UW Physics REU 2015 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

Fundamental Physics Measurements with Germanium Detector Arrays
Jason Detwiler

Our group is involved in the construction of the MAJORANA DEMONSTRATOR, an ultra-low background array of enriched germanium detectors that will perform a sensitive search for neutrinoless double-beta decay. The observation of this process would demonstrate that neutrinos are Majorana particles and that lepton number is not a conserved quantity, with implications for Grand Unification and the predominance of matter over antimatter in the universe. The same detector will also be sensitive to WIMP dark matter, solar axions, and other rare processes. We welcome a student with computing or hardware skills to assist in construction activities, make auxiliary measurements in local detector test stands, perform detector simulations, and analyze detector data.

On-Chip Entanglement of Solid-State Emitters
Kai-Mei Fu

We are developing a platform to realize scalable quantum information processing with the NV center in diamond. An undergraduate researcher will learn electromagnetic simulation software to simulate and optimize superconducting waveguide integrated single photon detectors. In addition to the simulation work, the undergraduate will take part in measurements of on-chip photonic device performance.

Ultracold Atoms and Molecules
Subhadeep Gupta

Through the orchestrated use of lasers and electronics, neutral atomic gases can be cooled and trapped at nano-Kelvin temperatures in a high-vacuum environment, where their properties are completely dominated by quantum mechanics. Here atoms interfere like laser beams and flow without friction. In our laboratory, we prepare and study such ultracold gases with a focus on understanding their behavior, testing fundamental quantum theories, and for future applications in quantum information science. In one project we work on resonantly interacting ultracold atoms to prepare and study ultracold molecules. In another, we perform atom interferometry experiments with Bose-Einstein condensates (BEC). Researchers in our group acquire a broad range of experimental skills while exploring frontier topics in low-temperature quantum physics. The REU student can engage in multiple aspects of the experiments - past REU students have made significant contributions by (for instance) designing and building electromagnetic atom trapping coils and building diode laser assemblies. Please see our website http://www.phys.washington.edu/users/deepg/ for further details.

Optical Generation and Electrical Control of Valley Excitons and Pseudospins in monolayer Semiconductors
Xiaodong Xu

Electronic valleys are energy extrema of Bloch bands in momentum space. In analogy to electrons with spin degrees of freedom, valley indexes can be considered as pseudospins for new modes of electronic and photonic device operation. In this project, the REU student will be involved in the investigation of these pseudospins using atomically-thin semiconductors, which are either single or bilayer group VI transition metal dichalcogenides. The student will learn material synthesis and device fabrication, and be involved in optical measurements of spin and valley physics through neutral and charged valley excitons with an electrical control.

Searching for new physics in the muon's magnetism and NMR
Alejandro Garcia and Eric Swanson

The magnetic moment of the muon is a fundamental quantity that is calculable with high precision. However, recent measurements show disagreement with expectations that may be hints of new physics. In order to determine the muon magnetic moment, reliable determination of magnetic fields are needed and will be done via nuclear magnetic resonance (NMR). The project will consist of building NMR probes and doing calculations to understand limitations. The student will get hands-on experience building equipment, working with NMR probes signals, developing electronics and data acquisition systems, and doing associated calculations.

Nuclear beta spectroscopy of the future
Alejandro Garcia and Matt Sternberg

The detection of electron emission from nuclear beta decays and photon conversions has been used to do a large number of experiments, from searches for new physics to nuclear spectroscopy in the past. Recently a new technique to determine electron energies via their cyclotron radiation in a magnetic field has been demonstrated at UW. The work showed that the technique works very well for electron energies of less than approximately 30 keV. This project would involve developing the technique for higher energy electrons, up to approximately 4 MeV, with the aim of searching for new physics by measuring the electron spectrum from 6He, a nucleus we produce with our local accelerator. The student would spend time understanding the emission, reception and amplification of the radiation and developing methods to calibrate the apparatus.

Metasurface based optical elements and information processing
Arka Majumdar

Metasurfaces (quasi-periodic two-dimensional array of sub-wavelength features), the two-dimensional analogue of metamaterials, offer a compact way of transforming the wavelength, momentum, and polarization distributions of optical signals. In addition to metasurface counterparts to macroscopic optical elements (such as lenses, gratings, and waveplates), these surfaces open up the possibility of arbitrary phase transformations on optical signals. This could lead to the realization of new metasurface enabled imaging platforms, solid-state spatial light modulators with subwavelength wavefront manipulation, or the implementation of complex decomposition algorithms for optical processing and sensing. The student will be involved in electromagnetic simulation (using rigorous coupled wave analysis and finite difference time domain software packages); as well as optical characterization of these devices (fabricated here at UW).

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. A student 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.

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. A REU student 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.

A Beamline in Box
Jerry Seidler

Advanced x-ray methods at synchrotron light sources are the basis for numerous advances in condensed matter and atomic physics, biology, physical and organic chemistry, and materials sciences, to name a few examples. However, at the same time, the scarcity of access to such facilities has become a limiting factor in several fields. This is perhaps noticeable in clean energy research where progress in developing improved battery chemistry and performance is often greatly aided by x-ray spectroscopies that have only been available at the large synchrotron facilities. Recently, however, the Seidler group at UW has developed a table-top x-ray spectroscopy system capable of performing many of the necessary studies on batteries. In the summer of 2014, we will finish construction and begin commissioning of a user facility for UW clean energy researchers that is based on our 'beamline in a box' strategy. The involved REU student will be given responsibility for part of this process and will actively participate in x-ray spectroscopic studies of the electronic structure of model batteries and other systems important for sustainable energy.

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 for Complex Systems
John J. Rehr

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