. Showcase TSTC Waco’s AAS programs in photonics
8. Explore opportunities to offer dual-credit photonics courses via collaboration between TSTC Waco and the high schools of the participating teachers

Goals of the Institutes

1. To increase the number of students in the Laser Electro-Optics Technology (LEOT) and Nanotechnology programs at TSTC Waco
2. To develop 4+2+2 career pathways for high school students in photonics-enabled technology programs
3. To increase the number of people who graduate from these programs and are qualified for employment in photonics and related fields
How the Institutes Have Evolved Over Time

Students and secondary teachers from high schools in Texas were invited to participate in three five-day events during the summers of 2007 and 2008. (The initial focus was on teachers, but students were admitted to fill out the classes. Student participation in 2007 benefited the program by contributing to significant increases in student enrollment in 2008.)

Participants came from over 100 miles away (Leander, Denton, and Round Rock). In initial recruiting efforts, high schools were visited by TSTC Waco staff and faculty members, along with an OP-TEC-funded recruiter, to alert high schools to the goals, objectives, and benefits of the institutes. Each applicant was asked to write an essay on photonics. Successful essays were the participants’ passports to the institutes. Students and instructors completed application forms as well.

During year one of the grant, it was understood that the first institute would serve as a trial run, providing feedback that would enable OP-TEC and TSTC Waco to work out unforeseen challenges and make improvements for the institutes to be held during years two through four of the grant. A debriefing session for TSTC Waco staff and faculty members was held immediately following the first institute to discuss how the event might be improved. The first year’s institute was a success, but participation by teachers was limited. The first-year participants consisted of two teachers and eleven students.

Feedback from the high school teachers was extremely positive. Both said that they would encourage their colleagues and send their students to future institutes. Teachers also expressed their approval of having teachers and students continue to work side by side.

Six of the eleven students stated that, as a result of their experience at the 2007 institute, they planned to attend TSTC Waco after high school graduation.

In summer 2008 two institutes were held, also on the TSTC Waco campus. They were also successful and well attended. Sixteen students and six high school teachers participated. Thus far, the institutes have introduced 35 participants to photonics technology and TSTC Waco’s Laser/Electro-Optics Technology programs.

From year one to year two, the institutes experienced a 400 percent increase in participation by high school teachers. This is significant since, on average, each teacher may reach 30 to 60 students as potential enrollees at TSTC Waco. The enrollment for this year’s (2009) institute has reached 30 participants. Overall attendance has doubled each year (teachers and students combined). If that trend holds, the 2010 enrollment should be 60.

Typical Agenda

<table>
<thead>
<tr>
<th>Day</th>
<th>Date</th>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>Monday</td>
<td>July 23</td>
<td>11:00 A.M.–3:00 P.M.</td>
<td>Arrival and check-in at Village Oaks</td>
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<td>3:00–4:00 P.M.</td>
<td>Free time</td>
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<td>4:00 P.M.</td>
<td>Pick-up time at Village Oaks for barbecue</td>
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<td>Tuesday</td>
<td>July 24</td>
<td>7:00–8:00 A.M.</td>
<td>Breakfast in the Ideas Center</td>
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<td>8:00 A.M.</td>
<td>Department tour</td>
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<td>8:30 A.M.</td>
<td>Introduce course and hand out books</td>
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<td>9:00 A.M.</td>
<td>Lecture: HeNe Operation and Safety</td>
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<td>Day</td>
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<td>Tuesday</td>
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<td>10:00 A.M.</td>
<td>Alignments:</td>
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<td><strong>Lab 1</strong> Alignment Down a Rail</td>
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<td><strong>Lab 2</strong> Capillary Tube Alignment</td>
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<td>12:00 Noon</td>
<td>Lunch</td>
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<td>1:00–4:00 P.M.</td>
<td>Lecture: Law of Reflection</td>
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<td><strong>Lab 3</strong> Alignment with Two Mirrors through Capillary Tube</td>
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<td><strong>Lab 4</strong> Reflected Power Experiment</td>
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<td>4:00–5:00 P.M.</td>
<td>Wrap-up</td>
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<td>Wednesday</td>
<td>July 25</td>
<td>7:00–8:00 A.M.</td>
<td>Breakfast in the Ideas Center</td>
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<td>8:00 A.M.</td>
<td>Basic optics definitions</td>
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<td><strong>Index of refraction</strong></td>
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<td><strong>Prism theory</strong></td>
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<td>9:00 A.M.</td>
<td>Prism experiments</td>
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<td><strong>Lab 5</strong> Spectrometer Experiment</td>
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<td><strong>Video: Science at the Edge</strong></td>
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<td>11:00 A.M.</td>
<td>Lecture: Basic Lens Theory</td>
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<td>12:00 Noon</td>
<td>Lunch</td>
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<td>1:00 P.M.</td>
<td>Lens experiments</td>
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<td><strong>Lab 6</strong> Collimators</td>
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<td><strong>Lab 7</strong> Newton’s rings</td>
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<td>3:00–5:00 P.M.</td>
<td>Recruiting presentation</td>
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<td>TSTC laser/nano placement</td>
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<td>Thursday</td>
<td>July 26</td>
<td>7:00–8:00 A.M.</td>
<td>Breakfast in the Ideas Center</td>
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<td>8:00 A.M.</td>
<td>Lecture: Windows Theory and Brewster’s Angle</td>
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<td>9:00 A.M.</td>
<td>Windows experiments</td>
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<td><strong>Lab 8</strong> Brewster’s Angle and Index of Refraction</td>
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<td><strong>Lab 9</strong> Coefficient of Absorption</td>
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<td><strong>Lab 10</strong> Transmission Experiment</td>
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<td>12:00 Noon</td>
<td>Lunch</td>
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<td>1:00 P.M.</td>
<td>Nanotechnology lab tour</td>
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<td>3:00 P.M.</td>
<td>Video: Real Genius</td>
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<td>Friday</td>
<td>July 27</td>
<td>8:00 A.M.</td>
<td>Breakfast and certificates</td>
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**Costs per Institute**

- Housing on TSTC Waco campus (16 participants, 4 nights @ $20/night) $1,280
- Meals (16 participants, 4 days) $1,200
- Awards (trophies for teachers/certificates for students) $100
- Chaperones $1,500
- Total costs $4,080
**Institute Manual**
Each participant received a manual containing PowerPoint presentations, labs, and other materials taught during the week. The manuals served the dual purpose of supporting the week’s activities and familiarizing participants with the lab format used in TSTC Waco’s LEOT program. Copies of the manual are available from OP-TEC.

**Workshop Facility—Lab Layout**

![Lab Layout Diagram](image-url)
Equipment per Station

Additional equipment and supplies:

- First surface mirrors
- Safety glasses
- Spring clip filter holder
- Rotary stage
- Sliding grip lens holders
- Carriages
- 8 posts
- Mirror mount
- Vertical rotary stage
- 1 Meter ruler

SPIE Grant for Teacher Stipends
SPIE provided a supplemental education outreach grant to support teacher participation. After completing the institute evaluation form and providing information required by SPIE, each participating teacher was issued a check. The availability of stipends increased the number of teacher participants.

Awarding CEUs to Enhance Teacher Recruitment
TSTC is authorized to issue CEUs to institute participants. TSTC’s authorization number is printed on the teacher certificate. The teacher is then able to take that number to his or her
district and get credit for attending the institute. The availability of CEUs for participating teachers increased the number of participants.

**Evaluation of the Institutes**

Each participant was asked to complete an evaluation instrument covering the following topics:

- Housing
- Meals
- Lectures
- Lab activities
- Lab equipment
- Problem exercises
- Recruiting presentation
- Instructors/facilitators

Participants rated all elements as very good or satisfactory. The following comments were provided.

**Testimonials from teachers**

- *This is my second year to attend the Summer Institute. The presenters and the presentations were excellent and the material covered was relevant. I will be recommending this venue to my counterparts and to my students. One of my current students will be attending the July session. I expect him to return with a wealth of new knowledge and a new perspective.* R. V.

- *I really enjoyed the Institute because of the instructional time followed by lab activities and the application situations with TSTC instructors. The TSTC faculty and staff were excellent at presenting material and topics. I would recommend this institute to anyone looking to further their knowledge and show the variety of courses offered at TSTC.* B. A.

**Testimonials from students**

- *The OP-TEC Institute is a very interesting program because not only does it teach you about lasers and how to use them, but this program also allows you to work with optics. I think that is what makes this program.* A.B.

- *The Laser Electro-Optec Program is really awesome. The program doesn’t just teach you about lasers, it also teaches responsibilities. In the program, it teaches how to align lasers and mirrors. I do plan on coming back next year for more education on lasers. I also hope to come to TSTC for college after high school. This has taught me a lot of things and I will never forget this education that I have learned. Thanks, TSTC, for having a great program!* J.R.

- *Everything was fun, but there was one moment that I enjoyed the most. It was shooting the laser. Shooting the laser was exciting and interesting because we had to shoot the laser*
through a capillary tube and reflect the laser with mirrors, and I learned a lot from doing that activity. M.G.

- Everything was so much fun and very interesting. I’ve never really wanted to work with lasers but after seeing and doing the alignments and reflections, it seems like something I would really enjoy doing. The activities were amazing and challenging! D.M.

- Working with the lasers has opened more possible career paths that I may take. I really liked taking a tour through the laser lab and learning many tricks about aligning the lasers. Learning about the anatomy of the eye and how lasers apply to it was really interesting. The teacher that taught us was really great and I was able to learn something new. Also, it helped me see college life. D.M.

- I thought that nanotechnology is very interesting and I would like to get involved with it. I thought the same thing about the holograms. A.J.

- I enjoyed many of the tours through the facilities and seeing many of the applications of laser technology. I also enjoyed the staff members, who were enthusiastic and very entertaining. C.N.

- Aligning the lasers was amazing! Seeing actual lasers in action was something unforgettable. Thanks a lot! K.S.

- While doing the activities about lasers, I enjoyed being able to have a hands-on experience and learn how much laser tech is used in our daily lives. I enjoyed working with lasers because there’s many ways that we used them. C.N.

- Working with lasers was an amazing experience that I wouldn’t have enjoyed without TSTC’s offer. Having the time to see all the new high and great technology has had a great impact. M.H.

- I love the part on the presentation where we went to the lasers with Mr. Pedrotti. We had to line the dots onto the laser and then see on the X to see if we did it right. I learned a lot with lasers and will love to do it again. Working with lasers is challenging but, if you don’t give up then you will get it. C.D.

- For me making a dot appear on the other side of the tube was inspiring. It made me realize that I could accomplish anything if I just concentrate, get serious, and try. I really liked the program because it lets you see what you can do with technology and experience. D.O.

- For me aligning the laser was extremely fun to do. Aligning the laser was a challenge to do and was completely amazing to do. Coming to the Summer Institute was a really great time for me to learn about lasers and how they work. J.G.

- The lasers were fun and interesting. I would like to learn more interesting things about lasers. C.B.
**Recommendations**

Emerging technologies such as photonics and nanotechnology must be experienced to be appreciated. Unfortunately, community and technical college offerings in these fields are one of the best-kept secrets in the country. High school teachers and counselors need to experience these technologies first hand, and they need to learn about the wonderful, rewarding career opportunities that are available to young people. Visits to high schools and “gee whiz” talks and demonstrations aren’t enough. The “middle 50%” of our high school achievers are frequently not encouraged to consider careers in emerging technologies. Most of these young people are capable of mastering the math, science, and technology that these careers require—and they are capable of enjoying education when they see that it has a purpose. They deserve the rewarding jobs that are available to them, and our country deserves the talents that they can provide if they are encouraged and educated.

Outreach initiatives such as TSTC Waco’s Photonics Summer Institutes for high school teachers, counselors, and students are a proven strategy for recruiting students into two-year programs in emerging technologies.

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