

UW Physics REU 2012 Project List

Projects are offered from the following physics subfields:

- Cosmology and astrophysics
- Elementary particle physics
- Nuclear physics and astrophysics
- Atomic physics
- Physics education
- Condensed matter and nanostructure physics
- Numerical modeling and simulations

If you have a special interest not represented in the list below, feel free to contact either Subhadeep Gupta or Alejandro Garcia for help. They may be able to design new projects that align with your interests.

Experimental Projects

The MuSun Experiment

Peter Kammel

This experiment (<http://muon.npl.washington.edu/exp/MuSun/>) will measure a basic weak reaction of negative muons in ultra-pure deuterium with high precision. As the standard model of particle physics describes processes of muons and electrons in a unified manner, the reaction can also provide important information about fundamental astrophysics processes involving electrons, like the solar pp fusion, which are too weak to be measured directly in the laboratory. A first production run has been performed in 2011 using a novel experimental technique based on a cryogenic time-projection-chamber. This instrument will be upgraded with optimized cryogenic electronics in our lab at the UW physics department. Depending on the candidate's interests the REU project will focus on hardware or analysis tasks in collaboration with our postdocs and graduate students.

Solid-state spins for quantum computation and sensing

Kai-Mei Fu

Single defects and impurities in solids can be used both as quantum bits and as highly sensitive magnetometers. Our lab currently has research on identifying new types of quantum bits, optically connecting quantum bits, and developing a new optically-detected magnetic microscope. Possible undergraduate projects include (1) instrument control of a narrow-band tunable laser to resonantly excite impurities in III-V semiconductors, and (2) design, fabrication, and testing of a microwave circuit to be used in our magneto-microscope.

Bilayer Graphene Optoelectronics

Xiaodong Xu

Bilayer graphene has extraordinary physical properties: an electrically tunable bandgap (0-250 meV) and large photon absorption (~5%). It holds great potential for dynamically tunable optoelectronics at room temperature. However, little is known about the optoelectronic properties of bilayer graphene. There is also lack of a growth method to synthesis large scale bilayer graphene. In this project, REU students will be involved in the development of chemical vapor deposition growth of bilayer graphene, and measure the optoelectronic properties of tunable-bandgap bilayer graphene devices using scanning photocurrent microscopy.

Laser trapping of ^6He

Alejandro Garcia

This project aims at determining the angular correlation between the electron and the neutrino in the decay of ^6He . We plan to use a Magneto-Optical laser trap to hold the ^6He atoms so that the decay particles can be observed with minimal interference. The student will participate in setting up the laser equipment and in the first tries to trap ^6He .

Fundamental Physics with Torsion Balance Experiments

Eric Adelberger, Frank Fleischer

The Eot-Wash group works on extremely precise laboratory experiments designed to explore fundamental physics questions. Examples are tests of Einstein's equivalence principle or of the gravitational inverse-square law and a search for axion-like particles. The REU project could contribute to hardware developments for a new cryogenic torsion balance or for an improved search for axion-like particles. In either case, the project requires hands-on hardware work, possibly some software development and data analysis.

Search for Dark Matter

Leslie Rosenberg

Our group is operating the Axion Dark Matter eXperiment (ADMX), a detector to search for the axion, a hypothetical particle that may form the dark matter in our galaxy. We recently commissioned a new data channel that looks for axions that have recently fallen into our galactic dark-matter halo. Also, we're in the process of rebuilding the detector for its next and more sensitive phase. We welcome someone with computing and mechanical skills who can join our group and who has an interest in experimental cosmology.

Quantum Computing with Trapped Ions

Boris Blinov

In the trapped ion quantum computing lab at the University of Washington we experimentally investigate the techniques for building a conceptually new type of computational device. A quantum computer will be extremely fast at solving some important computational problems, such as the factoring and the database search. While days of practical quantum computing may be quite far in the future, we are developing the main building blocks of such a device – the quantum bits ("qubits"), the basic logic operations, the qubit readout... The physical implementation of the qubit in our lab is the hyperfine spin of a single, trapped barium ion.

Students in this REU project will participate in experiments with laser-cooled, RF-trapped single ions, will help develop techniques for single- and multi-qubit manipulation via microwave-induced hyperfine transitions and ultrafast laser-driven excitations. They will gain valuable hands-on experience with lasers and optics, RF and digital electronics, and ultrahigh vacuum technology.

Next generation neutrino detectors

Nikolai Tolich

Our group is involved in a number of experiments to detect neutrinos. Neutrinos are elusive particles that pass through matter almost completely unhindered, which makes them excellent probes of the physics occurring deep inside objects such as the earth and the sun, but also makes them extremely difficult to detect. We are currently working on ideas for two different neutrino detectors, which both use liquid scintillator as the detection medium. One detector, around 1 kton in mass, could be used to measure neutrinos coming from the earth. This would allow us to measure the main source of heat within the Earth, which is thought to power mantle convection, earthquakes, and plate tectonics. The other detector, around 50 to 100 kton in mass, could measure neutrino oscillations from a man-made neutrino source. This would allow us to understand the nature of neutrinos. An REU student could help us simulate new detector designs, or could help us make measurements of the optical properties of the liquid scintillator to see if such detectors would be possible. For more information on our research group, see: <http://www.phys.washington.edu/users/ntolich/>

Research-based Instructional Strategies for Teaching Physics

Lillian C. McDermott, Paula Heron, Peter Shaffer

The Physics Education Group conducts research on student understanding of physics and uses the results to guide the design of instructional materials, which are intended for national distribution. The effectiveness of these curricula is assessed at the University of Washington and at many other institutions. REU students will have the opportunity to participate in programs shaped by the group's research, such as the summer program for K-12 teachers and the tutorials for the introductory physics course. In addition to taking part in classroom activities, previous REU participants assisted in investigations of the effect of different instructional strategies on student understanding of important fundamental concepts.

Chiral photocurrent in carbon nanotubes and graphene

David Cobden

In our group we look for new physics in devices made from single nanotubes, nanowires and nanosheets (such as graphene). For example, one can see low-dimensional phenomena, unusual collective excitations, topological quantum effects and phase transitions in them. The combined techniques of laser optics and electrical transport can be brought to bear simultaneously on one of these devices. As an example, which is the suggested topic of this project, we will set out to measure the circular photocurrent effect in chiral carbon nanotubes and bilayer graphene. This light-generated current, which changes direction with the handedness of the light, has been recently predicted to offer a new means to probe interaction effects such as Luttinger-liquid and Wigner-crystal behavior in low dimensional electronic systems.

Transparent Conductive Oxides

Marjorie Olmstead

Gallium oxide is transparent into the near ultraviolet, and yet can be made to conduct electricity. This REU project would focus on understanding the growth of gallium oxide nanoscale films with pulsed laser deposition, including alloying with other materials (e.g. Aluminum or chromium oxide) and the nanoscale mechanical and electronic structure of electrical contacts. Depending on student interest, experiments may include photoemission spectroscopy, optical spectroscopy, scanning probe microscopy or electrical transport measurements.

X-ray Optics, Nonlinear Spectral Signatures, and Economics

Jerry Seidler

The Linac Coherent Light Source (LCLS), recently completed and commissioned at SLAC, is the world's first hard x-ray laser. It will allow measurements with unprecedented spatial and time resolution across multiple disciplines of science. Specific endstations are under construction to focus on: nonlinear x-ray optics in atomic physics, correlated electron physics in solid state and nanophase materials, pump-probe studies of biological and synthetic photochemistry, and plasma physics relevant for astrophysical nebula and planetary and stellar interiors. Science at the LCLS will, however, be constrained by a fundamental limit: it costs approximately \$100,000 per hour to operate the light source, and therefore beam time is a scarce resource and high-efficiency experimental methods become precious. Our group has recently developed two new types of x-ray emission spectrometers that can greatly decrease the measurement time for x-ray emission spectroscopy at the LCLS, and similarly increase experimental throughput at other time-resolved x-ray facilities. Interested students will get an in-depth experience in experimental instrument design, including both a broad introduction to modern x-ray techniques and also complete training in CAD software. Scheduling permitting, students will also participate in one of my group's trips to a synchrotron x-ray light source.

Theory/Numerical Modeling Projects

Light Front Quantum Mechanics

Jerry Miller

In 1947 Dirac introduced a new form of relativistic quantum mechanics in which the variable $ct + z$ acts as a "time" coordinate and $ct - z$ acts as a "space" coordinate. This so-called light front formalism was largely forgotten until the 1970's, when it turned out to be useful in analyzing a variety of high energy experiments. Despite the phenomenological success of this formalism, it has enjoyed only limited use in computing wave functions of particles and atomic nuclei. The present project is devoted to using the light front formalism to solve quantum mechanics problems involving bound and scattering states. A mathematically strong REU student would learn about relativistic quantum mechanics through the process of solving the relevant relativistic equations. This project would involve working on interesting and timely topics and could provide great preparation for graduate school quantum mechanics, field theory or even string theory. A full year of quantum mechanics is a necessary prerequisite.

Computational Condensed Matter Theory and Response Functions: Real-time and Real-space Methods

John J. Rehr

This project deals with high performance computer calculations of electronic response functions, such as the absorption and emission of x-rays, modern real-space and real-time computational algorithms. Our real-space codes are based on a Green's function (RSGF) formalism as implemented in the FEFF codes. Our real-time codes are based on time-dependent density functional theory using an extension of SIESTA. These codes are applicable to complex, nano-scale systems. This project is appropriate for students with an interest in theoretical condensed matter physics and computational physics.