Lehigh Physics Research Areas

Faculty in the Lehigh Physics Department conduct research in a number of fields of physics. This document lists the research areas that are currently active. This list does not necessarily indicate areas that are currently taking on new graduate students, but rather provides an overview of active areas of research.

Astronomy and Astrophysics

- ***Observational***: Investigating the formation of disks around Be stars; measuring the properties of Mira and other variable stars; fundamental properties of massive stars; ages, composition, and dynamics of young stellar clusters; interactions between stars and compact objects in high mass X-ray binaries and gamma-ray binaries (McSwain). Discovery of new exoplanets and variable stars; characterizing the properties of populations of variable stars; identifying rare eclipsing or pulsating objects (Pepper).
- ***Theoretical***: Modeling the atmospheres and internal structure of stars (McSwain). Design and optimization of astronomical surveys, specifically for exoplanets and stars (Pepper).

Atomic, Molecular, & Optical Physics

- ***Experiment****:* Thermalization and condensation of photons in dye media confined within a narrow optical cavity (Kim). Current research investigates the physics of quantum many-body systems through studies of ultracold atomic gases. Topics include superfluidity, spin and heat transport, and thermodynamics of strongly-interacting Fermi gases. Experiments employ laser cooling and optical trapping to produce quantum degenerate atomic gases, and tailored optical potentials, radiofrequency spectroscopy and other techniques to perform measurements (Sommer). Other topics include multi-photon interactions mediated by matter (nonlinear optics) and the use of optical tools for research in condensed matter physics (Biaggio, Dierolf, Toulouse).

Biophysics

Researchers in the physics department employ the tools of physics to study the organization and dynamics of biological systems. They are involved in interdisciplinary collaborations with researchers in biology, bioengineering and related fields.

- ***Theory****:* Mathematical and computational studies of cell division, cell motion, polarized growth, and mating; physics of cytoskeletal self-organization. Statistical mechanics and soft matter physics applied to actin protein assemblies and the emergent collective properties. (Vavylonis).
- ***Experiment****:* Application of optical imaging, trapping, and manipulation for cell mechanics studies (Ou-Yang). A combination of fluorescence microscopy, lipid physical

chemistry, and fluid mechanics is used to investigate the mechanical principles underlying the response of living cells to fluid flow (Honerkamp-Smith).

Computational Physics

- Many of the fields of physics research at Lehigh involve the use of state-of-the-art computers to address large-scale computational problems. Researchers in the physics department employ diverse computational approaches to model complex many-body systems in condensed matter and quantum systems (Ekuma); the detection of variable signals in large astronomical surveys (Pepper); coarse-grained models of biological systems with molecular dynamics, statistical, and continuum methods (Vavylonis); large-scale data analysis in high energy and nuclear physics (Reed). Development of reinforcement-learning-based atomic force microscopy (Dierolf). The computational research is performed at both high performance computing facilities on campus and in national facilities.

Condensed Matter Physics

- ***Experiment****:* Charge transport in insulators and semiconductors; exciton dynamics in molecular materials, singlet exciton and triplet exciton fission, fusion, and transport; nonlinear optical spectroscopy (Biaggio). Point defects in insulating materials with ferroelectric domain walls and other dopants; optical spectroscopy under application of hydrostatic pressure, and magnetic fields; excitation processes of rare earth in wide band gap semiconductors, formation dynamcis of single crystals in glass (Dierolf). Defects in semiconductors. Current interest is in defect complexes that contain light-element impurities such as H, C, O, and N. Vibrational spectroscopy and uniaxial stress techniques are used to elucidate microscopic properties (Stavola). Raman and neutron scattering, dielectric and ultrasonic spectroscopies, collective vibrational dynamics of disordered ferroelectrics and glasses (Toulouse).
- ***Theory****:* Novel two-dimensional layered materials and their hybrids, heterostructures, and interfaces; Electronic and related properties of bulk semiconductors and insulators; Impurities and defects in materials including their interplay in strongly correlated materials/systems; The physics of carrier localization in model systems and real materials (Ekuma). Topological condensed matter physics and quantum critical phenomena in strongly correlated and disordered systems (Roy).

High Energy Physics

- ***Theory****:* Quantum field theory and string theory, and their applications to theoretical cosmology, quantum gravity and strongly coupled gauge theories. This includes fundamental aspects of the holographic gauge/gravity duality as well as phenomenological applications to a variety of strongly correlated phases of matter (Cremonini).

- ***Experiment**:* Use of the Solenoidal Tracker (STAR) detector and the proposed sPHENIX detector at the Relativistic Heavy Ion Collider (RHIC) to understand the quark gluon plasma (Reed).

Nonlinear Optics and Photonics

- ***Experiment**:* Multiple orders of light-matter interactions. Time-resolved spectroscopy of second and third-order nonlinear optical effects in organic and inorganic materials. New molecular materials for photonics. Optical frequency conversion and all-optical switching (Biaggio). Fiber optics. Nonlinear effects in optical fibers and waveguides (Dierolf, Toulouse).

Plasma Physics

- ***Experiment**:* Collisional and collisionless phenomena of very dense plasmas in or near a local thermodynamic equilibrium; radiation transport and lowering of ionization potentials in dense plasmas; nanocrystallites in plasma flow (Kim).

Soft Condensed Matter Physics and Complex Fluids

- ***Experiment**:* Nonlinear dynamics in fluid systems; dynamics of small particle suspensions; light scattering. Polymer and colloid physics (Ou-Yang).

Statistical & Thermal Physics

- ***Experiment**:* Intrinsic fluctuations in fluids under external forcing; light scattering from fractals; 1/f-dynamics of granular avalanches (Kim).
- ***Theory***: Disorder and transport in metallic alloys; nanocrystallite formation at near melting point; network theory modeling of entropy production (Kim).