the SPS Observer

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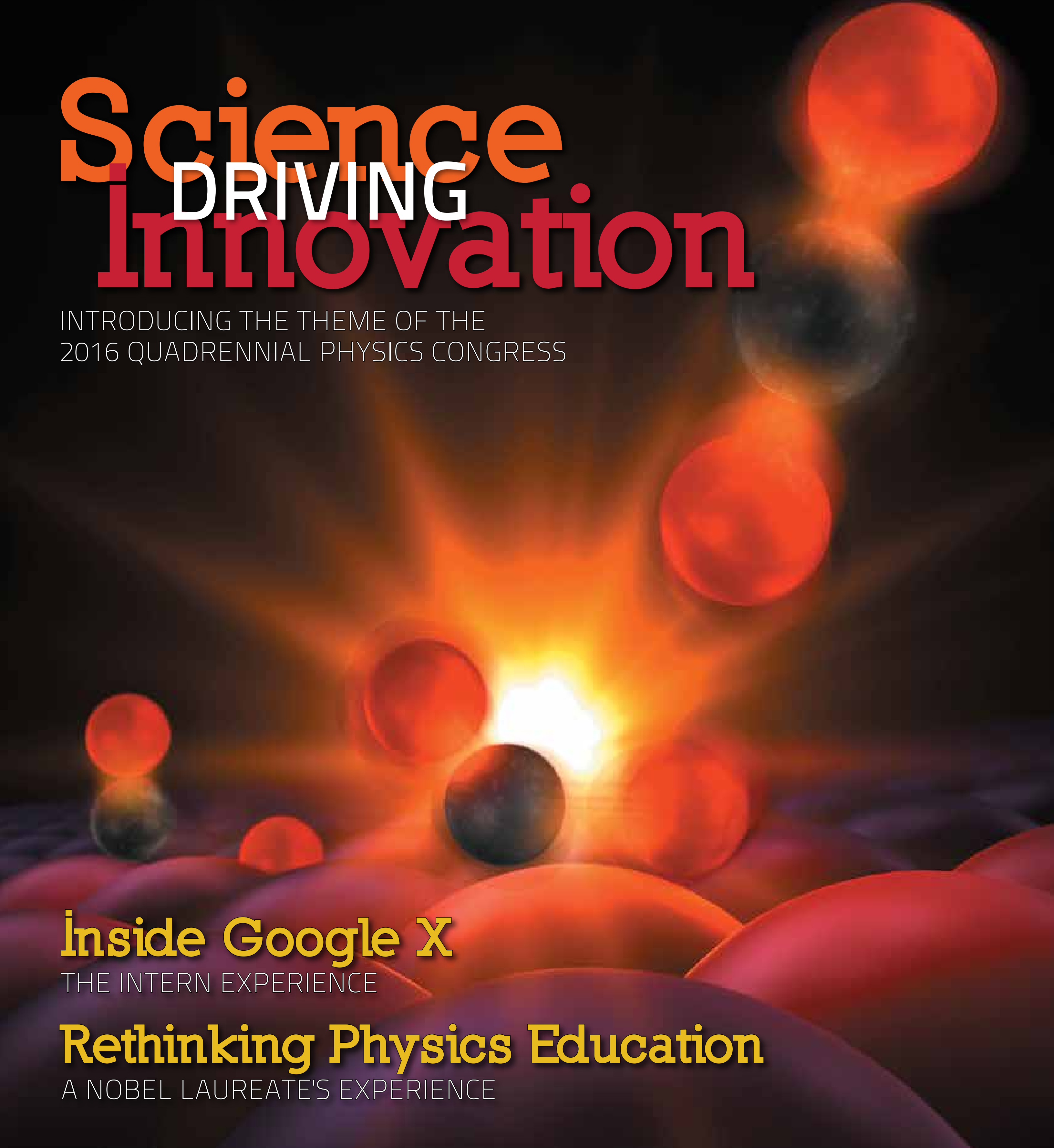

Science DRIVING Innovation

INTRODUCING THE THEME OF THE
2016 QUADRENNIAL PHYSICS CONGRESS

Inside Google X

THE INTERN EXPERIENCE

Rethinking Physics Education

A NOBEL LAUREATE'S EXPERIENCE

SOCIETY OF PHYSICS STUDENTS

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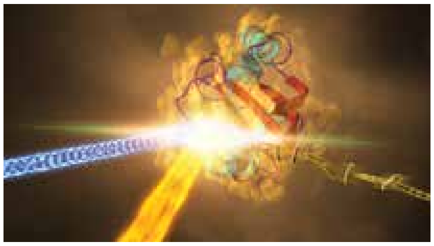
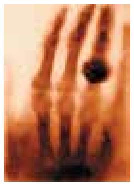
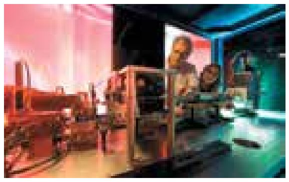


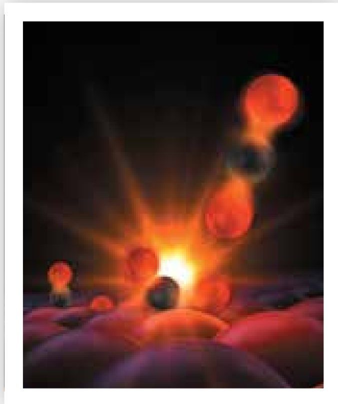




Science Driving Innovation

Special Feature

DEPARTMENTS



ON THE COVER
This illustration shows atoms forming a tentative bond, a moment captured for the first time in experiments with an X-ray laser at SLAC National Accelerator Laboratory. Learn more about SLAC on page 18. Image courtesy of SLAC.

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Unifying Fields

SCIENCE DRIVING INNOVATION

INTRODUCING THE THEME OF THE 2016 QUADRENNIAL CONGRESS OF SIGMA PI SIGMA

by William DeGraffenreid
Professor of Physics and Department Chair at the University of California, Sacramento
Co-Chair of the 2016 Quadrennial Physics Congress Planning Committee

If you were to ask random people to describe what Silicon Valley means to them in one word, I would venture a guess that answers such as "innovation," "technology," "computers," and "money" would be popular.

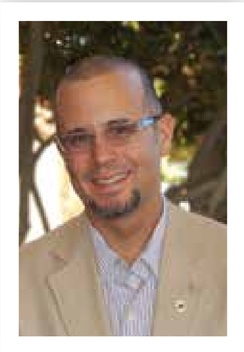


Photo by Liz Dart Caron.

If you were to ask members of the SPS National Council the same question, you might get a different answer: "Congress."

Sigma Pi Sigma and the Society of Physics Students have begun planning the 2016 Quadrennial Physics Congress. It will take place just outside of San Francisco, CA, a city that has been fundamentally changed by the energy of Silicon Valley in recent years. Drive around the Bay Area and you'll see names like Google and Facebook on the sides of the buildings. The region is a hotbed of movers and shakers, with few peers anywhere else in the world.

This location is a fitting place for the Congress, which brings together physics students, alumni, and faculty members for a high-energy, exciting weekend packed with cutting-edge physics, networking events, and opportunities for personal and professional growth. The location also echoes the theme for the 2016 Congress, around which the program is designed—Unifying Fields: Science Driving Innovation.

In line with that theme, this issue of *The SPS Observer* brings together examples of how people are using their understanding of physics, and the skills they developed while students of physics, to move our society forward. Meet Ben Perez, an SPS member who spent a summer on an ambitious Google X project that uses balloon-mounted lasers to send and receive data. Read about X-ray innovations coming out of the Stanford Linear Accelerator Center. Hear the story of how exploring frontier physics topics changed the course of SPS alum Sean Bearden's life. Test your knowledge on some of the physics discoveries that have led to game-changing inventions.

Almost all of the new freshmen physics majors who come to orientation at my university indicate that their goal is to attend graduate school, earn a PhD, and then get a great job at a university or national laboratory. While I know that this is a path that some will follow, I also know that it isn't for everyone. As you progress through your classes, attend department seminars, read *Physics Today* and *The SPS Observer*, and talk to your professors, you will learn about the wide variety of opportunities that exist beyond academia, many of which can catapult you to the forefront of innovation. (For an example, read Sandeep Giri's excellent piece on his own path on page 6.)

Leveraging our understanding of the physical world to push society forward is not new. From fundamental "simple machines" to complex electromechanical systems, the laws of physics have been exploited time and time again to make our lives easier, longer, and better. We hope that you will come to the 2016 Congress and join the conversation about how to continue using science to drive innovation. //

CALIFORNIA'S SILICON VALLEY, JUST OUTSIDE SAN FRANCISCO, is the setting for the 2016 Quadrennial Physics Congress.

Unifying Fields
SCIENCE DRIVING INNOVATION

#PhysCon

2016 Quadrennial Physics Congress
November 3-5, 2016 • Silicon Valley, CA
Host hotel: Hyatt Regency-San Francisco Airport
Hosted by Sigma Pi Sigma, the physics honor society

www.sigmapisigma.org/congress/2016

The Physics-Engineering Debate

by Sean Bentley
Director, Society of Physics Students and Sigma Pi Sigma

Thanks largely to popular media, there is a misconception that physicists never consider anything of practical concern. Meanwhile, engineers (while badly represented by the media in their own right) are credited with making our day-to-day lives better. Along with this is the mistaken view that if you study physics your only employable options are a PhD or high school teaching, whereas the fast road to a lucrative career is a degree in engineering.

When selecting a major, I heard similar things, even from those whom we expect to trust for advice, such as high school guidance counselors. Thus as someone who wanted to work at NASA as soon as possible, I started my degree in electrical engineering. After a few semesters of pragmatic courses and an internship at my hometown utility company, I knew I was more drawn to the fundamental questions than developing a product, process, or network. I took as much quantum, solid state, electromagnetics, and optics as I could. As I was still under the illusion that a physics degree was not the route to a career, I continued on my original path, but happily added a physics minor. The hook then became fully set, and I completed my PhD and became a physics professor.

But what of the advice I was given? Over the years, I have interacted with a large number of people like me who migrated from engineering into physics, and an even larger group who started in physics and now work in engineering. The line between these fields is much more blurry than many would have you believe. I've heard it said that everything starts as physics, and if it is useful it is claimed by engineering. While this is an oversimplification, there is some truth here. All engineering is based on fundamentals often developed in physics. Science truly does drive innovation.

While some research may not seem to have any immediately obvious applications, many physicists are working on problems that could well be applicable to engineering within years if not less. The tools developed by engineers in turn allow physicists to probe more deeply and accurately. At the edge of high-tech, scientists and engineers often work side by side and can be hard to distinguish. As for employment possibilities, our own Career Pathways data shows that many students go directly from a bachelors in physics into the workforce, and often find jobs in engineering.

Whether you want to work in pure physics research, engineering, or something completely unrelated, rest assured that studying physics will teach you to think creatively and solve complex problems—two of the most needed skills for many jobs, and ultimately for navigating life. //

THE LINE BETWEEN THESE FIELDS **is much more blurry** THAN MANY WOULD HAVE YOU THINK.

THE AUTHOR IN TRANSITION... wearing his engineering honor society shirt while working in an ultrafast optics lab during his PhD training.

Swinging Physics

BEYOND THE TEXTBOOK: FUN WITH PENDULUMS

by Donald Simanek, Professor Emeritus, Lock Haven University of Pennsylvania

Pendulums are objects swinging periodically from a fixed support in a gravitational field. A simple pendulum is a negligibly small object called a bob, suspended by a string of negligible weight from a fixed point. Its period is given by $T = 2\pi\sqrt{(R/g)}$, where R is the length of the suspension string and g is the acceleration due to gravity. This equation is good in the approximation of small angles of swing.

But the idealized swinging point mass is a bit unrealistic. Increase the size of the bob and you get a slightly different result. If the swinging object is of considerable size, or the angle of swing very large, the result can be very different.

One example of a nonsimple pendulum is the very familiar porch swing: a chair, usually seating two people, suspended from the ceiling by four ropes. Let's consider the simplest type in which the four ropes are of equal length and all parallel, attached between the chair arms and the ceiling. By itself, it has a natural period, T, swinging in the usual way, front to back. The formula above applies, but only if you insert an appropriate value for the suspension length, R. Should this be

A SWING with four parallel ropes supporting it. Author image.

a. the length of the supporting ropes?
b. the distance from the ceiling support to the chair seat?
c. the average of the above two distances?
d. the sum of the rope lengths?

Suppose Galileo—an aficionado of the pendulum—and his daughter Maria Celeste sit on the swing, enjoying the relaxing front-to-back motion, back and forth. What is the period of this motion now?

a. greater than the unloaded swing
b. the same as the unloaded swing
c. less than the unloaded swing

Now suppose that our esteemed Italian scientist and his daughter are bored with swinging forward and backward. They decide to swing sideways. What is the period of the motion now?

a. greater than the unloaded swing
b. the same as the unloaded swing
c. less than the unloaded swing

Ready for the answers? Turn to page 28.

SHARE YOUR PHOTOS

Email sps-programs@aip.org a photo of your chapter exploring porch swing physics, and you could be featured in the next issue of *The SPS Observer*!

Going Google

WHY I DECIDED TO QUIT GRADUATE SCHOOL AND MOVE TO INDUSTRY

by Sandeep Giri
Manager, Advanced Technology Manufacturing (Project Loon) at Google X in Mountain View, CA

When I was a teenager, I moved from India to a small college town in Iowa. I wanted to study computer science. I ended up in physics (and joined SPS) thanks to a very convincing undergraduate advisor.

First he suggested I take a physics class, which turned out to be easy for me. Then he invited me to his lab to melt some glass.

The next thing I knew I was deep into glass research with him. He sent me to Fermilab and Oak Ridge. I presented at conferences, and we published half a dozen papers together. I went on to start a PhD program at Stanford, where I worked on chemical vapor deposition tools.

I was working on a research project that was going well when I decided to quit academic research. In retrospect, it was one of the best decisions I ever made.

Today, 10 years later, I work at Google X, a "moonshot" wing of the company responsible for many of its major technological advancements. I lead a multidisciplinary team of manufacturing engineers working on Project Loon, an effort to use stratospheric balloons to provide Internet access to places where ground infrastructure is difficult to build (see Ben Perez's story on page 16).

Knowing when to quit is difficult, but quitting is actually not a bad thing. Let me explain.

As a graduate student, I felt like I wasn't learning and growing at the rate I wanted. I walked into my PhD program with the impression that it was going to shape me, that I would have a wide variety of experiences and build incredible projects.

Instead it felt like a very sheltered environment. I went from my apartment to my department every day. I published papers. I went to conferences and talked to like-minded people. That was my graduate school experience.

SANDEEP POSES WITH ONE OF PROJECT LOON'S BALLOONS (left), destined to ride the winds of the stratosphere (middle). To the right, Sandeep and intern Ben Perez (left) pose with one of Google's street-view cars. Photos courtesy of the author.

THE AUTHOR (left) and intern Ben Perez (right). Photo courtesy of the author.

Then I had dinner with a friend who had been working in industry for a long time. He started talking about all the things he had done at Apple. He used terminology I had never heard before. He had just come back from a business trip to China, where he had been part of setting up a manufacturing process for iPods. He had been working with different companies in Japan and Taiwan. He had learned about reliability and quality testing, and talked about the organizational structure of his company.

I had just spent a day in the lab trying to deposit the same crystals I had been trying to deposit for three months. My experience felt very bland and narrow compared to his.

I wanted to emulate him.

It's kind of ironic, but I made the decision to quit the day after I passed my qualifying exams at Stanford. I told my advisor I was leaving in three months. She didn't want me to. I was in the thick of things. I had built new tools. It would take awhile to bring in someone new and bring them up to speed. She tried to persuade me to stay.

There was a little bit of guilt. I felt like I was betraying my project and my professor, who had invested time and resources in me. I was also leaving a school with a department that was number one in the country.

I was leaving a lot at the table, but I stuck to my guns. In the end, it was the right choice for me.

I still do research in industry, but I study different things at a faster pace and with more more resources. At my first post-Stanford job, at Qualcomm, I jumped into product development. I worked on solar technologies and MEMS-based screens for mp3 players, smartphones, e-readers, and smart watches. In 2011 I packed my bags, took my family, and became an expat, setting up manufacturing facilities in Taiwan.

When I came back to Silicon Valley, people were looking for folks with that hands-on experience. I took a position at Google X and helped to bring up manufacturing processes for Google Glass in Singapore, Switzerland, and the United States. I developed optical technologies for the next generation of Glass before moving over to Project Loon.

> Knowing when to quit is difficult,
> BUT QUITTING IS ACTUALLY NOT A BAD THING.

My advice to undergraduates is to explore your options. Start by doing some research in a university lab or a national lab to get a feel for academic research. Do some research in an industrial setting too. Talk to people who took the PhD path, people who became postdocs and professors, and PhD researchers in industry. Talk to people who started working right after their undergraduate degree, or after a master's degree. Talk to people who did what I did, who quit and went to industry. Try to get a wide spectrum of perspectives from people on different career paths.

Have honest conversations with yourself. What motivates you? How much do you like working with equipment every day? Do you like the pace and culture of the academic environment? How would you respond to a faster-paced, more application-oriented environment? What kind of environment do you want to spend the majority of your twenties in?

I consider the twenties to be one of the most critical periods of our lives. We make several important decisions during that time, career direction being one of them. By the time most people finish their PhD, they've been in a university for a decade (including their undergraduate experience). That experience is rewarding for many people, and it can lead to groundbreaking discoveries and advancements, but it's not for everyone.

If I could go back to my time as an undergraduate, I would look outside the walls of my university. I would volunteer at Rockwell Collins, which had a facility right next to my alma mater. I would go work for free. There are all these nuances about working in industry that aren't usually taught in the classroom. What's the pace like? How do you write professional emails? How do you prepare presentations for the business environment? How are meetings conducted? How does a company partner with external companies?

Go get your foot in the door. //

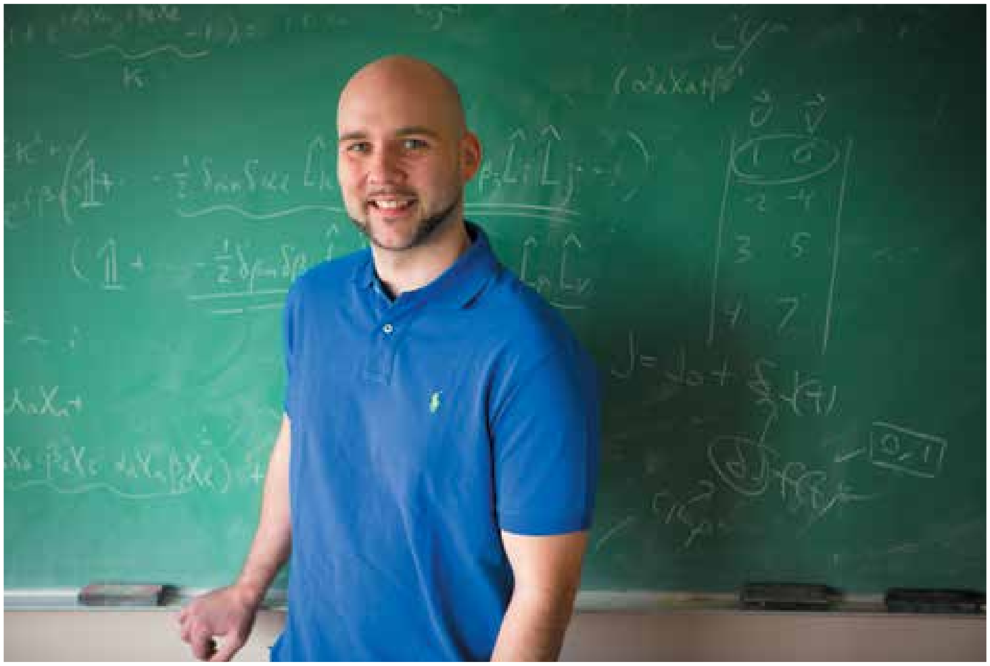
LEARN MORE

- **For more information on Google's balloon-powered Internet, see www.google.com/loon/.**

Sean Bearden's Redemption Road

HOW A PRISON SENTENCE INSPIRED A YOUNG MAN TO PURSUE PHYSICS

by Charles Anzalone, University at Buffalo, NY



SEAN BEARDEN is now at the University of California, San Diego, studying condensed matter experimental physics with physicist Dmitri Basov. Photo by Douglas Levere.

Society of Physics Students alum Sean Bearden is an applied mathematics and physics whiz. The recipient of a Barry M. Goldwater Scholarship and a National Science Foundation (NSF) Graduate Research Fellowship that will exceed $100,000, he studies the properties of spin lasers as a graduate student at the University of California, San Diego.

For Bearden, 30, of Tonawanda, NY, those tremendous scholarly successes are the latest in a sequence of unusual and contrasting events. As a teenager, he dropped out of high school and plead guilty to attempted assault. A more-than-six-year prison term fostered a fascination with quantum mechanics, which led to a renewed "drive" to salvage his life.

"I think Sean Bearden is a story of redemption and how education is the way out of difficult situations," says Elizabeth A. Colucci, coordinator of fellowships and scholarships for the University at Buffalo (UB) in New York.

As an undergraduate at UB, Bearden became a volunteer tutor for other students in the physics department. He brought new life to UB's SPS chapter as president and mentored other officers. He organized additional activities, such as tutoring and student Q&A sessions with distinguished speakers. He has been a College of Arts and Sciences' ambassador for physics and mathematics, as well as the public relations officer for the UB Combined Martial Arts Club.

"To see how someone can change his life in this way and become a dedicated physicist is incredible," wrote one referee judging Bearden's NSF application. "I am impressed by the change he underwent in his life and believe he would be a great ambassador for the overused sentence, 'If you believe in yourself, you can do everything.'"

Bearden clearly remembers a substitute fourth-grade teacher at Benjamin Franklin Elementary School in Tonawanda accusing him of cheating after he solved three-digit multiplication problems in his head. His classmates stood up for him, Bearden says.

"No, no, no," Bearden remembers them telling the substitute. "He can do that."

Bearden's ability to astound those around him continued at Franklin Middle School. "I used to answer things just by looking at the board," Bearden says. "No work or anything. There was a corner of the board dedicated to the times I was wrong because it was so rare. It wasn't to belittle me. It was almost a way of teaching me to slow down."

Junior high was also the time when Bearden's nonconformity turned dark. On the first day of ninth grade, Bearden left school at lunch with some older kids. "We just walked out of school, and we did it, and then we came back," Bearden says. "That kind of opened a door to 'I don't have to do school anymore.'"

Within a week, he was kicked out of honor's math. He got expelled from Kenmore

East High School before he made it through ninth grade, then was expelled or dropped out of two more alternative high school programs.

By the time he was 17, Bearden was delivering pizzas in North Buffalo, still going down the wrong path. When he was 19, he got into a confrontation at a gas station near his North Buffalo apartment. He pulled out an unregistered handgun and shot the man confronting him when he felt he was "in too deep" and couldn't get away any other way. He pleaded guilty to attempted assault rather than being charged with attempted murder and in 2005 began an eight-year prison sentence.

In prison he found what he calls a "drive," a "joy," or a "groove" that had eluded him throughout his previous life. He read constantly, mostly nonfiction books about science. The more he read, the more he realized those people who had treated him differently were on to something.

"I knew I was gifted in math," he says. "I knew it. And it was like, 'What am I going to do with that?'"

His mother told him about his "kooky" great uncle, who wrote extensively about topics such as perpetual motion, which caught Bearden's attention. The two men started writing back and forth. Bearden became fascinated with quantum mechanics. Exchanging ideas with his uncle, Bearden became absorbed with how this brand of physics seemingly defies conventional logic.

With his passion for chasing knowledge awakening, Bearden earned his associates degree from Ohio University while in Collins Correctional Facility. In 2012 he enrolled in UB to study physics and applied mathematics, surprised that the university accepted him despite his criminal record.

Prison gave Bearden a different perspective than that of the typical freshman, or himself when he was 18 years old, he says. "For me, it's best to be here now," he says. "I doubt I would have won any of the scholarships I have won, because I would have wanted to party."

Professor Igor Zutic invited Bearden to join his theoretical materials science research group after Bearden was the only student who got a perfect score on a test assessing students' mathematical preparation.

"What sets Sean apart is his unwavering desire to understand novel phenomena and being fearless when it comes to obstacles he has to overcome," Zutic says. "He is prepared to calmly deal with his own setbacks in tackling a research project, or patiently hone his skills identifying the key questions that he wants to answer."

Bearden left for the University of California, San Diego, in June to work as a graduate student researcher in condensed matter experimental physics with physicist Dimitri Basov.

Like the Bob Dylan song says, Bearden still feels pressure to serve somebody. But this time, it's an audience far different from the ones he fiercely defied as a youth.

"People who were watching TV in prison while I was sitting there studying noticed," says Bearden. "I almost became someone like 'If you can't do it, nobody can.' I had to live up to this to show them they could do something, too." //

A MORE-THAN-SIX-YEAR PRISON TERM FOSTERED A FASCINATION WITH QUANTUM MECHANICS, **which led to a renewed 'drive' to salvage his life.**

A longer version of this article originally appeared in the UB Reporter. To read the full text, visit http://bit.ly/1LnUYVr.

Are You Ready to SOCK?

REQUEST YOUR 2015 SPS SCIENCE OUTREACH CATALYST KIT TODAY

by Hannah E. Pell, SPS SOCK Intern 2015, Class of 2016 at Lebanon Valley College in Annville, PA
by Shauna LeFebvre, 2015 SPS SOCK/NIST Summer Institute Intern, Class of 2016 at Union College in Schenectady, NY

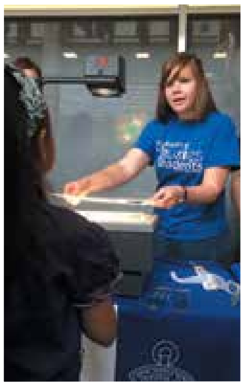
During our summer internship with the Society of Physics Students, we came into work one day and found a huge stack of thank-you letters. Third graders at the Tuckahoe Elementary School in Arlington, Virginia, had written to us after we ran a series of physics activities at their school. Reading through the letters was a highlight of our summer. It showed us the impact of the activity kit we developed and tested at the school—the 2015 Science Outreach Catalyst Kit (SOCK).

"Today I learned about physics and that it's science, math, and music… Now I really like physics!" one student noted. "And PS. You guys are super kewl!!!"

The SOCK, an annual product of SPS, is created over the course of a summer each year by two SOCK interns. It is quite literally a giant sock filled with materials used to conduct physics activities for science outreach events.

This year we created a kit focused on acoustics. Both of us have musical backgrounds, so we jumped at the opportunity to intertwine the arts with the sciences. We feel that acoustics

HANNAH PELL (LEFT) AND SHAUNA LEFEBVRE SHOPPING FOR SUPPLIES to fill the SOCKs! Photo by Courtney Lemon.



LEADING INTERACTIVE PHYSICS ACTIVITIES exploring sound and light at Tuckahoe Elementary School and the annual Howard County STEM Festival. Photos by Courtney Lemon.

TEACHING PHYSICS to 120 third graders is a group effort! SPS leaders pictured here (left to right): Aman Gill, Connor Day, Pat Mangan, Hannah Pell, Shauna LeFebvre, and Brean Prefontaine. Not pictured: Kyle Elliott. Photos by Courtney Lemon.

THE SOCK INTERNS WITH THEIR MENTORS on final presentation day at the American Center for Physics. From left: Sean Bentley, Katherine Rimmer, Shauna LeFebvre, Hannah Pell, Kendra Redmond, and Courtney Lemon. Photo by Matt Payne.

is not emphasized enough in introductory physics courses, even though it is a highly versatile field of study.

The 2015 SOCK explores the characteristics and behavior of sound waves, from the acoustical properties of various types of instruments (strings, woodwinds, percussion) to the amplification of sound and communication over long distances. Some activities allow students to build their own instruments and even include music, so they can learn to play tunes!

Being in the business of science outreach, we tested our SOCK at several events over the summer. In addition to the third graders, honors-level physics classes at Yorktown High School in Virginia tried out some of the activities. So did middle school teachers from across the country at the National Institute of Standards and Technology Summer Institute for Middle School Science Teachers, our partner on the SOCK.

Working with different audiences at these and other events allowed us to refine the SOCK. The material is appropriate, easy to understand, and, most importantly, fun!

SOCKs are given away at no cost to approximately 25 SPS chapters each year. To apply for a 2015 SOCK, visit www.spsnational.org/programs/outreach. If your SPS chapter is not one of the lucky 25, don't worry. All supplementary components—the manual, worksheets, and list of necessary materials—are available on the SPS website. You can assemble your very own! //

The 2015 SOCK explores the characteristics and behavior of sound waves.

PULL YOUR SOCKS UP

Request a free 2015–16 SOCK and browse SOCKs from previous years at www.spsnational.org/programs/outreach/science-outreach-catalyst-kits.

Read the blogs Hannah and Shauna kept about their experiences at www.spsnational.org/programs/internships/interns/2015.

BE AN SPS INTERN

SPS has internship positions each summer in outreach, education, policy, and research. See details at https://www.spsnational.org/programs/internships.

Applications are due February 1.

FALL SPS AWARD & PROGRAM DEADLINES

October 15
Future Faces of Physics Award proposal due

November 15
Marsh W. White Award proposals due
SPS Chapter Research Award proposals due

December 15
Sigma Pi Sigma Chapter Project Award proposals due
Call for nominations for National and Zone SPS offices
Final report due from SPS Chapter Research Award winners

NOTE: *If a deadline falls on a weekend or federal holiday, it is moved to the next business day.*

Physics Camp Born in New Mexico

> "This silly game of simple questions turned into a major bonding moment…"

STUDENTS FROM OUR CAMP participating in the hands-on portion of our demo hour. Photos courtesy of Khadijih Mitchell.

SPS CHAPTER CREATES UNEXPECTED BONDS OVER THE SUMMER

by Khadijih Mitchell, SPS Chapter President, Class of 2016 at New Mexico State University in Las Cruces

On the last day of physics summer camp, we all sat in a circle and passed around a juice pack, which served as a sort of hot potato. The person with the juice had to answer one of several questions that we had formulated the day before, such as "Who is your favorite scientist?" or "What is your favorite shape?"

This silly game of simple questions turned into a major bonding moment for everyone involved. The high school students attending our camp talked about their fears and concerns about the future. They showed us their personalities outside of the physics-related activities we had been doing together for days.

I and the three other SPS members in the circle running the camp talked about our pasts, our struggles, and the high points of our physics careers. We connected.

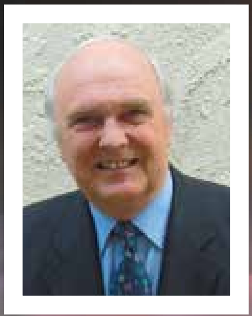
The students also shared their appreciation for the experiences they had at our physics camp, the first one ever organized by New Mexico State University (NMSU). The idea started in January, when Stefan Zollner, head of our physics department, challenged our SPS chapter to organize and produce a summer event to teach high school students physics concepts.

In July we hosted 10 students from several different schools for five days. The experience was free of charge and consisted of lab experiments, demos, presentations, and tours. Students learned about forces, waves, resonant modes, and electricity and magnetism. They were able to visit laboratories in the physics department and other departments on campus. We also organized a movie night and a trivia game. SPS member Joni Clark documented the entire experience so future SPS leaders will have a baseline from which to grow.

By the end, it was clear that the students had a wonderful time and felt like they had benefited greatly from the experience. The Society of Physics Students chapter at New Mexico State University greatly values reaching out to our community. We were grateful for the opportunity to produce this summer camp.

A special thanks to the SPS summer mentors, Chas Hammond, Joni Clark, and Tegan Fuqua; our department head, Dr. Stefan Zollner; and to Zahra Nasrollahi, Rosa Christensen, and Loretta Gonzalez for making the summer camp both possible and a huge success. //

Science DRIVING Innovation



AIP photo.

INVESTING IN RESEARCH REAPS HUGE ECONOMIC REWARDS

by Robert Brown, Chief Executive Officer
American Institute of Physics in College Park, MD

SCIENTISTS GET FIRST GLIMPSE OF A CHEMICAL BOND BEING BORN. This illustration shows atoms forming a tentative bond, a moment captured for the first time in experiments with an X-ray laser at SLAC National Accelerator Laboratory. Image courtesy of SLAC.

Innovation is the lifeblood of next-generation products, competitive business, growth, employment, and wealth creation. Modern physics research and development, as practiced in corporate and government research laboratories, deals heavily in applied science and engineering, often with a focus on the path to invention.

So important is the connection between science and innovation that the upcoming 2016 Sigma Pi Sigma Quadrennial Congress just outside of San Francisco will be devoted to the topic; its theme will be "Unifying Fields: Science Driving Innovation."

Innovation improves our quality of life, making possible a continuous stream of new technologies and better ways of doing things. But remember that innovation is a product of knowledge and discoveries accumulated over *decades*. Take an everyday example of an electronic mobile device—your smart phone or tablet. To bring such products to market, innovators successfully exploited advances in the physics of semiconductor devices, such as the creation of blue and green LEDs and laser diodes, progress in nano-micro silicon electronics, new kinds of liquid crystals, the development of ultrastrong glass, and the formulation of novel polymers. Display technologies and supercompact electronics are made possible by physics research done over the last 20 years—one could even argue 80 years—involving *millions* of dollars of up-front research investment. The payoff? *Billions* of dollars pumped into the global economy.

With this degree of return on investment (ROI), it seems obvious that sales revenue and taxes ought to be invested in future research to support the future economy. Yet today's Western world is reluctant to make serious investments or take the risks necessary for high payoff. As a result, we have limited our capacity to build competitive new products. Big R&D initiatives are unpredictable, expensive, and often beset with failures en route to successful innovation. Compared to our Asian competitors, who have come to dominate global manufacturing, we do not invest much in the translating of physics into devices and products.

Much of the technology we purchase today comes from Asia, and that region benefits from the wealth creation. By diluting the investment and risk, we siphon the potential ROI.

The risks of translating science to products are so recognized that they inspired the term "Valley of Death," which refers to the probability that a start-up company will die before financiers can recoup their investments. The current trend is toward immediate or short-term payoffs, but we must advocate for the long term, the big investments in science that will help the United States maintain (or perhaps regain) its global leadership as an innovation superpower.

The following feature articles focus on innovation and how R&D activities based on solid science drive our future economy. Meet an SPS member helping to push forward new products as an intern at Google. Test your knowledge about how past physics experiments have driven today's innovations. Learn about new innovations in education that began with physics classrooms. Explore recent developments at the Stanford Linear Accelerator Center, one of the sites you will have the opportunity to tour at the upcoming Sigma Pi Sigma Congress. //

COME TO THE 2016 Quadrennial Physics Congress

2016 Quadrennial Physics Congress
November 3-5, 2016 • Silicon Valley, CA
Host hotel: Hyatt Regency-San Francisco Airport
Hosted by Sigma Pi Sigma, the physics honor society

HERE'S WHY...

This quadrennial meeting brings together physics students, alumni, and faculty members for three days of frontier physics, interactive professional development workshops, and networking. It includes the largest gathering of undergraduate physics students in the world!

The 2016 Physics Congress (PhysCon) will be a cutting-edge, life-changing meeting where undergraduate physics students, alongside mentors and alumni, will be immersed in the topics of innovation and technology.

This meeting happens just once every four years, and presents unique opportunities for attendees to:

- Bond with fellow physics students from across the United States and beyond
- Explore graduate programs, summer research opportunities, and workforce options
- Be inspired by renowned physicists and tours of labs at the forefront of science and technology
- Grow professionally through workshops on communication, inclusion, and leadership
- Expand their understanding of physics and its variety of applications
- Present their research to fellow students, potential graduate school advisors, and potential employers

TOUR SITES

- SLAC National Accelerator Laboratory
- NASA's Ames Research Center
- Google

WORKSHOP TOPICS

- Careers for Physicists
- Public Relations for Physicists
- Taking Your SPS Chapter to the Next Level
- Building up the Community
- Life as a Graduate Student

SPEAKERS

- **Jocelyn Bell Burnell (pictured at right),** Visiting Professor at the University of Oxford, and Honorary Chair of the 2016 Physics Congress
- **Eric Cornell**, Senior Scientist at JILA, NIST, and the Department of Physics, University of Colorado at Boulder, and 2001 Physics Nobel Laureate
- **Persis Drell**, Dean of Stanford University School of Engineering and Director Emerita of the SLAC National Accelerator Laboratory
- **S. James Gates**, Distinguished Professor and Director, Center for String & Particle Theory at the University of Maryland
- Additional speakers will be announced soon—visit the website for updates!

Unifying Fields
SCIENCE DRIVING INNOVATION

#PhysCon

www.sigmapisigma.org/congress/2016

FROM LEFT:
A poster session, workshop, and dance party at the 2012 Quadrennial Physics Congress. AIP Photos.

REFLECTIONS FROM 2012

Looking back, what was your favorite part of PhysCon 2012?

"Getting to meet new friends from all over the country that share a passion for a compelling field." *–Cory Schrandt*

"The great (not just good) plenary speakers."
–Rusty Towell

"I loved the variety of workshops; they gave insight to a lot of areas in physics in a hands-on manner which was refreshing compared to only science talks (which I certainly enjoy as well, but aren't as interactive)."
–Audrey Burkart

"The fact that I was able to interact with so many great, motivated students in such an intimate environment."
–Lynde Ritzow

"I loved the laid back nature of the conference, and the participants too."
–Jess Smith

"I enjoyed connecting with other students from various institutions and faculty from prospective universities in my graduate degree."
–Janeil Pinder

How did your PhysCon 2012 experience impact your life and/or the life of your SPS chapter or physics department?

"We had a long trip there and back over which we all got to know one another much better. It made everyone in our chapter better friends."
–Tim Head

"It made me excited about SPS again, since our department was so small and physics was not a common subject to be interested in."
–Jess Smith

"It energized our local SPS chapter."
–Rusty Towell

"[PhysCon] encouraged more of our physics majors to play a more active role in local chapter activities."
–Chuck Stone

"I had always felt a bit like a 'pretend' physicist, or perhaps I didn't fit right. While I'm not working in physics after graduation, PhysCon cemented my belonging in the science world."
–Audrey Burkart

What advice would you give to students thinking about attending an upcoming Physics Congress?

"If for nothing else, go to see what other physics majors around the country are like. Your differences won't surprise you as much as your similarities."
–Kofi Christie

"Get rested up the week before because there's going to be a lot to take in."
–Cory Schrandt

"Attend! and start planning now."
–Tim Head

"It's worth it to go to the Congress, and go to everything you can, since the entire thing is a fantastic experience!"
–Jess Smith

"PhysCon will allow you to network with the largest number of fellow physics majors in the US!!"
–Jack Hehn

"Plan to take in *all* of the activities. There was not a single "boring" event and the field trip is extraordinary (at PhysCon 2012 we visited NASA's Kennedy Space Center)."
–Rich Bergmann

"Go!"
–Gus Hart

"Attending the 2012 Congress was one of the most influential weekends of my undergraduate career."
–Danielle Weiland

INSIDE Google X

BEN PEREZ poses at the entrance of Google X. Photo by Sandeep Giri.

MY INTERNSHIP WORKING ON INTERNET BALLOONS AT GOOGLE'S SECRETIVE RESEARCH FACILITY

by Ben Perez, Class of 2016, Coe College in Cedar Rapids, IA

Innovations in communication have been a key part of human history. Each generation improves upon the work of the previous one to bring about a more-connected society. Just think about how Snapchat and text messages have influenced our ability to stay in touch with our friends and family today.

Without question, future technology will bring another wave of innovation, forever changing how we talk to each other. Many companies are working to push forward our capabilities.

This summer I landed an opportunity to work with one of the biggest players in today's communication race: Google. As an intern at Google X, I joined Project Loon.

Loon's goal is to provide Internet service to the world with balloons that use the winds in the upper atmosphere to navigate around the globe, eliminating the need for land structures. Being free from ground limitations could allow Internet access in places that have been hard to reach before.

The Amazonian rain forest, Sub-Saharan Africa, and Siberia could be connected using this new Internet source. These locations have long been either too remote, too uneconomical, or too environmentally sensitive to develop. With Loon, workers will not have to build towers in these extreme environments, and no ecosystems will be disturbed.

During my time at Google X, I used a combination of computer programs with preloaded optics equations and back-of-the-envelope calculations to validate an optics tool I developed. Science informed my entire project, whether the physics worked behind the scenes of the software program or was scribbled all over scratch paper. For instance, Snell's law, which relates the velocity of light in a medium to its angle of incidence, enabled more accurate predictions than a paraxial approximation. I used this understanding of how light truly interacts with lenses throughout the optics system I worked on.

As an undergraduate, I have worked in three primary types of research environments: academia, government, and industry. Each had its own culture. At Coe College, where I go to school, people have a lot of flexibility to seek out their own research project. But the pace of research is slower, and the main mission is to find new phenomena that do not necessarily have an immediate application. As for the government level, I spent a summer as an SPS intern working at the National Institute of Standards and Technology. Much of the research there was closely tied to federal priorities. In industry, at Google X, specifically, I was given a lot of autonomy and had plenty of funding, but I was expected to meet tight deadlines for the project and produce good results consistently.

The team I worked with at Google X was truly multidisciplinary, with experts not only in optics but in materials, manufacturing, and many other areas. The scientists and engineers at Google X have diverse backgrounds that come together to work toward an operable system. They know their work will impact potentially billions of people.

Think about the possibilities in a world completely connected by Loon, where people in all parts of the world can stay up to date on the issues that are important to them and seek information. Imagine if we utilized Loon to offer free education to children and adults who have no access to school. We possibly could uncover the next great physicist, someone who has natural abilities but no current access to a proper education, and let those skills flourish. Or help to educate and empower a child in an impoverished area to raise the standard of living in their community. Or provide a tool by which people in rural areas can communicate with help reliably during an emergency.

Loon has come a long way since Google's leadership held its first brainstorming sessions about how to solve the dramatic problem of Internet access. The project pushes the boundaries of what is possible and could revolutionize communications. It's one of the ways that technology is driving innovation, and I was lucky enough to be a small part of that progress. //

MORE INFORMATION

Interested in working at the National Institute for Standards and Technology for a summer? Explore the SPS internship program at https://www.spsnational.org/programs/internships. Applications are due February 1.

ONE OF THE BALLOONS Google launched from New Zealand in June 2013. Photo by Doug Coldwell.

THIS ILLUSTRATION how a protein from sponse to light. Sar photoactive yellow p LCLS X-ray laser be lized proteins had b trigger shape chang laser hit the crystals of the protein (cente its shape. Image cou

ATOM SMASHER DOESN'T SLAC Off

VENERABLE PARTICLE COLLIDER FINDS NEW APPLICATIONS

by Melinda Lee
Community Relations Officer at the Stanford Linear Accelerator Center in Menlo Park, CA

Want another reason to be excited about the 2016 Sigma Pi Sigma Quadrennial Congress? How about a tour of the Stanford Linear Accelerator Center (SLAC)? Join SLAC researchers for an inside look at one of the world's most celebrated particle colliders. In anticipation of this event, we present here a quick look at how the machine has evolved in recent years ...

When construction started on Stanford University's linear accelerator (Linac) in 1962, the minds behind the massive machine hoped to gain a better understanding of the universe at its smallest scales. The idea was to accelerate electrons (or positrons) very close to the speed of light, collide them with protons or neutrons, and search the subatomic debris for signs of new particles.

Four years later, the two-mile-long accelerator turned on and began its illustrious career. It wasn't long until it had demonstrated that protons and neutrons were made of even smaller particles called quarks. That work earned the 1990 Nobel Prize in Physics.

As years went by and facilities capable of achieving higher energies came online elsewhere in the world, SLAC moved in other directions. Machines at SLAC that had been built to push the frontiers of particle physics found new applications in chemistry and biology—including shooting what may be the fastest movies ever made.

The unusual films were made possible by additional pieces of equipment added to the Linac over the years. The first was the Stanford Positron Electron Asymmetric Ring (SPEAR), a curved tunnel used to accelerate electrons. It achieved electron–positron collisions with energies of up to 7.4 GeV. Two Nobel Prizes came out of work done at SPEAR: the 1976 prize for the discovery of the psi particle and the 1995 prize for the discovery of the tau lepton.

Electrons traveling around a circular path also shed radiation. That phenomenon allowed the SPEAR storage ring to evolve into the Stanford Synchrotron Radiation Lightsource (SSRL), which generates synchrotron radiation used in 30 experimental stations. Some 2,000 people use the facility each year to take

DEPICTS AN EXPERIMENT AT SLAC that revealed photosynthetic bacteria changes shape in re- mples of the crystallized protein (right), called rotein or PYP, were jetted into the path of SLAC's eam (fiery beam from bottom left). The crystal- een exposed to blue light (coming from left) to ges. Diffraction patterns created when the X-ray s allowed scientists to recreate the 3-D structure er) and determine how light exposure changes urtesy of SLAC National Accelerator Laboratory.

advantage of the high-intensity light, which spans the spectrum from infrared to X-ray.

The Linac itself has undergone a recent transformation. It has been repurposed for two new experiments: the Linac Coherent Light Source (LCLS), which commandeered and modified a third of the original linear accelerator, and the Facility for Advanced Accelerator Experimental Tests (FACET), which laid claim to the rest of it.

LCLS is a free-electron laser facility that can deliver intense, coherent X-ray radiation; it's an X-ray laser, if you will. Ranging in energy from 200 to 2,000 eV, the X-rays produced by LCLS have a much higher energy than those that could be produced by SSRL. To generate these X-rays, LCLS sends high-energy electrons through a series of closely spaced magnets, aka the undulator, that rapidly oscillate the electrons as the particles move through the spatially alternating magnetic field. These oscillations generate coherent X-rays directed into the six experimental stations that users from around the world compete for time on. Since it turned on in 2009, LCLS has been used by approximately 600 scientists each year and generated around 500 peer-reviewed publications.

One of the most interesting sets of experiments to come out of LCLS in the past few years made "molecular movies" that revealed the dynamics of chemical reactions. Scientists tracked structural changes of complex, ring-shaped molecules responding to a broken bond and evolving into linear molecules. One study focused on how 1,3-cyclohexadiene (CHD), a ring-shaped molecule similar to many that have biological and chemical importance, evolved after being excited by an ultraviolet laser pulse. The pulse initiated an unfurling of the ring shape, and subsequent pulses from LCLS's X-rays proved the shape of the resulting molecule.

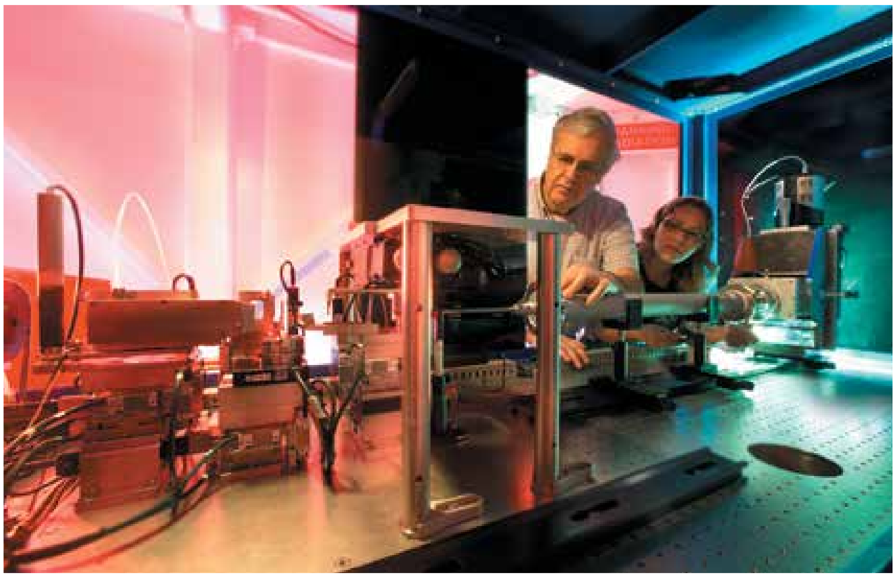
By sending in probe pulses at different time intervals from the initial pulse, scientists were able to use the experimental data and computer simulations to determine how the shape of the molecule changed over the first 200 quadrillionths of a second after opening. Researchers made a movie showing the evolution with a ridiculously fast frame rate. Each frame of the movie represented a time interval of "25 quadrillionths of a second—about 1.3 trillion times faster than the typical 30-frames-per-second rate used to display TV shows," according to the SLAC researchers. SLAC has produced a YouTube video about this experiment that can be found at https://www.youtube.com/watch?v=HhmBKd-_sRM.

"This fulfills a promise of LCLS: Before your eyes, a chemical reaction is occurring that has never been seen before in this way," said Mike Minitti, the SLAC scientist who led the experiment in collaboration with Peter Weber of Brown University. The results were featured in the June 22 edition of *Physical Review Letters*. "LCLS is a game changer in giving us the ability to probe this and other reactions in record-fast time scales," Minitti said, "down to the motion of individual atoms." The same method can be used to study more complex molecules and chemistry.

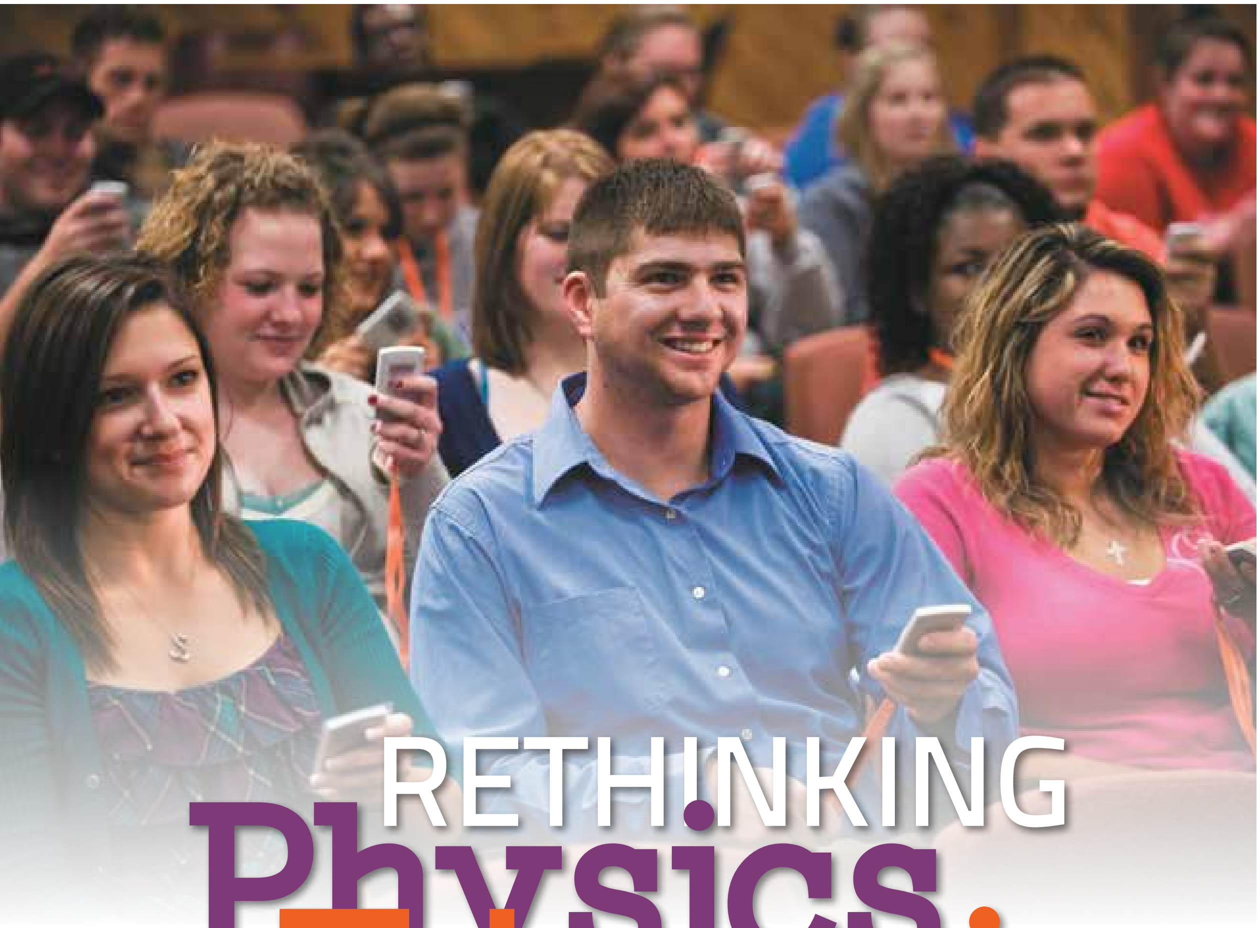
As you tour the X-ray laser facility at the 2016 Congress, I encourage you to reflect on both the original technological innovations that allowed this awe-inspiring machine to open new doors in physics decades ago and on the recent innovations that have granted it new roles in the sciences outside physics. Often, the machines physicists design for their experiments have broader impacts than even their creators could have imagined. //

MORE INFORMATION

- **Learn more about SLAC science at www.slac.stanford.edu.**



STANFORD SYNCHROTRON RADIATION LIGHTSOURCE (SSRL) scientists Piero Pianetta and Jacqueline Kerlegan (bottom) inspect SSRL's newest X-ray microscope at Beamline 6-2. At top, SLAC is picured at night. Photos courtesy of SLAC National Accelerator Laboratory.



ONE INSTRUCTIONAL STRATEGY stemming from physics education research (PER) that has been adopted by many physics faculty members is the use of clickers to collect and aggregate student answers to physics questions in real time. Photo Courtesy of Turning Technologies.

RETHINKING Physics Education

EXPLORING CUTTING-EDGE PHYSICS EDUCATION RESEARCH

by Carl Wieman, Professor of Physics, Stanford University in Palo Alto, CA, and 2001 Physics Nobel Laureate

The science of how physics is best taught and learned at the undergraduate level has led to considerable innovation in the teaching of physics. Physics education research (PER) is a relatively new and growing field of physics research, carried out by physicists, and recognized in the physics community with its own Physical Review Special Topics journal sponsored by the American Physical Society and the American Association of Physics Teachers.

Physics has led the way among the sciences in this type of research, but other disciplines, such as biology and earth sciences, are now copying many of the ideas and research approaches to good effect.

One of the early results of PER was better measures of learning. Carefully designed tests probed how well students could use concepts like a physicist. Those tests showed that many college students could complete typical textbook and exam problems very successfully, but when confronted with simple real-world situations were unable to apply basic concepts as a physicist would to correctly understand or predict behavior.

Early work also revealed particular areas of physics that students found difficult. That work led to experiments in teaching that explicitly targeted areas of student difficulty and had students more directly practice explanations and the use of basic concepts. In carefully controlled experiments, students taught in this way showed dramatically improved conceptual mastery compared to similar groups of students who were taught by the traditional lecture format.

Touching on all of these areas and more has been the introduction of technology into the teaching of physics, as well as research on its effectiveness and how to optimize that effectiveness. This includes research on various types of personal response systems in the classroom, computer-based homework, interactive simulations, and other computer tools.

PER research findings and research-based teaching innovations are slowly but steadily changing how physics is being taught, particularly at the introductory undergraduate level. It is now much more common to find students in a physics class working out problems, discussing and answering questions in small groups, and providing reasoning and conceptual arguments, rather than simply listening to the instructor lecture. The instructor's role has also evolved in response to this research. They are acting more to guide students, responding to specific student difficulties and questions rather than simply attempting to rapidly transfer information.

A recent direction in PER is to more directly couple the work to findings in cognitive psychology. Insights from that field into how the brain functions and organizes and processes ideas are being increasingly applied in PER. This includes the cognitive psychology research on what makes up thinking like an "expert" (in this case a practicing physicist) and how that expertise develops only as a result of intense practice on the specific components of thinking, with guided feedback that provides a general framework for understanding many of the past observations and successes of PER and suggests areas of future research.

Another new area of PER that is providing immediate dividends for innovations in teaching is learning in upper-division physics courses. Although there is relatively little work, so far it shows that most of the same methods of measuring and improving learning demonstrated in introductory courses provide similar benefits when appropriately mapped onto the content and thinking involved for advanced material.

ANOTHER INITIATIVE RESULTING FROM PHYSICS EDUCATION RESEARCH (PER) is to change the setup of physics classrooms from traditional lecture halls to studio-style classrooms to facilitate teamwork and allow instructors to move between groups. This is called SCALE-UP, a Student-Centered Active Learning Environment for Undergraduate Programs. Image courtesy of Florida State University.

A very new area of PER research is stand-alone laboratory courses. For a long time, lab courses have been problematic parts of the physics curriculum. One approach that PER has studied for some time, and demonstrated the benefits of, is to eliminate stand-alone lab courses and instead have small experiments and/or interactive lecture demonstrations integrated into a course. PER researchers have now begun to examine stand-alone lab courses at all levels to understand how and why they are failing to achieve many of the intended learning goals and how they might be modified to become more effective.

Another relatively small but growing area of PER research activity is to move beyond looking at the composite learning of all the students in a course and explore more deeply the variations across groups of individuals. This couples with research on the social-psychological factors of learning math, science, and engineering. We can anticipate this research leading to future innovations that are similar in principle to what has been demonstrated for students in general, but also can provide a deeper understanding of the learning challenges and more effective teaching methods for different subpopulations of students taking physics courses.

Despite the progress made, an ongoing challenge is to convince many physics faculty to use a scientific PER approach to teaching, rather than relying on tradition. If you have an interest in education, I encourage you to read the literature and explore the exciting, emerging science of physics education research. //

EDUCATE YOURSELF

For more information on how different sciences are improving learning, see "Discipline Based Education Research," a synthesis study by the National Research Council that was funded by the National Science Foundation at www.nap.edu/catalog/13362/discipline-based-education-research-understanding-and-improving-learning-in-undergraduate.

To dive deeper into PER advances, see "Lessons from the Physics Education Reform Effort" by Richard Hake at Indiana University at www.ecologyandsociety.org/vol5/iss2/art28/.

Check out Wieman's 2011 *Science* article, "Improved Learning in a Large-Enrollment Physics Class," on why active learning trumps lecturing at www.sciencemag.org/content/332/6031/862.abstract.

Or read his 2005 *Physics Today* article, "Transforming Physics Education," at http://scitation.aip.org/content/aip/magazine/physicstoday/article/58/11/10.1063/1.2155756.

Innovation THROUGH THE Ages

Discoveries in the physical sciences have a long history of fueling innovation. They often lead to new devices and new inventions that even the discoverers could not have imagined.

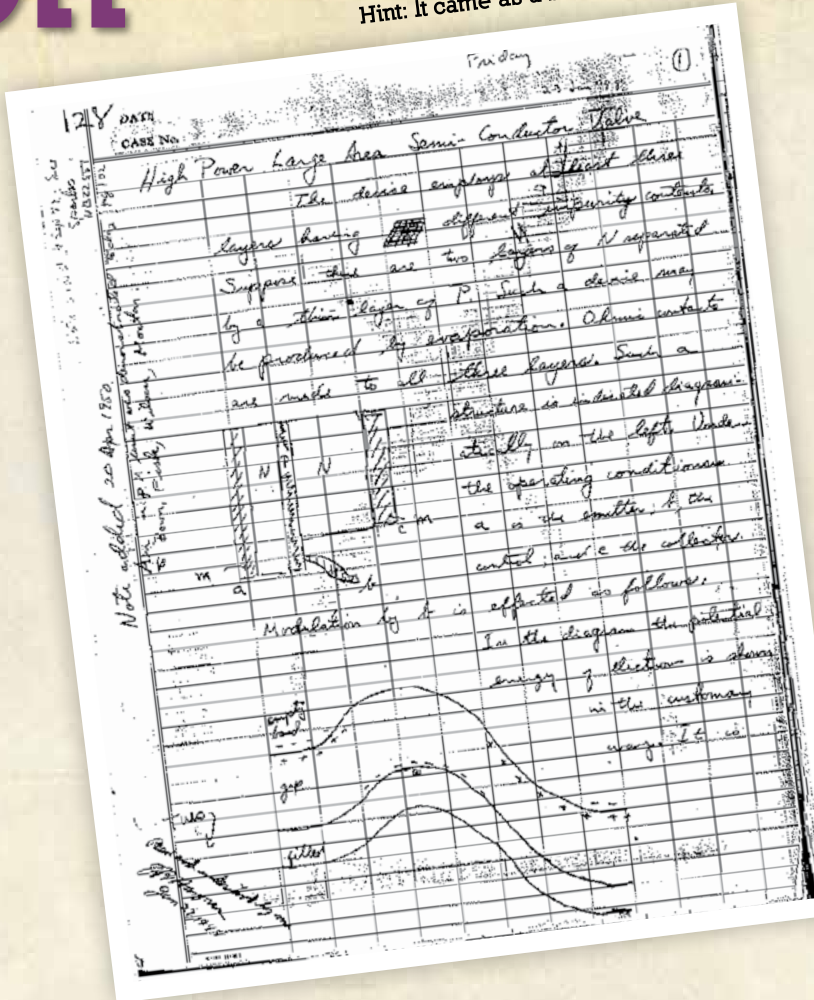
Working with the Emilio Segrè Visual Archives at the American Center for Physics in College Park, Maryland, we dug up images from classic physics experiments conducted over the last two centuries. We also found some swell pics of technological advances ranging from police radar guns to space telescopes.

Can you match each experiment (on this page) to the innovations it made possible (on the next page)?

See the bottom of the next page for the answers.

EXPERIMENT #4:

Hint: It came as a Shockley.

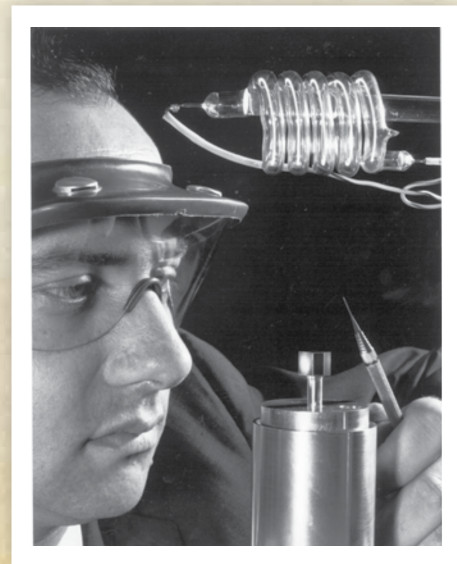


EXPERIMENT #1:

Hint: He saw right through her.

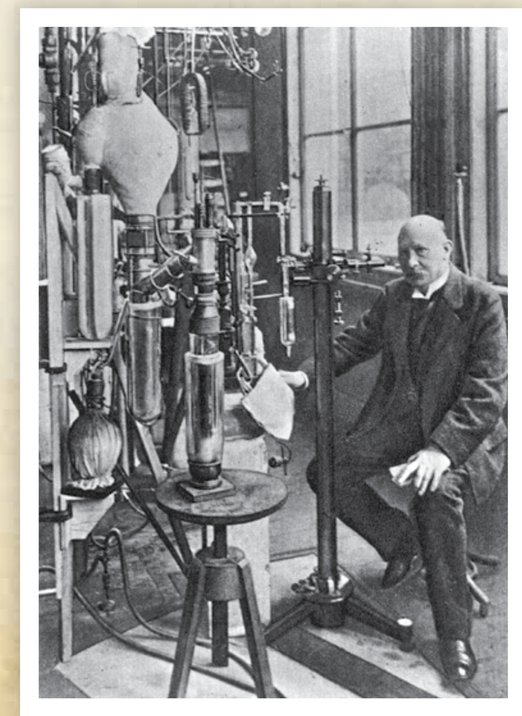
EXPERIMENT #2:

Hint: Red as a ruby, it was.



EXPERIMENT #3:

Hint: Resistance was futile.



E. Brun

Alex Needham

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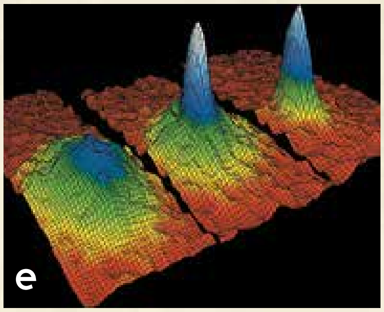


NIST/JILA/CU-Boulder

NASA

Fábio Pozzebom/ABr

NASA

Answers

EXPERIMENT #1:

Wilhelm Röntgen, discoverer of X-rays, took this radiograph of his wife's left hand, setting the stage for a) recent scans of Roman scrolls burned by the Vesuvius eruption revealing what appear to be letters; c) Marie Curie's "petite Curie," a mobile X-ray unit used on the front lines of World War I; and h) the Chandra X-ray Observatory, which provided the first X-ray images of many stars, supernovae, and black holes.

EXPERIMENT #2:

Theodore Maiman's ruby laser made possible, among other things, e) the creation of Bose-Einstein condensate through laser cooling; and g) the radar guns used by police to catch speeders f) the photoreflectors NASA bounced lasers off of to measure the distance to the Moon.

EXPERIMENT #3:

Heike Kamerlingh Onnes (shown here in his lab) demonstrated that mercury is a superconductor, opening the door to the creation of b) maglev trains such as this one shown in front of the Shanghai airport; d) cell phone towers, which use high temperature superconductors to boost bandwidth; and e) Bose-Einstein condensate, a phase of matter in which separate atoms function as a single quantum entities.

EXPERIMENT #4:

William Shockley's early sketches illustrate the transistor, developed with John Bardeen and Walter Brattain, an invention so fundamental to modern life that it plays a role in every innovation shown here!

Get Involved in the International Association of Physics Students

BROADEN YOUR PHYSICS COMMUNITY AND MEET STUDENTS OVERSEAS

by Amanda Landcastle
Graduate student at Purdue University in West Lafayette, IN

AMANDA LANDCASTLE. Author photo.

In 2014 Stephen Hawking gave a lecture to a room full of physics students just like you. Audience members got the chance to learn from one of the most well-respected physicists in the world.

If you had this opportunity, would you take advantage of it?

Well, just a little tidbit of information for all of you readers saying, “Of course I would, it’s Stephen Hawking!” … You did have the opportunity to attend this event.

The good news is that you will still have plenty of opportunities to be involved in events like the one mentioned, events sponsored by the International Association of Physics Students (IAPS). And now you have someone to keep you informed about how to go about doing so. That someone would be me.

Did you know that you are already a member of IAPS? It's true. SPS has been on the US National Committee for IAPS for several years. This means that every SPS member is also an IAPS member.

My introduction to IAPS started with an SPS Award for Outstanding Undergraduate Research I received in the spring of 2015. Being involved in SPS has opened so many doors for me, and receiving this award just before I was about to graduate and leave the “SPS bubble” provided me with an opportunity unlike any I have had before. Because I received this award, in August 2015, SPS flew me to Zagreb, Croatia, to present my research at the International Conference for Physics Students (ICPS), hosted by IAPS.

SPS invited me to arrive in Croatia a couple of days before ICPS began to participate in Delegate Days on its behalf. The ICPS Delegate Days are when student leaders in physics from each country meet to discuss IAPS regulations and activities. While I was listening to the discussions, I realized how irrelevant to the discussion I was as a US student. I was inspired to change that.

IAPS was established in Europe and has flourished there. They offer events galore for European students. But non-European involvement is essentially nonexistent in comparison. At the beginning of the meeting, when they asked for the US National Committee’s input, I gave them blank stares in response. I had no idea what they were talking about. But as the discussions continued, I decided that I wanted to make what they were talking about relevant to me and to SPS.

I ran for a position on the IAPS Executive Committee and was elected at the Annual General Meeting during ICPS. I am now serving as the vice president and the general officer responsible for outreach and education. The rest of IAPS recognizes the need to involve non-European countries, and they have entrusted me with getting that task started here in the US.

IAPS was established in 1987 with the intention to promote peaceful collaboration among its members all over the globe. We support our members in their academic and professional work while providing an atmosphere that promotes intercultural networking and enables individual physics organizations from all over the world to get together for great impact. We are an association run entirely by physics students and for physics students. We wouldn’t have it any other way.

ICPS 2016 will take place in Malta in the summer of 2016. SPS members are encouraged to attend. To help with the financial strain of travel costs, look into applying for the ICPS Worldwide Grant and the SPS Award for Outstanding Undergraduate Research. You can also talk to your department and research advisor about travel support. Hopefully, if we can build more US and Canadian involvement in IAPS, we will be able to start talking about hosting ICPS in the United States within the next few years.

The event at which Hawking spoke took place in Utrecht, the Netherlands, as part of the opening ceremony and symposium for an international physics contest sponsored by IAPS called PLANCKS, in which teams tackle difficult physics exercises. PLANCKS 2016 will be held in Romania in May 2016. There are several other events planned for the coming year, such as trips to CERN and Gran Sasso. You can find information about them on our website: www.iaps.info.

GROUP PHOTO OF THE ICPS 2015 PARTICIPANTS taken in Zagreb, Croatia in August 2015 (inset). Photo courtesy of Amanda Landcastle.

STEPHEN HAWKING on stage at the IAPS-hosted PLANCKS competition in 2014. Photo courtesy of Amanda Landcastle.

One of my goals is to help SPS members further develop as physicists and as leaders through involvement with IAPS. My vision is that within the next year SPS members will start getting involved with IAPS both internationally and in the United States. It is my job to help facilitate this, and I have a lot of plans for my position, including an IAPS event held by SPS members in the United States.

Please contact SPS if you have any questions regarding IAPS or if you want to get involved. You can find more information on the IAPS website or on the IAPS Facebook page. //

MORE INFORMATION

For more information on IAPS and ICPS:

- Visit the IAPS website at www.iaps.info.
- Read about ICPS 2016 at www.iaps.info/event/icps-2016-malta.
- Like the IAPS Facebook page at https://www.facebook.com/iapsfb?fref=ts.

For more information on the SPS Award for Outstanding Undergraduate Research, visit the SPS website at www.spsnational.org/awards/outstanding-undergraduate-research. Winners are chosen on the basis of their research, letters of recommendation, and SPS participation. Winners receive an all-expense-paid trip to ICPS 2016, along with a $500 honorarium for themselves and a $500 honorarium for their SPS chapter. Applications are due March 15.

To read more about Amanda and her experience at ICPS 2015, along with the experience of Ariel Matalon, who also received a 2015 SPS Award for Outstanding Undergraduate Research, visit the SPS website at www.spsnational.org/awards/outstanding-undergraduate-research/recipients/2015. To connect with Amanda, email SPS at sps-programs@aip.org.

So You Want to Host a Zone Meeting?

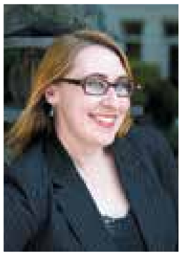


Photo by Matt Payne.

TIPS ON PLANNING, ORGANIZING, AND EXECUTING A SUCCESSFUL REGIONAL SPS GATHERING

by Courtney Lemon, Programs Specialist at the Society of Physics Students, 2010–12 Associate Zone Councilor for SPS Zone 18, and Co-Chair of the 2011 SPS Zone 18 Meeting

Has your chapter decided it's time to take the next step? Do you want to interact and network with other students from your area? Do you want to have an AWESOME, fun-filled weekend with your physics peers? Then it's time for your chapter to host an SPS zone meeting!

Chapters in each of the 18 regional zones of SPS gather to network, socialize, present research, hear cutting-edge science talks, and share experiences at least once each year. Through lab tours, research presentations, keynotes, and trivia, SPS members build their networks and make connections to other students in their region. Each zone meeting is made possible by an active SPS chapter that decides to step up and host a meeting on its campus.

How do you get the ball rolling on an excellent zone meeting?

HOSTING A ZONE MEETING IS ONE OF THE BEST WAYS TO ENGAGE YOUR CHAPTER and take it to the next level.

One of the best ways to see if your chapter is ready to host a zone meeting is to attend one. You want to make your meeting unique, but seeing what activities work at another zone meeting can be a great starting point. Visit the SPS website to see what zone meetings are coming up near you. Most zone meeting hosts also submit reports about their experience that are posted on the SPS website. These are great resources for future hosts.

Before you commit to hosting a zone meeting, make sure that your department and institution will support your chapter's endeavors. You may need to use classrooms or other spaces in your physics building, and having your department's support is invaluable in making room reservations, unlocking doors, etc. Your department may also be willing to help offset the cost to participants with some financial support.

The next step is to contact your associate zone councilor (AZC) and zone councilor (ZC). These are members of the SPS National Council that you and your fellow chapters have elected to represent your region. It's important to discuss hosting a zone meeting with them because they will know whether other zone meetings are planned for your region, and they will be able to offer support, ideas, and information about the resources available to zone meeting hosts.

Your AZC and ZC can connect you with active chapters in your area, and it's a good idea to involve them in the planning process. Consider asking a few students from other chapters to join a "planning committee." If they do, you'll know that there's interest as well as engagement, and a serious commitment to attend. They will likely contribute valuable ideas and be able to expand your program options.

When you are looking to set a date, check the school calendars around your area and consult with members of your planning committee from other institutions. Try to plan around midterms, finals, breaks, federal holidays, and the physics GRE. Physics students are likely to have previous obligations on those dates. You can also look around for an American Association of Physics Teachers (AAPT) or American Physical Society (APS) section meeting to team up with, allowing students to attend two meetings for the price of one!

Once you've got a date set, reach out to the SPS National Office along with your ZC and AZC for marketing help. They can help you distribute information to all of the schools in your region. They can also help you find your zone's Facebook page and other social media resources. Also, contact the SPS National Office at sps@aip.org so that your meeting is added to the SPS calendar. The SPS National Office also sends recruitment packages full of SPS goodies to zone meeting hosts, as well as up to $500 to help fund zone meetings! In addition, the SPS National Office can provide registration services, connections to potential speakers, an SPS National representative at your meeting, and maybe even some travel support for attendees.

So, what ACTUALLY happens at a zone meeting?

Well, this part is up to you! Zone meetings can showcase the host school's labs through tours, and its outstanding faculty through keynote talks. They can incorporate demonstration shows, social activities, and physics competitions. They traditionally offer students the opportunity to present their research and outreach activities in talks or at a poster session. Many zone meetings also include talks by physicists working at national labs or in industry positions in the region.

Many zone meetings begin on Friday evening and continue into Saturday evening, ending with enough time for students to do homework or drive back to their home universities, while others last through

THE 2015 ZONE 18 MEETING at the University of California, Berkeley, brought together students from all over California. Photo by Joe Costello.

Sunday morning. Kick-off the meeting with a public lecture, science café, a physics party (think trivia, competitions, and liquid-nitrogen ice cream!), or even a Friday night keynote.

Events on Saturday often include student talks and posters, keynote talks, networking opportunities, lab tours, career workshops or panels, and a banquet. If transportation is easy, you might consider going to a local planetarium or facility for a tour, or even doing outreach at a local street festival. Schedule time to take a group picture to send to SPS National!

Make sure that you take lots of pictures and document the meeting! Create a hashtag that people can use on Twitter, Instagram, and Facebook to track participation. Contact your local newspaper or your school's newspaper, and invite reporters to come to the keynote and share what your chapter has accomplished. If your university has a photojournalism club, invite members to help capture the event as well. Collect comments from attendees at the end of the meeting. Write a story for *The SPS Observer* about your meeting!

As other chapters that have done it will attest, hosting a zone meeting is one of the best ways to engage your chapter and take it to the next level. Meeting other students in your area will really help you connect to the larger physics community. //

2015-16 SPS ZONE MEETINGS

FALL 2015

Zone 16
NORTHERN ARIZONA UNIVERSITY
October 2–4

Zone 5
DAVIDSON COLLEGE (NC)
October 16–17

Zone 7
CLEVELAND STATE UNIVERSITY (OH)
October 16–17

Zone 12
EAST CENTRAL UNIVERSITY (OK)
October 23–24

Zone 13
BAYLOR UNIVERSITY (TX)
October 29–31

SPRING 2016

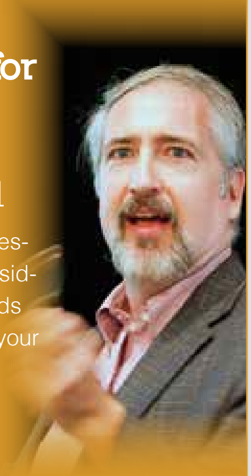
Zone 10
UNIVERSITY OF CENTRAL ARKANSAS
March 4–5

Zone 11
SOUTH DAKOTA SCHOOL OF MINES
March 11–13

Zone 6
EMBRY-RIDDLE AERONAUTICAL UNIVERSITY (FL)
March 18–20

More dates to be announced
Go to www.spsnational.org/meetings/zone-meetings for the latest updates.

Need help? As you start planning, be sure to check out the resources available on the SPS website at www.spsnational.org/meetings/zone-meetings.



Searching for speakers? Contact the SPS National Office for suggestions, and also consider alumni and friends and colleagues of your faculty members.

SPS also offers free careers workshops at zone meetings. Contact the National Office at sps-programs@aip.org for information on these.

Swinging Physics

THE ANSWER
(SEE PAGE 5 FOR THE QUESTION)

by Donald Simanek, Professor Emeritus, Lock Haven University of Pennsylvania

The period of the swing is the same as that of a simple pendulum of length *R*, where *R* is the length of the supporting ropes. The parallel rope suspension allows the chair to swing without rotation. Therefore each and every little piece of the chair swings in an arc of the same radius. Imagine all of these pieces separated, swinging in synchronism. Each would have period $T = 2\pi\sqrt{(R/g)}$, where *R* is the radius of the arc of motion of each piece. So the entire porch swing also has that period—the period of a simple pendulum. In fact, an object of any shape and mass suspended from three or four parallel ropes of equal length also has the same period.

Such parallel suspension ensures that the object swings but does not rotate. The period is the same for forward swinging or side-wise swinging, or even swinging in an oval path. This can be thought of as a superposition of left-right and forward-back motions of the same period. And the period is independent of the mass on the swing.

But if the suspension ropes are nonparallel, some interesting motion results. A flat plate suspended by two ropes on either side that meet at the ceiling can swing with a rocking motion. Definitely not elementary, but quite relaxing. In fact, this could easily lead us to suspensions causing gentle rocking, as in the piece of furniture known as the platform rocking chair.

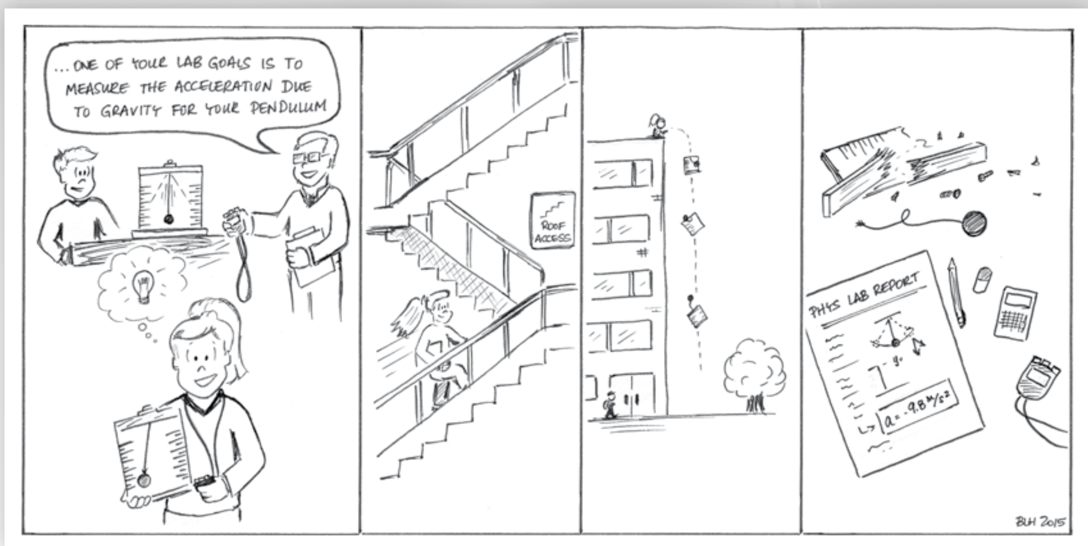
In this solution we have used the same argument that Galileo used to conclude that the time it takes a body to fall a given distance is independent of the body's mass. He imagined dropping two identical bodies side by side, close to one another. Being identical, they take the same time to fall. Fasten them together and they still take the same time, though now the composite body has twice as much mass.

Another neat application of this principle is to explore something seldom proven in elementary physics textbooks. Why is the period of a simple pendulum (moving in a vertical plane) independent of its mass? Imagine two identical simple pendulums swinging side by side in synchronism. Of course their periods are the same since they are identical. Now bring them close together side by side, so the pendulum bobs are nearly touching. Both periods are still the same. Now glue the bobs together so they are, in effect, one pendulum. The period of this composite body is still the same, though it is twice the mass of either of the original pendulums, illustrating that the period of a simple pendulum is independent of the mass.

The argument still requires that we show the generality of the result. Imagine splitting a pendulum bob into two equal parts. Each has the same period. Three equal parts, same period. *N* parts ... same period. Small bobs can be recombined in whatever ways are required to make pendulums of different masses all with the same period.

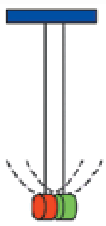
This works even if the pendulum bobs are large, so long as both bobs swing in exactly the same way, that is, along the same arc. And it even works if the angle of the swing is large. If the individual pieces didn't swing in an arc of the same radius, gluing them together would result in a swing around some other arc, with a different period. This reminds us that the *R* in the formula for a simple pendulum is the radius of the arc of the bob's motion, not simply the suspension length. A mass sliding on a frictionless track curved in the same circular arc would have the same period. Textbooks somewhat mislead by using *L* in the formula for the period, implying the length of the supporting string. The pendulum with a string support is only a special case.

If you would like more rigorous proof, you can derive the period starting with conservation of energy. //



CONTACT SPS

Have thoughts on this puzzle? Send them to us at sps-programs@aip.org.



TWO BOBS GLUED TOGETHER swing with the same period as each bob individually. Author image.

An En-Nobeling Experience

BUMPING INTO NOBEL LAUREATES AT THE CONFERENCE ON LASERS AND ELECTRO-OPTICS IN SAN JOSE, CA, MAY 10–15

by Everest Law
Graduate Student, The University of Edinburgh in Scotland

What should one do when one is sitting next to a Nobel laureate? First, look up his picture on Google to ascertain his identity. Then, build up some courage and talk to him.

That's what I did when I realized that Hiroshi Amano, coinventor of the blue LED and a 2014 Nobel laureate in physics, was reading a novel on my left. We were both on the same flight from Los Angeles to San Jose, heading to The Optical Society's Conference on Lasers and Electro-Optics (CLEO).

Despite his achievements, Amano turned out to be an amiable and humble person. The "only change" in his life brought by the Nobel Prize, he said, is that he can now fly first class. The reason why he chose a career in science, he said, was that he wanted to "serve humanity." I believe those were honest words.

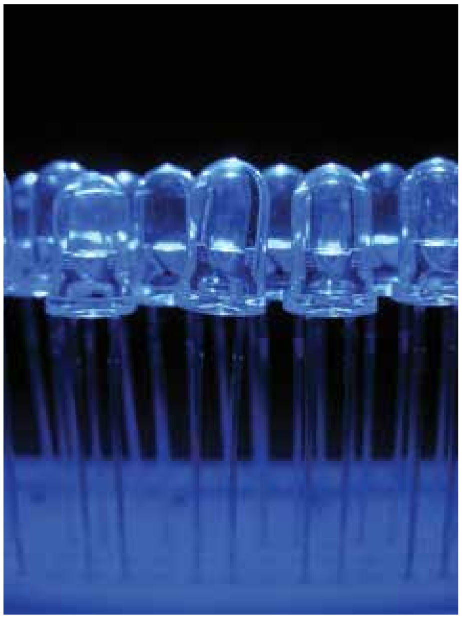
What really surprised me was that he didn't have specific expectations for the CLEO conference. Conferences are sometimes just a way to catch up on new developments and research techniques.

That conversation set the overall tone of my trip. It was the first time I had attended a scientific conference, and the experience was certainly eye-opening! On the day I arrived, there were plenaries by Amano and Steven Chu, a professor at Stanford University in California and former secretary of energy.

Chu also won a Nobel Prize in Physics, for developing optical atom traps. Now he is transitioning to biophysics. Drawing on his own research, Chu discussed techniques for obtaining optical images of single biomolecules. Laughter resounded in the lecture hall when he rhetorically asked whether it is possible to get resolutions below 10 nm. He replied, "Yes, we can!"—echoing the famous statement from his "former boss" during the 2008 presidential campaign. All in all, Chu's presentation was simultaneously informative and entertaining. He is a master of scientific communication.

THE AUTHOR (right) and plenary speaker Steven Chu. Photo courtesy of Everest Law.

After the plenary, I wandered around and entered the student lounge on a whim. Surprise, surprise—both Amano and Chu were there, talking to young people from across the world. A multiethnic group of British students enthusiastically introduced themselves to Chu, while others could be heard speaking Russian and Mandarin Chinese. At that moment I felt rather happy: What better place is there to be for a physics student than a gathering of like-minded people freely exchanging ideas and building friendships? //



HIROSHI AMANO won the 2014 Nobel Prize in Physics for the invention of the blue LED. Photo by Gussisaurio.

LIGHT YOUR WAY

Interested in optics? Check out the full list of upcoming meetings hosted by The Optical Society at www.osa.org/en-us/meetings/.

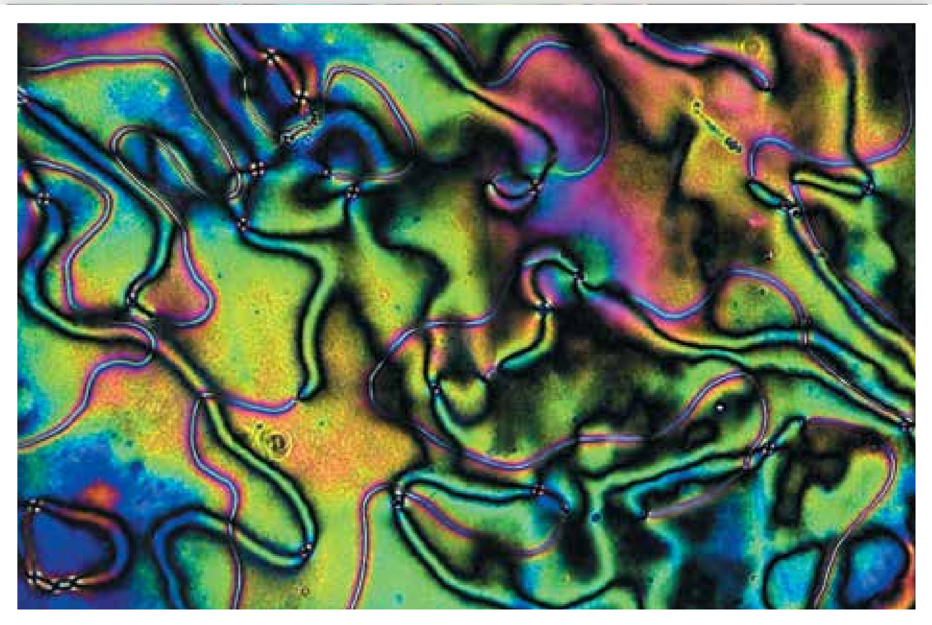
Learn more about Amano's story at www.nobelprize.org/nobel_prizes/physics/laureates/2014/amano-interview.html.

Watch a video of Chu talking about his Nobel Prize–winning work at www.nobelprize.org/nobel_prizes/physics/laureates/1997/chu-interview.html.

A Weekend with Liquid Crystals

MEETING PHYSICS PIONEERS AT THE 2015 GORDON RESEARCH CONFERENCE ON LIQUID CRYSTALS IN BIDDEFORD, ME, JUNE 21–26

by Andrew Mascioli, Class of 2017, and Ian Hunter, Class of 2016,
Tufts University in Medford, MA



A LIQUID CRYSTAL SAMPLE. Photo by Verduzco Laboratory - Rice University.

Standing in front of my poster, I (Andrew) spoke in detail about one of the methods I used to perform the simulations in my work. As I was about to continue, a senior researcher in the small crowd listening to me interrupted me with a question. I listened intently as he described the work of a leading researcher in the field who had done work related to mine but with different methods. Another person jumped in with a comment.

Soon a discussion emerged. Criticisms and praise for one method or another were tossed around, and I threw my own opinions into the mix. Afterward, ideas about how I could improve my own research ran through my head.

Those kinds of interactions defined the Gordon Research Conference (GRC) we attended in secluded Biddeford, Maine. In a town that seemed more suited for a summer camp than a scientific conference, 150 top researchers, students (mostly graduate students), and industry professionals gathered to discuss liquid crystals. Liquid crystals are materials that flow like liquids but have long-range order like crystals. Responsive to both light and applied fields, they are a key component in displays, electronic paper, and, as we learned, artificial muscles and sensors.

The atmosphere was informal and casual. Conversations about cutting-edge research went hand-in-hand with social activities such as kayaking. With the understanding that all research information shared at the conference was confidential, the discourse flowed freely.

"We don't know yet," we heard again and again, as participants discussed new, exciting observations that had yet to be explained. The GRC sets itself apart as a different kind of conference that embraces the spirit of collaboration in the pursuit of scientific progress. One of this year's conference vice chairs and an established liquid crystal experimentalist, Professor Linda Hirst from the University of California, Merced, told us that the primary goals of the GRC are to encourage collaboration, get graduate students to talk to established professors, and avoid cliquishness. Hirst saw those goals as distinct from those of larger conferences, which often serve primarily as a means for scientists to display their completed work.

The opportunity to attend such a conference as an undergraduate not only proved to be a boon for our own research, but also shaped our opinion of the scientific community. If nothing else, the GRC inspired us to continue being engaged in that community. //

FIND OUT MORE

- **Peruse the full lineup of Gordon Research Conferences at www.grc.org.**

IAN (FAR LEFT) AND ANDREW (FAR RIGHT) enjoy a lobster dinner at the conference. Photo courtesy of Andrew Mascioli.

IAN (FAR LEFT) AND ANDREW (FAR RIGHT) prepare for a kayaking trip with fellow Tufts researchers. Photo courtesy of Andrew Mascioli.

In the Middle of a Revolution

WADING INTO DEBATE AT THE CONFERENCE ON STRONGLY CORRELATED TOPOLOGICAL INSULATORS: SmB_6 AND BEYOND AT THE UNIVERSITY OF MICHIGAN IN ANN ARBOR, MI, JUNE 2–5, 2015

by Pavel Shibayev, Class of 2015, Princeton University in Princeton, NJ

A SAMPLE OF BISMUTH SELENIDE, a topological insulator. Photo by Bryce Vickmark.

"Let me make a bet," suddenly announced the discussion session chair, to the gasp of the 60 people in an audience of theorists and experimentalists known to be leaders of their subfields. He nonchalantly continued, "If we make it 1:1, it wouldn't be a fair bet, so let us do 5:1." Cheers and applause erupted.

The light-hearted manner with which these words were uttered could have left someone walking into the room at that moment wondering whether they were in the right place—but only momentarily. The discussion immediately resumed its natural academic style.

Subsequent conversation during the session, articulated in an exceptionally civil but almost impatient tone, addressed the speaker's bet. Under discussion was an ongoing controversy centered around SmB_6, which was recently found to possess properties of a topological insulator, a material that conducts like a metal at its surface while remaining an insulator at its core.

The unique exchange took place at this summer's conference on recent developments in research conducted on SmB_6 and related strongly correlated systems. I flew to the meeting at the University of Michigan the night after my graduation from Princeton.

It was encouraging to see every prominent direction in ongoing research of the hexaborides covered or cited during the four-day event. When I interviewed Professor Sankar Das Sarma, director of the Condensed Matter Theory Center at the University of Maryland in College Park, he stated that in physics "by definition, a new frontier should be broken very rarely." Scientists should therefore be skeptical of new findings, and the opportunity for a speaker to interact with audience members questioning the conclusions is crucial, he added. He also mentioned that the conference far surpassed his expectations precisely because its format was conducive to this lively discussion.

Professor Piers Coleman of Rutgers University in Piscataway, New Jersey, gave the concluding talk, declaring, "We are in the middle of a revolution, right now, right here." He went on to reconstruct a conceptual timeline of emerging physics projected in two directions: strongly correlated electron systems and topology. The two strands have been gradually converging over time in a recently introduced field, topotronics. When I interviewed Coleman after his talk, he noted, "It's science in the making. There's controversy, there's disagreement, there are new ideas, there are experiments that don't entirely match up to each other, but that's how active science is." On the topic of the nature of SmB_6, he immediately remarked, "I think there is a growing consensus that it is a topological insulator."

Such a strong level of engagement with the presentations at a meeting attended by less than 100 people was in stark contrast to what I had witnessed at the APS March Meeting held in San Antonio, Texas earlier this year, where time constraints severely limited wider discussions of work during the sessions. For this reason, the SmB_6 conference was highly valuable to me as a developing researcher in condensed matter physics. //

"THERE'S CONTROVERSY, THERE'S DISAGREEMENT, THERE ARE NEW IDEAS, THERE ARE EXPERIMENTS THAT DON'T ENTIRELY MATCH UP TO EACH OTHER, BUT that's how active science is."

–Professor Piers Coleman, Rutgers University

A TOPOLOGICAL TOPIC

Learn more about the topological insulators Shibayev studies at http://arxiv.org/pdf/1002.3895.pdf.

the SPS Observer
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Let us know what you think of the stories in the pages of *The SPS Observer*. Send feedback and letters to the editor to sps-programs@aip.org or via the online contact form.