University of Washington
Physics Colloquium Schedule
Autumn Quarter 2008

Mondays, 4:00 P.M. Ronald Geballe Auditorium, Rm. A102
Coffee & cookies at 3:45 P.M. in the lobby

www.phys.washington.edu/colloquia.htm
~Autumn Quarter Colloquium Chair: Professor Boris Blinov~

September 29 **Mark Bokrath (California Institute of Technology)**

Title: "Carbon nanoelectronics: from correlated electrons to sensors and devices"

Abstract: In my talk I will discuss a number of our ongoing research projects on carbon nanotubes and graphene, with the goals of studying fundamental physics in nanostructures as well as developing sensing and device applications. In particular, I will highlight our recent results demonstrating the following: (1) strongly correlated electron behavior in ultra-clean carbon nanotubes, specifically, one-dimensional (1D) Wigner crystallization of dilute holes in semiconducting nanotubes, and the formation of a 1D Mott insulator in nominally metallic nanotubes, indicating that carbon nanotubes are never truly metallic.
Our results underscore nanotubes' promise for studying a variety of tunable correlated electron phenomena in 1D; (2) individual carbon nanotube nanomechanical resonators as atomic-scale resolution inertial mass sensors, with the prospects for single atomic mass unit sensitivity and chemical or isotope discrimination; and (3) non-volatile graphene atomic switches, which we understand by a model of electric field driven motion of single-atom wide chains of carbon. These devices have the potential for high density, long term storage of information.

October 6 **Chun Ning (Jeanie) Lau (University of California Riverside)**

Title: *"Graphene Quantum Electronics and Devices"*

Abstract: Graphene, a two-dimensional single atomic layer of carbon, has recently emerged as a promising candidate for electronic materials, as well as a new model system for condensed matter physics. In this talk I will give a brief overview of this rapidly expanding field, and discuss our recent results on novel transport phenomena in graphene, including coherent interference of multiply-reflected charge waves, quantum hall states in p-n junctions, gate-tunable Josephson supercurrent transistors, and graphene atomic switches. I will conclude the talk with a brief discussion of the challenges and promises offered by this fascinating 2D system.

October 13 **Valery Milner (University of British Columbia)**

Title: "Coherent Scattering with Incoherent Light: New Spectroscopy with Ultra-Short Laser Pulses"

Abstract: High peak power ultrafast lasers are widely used in nonlinear spectroscopy but often limit its spectral resolution because of the broad frequency bandwidth of ultrashort laser pulses. Improving the resolution by achieving spectrally narrow excitation of, or emission from, the resonant medium has been the focus of many recent developments in ultrafast spectroscopy. Similar to many traditional nonlinear optical methods, state-of-the-art ultrafast spectroscopy relies on the coherence of laser pulses. In my talk, I will show that contrary to the common belief that spectral noise is detrimental to coherent spectroscopic measurements, it can be used for improving the resolution, efficiency and robustness against unavoidable degradation of pulse coherence. Using the example of Coherent Anti-Stokes Raman Scattering (CARS), I will review a few novel approaches to nonlinear ultrafast spectroscopy, in which random or pseudo-random noise is deliberately introduced and successfully used for the retrieval of high-resolution spectral information about the medium of interest.

October 20 **Dave Bacon (UW Computer Science & Engineering)**
Title: *"Who Will Build a Quantum Computer: the Physicists or the Computer Engineers?"*
Abstract: Building a quantum computer large enough to perform a task beyond the capability of today's classical computers (breaking a cryptographic code or simulating a complex quantum system) is a daunting task. On the fundamental side, this difficulty arises from the fact that quantum systems like to decohere, and that we cannot control a quantum system with perfect accuracy. On the technical side, the obstacles toward build a quantum computer arise from the severe engineering constraints imposed by manipulating individual quantum systems. The theoretical solution to the problems of decoherence and lack of control was worked out in the ninties and is known as the threshold theorem for fault-tolerant quantum computing. The great debate in quantum computing today is how the technical difficulties of building a quantum computer will be overcome. In this talk I will outline two very distinct camps on how this will be achieved: one centered very squarely on engineering and the other with roots in condensed matter physics. This is a battle for the soul of future quantum computers and will determine whether quantum computers are years, decades, or centuries away from being built.

October 27 **Robert A. Kaindl (Lawrence Berkeley National Laboratory)**
Title: *"Ultrafast Terahertz Spectroscopy: From Excitons to Cooper-Pairs"*
Abstract: Ultrafast spectroscopy is a powerful tool to study key microscopic processes that occur on short timescales in molecules, solids, and biological systems. I will discuss experiments that employ coherent THz light pulses to study the dynamics of low-energy excitations and carrier correlations in semiconductors and superconductors. Bound electron-hole pairs (excitons) in semiconductors exhibit characteristic inter-level transitions analogous to atoms. This enables "intra-excitonic" spectroscopy as a new tool to explore the physics of electron-hole pairs in low-dimensional systems. I will review experiments that trace the temperature, density, excitation energy, and time dependence of intra- excitonic resonances, to directly map out excitonic phase diagrams and to follow exciton formation and ionization kinetics. A quite different type of charge pairing, whose mechanism is not yet understood, occurs in high-T_C cuprate superconductors such as YBCO or Bi-2212.
Femtosecond studies covering an ultrabroadband THz range reveal the ultrafast fill-in of the infrared pseudogap and a complex, multi-component recovery dynamics. The electromagnetic response in the few-THz range, in turn, couples directly to Cooper pairs and quasiparticle excitations. This allows for direct probing of these species on ultrafast timescales and provides insight into the kinetics of charge pair formation. Such experiments trace correlated states via their transient low-energy response, motivating further ultrafast studies and the use of intense THz pulses for resonant excitation, probing, and control of low-energy states in complex materials.

November 3 **Raymond Chiao (University of California Merced)**
Title: *"Experiments at the interface of quantum mechanics and general relativity: The interaction of gravitational waves with coherent quantum matter"*
Abstract: The interaction of charged, macroscopically coherent quantum systems, such as a pair of charged superconducting spheres, with both electromagnetic (EM) and gravitational (GR) waves, will be considered. When the charge-to-mass ratio of a pair of identical superconducting spheres is adjusted so as to satisfy the "criticality" condition Q/M =

$(4\pi\varepsilon_0 G)^{1/2}$ where ε_0 is the permittivity of free space, and G is Newton's gravitational constant, the gravitational force of attraction will be balanced against the electrostatic force of repulsion between the two spheres. At criticality, when these two spheres in a given pair of charged superconducting spheres undergo simple harmonic motion relative to each other, they will radiate equal amounts of quadrupolar GR and EM radiations.

The superconducting spheres possess an energy gap (the BCS gap) separating the ground state from all excited states. The quantum adiabatic theorem then implies that the quantum phase everywhere inside the superconductors, in their linear response to both kinds of weak incident electromagnetic and gravitational radiation fields, whose frequencies are less than the BCS gap frequency, such as at microwave frequencies, will remain single-valued at all positions and times. This linear response of these coherent quantum systems leads to hard-wall boundary conditions at the surfaces of the spheres, in which both the incident EM and GR radiation fields will undergo specular reflections at the surface of these superconducting spheres. Therefore the scattering cross-sections for both kinds of radiation fields will be on the order of $\sigma = \pi a^2$, where a is the radius of the spheres, when the radius a is comparable to, or larger than, the microwave wavelength. The distance separating the two spheres in a given pair of spheres will also be assumed to be comparable, or larger than, the microwave wavelength. Under these circumstances, the scattering cross-sections of pairs of charged superconducting spheres for both EM and GR radiations at microwave frequencies will be nonnegligible.

At sufficiently low temperatures with respect to the BCS gap, all dissipative degrees of freedom of the spheres will be frozen out by the Boltzmann factor. Then at criticality, by time-reversal symmetry there will be an equipartition of both kinds of incident radiation, so that the scattering cross-section is the same for the time-reverse process as for the time-forward process. This implies that a Hertz-like experiment, i.e., a transmitter-receiver experiment, in which GR waves are generated at the emitter or transmitter by incident microwaves incident on two charged superconducting spheres at criticality, and detected at the receiver or detector by another two charged superconducting spheres at criticality, should be experimentally feasible to perform.

November 10 Margaret Murnane (JILA/University of Colorado, Boulder)
Fred Schmidt Memorial Lecture, Partially funded by the GSFEI
Title: *"Harnessing Attosecond Science for Coherent X-Ray Generation and Applications"*
Abstract: To generate coherent x-ray beams, extreme nonlinear optical techniques have succeeded in upshifting visible laser light into the x-ray region of the spectrum. This ability has given us a new coherent light source that spans such a large region of the spectrum that we now access processes that occur on sub-femtosecond or attosecond (1 as=10^{-18} s) time-scales. Equally intriguing is the fact that we have learned how to use femtosecond laser light to coherently manipulate electrons in atoms and molecules on their fundamental, attosecond timescales. The richness and complexity of attosecond science and technology is only just beginning to be uncovered. As I will discuss in this talk, attosecond science can capture the complex, interwoven dance of electrons in molecules and materials. Attosecond science also shows great promise for developing new ultrasensitive molecular imaging and spectroscopic techniques.
Finally, attosecond science represents the most promising avenue to achieve what had seemed hopelessly impractical until now -- the generation of bright, coherent, hard x-ray beams using a tabletop-scale apparatus.
[1] H. C. Kapteyn et al., Science 317, 775 (2007).
[2] E. Gagnon et al., Science 317, 1374 (2007).
[3] X. Zhou et al." Physical Review Letters 100, 073902 (2008).
[4] R. Sandberg et al., Proc. Nat. Acad. Sci. 105, 24 (2008).

November 17 Dan Stamper - Kurn (University of California, Berkeley)

Title: *"Magnetic phases of a dipolar spin-1 quantum gas"*

Abstract: A spinor Bose gas, composed of atoms which can occupy all states of a non-zero hyperfine spin, can manifest both the phenomena of magnetism and of superfluidity, both of which result from long-range coherence of the spinor wavefunction and also result from symmetry breaking. Having developed techniques for sensitive in-situ measurements of the magnetization in a spin-1 rubidium gas, we have explored both its dynamic and static properties. Our findings include the observation of spontaneous symmetry-breaking upon the traversal of a quantum phase transition, the characterization of a near-quantum-limited spin amplifier based on coherent atomic scattering, the establishment of the importance of magnetic dipole interactions, and, finally, the discovery of an unforeseen low-temperature crystalline phase of this quantum gas.

November 24 Juan Collar (University of Chicago)

Title: "*Something Old, Something New"*

Abstract: We'll discuss two initiatives in astroparticle and neutrino physics at the University of Chicago, both sharing in common the revival and revision of old technologies to address new experimental challenges.

COUPP employs ultra-stable heavy liquid bubble chambers to search for WIMP dark matter. First results leading to improved limits on spin-dependent WIMP couplings will be presented, together with the most recent progress. COGENT aims at the detection of very faint (~100 eV) signals in detectors massive enough to allow searches for rare processes, using recently developed p-type point contact (ppc) Germanium detectors. The broad range of applications (coherent neutrino scattering, light WIMP searches, double-beta decay) available for these new semiconductor devices will be described, as well as the status of an ongoing reactor (anti)neutrino experiment.

December 1 **Gregory Gabadadze (New York University)**

Partially funded by the GSFEI

Title: "*Universal Aspects of Modified Gravity"*

Abstract: I will review the arguments that motivate studies of modified general relativity at cosmological distances, and discuss model-independent shorter-scale observational consequences of these modifications.

December 2 **Bob McKeown (California Institute of Technology)**

(Held in Rm. C-520, PAT)

Title: "*Neutrino Oscillations: Recent Triumphs and Future Challenges"*

Abstract: Recent studies of neutrino oscillations have established the existence of finite neutrino masses and mixing between generations of neutrinos. The combined results from studies of atmospheric neutrinos, solar neutrinos, reactor antineutrinos and neutrinos produced at accelerators paint an intriguing picture that clearly requires modification of the standard model of particle physics. These results also provide clear motivation for future neutrino oscillation experiments as well as searches for direct neutrino mass and nuclear double-beta decay. I will summarize the status of experimental and theoretical work in this field and discuss the future opportunities that have emerged in light of recent discoveries.