Physics Flash

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Glen Wurden

Bringing lifelong energy to the study of fusion science

By Diana Del Mauro
ADEPS Communications

Glen Wurden began dreaming of a civilization powered by fusion energy as a college senior. By the completion of his PhD in plasma physics at Princeton in 1982, fusion science was at its peak and scientists hoped to attain fusion energy in a mere 15 years.

Glen Wurden cools down a gamma detector with liquid nitrogen for Trident neutron measurements in June.

Such a feat, akin to creating the inner workings of a star, turned out to be much more difficult than originally thought. Scientists have demonstrated controlled fusion in the lab, but their experiments have yet to produce usable electricity.

Wurden's dream might not come to pass during his lifetime—and he said it definitely won't be soon enough to thwart global warming—but he has no plans of abandoning this grand scientific challenge. "You can't give up," the Plasma Physics (P-24) researcher said. "Producing and harnessing controlled fusion energy is a multi-generational problem."

The study of nuclear fusion at Los Alamos dates back to the Manhattan Project and the Laboratory remains a vital contributor to the national fusion program. "Although LANL has never had the largest program, we have a pedigree and a tradition of innovation in this field," P-24 Group Leader Juan Fernández said.

Wurden has seen machines come and go, like the ones pictured in a 1985 newspaper article, "Lab finds promise in magnet fusion," posted on his office white board. He has seen scientists come and go, and he has been among them. He was teaching at the University of Washington in

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State of the Division featured in July All-Hands Meeting

Physics Division Leader Doug Fulton reported on the state of the Division at a well-attended All-Hands Meeting recently at the Los Alamos Neutron Science Center.

First, the budget: All Physics Division staffers are now fully funded, which attendees said was a big relief to hear. The overall budget, at $93 million, is somewhat lower than last fiscal year's budget at $106 million. The Division is still recovering from some hits to large projects, such as active interrogation and quantum cryptography. Primary sources of funding for Physics Division are the weapons program, the Office of Science, and LDRD with high-energy physics a potential growth area. Fulton discussed the strategic planning that the Division Leadership Team engages in and identified the major thrust areas and champions.

Fulton didn't shy away from hard topics. In a first-ever pilot survey conducted by the human resources department, 34 Physics Division managers were evaluated regarding leadership skills and a fair work environment by workers above and below them. Blow by blow, Fulton reviewed the results specific to him, including the need to create a plan for the future with adequate input from technical staffers about the science, not just compliance, safety, and money issues.

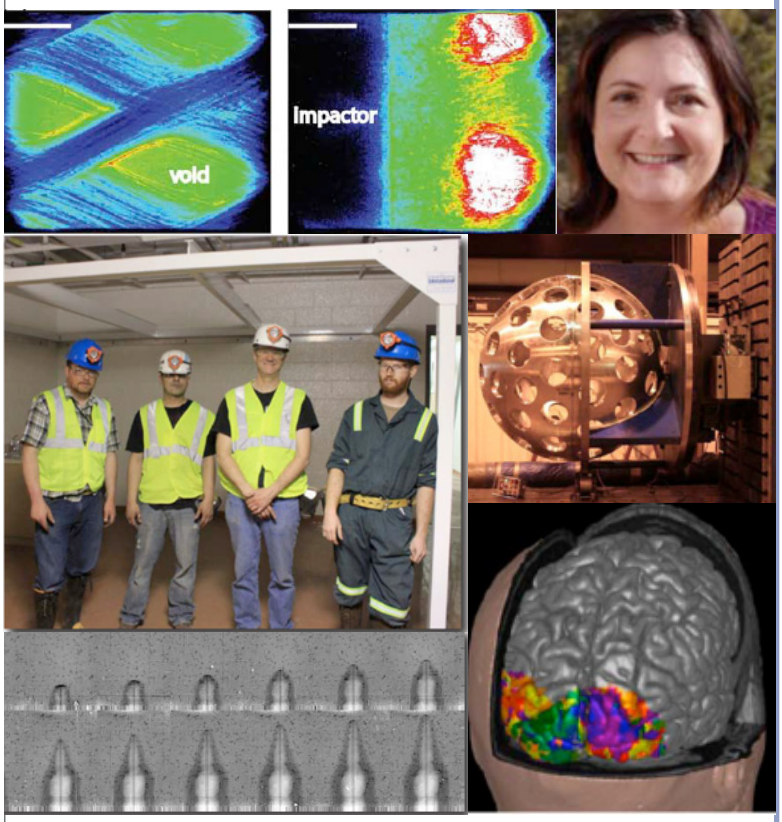
"To share something like that was a huge effort on his part," one attendee said after the meeting. "He gets high kudos for baring it all, basically."

When asked by Gerry Garvey (Subatomic Physics, P-25) to sum up the purpose of his job, Fulton said, "to try to find an environment where the actual technical leaders can be successful." He said he strives to guide scientists toward cutting-edge science that someone will pay for and shield them from bureaucratic burdens. Compared with the graduation rates for PhD physicists coming out of graduate school Physics has a disproportionate number of white, male scientists and engineers. In actions he is taking, Fulton said, "Perhaps the biggest change is that all hiring actions must document attempts to increase the diversity of the candidate pool and all postdoc positions will be advertised." In 2010, women filled about 12 percent of scientist and engineering positions in Physics Division and the statistics for postdoctoral researchers were approximately the same. Since then, the Division has successfully attracted more female postdoctoral researchers (25 percent). Yet, that effort hasn't translated into more female staffers, still at approximately 12 percent, in part because it will take time for hiring actions into staff positions to reflect the new hiring pool statistics, Fulton said.

In May of 2010, Fulton invited the American Physical Society's Committee on the Status of Women in Physics to visit Physics Division and conduct an in-house survey. His responses to the committee's 15 recommendations are posted on the Division's internal website. Minorities are underrepresented, too, but Fulton noted some improvement: 23 percent of minority scientists and engineers now, up from 19 percent four years ago.

"It's always a commendable thing to be looking at making sure there's the right proportion of women and diversity," Vincent Yuan (Neutron Science and Technology, P-23) said. All the same, the pursuit of science captivated Yuan as much as anything at the meeting. He was interested in what four scientists had to say about their progress on impressive, long-term projects: Hubert van Hecke (Subatomic Physics, P-25) on the PHENIX experiment hitting the highest man-made temperature of 7.2 trillion degrees Fahrenheit, a Guinness World Record; Scott Hsu (P-24) on building a new experimental facility to study supersonic plasma jets; Ray Newell (Applied Modern Physics, P-21) on quantum cryptology and finding a secure way to transmit data in a device the size of your pinkie; and John Pretz (Neutron Science and Technology, P-23) on HAWC (High-Altitude Water Cherenkov Gamma-Ray Observatory) and the effort to build a 300-tank array in Mexico to study cosmic rays.

Slides from the All-Hands Meeting and the Division's response to issues identified during the APS committee's site visit can be found at int.lanl.gov/org/padste/adeps/physics/resources.shtml.



Images from recent Physics Division scientific and technical highlights.

Wurden . . . 1990 when the Laboratory's Controlled Thermonuclear Research (CTR) Division was eliminated in a restructuring aimed at adapting to new national fusion program funding priorities. Many CTR staff joined the High Energy Density Physics (P-1) group, later transformed into P-24, and continued their research in fusion activities still supported by the national program.

Two years later, Wurden returned to help rejuvenate fusion energy research at Los Alamos. "The team of people is the most important thing," he said. Rebuilding the team happened gradually, over the span of 20 years.

Since 1995 he has been P-24's magnetic fusion experiments team leader. "After the demise of CTR Division, my team developed the first new plasma confinement experiment at LANL in nearly 10 years," he said.

Pursuing all approaches

In this highly competitive field, Los Alamos scientists are sought after for their specialties in plasma experiments and diagnostics, laser diagnostics, high-energy density physics, and materials science. Wurden, an avid experimentalist, has built more than 30 plasma diagnostics and continues to develop new kinds of measurements. "We are world leaders in magnetized target fusion," he said.

Wurden wore the hat of program manager for the last 10 years, representing the Laboratory to the Department of Energy's Office of Fusion Energy Sciences. Faced with a national budget for fusion research that has been flat for more than a decade, writing successful proposals is a vital sidelight to the science he does, as is traveling to Germany, Japan, and France to participate in international fusion experiments.

"Glen has acquired considerable stature in the fusion research community," Fernández said. "He provides to LANL, and to our research program in this area, a larger profile and influence than the size of our program would warrant otherwise."

Wurden believes in pursuing all fusion energy approaches, simultaneously. P-24 investigates two rival concepts: magnetic confinement (tokamaks and stellarators) and inertial fusion, which uses lasers to implode targets, simulating some aspects of nuclear explosion physics.

Lately, Wurden's enthusiasm is mounting. "It's time to show what we can do," he said, noting 15 years of toil on a magnetized target fusion experiment. Can the Shiva Star team achieve fusion by crushing plasma inside an aluminum can with jolts of electricity—the equivalent of two sticks of dynamite—rather that using lasers to implode the can? Four shots at the Air Force Weapons Laboratory in Albuquerque may soon prove the concept."This is our special idea that we think is a uniquely different way of doing fusion," Wurden said. "There's nothing like this in the world anywhere."

Some of Glen Wurden's favorite experiments:

I would have to say my favorite science experiments have been ones I have done while mentoring my three children over the years.

After seeing a big ball of plasma sitting on a power pole in Gaithersburg, Maryland, during a huge lightning storm, I told my youngest daughter, Caroline, about it. She found a video of some German scientists making ball plasmas in their lab in Berlin. Well, I knew the guys! So after we visited the Berlin lab, Caroline decided to make ball plasmas for her science fair project, buying equipment to do it from The Black Hole (a lab surplus store in Los Alamos).

The two of us studied beautifully colored ball plasmas with cameras and photodiodes and spectroscopy. Caroline won quite a few prizes at the International Science & Engineering Fair for two years in a row, and even got a main belt asteroid named for her (23265 von Wurden)! She is now a physics major at Berkeley.

Recently, in 2011, Caroline and I published a short paper together on the topic of atmospheric pressure ball plasmas, in the Institute of Electrical and Electronics Engineers' *Transactions on Plasma Science.*

The unique route to half-cycle XUV/x-ray pulses

Since their discovery 110 years ago, x-rays have played an important role in society from science to medicine. In recent years, coherent sources of x-rays have been developed using free-electron lasers or ionized gas high-harmonic generation. All these coherent sources generate pulses containing many cycles.

In a recent paper (*Nature Photonics,* May 2012), Hui-Chun Wu (P-24) and colleague present the first report of a novel method to generate giant half-cycle attosecond XUV/x-ray pulses, making use of high-contrast few-cycle laser pulses at relativistic intensity incident on nanometer-structured targets. Wu's new discoveries potentially will push x-rays into the half-cycle regime for the first time. The potential impact and influence of his work is extremely high.

High-contrast laser pulses, focused on nanometer-thick solid layers, may take along all electrons contained in the layer and form dense

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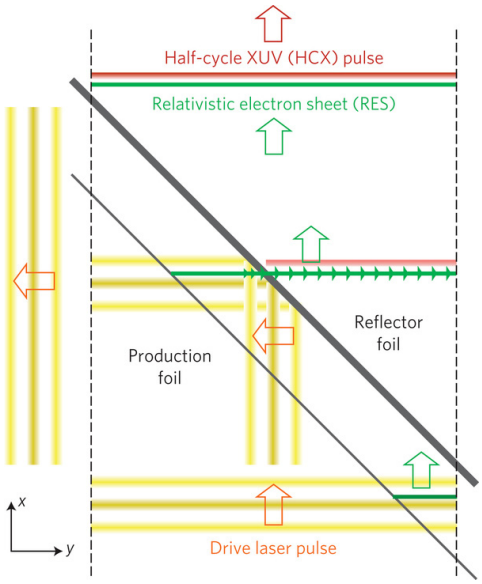

Schematic of target interaction and half-cycle emission. A three-cycle laser pulse, obliquely incident on a double foil target, is shown at different times, with yellow arrows indicating propagation direction: (i) when starting electron blowout from the production foil, (ii) while diverted by the reflector foil, and (iii) after reflection. The relativistic electron sheet (green) passes the reflector in the direction of the green arrows, picking up transverse momentum (small green arrows) due to interaction with reflected light. The transverse current radiates the half-cycle attosecond XUV (HCX, red) pulse propagating in front of the electron layer in the direction of the incident light.

XUV/x-ray . . . flying relativistic electron sheets, separated from the ions and surfing on the laser wave front. A previous paper [Wu et al., *PRL* **104**, 234801 (2010)] describes how these sheets can be used as relativistic mirrors for coherent Thomson scattering, compressing probe pulses by a factor of $4\gamma^2$. This requires double foil targets with the second foil reflecting the drive pulse, while electrons move straight on. Exploring this configuration for obliquely incident light, Wu made an outstanding new discovery, which may be of high importance for XUV/x-ray optics.

When passing the reflector foil, all electrons of the relativistic sheet acquire same transverse momentum in the plane of the sheet. This is in addition to the relativistic momentum in the direction normal to the sheet and makes the sheet an antenna emitting a unilateral/unipolar electromagnetic pulse. The mechanism described in the paper to generate single attosecond pulses is quite different from any other proposed.

These powerful half-cycle XUV/x-ray pulses will open a new era of XUV/x-ray optics and attoscience. First, the peak power (terawatt) is two orders of magnitude larger than expensive free-electron lasers, so they can be used in nonlinear XUV/x-ray optics and attosecond pump-probe experiments. Second, the unipolar field structure will find novel applications, such as inducing an electron current and manipulating electron motion in atoms, molecules, and solids. This work is supported by LDRD Program 20110341ER at Los Alamos National Laboratory. Authors are H.-C. Wu (P-24) and Meyer-ter-Vehn (Max-Planck-Institut fuer Quantenoptik, Germany).

Technical contact: Hui-Chun Wu

All-optical Compton gamma-ray source developed

One of the most promising approaches for using laser-accelerated electrons to generate hard x-rays is to counter-propagate them into a second laser pulse. Doppler shifting will then produce keV to MeV photons, depending on the energy of the electron beam. Rahul Shah (P-24) and collaborators developed a tabletop-scale, narrow-divergence, and ultra-fast source. The method relies on a simple and original scheme of Compton backscattering in a laser-plasma accelerator. *Nature Photonics* featured the work on the journal's cover.

A technical complexity is the overlapping between the electrons and colliding laser pulse. The researchers solved this problem by using a simple piece of foil to produce the x-rays with a single laser pulse. The foil is ionized, forming a plasma mirror (measured reflectivity up to 70%) that reflects the laser pulse driving the wakefield acceleration for the backscattering. The x-ray beams are generated in a broadband energy range, extending up to a few hundred keV. The x-ray radiation is collimated within a 18 mrad (FWHM) beam with a source size of less than 3 micron (FWHM), and the total number of x-ray photons is estimated to be approximately 1×10^8. The high brightness with respect to conventional Compton sources is a result of the micrometer-scale source size and the femtosecond duration, features inherent to this all-optical scheme. Although the peak brightness is slightly inferior to a betatron source, the Compton source offers a much higher photon energy at a given electron energy. The scientists seek to optimize the source by carefully maximizing electron charge and spectral quality.

The work creates a new tool, resulting from laser-plasma accelerator research, with potential applications encompassing medicine, materials science, biology, and homeland security. The work supports the Lab's Global Security and Energy Security mission areas and the Materials for the Future science pillar. Reference: "All-optical Compton Gamma-ray Source," *Nature Photonics* **6**, 308 (2012). Researchers include Rahul Shah (P-24) and collaborators K. Ta Phuoc, S. Corde, C. Thaury, V. Malka, A. Tafzi, J. P. Goddet, S. Sebban, and A. Rousse (Laboratoire d' Optique Appliquee, France).

Technical contact: Rahul Shah

HeadsUP!

WSST Fest a success

Laboratory workers had the opportunity to learn about employee-driven safety programs and successes at the recently held WSST Fest. The event included information booths by organizational Worker Safety and Security Teams, a safety showcase with safety products and services from Laboratory suppliers, and health screening sessions for employees. To see a slideshow of the event, please see int.lanl.gov/news/newsbulletin/QuickTimes/wsst-fest-2012.mov.

New home for Employee Assistance Program

The Employee Assistance Program has moved to the Occupational Medicine building at TA-3 from the Los Alamos Neutron Science Center.

The EAP is a counseling and referral service that assists employees in addressing behavioral health issues. Its phone number remains 667-7339. EAP's free, confidential counseling services are available to all badge holders and their family members. Questions? Contact James Barber or Lisa Celosse at 667-7339.

Reminder: Rains are here, but continue practicing fire safety

Increased humidity and rain has lessened fire danger on LANL property and in the nearby forests. But LANL emergency operations managers remind employees to continue practicing fire safety.

Employees should:

- Smoke only in designated smoking areas and discard cigarette butts in proper receptacles.
- Don't park cars along shoulders in forest roads; engines running can emit sparks that start a fire.
- Report, and if possible, remove downed branches, heavy growth of shrubs that can ignite and quickly explode into a large fire.
- Practice defensible space at work and at home.

Employees are reminded to call 9-1-1 if they spot a fire on or off Lab property, and to call Emergency Operations at 7-6211 if they spot a potential hazard, such as a power line that may be in danger from a tree or a downed power line. Employees also should call Emergency Operations if they encounter wildlife.

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Valle clouds, Robb Kramer

Celebrating service

Congratulations to the following Physics Division employees celebrating service anniversaries this month:

William Louis, P-25	25 years
Jeffrey Bacon, P-25	10 years