UW Physics REU 2017 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

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

Experimental Projects

New Radiofrequency Detectors for Particle Physics
Gray Rybka

Advances in ultra low noise microwave electronics have opened the door to a new generation of detectors with extreme sensitivity to very low energy signals. This project will be related to developing detectors that have applications to astroparticle physics: axion dark matter and neutrino mass measurements.

Engineering the properties of quantum defects
Kai-Mei Fu

The REU project will determine if the nitrogen-vacancy center in diamond, a quantum defect of interest for quantum sensing and quantum information applications, is able to re-orient at very high temperatures (1100). The project will involve single quantum defect imaging, optically-detected electron-spin resonance, and optical polarization-revolved imaging.

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.

Optoelectronics of 2D Semiconductor Heterostructures
Xiaodong Xu

Heterostructures of 3D semiconductors are a central component of condensed matter physics and modern solid state technologies (such as diode lasers and high-speed transistors). The recent discovery of monolayer semiconductors offers exciting opportunities to engineer analogous 2D heterostructures for exploring a wide range of new properties and functionalities. In this project, the REU student will be involved in the investigation optoelectronic properties of the 2D heterostructures. The student will learn how to obtain monolayer semiconductors, heterostructure device fabrication and characterization, and be involved in optical measurements (such as polarization and time-resolved photoluminescence, Raman spectroscopy, second harmonic generation etc.).

Nuclear beta spectroscopy of the future
Alejandro Garcia

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 cavity
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 novel cavity, where we can realize interesting mode profile, including vector beams. Such cavity can distinguish different polarizations, opening up new directions in the field of cavity quantum electrodynamics. One interesting direction will be to explore neutron like activity in this type of cavities. 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, Suzanne Brahmia, Paula Heron, & Peter Shaffer

The Physics Education Group at the University of Washington (UW) 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 the curricula is assessed at many institutions. An REU student will have the opportunity to participate in various research, curriculum development, and instructional programs of the group, for example Tutorials for introductory and advanced physics courses. In addition to taking part in classroom activities, previous REU participants have assisted in investigations of the effect of different instructional strategies on student understanding of important fundamental concepts and the reasoning skills need to apply these concepts.

Photocurrent in two-dimensional heterostructures
David Cobden

In our group we investigate new physics in devices made from nanotubes, nanowires, graphene, and other two-dimensional materials, as well of combinations of these. In such systems one can see a variety of low-dimensional phenomena, collective excitations, topological quantum effects, and phase transitions. A particular experimental approach to these systems with great potential is the combination of laser optics and electrical transport. For example one can measure the light-generated current, or photocurrent, as a function of the position of a laser spot, while varying polarization, intensity, temperature and magnetic field. This can give unique information about features in the density of states, edge states, optical transition strengths and relaxation mechanisms. In this project we will aim to measure photocurrent in two-dimensional devices built from combinations of the semimetal graphene, the insulator boron nitride, the semiconductor WSe2, the semimetal WTe2, and the superconductor NbSe2.

Nonlocal Energy Transport and New Directions in X-ray Free Electron Laser Science
Jerry Seidler

The latest development in x-ray science is the construction and commissioning for user operations of x-ray free electron lasers (XFELs) in both the US and Europe. These billion-dollar facilities provide the ultimate in microscopic interrogation using x-ray pulses that are much faster than any inter-atomic motion, giving snapshots in time that allow extreme refinement of understanding of the electronic properties of materials undergoing, e.g., chemical changes. This is leading to new understandings of many fundamental and applied problems spanning physics, chemistry, biology, geosciences, and engineering. And, you can use them to blow stuff up. That's what we do. The XFEL pulses, when suitably focused, are able to heat the electrons in a solid phase to as high as 1 Million Kelvin before the ion core has a chance to appreciably move. This type of 'frozen hot' dense plasma can give new insight into theoretical methods needed in dense plasma physics for inertial confinement fusion studies or for better descriptions of the cores of gas giant planets. Here, the interested student will design, plan, and execute experiments that selectively probe a key mechanism in XFEL heating of solids: the issue of the nonlocal energy transport over submicron distances by high-energy primary and secondary photoelectrons. Working with other members of the group, the student will perform materials synthesis by thin film deposition, strongly participate in experimental design and construction of needed components for an x-ray fluorescence cascade study, and take leadership responsibility for executing and analyzing the experiment. The results of this study will help with an ongoing research program aimed at developing complex nanoscale targets for XFEL x-ray heating studies.

Experimental Neutrino Physics
Jason Detwiler

Our group participates in the neutrinoless double-beta decay experiments Majorana and LEGEND, and the neutrino scattering experiment COHERENT. Options for summer projects include:

- Analysis of Majorana Demonstrator data (spectral analysis, background estimation, data cleaning, Monte Carlo simulation, pulse shape analysis, ...)
- Alpha scans on passivated surfaces of PPC HPGe detectors for the Majorana Demonstrator and LEGEND (including construction and operation of an apparatus, and subsequent data analysis)
- LAr light readout R&D for LEGEND (including construction and operation of an apparatus, and subsequent data analysis)
- Data analysis for the "NaIvE" detector (185 kg array of NaI detectors running at the SNS as part of the COHERENT project): energy estimation, calibration, data cleaning, spectral analysis...
- Development of PMT amplification electronics for a ton-scale NaI array in COHERENT
- NaI crystal characterization and internal background measurement for COHERENT

Determine the phase diagram of broken symmetry phases in layered materials
Jiun-Haw Chu

Unconventional and high temperature superconductivity often emerge in the vicinity often broken symmetry instability, such as electron nematicity, charge and spin density wave. The layered materials have been a fertile ground for such phenomena because of its enhance Fermi surface nesting and fluctuations due to its reduced dimensionality. The REU project will focus on single crystal growths, low temperature electrical transport and thermodynamic measurements. The goal is to determine the temperature-composition phase diagram in several unexplored layered materials.

Theory/Numerical Modeling Projects

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.