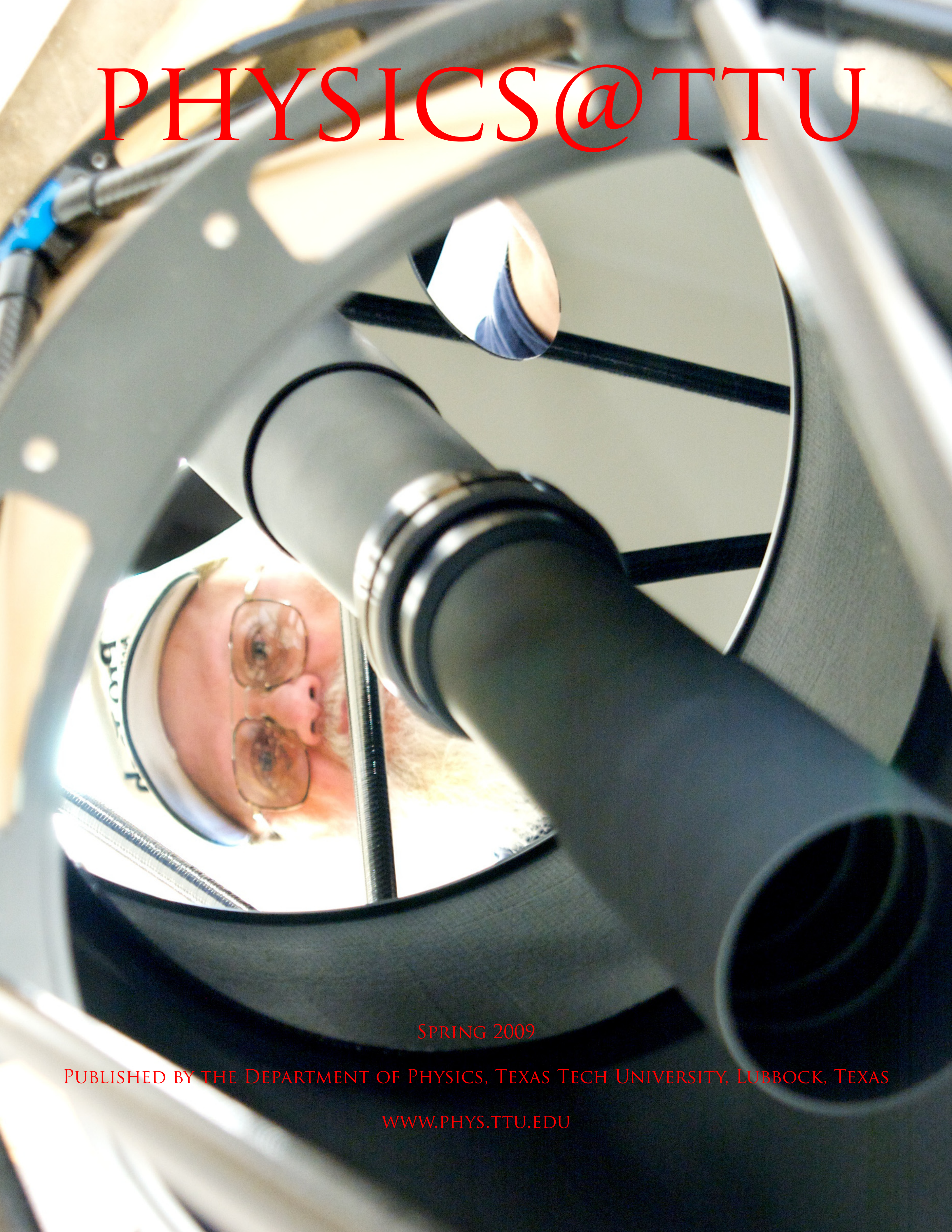
# PHYSICS@TTU



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## *In This Issue:*




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# The View from the Chair

I am happy to share our departmental news with you in this second of issue of *physics@ttu*. Although much remains to be done, we accomplished a great deal in the last year. Let me mention the highlights.

Dr. Douglas Barlow joined us in July 2008 in a newly created position as the Director of Instructional Laboratories. His objective is to modernize our laboratories to enhance student learning. He works closely with the lecturers and coordinates more than 20 teaching assistants. We have upgraded nearly all equipment and will continue to renew all labs in the undergraduate curriculum. Doug fills a critical role in this area and brings considerable expertise and insight to his position. Doug and Sarah Stubbs, a long-time staff member, make an effective team to face these challenges.

We have observed an ~14% increase in the last two semester's enrollment in our introductory courses: two astronomy (ASTR1400 and 1401) and the four physics courses (algebra-based PHYS1403 and 1404, and calculus-based PHYS1408 and 2401). This increase is significant because we wish to make the highest quality courses available to all TTU students, and at the same time, increase the revenue base to realize new projects in teaching. We will continue to explore ways of better serving an even larger student population in the coming semesters. For example, we have added several new courses to our program. Physics of Living Matter (PHYS1402) is a new course designed to convey physics concepts using biological systems and will be offered for the first time in Fall 2009. Quantum Mechanics II (PHYS4308) is also new and will extend the topic coverage beyond Quantum Mechanics I (*e.g.* perturbation theory, variational principle, approximation techniques, and scattering). There are also several new courses in different stages of the approval process for graduate students: Molecular Biophysics, Methods in Biophysics, Elementary Particle Physics, Nanophotonics, Physics Pedagogy, Statistical Mechanics II, Advanced Quantum Mechanics, and Quantum Field Theory.

Two special sections of Physics I and II courses designed for our majors have also proved successful. These sections are limited to 25 students who are encouraged to work closely with each other and the instructor in a workshop setting where the lectures are mixed with experimentation and problem solving. The student response has been overwhelmingly positive.

As we make gradual changes in the undergraduate program, we remain concerned that we assess learning outcomes correctly. Meaningful learning assessment is a challenge, and we are in the process of sifting through the data gathered last semester so as to understand how we must prioritize our efforts. We intend to stay current with the leading pedagogies and assessment techniques and to be favorably compared with the best physics departments in the US.

A new 20-inch Schmidt-Cassegrain telescope arrived on campus last week, thanks to support from the Dean of College of Arts and Sciences and Ms. Orene Gott (see the cover page for a reflected image on the primary mirror). This telescope replaces the 16-inch Newtonian and features a research-grade spectrometer as well as other sophisticated imaging hardware and software. The architectural drawings of the observatory extension are complete, and the bidding process is underway. If all goes well, we will have a much improved observatory building with a beautiful telescope for the fall semester.

We are proud of our recent graduates. Alden Astwood, Andris Docaj, George Laity, Austin Meyer, and Jordan Phillips graduated in May and Corey Petty in December 2008 with bachelor degrees. They are all currently at various graduate schools. Alicja Idziaszek graduated with an MS degree in August. Her thesis was *Interference in Arrayed Waveguide Gratings Illuminated with Ultrafast Pulses of Light*. Micah Gatz received his MS degree in December with a thesis titled *Measurement of Propagation Losses in Ring Resonators Based in Silica on Silicon Waveguides*. Professor Luis Grave de Peralta supervised both students –he has also provided us an update on his current research on pages 5-7 of this

issue. Miranda Martin received her MSI degree in August with a report, *Burn In and Device Failure*. Drs. William Lee Powell and Kazim Gumus, the recipients of doctoral degrees in 2008, summarize their work on pages 23-24. We wish our young colleagues the best.

Professor Walter Borst will retire this year after an illustrious career that has spanned 25 years at TTU. Walter came to TTU as Chair in 1984. His administrative skills, research program, and dedication to teaching have greatly enhanced the department, and over the years, he has enriched many lives. Ginger Kerrick is one of many students whom Walter caringly helped mentor –her story appears on pages 8-9. His retirement party is scheduled for October 3, 2009. All are invited. He would particularly love to see old students, colleagues, and friends. Please watch the departmental web page for updates and further information. Walter's most recent project has been the Physics of Sound and Music (PHYS1406) –a popular course that quickly fills on the first day of registration. In this course, Walter beautifully blends art and science and shows how one without the other is a glass half full. He will continue to teach it on a part-time basis in the coming years.

I am in the process of establishing a Physics Advisory Board (PAB) that will fulfill several critical functions in executing our strategic and long-term plan. I have had the pleasure of speaking with several enthusiastic alumni and friends about the function and makeup of this board, but I would also like to hear ideas from a broader TTU physics family. I wish to see our department grow not only in numbers of faculty and students but also in scientific stature. As well as building on our strengths, we must expand into new disciplines that hold the promise of discoveries and inventions to address the most pressing problems of the day. Our physics department cannot be disconnected from daily concerns when the world is facing a serious energy crisis, for example, but neither can we afford to be bystanders to the puzzle of what makes up the universe as long as dark matter and dark energy remain enigmas. We will have to think hard about how to be effective participants in many types of journeys. One thing is clear, though: it will take sustained personal and institutional commitment to make major strides. I invite all of us to think ahead and do what we can for our department. I expect that the PAB will be in place early this year to help us consider some strategic initiatives.

I congratulate our faculty for a productive year in research. The external funding level is up to $2.45M in FY2008, from $1.56M in FY2007. The number of refereed publications is ~60 in CY2008, essentially the same as last year. We are, of course, looking forward to an even better year in 2009.

The Bucy Distinguished Lecture series restarts with Allan H. MacDonald, Professor of Physics and holder of the Sid W. Richardson Foundation Regents Chair at the University of Texas at Austin, as our speaker on April 2, 2009. Another important event is the SPS Spring Banquet, which is scheduled for the evening of April 17, 2009, where we acknowledge scholarship and award recipients for academic excellence. We look forward to this celebration. Mark your calendars.

Finally, with great sadness, I must report the death of Emmanuel Nenghabi, a graduate student of to $2.45M condensed matter theory, in January 2009 after a brief illness. He was planning to graduate in August and had already published a part of his thesis research in *Physical Review B* with Professor Myles.

Many of you sent emails or called to say hi in response to our previous issue of *physics@ttu*. Thank you all. As I wrote therein, on the road ahead of us, we will need all our dedicated alumni and friends to make TTU Physics the place to be.

Sincerely yours,

Nural Akchurin
Professor and Chair
(nural.akchurin@ttu.edu)

# *Darkness is not so Dark After All*

*Luis Grave de Peralta*

Optical pulse shapers (PS) are devices designed for shaping ultrafast pulses of light. PS allow precise control in the time and frequency domains of ultrafast pulses in multiple applications. These applications include, but are not limited to, optical code-division multiple-access communication networks, coherent control of chemical reactions, generation of terahertz radiation in semiconductor materials, encrypted ultra-fast imaging, and quantum computation. I have been working with integrated optics PS during the last four years as a natural continuation of my previous work in arrayed waveguide gratings (AWG). Miniaturization and loss minimization have fueled the development of planar lightwave circuits (PLC), where semiconductor industry initiated tools (namely photolithography and reactive-ion etching) are applied to the fabrication of optical devices. PLC-based fabrication is frequently employed in a wide range of integrated optics devices, such as power splitters, tapped delay lines, and AWGs.

AWGs are miniature spectrometers commonly used as multiplexers and de-multiplexers in currently deployed optical communication networks. They are often designed for continuous wave operation, but in the Nano Tech Center, we became interested in the ultrafast response of AWGs. The underlying physical principle behind the spectrometer's capability is the occurrence of multiple slit interference in light traversing the instrument through a multitude of paths. Interference is a crucial phenomenon that distinguishes particles from waves, and the double slit interference experiment is considered one of the all-time most beautiful experiments in physics. In his legendary lectures, the famous Nobel Prize recipient Richard Feynman referred to this experiment as "the only mystery" of quantum mechanics. When a wave-front-division-based spectrometer (AWG) is illuminated with a monochromatic laser, numerous beams defined by the grating superpose in the common path of the device. As a result, bright (or dark) spots are formed wherever the beams interfere constructively (or destructively). However, short pulses of light traverse the instrument through many different paths when the spectrometer is illuminated with a coherent source of pulsed light. These pulses may perhaps never superpose in the common path of the device. Thus, it is not a trivial task to predict if the spectrometer will still work when illuminated with a mode-locked laser.

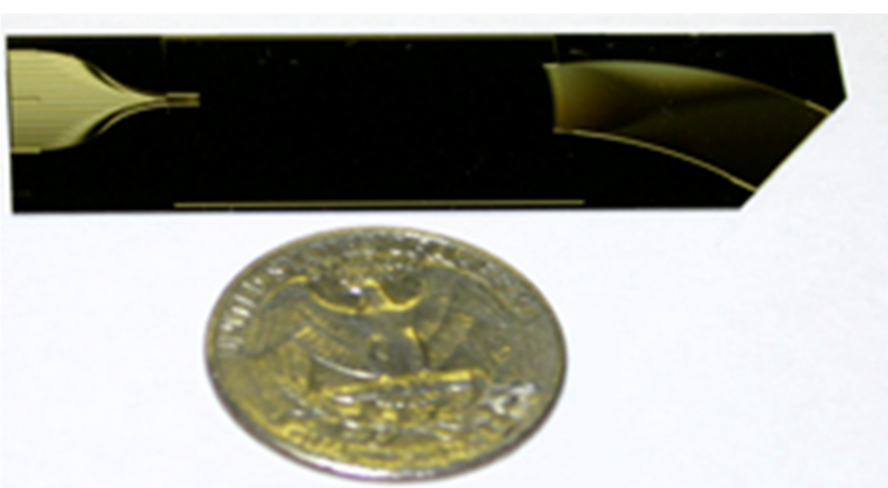


Figure 1: Photograph of a reflective AWG for communication applications developed at TTU.

We decided to investigate what happens inside an AWG when it is illuminated with pulsed light. We were encouraged by both fundamental and practical considerations. Specially designed AWGs are magnificent optical pulse shapers when illuminated with a mode-locked laser; thus, we expected to improve our knowledge about PS design and performance. Investigating the ultrafast response of AWGs is interesting from a more fundamental point of view. Interference by multiple slit experiments has been realized in a variety of conditions, including when the multiple slit is illuminated with intense monochromatic light, or single photons, or a beam of electrons, atoms and even molecules. However, we were surprised by the absence of multiple slit experiments with ultra-short pulses of light. In order to fill this unexpected gap, we designed an extreme integrated optics spectrometer. The device was fabricated in a state of the art Si-foundry that specializes in fabrication of PLC devices.

We designed our experiments so that there could never be more than a single pulse at the slab, which is the only place inside of the AWG where paths of different pulses traversing distinct waveguides of the grating cross each other. Consequently, if interference were observed, we could be sure that it was not produced by superposition of pulses inside of the AWG. Nevertheless, we experimentally determined that light with different frequencies (colors) left distinct output waveguides of the device. Our findings were published with the corresponding theoretical explanation in 2007 (*Ultra fast response of arrayed waveguide gratings*, L. Grave de Peralta, A. A. Bernussi and H. Temkin, IEEE Journal of Quantum Electronics, **43**, 473 (2007)).

Basically we observed a counter-intuitive phenomenon: interference between minima of interference. Pulses are flashes of light formed by constructive interference between numerous monochromatic modes that simultaneously lase in the cavity of the mode-locked laser used as a source of pulsed illumination in our experiments. Between one pulse and the next one there is a long and dark interference minimum due to destructive interference between the same monochromatic modes responsible for the bright flashes of light. Beating between the locked modes of the laser produces both the bright flashes and the darkness in between consecutive pulses. It is not difficult to imagine that the superposition of bright pulses traveling through different paths inside of the spectrometer may result in interference effects. However, it requires some thinking to figure out that the superposition of the dark regions in between pulses also results in interference.

As an external reviewer of our work pointed out, "Extraordinary claims require extraordinary evidence." After all, in our experiments, we did not measure what happened inside the extreme AWG; we measured only the output spectra and temporal response of the device. A skeptical thinker may argue that the observed interference effect (light with different frequencies left distinct output waveguides of the device) was due to the necessary use of an external apparatus for carrying out the measurements. In order to address these concerns, we decided to make a detailed calculation of how the electromagnetic energy carried by the light flows through the slab, which is the only region inside of the AWG where the dark regions in between pulses superpose each other. We were able to produce short video clips showing 80 consecutive instantaneous shots of the electromagnetic energy distribution in the slab region. A time delay of one picosecond (a million part of a million part of a second) separates consecutive images in the movie. These results were recently published (*Interference in wave-front-*

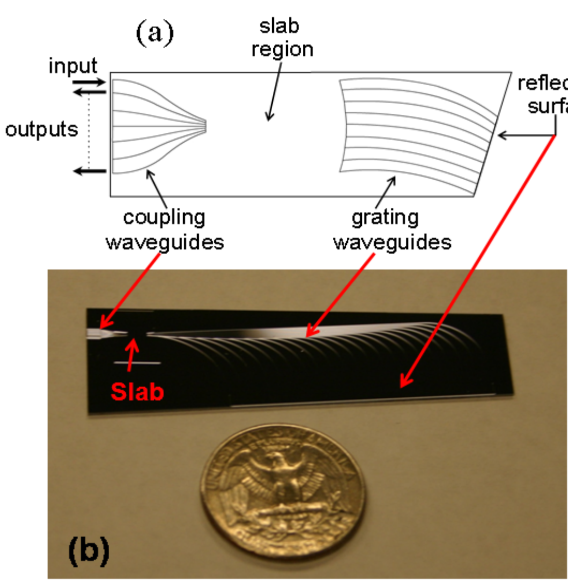



Figure 2: Schematic (a) and photograph (b) of the fabricated pulse shaper.

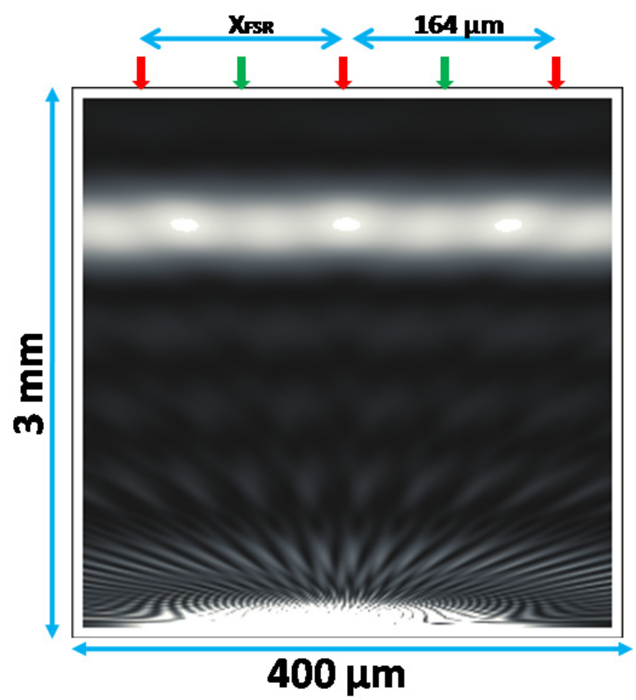



Figure 3: Instantaneous distribution of the magnitude of the energy flux in the slab region. The beating between waves with different frequencies results in a pulse of light (horizontal bright band). The interference between waves with the same frequency coming out of distinct slits produces a transversal structure in the pulse. Arrows point to local interference maxima.

*division-based spectrometers illuminated with ultra fast pulses of light*, L. Grave de Peralta, Journal of Applied Physics, **105**, 013111 (2009)).

This research is a good example of what physicists do. We were working in optical pulse shaping, a state of the art application of optics to engineering, when we realized that we had the opportunity to go deep into the fundamentals of physical science. Then we had a lot of fun. We immersed ourselves in the ever exciting journey of discovery and inquiry about nature. Physicists and engineers, working together with our students at the TTU Nano Tech Center, increased our understanding about the design and working of optical pulse shapers. We made it clear that the dispersing ability of spectrometers extends to pulses of arbitrarily short duration as long as the spectral components, corresponding to pulses following distinct optical paths, overlap coherently in the common path of the spectrometer. Now, I can't help but enjoy the "Wow" faces of my physics major students during my lectures on optics when I use the results of our experiments to explain to them why darkness is not synonymous with emptiness.

*Professor Luis Grave de Peralta (luis.grave-de-peralta@ttu.edu) is an assistant professor in our department. He received his PhD in 2000 from TTU. His research concentrates in ultrafast and quantum optics, plasmonics, and nanophotonics. He works closely with the researchers at TTU's Nano Tech Center.*

## ON THE WEB

www.youtube.com/watch?v=DfPeprQ7oGc

physicsworld.com/cws/article/print/9745

www.luisgrave.com

www.physics.gatech.edu/frog

# *At the Helm at NASA: Lead Station Flight Director*

The day before launch, she decided to take a day off and relax. After all, she'd spent a year coming up with plan Bs and even plan Cs for every failure contingency she and her team could imagine. That's Ginger Kerrick's job as lead station flight director at Johnson Space Center in Houston. Keep the astronauts safe and ensure success with the mission.

With her feet firmly on Texas soil, the Texas Tech alumna at least transcendentally joined the Shuttle Endeavor's crew in space during the Nov. 14 mission. She held the lives of seven astronauts in her hands for what would seem like a nerve-wracking 16-day mission to some. But to her, it was cake.

"A lot of people look at this job and think 'Oh, I can't do that,'" she said. "Yeah, you can. Anyone who has a bachelor's in science or engineering can do this job."


Flight Director **Ginger Kerrick** (BS 1991, MS 1993) poses for a portrait in the Shuttle Flight Control Room in Houston's Mission Control Center.

This trip, Shuttle Endeavour delivered a new crew member to the International Space Station, spiders and butterflies, as well as a state-of-the-art urine-to-water recycling system, toilet, sleeping quarters and exercise equipment needed for larger crews beginning in spring 2009.

The mission also included four spacewalks to service rotary joints that allow the station's solar arrays to track the sun and generate power.

"A year ago, we noticed some high current spikes, indicative of a lot of friction," she said, describing the joint issues. "We saw that the ring on the panel's rotating shoulder looked to be eating away at itself. So, we didn't allow it to track the sun. That limits our energy production. So, the astronauts went outside on three different space walks to repair the shoulder joint on one side of the station. While out there, they went to the other side and applied some lubricant to the shoulder joint there."

This is her dream – one borne of a library book at 5 years old. Since that time, nothing has swayed her or changed her mind. Exploring space would become her primary purpose. And despite the obstacles that stood in her way, she pushed, she fought, and she found her way to the top of her career.

"My dad took me to the library all the time," she said. "One particular trip, I got to pick out a book on astronomy, but in the back, it started talking about manned space flight. I said 'I want to do this. I want to be an astronaut.' It hit me then and it never left. When I graduated from high school, my mom said she would help me buy a car or she'd take me to all the space centers. I chose the latter. I said if I wanted to go anywhere, I'd just hitch a ride. I was 17. I knew what was going on."

That dream helped her through tough times, Kerrick said. Her dad died when she was 11, and her mother had four kids and didn't work. An academic scholarship got her to University of Texas at El Paso, where she hoped to play basketball, but blew out her knee shortly before the start of the first season. So, she elected to go to Texas Tech University just like her father and grandfather had. And that blown knee served as an impetus for her to apply.

"I wanted to transfer, and I started talking about going to Texas Tech," Kerrick said. "But my mother said she couldn't afford it. I started writing to Dr. Borst in the physics department saying I wanted to go to the university and asking him about jobs. He said 'Why don't you come down here for a visit?' We came, and I explained the situation of how I wanted to go to NASA and the financial issues of going to Texas Tech. He sent us off on a tour of the campus. When we came back, he had $4,000 worth of scholarships and two jobs.

"That would get me through the first year. Dr. Borst is the only reason why I was able to go to Texas Tech. He made it possible for me to go. My mom started crying… it was just awesome."

Walter Borst, professor of physics, said he could tell through that meeting with Kerrick that she was determined to make it to NASA.

"I saw a great potential in her," he said. "Her mother was a little apprehensive about her little daughter going so far away. But Ginger was rather persistent. We offered her some financial support, and I think that was most important to her in doing her studies here."

Borst, who served as the department chairman at the time, said Kerrick even taught astronomy classes as an undergraduate. She was serious about learning as much as she could and completing her mission to NASA, and he was happy to help wherever he could. She earned her bachelor's degree in physics in 1991 and a master's degree in physics in 1993.

"She got a bachelor's degree, and we encouraged her to stay for a master's," he said. "She's very determined, but on the other hand, very pleasant. You knew she wanted to get far. She was very pleasant to deal with and she always told you what she wanted. I'm very pleased and proud of her. She has pretty much done what she wanted, and she managed to stay there and advance up the ladder. We would like to have many students like her."

Borst even helped Kerrick get an internship at NASA after graduation. She credits Borst with giving her the chance she needed to make her dream come true.

"I can't imagine doing anything else that can compare to this," she said. "This is a once-in-a-lifetime kind of job. There are fewer flight directors than astronauts. To date, there have only been 78 flight directors in the history of the program, 11 of which have been women. Comparatively, there have been a total of about 480 cosmonauts and astronauts."

*(This article was written by John Davis of TTU's Office of Communications and Marketing and is reproduced here with his permission.)*

# *Controlling the Properties of Materials with Impurities: What's New?*

*Stefan K. Estreicher*

**From trial-and-error to quantitative studies:** Studying impurities in materials may appear to be a strange way to make a living. Instinctively, one seeks perfection, and impurities should be avoided. Yet, while it is admirable to date a saint, arguments can be made for dating a sinner. The same holds true for materials. Perfect materials have few uses. Ultra-pure Si is shiny but useless. Much more can be done with materials when you learn how to manipulate their properties by the careful incorporation of selected impurities. This is defect engineering.

The oldest example of this that I can think of dates back at least 5,000 years. Copper, a soft metal, was used for decorative purposes until someone realized that the addition of a little tin had interesting consequences: the melting point drops (making the metal easier to melt), the viscosity at the melting point increases (making it easier to cast) and, after cooling, the metal is much harder than copper. It is bronze. Creating this material allows the manufacture of tools, shields, and weapons. Later, carbon was added to iron to make steel, allowing the construction of skyscrapers.

Since World War II, we know that the electrical conductivity of semiconductors can be manipulated almost at will through the incorporation of dopants, such as B or P in Si. Today, impurity engineering has advanced so much that we take for granted cell phones capable of taking pictures and receiving emails, high-density DVDs and memory sticks, and many other high-tech gadgets. Modern materials and devices exist because we learned how to manipulate their mechanical, electrical, optical, and magnetic properties with impurities.

Using impurities to our advantage implies knowing a whole lot about them: their equilibrium sites, solubility, charge and spin states, electrical activity, diffusion path, and various activation energies, as well as their interactions with other common impurities and native defects. The understanding required to make all this happen started with trial-and-error techniques in the Bronze Age. Today, there is little room for guesswork.

In the case of semiconductors, experimental physicists provide the tools needed to measure the properties of defects. Magnetic techniques such as electron paramagnetic resonance (EPR) measure spin densities, atomic composition, and symmetry. Electrical tools such as deep-level transient spectroscopy (DLTS) give electrically-active energy levels in the forbidden gap of the material. Raman and Fourier-transform infrared absorption (FTIR) spectroscopies characterize the optical signature of light impurities through their vibrational modes. But experiment has limitations. For example, in order to be EPR active, a defect center must have at least one odd electron and be present in concentrations of the order of $10^{16}\,cm^{-3}$. Theory is needed to complement experiment, provided that the theory is quantitative.

The theoretical problem is huge. One must solve quantum mechanically a system containing an enormous number of nuclei and electrons, without symmetry assumption and with sufficient accuracy to be useful: energetics within a tenth of an eV or so, vibrational frequencies within a percent or two of the measured ones. Theorists must understand the physics and chemistry of impurities in crystals, learn how to properly describe the host crystal, and find clever approximations to solve the huge electronic problem. They also need the kind of computer power that is becoming available today. The history and status of the field are described in *Theory of Defects in Semiconductors*, eds. D. A. Drabold and S. K. Estreicher, Springer, Berlin, 2006.

**Theoretical tools:** The basic ingredients of theory are as follows. The host crystal is approximated by a cell of *N* host atoms to which periodic boundary conditions are applied in all directions of space so that no surface or surface-related problem exists. The result is a 'supercell'. The impurity is placed in the cell, and the boundary conditions apply to it as well. As a result, the system described by theory is a 3D periodic array of impurities. Obviously, the cell needs to be large enough for impurity-impurity interactions between neighboring cells to be negligible but also small enough for calculations to be tractable at the desired level of theory. Until recently, our cell of choice was $Si_{64}$. We are now moving up to $Si_{128}$ and $Si_{216}$ and have performed test runs in $Si_{512}$ and $Si_{768}$. The calculation of the $Si_{768}$ dynamical matrix required about 6 weeks of CPU time on 16 quad-core processors. Clearly, systematic calculations in a cell of this size are not practical (yet), but we have moved beyond impurity concentrations of 1 atomic percent and approaching the 0.1 atomic percent level. These are quite realistic numbers.

The next step is to separate the nuclei from the electrons using the Born-Oppenheimer approximation. This is very justifiable unless one describes orbital degeneracies: these are Jahn-Teller situations that require the use of vibronic wavefunctions. Nobody knows how to do that in systems of that size. This is not a major issue here (as long as one remains aware of it).

The nuclei are treated classically: the force on each nucleus at the time *t* is obtained by deriving the energy relative to nuclear coordinates (the Hellmann-Feynman theorem). Once the forces are known, the accelerations are also known. The velocity and position of each nucleus are computed at the time $t+\Delta t$ from Newton's Laws of Motion. The nuclei are moved to their new position, and assigned their new velocities, and the cycle starts again. This is the idea behind molecular-dynamics (MD) simulations. But accurate forces require quantum-mechanically accurate energies.

The electronic problem is divided into two parts. The regions close to each nucleus, where the electron densities become very high, are replaced by norm-conserving, angular-momentum-dependent pseudopotentials. This is more an art than an exact science and requires a lot of care. Finally, the valence regions are described using first-principles density-functional theory. Beyond this basic description are numerous technical details to be worked out.

The next step is to calculate the dynamical matrix. Its eigenvalues are all the normal-mode frequencies of the cell. Here is a direct link to Raman and IR spectroscopy, and in some cases to photoluminescence data. We also get phonon densities of state, allowing us to calculate vibrational free energies and specific heats. But the eigenvectors of the dynamical matrix, often ignored by theorists, turn out to be the most useful. They can be used to find all the localized vibrational modes associated with any atom (or group of atoms) and to prepare a supercell (or parts of a supercell) in thermal equilibrium at the temperature of our choosing, as long as our choice is below a few hundred degrees *K*. Then, we can perform MD simulations at non-zero temperatures without thermalization or thermostat. The technical details are not complicated but involve equations with more indices than most people care to contemplate.

*Paul W. Horn Professor Stefan K. Estreicher (Stefan.Estreicher@ttu.edu) joined the physics department in 1986. He is a Fellow of the American Physical Society and of the Institute of Physics (UK). His research involves first-principles calculations of the properties of defects in semiconductors. His hobby, the history of wine, has resulted in numerous invitations to talk on the subject and has generated a book* Wine: From Neolithic Times to the 21st Century *(Algora, New York, 2006).*

In the past few years, my group has been fine-tuning these skills. We have calculated many local and pseudolocal vibrational modes, the isotope dependence of specific heats, and even the temperature dependence of vibrational lifetimes, all with excellent accuracy.

So now: what is new?

**Thermal conductivities:** Impurities are used to control the mechanical, electrical, optical, and magnetic properties of semiconductors – sometimes changing them by many orders of magnitude. But what can be done about the thermal properties of the material? Is it possible to implant a narrow channel on a chip that has a very different thermal conductivity κ than the rest of the device, thus creating a thermal gradient? Can a 'thermal circuit' be implanted to control the heat flow? Is there some 'perfect' impurity which, when introduced in some 'perfect' concentration, changes κ by a very large amount? These are very basic questions, but has anyone tried to answer them?

Two types of experimental data encourage us to start calculating. The thermal conductivities of isotopically natural diamond (98.9% $^{12}C$ and 1.1% $^{13}C$) and isotopically pure diamond (well, 99.999% $^{12}C$) differ by more than a factor of 10. The same effect is reported in isotopically pure *vs.* natural abundance Si and Ge. In $In_xGa_{1-x}N$ and $Al_xGa_{1-x}N$, κ drops sharply as $x$ increases from 0.2 to 0.4. But κ increases in $In_xAl_{1-x}N$. Why is that?

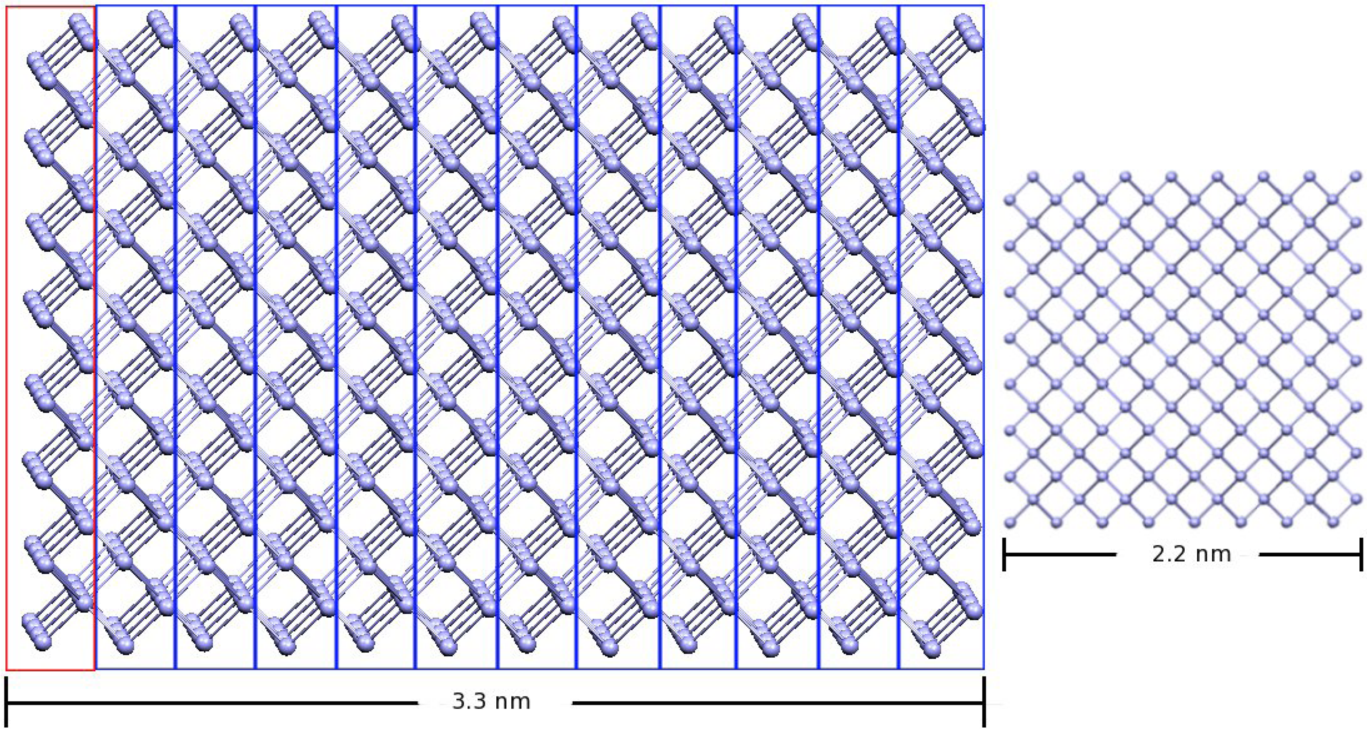



Figure 1: This $Si_{768}$ supercell has one slice (red box) prepared at $T_{hot}$ and 11 slices (blue boxes) at $T_{cold}$. The temperature $T(x,t)$ is monitored in the middle slice. The cross-section of the cell is shown on the right.

Experimentally, understanding and optimizing such phenomena would require growing many samples containing many different concentrations of many different impurities, and then measuring their thermal conductivity *vs.* temperature. This would be a huge undertaking. Can theory provide some guidance as to where to look?

This brings the next question: can we calculate thermal conductivities from first principles as a function of isotopic composition, impurity content (type, mass, concentration), and temperature? My first reaction was "Sure, this is Texas Tech." But the conventional calculations of $\kappa(T)$ are far from trivial. They involve the fluctuation-dissipation theorem, the Green-Kubo formalism, the calculation of autocorrelation functions that sometimes never converge... The few who have used the Green-Kubo formalism have done so in isotropic materials used semiempirical MD and called the effort "heroic." I don't want to be heroic, and my material is everything but isotropic.

What about learning from experimentalists? In a nutshell, thermal conductivities are measured as follows. At the time $t$=0, a burst of heat (a laser pulse, for example) is applied to one end ($x$=0) of a sample, and one measures how the temperature $T(x,t)$ changes with time at the other end. The data are then fit to an equation which contains the thermal diffusivity, and this quantity is related to the thermal conductivity. This approach is appealing because we can mimic this situation and are good at calculating temperatures. The required non-equilibrium MD simulations are hated by theorists because the temperature fluctuations can be large. But we know how to control them because we can prepare a cell in thermal equilibrium (see above).

Our theoretical setup is shown in Figure 1: a supercell is constructed from $N$ small slices. The first slice is prepared in thermal equilibrium at the temperature $T_{hot}$; the other slices are also in thermal equilibrium but at the temperature $T_{cold}$. At the time $t$=0, the system is allowed to evolve and we monitor how a slice near the middle reaches equilibrium. This gives $T(x,t)$, which we fit to the same equation used by experimentalists.

The results must be averaged over several runs (typically 20) to compensate for the random nature of the initial phases and energies of each normal mode. A typical result is shown in Figure 2.

We have observed isotope effects in $Si_{192}$ that are consistent with experimental observations. The flexibility of our approach is complete. Indeed, we can place any type and concentration of isotopes, impurities, and/or defects in the cell, study alloys such as $Si_xGe_{1-x}$, or even incorporate dopants and calculate the charge carrier and phonon contribution

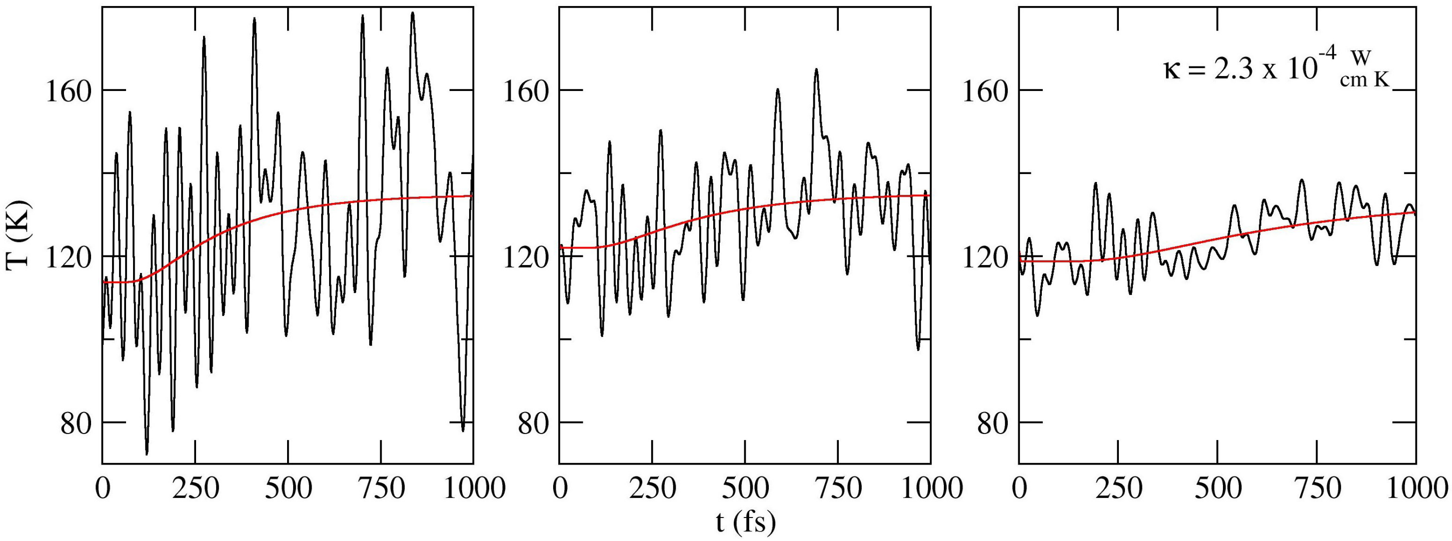



Figure 2: Fitted $T(x,t)$ in the middle slices of the $Si_{192}$ supercell averaged over 1, 10, and 20 runs, with $T_{hot} = 90$ K and $T_{cold} = 10$ K. The final value is close to that expected for a Si nanowire of the same diameter at $T$=17 K.

to κ. The main obstacles to all this are manpower and computer time.

One early result worth noticing is shown in Figure 3. This is a $Si_{192}$ calculation, but the cell contains 182 Si atoms with the normal Si mass (28) and 10 Si atoms with mass $M$, which we vary over a wide range. Although such isotopes of Si do not exist, this procedure allows us to isolate the effect of the mass of an impurity from other parameters. So we varied $M$ just to see the impact on κ. The results suggest that κ has a deep minimum for $M$~56 (which coincidentally happens to be 2×28). There may be other minima at higher masses, and we need to investigate the region around $M = 56$ more carefully.

Given a little luck, a lot of work, and enough computer time, we will be able to predict if some type of resonance occurs, that is, if a particular combination of impurity mass and concentration produces a sharp drop in κ. This is important for many thermoelectric applications. Indeed, the "figure of merit" is inversely proportional to κ, and a drop in κ (all else being constant) increases with the figure of merit. In order to gain predictive power, we want to correlate any substantial changes in κ with some basic properties of the host material and of the impurity, as well as changes in the phonon density of states. Wish us luck, and let the funding continue.

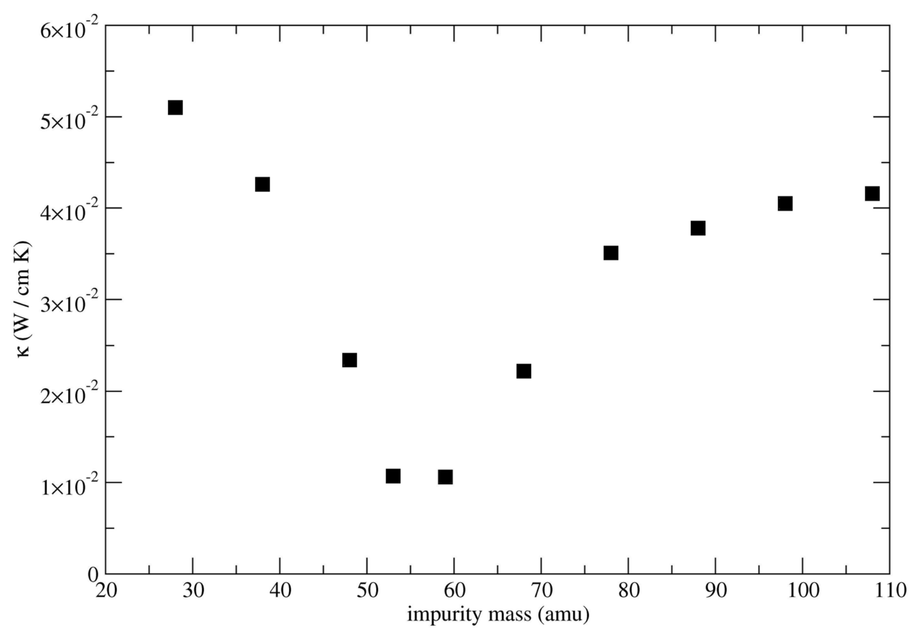



Figure 3: Variation of κ($T$=125 K) with $M$ when the $Si_{192}$ supercell contains 10 Si atoms with mass $M$. Something unexpected occurs at $M$=56.

↗ ON THE WEB ↗

www.ttu.edu/profiles/profile.php?id=2

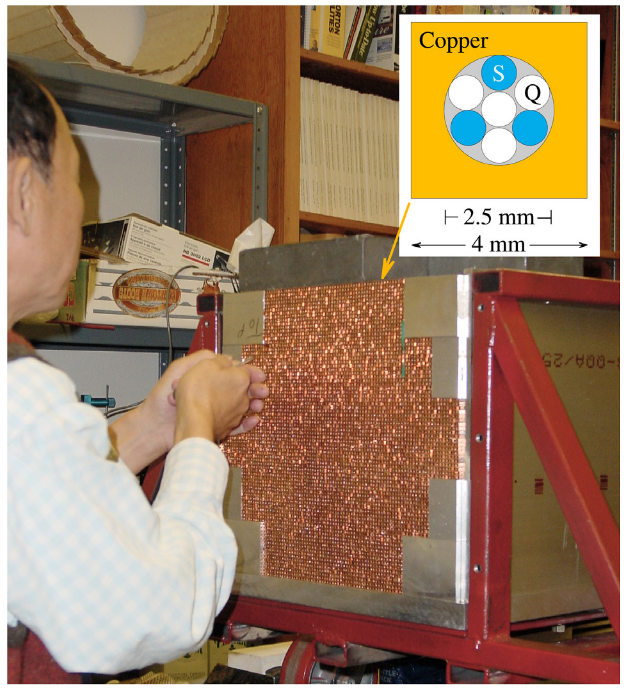
# DREAMing about a Better Future

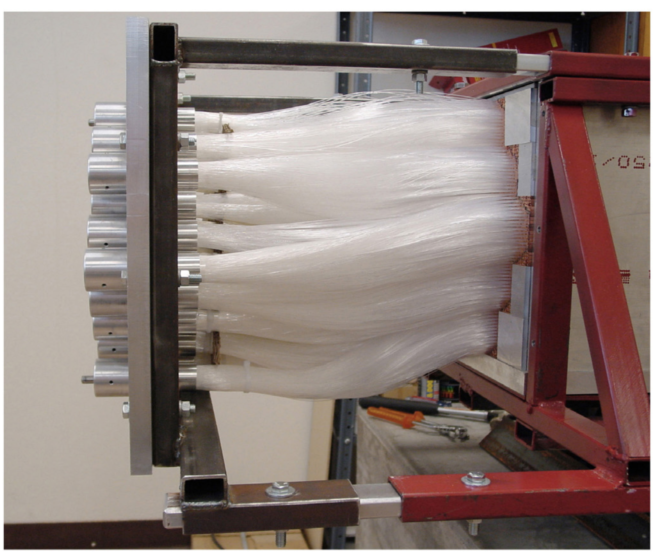
*Richard Wigmans*

The developments in observational sciences such as physics, astronomy and biology have always been driven by the quality of the tools with which the observations are being made. In biology, the development of the microscope led to a quantum leap in understanding the functioning of living organisms. In astronomy, the notion of our place in space and time has evolved hand in hand with the precision of the telescopes at our disposal. And the innermost structure of matter, and other secrets of the quantum world, would have been inaccessible without the ever more powerful particle accelerators that have been developed in the past 100 years.

Sometimes, factors unrelated to the quality of our instruments prevent further improvement. For example, the angular resolution of a telescope is ultimately limited by diffraction (Rayleigh's criterion). However, in practice, atmospheric turbulence limits the resolution to values that are much larger than the diffraction limit. In such situations, ingenuity is needed: Using optical interferometry between different telescopes, the effects of this turbulence can be measured and thus eliminated.

A similar situation occurs in particle physics. In the last quarter century, calorimeters have evolved as the particle detectors of choice in frontier experiments such as those at the Large Hadron Collider (LHC) at CERN in which



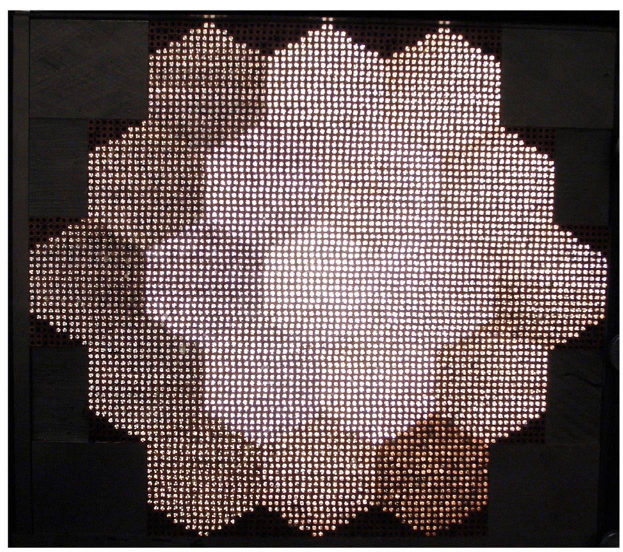


Figure 1: The basic building block of the DREAM detector is a 4×4 mm² extruded hollow copper rod of 2 meters length, with a 2.5 mm diameter central hole. Seven optical fibers (4 clear and 3 scintillating fibers) with a diameter of 0.8 mm each are inserted in this hole (inset top right). The DREAM detector consists of 5,580 such rods, containing about 60 miles of optical fibers (top right). It has a total instrumented mass of 1,200 kg. The fibers exiting from the rear face of the detector are split into the two types, bunched separately and connected to photomultiplier tubes (bottom left). The hexagonal readout structure is made visible by illuminating the fiber bunches (bottom right).

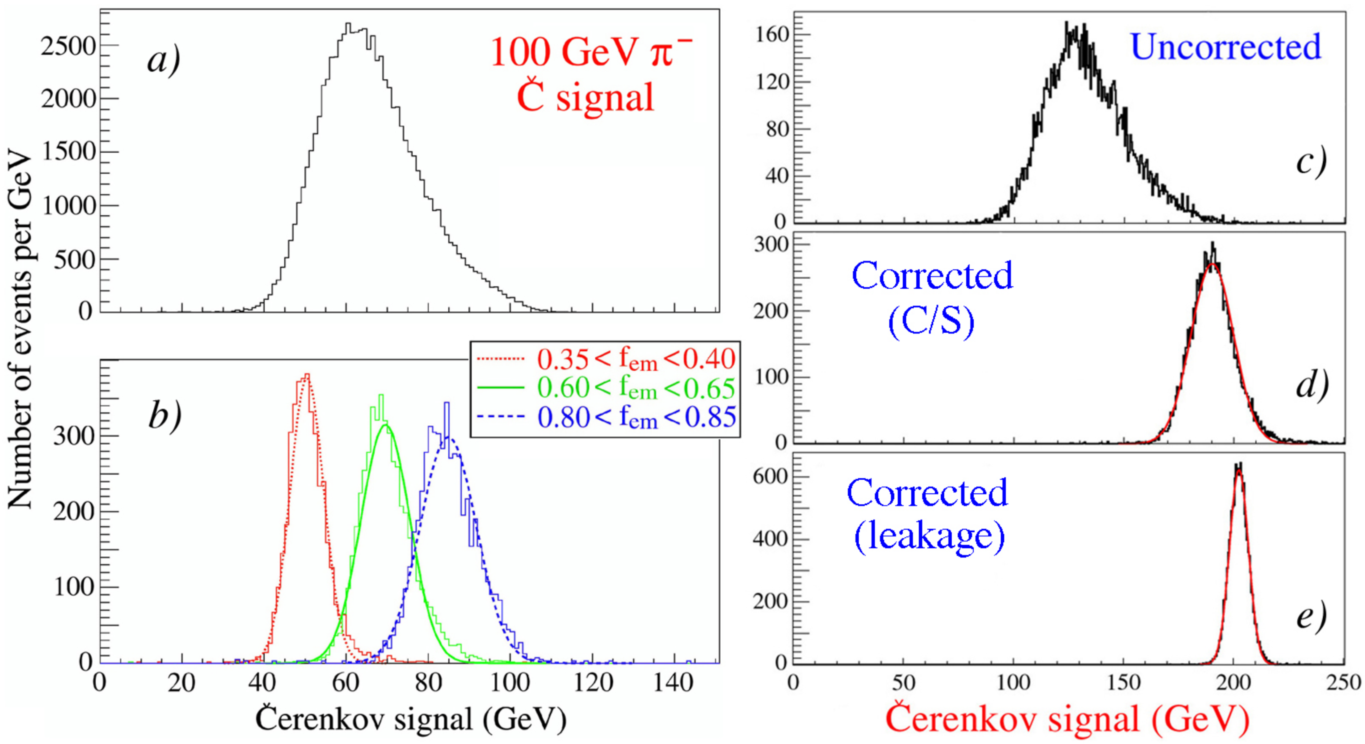



Figure 2: Signal distribution for 100 GeV pions (*a*) and distributions for subsamples of events selected on the basis of the measured $f_{em}$ value (*b*). Signal distributions for 200 GeV multi-particle "jets" before (*c*) and after (*d*) corrections on the basis of the observed Cherenkov/scintillator signal ratio were applied. In diagram (*e*), energy constraints were used, which eliminated the effects of lateral shower fluctuations that dominate the resolution in (*d*).

our group participates. Calorimeters are massive detectors in which the particles to be measured are completely absorbed.

In this absorption process (called "showering"), a measurable signal is produced, *e.g.* in the form of light or ionization charge. Because of the statistical nature of the processes involved, the precision with which this signal reveals the properties of the showering particle, *e.g.* the energy resolution, improves as the energy increases. This is one of the reasons why calorimeters have become so popular.

However, development of the full potential of these detectors is hampered by an effect comparable to the atmospheric turbulence mentioned above. In this case, the problem is caused by the fact that electrons and photons generated in the shower development produce significantly larger signals than equally energetic protons and pions generated in this process. And since the energy sharing between these different classes of shower particles (the electromagnetic fraction, $f_{em}$) varies strongly from one event to the next, the energy resolution improves much less with energy than one would expect in the absence of this effect.

We have developed a solution for this problem. This solution is based on the fact that the particles produced in the absorption of electrons and photons tend to be relativistic, whereas the nuclear reaction products produced by protons and pions are much slower than the speed of light. This is of course a consequence of the very large mass difference between electrons and protons. As a result, the electrons produce Cherenkov light when they travel faster than *c/n* in a medium with refractive index *n*. The Cherenkov effect is the optical equivalent of the sonic boom. The shower protons are almost always too slow to produce this type of light.

The detector that we built takes advantage of this difference. This calorimeter is equipped with two types of signal-generating media: Scintillating optical fibers produce a light signal for every charged particle that traverses them; clear optical fibers are only sensitive to the relativistic shower particles that generate Cherenkov light. By comparing the signals from these two types of fibers, the fraction of the total energy carried by the electromagnetic shower component ($f_{em}$) can be determined, event by event. Figure 1 shows some pictures of this detector, which has become known as the DREAM (for Dual-REAdout Method) calorimeter.

The spectacular improvement in energy resolution achieved with this dual-readout method is illustrated in Figure 2. If only one of the two signals were available, the response function of this instrument would look like diagram *a* (100 GeV pions) or *c* (200 GeV multi-particle events). However, the ratio of the Cherenkov and scintillation signals makes it possible to determine $f_{em}$ for each individual event.

Diagram *b* shows that each $f_{em}$ bin probes a certain region of the overall signal distribution, and the average value of the subsample distribution increases with $f_{em}$. Once the value of $f_{em}$ is determined, the signals can be corrected in a straightforward way for the effects of the different calorimeter responses to the various types of shower particles. In this process, the energy resolution improves, the signal distribution becomes much more Gaussian and, most importantly, the hadronic energy is correctly reproduced. This is illustrated in diagrams *c-e*, which show the signal distributions for 200 GeV hadron multi-particle "jets" before and after the correction. The energy resolution improved from 14% (*c*) to less than 5% (*d*) in our detector, and would further improve to 2% if our detector had been sufficiently large to fully contain the showers (*e*).

*Professor Richard Wigmans (richard.wigmans@ttu.edu) joined the TTU faculty in 1992 as the Bucy Chair in physics, and founded the successful particle physics group. In recent years, he has also developed an interest in astrophysics and cosmology. He currently teaches a course titled "Cosmophysics - the Universe as a Physics Lab." In this article, he describes a project for a novel type of particle detector that was started in 2002 at TTU and is now generating worldwide interest.*

The DREAM project is based on an idea I developed about 10 years ago. In 2002, we started building the first detector here at TTU, and in 2003, this detector was tested for the first time in high-energy particle beams at CERN. Based on the successes of this project, DREAM has now grown into an international collaboration of some 25 scientists from 8 institutions. Our results are described in16 papers in the refereed literature, and DREAM calorimeters are the leading candidate detectors for experiments at a future linear electron-positron collider.

## ON THE WEB

highenergy.phys.ttu.edu

www.cern.ch

www.fnal.gov

www.ilc.org

# *Scholarships & Awards*

The Scholarship Committee, chaired by Professor Thacker, reviewed many strong undergraduate and graduate applications for departmental scholarships and awards. The 2008 winners are listed below. The award ceremony was held on April 11, 2008 in the department (see photos below) followed by the SPS spring banquet in the evening. Congratulations to all. We are also grateful to alumni and friends who generously established funds that make these scholarships possible. Thank you.

- Bucy Undergraduate Award to Catherine Chesnutt ($2,000), Gary Stinnett ($2,000), Stephen Torrence ($2,000), and Ryan-Deshawn Wrightmore ($2,000)
- Gott Gold Tooth Award to Gwen Armstrong ($500)
- Howe and Bucy Applied Physics Award to Daniel Backlund ($2,000)
- Menzel Award to Mohammad Alwarawrah ($2,000)
- C. C. Schmidt and Alma K. Schmidt Award to Michael Wynne ($2,000)
- Bucy Applied Physics Awards to John Como ($2,000) and Wei Wang ($2,000)
- Seibt and Bucy Applied Physics Awards to Youn Roh ($2,000)
- Outstanding Undergraduate Scholar Award to Alden Astwood
- Outstanding MSI Scholar Award to Miranda Martin
- Outstanding Doctor of Philosophy Award to Emmanuel Nenghabi

# *Society of Physics Students*

*Catherine Chesnutt*

This past year the SPS chapter in the Texas Tech Department of Physics has been more active than ever. In addition to holding several successful annual events, the student members have taken an active role in integrating freshman students into the department, as well as helping one another understand physics.

In February, the SPS took a tour of the Joe Arrington Cancer Research Center in Lubbock, which provided the students a window into the world of applied medical physics. Dr. Murali Nair was kind enough to give the tour, which was especially interesting for the students because medical physics is becoming such an important field.

In early April, the students hosted the annual Scholarship Award Banquet at the Merket Alumni Center on campus. The recipients of the 2008 scholarships were recognized, and **Dr. Rusty Harris** (BS 1997, PhD 2003) of AMD flew in to give a speech about physics in the business world, which was both motivating and informative for the students. Delicious salmon and Texas steak were served, and the Martinez Quartet entertained the guests.

To explore classical physics firsthand and have fun at the same time, the SPS held their annual Ballistics Day at the outdoor Rustic Range, and were granted perfect shooting weather. As usual, Professor Glab contributed the firearms

**Dr. Rusty Harris** (BS 1997, PhD 2003) (front left), the SPS Spring Banquet speaker, is shown with some of the physics majors. Alden Astwood, George Laity, Jordan Phillips, Eric Andersen, Anthony Chapa (left to right, back row), Rusty Harris, Stephen Torrence and Ashley Millet (left to right, front row).

for the students to shoot and taught the students safety techniques.

To keep in touch with the community, the SPS students hosted the annual rocketry contest in May. The 8th grade science class of local teacher Brett Peikert brought their rockets to the park, and the SPS students brought the de-

partment's t-shirt cannon, which was a huge success with the younger students. The winner of the contest won the prize of a rocket.

The SPS students decided to explore the research facilities in their own backyard by taking a tour of the Nano Tech Center at Texas Tech last spring. They were excited to learn about the research equipment there, such as the scanning electron microscopy (SEM) and a complete lithography lab. The Nano Tech Center works together with the physics department and gives physics students research opportunities; one of the SPS members works there as an undergraduate assistant.

Along with the entire physics department and countless others in the city of Lubbock, the SPS students were excited on September 9th to be able to celebrate the first power-on of the Large Hadron Collider (LHC). Several of their professors have contributed to the work there and could explain the finer details of the project. SPS students helped to set up the public event, at which Drs. Akchurin, Wigmans, and Lee gave informative lectures on the LHC project to those present.

The APS held their annual Four Corners Joint Meeting in El Paso in October, only a nine-hour drive from Texas Tech. Daniel Dominguez, a physics undergraduate student and member of SPS, travelled there with the graduate students from the physics department to represent the SPS chapter. Both graduates and undergraduates met there to present

projects and share ideas for their respective SPS chapters. Dominguez reported a very diverse crowd of students present at the event and that a good time was had by all.

The SPS students hosted their annual Star Party on November 15th and were granted perfect star-gazing weather. The event was held at the Gott Observatory, and was very well attended. The South Plains Astronomy Club (SPAC) joined the party, as usual, along with students of the astronomy class. Professor Wilhelm gave a brief talk about the planned expansions to the Skyview site, including a new classroom and telescope. The SPAC then guided attendees on a tour of the crisp November sky. Those who stayed late enough were treated to a spectacular moonrise.

*SPS*
*is committed to developing a cohesive community among the physics students of Texas Tech University. Over the past couple of years we have revitalized our chapter, increased membership, and expanded the breadth of our activities. We are now in the process of creating a new web presence, enhancing relationships with local educators, and encouraging bonds between students and faculty. We aim to continue these trends throughout next year and into the future. It has been my pleasure to serve as president over the last two years and I look forward to passing on leadership of the organization to a bright new generation of physics students this spring.*

Stephen Torrence
SPS President

Last fall SPS students manned the physics booth at Texas Tech's University Day. Wearing their SPS shirts and showing prospective students demonstrations, including an electroscope and a can of angular momentum, they were distinctive among the many other booths. They took the time to talk to students at length about majoring in physics, future career opportunities, and why they themselves chose the physics department at Texas Tech.


The SPS students have also greatly improved their base of operations this past year. The department provided them with their own room (SPS Lounge), which they turned into a kind of perpetual study area. In addition to holding meetings there, many of the SPS members study or work out problems together on the new white board. The walls are filled with information about physics study opportunities around the world. However, the SPS Lounge, like many other rooms on the ground floor, was flooded on September 11th. On that day we had a record rainfall of 7.8 inches.

The SPS homepage is also now officially on the web at *www.ttusps.org*. The chapter's officers are working hard to finish construction on it, but the site already looks quite professional, with dozens of photos, a forum for the students, and the beginning of the SPS podcasts.

In 2009, SPS plans to host all of the aforementioned annual events again since they were all a great success last year. The SPS students also aspire to conduct a collective physics project that will involve the surrounding community, which they will detail in a proposal to be potentially funded by the National SPS.

## ON THE WEB

www.ttusps.org
www.aip.org/education/sps

# We Hear that...

**Jennifer Doak** (BS 2002) sent us a beautiful New Year's card from Alexandria, VA. She says that she enjoys her job as a patent examiner and has been quilting and learning to golf, as well as taking some dance lessons.

**Bill Ford** (PhD 1986) writes, "I currently work for RTR Technologies, LLC, a small defense firm headquartered in Aberdeen, MD. I am the technical lead and Verification, Validation, & Accreditation (VV&A) Coordinator to the Government Modeling and Simulation Integrated Product Team for the P-8A Poseidon (P-3C Orion replacement) modeling and simulation VV&A effort. I am in charge of adjudicating the fitness of models and simulations for their intended use on the program. I also provide support to the Strategic Director for Modeling and Simulation for AIR 4.10 at the Patuxent River Naval Air Station. This involves attempting to craft Navy-wide policies regarding model and simulation VV&A.

Hope things are going well with all of you. I hear from Charley (briefly) from time to time. Tell all the "old hands" (Dr. Quade, Dr. Lodhi, Dr. Lichti, and others that were around when I was) "HI" for me. I'd love to hear from them."

Dr. William C. Ford, Jr., RTR Technologies, LLC, 998 Hospitality Way, Suite 203, Aberdeen, MD 21001. Email: wcford@hotmail.com.

**Ralph Fullwood** (BS 1952) writes, "I graduated in 1952, receiving an assistantship to Harvard. I was drafted in 1956 after receiving the AM. In the Army I worked on transport theory and reciprocity. After getting out, I joined the Knolls Atomic Power Lab under GE measuring the eta of U-233. I left after a year for an assistantship at U. of Pennsylvania doing pion research and the construction of a synchrotron. I left before completion of the PhD to join Rensselaer Poly Inst. to earn a PhD in Nuclear engineering and Science being the supervision of the linac and instrumentation. I joined Los Alamos for 6 years and joined SAIC, doing Probabilistic Nuclear Safety for 13 years, and retired from Brookhaven National Lab after 16 years. I authored 3 books and about 200 publications. If you wish to know more about me, I suggest you check www.ralphfullwood.com where I have put my physics book, *Natural Philosophy: Physics with a Personal Computer*."

**William Lee Powell** (PhD 2008) let us know that he started his position at Texas Lutheran University in Seguin, TX this fall (2008) as a tenure-track assistant professor. His email address is LPowell@TLU.edu.

After graduating from TTU with a BS in physics, **Chris Cowden** (BS 2006) enrolled in the graduate program in physics at Cambridge University in the UK, and he says, "I've been working on supersymmetry searches and background estimation from data. Of course, we have no real data at the moment, so I play with fully simulated data sets. These searches use the $m_T^2$ (transverse mass) variable. I've developed quite a bit of code to processes multiple ntuples and plot various variables, even user defined variables on the fly. I've also done some work on electron ID and reconstruction in the ATLAS detector." Chris can be reached at cowden@hep.phy.cam.ac.uk.

**Dac Crossley** (BA 1949, MS 1951 Biology) thanks us for the newsletter and writes, "I didn't take physics at Texas Tech but my wife did. **Nettie Lou Crossley**, nee Keirsey who died in 1959. Physics Department was smaller, I guess, in the late 1940's - early 50's. The department head was a kind old gentleman named Schmidt, I remember him well. And Preston Frazer Gott, there on p. 25 (*physics@ttu*, Spring 2008 issue). He had a son, Eugene, about 2-3 years old, who could tell you 2.54 centimeters to the inch and 93 million miles to the sun. We always thought Gott should have been an engineer, building dams.

Wish I could remember more names. One professor was noted for his very ragged shirt collars, and the menagerie of dogs living with him. When you visited and opened his door, a dozen dogs would run out and another dozen run in.

An elderly professor drove an ancient Rolls Royce. He explained that you had to replace a Ford every other year, but a Rolls was good for 20 years. And next year was his time to buy one!

A big annual event was the Engineering Show, and the Physics Club participated. Along with breadboard radios and the ever popular Leyden jar, they demonstrated an "atmospheric dehumidifier," the answer to water shortages in the Panhandle, and a rotating magnetic field, and a perpetually moving electric light bulb. Even a microwave transmitter."

**Kazim Gumus** (PhD 2008) moved to Austin after graduation and works for the Harmony Science Academy, 930 East Rundberg Lane, Austin, TX 78753. His email is gumusz@hotmail.com.

**Timothy L. Head** (BS 2000) writes, "I graduated from TTU in May of 2000. From there, I went to UIUC (I think they want to be called 'Illinois' now.) While there, I worked with Professor James P. Wolfe. Our primary work was on phonon imaging in Lead (Pb). We were able to use the phonon-imaging technique to show that a spin-density-wave ground state in Pb is unlikely. I received my Ph.D. in Dec. of 2007. In Aug. of 2007 I was hired as an assistant professor of physics at Abilene Christian University. Since starting here, I have been busy teaching and getting my research lab started.

This past summer, a student and I worked in collaboration with Professor Madeleine Msall of Bowdoin College in Maine and Jim Wolfe at UIUC. We used the phonon-imaging technique to help characterize the elastic constants of $CaWO_4$ (Calcium Tungstate). The CRESST group searching for dark matter needs these values so that they can use calcium tungstate as part of their detectors.

Since the summer, I have been working with students here to set up my own phonon-imaging lab at ACU. I hope that it will be operational by the end of the semester."

Tim can be reached at Department of Physics, Abilene Christian University, 317 Foster Science Building, Abilene, TX 79699. Tel:(325) 674-2002.

Please send your news to joyce.norton@ttu.edu, and we will be happy to share it with alumni and friends.

# *New Staff*

Dr. Douglas A. Barlow earned his BS degree from the University of Florida in 1996 and his PhD from the University of Alabama, Huntsville in 2003. Before joining our department in July of 2008 as a senior research associate, Dr. Barlow served as a visiting assistant professor of physics at Westmont College and as an assistant professor of chemistry and physics at East Texas Baptist University. Dr. Barlow manages our undergraduate teaching labs and maintains an active research program in theoretical chemical physics.

Patti Shelton joined our department in February 2008 as a senior office assistant. She transferred from the TTU HSC Department of Ophthalmology. She quickly became indispensible and was promoted to Senior Business Assistant in December 2008. She works in several different areas, from budgeting to undergraduate student registration. When you call the physics department, you will probably be speaking to her.

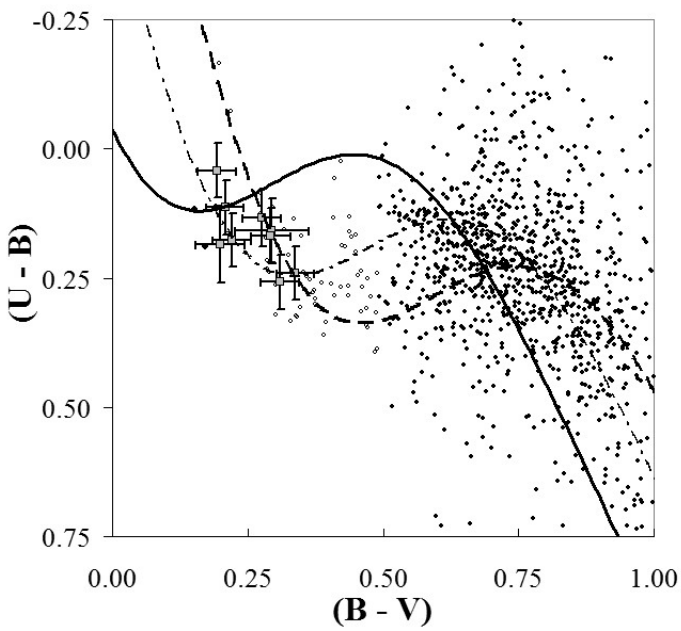
# Recent PhDs

**William Lee Powell** received his PhD in May 2008 and he describes his work for us below:

My dissertation focused on the nature of a part of the Milky Way that is known as the Canis Major Over-Density (CMa). The CMa is an apparent excess of stars in the constellation Canis Major, which was discovered by Martin and coworkers in 2003, that has been explained as the signature of a disrupted dwarf galaxy consumed by the Milky Way. This conclusion has been challenged by some groups who suggest that an extra-galactic origin for the CMa is not necessary. The most accepted alternative explanation is that the CMa is instead just a manifestation of the warped disk of the Milky Way. Since the warp in the third galactic quadrant is poorly understood, some models suggest that the warp is co-spatial with the CMa while other models suggest that it is not. This disparity has allowed the debate to continue for several years.

I set out to solve the issue by targeting the blue stars in the CMa for observation both photometrically (determining the brightness of the stars in different parts of the spectrum) and spectroscopically (using the spectral lines to measure the radial velocity, temperature, and size of stars). The preliminary photometry data were taken with the 0.8m telescope at McDonald Observatory in Fort Davis, TX and on the 0.9 m telescope at Cerro Tololo Inter-American Observatory in Chile. The CTIO data proved to be of superior quality. These data allowed us to study the populations in the CMa and to select stars for spectroscopic observation. The photometry data were then used to calibrate these spectra and provide a means of measuring the interstellar reddening in this region of the galaxy. The spectroscopic data were taken on the 2.7 m telescope at McDonald Observatory and on the WIYN 3.5 m telescope at Kitt Peak National Observatory in Tucson, AZ.

The conclusion I draw from these data is that the CMa must be due to the warp of the galactic disk. I measure the effect of the dust in this region of the galaxy to be much more differential than has previously been known. The previous work used to support the extra-galactic origin of the CMa was based on a faulty accounting of the reddening because it lacked the insight our combined approach yields. The corrected picture of the CMa that I find fits the galactic warp hypothesis best. The novel method we developed to measure the interstellar reddening could be used to study the warp of the disk in other parts of the galaxy. Dr. Wilhelm and I will continue this work in the future.



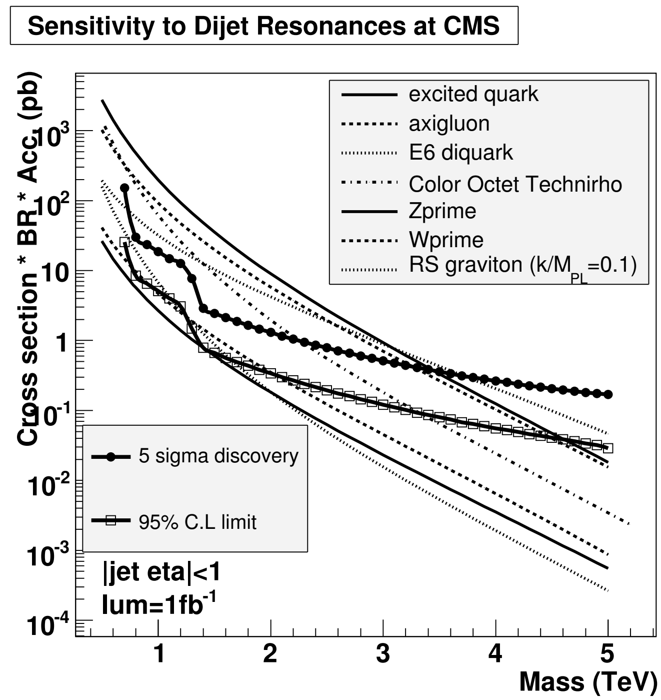

The plot above is known as a color-color plot and was produced from the photometry data for one field. The stars marked with the large, filled dots are those for which I also have spectra. The curves are the expected behavior for these stars, assuming various amounts of dust. (The dust produces the interstellar reddening effect that makes stars look redder and fainter.) Note that with just this plot, a given star could be fit to any of these curves, even though the lowest curve represents more than twice as much dust as the top curve. The implication is that the reddening for an individual star is not uniquely measurable with just photometry. Individual features in the spectrum of a star are not affected by reddening, so combining measurements of spectral lines with photometry (which is affected by reddening) we can determine the amount of reddening for an

individual star. Our findings show that reddening changes rapidly in this area of the Galaxy with a wide variety of reddening corrections needed for the stars in the CMa. Since previous studies have used only one correction for all the stars, the distances they compute are inconsistent with our findings. This ultimately brings into question the dwarf galaxy interpretation of the CMa.

**Kazim Gumus** received his PhD degree in August 2008. He shares the following with us:

My doctoral study consisted of two projects. The first one was a Monte Carlo study of a search for seven new particles beyond the Standard Model at the CMS experiment at the Large Hadron Collider: axigluon, coloron, excited quark, color-octet technirho, *W'*, *Z'*, and Randal Sundrum graviton. I performed a generic search that encompassed all of these resonances because they were all anticipated at the CMS. I determined the mass regions at which these new particles can be discovered at 5-sigma significance (or at which they can be excluded with 95% confidence level). The figure at the right compares the cross-section of a resonance signal that can be discovered with 5-sigma significance (solid circles) or excluded at 95% CL (open squares), with the cross-sections for various resonance models at 1 $fb^{-1}$ luminosity. The conclusions I drew at the end of this study are as follows: A 5-sigma discovery of a multi-TeV dijet resonance is possible for an axigluon, excited quark, and E6 diquarks because of their large cross-sections. However, a 5-sigma discovery cannot be projected with confidence for a *W'* or *Z'* or the Randall-Sundrum gravitons due to their low cross-sections. On the other hand, 95% CL exclusion mass regions can be measured for all resonances at high luminosities.

In the second project of my dissertation, I performed the analysis of the 2006 CMS combined calorimeter test beam data. I measured the CMS barrel calorimeters' response to a variety of beam particles in a wide momentum range from 1 to 350 GeV/*c*. Using single particle response information, I also developed a novel algorithm to compute the CMS calorimeter response to high energy jets. I obtained jet energy correction based on the test beam data.



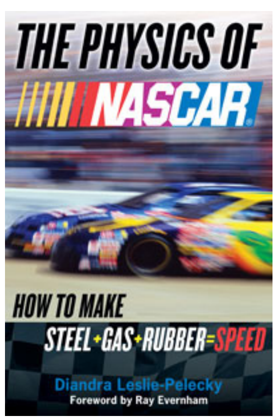

I enjoyed my graduate work at the TTU physics department; the staff is so nice and the professors so helpful. As a teaching assistant, I had the opportunity to learn and implement new teaching methods in the classroom environment. As a research assistant, I had the chance to work at great national and international labs such as Fermilab and CERN.

# *Accolades, News, etc.*

- Kenneth Carrell, William Powell, and Professor Ron Wilhelm were allocated observation time at the Cerro Tololo Inter-American Observatory by the National Optical Astronomy Observatory Telescope Allocation Committee in January 2008.
- The TTU Information Technology Division was invited to conduct a review of the information technology resources of the physics department. The review, completed in February 2008, makes recommendations and paves the way for systematic upgrades. The report may be requested from the department.
- The 52nd South Plains Regional Science and Engineering Fair was held at the United Spirit Arena on March 28-29, 2008. Professor Walter Borst, the Chair of the Board and Secretary Treasurer for 15 years, was one of the organizers of the event. Professors Kelvin Cheng, Thomas Gibson, David Lamp, Sung-Won Lee, and Igor Volobouev served as judges and helped to make the event a success.
- Professor Thomas Gibson received a Professing Excellence Award on April 10th. This is a student initiated award that is administered through University Student Housing. He was one of nine faculty from across the university to be so honored.
- TTU service pins were awarded to Professors Mahdi Sanati and Ron Wilhelm (5 years). Dr. Susan Holtz and Ms. Joyce Norton were also recognized for their 10 years of dedicated service to TTU.
- Jason Sargent, an electronics technician in our department, left to join the US Navy in May 2008. Diving has always been his passion.
- Professor Borst was selected as Outstanding Professor in 2007 and 2008 by new student members in Phi Beta Kappa at TTU. Each new student was given the opportunity to identify a faculty member who has been an outstanding professor and who has had a positive influence on the student's intellectual development.
- Professor Stefan Estreicher gave several seminars in June and early July in Europe. Included in the seminar series were Ecole Polytechnique Federale in Lausanne (Switzerland), the Rossendorf Froschung Zentrum (Germany), the Technical University in Dresden (Germany), the University of Exeter (UK), and King's College in London (UK). Dr. Estreicher served as the external examiner at the PhD defense of Giancarlo Moras at King's College.
- Professor Juyang Huang was appointed an Adjunct Associate Professor in the Department of Cell Physiology and Molecular Biophysics at the TTU School of Medicine.
- Professor David Lamp conducted a week-long series of workshops for elementary, middle, and high school teachers concerning how to teach science, specifically physics, to small children in June 9-13, 2008.
- Professor Stefan Estreicher gave an invited talk on the passivation of transition metal impurities in multi-crystalline silicon solar cells at the 18th Workshop Crystalline Silicon Solar Cells and Modules: Materials and Processes. This workshop, held in Vail, Colorado, was organized by the National Renewable Energy Laboratory.
- Dr. Nadeshda Kudryasheva of the Institute of Biophysics of Russian Academy of Sciences from Krasnoyarsk, Russia is a visiting Fulbright Scholar in our department this year. She works with Professor Kelvin Cheng in effects of heavy atoms in bioluminescent reactions.
- Professor John Hauptman from Iowa State University spent the fall 2008 semester in our department as part of his sabbatical leave. He taught an introductory physics class and worked with the members of the high energy physics group.
- Professor Kelvin Cheng was on faculty development leave as a Visiting Professor in the Department of Physics at the University Texas at Arlington in the fall 2008 semester. He collaborated with Dr. Wei Chen at UT-Arlington.
- Serkan Balyimez and Emmanuel Nenghabi, graduate students, were recipients of the graduate school scholarships. Serkan was also awarded a Helen DeVitt Jones Graduate Fellowship ($3,500 per year for three academic years).
- Payam Norouzzadeh was awarded an AT&T Chancel-

lor's Endowed Fellowship ($9,000) to pursue a doctoral degree in our department, an honor given to outstanding graduate students at TTU System.


- The high-energy physics group hosted an open night and public lecture in celebration of the first circulation of protons in the Large Hadron Collider (LHC) at the European Laboratory for Particle Physics (CERN) on September 9, 2008. Over 100 people attended the event. TTU high energy physicists, Drs. Nural Akchurin, Sung-Won Lee, Alan Sill, Igor Volobouev, and Richard Wigmans, were featured in the September 10th edition of the Lubbock Avalanche Journal concerning their contributions to the LHC-CMS experiment in the article "Tech Professors Play Role in Historic Physics Experiment."
- Professor David Lamp was nominated for the Chancellor's Council Distinguished Teaching Award this year.
- Professor Diandra Leslie-Pelecky from the University of Texas at Dallas gave a public lecture on September 11, 2008 "The Physics of NASCAR," to a well attended audience on the same night 7.8 inches of rain fell in Lubbock. She is the author of a popular book by the same title.




- The Joint Fall Meeting of the Texas and Four Corners Sections of the APS, AAPT and Zones 13 and 16 of SPS, and the Societies of Hispanic and Black Physicists met in El Paso in October 2008. Among the graduate students who presented their work were Jacob Ajimo, Chiyoung Jeong, Payam Norouzzadeh, Liming Qiu, and Vanalet Rusuriye. Faculty members Kelvin Cheng, Sung-Won Lee, M. A. K. Lodhi, Juyang Huang, Soyeun Park, and Mahdi Sanati participated in the meeting.
- Professor David Lamp presented a workshop entitled *Physics for Early Childhood* at the Region 16 Education Service Center as a part of continuing education and training programs for secondary school educators on October 22, 2008.
- Professor Stefan Estreicher, the author of *Wine from Neolithic Times to the 21st Century*, was one among three winners of Texas Tech University's President's Book Award this year.
- Professor M. A. K. Lodhi has been awarded a Fulbright Award by the Bureau of Education and Cultural Affairs of the Department of State to lecture and conduct research in Pakistan for the year 2008-2009.
- Professor Wallace Glab was one of five faculty at Texas Tech University recognized by Mortar Board for their contributions to undergraduate education. Dr. Glab and colleagues were honored during the halftime show at the Oklahoma State football game on November 8th. The notification letter from Mortar Board indicated that the organization received a phenomenal number of nominations from students in his name.
- Ginger Kerrick was the lead station flight director for the NASA STS-126 mission in November 2008 (see article on pages 8-9).
- Professor Bill Poirier from the Department of Chemistry and Biochemistry and Joint Professor in the Department of Physics, is the 2008 recipient of the Texas Tech University System Chancellor's Council Distinguished Research Award. Bill received a plaque and a $10,000 cash award.
- Professor M. A. K. Lodhi, as an "acknowledged authority" on Alkali Metal Thermal to Electrical Conversion (AMTEC), has been invited by the editor-in-chief of the Encyclopedia of Electrochemical Power Sources to write a comprehensive article on "Basic AMTEC Energy Converter" for this encyclopedia.
- Professor Igor Volobouev was awarded a URA fellowship and he will spend the spring 2009 semester conducting research at Fermilab.
- Silvia Franchino, a physics graduate student from the University of Pavia (Italy), spent two and a half months in our department working with Professor Richard Wigmans analyzing data from beam tests in the context of the DREAM project at CERN. Her visit was a part of mutual exchange agreement between TTU and the University of Pavia.

# *Moments in Time*

Professor Charley Myles joined the department in 1978. This photo is circa 1985.

Professor Walter Borst in his laser fluorescence laboratory (1990). Walter is retiring this year after 25 years of service at TTU. Good luck and thank you, Walter.

Edward Teller was a frequent visitor and a friend of the department. He is seen in our conference room before his colloquium talk in 1991.


Professors Kamalaksha Das Gupta (left) and Roland Menzel were close colleagues and enjoyed discussing physics whenever they could (1990).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