Department Happenings

— from the Chair, Daniel Gauthier

The 2006–2007 academic year has been a time of great activity and of great loss. On the upside, several faculty were reviewed for reappointment or promotion, an external review team evaluated the Department, faculty searches were underway, and our research and teaching activities again flourished. Tragically, Dr. Mary Creason, Director of Introductory Laboratories, was killed in an automobile accident late in the spring (see the article on page 9 by Dr. Robert Brown). She will be greatly missed in the department.

In this note, I'll summarize some of our activities. In separate articles, you can learn more about developments in our teaching programs, our undergraduate and graduate students’ accomplishments, and several exciting research topics currently being pursued here at Duke Physics.

External Review

All Departments at Duke undergo an external review of the research and teaching programs, typically every five years. In March 2007, Profs. Robert Austin (Princeton), Lene Hau (Harvard), Wick Haxton (University of Washington), James Langer (University of California, Santa Barbara), and Tom Lubansky (University of Pennsylvania) visited the Department for two days where they met with administrators, faculty, and students as part of our review.

In their opinion, Duke Physics is an excellent Department, but its national reputation is not commensurate with the reputation of Duke University as a whole. To attain the next level of excellence, they advise the Department to: 1) focus several new faculty hires in the area of biophysics in consultation with the biological and medical communities at Duke, with care taken to ensure that its primary focus be in Physics; and 2) hire faculty in the general area of neutrino physics and related nuclear/particle astrophysics, where these faculty would be part...
of a joint effort between TUNL and the particle-physics group as well as efforts at other Triangle universities. The Department will be discussing this advice over the fall semester and will incorporate it into our plan for the future.

Bricks and Mortar
Both major building projects were completed on time this year! The French Sciences Building opened in January 2007, where Physics has a relatively small amount of space in the building. TUNL has a large assembly area that makes up for the loss of the High Resolution Laboratory, which was torn down to make room for the new building. In addition, we have added approximately 4,500 sq. ft. of modern laboratory space for Profs. Chang, Gao, and Lin, with the possibility of adding another 2,200 sq. ft. in the future. Also, we have four faculty offices, one post-doc office, a small conference room, and a graduate student office for up to 15 students. This space is near chemistry faculty involved with imaging and nanoscience.

The Advanced Physics Laboratory area (in the sub-basement) was completed last summer in time for classes. The area houses the Advanced Laboratory (PHY 217), and the laboratories for Modern Physics (PHY 143) and Electronics (PHY 171). The space is greatly improved, has a seminar room and (finally) a bathroom! In fall 2007, the space will be dedicated officially in honor of Profs. Hertha Sponer (who originally used the space for spectroscopy experiments) and Horst Meyer (who created and taught for many years the Advanced Laboratory course).

Faculty News
The department was very busy this year reviewing faculty progress. I am happy to report that: Profs. Mark Kruse, Kate Scholberg, and Ying Wu have been promoted to Associate Professor with tenure, effective July 1, 2007; Prof. Chris Walter has been reappointed for a second four-
year term as an Assistant Professor, effective January 1, 2007; Prof. Thomas Phillips has been reappointed for a four-year term as an Associate Research Professor, effective July 1, 2008, and Dr. William McNairy has been reappointed for a one-year term as Lecturer, effective August 1, 2008. Congratulations to all!

Drs. Karen Daniels and Dipangkar Dutta, have been named Adjunct Assistant Professors of Physics. Prof. Daniels is on the faculty at NC State University and conducts experimental research on nonequilibrium/nonlinear systems including granular materials, gels, surfactants, and thin liquid films. Prof. Dutta is on the faculty of Mississippi State University and conducts experimental research focused on precision measurement of fundamental properties of nucleons.

We are fortunate to have several visitors this year. Drs. Martine Chevrollier and Marcos Oriá are both from the Departamento de Física—CCEN, Federal University of Paraíba, João Pessoa, Brazil. Prof. Chevrollier is working with Prof. John Thomas's group and Prof. Oriá is working with my group. Dr. Rongchun Lu hails from the Institute of Modern Physics, Chinese Academy of Science, and is working with Prof. Haiyan Gao’s group. Dr. Rodolfo Jalabert is from IPCMS—Gemme, Strasbourg, France and worked with Prof. Harold Baranger’s group. Dr. Kang Seog Lee is from Chonnam National University, South Korea, and Dr. Ghi Ryang Shin is from Andong National University, South Korea and both will be working with Prof. Berndt Mueller.

Drs. Mary Creason and William McNairy, as officers of the North Carolina Section of AAPT, were part of the group organizing the National AAPT meeting, which was held in Greensboro, NC, July 28–August 3, 2007.

Two of our faculty members have been named Fellows of the American Physics Society! This is a prestigious honor—only a small percentage of the membership can be elected as Fellows. Prof. Calvin Howell is cited “For precision measurements of the nucleon-nucleon interaction in few-body systems using polarization observables and for service to the scientific community, especially by mentoring students at historically black colleges and universities.” Prof. Glenn Edward is cited “For seminal research in the rapid thermodynamics governing infrared-laser ablation of tissue and for quantifying force producing processes in tissue dynamics during dorsal closure, a stage of Drosophila morphogenesis.”

Prof. Berndt Mueller was recently recognized as a HOPE professor. HOPE, or Honoring Our Professors’ Excellence, is the university’s way of recognizing faculty members who have made a positive impact in the lives of our students. HOPE professors are selected based on nominations by undergraduates who were invited to identify a professor who has made a “difference that matters” in their undergraduate experience.

Prof. Petters is in the news again! Through his organization, the Petters Research Institute, he is promoting excellence in the fields of math and science in Belize. During the past summer, he ran a three-week “boot camp” to train cadets in the Belize Defence Force. Stories about his work appeared in a story from Channel 5 (Belize) and on a recent NOVA program (see: http://www.pbs.org/wgbh/nova/sciencenow/3411/04.html)

Our Experimental High Energy Physics group has been making waves again. On January 8, 2007, the results of a precision measurement of the mass of the W boson were announced. The W boson is the carrier of the weak nuclear force and a key parameter of the Standard Model of particles and forces. This project was spearheaded by Prof. Ashutosh Kotwal. This new measurement places important constraints on a possible Higgs particle, indicating that it is lighter than anticipated. With this lighter mass, there is the possibility that the Higgs can be discovered at FermiLab. With this in mind, FermiLab has created a “Higgs discovery group,” which is co-Convened by Prof. Mark Kruse. Perhaps data collected at FermiLab might allow for detection of the Higgs before the Large Hadron Collider turns on.

Bob Behringer's group, in collaboration with Prof. Luding's group at the Technische Universiteit Delft in the Netherlands, recently published a paper in Physical Review Letters describing their observation of a jamming transition in granular systems. For the first time, they observed a power-law increase in the number of contacts and the pressure of the material, and find good agreement with simulations and reasonable agreement with a mean-field theory. Talk of the work has appeared in the New Scientist, Science Magazine, and the Virtual Journal of Nanoscale Science & Technology.
Prof. Anna Lin will be on a leave of absence for the coming academic year to further develop her interests in clinical psychology. In an effort to develop a history of the Department, Prof. Horst Meyer has started to create websites about some of our more prominent faculty. So far, he has compiled sites for Profs. Walter Gordy, Hertha Sponer, and Fritz London. (See: http://www.phy.duke.edu/people/). We are also in the process of putting together a more comprehensive history of the Department (see Department History below).

Postdoc News

Dr. Andrey Turlopov, a post-doctoral research associate in Prof. Thomas’ group, has accepted a permanent position as a Research Scientist in the Institute of Applied Physics, Russian Academy of Sciences, Nizhniy Novgorod, Russia. Andrey started his position in November 2007.

Dr. Lucas Illing, a senior research scientist in my group, has recently started as an Assistant Professor at Reed College in Portland, Oregon. Reed is a liberal arts college with a strong commitment to undergraduate teaching and research.

Congratulations to both Drs. Turlopov and Illing!

Staff News

I am sorry to report that, after 17 years of dedicated service to Duke and the Department, Ms. Maxine Stern will be retiring. She will continue with us part time through spring 2008 to help with the transition and to work on specialized projects. We all owe her a great round of thanks for all that she has done for us.

Mr. Randall (Randy) Best will be taking over Maxine’s responsibilities as Administrative Manager of the Department. Randy was previously the Associate Director of the Duke Center on Global Change. Before that, he took a course of study to be certified as an Ethical Culture Leader, was the Administrative Manager for the Duke Chemistry Department for 9 years, was the Director of Administration and Finance for the Capital Area Transit Authority in Raleigh for 3 years, and was the Deputy Director of Budget and Finance for the Rapid Transit Operations Department of the New York City Transit Authority for 9 years, and held various other positions in transit authorities around the country. He brings a wealth of management and financial skills, is very familiar with the Duke system, and has run complex operations like the Physics Department in the past. He also has served as a voluntary mediator on campus and has been an active participant in refining the Duke Harassment policy. We look forward to working with Randy in the coming years!

Leadership Changes

The Department now has a new Director of Graduate Studies. Prof. Roxanne Springer stepped down on June 30 after a three year term as DGS. She has been truly dedicated to the graduate students in the Department, striving to make the rules and regulations as transparent as possible and to create a system that is fair to all. I would like to thank her for her dedicated service to the Department and program. The new DGS is Prof. Richard Palmer, who is also committed to excellence in our graduate program.

Department History

Many of us are in the dark regarding the history of Duke Physics. Before all records are lost, I have asked Maxine Stern to begin to compile information about the Department, starting from the beginning. She will be going through the Duke archives as well as old files hidden in nooks and crannies in the Physics Building. Please send her any anecdotes or photographs that you think might be appropriate for this compilation. We hope to have the beginnings of a Departmental history on our web site in the not-too-distant future.

Outreach

While many in the Department are very active in outreach activities in the community, I would like to mention an especially “visible” event. Prof. Ronen Plesser hosted a viewing of the lunar eclipse in March at Forrest View Elementary school. The weather cooperated with clear skies to the east and it was not too cold out. The rising of the moon was clearly visible even in its eclipsed state, and it was spectacular to watch as the moon moved out from the earth’s shadow. Approximately 150 people attended the event, with many from the Physics Department in attendance.
In the May 2007 Duke Graduation Ceremonies, nine Physics students received Ph.D.'s:

1. **Sebastian Carron-Montero** for “Measurement of the $t\bar{t}$, $WW$ and $Z_\tau \tau$ Production Cross Sections in $p\bar{p}$ Collisions at $\sqrt{s}=1.96$ TeV,” with Mark Kruse;
2. **Yao-Li Chuang** for “Stability and Scalability of 2D Swarming Patterns,” with Andrea Bertozzi;
3. **Fu-Jiu Jiang** for “The Phase Diagram of Two Color Lattice QCD at Strong Coupling,” with Shailesh Chandrasekharan;
4. **Emily Longhi** for “Coherent Harmonic Generation in Storage Ring Free Electron Lasers,” with Vladimir Litvinenko;
5. **Trushant Majmudar** for “Contact Force Measurements in Sheared and Isotropically Compressed Granular Systems,” with Bob Behringer;
6. **Bradley Marts** for “Dynamics and Pattern Formation in a Parametrically Forced Oscillatory Reaction-Diffusion System,” with Anna Lin;
7. **Anand Priyadarshee** for “Quantum Critical Behavior of 2D Hard-Core Bosons,” with Harold Baranger;
8. **Brian Tighe** for “Force Distributions and Stress Response in Granular Materials,” with Josh Socolar; and

Congratulations to these students and their advisors. We look forward to hearing great things from you in the future.

Preliminary exams were passed this past academic year by Leah Broussard, Wei Chen, Nasser Demir, Botao Jia, Mary Kidd, Nathan Kundtz, Peng Li, Shomeek Mukhopadhyay, Bryon Neufeld, Hans Norrell, Changchun Sun, and Huidong Xu. Congratulations to them on becoming candidates for the Physics Ph.D. Chee Liang Hoe earned an MA degree and Jun Uehara earned an MS (with thesis) degree.

Duke graduates make use of their physics Masters and Ph.D. degrees to pursue a wide variety of careers. We hope they will continue to maintain contact with Duke Physics and be a mentoring resource for our Physics graduate students. Our recent (or soon-to-be) graduates are (or will be) employed in the following positions: Brian Bunton, visiting assistant professor at Coastal Carolina University; Sebastian Carron-Montero, postdoc at the University of Toronto in high energy particle physics; Yao-Li Chuang, postdoc at UC-Irvine in Applied Math; Joe Kinast, postdoc at the University of Arizona in Electrical and Computer Engineering; Emily Longhi, Diamond Light Source, UK; Trushant Majmudar, postdoc at MIT in Mechanical Engineering; Alex Makarovski, postdoc at Duke in Physics; Bradley Marts, postdoc at Florida State, Department of Chemistry; Matthew Prior, Principal Scientist at GlaxoSmithKline; Samadrita Roychowdhury, Scientist at Xerox; Amanda Sabourova, Idaho National Laboratory; Robert Saunders, postdoc at Duke in Radiology; Jun Uehara, Scientist at Northrop Grumman; and John Wambaugh, Physicist at the National Center for Computational Toxicology, US EPA.

**Awards:** Xing Zong (pictured) won the Graduate Student Samuel DuBois Cook Society Award; John Foreman won the Fritz-London Graduate Fellowship. Last year’s Graduate Teaching Fellowship was earned by Hans Norrell; Kristine Callan is the recipient for the coming year. Andy Dawes won a prize as a finalist for the Optical Society of America’s New Focus/Bookham Student Award at the 2006 Conference on Lasers and Electro-Optics.
This January 2007, five graduate students successfully completed their qualifier exam requirement. This May of 2007 an additional eight students completed that requirement.

The graduate student mentors this year were very important in helping to make our Fall 2006 incoming graduate class feel welcome. Thank you for your efforts Carolyn Berger, Matthew Blackston, Kristine Callan, Wei Chen, Andy Dawes, Nasser Demir, Joel Greenberg, Mary Kidd, Matt Kiser, Nathan Kundtz, Peng Li, Hans Norrell, Phillip Wu, Alan Ye, Peidong Yu, and Xing Zong.

Thank you to the Physics Graduate Student Organization for again marshalling the considerable talent and enthusiasm of our graduate students to help with recruiting during our Open House 2007, held February 15–16. Educating our applicants about what life for them might be like at Duke is not possible without our graduate students to showcase the research done here.

Our Fall 2007 incoming class consists of ten students. They originate from China, Iran, and the United States. We will also host one exchange student. Four matriculants are already on campus doing research this summer of 2007. The interests of the class include nanophysics, atomic physics, quantum optics, nuclear physics, and high energy physics.

I would like to thank everyone who made the position of DGS a rewarding one for me during my three-year term. The graduate students themselves, their intelligence and enthusiasm, made it a pleasure for me to help guide the next generation of scientific leaders.

I wish to welcome Richard Palmer as the new Physics Director of Graduate Studies for the 2007–2010 academic years. I have every confidence that Richard will build on the changes I have instituted over the past three years, adjust those procedures that need adjusting, implement further improvements, and create a dynamic and intellectually challenging environment for our students.

A special thank you to Donna Ruger, DGS-Assistant, for her dedication and commitment to providing support to our graduate students, bringing her considerable creative problem solving abilities to helping students navigate the sometimes intricate Duke system.

Left to right, top: Richard Palmer, DGS; Mengyang Sun; Ethan Elliott; Sebastian Eiser (exchange student); Baolei Li; Donna Ruger, DGSA.

Left to right, bottom: Yang Yang; Willie Ong; Rene Zhu; Jie Ren; Seth Cohen.

Somayeh Farhadi (above, left) and Mark Steadman (above, right) also join the Fall 2007 incoming class.
I am very happy to take on the role of Director of Graduate Studies (DGS) for Physics. I care deeply about the graduate students and the Physics Department, and I believe that I can improve it, particularly by fostering a more welcoming culture in our community. Making the system run smoothly and making everyone feel part of the community will help us better achieve our teaching and research goals.

I have the “Responsibilities of the DGS” from the Graduate School’s manual. There are many different tasks the DGS performs, from signing forms to serving on committees. But the best part for me is serving “as initial advisor and continuing advocate for all graduate students.” Of course I will help with one-on-one mentoring, resolving conflicts, monitoring students’ progress, and so on, but beyond that I will look for ways to improve the social and working lives of our graduate students. I will work with the Graduate Student Organization (GSO) to organize social activities, make connections to other departments and the Graduate School, and to establish a truly international climate. With the Chair, I will attempt to locate space for a Graduate Lounge.

There is a power differential between graduate students and the faculty, and this will continue to exist, but I think that we can establish more respectful and productive interactions, including get-togethers, receptions, and events. Also, I will ask the faculty to add graduate student representatives to some additional Physics committees and meetings.

I have had an interest in gender issues for over 20 years, in race issues for about 10 years, and in national origin issues for about 3 years. I believe that we all have stereotypes, and we use them many ways. Virginia Valian has said “gender schemas [essentially stereotypes] are ubiquitous, persistent, and resist change, so we have to be constantly working to counter them” (APS News, June 2007). As the DGS, I can, and will, be “constantly working to counter” gender stereotypes, race stereotypes, and national origin stereotypes.

I plan to develop better graduate program webpages, including opportunities and brochures for applicants, resources for present students, and news for present and former students. The Graduate Brochure has been “in the process of being updated” for several years, but it is now one of my tasks and I intend to act upon it. Our department has not offered much in the way of career planning beyond the standard academic track. Like most other faculty, I don’t have much expertise outside the academic track, but my goal is to develop programs and contacts to address the career needs of all of our graduate students. Some written department policies are clear and useful, but many are not. I will work, with other departmental leaders, to improve policies and expectations, and create web sites that adveritze them. Too often there are implicit expectations; I intend to make these explicit. At the same time, I will be careful to acknowledge and retain graduate student rights and responsibilities.

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For most I wish to develop a more welcoming community in our graduate program. Therefore I will not tolerate poor behavior. My creed: “Be Nice Or Leave.”

I thank Roxanne Springer for helpful comments.
With summer over and the new school year underway, it is a good time to reflect on the past and plan the year ahead. Undergraduate teaching is one of our prime objectives and we always need to evaluate ourselves to see if we are putting forth our best efforts. This was my first year as the Director of Undergraduate Studies. As with everyone who starts a new responsibility, there were ideas and plans which met reality. But overall, we survived another year very well with tireless help from Chrystal Stefani and Donna Ruger.

This year, nineteen students received physics degrees in the 2007 academic year. Two were December 2006 graduates. Fourteen students were physics primary majors, three were physics secondary majors and three were minors. Out of thirteen primary majors, seven are headed to graduate schools: Ray Aikens—San Francisco State University, Alvaro Chavarria—Princeton, Joyce Coppock—University of Maryland, Konstantyn Fastovets—Graduate School in Moscow or Kiev, Troy Mestler—Princeton, Richard Wall—Yale, Katie West—University of Houston. Two students (Eric Conn and Roarke Horstmeyer) are entering into teaching. Jeremy Huang went back to Singapore to join the civil service. Benjamin Reed is planning to go to the Middle East to learn language. The plans for William Meyers and Thayer Moeller are not yet concrete. Much good luck to them all.

I am certain that all in the department are proud of their accomplishment as this class followed in the tradition of academic excellence. One impressive example of the work of some of the students is their senior thesis. Six of our seniors graduated with department distinction (highest honor) by completing a research project and writing and defending their theses in front of four faculty members. Their theses are on the web (http://www.phy.duke.edu/ugrad/senior_thesis.ptml) and are very good in quality.

Taking in students and guiding them is a lot of effort, and I would like to praise the faculty members who have done such an excellent mentoring job. I believe that undergraduate research is one of the areas in which our department excels. Students also very much appreciate the discussion time with faculty members (whether or not it is about physics).

We initiated a couple of programs to broaden the options for the majors. One was an astronomy concentration program, in cooperation with the UNC Department of Physics. The concentration still requires all core courses including QM courses, but replaces the electives and Advanced Laboratory course with astronomy and astrophysics courses. Some of the courses can be taken at UNC. Another initiative was in biophysics. With the exciting recent progress in biology in areas like genetics, physicists trained in computation and problem solving can make key contributions. Presently the only way to major in biophysics is through program II, which is somewhat cumbersome. In cooperation with the biology department, we are trying to create a major in biophysics. Initial feasibility studies were carried out and the purpose and course outlines were created. The course outlines can be used by Program II students. We hope to get University approval in the coming year.

One bit of information I would like to share is the set of survey results involving students who were in the major physics sequence courses, including first and second year students. I believe this was the first survey that focused on our majors. The survey indicated that students are generally satisfied with course offerings, and with the quality of courses and instructors. These findings are not very different from the course evaluations filled out by students every semester. One area that can be improved immediately concerns introducing students to the research in the department and the independent study opportunities. We (with SPS) plan to organize a gathering once a month with all undergraduate students interested in physics. This would be informal and a faculty member would give a 20 minute presentation of his/her research area with a lot of open discussion. This is not too different from the present successful seminar course for graduate students. This type of gathering could also increase faculty interaction with students.

The survey revealed some gender problems. When asked if the courses have fostered and deepened their interest in physics, the female students tend to be less positive than male
students. A similar response showed up regarding research and outside class experiences. Overall, female students are less satisfied than male students. It is also interesting to note that the first and second year students were less positive than upper class students. Some of these problems can be rectified by providing and encouraging more contact with the faculty inside and outside of class. We will make a concerted effort to correct this.

For our annual department poster session held with graduate students in May, there were eight undergraduate research posters, where students presented their latest research results. This is an opportunity for students to show off their work. As usual, the quality of topics and work were very good. First prize went to Katie West for her neutrino related work. During the poster session, twelve students were inducted into the Duke chapter of ΣΠΣ, the national physics honor society. Prof. William McNairy, the faculty adviser, conducted the ceremony. The new members are: Alejandro Caceres, Alexander Frank, Christina Herring, Christopher Lester, Sepehr Sadighpour, Tutanon Sinthuprasith, David Staub, Jefferson Kist, Sebastian Liska, Crystal Senko, Woo Jhon Choi, and Daniel Roberts.

As some of the SPS (Society of Physics Students) members graduated, new officials were elected. For the 2008 academic year the new officials are: Barry Wright (President), Sebastian Lisko (Vice President), Tutanon Sinthuprasith (Secretary), Ariana Minot (Treasurer), and Alex Tuna (Social Chair).

SPS has been successful in promoting friendship and information sharing among students. It holds regular meetings with food and occasional seminars. We are encouraging SPS to be more active this year. The gathering with faculty mentioned earlier will likely be sponsored by SPS. There are also plans to form a GRE study group and hold seminars on career and graduate school planning. In order for SPS to be more successful, I would like to make a strong pitch to all faculty that they make an effort to participate in some of these activities. Students may not say it explicitly, but they appreciate when faculty show interest in their lives.
On May 12, 2007, Dr. Mary Creason and her husband Jim were both killed in an automobile accident near their home in Kernersville, North Carolina. She was survived by both parents and her four children, Joe, Shannon, Cory and David. Mary was a truly beloved member of the physics department. Her joy in life, her passion for teaching, the love she showed to both her colleagues and the students she worked with, and the excellence of her work supporting the teaching of many, many physics classes will be sorely missed by students and faculty alike.

In the late 1990’s the physics department underwent something of a crisis in undergraduate teaching. The department was still using lab equipment that was purchased some time around World War II in much of its undergraduate teaching and the global demographics of our graduate student teaching assistants was undergoing a sea change of sorts, with far more students from overseas arriving with relatively poor English skills and little teaching experience. These students were then expected to work as teaching assistants in the introductory courses with little faculty oversight or mentoring, often with disastrous results.

Then one day Mary was just there, as if she’d always been there. She took over the labs and over the next eight years our labs steadily improved. She took our entering graduate students under her wing and was their boss, their mentor, their teacher…and their friend. Working closely with the teaching faculty, holes were plugged, problems were solved, poor English skills were strengthened, new things were tried. And yes, things got better. A lot better.

Mary was a tireless advocate of good teaching. She was extremely active in the Association of American Physics Teachers (AAPT) and held office there as she helped to organize meetings and promote the development of still-better teaching methodology. She was a pre-major advisor. She taught a course in Forensic Physics that was one of the most popular courses we ever offered (where ironically, students were given problems analyzing the skid marks made by vehicles as they collided). Mary could make a physics experiment out of inner tubes and water balloons, out of blocks and boards, out of screws and some magnet wire—and make them fun.

Over the years I and many of my colleagues and friends spent many hours sitting in Mary’s office, talking about this and that—our children, the home she and her husband were building with their own hands, how to put just a little more inspiration into the courses we taught together and get just a little more effort out of the students in those courses in return. Sometimes students would join us, or other faculty—Mary’s door was basically never closed.

Alas, now it is closed forever, and we miss her.

In Memoriam: Dr. Mary Creason

Dr. Mary Creason

Creason Graduate Student Excellence in Teaching Award for Physics

At the wish of Mary’s children Shannon, David, Cory and Joe, the Physics Department established a special fund in Mary’s name to provide an annual fellowship to be given to a student who excels in teaching physics in the Introductory Physics Laboratories at Duke.

If you would like to contribute to this fund, please send a check to Randy Best, payable to Duke University, with “Creason Fund” written on the check’s memo line. All contributions to this fund are tax deductible. Donors will receive an acknowledgment from the Duke Physics Department. Our goal is to try and raise $25,000 for the fund.

Contributions may be sent to: Randy Best, Duke University, Department of Physics, Box 90305, Durham, NC 27708.
On July 19, 2007, one of the Physics Department’s former graduate students, Michael Ryschkewitsch, was named Chief Engineer of NASA by the agency’s Administrator, Michael Griffin. Quoting from the official NASA announcement: “As chief engineer, Ryschkewitsch will be responsible for the overall review and technical readiness of all NASA programs. The Office of the Chief Engineer assures that the agency’s development efforts and mission operations are being planned and conducted on a sound engineering basis with proper controls and management of technical risks.” This is a highly significant appointment with substantial responsibility.

Michael came to Duke as a graduate student in 1973 after graduating with a B.S. in physics from the University of Florida in Gainesville. He joined the low temperature physics group of Horst Meyer and first he collaborated with a Duke postdoctoral associate, Moses Chan, performing high-precision measurements of the dielectric constant of liquid and solid $^4$He. (Chan himself, since 1980 at Pennsylvania State University, has a distinguished career of his own, recipient of the Fritz London Prize in 1996 and member of the National Academy of Sciences). Subsequently Mike was involved with Chan and other graduate students in measuring static and dynamic properties of liquid $^3$He-$^4$He mixtures near phase transitions. He was a very practical person who not only got his equipment to work, was perseverant and very good in data taking, but also was frequently consulted by friends in distress over cryostat problems, and usually came up with practical and simple solutions that others had not thought about. He truly got things done and was fun to work with.

After obtaining his PhD in summer 1978, Mike became a postdoctoral associate at the University of Delaware, doing high pressure physics research under the direction of a prominent specialist in this field, William Daniels. In 1982 he joined the NASA Goddard Space Flight Center as a cryogenic engineer and worked on the Cosmic Background Explorer mission. He gradually became involved in increasingly important management responsibilities. Among them was the first servicing mission of the Hubble Space Telescope in 1993, and most recently the mission on the Aeronomy of Ice in the Mesosphere (AIM), launched in April 2007. The AIM satellite is to study polar mesospheric clouds, which occur in the Earth’s atmosphere at altitudes far higher than other clouds.

Ryschkewitsch has received numerous recognitions during his career at NASA, among them the NASA Exceptional Service Medal and the NASA Medal for Outstanding Leadership.
Jimmy Dorff

Jimmy Dorff joined the Duke Physics department in November 2005 as the senior systems programmer. In this role he keeps the departments many servers and computer infrastructure running smoothly. Before joining the department, Jimmy had worked for Nortel Networks in Research Triangle Park for seven years. While at Nortel, Jimmy worked on telephone billing systems and network management applications, always focused on the operating system component of those products. “My professional interests and experience are in UNIX systems, so I was happy to join a Linux focused department” Jimmy explains, “I’ve also had a life long interest in science, so this position is ideal.”

Jimmy and his wife Jennifer live near RTP in Morrisville, NC. “Our backyard adjoins RTP, so you really can’t live any closer to RTP.” Jennifer works in RTP for American Scientist magazine, published by Sigma Xi, The Scientific Research Society. She is completing the MBA program at Meredith College this fall. Jennifer and Jimmy met while they were both undergraduates at High Point University. Jimmy later earned a Master’s degree in Computer Science from Wake Forest University.

Jimmy and Jennifer enjoy traveling, although some of their trips are non-traditional. “I love attending auto shows, so we normally take a weekend trip to Detroit in January. That’s not a ‘standard’ vacation in any sense” says Jimmy. Other odd trips include going to see the Green Bank Radio Telescope and catching up with a team driving around the world in the most fuel efficient production car. Jimmy says he has “always been interested in cars, especially the small and unusual.” His other interests include photography, both analog and digital. He photographed two weddings last summer and has taken several photography classes at the Durham Arts Council.

Randall Best

Randy spent 16 years working in Public Transportation at the Federal, State and Local levels. In 1994 has began working at Duke as the Administrative Manager of the Chemistry Department. In 2003–2004 he took a year’s educational leave to complete his training as an Ethical Culture Leader (Humanist Minister). Upon returning to Duke he worked in the DCRI and the Center on Global Change before coming to the Physics Department in April 2007.

Randy lives in Durham with his wife Sarah, a ceramic artist. They have home-schooled their four children; the oldest three are currently attending college. Randy also commutes to work every day by bicycle.
Basketball

There's no denying the fact that when you come to Duke University, you inevitably become a basketball fan. The fervor held by the undergraduates is contagious.

The games are so popular that tickets for graduate students must be won through a test of endurance known as “camp-out.” For thirty-six hours, students must be ready at any moment for random check-ins. Those present at every check-in are then entered into a drawing for the chance to buy season tickets. The participants in this year’s camp-out from the physics department were Kristine Callan, Matt Kiser, Abhijit Mehta, Bryon Neufeld, Peng Li, Nathan Kundtz, Brad Marts, Adrian Juarez, and Ivan Borzenets. Five season tickets were won, which were shared among the participants.

Graduate students don't just watch basketball. A group of physics grad students and postdocs gets together most Thursday evenings for some basketball action. There are usually 6–12 participants. Recently, the biology-ballers have also been invited to join. To get on the hoops e-mail list, please go to http://mail.tunl.duke.edu/mailman/listinfo/hoops.

GSO Events

One of the goals of the Graduate Student Organization this year was to promote a feeling of community within the department. The department sponsored a Math/Physics Social to further this cause. The social was well attended from both sides and hopefully there will be more in the future.

Grad Student Travel

Much of physics research can be done from a desk through a computer. However, some research requires specific or unique facilities. Physics collaborations allow students at different locations to take advantage of these valuable resources. One example is Leah Broussard, who is studying the lifetime of Neon-19 at the TRImP facility at the Kernfysich Versneller Instituut in Holland. Leah has made multiple trips to Holland in the past year to contribute to the experiment being performed there. Leah also travels to Los Alamos National Lab where she is a part of the UCNA Collaboration, which measures the beta asymmetry of the neutron.

Volleyball

Every spring, the physics graduate students begin their weekly games of volleyball. A friendly, non-competitive atmosphere contributes to the popularity of the games. This year, the weekly sessions were advertised on the GPSC student forum, and the games now include students from many different fields. This is an excellent way to meet graduate students in other concentrations, such as BME, biology, and chemistry. Join us on Wednesdays at 6:00 pm behind Gross Chemistry.

GSS

The Graduate Student Seminar has always been a forum for graduate students to present their research to a friendly audience of their peers. This year, GSS expanded to include alumni of the department who spoke about finding a postdoc, and a casual session which focused on graduate student life. GSS meets on Fridays at noon and lunch is provided by the department.

Department Picnic

The 2007 Physics Departmental Picnic was a well attended event where we welcomed the new members of our community. Besides eating traditional cookout food, there were several activities to enjoy during the picnic, such as walking the slack line, and a friendly game of volleyball.

Walking the slack line at the 2007 Physics Picnic.
My research revolves around investigating the properties of highly excited strongly interacting matter, which is governed by the laws of Quantum Chromodynamics (QCD), one of the four fundamental forces of nature. The basic constituents of QCD are quarks which interact through the exchange of gluons. It is believed that shortly after the creation of the universe in the Big Bang all matter was in a state called the Quark Gluon Plasma (QGP). Due to the rapid expansion and cooling of the Universe, this plasma underwent a transition to form hadrons—most importantly nucleons—which constitute the building blocks of matter as we know it today. The investigation of QGP properties and the nature of the QGP to hadron transition will yield important novel insights into the development of the early universe and the behavior of QCD under extreme conditions.

More than a thousand experimentalists are working to recreate this highly excited state of primordial matter under controlled laboratory conditions by colliding two heavy atomic nuclei (i.e. heavy-ions) at relativistic energies and to study its properties. These experiments are currently underway at the Relativistic Heavy-Ion Collider (RHIC) at Brookhaven National Laboratory. Data from the first years of RHIC operations have yielded many interesting and sometimes surprising results which have not yet been fully evaluated or understood by theory.

The central problem in the study of the QGP is that the deconfined quanta of a QGP are not directly observable due to the fundamental confining property of the physical QCD vacuum. Instead, nature chooses to hide those constituents within the confines of color neutral composite many body systems—hadrons. One of the main tasks in relativistic heavy-ion research is to find clear and unambiguous connections between the transient (quark-gluon) plasma state and the experimentally observable hadronic final state.

My particular approach to this problem is the application of transport theory. Utilizing transport theory, models for the time-evolution of heavy-ion reactions can be developed which allow to establish the aforementioned connections between the fundamental properties of the transient QGP state and the hadronic final state. In microscopic transport models the full space-time evolution of all microscopic degrees of freedom—either all hadrons present in the system or alternatively (at higher densities and temperatures) quarks and gluons—is calculated from the initial state to the final break-up of the system. Over the past several years I have co-developed and worked on two such approaches, the Ultra-relativistic Quantum Molecular Dynamics (UrQMD) approach for the description of a hot and dense system of hadrons, and the Parton Cascade Model (PCM) for the evolution of a hot system of quarks and gluons. In addition I have spearheaded the development of a novel hybrid macroscopical/microscopical transport model, employing relativistic hydrodynamics for the early dense reaction phase of a heavy-ion reaction and microscopic non-equilibrium dynamics for the later, dilute reaction stages. Such hybrid models are to date the most successful approaches for the description of RHIC experiments, as has been confirmed by the latest fully 3+1 dimensional implementation of this model, which was recently completed by my former postdoctoral research associate Chiho Nonaka and myself (Chiho now has the equivalent of a tenured assistant professor position at Nagoya University). My graduate student, Nasser Demir, is currently involved in extracting transport coefficients (such as the shear viscosity and diffusion constant) from the microscopic evolution part of this model.

The early collisions among quarks and gluons that lead to the formation of the QGP often engender hard scattering which leads to the formation of two back-to-back partons with large transverse momenta. These traverse the dense medium and lose energy by gluon radiation before finally fragmenting into hadrons—a phenomenon which has been called jet-quenching.

Computations of such jet modifications have
acquired a certain sophistication in regards to the incorporation of the partonic processes involved. However, the role of the medium has so far been relegated to a furnishing of an overall density and its variation with time. The availability of a three-dimensional hydrodynamic evolution code as developed by Chiho Nonaka and myself allows for a much more detailed study of jet interactions in a longitudinally and transversely expanding medium. These interactions may lead for example to the formation of Mach-cones, since the speed of the high-$P_t$ parton exceeds that of the speed of sound of the QGP. Our group’s current postdoctoral research associate, Abhijit Majumder has developed a sophisticated state of the art jet energy-loss formalism, which allows him to use the aforementioned hybrid transport model to conduct a realistic and consistent calculation of all jet-quenching phenomena.

In addition to my work on QCD transport theory I have been active in the general area of QGP phenomenology, seeking out new observables which are sensitive to the properties of the transient QGP medium. In collaboration with Berndt Müller and our then postdoctoral research associates Rainer Fries (now an assistant professor at Texas A&M University and RIKEN-BNL Center Fellow) and Chiho Nonaka, I have been involved in developing the parton recombination model: data taken at RHIC on hadron spectra and emission patterns in heavy-ion collisions at transverse momenta ($P_t$) above 2 GeV/c have exhibited features which cannot be understood in the framework of basic perturbative QCD—which is surprising, since elementary proton+proton interactions in the very same domain of energy and transverse momentum are perfectly well described in that framework. My collaborators and I have shown for the first time that these tantalizing measurements are compatible with the assumption of hadrons being created via the recombination/coalescence of constituent quarks. A direct observation of hadronization via quark recombination of course implies the existence of a deconfined phase of partons (i.e. a QGP) from which these hadrons have been formed and is therefore of great significance to the field of QGP research.

**Figure 1:** Time evolution of a heavy-ion collision at RHIC and survey of applicable transport models to describe the dynamical evolution of the collision.
The Super-Kamiokande experiment is a giant underground water Cherenkov experiment in Mozumi, Japan, designed to capture neutrinos from the Sun and sky: the 11,000 inner detector photomultiplier tubes (PMTs) record photons from the charged products of neutrino interactions in the ultrapure water. In 1998, Super-K showed that muon neutrinos produced by cosmic ray collisions in the Earth’s atmosphere “disappear” by changing to almost-invisible tau flavor: the neutrinos “oscillate” from one flavor to another by interference of mass states. Such flavor change is only possible if neutrinos have mass. Neutrino masses and the parameters which govern neutrino flavor oscillation are deeply connected to both fundamental particle physics and cosmology.

Over the next few years, the Super-K atmospheric neutrino result was confirmed with K2K (“KEK to Kamioka”), a beam of artificial neutrinos sent 250 km through the Earth to Super-K from the KEK accelerator laboratory in Mozumi, Japan. The beam neutrinos “went missing” after their sub-Japan flight in exactly the numbers expected, and with exactly the expected energy dependence predicted by the oscillation hypothesis.

In 2001, an accident at Super-K—a chain reaction implosion of phototubes after a routine phototube replacement upgrade—destroyed two thirds of the light sensors. The surviving ones, along with available new ones, were redistributed around the detector (now with acrylic shell protection). “Super-K II” with half of the original PMT density ran from 2003 to 2005. Over the winter of 05/06, Super-K’s phototubes were fully replenished. Duke personnel spent many weeks in Japan working on the full reconstruction of Super-K. Duke’s particular responsibility was replacement of Tyvek (a white reflective material) in the outer part of the detector.

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Top: Grad student Roger Wendell, postdoc Naho Tanimoto, and faculty members Kate Scholberg and Chris Walter rest a moment floating in the center of Super-K, in front of the array of photomultiplier tubes, after the intense rebuild effort during the winter of ’05/06.

Bottom left: Replacing outer detector Tyvek.

Bottom right: The unusual amount of snow forced closure of the usual mine access tunnel, and we had to take the train into the mine.
A fully rebuilt “Super-K III” has been running since mid-2006, and the first analyses of the new data are underway.

The next physics quest for Super-K is the search for the last unknown neutrino oscillation parameter, \( \Theta_{13} \) (theta-1-3). The signature of non-zero \( \Theta_{13} \) is a tiny amount of electron neutrino appearance in a beam of muon neutrinos. The T2K (Tokai to Kamioka) experiment will provide a beam about 100 times more intense than K2K, starting in 2009. In preparation for T2K, Super-K is undergoing an electronics upgrade, and a software revamp as well. Postdocs Maxim Fechner and Naho Tanimoto are playing key roles in this upgrade.

The T2K experiment will comprise the beam, the Super-K detector at 295 km, plus two near detectors. One detector 280 m from the neutrino source will characterize the neutrinos before they fly off to Super-K. An additional detector 2 km from the source with a water Cherenkov detector, fine-grain tracker, and muon ranger components, will observe a flux nearly identical to that at Super-K. This “2KM” detector effort is being led on the US side by Prof. Walter.

The observation of non-zero \( \Theta_{13} \) is the first step for answering the question of CP (charge conjugation-parity) violation in neutrinos. It’s now well known that processes involving quarks violate CP symmetry; it’s suspected that the same is true for leptons (such as neutrinos), but leptonic CP violation is as yet unobserved. We hope that the understanding of CP violation, along with knowledge of the other neutrino parameters, may lead to insight into the question of the observed matter-antimatter asymmetry of the universe.

The long-term program of Super-K and the T2K long baseline neutrino beam experiment aims to answer these questions.

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The components of the T2K experiment.

The T2K 2KM detector. Note the scale relative to the people shown to the left of the LAr (Liquid Argon) component of the detector.
One of the great frontier problems in science is how brains work: how does a 3-pound 20-watt adult human brain consisting of one hundred billion ($10^{11}$) neurons with 100 trillion ($10^{14}$) interconnections self-assemble and carry out memory, vision, movement, learning, language, and insight? Although understanding brains would seem to be a problem more appropriate for biologists and psychologists, physicists have in fact made many experimental and theoretical contributions to brain science. Indeed, the next few decades should be golden years for physicists to become involved with brain research because of many experimental advances that are providing a flood of data regarding brain dynamics, and because of the need for quantitative thinking to understand such data.

From a physicist’s point of view, brains are intricate dynamical networks whose properties have some analogies to experimental systems studied in condensed matter physics, statistical mechanics, nonlinear dynamics, fluid dynamics, and network physics. But so far, brains are not easily understood, or not understood at all, in terms of these physics subfields and it is likely that new paradigms need to be developed. The key experimental and conceptual challenge arises from the high connectivity, with neurons in the human cortex receiving inputs from about 10,000 other neurons on average, and with some neurons receiving as many as 100,000 inputs (the Purkinje cells in the cerebellum). No experimental method is currently able to monitor all the signals that are transmitted to a given neuron from other neurons. As a result, it is not yet known what role any given neuron plays in brain information processing, and this of course hinders understanding how a massive network of such neurons function. Even if we could measure such signals for one or many neurons, theorists are not well prepared to understand such high-dimensional nonstationary data.

Excited by the abundant brain data becoming available and by neurobiology researchers that he has met at Duke, Professor Henry Greenside has spent the last several years shifting his research interests from nonequilibrium pattern formation to theoretical neurobiology. A two-year K25 award from the National Institute of Health, which started in June of 2006, has especially helped this transition by letting Professor Greenside learn about and carry out brain research full time, without having to teach. He is spending these two years in the lab of Duke Neurobiology Professor Richard Mooney. There, Professor Greenside is developing and testing theoretical models to understand some features of Professor Mooney’s experimental data, and carrying out some experiments so that he can appreciate first-hand how different kinds of data (physiological and anatomical) are obtained and analyzed.

Professor Mooney’s group uses songbirds to study so-called “auditory-guided vocal learning.” It turns out that there are only a few species—songbirds, parrots, hummingbirds, bats, humans, and cetaceans (whales and dolphins)—that don’t produce sounds instinctively at birth but instead learn to vocalize by an iterative process in which patterns of muscle activity are modified based on how the animal hears the sound it produces. Songbirds learn to sing in a rather different way than how humans learn to speak. A young male songbird (only the males sing in most songbird species) listens to its father several times and somehow memorizes precisely the sound of its father song. The young male then no longer needs its father for song learning, and starts to practice singing on its own, proceeding from a disorganized highly variable form of song to the highly precise and reproducible adult song. For zebra finches (the songbird species most preferred in neurobiology experiments because...
of the ease of breeding them), the convergence takes about two months and perhaps 50,000 repetitions.

Professor Greenside is currently interested in the question of how zebra finches produce their song, as a step toward understanding broader issues of how brains learn, recognize, and generate temporal sequences. Anatomical and physiological studies of male zebra finch brains show that, unlike human brains which have a continuous sheet of cortex for processing all kinds of information, songbirds have discrete regions of brain tissue known as nuclei that are involved with song learning and production (see Figure 2). The discreteness of the nuclei raises the possibility that each nucleus has a specific computational purpose that can be identified.

Experiments have further shown that one songbird nucleus called HVC is especially intriguing. This is the first nucleus along the pathway of neurons between the ear and song-producing muscles that, if destroyed, prevents a bird from singing. Experiments further show that some of the neurons in HVC are highly sensitive to sounds vocalized by the bird which suggests that HVC is where sensory (auditory) input is combined with motor commands that direct muscles to aid auditory guided learning.

In a pioneering 2002 experiment, physicist and songbird researcher Michale Fee and collaborators found that a certain subclass of neurons in nucleus HVC—the ones that send information to the next nucleus RA that is involved with muscle commands—have the remarkable property of being active (transmitting information) only for a 6-millisecond interval that is extremely short compared to the 1-second duration of the song. Further, different observed neurons (the experiments could only observe about 20 out of the 40,000 total such neurons in HVC) were active at different times during the song, with their activity aligned with certain features of the song to better than 1 ms. This unexpected simplicity and precision in the firing patterns of these neurons suggested to Fee and his collaborators that these neurons might provide a key mechanism for organizing the temporal structure of a bird’s song. Fee and others hypothesized that these neurons were organized in some kind of chain such that the firing of one neuron activated the next neuron in the chain. These scientists proposed that the output from these neurons could then be used to organize temporal events with a time resolution of about 10 ms, which is about the time scale of fine structure in a zebra finch’s song.

In 2004, Professor Greenside and his PhD student, MengRu Li, carried out theoretical calculations to test the plausibility of Fee’s hypothesis. (Dr. Li got his Physics PhD in June of 2006 based on these calculations.) Greenside and Li went one step further than Fee and his collaborators by connecting the experimental data to the theoretical concept of a “synfire chain” (see Figure 4). Such chains were originally proposed and studied by the Israeli scientist Moshe Abeles in the early 1990s in a different context, as a way to answer the question of how large mammalian brains can transmit precise temporal information over large distances (centimeters or more) through the cortex when it was known experimentally that neurons were noisy and this noise corrupts signals. Abeles suggested that a convergent-divergent feed-forward network of pools of neurons such that a neuron in a given pool sent divergent information to different neurons in the next pool, and a given neuron in the next pool received converging information from several neurons in the previous pool, would lead to spontaneous synchronization of transmission signals within a pool that could robustly transmit precise information, even in a noisy environment.
Li and Greenside’s theoretical calculations showed that various kinds of synfire chains, based on mathematical neurons constrained by experimental data, were in fact consistent with several key details observed in zebra finch HVC experiments so that Fee’s hypothesis was indeed plausible. The calculations helped further to illuminate how the number of neurons in a synfire pool had to increase with an increase in noise strength or with a decrease in the strength of the neuronal connections between pools to transmit information reliably. The calculations also suggested some new kinds of experiments to try since synfire propagation would imply that each of the single neurons originally observed by Fee et al. would have to be part of a pool of about 50–100 other neurons, that would all fire in tight synchrony, at a unique moment during each song. The calculations also suggested novel dynamical states that might be observed if appropriate stimulation protocols could be developed.

At this point, Professor Greenside is continuing to learn about songbird neurobiology, improving his knowledge of theoretical neurobiological techniques, and is exploring further ways to compare theory with ongoing and future experiments. As mentioned above, it remains extremely difficult to measure the activity of many neurons at once, especially in an awake behaving animal (immobilized anesthetized birds don’t sing!), so testing the predictions of synfire and other models will require further advances in experimental and data analysis techniques.

After returning to teaching in fall of 2008, Professor Greenside plans to incorporate his neurobiology research experiences into some new physics courses. One course will be an interdisciplinary freshman seminar for science students interested in thinking quantitatively about the brain, while a second course would be an upper-level biophysics course similar to the one recently created by Duke Physics Professor Glenn Edwards. These are exciting times indeed for physicists interested in neurobiology and Professor Greenside would like to share this excitement and get physics undergraduates and graduate students involved with brain-related research.

**Figure 2:** Slice of an adult male zebra finch brain, stained to reveal two of the nuclei, HVC and RA involved with song production. Nucleus HVC has especially attracted attention since it seems to be the location where auditory sensory input interacts with motor commands to aid vocal learning. HVC sends information to two nuclei, a nucleus RA that sends information to muscles, and to area X (not shown), which is one of several nuclei involved with song learning.

**Figure 3:** Diagram of a synfire chain, a feed-forward convergent-divergent network of neurons that can propagate information reliably and precisely in the presence of noise. Neurons are organized in pools (the vertical columns) such that each neuron in a given pool transmits information to multiple neurons in the next pool (divergence) and each neuron in the next pool receives input from several neurons in the previous pool (convergence). Calculations by Physics graduate student MengRu Li and Prof. Greenside show that synfire chains can propagate bursts of action potential, as suggested by recent experimental data.
Professor Chang’s research focuses on new phenomena exhibited by correlated electronic systems in nanostructured devices. These phenomena are investigated at low temperatures, typically at liquid helium temperatures (-452 F) and below. One major thrust will be the study of fractional statistics of exotic, fractionally-charge particles, which are predicted to exist in unusual states of matter created under extreme conditions. The necessary conditions are low temperatures, high magnetic fields, and restricted geometry, where an interacting electronic system is confined to move in a 2-dimensional plane. Prof. Chang has received funding from the National Science Foundation Division of Materials Research for this project entitled “Probing Fractional Statistics and Correlated States in Cleaved-Edge-Devices.” His collaborator is Dr. Loren Pfeiffer at Bell Laboratory, Alcatel-Lucent.

The behaviors of systems composed of electrons interacting with other electrons can change dramatically when confined in spatial dimensions less than the familiar three dimensions in which we live. For example, in a two-dimensional world, placing the interacting electrons in a very strong magnetic field creates unusual matters, which contain new entities with a fraction of the electron charge. Moreover, such new entities, call “quasi-particles,” behave neither as light particles (photons) nor electrons. Photons are bosons obeying Bose statistics. Bosonic statistics dictate that bosons like to aggregate into the

![Fig. 1 (a)](image1.png) The original setup of a Hanbury-Brown-Twiss temporal correlation experiment on particles of light (photons). The light beam from a coherent source—here a partially coherent mercury lamp—is split into two by the beam splitter. The arrival of photons at the two collectors (detectors) for the two beams is recorded, and a correlation between the respective time traces of arrival is computed. Photons obey bosonic statistics, and tend to bunch together, yielding a positive correlation between arrivals in the two detectors. Similar experiments on electrons, which obey fermionic statistics, have yielded anti-correlated behaviors, reflecting an anti-bunching in the arrival.

![Fig. 1 (b)](image2.png) A similar setup to (a) for detecting the fractional statistics of fractionally-charged quasi-particles. Here the source is labeled contact 3, and the collectors, contacts 1 and 2. The quasi-particles propagate in so-called “edge-states” in the direction of the small arrows. Evidence for fractional statistics will be reflected in unusual temporal correlations for the electrical currents received in the two collectors. The correlations are expected to be intermediate between the bosonic and the fermionic cases.
same quantum-mechanical state, rendering it possible to build lasers out of photons, for instance. Electrons, on the other hand, obey Fermi statistics, and consequently tend to avoid each other; two identical Fermions (e.g. electrons) are forbidden to occupy the same quantum state. This property leads to the well-known quantum-mechanical behaviors of solids as conductors, semiconductors, and insulators.

The new quasi-particles to be investigated are neither bosons nor fermions. They are believed to obey a new type of quantum statistics called fractional statistics. Using specially created semiconductor devices fabricated on the cleaved-edge of a GaAs/AlGaAs semiconductor crystal, it is possible to probe the electrical conduction properties of these unique systems. In particular, in such devices by measuring the temporal correlation of the noise in the electrical currents injected into different collectors from a single coherent source of charge carriers, one expects to obtain evidence indicative of fractional statistics, intermediate between the familiar bosonic and fermionic statistics. This type of experiment is analogous to the Hanbury-Brown-Twiss experiment in optics, which has been used to establish the bosonic properties of light particles (photons). Please see Fig. 1 for a schematic of the experimental setup. As bosons, photons exhibit bunching behavior in the temporal correlation of the arrival at the two detectors. The detectors collect photons coming from the coherent source after the beam split into two by a beam-splitter. Similar experiments for electrons have shown antibunching correlation, indicative of the fermionic statistics.

A related topic to unusual quantum statistics is the study of new states of matter with a new type of ordering, so called “topological order,” very different from familiar ordering such as the alignment of spins, responsible for the magnetism in iron. By employing an alternative method of investigation, in which the magnetic field period of the Aharonov-Bohm quantum interference modulation is measured, evidence could be uncovered, which may reveal the unusual topological quantum orders in the wave functions of the “Pfaffian” fractional quantum Hall states. The Pfaffian states are predicted to support quasi-particles, which obey non-abelian quantum statistics. Uncovering such statistical properties of different types of exotic quasi-particles can help bring a greater understanding of a new type of superconductivity termed “anyon superconductivity,” and may enable future realization of topological quantum computation, a scheme largely free of decoherence effects.

In a separate project, very narrow one-dimensional superconducting metallic wires will be investigated to probe the existence of new quantum phase transitions. Understanding the behaviors of ultra-narrow superconducting wires will have impact on their application as interconnects in ultra dense electronic circuitry, such as future generation computer chips. In 1-d superconducting nanowires, due to the relative ease in producing a type of defects termed “phase slips,” the resistance remains finite below the transition temperature into the superconducting state. This behavior is in complete contrast to the behavior of superconductors either in bulk 3-dimensional

Fig. 2 Scanning Electron Microscope (SEM) micrograph images of of a nominally 8 nm wide by 8 nm thick superconducting Aluminum nanowire. The length is 10 µm. The nanowire is visible as the narrow horizontal line in both the top and bottom panels. Bottom panel depicts an expanded view.
form, or in 2-dimensional films, for which the resistance becomes zero below the transition. In Fig. 2, we show an Al nanowire of nominal size 8 nm in width and 8 nm in height, but 10 μm in length. The length to width ratio is a remarkable 1,250 to 1! This nanowire was fabricated by Dr. Fabio Altomare, who was a former postdoctoral associate in Prof. Chang’s group. Currently, graduate student Peng Li is carrying out the research on 1-d Al superconducting nanowires.

Two other major areas of research are being pursued in Prof. Chang’s group. These include: (i) spintronics, which is a field devoted to exploring the possibility of utilizing the spin degree of freedom in place of the conventional charge degree of freedom to perform switching in spintronic devices, and (ii) scanning Hall probe microscopy to image local surface magnetic fields on the sub-micron size scale. Examples of spintronics include ongoing work by graduate student Phillip Wu to generate spin current in double-quantum-dots in a controlled way, charge and spin detection using metallic single-electron-transistors (SETs) shown in Fig. 3, and the development of 2-dimensional GaMnAs ferromagnetic semiconductor material with the aim of producing ferromagnetic quantum dots (graduate student Angelo Bove). Ferromagnetic quantum dots are useful for spin filtering and spin detector applications. Work on scanning Hall probe microscopy by graduate student, Nathan Kundtz, will focus on the imaging of magnetic vortices (quantized magnetic fluxes) in superconducting films, and magnetic domains in novel ferromagnetic systems.

**Fig. 3** An SEM micrograph of a double-quantum-dot/double-single-electron transistor (DQD-DSET) structure, patterned on the surface of a GaAs/AlGaAs heterostructure. Such a device is being developed for sensitive charge detection and electronic spin detection at high frequencies. The two aluminum SETs are formed between leads 1 and 7 in the center of the pattern.