Department of Physics

The Department of Physics has been a national resource since the turn of the century. It has been at the center of the twentieth-century revolution in understanding the nature of matter and energy and the dynamics of the cosmos. Our faculty—of whom four hold Nobel Prizes and 23 are members of the National Academy of Sciences—include leaders in nearly every major area of physics. In addition, nine alumni have won Nobel Prizes (four since 1997). Robert Noyce and Jay Last, two of the eight founders of Fairchild Semiconductor, earned PhDs in our Department. Fairchild is the company that gave birth to Intel and, arguably, all of Silicon Valley. The number of SB degrees awarded to students majoring in physics was higher in 2006 than we have seen since the 1980s and more than twice the number in 2000. At the graduate level, more than 50 percent of our offers were accepted. *U.S. News and World Report* rated us the number one physics program, a distinction we have held since 2002. Physics faculty continue to win prizes for research and teaching, and we attract the best physicists in the field at all levels of seniority.

Honors and Awards

Following are a few of the many honors and awards conferred on physics faculty during the 2006 academic year. Patrick Lee was awarded the Dirac Medal of the International Centre for Theoretical Physics in Trieste. Of the 41 theoretical physicists throughout the world who have won this honor since it was initiated in 1985, five, in addition to Lee, are on our faculty: Daniel Freedman, Jeffrey Goldstone, Alan Guth, Roman Jakiw, and Frank Wilczek. The same group continues to receive accolades for their work, with Freedman receiving the Dannie Heineman Prize of the American Physical Society in 2006.

Wolfgang Ketterle continues to receive wide acclaim for his work in atomic physics, earning the Institute's prestigious 33rd Killian Faculty Achievement Award; membership in the German Academy of Natural Scientists Leopoldina; Honorary Doctorate Degree of Sciences, Gustavus Adolphus College; and four named lecturers—the Van Vleck Lecture of the University of Minnesota; the Wolfgang Pauli Lecture, ETH Zurich; the C.N. Yang Nobel Lecture, Tsinghua University; and the 32nd Annual Hanan Rosenthal Memorial Lecture, Yale University. All were awarded in the past year. Mildred Dresselhaus was also bestowed a number of awards during the past year, including the Heinz Award for Technology, the Economy and Employment and the Pender Award; in addition, she was named an Honorary Fellow of the Institute of Physics. Deepto Chakrabarty won the Bruno Rossi Prize for High Energy Astrophysics from the American Astronomical Society. Samuel Ting was named an Honorary Fellow of the Tata Institute of Fundamental Research, Mumbai.

Many retired faculty members also continue to receive accolades for their work, including Ali Javan's selection to the National Inventors Hall of Fame and Robert Birgeneau's receipt of the Founder's Award from the American Academy of Arts and Sciences. Jerome Friedman, our most recent retiree, was awarded the Gian Carlo Wick Medal and was inducted into the Korean Academy of Science and Technology. The Department is home to many award-winning teachers as well as outstanding researchers. In 2005, Scott Hughes won both the Department's Buechner Teaching Prize and the School of Science's Teaching Prize.

Two faculty members were named chairs. Scott Hughes was awarded the Class of 1956 Career Development Chair. Ernest Moniz is the newest holder of a Cecil and Ida Green Chair. Assistant professors Iain Stewart and Nergis Mavalvala were both awarded Sloan Foundation fellowships and Eric Hudson, also an assistant professor, was named a Cottrell Scholar.

This academic year was a busy and successful one for faculty promotions and appointments. Scott Burles, Young Lee, and Gunther Roland were promoted to associate professor, and Christoph Paus was granted tenure. The Department added two faculty members. John McGreevy joins the string theory effort among other research initiatives in the Center for Theoretical Physics. Before joining MIT, McGreevy was a research scientist at Stanford University. Martin Zwierlein, a recent graduate of the Department's doctoral program under the supervision of Wolfgang Ketterle, will join the Department in fall 2007 to continue his work in atomic physics.

Education

We continued to integrate the TEAL (Technology Enabled Active Learning) format into first-year physics at MIT. This was the fourth year in which 8.02 Physics II was offered on a large scale. More than 600 students enrolled in the subject during the fall and spring terms. For the first year, all freshman were taught 8.01 physics in the TEAL format; 8.01L continued to be offered for students with weak backgrounds, but will be restructured to include some of the TEAL modules. The Department will continue to offer 8.012 and 8.022 to students who desire a more intensive study of Physics I and II. Although lecture/recitation will be retained as the teaching format in these subjects, TEAL is being incorporated into the curriculum via experiment assignments that were traditionally offered in a laboratory.

The number of SB degrees awarded this year in physics, 83, continued the steady growth, increasing from a low of 35 in 2000. Current enrollments at the sophomore and junior levels indicate that the number of undergraduate degrees in physics should hold steady for the next few years. The 8B degree was awarded to 70 percent of our undergraduates, an option that continues its popularity, and 29 percent of our undergraduate degree recipients received two degrees.

The graduate program continues to thrive. This year, 45 students graduated from our PhD program, with many going onto prestigious fellowships and one joining our faculty; 50 percent of the students to whom we made offers accepted them, whereas we usually get about 30 percent acceptance. Considering the number of outstanding physics departments with which we compete, 30 percent is a very good yield, but 50 percent is amazing. We are convinced that a large part of this success results from the increased number of first-year fellowships we have been able to offer. The fellowship offers are attractive to prospective students, but they also make current students happier, and that makes recruiting more successful.

Diversity

The Department of Physics is in the forefront in producing minority PhDs. To recruit new minority graduate students, the Department supports students' membership in the National Conference of Black Physics Students and the National Society of Black Physicists. The Department also supports North American underrepresented scholars through the Physics Department Head Fellowships. The Department funds all travel expenses for underrepresented North American candidates as well as all North American female candidates. Professor Eric Hudson tracked all minority applications through the admissions process to ensure that due diligence was considered in their candidacy. However, the pool of qualified minority candidates for graduate school remains extremely small, and the competition aggressively recruits qualified students. Thus, in spite of our efforts, the percentage of minority graduate students has not increased.

Our percentage of women graduate students is higher than in most institutions but remains quite small. We support the Women in Physics group, which consists of current female graduate students, by providing space and funding for biweekly dinners and other events. The group actively recruits female candidates to the program; for example, they host a reception during Open House for female candidates, and they telephone individual female candidates. They annually organize a dinner, open to all undergraduates, to discuss graduate school in physics, physics research at MIT, and career choices in general. Last year, they began a mentoring program with the Undergraduate Women in Physics group for female undergraduate physics majors at MIT. The program was developed to foster a closer interaction between undergraduate and graduate physics students to benefit both groups of women. All these activities are listed on their websites web.mit.edu/physics/wphys/ and web.mit.edu/uwip/. This group also receives financial support from a generous alumna of our Department.

Finally, the Department continues to recognize the importance of recruiting and retaining underrepresented minorities and women to its faculty. Throughout the recruitment process, advertising is targeted to reach these groups through diversity and organizational job boards and publications. Applicant data is closely tracked and applications from qualified women and minority candidates are given consideration across all the divisions. Our system is effective, as one of our incoming faculty members is an underrepresented minority.

Our Pappalardo Fellowship program, discussed below, is a wonderful opportunity for us to meet with and identify female physicists who will soon be prospective faculty members. Through a review of applicants by the committee, which includes representatives from all physics subfields, we have been able to make offers to 33 percent of the female applicants interviewed, with 25 percent joining the Department. In any year, the program has a much greater representation of women at other levels in the Department. The program also provides the postdoctoral candidates the opportunity to get to know the Department in a more informal way than they would as postdoctoral associates appointed in labs or centers, or if they were simply visiting MIT as interviewees. We have hired several faculty members who had Pappalardo Fellowships, including Gabriella Sciolla.

Pappalardo Fellowships in Physics

In 2000, Mr. A. Neil Pappalardo (EE 1964) provided the funds to inaugurate and sustain a competitive postdoctoral fellowship program for physics, named the Pappalardo Fellowships in Physics. He recognized that a distinguishing feature of the sciences in general, and physics in particular, is the invaluable contribution made by the accomplishments of outstanding individuals. With this in mind, the mission of the Pappalardo Fellowships in Physics focused on creating a preeminent postdoctoral program for the Department that would identify, recruit, and support the most talented and promising young physicists at an early stage in their careers.

The program appoints three new fellows per academic year for a three-year fellowship term each. Fellows are selected by means of an annual competition, global in scope, for which candidates cannot apply directly but must be nominated by a faculty member or senior researcher from the international community of physics, astronomy, and related fields. Two notable features of the program are the fellows' complete freedom of choice in research direction (within the Department) throughout their fellowship appointment and the active faculty mentoring of fellows, fostered by weekly luncheons and monthly dinners with the Department's faculty throughout the academic year.

The Department head appoints the 10 members of the program's executive committee, which encompasses a 9-member faculty committee and a staff administrator, who directly manages the program. Each division of the Department is represented on the committee by senior faculty members in both theory and experiment, whose primary responsibilities are to carefully review and evaluate the fellowship candidates in their respective area of physics as well as to select and interview each year's 18–20 finalists during the 2-day, on-campus "marathon" of panel-style interviews.

Former fellows are now faculty members at MIT, Duke University, and Oxford University, among many others. Three are on the faculty at MIT: Marin Soljacic studies novel ways to control light, Gabriella Sciolla uses high-energy physics in exploring some profound symmetries of nature, and Robert Simcoe hunts for the first stars in our universe and experimental evidence of inflation.

Green Center

After years of effort, the Green Center for Physics is about to get a great home. Construction of the Green Center is well under way; pictures can be seen on our website at http://web.mit.edu/physics/alumniandfriends/demolition_album/viewer.swf. It is truly amazing to watch as the old MIT buildings are transformed to house most of theoretical physics, the headquarters and education offices, the junior lab, and many community spaces. The Green Center is expected to be complete in spring 2007.

Research Highlights

Photonic Crystal Enhancement of Optical Nonlinearities

The physical phenomenon of optical nonlinearities describes the fact that high-intensity light can modify the index of refraction of the material in which it propagates. Typically, this effect is fairly weak. However, the emerging field of nonlinear photonic crystals appears destined to change this situation dramatically, to the extent that even all-optical signal processing might become feasible. All-optical devices enabled by photonic crystal designs can be smaller than the wavelength of light and can operate at very low powers, with bandwidths that are difficult to achieve electronically.

In recent decades, electronics have demonstrated enormous success in advancing almost any application that has to do with information processing: following Moore's law, data density on a chip has doubled every 18 months. Although such exponential growth is likely to continue for another decade, inherent physical limitations of electronics are expected to prevent such growth from lasting indefinitely. Some of the physical limitations are already becoming manifest today; as electronics in modern computers are forced to operate at ever-higher frequencies, power dissipation and consequent hardware heating are becoming serious problems. In nodes of optical telecommunication networks, where data needs to be processed electronically at operational frequencies that are even higher, the problem is more evident. Electronics are simply not suitable for operating at very high frequencies or bandwidths. In contrast, the optical domain is perfectly suited to operate at high frequencies. Consequently, it has been a trend in telecommunication networks to try to minimize the involvement of electronics in signal manipulation and to keep signals in the optical domain for as long as possible. Moreover, it is very likely that even data transport between various electronic desktop computer parts—for example, between different parts of the processor or between the memory and the processor—will very soon be done in the optical domain. Unfortunately, some inherent physical limitations of optics make signal manipulation in the optical domain difficult. Therefore, there is a rapidly growing need to find new physical mechanisms that will improve our ability to manipulate light. In the quest for the optimal solution, nonlinear photonic crystals have emerged. (From "Photonic Crystal Enhancement of Optical Non-linearities," Marin Soljacic, assistant professor, MIT, physics@mit fall 2006.)

The Mystery of CP Violation

The study of CP violation addresses a fundamental question: are the laws of physics the same for matter and antimatter, or are matter and antimatter intrinsically different? The answer to this question may hold the key to solving the mystery of the matter-dominated Universe.

According to the Big Bang theory, equal amounts of matter and antimatter were initially created. When matter and antimatter come into contact, they annihilate into pure energy, producing photons and nothing else. The relic of this primordial annihilation is the Cosmic Microwave Background, the 2.7-Kelvin radiation that fills the Universe. But not all the matter annihilated into photons: about one of every billion quarks survived and originated the Universe as we know it today. How could some matter survive the primordial annihilation? Where did the corresponding antimatter go? Why did matter survive instead of antimatter?

In 1967, the Russian physicist Andrei Sakharov proposed a solution to this puzzle. His explanation required the violation of what was considered a fundamental symmetry of nature: the CP symmetry. (From "The Mystery of CP Violation," Gabriella Sciolla, assistant professor, MIT, physics@mit fall 2006.)

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More information on the Physics Department can be found at http://web.mit.edu/physics/.