Editors: Professor Alfred Goshaw and Delphenia Avent

Department Happenings

—From the Chair; Harold U. Baranger

We have had a good and active year here in Duke Physics: research groups are expanding, graduate recruitment was excellent, visibility increased both within and beyond campus, a new colloquium series has brought the department together more often, and we carried out the first phase of a reevaluation of our teaching of introductory physics. In this first section, I’ll touch on general issues that affect the department as well as faculty news. The following sections cover developments in our undergraduate and graduate program, and then present several exciting research topics currently being pursued here at Duke.

Bricks and Mortar:

Construction of a new sciences building got under way this year. The French Sciences Center (named after donor Melinda French Gates) will be constructed behind the Physics and Biology buildings so as to bridge the gap between them. Currently the construction site (see picture) consists of a large hole as the utilities and infrastructure are established. Physics is currently allotted 12,000 net square feet in the new building with occupation expected in about two years.

An unfortunate consequence of the new construction is that the High Resolution Lab of TUNL was demolished last spring. As many of you know better than I, the 3 MeV machine located in that building was a remarkable facility which produced excellent physics over the last several decades. We view its demolition with regret but also look forward to the new opportunities made possible by the French Center.

Our neighbors in the Engineering School have largely completed their new building, the Center for Interdisciplinary Engineering, Medical, and Applied Sciences (CIEMAS) (see picture). The Photonics Center and joint instrumentation facility which are housed in CIEMAS are both important for members of our department.

DFELL and TUNL completed an expansion of the DFELL building in order to house a booster ring that will inject into the current storage ring (see article). This will make possible novel ultraviolet and gamma-ray light sources.

Finally, we are starting a general upgrade of graduate student offices and lab space here in the Physics building. The first three graduate student offices were completed this summer with seven more scheduled in the next couple years.

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Faculty News:

We had the pleasure of hiring two new assistant professors this year: Chris Walter and Kate Scholberg. They have both arrived and are starting a new thrust in neutrino physics within our experimental high-energy physics program (see article p.8).

Albert Chang, a new senior faculty member, arrived last August from Purdue University. He has since set up an active lab in nanoscale physics in fully renovated space in our sub-basement (see article p.7).

Two distinguished members of our faculty retired this year, Richard Walter from TUNL and Horst Meyer from the low-temperature and nonlinear systems groups. However, I expect that they will both be around the department and available for consultation or discussion in their roles as emeritus professors. On behalf of the department, I would like to thank them for their many contributions over the years.

Two faculty members have left Duke recently. Vladimir Litvinenko has moved to Brookhaven National Lab and Andrea Bertozzi (primary appointment in mathematics) has decided to stay at UCLA. I wish them the very best in their future endeavors.

I'm pleased to report that Berndt Mueller has completed his term as Dean of Natural Sciences and is now back in our department.

Finally, I would like to mention several significant honors and promotions: Assistant Professors Anna Lin and Kate Scholberg both won a Career Award from the NSF, the foundation’s highest honor for junior faculty. Assistant Professor Ashutosh Kotwal has been appointed Guest Scientist and co-leader of the CDF Offline Analysis and Computing Organization, one of the top eight leadership positions in the large international CDF collaboration, at Fermilab. Dan Gauthier was promoted to Professor. And John Thomas has become the latest Fritz London Distinguished Professor. Congratulations to all five!

Leadership Changes:

There have been several important leadership changes in the university administration this past year. Richard Brodhead from Yale has taken over as President of the university. George McLendon, former chair of chemistry at Princeton, is now Dean of the Faculty of Arts and Science. And Steve Nowicki, professor of Biology, is Dean of Natural Sciences. (See the general Duke website for more information.)

Here in the physics department, there has been one leadership change: Roxanne Springer has become the Director of Graduate Studies (DGS), taking over from Henry Weller. Henry thus completes an unusually long term of service — 12 years as our DGS! I would like to take this opportunity to both thank and salute Henry for all his efforts toward improving our graduate program over the last decade.
The Graduate Curriculum Committee (GCC), chaired by Richard Palmer, has been very productive. Shailesh Chandraskeharan and Mark Kruse are faculty members on the GCC; Caroline Berger and Ilarion Melnikov are the student representatives. Their activities include:

1. **Changes to the qualifier examination policy.** These were approved by the faculty. Basically, students will now have the opportunity to take the four core exams (classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics) more frequently (both in January and in May) and only those sections failed need be retaken. Students are allowed two attempts at each section.

2. **Clarifying the preliminary exam procedures.** The new preliminary exam policies were approved by the faculty. They create a clear time-line and set of student and faculty responsibilities. For instance, by Duke Graduate School policy, it is not the responsibility of the student to arrange preliminary exams. Also, while there has long been a department policy of the prelim committee meeting with the student annually, this will now be enforced. The prelim web site has been updated.

3. **Distribution Courses:** “Astrophysics” has been added to the list of courses which count towards the distribution requirement. The previous “Introduction to Nuclear Physics” and “Introduction to Particle Physics” courses have been combined to form one course, “Introduction to Nuclear and Particle Physics.” Haiyan Guo will teach it this Fall.

4. **Core Courses:** The GCC will soon undertake a global review of the graduate curriculum. This is likely to include a consideration of the type and number of courses required for distribution, and an update of the core requirements.

I thank the GCC for its hard work and excellent results.

We are going to try a number of experiments with the graduate experience, some of which are already in their testing phase. The GSO continues to be very supportive with help and advice with these experiments. They include:

1. **Mentors:** Each of the incoming graduate students has been assigned three mentors; two senior graduate student mentors and one faculty mentor. The department sponsors events for mentors and their mentees, beginning with a welcome lunch during orientation week.

2. **Research Rotations:** Many research groups have volunteered to host students who wish in-depth exposure to life as a graduate student in a particular group. This serves both as a recruiting tool for research groups, and allows students to those who have hosted Study Nights.

Last March we held an Open House for prospective graduate students. We had an excellent response. Students, postdocs, faculty, and staff put together effective posters and presentations. I thank and congratulate all those involved on a great effort. Physics Study Nights, held Thursdays during the semester, continue to be very successful and broadly attended (particularly when problem sets are due on Friday). At these Study Nights, Physics majors and our graduate population gather to work on problems and interact with the faculty host. Thank you.
to make informed choices about which research group to ultimately join.

(3) **Professional Development Mentor:** In response to popular demand, the department now has a faculty member dedicated to mentoring students who wish to investigate possible career options outside of academia. We are grateful to Dr. Robert Guenther for accepting this responsibility.

(4) **Recruitment visits:** Duke Physics faculty travelling to give talks at universities and conferences are encouraged to meet with undergraduates who might have an interest in attending the Duke Physics graduate program. Henry Weller and Donna Ruger oversaw the design and creation of Duke Physics bookmarks for distribution.

(5) **Placement exams:** Students will have the opportunity to test out of core courses if they wish to do so.

Also, we would like to begin to recognize those students who perform with excellence in their teaching duties. Special mention this year goes to Andrew Dawes for his efforts in 171.

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**Graduate Student Organization**

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—From the President of the GSO, John Wambaugh

**Graduate Student Seminar**

The weekly Graduate Student Seminar reached the ripe-old age of one year this summer. Every Friday roughly thirty graduate students have crowded into the Faculty Lounge for a student lecture and lots of pizza. Either way you figure it, a representative of the Everitt lab gave the one-year anniversary talk — Hongying Peng, a post-doc in the Everitt lab, gave a talk entitled “Time-resolved Spectroscopic Analysis of Eu3+ Clusters in GaN” nearest to the date that Matthew Prior, now a fifth-year student, gave the first talk, while the 52nd seminar was given a few weeks later by second-year student John Foreman, entitled “Characterization and Applications of Ultrafast Optical Pulses”.

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**Open House for Prospectives**

Seventeen prospective graduate students from as far away as UCLA and as close to home as Hampden-Sydney, in Virginia, visited campus in early March. Brian Tighe, the Graduate Student Organization’s Recruitment Chair, and Professor Roxanne Springer sweated out the details of a new Open House format that included brief talks by many different researchers and a poster session/dinner to allow prospective students to experience as much of the Duke physics research community as possible. Twenty-three research groups and individual students presented posters on research opportunities in their group.

**Grad Student Activities**

Over the past year, physics graduate students have been involved in a variety of activities together. In the fall, six physics students joined camps with students from the department of Biomedical Engineering for the annual basketball ticket campout. Having survived thirty-six hours in a field with nothing to do but talk, dance, and play games and DVD’s (thanks to the BME generator), all the while barely subsisting on snackfood as well as the pizza delivered by other physics students, a pool of seven graduate students won five season passes.
For a second year, physics graduate students played volleyball most every Tuesday night on the sand court of the Gross chemistry building. The more hard-core students also honed their skills on Fridays. The Thursday basketball game continued to be popular, albeit drawing an unwavering 0.0 Nielsen share. A few graduate students have even begun to regularly risk their physical well-being with touch football on Saturdays.

Throughout the year, the Graduate Student Organization orchestrated a potluck, a barbecue and several movie nights of arguable taste (the movies, not the food).

**Ph.D.’s Earned**

Junfei Geng, August 2003  
Ilan Harrington, July 2004  
Justin Lancaster, August 2003  
Rob Macri, February 2004  
Michael Stenner, December 2003  
Shigeyuki Tajima, December 2003

**The Undergraduate Corner**

---From the DUS, Prof. Calvin Howell---

**The Class of 2004:**

The graduating class of 2004 was academically impressive and notably diverse in their immediate pursuits. This year 16 students graduated with bachelor degrees in physics. Of these, eleven graduates were first majors. They are shown in the photograph with the current Director of Undergraduate Studies, Calvin Howell. The graduating second majors, not shown in the photo, are: Kengyeh Chu, Eric Diebold, Nicolas Horvath, Joseph Keefe and Ryan Letchworth. Of our graduating majors, ten graduated with university honors and six graduated with department distinction. About 50% of this class will go to graduate school either this year or next year in physics or related fields. Two will go to medical school. Others will take positions in government and business. Of special note is that two graduates were awarded fellowships to conduct work abroad. Nicole Czakon has a Fulbright Scholarship to study nanophotonics for a year in Minsk, Belarus starting in the summer 2004. She plans to start graduate school in physics in the fall 2005. David Blocher was awarded a Lewis Hine Documentary Fellowship by the Duke University Center for Documentary Studies. David will spend ten months abroad conducting photo-documentary work in collaboration with international humanitarian organizations that focus on the needs of young children, their families and their communities. He plans to attend graduate school in physics starting in the fall 2006.

Our department continues to attract some of the brightest students at Duke as physics majors. We believe that providing them with opportunities to participate in frontier research projects is an important contributing factor to our success in attracting these outstanding young scholars. Six of our majors in the graduating class of 2004 completed honors thesis projects. They were: **Fernando Boschini**, “Tissue Dynamics of Dorsal Closure in Drosophila Fly Embryos”, supervised by Glenn Edwards; **Susan Clark**, “Polarization Instabilities of Laser Beams Counter propagating Through a Rubidium Vapor”, supervised by Daniel Gauthier; **Nicole Czakon**, “Temperature Dependence in Dorsal Closure”, supervised by Glenn Edwards; **Chandra Jacobs**, “Variable Stars of Globular Cluster W14”, supervised by Henry Everitt; **Joseph Keefe**, “Noise Exposure Associated with Marching & Prep Band Rehearsals & Performances”, supervised by Dewey Lawson; and **Albert Mao**, “Holographic Modulation of a Pulsed UV Laser Microbeam”, supervised by Glenn Edwards and Daniel Kiehart.

**SPS and Sigma-Pi-Sigma News:**

At the conclusion of the annual department poster session for graduate and undergraduate research, nine students were inducted into the Duke chapter of Sigma-Pi-Sigma. Dr. William McNairy, the faculty advisor for the Duke chapter presided over the induction ceremony, which was held on April 13, 2004. The new members are: David Blocher (class of 2004), Fernando Boschini (class of 2004), Peter Blair (class of 2006), Edward Daverman (class 2006), David Foster (class of 2005), Ethan Neil (class of 2005), Joshua Nimocks (class of 2005), Stephen Rawson (class of 2005) and Tora Unuvar (class of 2004).

New officers for the SPS were elected in the spring 2004 to replace the seniors. Susan Clark and Kengyeh Chu served as co-presidents, and Albert Mao was the secretary until graduating in May 2004. Abhijit Mehta will continue as the treasurer. The new officers are **Peter Blair** (president), **Charleston Lewis** (vice president) and **Daphne Chang** (secretary).
**Course Highlights:**

Courses that engage undergraduate students in frontier research projects or expose them to current research topics are among our most popular and successful courses. One such example is PHY 193, Capstone Design of Applied Science, which is taught by Professor Robert Guenther. A project by four students in the PHY 193 course in the fall 2003 was selected as one of the eight final projects to be judged in the annual Collegiate Inventors Competition. This competition is a program of the National Inventors Hall of Fame and is sponsored by Hewlett-Packard and the United States Patent and Trademark Office. It recognizes and rewards innovations, discoveries and research by college and university students and their faculty advisors. For their project in the PHY 193 course, Hamza Aziz, Michael Amiet, Max Cohen and Tora Unvar worked to develop a low-cost Braille reader to make the cyber world more accessible to the visually impaired.

**Student Scholarships:**

In this section we recognize physics majors who were awarded national scholarships and fellowships during the 2003-2004 academic year.

**Phillip Kurian**, who is majoring in public policy studies and physics, was awarded a Truman Scholarship. He was one of 77 other undergraduate students nationally who received this highly coveted award. The federal government awards Truman Scholarships annually to intellectually passionate student leaders who are committed to community service and who want to go to graduate school in preparation for a career in public service.

**Peter Blair** was awarded a Scholarship for Minority Undergraduate Physics Majors by the American Physical Society. This scholarship is designed to attracted talented undergraduates from traditionally under represented communities into physics. Peter received one of the twenty scholarships that were awarded nationally last year. Associated with the scholarship is an annual award of $500 to the hosting department for each scholarship recipient. Peter also received a scholarship awarded jointly by the National Association of Black Physicists and Lawrence Livermore National Laboratory. He was presented with this scholarship in February 2004 at the Annual Conference of the National Society of Black Physicists. Both scholarships are renewable until graduation.

The 2004 graduates with first majors in physics are shown in the above photo. The names of those in the photo from left to right are: Hany Elmariah, David Blocher, Daryl Hare, Susan Clarke, Nicole Czakon, Matthew Toups, Albert Mao, Fernando Boschini, Chandra Jacobs, Tora Unvar, Eric Fountain, Prof. Calvin Howell (DUS).
Quantum Dots and Metallic Nano Wires

Prof. A.M. Chang joined the Duke faculty in July, 2003. His Nanophysics group is engaged in pioneering work in several directions. In this short article, two recent results will be described: (i) spin-entanglement in double quantum dots, and (ii) superconductivity in ultra-narrow aluminum nanowires 20-30 atoms across.

Nanophysics deals with novel properties of physical systems in which one or more dimensions are below 100 nm (nanometer) in size. This 100 nm size corresponds roughly to 1/1000-th the thickness of a human hair, or equivalently, 400 atoms across. At such sizes, quantum effects play a dominant role. At the same time interaction between electrons can give rise to unusual and strongly correlated behaviors. Examples include the Kondo effect in a quantum dot, in which conduction electrons in the leads screen the impurity-spin on the quantum dot, and superconducting correlations in reduced dimension. In particular, for 1-d, superconductivity can be modified and destroyed by the presence of quantum phase slips.

Fig. 1 exhibits an electron micrograph of a semiconductor double quantum-dot. The starting material is a GaAs/AlGaAs heterojunction semiconductor crystal grown via the layer-by-layer growth molecular-beam-epitaxy (MBE) technique. This type of heterojunction confines the electrons in a 2-dimensional sheet at the GaAs/AlGaAs interface. Using state-of-the-art electron beam lithography, sub-micron finger-like metallic gates are deposited on the top surface of the crystal. By applying appropriate voltages, the two sets of encircling gates drive away electrons underneath them, further confining the electrons and creating two puddles of electrons within the semiconductor. Each of these puddles represents a quantum dot. Our complex device is in essence two sophisticated quantum field-effect transistors side by side, and is a more sophisticated version of the silicon MOSFET transistors in computer chips. Typically, each electron puddle contains roughly 30-60 electrons. When the electron number is even, the electron spins cancel out. However, if odd, a residual ½ spin remains. This spin ½ quantum dot can then be the basis for a quantum-bit, or qubit, useful for quantum computation applications. An up pointing spin would indicate a “1,” while a down a “0.” In our device, we can also tune each quantum dot puddle to enable it to interact with the conduction electrons in the surround leads. The lead conduction electrons screen the spin ½ quantum dot to form a many body correlated, spin-singlet Kondo state. When we tune the interaction between the two dots, however, the inter-dot interaction can dominate over the dot-lead interaction, leading to the formation of a spin-singlet between the two spins instead, one on each dot. This inter-dot spin-singlet is the Einstein-Podolsky-Rosen entangled state. Our success in demonstrating controlled spin entanglement bodes well for future quantum computation/communication applications.

This work was featured in a Duke Dialogue article (http://www.dukenews.duke.edu/news/scientist_0404.html).

In a separate research direction, Prof. Chang’s group has recently developed a new method of fabricating ultra narrow metallic nanowires. Such nanowires may become useful as interconnects in today’s ever more densely packed ULSI (Ultra-Large-Scale Integration) semiconductor chips. By using a method which exploits the atomic precision of the MBE crystal growth to provide a template of atomic dimensions, and a subsequent metal deposition onto such a template, wires as narrow as 5 nm have now been successfully fabricated and tested. Fabio Altomare, who works with Prof. Chang on this project, has now observed clear signatures of superconductivity in an aluminum nanowire with a cross section of 20 atoms x 32 atoms (5 nm x 8 nm), which is 400,000 atoms (100 microns) long. To provide a sense of the geometry, this is analogous to having a perfectly straight conducting wire 1/4” x 3/8” in its cross-section, which stretches across an entire football field in its length, albeit at the nanoscale. This is also one of the world’s narrowest superconducting wire. The superconductivity
Neutrino Physics Comes to the Duke High Energy Physics Group

“Neutrinos, they are very small. They have no charge and have no mass And do not interact at all. The earth is just a silly ball To them, through which they simply pass...”
John Updike’s “Cosmic Gall”

The last half-decade has been an incredibly exciting time in neutrino physics. In 1998, conclusive evidence emerged from a giant detector buried deep under a mountain in the Japanese Alps that Mr. Updike was wrong and neutrinos actually do have mass. Since that time, more evidence has emerged that neutrinos have mass, coming from such diverse sources as the Sun, particle accelerators, and nuclear reactors. Understanding the origin of these masses and why they seem to be so small has important intellectual implications for all of physics and cosmology.

Professors Kate Scholberg and Chris Walter helped build and work on the experiment in Japan that proved neutrinos have mass and have moved to Duke to start a neutrino effort here, as part of the high energy physics group. Their research uses the Super-Kamiokande (Super-K) detector. This detector is located one kilometer underground in the mountains of central Japan, in an ancient mine.

The detector itself is over 40 meters high and 40 meters wide and filled with 50,000 tons of ultra-pure water, viewed by thousands of sensitive detectors. This detector observes neutrinos from many sources, including those produced near Tokyo in an accelerator. Detectors that Professor Walter helped build measure those neutrinos before they travel 250 kilometers across Japan, where they are detected in Super-K. Super-K was built and is operated by a collaboration of over 150 physicists in Japan and the United States.

Super-K also studies other particle physics topics. For example, by watching the extremely large volume of water, it can search for the signature of the decay of a single proton in the water: a characteristic spray of particles. So far proton decay has never been observed. The discovery of the instability of the proton would have a profound impact on physics and would be an immensely important clue to help us piece together a theory that explains all of the fundamental forces in nature.

Super-K is also used as an astrophysical observatory. In addition to the gigantic flux of neutrinos coming from the sun, Super-K searches for more exotic neutrinos that may be coming from other sources in our solar-system, galaxy and universe, including dark matter, and giant black holes in the centers of galaxies.

Professor Scholberg is one of the leaders of a world-wide effort to detect the neutrinos that would be produced in a supernova when a star collapses, and helps administer a system that would notify optical astronomers hours before the light from a supernova reached the earth.

An intriguing possibility is that the origin of neutrino mass can be explained by physics of the highest energy scales. These energy scales cannot be directly approached with accelerators today, but existed in the early universe. Neutrinos may hold the imprint of actions in the beginning of our universe that determined the properties of the world today. Foremost among the questions it is hoped neutrinos may shed light on is “Why is today’s universe dominated by matter?”

Unfortunately, neutrino physicists are not yet at the point where they can begin to answer these questions. To do so requires a new generation of experiments. These new experi-

appears at very low temperatures, at 1.5K above absolute zero, and shows deviation from a 2-d aluminum film. The observed unusual behavior of the superconductivity may be related to a novel phenomenon of tunneling through quantum phase slips.

—contributed by Albert M. Chang, Professor of Physics
ments must take the step from confirming whether neutrinos have mass, to making precision measurements of the neutrino parameters that are already known, and attempting to measure effects that have not been seen because the values of the parameters that govern them are zero or too small.

Both Professors Scholberg and Walter are part of a new effort to build an experiment, which once again uses Super-K to measure these parameters. This time a new more powerful accelerator must be built, Super-K must be upgraded, and new detectors must be constructed at the accelerator to measure the neutrinos before they begin their voyage across Japan.

The next years promise to be an exciting time for both the field and the new group at Duke that will be in the midst of it all.

—contributed by Kate Scholberg and Christopher Walter, Assistant Professors of Physics

New Discoveries at the Relativistic Heavy Ion Collider (RHIC)

Collisions between heavy nuclei at relativistic energies create matter at densities much higher than those found in nuclei or even the cores of neutron stars. The theory of strong interactions, quantum chromodynamics, predicts that the structure of matter changes drastically above 5-10 times nuclear matter density, making a transition to a “quark-gluon plasma”, in which quarks are light and move freely. The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory was constructed to pursue the exploration of matter in this density regime. RHIC has now operated four years and generated a wealth of data, which allow us to draw first conclusions about the properties of matter under such extreme conditions.

About 100 physicists assembled at Brookhaven on May 14-15 for a “New Discoveries at RHIC” workshop to discuss the meaning of the experimental results obtained so far. Duke physicist Berndt Mueller gave a keynote lecture entitled “Hadronic signals of deconfinement at RHIC”, in which he argued that the observations can be best understood assuming that quarks become free particles in the matter produced in collisions at RHIC and only reassemble into ordinary mesons and baryons when the matter expands to low densities. The talk summarized the results of the Duke theory group including Steffen Bass, postdocs Rainer Fries, Chiho Nonaka, and Thorsten Renk, as well as guest scientist Dinesh Srivastava.

In addition to collisions between heavy nuclei, RHIC allows scientists to study collisions between two protons and even light-heavy collisions between deuterium and Au nuclei, which serve as benchmarks for the phenomena observed in Au+Au collisions. Since the year 2000, RHIC has had three major experimental runs at collision energies of 130 GeV and 200 GeV per nucleon pair and involving all three systems mentioned above. A fourth run, again with colliding Au beams, has just been completed.

The data from Au+Au collisions show that hadrons containing any combination of quarks are produced according to the expectation that a quark-gluon plasma converts into hadrons when the temperature of the matter falls below a critical value \( T = 160 \pm 6 \) which agrees with theoretical predictions. Measurements of the flow patterns of the emitted particles provide additional evidence that they are created directly from a phase of independent quarks and antiquarks. The experiment makes use of the fact that the region of super-dense matter created in semiperipheral collisions between two nuclei is elongated, leading to an anisotropic flow. The measured anisotropy is a function of the momentum of the emitted particles and varies from one hadron species to another. The remarkable result is that the different flow patterns of all mesons and baryons convert into a common pattern for free quarks.

Another important discovery made in the RHIC experiments is the suppression of particle emission with large momentum transverse to the beam axis. These particles are created by the fragmentation of quarks and gluons, which are scattered at wide angles in the nuclear collision, but lose a large fraction of their kinetic energy on the way out of the dense matter. Because the yield of scattered particles fall rapidly as a function of the transverse momentum, the energy loss translates into a reduction of the observed yield at a given momentum. The fact that no suppression is observed in d+Au collisions demonstrates that it is a genuine effect of the matter created in the nuclear collision, which is densely packed with gluons.

The conclusion reached at the workshop is that the RHIC program is rapidly zeroing in on the discovery of a new state of matter with the properties of a quark-gluon plasma. The results from the latest Au+Au run, which are expected to provide further confirmation, are eagerly anticipated.

—contributed by Berndt Mueller, James B. Duke Professor of Physics

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**Novel UV and Gamma-Ray Light Sources**

On June 28th, Dean Berndt Mueller cut the ribbon to the 1,250 square foot expansion to the Free Electron Laser (FEL) Laboratory to celebrate a significant milestone for the FEL and TUNL communities. The expansion will house a booster ring that will inject into the storage ring with up to 1.2 GeV electrons. Currently 274 MeV electrons from a linac are injected and then accelerated to higher energies by the storage ring. The booster ring is the third of three upgrades currently in progress that will enable novel research opportunities in the physical, biological, and biomedical sciences.

**TUNL Research**

During the past several years, the high-intensity gamma-ray source (HyS) based on the OK-4 demonstrated the anticipated quality and the intensity of the linearly polarized beams. These beams have opened up new opportunities for fundamental studies in nuclear structure and nuclear astro-physics. For example, Nuclear Resonance Fluorescence studies allowed parity assignments of nuclear levels with a new level of precision and efficiency, providing a deeper understanding of some of the most fundamental modes of excitations in nuclei. Analyzing power measurements of the \((\gamma,n)\) reaction on several light nuclei have been used to reduce the uncertainty in the cross section for key reactions at energies relevant to Big-Bang nucleosynthesis. The upgrade to HyS based on the OK-5 enables linearly and/or circularly polarized beams with energies up to about 160 MeV, allowing investigations of some of the most basic theories of nuclear and particle physics. Although not an inclusive list, the following highlights future HyS applications in nuclear physics.

A great deal of progress has been made in understanding low-energy interactions of pions, nucleons, and photons using Chiral Perturbation Theory (ChPT). HyS is ideally suited to test these predictions of ChPT, including the polarizabilities of the nucleons. In a non-relativistic picture, the electric and magnetic polarizabilities measure the response of a system to external electric and magnetic fields: the ability to induce an electric and a magnetic dipole moment, respectively. HyS promises an order of magnitude improvement in our knowledge of these quantities.

Haiyan Gao heads a group developing a high-pressure polarized \(^3\)He target for double polarization experiments utilizing HyS. While deuterium targets have been used in the past in quasi-free Compton scattering for the extraction of the neutron electric and magnetic polarizabilities, a polarized \(^3\)He target combined with a circularly polarized beam is advantageous in probing the neutron spin polarizabilities. These are previously unobserved fundamental quantities which can be thought of as measuring the transient dipoles that are induced in the nucleon due to the rearrangements of its constituents interacting with the photon fields.

The circularly polarized beams at HyS and a TUNL polarized target are ideal for investigating the Gerasimov-Drell-Hearn Sum Rule. This sum rule is based upon very general principles: causality, unitarity, and gauge and Lorentz in variance and relates the polarized cross sections to static properties that describe the internal structure of the nucleon. The GDH integrand requires a measurement of the total absorption cross section when a \(\gamma\)-ray has its helicity directed parallel to the polarization vector of the target and then antiparallel. These arguments can be applied equally well to the deuteron. There are suggestions that the GDH sum rule may be violated for the nucleons. If so, possible explanations include the exchange of an as yet undiscovered meson between the \(\gamma\) and the nucleon, the photoproduction of a graviton, or even internal quark structure. The upgraded HIGS facility will be ideally suited to establishing this violation by comparing the sum rule values for the deuteron to that obtained for the nucleons at other laboratories.

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*—contributed by Henry Weller, Professor of Physics*
ranges. The second project is the upgrade of the RF cavity system in the storage ring, which is planned to be commissioned by summer’s end. The RF cavity will allow stable multibunch operation. The components for the booster ring began arriving from Novosibirsk this summer and assembly in the building expansion is underway. In the past, the lifetime of the stored electron-beam ranged from minutes to hours, depending on the mode of operation. The new booster ring will provide top-off injection to enable quasi-continuous operation of the light sources.

Both UV FEL and gamma ray sources are driven by the optical klystron (OK) system, such as the OK-5 storage ring. The FEL cavity is formed with two high reflectivity mirrors lying outside the ring. As the relativistic electrons pass through the OK-5, kinetic energy of the electrons is converted into photons. The wavelength of the UV photons is tunable, determined by the electron-beam energy and magnetic field strength. Tunable gamma rays can then be produced by intracavity Compton backscattering of the UV photons and the electrons. So in a sense, these upgrades jointly promote, via Compton backscattering, UV and gamma-ray applications research. Although not an inclusive list, the following examples highlight user applications for the DFELL and TUNL communities.

Robert Pearlstein leads a team from the Duke Medical School collaborating with physics faculty on several biomedical research projects. One project is investigating the role of X-rays in arresting the inflammatory response with the goal of limiting postoperative neural tissue scarring. A second project is investigating protocols for wound healing and restoring biological function following injury to either the central or peripheral nervous systems.

Robert Nemanich from NC State heads the research group developing the UV-FEL photo electron emission microscope at DFELL. The UV light excites photoemission in condensed materials, which are subsequently imaged with an electron microscope at a spatial resolution approaching 10 nm. The group is investigating the dynamics of island structures during thin film growth processes, identifying attractive migration and coalescence as well as Ostwald ripening. The group also is investigating the influence of surface termination and step orientation on the dynamics of epitaxial growth in GaN and SiC as well as the precise control of ferroelectric and ferromagnetic domains. Recently John Simon’s group from the Duke chemistry department has been collaborating with the Nemanich group to investigate biological molecules isolated from human hair, demonstrating differences in photoionization for eumelanins. The tunable and selectively polarizable OK-5 FEL will provide novel contrast mechanisms for future investigations.

DFELL Research

The storage ring FEL is a tunable source of pulsed UV radiation in addition to gamma rays. The OK-4 FEL delivered nearly 3000 hours of beam time to the users community in 2003. This is a consequence of nearly two years of concentrated effort to address problems of magnet overheating and power supply instabilities, implementing additional diagnostics, and developing an advanced control and feedback systems, in particular orbit feedback. Currently research is underway to compensate for various magnetic optics errors in the storage ring, promising increased beam lifetime, brightness, and gain. Ultimately, the OK-5 will completely replace the OK-4 FEL, which has been operational since 1996. The OK-5 FEL will provide unique light source capabilities for applications research. The OK-5 will deliver both linear and circular polarizations, where the OK-4 produces only linear polarization. The OK-4 has pushed UV FEL lasing down to 194 nm; the OK-5 is expected to extend UV operation to 150 nm and below. Together with the new booster, the OK-5 will extend the gamma-ray range to as high as 160 MeV, where the OK-4 produces about 60 MeV gamma rays.

Two time-resolved spectroscopic techniques have been developed for biophysical research. One “two-color” technique uses the storage-ring FEL as a pulsed UV source to excite electronic transitions and the downstream bending magnet as a broadband infrared source to monitor infrared-active structural rearrangements in the subsequent relaxation processes. The second technique is based on UV resonant Raman spectroscopy and probes Raman-active structural rearrangements. These complementary techniques will track structural intermediates in biological molecules, i.e. cyclic nanomachines, which have been spectroscopically silent in the past. The selective polarization of the OK-5 FEL accesses new selection rules for these investigations. The biophysics program at DFELL also investigates fracture dynamics in biological molecules occurring on the nanosecond time scale after extremely rapid heating by the Mark-III FEL.

Robert Pearstein leads a team from the Duke Medical School collaborating with physics faculty on several biomedical research projects. One project is investigating the role of X-rays in arresting the inflammatory response with the goal of limiting postoperative neural tissue scarring. A second project is investigating protocols for wound healing and restoring biological function following injury to either the central or peripheral nervous systems.

Robert Nemanich from NC State heads the research group developing the UV-FEL photo electron emission microscope at DFELL. The UV light excites photoemission in condensed materials, which are subsequently imaged with an electron microscope at a spatial resolution approaching 10 nm. The group is investigating the dynamics of island structures during thin film growth processes, identifying attractive migration and coalescence as well as Ostwald ripening. The group also is investigating the influence of surface termination and step orientation on the dynamics of epitaxial growth in GaN and SiC as well as the precise control of ferroelectric and ferromagnetic domains. Recently John Simon’s group from the Duke chemistry department has been collaborating with the Nemanich group to investigate biological molecules isolated from human hair, demonstrating differences in photoionization for eumelanins. The tunable and selectively polarizable OK-5 FEL will provide novel contrast mechanisms for future investigations.

—contributed by Glenn Edwards, Director FEL Lab and Professor of Physics and Henry Weller, Professor of Physics
The Search for Color Transparency—A Color Coherence Effect in Nuclear Physics

Color Transparency (CT) refers to the vanishing of final and initial state interactions for hadrons that are produced in exclusive processes (on nuclei) with a large momentum transfer to the hadron. CT, a natural consequence of quantum chromodynamics (QCD), follows from the fact that as the momentum transfer (Q) in an interaction increases, the range of the interaction decreases. Therefore, an exclusive process at large momentum transfer preferentially selects out hadrons of reduced transverse size (see Fig. 1). This reduced size, color neutral object, then passes “undisturbed” through the nuclear medium before expanding to its equilibrium size. Nuclear transparency, defined as the ratio of the cross section per nucleon for a process on a bound nucleon in the nucleus to the cross section for the same process on a free nucleon, is a typical quantity used in CT searches. A clear signature for the onset of CT would involve a dramatic rise in the nuclear transparency as a function of the momentum transfer in the process. A number of searches for color transparency have been carried out in the last two decades; however, no conclusive model independent evidence for CT has been observed for three quark hadrons.

One would expect an earlier onset of CT for meson production than for proton, as it is much more probable to produce a small transverse size in a qq system than in a qqq system. Experiments performed at Fermilab and DESY seem to support this idea. Recently, we carried out the first measurement of nuclear transparency of the γ n → π−p process on 4He nuclei. This experiment was performed at Jefferson Lab (JLab Experiment E94104, Haiyan Gao and Roy Holt spokespersons), and employed several advantages of 4He such as its relatively small nuclear size. The results from our experiment suggest a CT-like behavior for the first time for such processes. However, the limited statistics of our results at the highest energy prevents conclusive statements.

Lacking any conclusive evidence for CT, there is an urgent need for a systematic study of the nuclear transparency of qq hadrons over a wide range of momentum transfer squared (Q^2) and nuclei. An experiment to measure pion nuclear transparency (Jlab experiment E01107, D. Dutta, R. Ent and K. Garrow, spokespersons) over a wide range of Q^2 and atomic number (A) is currently underway at JLab. This experiment will measure the exclusive electroproduction of pions from nuclei. The combined statistical and systematic uncertainty in nuclear transparency is expected to be 5-7%, while perturbative QCD (pQCD) based calculations predict enhancements due to CT as large as 40% between Q^2 of 1 to 5 (GeV/c)^2 for heavy nuclei. The projected results along with a pQCD based calculation and expectations of conventional nuclear physics calculations are shown in Fig. 2. This experiment should be able to clearly identify the predicted early onset of CT and preliminary results should be available in 2005.

—contributed by Dipangkar Dutta, Assistant Research Professor, Haiyan Gao, Associate Professor of Physics, and the Duke TUNL MEP Group

High Energy Physics with ATLAS

The ATLAS (A Toroidal LHC ApparatuS) experiment is a next generation high energy experiment utilizing the Large Hadron Collider (LHC) at the CERN laboratory near Geneva, Switzerland. There are 1800 physicists participating from more than 150 universities and laboratories in 34 countries. When the collider comes on line in 2007, it will produce the highest...
center of mass energy (14 TeV) proton-proton collisions, which is seven times more powerful than the collider at Fermi National Laboratory. The energy density in these high energy collisions is similar to the particle collision energy in the early universe less than a billionth of a second after the Big Bang.

The experiment is designed not only to search for the last undiscovered particle in the Standard Model, known as the Higgs but also to explore beyond the Standard Model. The Standard Model has been very successful but it has a few problems including what is known as the naturalness problem. This problem arises because a radiative correction to the Higgs mass becomes unstable at high energies. There are several candidates to solve the problems. Models based on SUSY (Super Symmetry) or extra dimensions are among the candidates.

The Duke HEP ATLAS group led by Prof. Seog Oh has been a member of the ATLAS collaboration since its early days. One of our main contributions was to design and construct a part of the inner detector called the Transition Radiation Tracker (TRT). It is a high precision ~100,000 channel tracking chamber whose main function is to track charged particles and identify electrons. A picture above (Figure A) shows the detector being assembled at CERN. The basic building blocks are called modules and Duke was responsible for constructing ~½ of the modules. Early this year, there was a milestone of successfully completing the module construction. The construction carried out on the second floor of our physics department took close to four years.

Inside a module, there are ~500 (on average) 4 mm diameter ~140 cm long straw tubes with sense wires inside. Each tube with special gas inside acts as an independent tracking element with resolution of 0.15 mm. In other words, a track can be located within ~0.15 mm in space in each tube. After the assembly, it will be lowered into the experimental area 100 meters underground. When the ATLAS detector (Figure B) is fully assembled, it will be one of the most complex and largest detectors in the world.

The expected ATLAS data output is more than 1000 Terabytes per year even after selecting interesting events through a sophisticated trigger system. The computing power necessary to analyze the data is estimated as ~100,000 nodes collaboration wide. These computers are connected through a Grid system. The Duke group has initiated a program to assemble ~1000 nodes with 10,000 Terabytes disk space.

Many of us in HEP believe that we are at a threshold of many exciting discoveries. The shortcomings of the Standard Model have to be resolved and the experiments, such as ATLAS, likely provide guidance to the path. If a model based on SUSY is correct, there will be dozens of new fundamental SUSY particles to be discovered. Stay tuned, the best is yet to come.

—contributed by Seog Oh, Professor of Physics

Figure A. The ATLAS Barrel TRT being assembled at CERN. The inner diameter is ~1.2 meters, the outer diameter is ~3 meters and the length is ~1.5 meters. The first layer is being assembled from the basic building blocks called modules. There are three layers and each layer consists of 32 modules. The Duke HEP group constructed ~½ of all the modules.

Figure B. The ATLAS detector. When fully assembled, it is 22 m high, 46 m long and 7000 metric tons. For scale, please note the people at the bottom. The Barrel TRT is a part of the Inner Detector located at the center.
Superfluidity in an Atomic Fermi Gas

Evidence for superfluidity in an atomic Fermi gas has been observed by researchers in the Quantum Optics group at Duke University. Using a bowl made of laser light to coral an ultracold gas of lithium-6 atoms, the researchers (students Joseph Kinast and Staci Hemmer, postdoctoral associates Michael Gehm and Andrey Turlapov, and professor John Thomas) find that the gas acts like a vibrating “jelly” which oscillates in and out. While the jelly-like (or “hydrodynamic”) behavior can arise in ordinary ultracold gases, the researchers have found evidence that their gas is a superfluid, a “perfect” jelly which vibrates for a very long time after being shaken. The behavior of the jelly may help to determine whether it’s possible to create super-high temperature superconductors which operate far above room temperature — materials which would enable energy-saving power lines and magnetically levitated trains. By changing the experimental parameters, the atomic jelly also can test theories of exotic systems in nature, such as a quark-gluon plasma which is not a superfluid, or a neutron star which can have superfluid components. What’s shared by all these systems is that they are made of strongly interacting fermions — particles which can be “spin-up” or “spin-down” (spin-up/down is analogous to bar magnets which point in opposite directions).

In their experiment, the researchers first precool lithium-6 atoms and then trap them in a focused laser beam which attracts and confines them near the focal point, producing a “bowl” made of laser light. Next, an applied magnetic field is adjusted to produce a collisional “resonance”, making the atoms strongly interact. Then, the temperature of the atoms is lowered to less than 50 billionths of a degree above absolute zero by “evaporative cooling,” a process in which hotter atoms are allowed to escape by slowly lowering the intensity of the trapping laser beam.

Then, the gas’s ability to act like a vibrating “jelly” is tested. To start vibrations in the gas, the trapping laser is turned off for a short time, allowing the gas to expand, and then turned back on again. The gas cloud quivers in and out, rising up and down the sides of the laser bowl. A series of pictures of the cloud shows the vibrations.

The cloud’s frequency of vibration is precisely measured, as well as how long the vibrations persist. When the magnetic field is adjusted so that the atoms are strongly interacting; the measured vibration frequency is 2837 Hz, in very close agreement with the theoretical prediction of 2830 Hz for a hydrodynamic Fermi gas. Evidence for superfluidity arises in lowering the temperature of the gas: This causes the vibrations or “oscillations” to last for a longer time, in contrast to an ordinary hydrodynamic gas, in which a lower temperature would cause the oscillations to “damp” or die out more quickly.

Currently, the researchers cannot claim a definitive observation of superfluidity: There is no theory of damping for strongly interacting superfluid Fermi gases with which to compare the measurements. Such a theory would help to precisely define a “transition temperature” below which superfluidity occurs. However, the experiments do provide the first evidence for superfluid hydrodynamics based on pairs of fermion atoms in a gas. The results were published in Kinast et al., Physical Review Letters, 16 April 2004.

The Information Velocity: From Superluminal Pulses to Relativistic Causality

For over a century, it has been know that a pulse of light propagating in an optical material with a frequency-dependent refractive index (also known as a dispersive material) can appear to travel faster than the speed of light in vacuum c. This possibility aroused great concern in the early 1900’s soon
after the development of Einstein’s special theory of relativity because it might indicate that information can be transmitted between two points in space faster than the light speed, directly contradicting the special theory. Through a mathematical analysis of Maxwell’s equations and a model of a dispersive optical material, Sommerfeld and Brillouin demonstrated that no signal can travel faster than the light speed even when the group velocity $v_g$ of a pulse (describing approximately the speed of the peak of the pulse) exceeds $c$. They also suggested that the group velocity loses physical significance when it exceeds $c$.

More recent work has shown that the group velocity does have meaning for smooth (gaussian-shaped) pulses when $v_g>c$ or even when $v_g$ is negative. A negative group velocity is a situation where the peak of a pulse emerges from the medium before the peak enters the medium.

Using modern quantum optical techniques, Prof. Gauthier’s group, with the support of the National Science Foundation and in collaboration with an information scientist from the University of Arizona, has been studying optical pulse propagation in this unusual so-called “superluminal” or “fast” regime. They have achieved large advancement of a pulse propagating through a laser-pumped dilute gas of potassium atoms in comparison to a pulse propagating over the same distance in vacuum as shown in the figure.

To directly test the predictions of the special theory of relativity, the researchers encoded a “bit” of information on the pulse by rapidly switching the amplitude of the waveform to a high (indicating a “1” bit) or a low value (indicated a “0” bit) and measure how fast the bit of information traveled through the dispersive material. The found that information travels at slightly less than $c$, consistent with Einstein’s special theory of relativity. A discussion of these research results can be found in: M.D. Stenner, D.J. Gauthier, and M.A. Neifeld, “The speed of information in a ‘fast light’ optical medium,” Nature 425, 665 (2003). This research has also attracted considerable public attention. A general discussion of the work with links to various popular articles can be found at: http://www.phy.duke.edu/research/photon/qelectron/proj/infv/.

While Prof. Gauthier’s research demonstrates that the special theory of relativity is not violated in “fast” light experiments, there still may be practical uses of dispersion-tailored optical materials. He is part of a new collaboration to study the use of “fast” and “slow” light materials for tunable optical buffers that will be an integral part of state-of-the-art ultra-high-speed telecommunication routers and switches. The collaboration involves researchers from the University of Rochester, Cornell University, University of California at Los Angeles, and University of California at Santa Barbara and supported by the Defense Advanced Research Projects Agency (DARPA).

—contributed by Daniel J. Gauthier, Anne T. and Robert M. Bass Professor of Physics and Professor of Biomedical Engineering

Granular Flow

The Physics Department at Duke is a key player in a field that is undergoing tremendous growth and discovery, namely that of granular materials. These materials are around us everywhere, and include coal, food grains, sand, pharmaceutical powders, and even dog food. The amount of money involved in handling these materials is truly staggering.

It might at first seem surprising that there is so much to be discovered in a field that seems to have a rather long history. In fact, Coulomb’s famous work on ‘friction’ was actually addressing granular materials (not blocks on planes). And, such greats of physics as Michael Faraday and Osborne Reynolds have all made significant contributions. But after more than two hundred years of often sophisticated research, our ability to describe even simple aspects of these materials still lags well behind that for more conventional matter, for example ordinary fluids and solids, for which nominal granular analogues exist. Engineering design relies heavily on empiricism, and the failures of granular handling devices are frequent.

Physics interest in these materials first appeared in the late ‘80s when a handful of papers began to appear in physics journals, including studies done at Duke. There is now an ever-increasing flow of new and exciting work from the physics community, as well as from of the more standard communities (engineering, geophysics...).
The challenge for physicists is to develop first principles models of many-body systems for which the interactions are strongly dissipative (due of course, to friction and restitutional losses). This is a really substantial challenge, equal to any of the grand challenge problems. Our usual tools of statistical mechanics must be replaced by new ones that deal with the fact that energy is not conserved. We are still struggling to answer seemingly simple questions, such as: how are forces carried in a granular material? Much progress has been made recently, but much more remains to be done.

The Duke group now involves faculty in both Math and Physics, and includes Josh Socolar, David Schaeffer, Tom Witelski and Bob Behringer. New interactions are forming too, most notably with Peter Malin and Nick Hayman in Geology. We also collaborate with a number of other institutions, including North Carolina State University, New Jersey Institute of Technology, Yale University, Cambridge University, The University of Stuttgart, The Technical University of Delft, the University of Paris VI, and Oriel Therapeutics in RTP.

A number of high school students, undergraduate students, graduate students, post-docs and visitors have participated in and contributed to the Duke physics granular program. These include Bill Baxter, Dahl Clark, Meenakshi Dutt, Junfei Geng, Bob Hartley, Dan Howell, Lou Kondic, Andy Lane, Guy Metcalfe, Brian Miller, Guillaume Overlez, Ben Painter, Hyuk Pak, Scott Paulson, Guillaume Reydellet, Sarath Tennakoon, Brian Utter, Eric van Doorn, and Loic Vanel. An interesting anecdote concerns Loic’s first visit to Duke. He set off to discover ‘centre ville’ in Durham. Although he was a bit disappointed on this quest, during this visit, he met his future wife. Current students and post-docs include Karen Daniels, John Helms, Trush Majmudar, David Marks, Jean-Philippe Matas, Matthias Sperl, Brian Tighe, John Wambaugh, and Peidong Yu.

With all the activity above, it would be impossible to discuss everything that we have done. However, there are a few results that are particularly interesting. The pioneering work of Bill Baxter was perhaps the first to point out the dominant nature of force fluctuations that occur in granular materials. We have gone on to characterize these fluctuations and to work towards theories that would correctly incorporate them into descriptions of granular mechanics. One significant offshoot of this work is a project that is currently scheduled to fly on the International Space Station. This project, with Karen Daniels playing a leading role, should tell us the way in which granular materials approach glassy and solid-like states. These studies can only be carried out in zero gravity, since gravity causes granular materials to collapse into a heap. We have also provided significant effort towards understanding the way forces are carried in granular materials. In fact, all grains do not contribute more or less equally, but rather, forces tend to be carried on filamentary structures known as force chains. The attached figure shows an example from the experiments of Dan Howell — bright corresponds to large force, and dark to low force. Recent work by Junfei Geng, Bob Hartley, Trush Majmudar, Brian Tighe, John Wambaugh, Josh Socolar and David Schaeffer have provided significant insight into the force transmission question. Recently, Brian Utter has shown that there is a fascinating connection between the way in which granular materials deform, and the way in which amorphous solids deform. And Jean-Philippe Matas has discovered novel wave structures in the classic Faraday vibrated system.

This work has received considerable attention in the scientific community, with numerous invitations to speak at professional meetings and to give colloquia and seminars. Again, a complete list is not possible. However, one noteworthy instance was last fall, at the Isaac Newton Institute at the University of Cambridge, for which Bob Behringer gave a series of lectures.

—contributed by Robert Behringer, James B. Duke Professor of Physics
This year marks the fiftieth anniversary of the death of Fritz London, who has been one of the most distinguished scientists on the Duke University faculty, and an internationally recognized theorist in Chemistry, Physics and the Philosophy of Science. His predictions in the field of low temperature Physics have deeply influenced the development of the fields of quantum fluids, quantum solids and superconductivity. Under quantum fluids and solids, one understands the fluid and solid phases of very light molecules such as $^3$He, $^4$He, H$_2$ and D$_2$. Both liquid $^3$He and $^4$He become superfluid at temperatures of respectively ~ 2 mK and ~2 K, depending on the pressure to which they are subjected. The solids have large zero-point motions leading to unusual properties. London made specific predictions on the properties in the superfluid and the normal state of these fluids, and on superconductors as presented in two classic monographs: “Superfluids I: Macroscopic Theory of Superconductivity and Superfluids II: Macroscopic Theory of Superfluid Helium.

London, a refugee who immigrated to the United States in 1939, was born in Breslau, Germany, (now Wroclaw, Poland) in 1900. He was appointed Professor of Chemistry at Duke University in 1939, following positions at Oxford University and at the College de France in Paris. He later held a joint appointment with the Physics Department, and became a James B. Duke Professor. His untimely death came at the age of only 54. His influence led to the creation of the low temperature physics laboratory at Duke in 1952 when William M. Fairbank joined the faculty. Fairbank had many fruitful interactions with London, and in February 1954 he and his graduate students were able to observe the beginning of the Fermi degeneracy in liquid $^4$He between 0.2 and 1 K, as measured by means of the nuclear susceptibility. This observation confirmed London’s expectations, shortly before very imaginative experiments with both $^3$He and $^4$He, and also with superconductors, and his laboratory became quickly recognized as an outstanding pioneer in this area. He left for Stanford in 1959, and Horst Meyer was appointed as his successor, further developing the program of Fairbank on the quantum fluids and solids. This program, which also included solid H$_2$ and D$_2$ and magnetism in solids, has been funded by federal agencies over a period of more than fifty years. In 1962, Henry Fairbank, William’s brother, joined the Physics Department as Chair and started his own laboratory with a Low Temperature Physics program on liquid and solid helium. Robert P. Behringer, appointed in 1982, led a group studying dynamic properties of liquid helium until 1999, when his interests became entirely directed to granular flow at room temperature.
To honor the memory of London, there is an annual endowed lecture, the Fritz London Memorial lecture, given by distinguished physicists and chemists. Among the 44 lecturers until this year, 23 obtained the Nobel Prize in Physics or in Chemistry, some of them receiving the Prize after presenting the lecture. The London lecture is sponsored in alternate years by the Physics and Chemistry Departments. In Spring 2004, with Physics as sponsor, the lecturer was Professor Myriam Sarachik, a distinguished Condensed Matter experimentalist and member of the National Academy of Sciences, who had just finished her tenure as President of the American Physical Society. Horst Meyer has organized the Physics lectures over the past 25 years. The endowment of these lectures was established by John Bardeen, a theorist like Fritz London and co-recipient of two Nobel Prizes. He was an ardent admirer of London and gave the money from his second Nobel prize to create the endowment at Duke to honor London.

Another memorial honoring London was created in 1957 by members of the low temperature physics community with the establishment of the Fritz London Memorial Prize. It is awarded on the first day of each International Conference on Low Temperature Physics, held every three years. This prize is intended to recognize outstanding experimental and theoretical contributions to low temperature physics. It is funded in part by the Bardeen endowment, by another endowment created at Duke University by other donors, and by a cash gift from Oxford Instruments Company. An international committee of five members distributes the Prize after due process of nominations and deliberations, and Duke University is responsible for the disbursement of the prize. * The next Prize distribution will be in 2005, and the present year is a busy one with the organization of the committee, and the call for nominations and their processing.

A scientific biography of Fritz London, written by K. Gavroglu, was published by Cambridge University Press in 1995, and includes a chapter written by John Bardeen containing an appraisal of London's work. This book gives an account of London's life and activities and describes the astonishing range of his interests and accomplishments. Both the late Mrs Edith London and Horst Meyer were very involved in the start and the completion of this book.

Fritz London remains a most remarkable and influential scientist, whose reputation has not diminished with time. This is demonstrated by the number of citations of his articles and books over the years. A search has been made by our librarian, Mary Ann Southern, starting in 1978. It shows that the number of citations, restricted to one article in 1938 and to the two books on superfluids published in ’50 and ’54, has remained steady at roughly 40 per year, a remarkable result. A quotation from a recent letter to Horst Meyer by Eric Cornell, Nobel Prize in Physics in 2000, is particularly revealing. He wrote:

“I rarely explicitly cite London, as important as his work is to the foundations of Bose-Einstein condensation, for the same reason that I rarely cite Einstein: the ideas are now so thoroughly incorporated into the community that one forgets one’s obligation to give credit for them!”

Hence several events: the lectures at Duke, the Prize at the International Conferences, as well the biography and frequent citations of his name and works in the scientific literature keep his name a familiar one in the scientific world.

*The three trustees for this prize are Robert C. Richardson (Cornell U), Moses Chan (Penn State U.) — both with strong connections to the Duke Physics Department — and Robert P. Behringer. Furthermore Horst Meyer, a former London Prize co-recipient, is the monitor and liaison between Duke University, the trustees and the Prize committee — contributed by Horst Meyer, Fritz London Emeritus Professor of Physics
Hertha Sponer, one of the three first women to obtain the PhD degree in physics in Germany, was Physics Professor at Duke University from 1936 until her retirement in 1965. She was well known for her experimental work on spectroscopy, where she had collaborated with the theorist Edward Teller, among others, and mentored several graduate students. This portrait is on long-term loan from the Duke Museum of Art to the Physics Department.