Physics Department Research Strategic Plan

Department Overview

Research in the department is organized around 3 subfields: (i) condensed matter physics (soft matter physics, and electronic, optical, magnetic, and nano materials) theory and experiment. (ii) biophysics, and (iii) fundamental interaction physics (sub-atomic particles, gravity and cosmology), theory and experiment. The condensed matter and biophysics groups are located in Hasbrouck, and the fundamental interaction groups are located in Lederle Tower.

Department Vision for the Future

Department ranking is a subjective study; however, several surveys indicate that the UMass Physics national ranking is approximately 50th. *The departments vision is to make reasonable and strategic investments in faculty and facilities, to become a much stronger and higher ranked department.* Going back to the 2013 Doctoral Program Review, Physics was clearly identified as a candidate for an expansion of its faculty. The average size for AAU public university physics departments is 46, whereas UMass Physics will go to 29.5 with presently authorized hires. Table 3 of the Review shows that Physics is tied with Economics for having the highest correlation between faculty size and scholarly activity per faculty member. The Review qualified Physics as an "Aspirant" department, with a *"high likelihood of moving into the top tier within the next 5 years if they receive appropriate additional resources."*

For this strategic planning exercise, each of the 3 sub-fields in the department were asked to develop a strategy and vision for their futures. The availability and quality of lab and office space, and the level of staff support, are critically examined in the strategic plan, as they are just as important to the future of the department as faculty hires.

Fundamental Interactions (FI)

- ***Strategic choices:*** The goal is to create one of the top groups studying the physics of fundamental symmetries and interactions in the country. For the theory group, look for synergy with the experimental effort, and exploit opportunities within the national Nuclear Physics program. For the experimental group, the long-standing goal of three faculty in each of the areas (1) the particle energy frontier, (2) accelerator based nuclear physics, and (3) cosmic physics, was never achieved and should now be redirected to exploit the interface opportunity provided by the Amherst Center for Fundamental Interactions, ACFI.
- ***Vision for FI theory:*** Build on its expertise and become recognized internationally as a focal point for fundamental research, capitalizing on the establishment of the ACFI. The theory group will provide scientific leadership through research in theoretical particle, nuclear, cosmological, and gravitational physics, and by helping to tie together experimental work in the high energy, intensity and cosmic frontiers.

Beyond the two theory hires that have been approved for this year, the group proposes to do two additional hires over the next 5 years. This brings the group size from its current 4.5 FTEs to 7.5.

- ***Vision for FI experiment:*** Focus on two frontiers, (A) physics at the highest energy particle accelerators, and (B) studies of fundamental symmetries at low and medium energies, including neutrinos and dark matter. The science drivers include, using the Higgs boson as a new tool for discovery, pursuing the physics associated with neutrino mass, identify the new physics of dark matter, understand cosmic acceleration (dark energy and inflation), and exploring the unknown (new particles, interactions, and physical principles).

The department has requested 2 searches in the area of FI Experiment for next academic year, filling the open Kumar and Cadonati positions. Beyond that, the group has identified a need to do 4 additional hires over the next 5 years, bringing the group size from 6 to 12.

Condensed Matter Physics

- ***Strategic choices:*** It is the size, not the quality, of the Condensed Matter research program that prevents it from becoming one of the finest CM groups in the country. To capitalize on existing strength, there is an essential need to hire faculty in theory and experiment, building on the excellence and potential of existing efforts, and at the same time broadening the group's expertise and bringing new fundamental problems into focus, e.g., physics of ultra-cold atoms.
- ***Vision for condensed matter theory:*** Key opportunities are in the areas of strongly correlated states and soft materials. Establish a center for *"Precision Many Body Physics"* with focus on theoretical techniques and experimental methods for predicting and measuring properties of strongly coupled many-body systems.

The theory group proposes to do 2 faculty hires in the area of quantum matter, and 2 hires in the areas of soft matter and biophysics. One of the searches is currently underway. The group size goes from 5 to 9.

- ***Vision for condensed matter experiment:*** Build on current strengths and expand in areas of (A) soft matter physics and (B) electronic, optical, magnetic, and nano-materials, which are growth areas from both scientific and funding perspectives. Redirect the group's substantial international visibility and reputation in low temperature physics to create a new group in modern cold atom physics. Become a nationally highly ranked group, rather than a small group of well-regarded individuals.

The CM experiment group proposes adding one faculty member per year working in areas (A) and (B), starting in 2017 and continuing into 2021. A search is already underway. The group size goes from 6 to 12. Create a new experimental group in cold atoms with a minimum of 3 faculty members.

Biophysics

- ***Strategic choices:*** Future hires should be in new areas leading to the critical size needed for major research and training grants. The next hire should be in biophysics theory.
- ***Vision:*** Broaden the groups effort into two new areas chosen for science impact, campus synergy, and funding opportunities; (A) the mechanisms by which microscopic degrees of freedom, which may be controlled by gene expression, interact via macroscopic transport physics to determine large-scale structure, and (B) tissue-scale research, such as spatial organization of bacterial colonies or neural computations in vitro or in the *C. elegans* model.

The Biophysics group proposes 3 hires, 1 theorist and 2 experimentalists, starting in 2018. The theory position is within the scope of hires proposed by the Condensed Matter Theory group.

Facilities

- **Lederle Graduate Research Tower:** The department supports the initiative among CNS tower departments to "re-stack" the tower for a more rational arrangement. However, in order to maintain the coherence of Fundamental Interaction Theory and the ACFI, it is essential that Physics continue to be the sole occupant of the 4th floor towers B and C, and the sole occupant of any assigned floors in tower C.
- **Hasbrouck:** The department has almost no available office or research lab space in Hasbrouck. To alleviate this crisis, the department has these recommendations:

- The 2nd floor of "old" Hasbrouck should be reassigned to Physics to create a "Center" for Condensed Matter Theory. Space given up by Geosciences should be compensated by comparable space in Morrill, or elsewhere. The other occupant of the floor is Mort Sternheim's STEM project, which has been winding down the past few years. STEM space could be reassigned to Physics as it becomes surplus to STEM.
- There will be a critical need for lab space for soft matter physics and biophysics starting in 2017. As PI's move from Hasbrouck to the PSB, the backfill space created in Hasbrouck should be retained by Physics, and then renovated for the use of those groups. The department proposes to move the Physics 131 and 132 teaching labs into the Integrated Learning Center room S110, freeing up the teaching labs in Hasbrouck 202, 204, 206, and 208 for research. This will positively impact the undergraduate experience, help to make UMass a destination of choice, and provide more research lab space in Hasbrouck. This could be accomplished as early as Spring 2016.

- **Physical Science Building:** There will be 7 open laboratory modules in PSB after the PI's slated for occupancy get moved in. The department expects these open modules could serve the research needs for 3 future hires in condensed matter experiment, and 3 future hires in fundamental interaction experiment. The department believes PSB will be a tremendous recruiting tool for potential faculty members and graduate students, and strongly endorses university investment in a helium recovery and liquefaction facility.

Staffing

In the last decade the department doubled its grant funding and lost 4 staff positions The department is in need of skilled accounting clerks who are capable of both pre-award and post-award administration of complex, multi-PI, multi-institutional federal grants; logistical support to ensure our physical facilities are maintained properly; HR support to ensure payroll and hiring processes are timely and accurate. The department needs to add one to two administrative positions in Hasbrouck and one in Lederle Tower to support increased spending on travel, equipment, supplies, personnel administration, and the growing ACFI workshop and visitor program. This increase is absolutely necessary in order to support the level of growth and activities expected in the next 3 to 10 years.

Moving forward with the strategic plan

If this plan were enacted in detail, the department national ranking would probably rise into the mid-20's, and its program would be comparable with the finest public university physics programs in the nation. Among some very ambitious ideas in the plan, there are also "low hanging fruit" that should be acted on in a timely way. Completing the vision for Fundamental Interaction Theory requires 2 additional hires over the next 5 years; completing the vision for Condensed Matter Theory requires 3 additional hires, one of which satisfies the strategic need for biophysics theory. These hires have relatively low startup costs and no lab requirements. Fundamental Interaction Experiment has redefined its vision and is now ready to hire into vacant faculty positions. Staff support has reached critically low levels, and hiring just one additional staff member early on to handle post-award grant administration would be very helpful. In the area of facilities, moving the Physics 131 and 132 labs into the Integrative Learning Center so that valuable research lab space can be freed up in Hasbrouck, and developing the 2nd floor of "old" Hasbrouck as a "Center" for the Condensed Matter Theory group, come at low cost to the University and should be acted on quickly.

Physics Doctoral Program Strategic Plan

Mission Statement: Our mission is to maintain and expand high quality learning for our graduate students, through a culture of research engagement, innovative coursework, and professional development. We work to foster a mindset of professional physicist for each student from the moment they arrive on campus – cultivating the attitudes of mastery, autonomy and proactive curiosity.

Our graduate teaching mission is the cornerstone on which both our research and teaching missions hinge. Both in terms of teaching and research, Physics is the foundational science upon which all other sciences build and flourish. With a robust and solid foundation in physics, our graduate students will be leaders in any field they choose, from traditional STEM fields to industry, politics, finance and media.

Size of the department is of utmost importance for the graduate program. In the 2013 Doctoral Program Review, Physics was clearly identified as a candidate for expansion of its faculty and was tagged as an "aspirant" department having a high likelihood of moving into the top tier if it were to receive the appropriate additional resources. The average size of an AAU public university program is 46, whereas the UMass department will go to 29.5 with presently authorized hires. Attracting the very best graduate students depends crucially on the growth of the department.

Established Excellence:

- Providing TA or RA support for all of our graduate students
- Providing strong research engagement over a breadth of research areas
- Intensive mentoring through frequent interactions with faculty
- Engaging and informative seminars and colloquium
- Interdisciplinary research opportunities
- Forefront engagement with a broader research community:
    - Amherst Center for Fundamental Interactions (ACFI)
    - NSF NSEC Center for Hierarchical Manufacturing
    - Annual soft matter physics summer school and soft/bio REU
    - Membership in large international collaborations
- Graduate student research seminar – for self-directed engagement
- A graduate student orientation
- Pathway for a reasonable time to PhD compared to national trend

Vision for the Future:

Our goal over the next five years is to improve the quality of the applicant pool and increase the number of excellent students matriculating to UMass Physics. Ultimately, this will enable us to increase our standing, resulting in a positive feedback loop that will allow us to better compete with those institutions that attract the very best students. To accomplish this, we will focus on enhancing those features of our program that we consider to be our special strengths, while also addressing areas where we are at a competitive disadvantage relative to our peers and aspirant institutions. The teaching and research missions both depend crucially on the quality of our graduate students. We will construct and implement metrics that assess the quality of the graduate program, based on recruitment of top students and the success of graduates in research, teaching, and future careers.

Realizing our Vision:

- **Teaching Assistantships:**
    - **Number of TAs:** Increasing the number of TA positions by 25% would allow for an incoming graduate class size of 15 students, on a consistent basis. This is the minimal number currently needed to accomplish our research goals (of 26 faculty and growing to 45). It will also create a genuine community of highly-motivated first-year students.
    - **Reduced load**: *A reduced load for TAs is a high priority for our program.* An increase in TA positions would also allow us to address the large TA burden (compared to competing institutions) that our current students bear by redistributing the load over

more persons. Grading and running lab and discussion sections is a large time burden. Overloading the TAs affects the teaching mission for our undergraduate curriculum, the research mission--because both overburdened TAs and faculty have less time for research, and graduate learning, because incoming graduate students have less time for coursework.

- **Competitive pay:** An increase in the academic-year TA stipend by at least 10% will place UMass in a position that is close to the median for competing institutes and allow us greater possibilities for attracting top students.

- **Programmatic Changes:**
  - **Scientific Thinking First:** Our doctoral program will be improved to ensure that the research component of the training begins as early as possible in the student's doctoral timeline.
    - This has significant overlap with enhanced professional development (see below)
    - New orientation (3 days) for incoming graduate students
    - New rotation fair / Introduction to Research Poster Session
  - **Coursework:**
    - Provide a *complete* and *coherent* set of courses offered regularly.
      - More frequent and regular offering of advanced, research-focused courses (i.e., those beyond the required core courses)
        - Example courses: Solid State, Many Body Theory, Continuum Mechanics, Advanced Particles and Fields.
        - Must be on par or beyond program offerings from competing institutions.
      - A required graduate course in *experimental physics* to cultivate curiosity, strengthen engagement, and facilitate research thinking
    - Requires more faculty to teach advanced course work on a regular basis.
  - **Professional Development (PD):**
    - More comprehensive graduate student orientation - multi day orientation to firmly establish a culture where students view themselves as colleagues & professional physicists.
    - Graduate student attendance and presentations at conferences. The department will stress participation in national and international conferences as an essential component.
    - Maintain the momentum of enthusiasm of entering grad students experience through early research engagement (activities that build upon the orientation experience.)
      - First-year PD coursework (1 credit, two semesters) developing skills of the professional physicist, including inquiry, research thinking, communication, reading the literature, ethics, teaching (TA training), data analytics, design thinking, preparing for career, and timely topics.
      - Research group topic explorations (e.g. 3 one-month rotations), managed under the framework of the first-year PD coursework.
      - Broader exposure to current research methods through short, intensive "bootcamp" courses. (Ex. BioBootCamp, Nanophysics BootCamp)
    - Improve support from mentors for advice on non-academic and teaching-intensive career trajectories. Work with graduate college to offer extra PD opportunities on negotiation, application strategies, and topics requested by students.
    - Co-instruction: Senior grad student instructors working alongside faculty instructors in PD activities (cultivating professionalism and forming near-peer network for junior grad students)
- **Recruitment of top students:**

    - Actively recruit and market the graduate programs
        - At colloquia and seminars given by our faculty at other institutions
        - REU programs
        - Marketing online and in print
        - Engage current graduate students in the recruiting process
    - Training grants to fund students and used as a recruiting tool.
    - Initial research fellowships. Early summer research (summer prior to first semester).
    - Recruiting Day/Departmental Retreat in Spring to recruit accepted students.
- **Teacher-Researcher Model:** Our service course mission is intimately tied to our graduate teaching mission since many of our graduates go on to teaching positions including high school and college-level. Further, regardless of if our students pursue careers in academia or any other field, one of the fundamental aspects of being a professional physicist is teaching and effective communication skills.
    - **Teacher training:**
        - Laboratory training. As laboratory TAs, the students are allowed to command their own class independently. Further, they strengthen their own experimental skills through helping the undergraduates take and report good measurements. Since the largest service courses are required to have laboratory sections for the departments they serve, we need to continue to have a sufficient number of excellent laboratory TAs.
        - Lecture teaching. Some of our graduates go to teaching at the high school, community college, and small liberal arts college levels. Teaching opportunities and training is essential for these future careers. There are summer opportunities for our graduate students to teach their own courses. Many times the best way to truly learn a subject is to teach it. Teaching opportunities offer learning opportunities for our graduate students.
        - We propose to purposely cycle graduate students through numerous types of TA positions (lab and lecture grading) and a variety of levels (service courses, majors courses, graduate courses) to expose them to teaching (and also learning) as many different levels as possible.
    - **Project Management skills**: both teaching and research train our grads in PM, an essential skill for majority of technological and management careers
- **Fifth Year Master's in Applied Physics:**
    - **Cohort building:** We have a current issue that we have a low number of incoming graduate students making it difficult to build a cohort. A lack of cohort is detrimental to student activities in teaching, research, and coursework. Including a set of 5th year master's students in the professional development program (see above), we will enable more cohort building.
    - **Revenue:** We anticipate this to be a for-pay activity to give our undergraduates the ability to learn an important skill set they cannot gain due to lack of time during the traditional 4-year BS programs (professional and applied tracks).
    - **Five-year plan of establishment:** We will assemble an exploratory committee to determine how best to serve our undergraduates with a 5th year masters program over the next two years. Talk to recruiters from grad schools and companies and look at other models, comparison to come up with a coherent plan (iCons Model). We anticipate that students will want a program that will enable a higher placement in graduate schools or technical industry. We anticipate that experimental methods, research thinking, quantitative problem solving, and data analytics enabling students to work with and handle "big data" will be major aspects of the program.