CITY COLLEGE OF NEW YORK

Physics Department

Information for Doctoral Students
Views of the planned CUNY Advanced Science Research Center and the new City College Science Building.

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Physics @ City College

The Physics Department of the City College of New York is a major participant in the doctoral program of the City University of New York. The Department offers opportunities for research on a number of topics at the very frontiers of our current understanding of the universe. Starting with doctoral students entering in 2008, Ph.D. degrees will be awarded jointly with the Graduate School and University Center of the CUNY.

The Physics Department of the City College of New York has a long tradition of distinguished faculty and students. Many of the Department's alumni have achieved prominence in academic, industrial and governmental physics positions. Three of our alumni, Arno Penzias, Leon Lederman and Robert Hofstadter, have won the Nobel Prize in Physics. Today the Department continues to reflect this tradition of scientific excellence. The faculty include members of the National Academy of Sciences, the National Academy of Engineering, several fellows of the American Physical Society, American Academy of Arts and Sciences, Optical Society of America and the Institute of Electrical and Electronic Engineers. Many of the faculty have also held elective and appointed positions in leading scientific and professional societies.

V. Parameswaran Nair
Chairman

Welcome to the Physics Department of the City College of New York. With the 'Decade of Science' initiative proclaimed by Chancellor Matthew Goldstein, and endorsed by President Gregory Williams, we are at the threshold of a major enhancement of the breadth and quality of scientific research at CUNY, making this a wonderful time to embark on doctoral study. In the following few pages you will find information about some of the exciting research which is carried out here and the great opportunities for doctoral study. For more details or any other information, do not hesitate to contact the Physics office or any faculty member.

AREAS OF CURRENT RESEARCH

- Biophysics (Experiment & Theory)
- Condensed Matter Theory
- Fluid Dynamics (Experiment & Theory)
- Foundations of Physics
- Theoretical High Energy Physics, Mathematical Physics
- Low Temperature Physics
  (Condensed Matter Experiment)
- Nuclear Magnetic Resonance
- Optical Spectroscopy (Condensed Matter Experiment)
- Photonics & Laser Physics
  (Experiment & Theory)
- Physics Education

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Albert Einstein in front of Shepard Hall at City College. On his first visit to the United States in 1921, Einstein came to City College to deliver his first public lecture.

Professor Michio Kaku’s book *Einstein’s Cosmos*, published for the centennial of the Special Theory of Relativity, is an evaluation of the impact of Einstein’s ideas on the development of Physics.
HIGH ENERGY THEORY, MATHEMATICAL PHYSICS

The central objective of all particle physics research is to understand the fundamental interactions of the basic forms of matter and their ultimate structure. Particle collisions at high energies is one method of investigating these. The high energy theory group's activity centers on a quantum-field-theoretical study of these interactions and related questions.

Topics of recent research interest include mathematical physics, topology of field theories, string theory, matrix models, noncommutative geometry, quark-gluon plasma, higher dimensional quantum Hall effect, bosonization, spin systems, integrable models, finite temperature field theory, etc.

Professors V. Parameswaran Nair and Aelxios Polychronakos work in this area and are supported by the National Science Foundation and by CUNY.

CONDENSED MATTER THEORY

Condensed matter physics is the study of the physical properties of macroscopical systems like solids and liquids. Novel properties emerge when the temperature is lowered and quantum mechanics begins to manifest itself at the macroscopic level. The interplay of the electron spin, Coulomb interactions between the electrons and the interactions of the electrons with the positive lattice background can give rise to exotic states of matter that have no analog in classical systems at say room temperature. Sophisticated field theoretic methods like bosonization, renormalization group theory and their topology are used to understand the properties of these systems. Special focus is on low dimensional physics in zero, one and two-dimensions.

Distinguished Professor Joseph Birman and Professors Joel Gersten, Alexander Punnoose and David Schmeltzer work in this area and are supported by the U.S. Department of Energy, the US–Israel Binational Science Foundation and by CUNY.

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How proteins control the rates and equilibria of electron and proton transfer reactions is one line of research in biophysics. The experimental work uses time–resolved optical spectroscopy to monitor electron–transfer reactions focusing on photosynthesis. On the theoretical side, computer calculations are carried out to test how the protein's structure can modify the free energy of charges in different locations. In addition, quantum–mechanical tunneling theories are used to elucidate electron–transfer rates under different conditions.

Another line of research involves the design and synthesis of novel proteins and their integration with other proteins to create new biomaterials for medical and ‘green’ industrial uses, for example, creating new enzyme–based cancer therapies and protein based biological solar energy devices – ‘green’ solar panels.

Professors Marilyn Gunner and Ronald Koder work in this area and are supported by the National Institutes of Health, the National Science Foundation and by CUNY.

The use of electron and nuclear spins to probe the structure and dynamics of diverse materials as well as to tackle problems of emerging technological importance is a field of research at the intersection of physics, chemistry and biology. At City College, the focus is on the characterization and control of nuclear spin dynamics in condensed matter systems, the use of optical methods to generate states of high nuclear magnetization as well as in the development and application of novel strategies for optical sensing of the nuclear spin, with emphasis the study of nanostructured materials. A unique infrastructure that articulates the well–known flexibility of multipulse NMR sequences to control nuclear spin systems with the spectral and spatial selectivity possible with time–resolved optical schemes is currently nearing completion.

Professor Carlos Meriles works in this area and is supported by the National Science Foundation, the Nanoscale Interdisciplinary Research Team and by CUNY.
The metal–insulator transition (MIT) has been a major area of research in low temperature physics, focusing on MIT in bulk doped semiconductors as a function of dopant concentration, pressure and magnetic field; the critical behavior approaching the MIT; hopping conduction in the insulating phase; and related physics. A particular strength of this research has been our focus on studying the effect of applying magnetic field. Within the last few years, a major effort has been devoted to studying the unexpected behavior and apparent metal–insulator transition (MIT) in the two-dimensional system of electrons in silicon MOSFETS (metal oxide semiconductor field effect transistors). This area continues to be one of very high current interest and activity; the physical origin of the unusual behavior remains unresolved.

A second line of research concerns investigations of the magnetic properties of molecular nanomagnets, such as Mn–12 acetate. These are organic crystals containing large-spin molecules regularly arranged on a lattice. The interest in these materials is both basic (their spins are intermediate between the classical and quantum mechanical regime) and applied (they may be useful for high-density data storage, or as qubits for quantum computers).

Yet another line of research is physical properties of electron systems of reduced dimensionality, such as two-dimensional films, quantum wires and quantum dots. These systems are of paramount importance for future electronics based on quantum behavior of the matter. The research focused on fundamental properties of the artificial nano–objects in regime at which the external excitations move electrons far away from thermal equilibrium.

Distinguished Professor Myriam Sarachik and Professor Sergey Vitkalov work in this area and are supported by the National Science Foundation and the U.S. Department of Energy.

**OPTICAL SPECTROSCOPY (CONDENSED MATTER EXPERIMENT)**

The Optical Spectroscopy group carries out optical scattering studies of superconductors and 2D–layered cobaltates including high Tc superconductors and the newly discovered superconductor MgB₂. Optical studies of nano–systems such as ultra–thin films, nano–wires and
nanomagnets, spectroscopy in the THz region for a contactless probe of low-dimensional nano-system, infrared and optical properties of semiconductors with applications as solid state x-ray and g-ray detectors are some of the related topics of research interest.

There is significant collaborative work with the Brookhaven National Laboratory utilizing the National Synchrotron Light Source.

Professor Jiufeng Tu works in this area and is supported by the U.S. Department of Energy and by CUNY.

**FLUID DYNAMICS (LEVICH INSTITUTE)**

Albert Einstein Professor Morton Denn and Professors Joel Koplik, Hernan Makse and Mark Shattuck work in the area of fluid dynamics and complex systems, jointly with other faculty at the Benjamin Levich Institute for Physicochemical Hydrodynamics.

Fluid dynamics at the nano- and molecular scales, including wetting phenomena, suspensions, drop and bubble dynamics, polymeric liquids and rheology, electrostatic phenomena, granular flow and its thermodynamic modeling, and jamming phenomena are topics of research interest.

Complex networks, dynamics of social networks, urban growth and random packing phenomena form another line of research.

The research is supported by the National Science Foundation, the U.S. Department of Energy and the Office of Naval Research.

**PHOTONICS & LASERS**

Photonics is a major research initiative at CUNY. A number of modern laser spectroscopic techniques have been pioneered at City College and are being used to study dynamical prop-

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erties of a variety of physical and biological systems. City College has one of the most active, nationally recognized, programs in photonics and lasers and operates the Institute for Ultrafast Spectroscopy and Lasers (IUSL), the DOD Center for Nanoscale Photonic Emitters and Sensors (DOD CNPES) and the NASA URC Center for Optical Sensing and Imaging (NASA COSI).

The research at IUSL is centered on photonics, the science and technology of generating and harnessing light and other forms of radiant energy whose quantum unit is photon. Photonics encompasses the generation, propagation, deflection, amplification, manipulation, detection, and various applications of light. Physicists at the IUSL have developed new near-infrared broadband laser materials with tunability ranges around triple those of earlier crystals.

Distinguished Professor Robert Alfano, Professors Swapan Gayen, Matthias Lenzner and Vladimir Petricevic work in the area of photonics and lasers. In addition, there are several post-doctoral research associates and students. Theoretical support is provided by Distinguished Professor Joseph Birman and Professor Joel Gersten. There is also collaborative work with Professors Maria Tamargo and Valeria Balogh-Nair (Chemistry), Les Isaac (Chemical Engineering) and M. Kassir (Civil Engineering). Some of the topics of research interest include:

1. Growth and optical spectroscopy of Cr$^{4+}$ and Cr$^{3+}$ based crystals and composites for near-infrared laser applications
2. Development of tunable solid-state lasers and amplifiers
3. Ultrafast laser and amplifier development and ultrafast laser spectroscopy
4. Nanoscale microscopy and imaging, nanoscale ultrafast spectroscopic probing techniques
5. Optical mammography
6. Prostate tumor detection using spectral polarization imaging
7. Optical pulse propagation through and optical imaging in highly scattering turbid media
8. Time-resolved optical polarization imaging for underwater target detection
9. Near-infrared tunable laser tissue welding

Institute for Ultrafast Spectroscopy and Lasers

THE SUPERCONTINUUM LIGHT SOURCE

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10. Photonic optical biopsy and pathology
11. Spectroscopic detection of bacteria, spores and viruses
12. Spectral, temporal and coherence properties of the supercontinuum
13. Infrared terahertz probing and imaging techniques, THz spectroscopy in biological molecules, chemicals, and semiconductors
14. Orbital angular momentum and spin of light
15. Semiconductor physics and technology such as high efficiency solar cells, multiple quantum well-based ultraviolet detectors
16. Hybrid organic–inorganic nanoscale materials
17. Nonlinear optics

Research at IUSL and the Photonics program are supported by Army Research Office, Air Force Office of Scientific Research, the Department of Defense, the Department of Energy, National Aeronautics and Space Administration, National Institutes of Health, National Science Foundation, US Army Research and Materiel Command, New York State Foundation for Science, Technology and Innovation (NYSTAR), by industrial concerns such as Boston Scientific, Corning Inc., Lockheed Martin, Mallinckrodt, Optical Semiconductors, Quantronix Corp., and by CUNY.

FOUNDATIONS OF PHYSICS

Professors Timothy Boyer and Daniel Greenberger investigate foundational questions in physics, particularly the interplay of quantum and classical phenomena. Topics of research interest include the use of classical electrodynamics to explain the Aharonov–Bohm effect, discriminants between classical and quantum physics (the Greenberger–Horne–Zeilinger theorem) and properties of entangled quantum states.

PHYSICS EDUCATION

Research in physics education focuses on how students learn science, physics in particular. Current research interests include understanding the impact of technological teaching tools in education classes, especially in physics classes, evaluating the effectiveness of new teaching strategies at City College, and investigating the difficulties that students have learning
quantum mechanics.

Professor Richard Steinberg works in this area and is supported by the National Science Foundation.

COLLABORATIONS

There are active research collaborations with the departments of Chemistry, Biochemistry, Electrical Engineering, Chemical Engineering, the Benjamin Levich Institute for Physicochemical Hydrodynamics and with the newly created Institute for Sustainable Energy Technologies.

Beyond the City College campus, there are active collaborations with Lehman College, Queens College and with the Brookhaven National Laboratory and the Abdus Salam International Centre for Theoretical Physics, Italy.

Professor Myriam Sarachik receives the Oliver Buckley Prize from Dr. Marvin Cohen, President of the American Physical Society in March 2005. Professor Sarachik also served as President of the APS in 2003.

Professor Robert Alfano receives the Charles Hard Townes Award from Dr. Rod C. Alferness, President of the Optical Society of America in May 2008.
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