The University Senate of Michigan Technological University

PROPOSAL 15-01

PHD PROGRAM IN ENGINEERING PHYSICS

The Senate approves the program as described below.

1. RELATED PROGRAMS: Own/Other

The Engineering Physics PhD degree is a spin off from the currently awarded Physics PhD degree at Michigan Technological University. No other university in the State of Michigan offers a PhD degree in Engineering Physics.

2. RATIONALE

The Doctor of Philosophy degree in Engineering Physics is designed to train students for industrial and academic jobs through the study and application of the principles of physics to analyze, evaluate and solve engineering problems. The emphasis of the program is to prepare the student to address problems of current technological import in an interdisciplinary fashion, without regard to formal boundaries between the fields of engineering and physics. The PhD in Engineering Physics meets an important need in today's world: to train scientists capable of tackling the technical problems of today and tomorrow in an increasingly multi-disciplinary technological environment. This degree is a natural spin off of the current PhD in Physics program based on current growth, research and expertise in the department of Physics and collaborations and joint-appointments with the departments of Materials Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering-Engineering Mechanics.

The job market for PhD's with degrees in physics disciplines is currently extremely strong. According to a recent article in *The Chronicle of Higher Education*, there is a very healthy job market for physicists in industry, consulting and in finance. The academic job market has improved slightly as well recently. According to *The Chronicle* (Gabriela Montell, *The Chronicle of Higher Education,* June 23, 2000):

```
        "Preliminary results of the physics institute's [American Institute of Physics] 1999 Initial
Employment Report showed that 70 percent of the new doctoral-degree recipients who took
permanent jobs were working at private companies, up from about 40 percent to 50 percent
a decade ago.

        Specializations such as optical, biological, computational, and condensed matter physics are
hot…"
```

The same article also reports, for example, that at the April 2000 meeting of the American Physical Society, "there were more than twice as many job openings in industry as job seekers." The Physics PhD program at Michigan Technological University has done extremely well in placing its graduates in positions in industry, national laboratories, universities and consulting firms. A spin-off PhD program in Engineering Physics is well positioned to continue and expand on this success.

3. ALIGNMENT OF THE PROPOSED PROGRAM WITH MTU'S STRATEGIC PLAN

Through the strategic planning and portfolio process, the development and implementation of a PhD in Engineering Physics was identified as a top priority for the Department of Physics, in collaboration with its partners in engineering. Implementation of the proposed program is also a top priority of the College of Sciences and Arts action plan for implementing the Strategic Plan.

The proposed PhD program in Engineering builds upon MTU's current strengths and fosters increased interdisciplinary collaboration among some of its top PhD granting departments. In particular, the proposed program directly impacts MTU Goal 2 "Expand our scholarship and research activities, sustaining successful existing programs while pursuing new endeavors in carefully targeted areas". PhD programs in Physics and the College of Engineering have traditionally been very strong in materials-related research. In addition, imaging sciences have emerged as an area of strength and excellence as well. The proposed program will further strengthen these efforts as they focus initially on two identified areas of national interest and critical need: nanotechnolgy and information technology. The program will also set a foundation for the development of further interdisciplinary collaborations as critical needs and faculty interests evolve. Several joint faculty appointments between physics and departments in the College of Engineering have already been implemented in recent years and lay a foundation for the implementation of this proposal.

The proposed program also assists MTU in the development of new PhD programs. In addition, student interest surveys indicate that it will assist in the goal of significantly increasing the number of PhD students recruited and graduated each year.

4. INVOLVEMENT OF FACULTY AND STUDENTS IN THE DEVELOPMENT OF THE PROGRAM

This proposal was originated in the Department of Physics and has been developed and reviewed by the faculty and chairs of the following departments:

Electrical and Computer Engineering

Materials Science and Engineering

Mechanical Engineering-Engineering Mechanics

Physics

The Department of Physics surveyed its graduate students on interests and concerns regarding the development of such a program. The response was extremely positive in that 1) it would have bolstered their confidence in choosing MTU for their PhD studies; 2) it would serve to enhance recruitment efforts; and 3) given the opportunity, several students would be interested in pursuing this degree option.

The following faculty have expressed interest in participating in the proposed program:

Physics
Jacek Borysow
Christ Ftaclas
Edward Nadgorny
Bryan Suits
John A. Jaszczak

Materials Science and Engineering
Jaroslaw Drelich
Steve Hackney
Jong K. Lee
Walter Milligan
Douglas Swenson

Miguel Levy (joint appointment between PH and MSE)
New faculty hire (joint appointment between MSE and PH)

Mechanical Engineering-Engineering Mechanics
Kee Moon

Electrical and Computer Engineering
Paul Bergstrom
Anand Kulkarni
Warren Perger

Current research and interdisciplinary collaborations that are relevant to this proposal are underway in the following areas:

• Micro Size PZN-PT Actuation System (M. Levy, Physics and Materials Science and Engineering; K. Moon, Mechanical Engineering-Engineering Mechanics)-
We are developing a micro size actuation system based on PZN-PT material for nano actuation applications. Dr. Levy has been developing a technology to manufacture the actuator. In particular, developing the technology to produce highly efficient single-crystal films of this piezoelectric material, better than any presently in use in the actuator and transducer application market. Dr. Moon has been developing a new nano-displacement sensor to measure the dynamic response of the actuator. The sensor can provide in-situ measurement capability for micro-size objects with nanometer resolution. Those types of sensors are not available on the market currently.

• Thin Film Oxides for Integrated Photonics and Micromechanical Applications (M. Levy, Physics and Materials Science and Engineering)-
This program involves the development and utilization of novel microfabrication techniques for integrated photonic and micromechanical device prototyping. Recent work has involved the development of ion implantation techniques to fabricate single-crystal magnetic garnet and ferroelectric films on non-lattice-matched substrates. Highly efficient electro-optic modulators and second-harmonic frequency converters have been demonstrated. Magnetic photonic crystals for the prototyping of highly efficient Faraday rotation isolators are presently being investigated during rf magnetron sputtering.

• Magnetic Resonance Detection and Imaging (B.H. Suits, Physics)-
Techniques and apparatus for materials detection, principally using ^{14}N nuclear quadrupole resonance (NQR) to detect explosives and narcotics, are being developed in a collaboration with scientists at the Naval Research Lab in Washington, D.C. Magnetic resonance imaging techniques for materials and flowing systems are being investigated, particularly using quadrupolar nuclei as a probe, for practical use both as a part of the materials detection effort and for on-line monitoring during manufacturing.

• Plasma Chemistry for Industrial Applications (J. Borysow, Physics)-
Research focuses on discharge chemistry and physics as they apply to plasma etching, deposition, and semiconductor processing. Laser spectroscopy is used to probe chemical reaction in plasma and at the surface of materials. We are particularly interested in such phenomena as: (1) collisional energy transfer, (2) kinetics of excited radicals, (3) nonlinear optics and novel form of coherent light generation.

• Laser Guiding of Particles for Novel Processing (E. M. Nadgorny, Physics)-
Novel growth, solidification and clustering processes of submicron particles guided by laser beams (in collaboration with Biomedical Engineering, Mathematical Sciences, and Materials Science and Engineering departments).

• Structural and Electronic Effects of Dislocations (E. M. Nadgorny, Physics)-
Structural and electronic effects of dislocations in semiconductors, intermetallics and metals (in collaboration with Materials Science and Engineering department).

• **Imaging Optical Systems (C. Ftaclas, Physics)-**
Test and model imaging optical systems. System characterization and performance prediction. Optical metrology and characterization of surface scatter properties.

• **Image Processing (C. Ftaclas, Physics)-**
Image analysis packages and two-dimensional data reduction systems. Phase retrieval.

5. ENDORSEMENT OF THE PROGRAM
The proposed PhD in Engineering Physics has been approved by the faculty in the Department of Physics, by the Chairs of the College of Engineering, and by the Deans of the College of Engineering and the College of Sciences and Arts.

6. CURRICULUM DESIGN
Candidates for the degree of PhD in Engineering Physics must complete all of the minimum requirements for the PhD degree set by the Graduate School of Michigan Technological University. Such requirements include residency, continuous enrollment, time limits, and credit hours. In addition, the following program requirements must be met:

• **Advisor and Advisory Committee:**
Students will initially be assigned the Chair of the Engineering Physics Graduate Studies Committee (composed of faculty from participating departments) as their advisor who will prepare with each student an initial course of study. By the end of the second term in residency each student selects a research advisor who will serve to guide and direct the student's subsequent course of study and research, and to chair the student's Advisory Committee. After choosing a research advisor, a four or more member Advisory Committee is formed to include, in addition to the research advisor, at least one member of the graduate faculty from the Physics Department and at least one member of a cognate engineering department. The Advisory Committee will ultimately serve on the student's examining committees. Committee members are chosen by the research advisor and the student, with approval of the Department Chair (form D2) corresponding to the department of the student's research advisor. The purpose of the Advisory Committee is to assist in the guiding and monitoring of the research work of the student.

• **Grades and Coursework:**
A grade of B or better is required in the following core courses:

Core Courses		(credits)
PH5010	Graduate Journal Club	(1)
PH5110	Classical Mechanics	(2)
PH5210	Electrodynamics I	(3)
PH5310	Statistical Mechanics	(3)
PH5320	Mathematical Physics	(3)
PH5410	Quantum Mechanics I	(3)

Exemptions from taking any of the required core courses on the basis of prior graduate work are to be determined by the Chair of the Engineering Physics Graduate Studies Committee.

In addition, a grade of B or better is required in at least three courses at the 4000 level or higher and including at least one course at the 5000 level or higher, as approved by the student's advisory committee, in the student's chosen area of specialization. Additional courses may also be required by the student's advisory committee. Typical courses could include:

EE4254 Image Processing
EE5340 Statistical Optics
EE5410 Engineering Electromagnetics
EE5430 Electronic Materials
EE5440 The Laser
EE5520 Fourier Optics
EE6410 Advanced Engineering Electromagnetics
EE6420 Interaction of Electromagnetic Waves and Materials
EE6450 Theory of Devices
EE6470 Thin Films

MY4530 Surfaces and Interfaces
MY4700 Electronic Properties of Materials
MY4710 Materials Science/Electronic Devices
MY5100/5110 Thermodynamics and Kinetics I & II
MY5400 Mechanical Behavior of Materials
MY5540/5550 Surface Chemistry I & II
MY6100 Computational Materials Science and Engineering
MY6500 Advanced Topics in Materials Processing

PH5211 Electrodynamics II
PH5250 Atomic & Molecular Physics
PH5411 Quantum Mechanics II
PH5510 Theory of Solids
PH5520 Materials Physics
PH6530 Imaging Systems
PH6510 Advanced Solid-State Physics

MY5XXX/PH5550/EEXXXX Device Fabrication (proposed new course)

Required courses will be listed on the Preliminary Program of Study Form (D3) and verified at least one semester before the final oral defense is scheduled on the Degree Schedule form (D5).

• Qualifying (Comprehensive) Examination:
Students accepted into the Engineering Physics PhD program must pass the Qualifying Examination, which is composed of a physics component and an engineering component.

The physics part of the Qualifying Exam will cover three out of four of the following topics, to be chosen in advance by the student: classical mechanics (including special relativity), electricity and magnetism, quantum mechanics and general physics. Each of these areas will be covered in a separate two-hour written examination to be given during the Fall semester by the Physics Department. Classical mechanics, electricity and magnetism and quantum mechanics qualifying problems may be solved using techniques taught at the advanced undergraduate level. The general physics exam will consist of short questions covering all areas of physics normally taught at the undergraduate level, including mechanics, relativity, electromagnetism (including AC and DC circuits), quantum and atomic physics, thermal and statistical physics, optics, and laboratory techniques including data analysis. Students are allowed two attempts to pass each physics section of the Qualifying Examination. After the first Fall semester following matriculation, students who have not yet passed any part of the exam and do not take it when it is offered, are considered to have failed it.

The engineering member(s) of the Advisory Committee shall formulate engineering component to the qualifying examination that is two to three hours in length that is appropriate to the student's chosen area of engineering physics interest.

• Preliminary Examination
The Preliminary Exam is taken after the Qualifying Exam has been passed. It is administered by the student's Advisory Committee for the purpose of reviewing the student's proposed plan for research. Once a student has identified a research problem in consultation with his or her research advisor, has become familiar with the related literature and has devised a plan for research, the Preliminary Exam should be scheduled. A paper describing the proposed research not exceeding fifteen pages in total length should be distributed to the Advisory Committee one week prior to the scheduled exam. The student should prepare a 30-minute talk outlining both the problem and the proposed research methods. The remainder of the exam will be devoted to questions and answers. Form D6 should be filed with the Graduate School, through the Chair of the Graduate Studies Committee, upon successful completion of the Preliminary Examination.

• Doctoral Dissertation and Final Oral Examination
The final examination may be scheduled anytime after a period of two academic terms following the successful completion of the Qualifying Examination, the successful completion of the Preliminary Examination, and upon completion of the dissertation in satisfactory form. Two weeks prior to the final examination a completed draft of the dissertation must be distributed to the examining committee. The Examining Committee will consist of the student's Advisory Committee and a member chosen from a cognate department or program.

7. NEW COURSE DESCRIPTIONS
Building on the interdisciplinary nature of this program, the following new course is proposed:

MYXXXX/PH5550/EEXXXX Device Fabrication-
An experimental course emphasizing various techniques essential to modern microfabrication technology. The course will cover the basics of photolithography, including the use of spinners and mask-aligners. It will also review the theory and operation of sputtering systems for thin film deposition, including rf and magnetron sputtering. Other tools will also be examined, such as ion milling and reactive ion etching for the patterning of microstructures on chip.

No other new courses are required.

To support the new course offering and to further stimulate seamless interdisciplinary research activities, one new faculty line is required. This new faculty line would preferably be a joint appointment between Physics and Electrical Engineering, or between Physics and Materials Science and Engineering departments.

8. PLANNED IMPLEMENTATION DATE
August 2001

9. ACCREDITATION REQUIREMENTS
None

10. RESOURCE REQUIREMENTS
The curricular and programmatic requirements cited to offer this program require the addition of 1.0 FTE new faculty. The Department of Physics and the College of Sciences and Arts will supply 0.33 FTE toward a joint position, while the Department of Materials Science and Engineering and College of Engineering will supply 0.67 FTE toward a joint position for a total of 1.0 FTE. Tenure for this joint position will be held in the Department of Materials Science and Engineering. Physics and Materials Science and Engineering have developed and approved a comprehensive agreement concerning both of the joint positions in which they have faculty members.

The journal and book holdings of the university library are in need of some additions to support the research and curricular needs of the proposed program. We anticipate that the necessary books can

be purchased through the normal allotments made to participating departments in the next year. The following journals are also highly desirable:

1) Ferroelectrics
2) Photonics Technology Letters, and
3) Journal of Lightwave Technology

In the absence of additional resources for journals, we anticipate that at least some of these journals can be obtained through the participating departments' examining their current journal subscriptions and judiciously terminating subscriptions deemed to be lower priority.

Adopted by Senate: April 25, 2001
Approved by President: June 22, 2001