

UW Physics REU 2019 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.

Ultracold Atoms and Quantum Gases

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 study superfluids and 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, diode laser assemblies, performing laser spectroscopies, and data analysis. Please see our website <http://faculty.washington.edu/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.

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 high-sensitivity scan. 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.

Advanced two-dimensional devices

David Cobden

In our group we investigate new physics in devices made from combinations of two-dimensional van der Waals materials, including graphene and many others. Phenomena under study include 2D topological phases, 2D superconductivity, 2D ferroelectricity, 2D magnetism and 2D phase transitions. In this project the student will learn to make their own 2D devices with a particular physics goal in mind, and then carry out a range of measurements, which are likely to include low temperature transport in high magnetic fields and suitable kinds of photoexcitation and spectroscopy.

Determine the phase diagram of broken symmetry phases in layered materials

Jiun-Haw Chu

Unconventional and high temperature superconductivity often emerge in the vicinity of broken symmetry instabilities, such as electron nematicity, charge and spin density waves. Layered materials have been a fertile ground for such phenomena because of their enhanced Fermi surface nesting and fluctuations due to their 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.

Large single-electron response CCDs to search for dark matter

Alvaro Chavarria

The next step in the DAMIC dark matter search is the development of an array of large area, thick charge-coupled devices (CCDs) capable of detecting extremely small energy depositions that ionize as little as two electron-hole pairs in the silicon target. These devices will provide unprecedented sensitivity to low-mass dark matter particle candidates in the galactic halo that may interact with nuclei or electrons in the target. The first prototypes of these novel “skipper” CCDs are due to arrive at the University of Washington in the first half of 2019. The REU student will participate in the characterization of the response of the first devices to ionizing radiation.

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, and extensions for finite temperature behavior. 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 interests both in theoretical condensed matter physics and computational physics.

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.

Exotic topological phases of matter

Lukasz Fidkowski

My research focus is on identifying and classifying exotic phases of quantum matter. This involves understanding how the myriad of electrons, spins, or other degrees of freedom can self-organize into a many-body wave-function, and what universal observables distinguish among such wavefunctions. One particular approach is to write down simplified models that can be solved exactly but still capture the important physics. The goal of the project is to construct such simplified models for some of the new exotic phases that have recently been proposed. Knowledge of linear algebra and quantum mechanics are required.

Quantum Simulation with Interacting Photons

Arka Majumdar

Understanding correlated many-body effects, including high-temperature superconductivity and fractional quantum Hall physics is not only of fundamental scientific interest but also has the

potential for transformational societal impact, with applications in faster, more efficient electronics and topological quantum computers. However, such systems are extremely difficult to study theoretically due to the massive computational resources required. An innovative solution is to build an alternative, well-controlled experimental platform to simulate the performance of these correlated electronic systems. Several physical systems, including cold atoms, ion traps, defect centers, and superconducting circuits, have been considered for quantum simulations. In particular, strongly interacting optical photons provide a unique approach to non-equilibrium many-body quantum simulation due to the ease of adding and destroying photons via external driving and photon loss, as well as measuring multi-photon correlations using readily available single photon detectors. Such interactions, however, require the realization and control of nonlinear optics (NLO) at the few photon level, a daunting task in practice. We have recently developed a platform using solution processed quantum dots coupled to an array of cavities. Unfortunately, in this platform, we cannot reach single photon nonlinearity easily. In the REU project, we plan to model this quantum system (using master equation and quantum trajectory method) and identify the steady-state observables, which exhibit quantum mechanical behavior, even in the absence of single photon nonlinearity. The project also aims to understand the use of this nonlinear coupled cavity array to problems such as quantum machine learning.