Graduate students currently engaged in research using BaPSF

Student	Institution/Group	Mentor(s)
Xin An	UCLA (Atmospheric and Oceanic Sciences)	J. Bortnick
Anton Bondarenko	UCLA	C. Niemann
Jeffrey Bonde	UCLA (BaPSF group)	W. Gekelman, S. Vincena
S. Eric Clark	UCLA	C. Niemann
Paul Crandall	UCLA	F. Jenko
Tim DeHaas	UCLA (BaPSF group)	W. Gekelman
Erik Everson	UCLA	C. Niemann
Daniel Guice	UCLA (BaPSF group)	T. Carter
Dooran Hong	UCLA (BaPSF group)	W. Gekelman
Mike Martin	UCLA (BaPSF group)	W. Gekelman, T. Carter
Samuel Nogami	WVU	M. Koepke
Adam Preweisch	UC Irvine	W. Heidbrink
Jeffrey Robertson	UCLA (BaPSF group)	T. Carter
Giovanni Rossi	UCLA (BaPSF group)	T. Carter
James Schroeder	U. Iowa	C. Kletzing, F. Skiff, G. Howes

Advanced degrees granted, last 5 year period

Student	Degree	Granting institution	Graduate advisor	Year
Nathaniel Moore	Ph.D.	University of California, Los Angeles	W. Gekelman	2015
Yiting Zhang	Ph.D.	University of Michigan	M. Kushner	2015
William Farmer	Ph.D.	University of California, Los Angeles	G. Morales	2014
Adam Kullberg	Ph.D.	University of California, Los Angeles	G. Morales	2014
Derek Schaeffer	Ph.D.	University of California, Los Angeles	C. Niemann	2014
Kris Kersten	Ph.D.	University of Minnesota	C. Cattell	2014
Brett Friedman	Ph.D.	University of California, Los Angeles	T. Carter	2013
David Schaffner	Ph.D.	University of California, Los Angeles	T. Carter	2013
Yuhou Wang	Ph.D.	University of California, Los Angeles	W. Gekelman	2013
Chris Cooper	Ph.D.	University of California, Los Angeles	W. Gekelman	2012
David Auerbach	Ph.D.	University of California, Los Angeles	T. Carter	2012
Shu Zhou	PhD.	University of California, Irvine	W. Heidbrink	2011
Gregoire Hornung	M.S.	Gent Universiteit, Belgium	G. Van Oost	2010
Andrew Collette	Ph.D.	University of California, Los Angeles	W. Gekelman	2010
Kim De Rose	M.S.	University of California, Los Angeles	W. Gekelman	2010
Brett Jacobs	Ph.D.	University of California, Los Angeles	W. Gekelman	2010
Alexey Karavaev	Ph.D.	University of Maryland	K. Papadopoulos	2010
Nathan Kugland	PhD.	University of California, Los Angeles	C. Niemann	2010
Eric Lawrence	Ph.D.	University of California, Los Angeles	W. Gekelman	2010
Franklin Chaing	Ph.D.	University of California, Los Angeles	J. Judy	2010

Current external user groups

Independent experimenter user groups

1. "Laser Driven shock waves in the LAPD", C. Niemann, C. Constantin (Dept. of Physics and Astronomy, UCLA.)
   High power lasers are used to drive collisionless magnetized shocks in LAPD. A high power (~ 100 J) Nd:YAG laser (repetition rate 10 minutes) is focused on a target in the LAPD plasma. Measurements and simulations corroborate the generation of a collisionless shock ($M_A \approx 2$) across the LAPD background field in the presence of the dense, LaB_6 plasma. The interaction is studied with the use of multiple magnetic and Mach probes, fast (3 ns) photography, and spectroscopy.

2. "Laboratory Investigation of Auroral Alfvén Electron Acceleration", C. Kletzing, F. Skiff, (Dept. of Physics, University of Iowa).
   This is a study of shear Alfvén waves with short perpendicular wavelengths as well as investigations of field-aligned acceleration of electrons due to the electric field of the waves. A series of antennas, which are phased arrays, has been developed at the University of Iowa and put on the LAPD. The propagation of waves launched by these antennas is studied and their dispersion mapped. Electron distribution functions perturbed by the Alfvén waves are measured using a novel whistler wave diagnostic developed by the Iowa group. The results will be compared with spacecraft measurements made in the Earth's auroral region.

3. "Tests of Electron Emission and Plasma Production via LaB6 Cathodes at High Confining Magnetic Field," Y. Song, D. Bui (Tri Alpha Energy- TAE), L. Schmidt (UCLA). The use of high emissivity cathode sources is explored by TAE for use in their fusion device. This is a synergistic effort as both TAE and BaPSf are interested in the behavior of LaB6 cathodes at magnetic fields approaching one Tesla. TAE provided a high-field magnet, vacuum chamber and power supplies for testing at UCLA. The UCLA group constructed a cathode (with TAE funds) designed to have minimum stress at high field. Tests at BaPSF have demonstrated the feasibility of the system by documenting the plasma production and source durability during pulsed operation. The system will now be tested at TAE, with BaPSF technical assistance, in the coming year.

4. "Development of Micro-Electromechanical systems (MEMS) probes for plasma diagnostics", J. Judy (Department of Electrical Engineering, UCLA) This project uses the expertise of the MEMS group at UCLA headed by Prof. J. Judy to fabricate a number of microscopic probes for plasma diagnostics. Prototypes include magnetic pickup coils, energy analyzers and electric field probes. Some of these could only be seen with a scanning electron microscope. The Debye length scale ($\sim 20\,\mu$m) electric probe was a crucial tool in the electron hole experiment by Li-Jen Chen.

Theory-driven studies

1. “Proposal for an Experimental Study of Magnetospheric Wave Processes", P. Colestock and M. Light (Los Alamos National Laboratory)
   This project is driven by a LANL program on radiation belt remediation, which has developed large-scale simulations that model the interaction of electrostatic lower hybrid (LH) waves with structured plasmas. Cases of interest are field-aligned density striations (both depletions and enhancements.) To execute the work, a high power, high frequency, slow wave structure was constructed to launch the LH waves. With funds supplied by LANL, the antenna and 16 completely independent RF drivers (1-100 MHz, 300W each) have been installed on the LAPD. Each antenna element is controlled by its own arbitrary waveform generator and used to systematically vary the spatial phasing and amplitude patterns on the array. The resulting LH waves (incident on striations) are observed to scatter from them; to create standing modes within them; and to mode convert into whistler waves. The conversion efficiency of LH to whistler waves on a density gradient is measured using high-frequency electric and magnetic probes; this efficiency is found to be many orders of magnitude lower than current theoretical and simulation predictions.

2. “Whistler Wave Pitch Angle Scattering of Electrons”, Jacob Bortnick (UCLA Earth and Space Science), R.M. Thorne and Xi An (UCLA Department of Atmospheric and Oceanic Sciences)
   This is a study of whistler wave scattering of a beam of energetic electrons. A low-density electron beam, with adjustable pitch angle relative to the background magnetic field, produces the energetic electrons. The velocity distribution function is measured with small velocity analyzers. This is done with and without background whistler waves. The waves are launched with a small loop antenna. Results are compared to theoretical predictions.

3. “Tearing of a Current Sheet into Magnetic Flux Ropes”, W. Daughton, J. Finn (LANL), H. Karimabadi (UCSD)
   A fully 3D kinetic code developed at Los Alamos and using the largest multiprocessor computer in the world is used to model the tearing of a current sheet into multiple magnetic flux ropes. In full 3D computations it has been observed that the magnetic islands, which are the result of the tearing of the current sheet, are helical flux ropes which interact with one another. A new high emissivity cathode, (installed in the summer of 2013) is masked to make a thin (dy/dx=20) current sheet. The full three-dimensional evolution of the current is measured in the LAPD, and detailed comparisons with theory and the petascale simulations are done.

4. “Investigation of Sheaths near RF antennas for fusion”
   D. D’Ippolito, J. Myra (Lodestar)
   This is a study of the RF sheaths on antennas immersed in a magnetoplasma. The antennas radiate in the ICRF, Fast Wave, regime. Antennas are being constructed at UCLA and waves launched at low and high powers into the LAPD edge plasma. A variety of probes and optical techniques are used to study the sheath plasma waves and their coupling to fast waves and under appropriate conditions to shear Alfvén waves. The experiments are complemented with a modeling effort at Lodestar.

5. “Experimental and Numerical Studies of Whistler Wave Ducting,” A. Streltsov (Embry-Riddle Aeronautical University)

This study is aimed at studying the propagation of VLF whistler modes in a laboratory plasma and to compare these results with numerical predictions. A key goal is to model the propagation in magnetic field-aligned irregularities (also called channels or ducts). High frequency ($f \geq f_{ce}/2$) and low-frequency ($f \leq f_{ce}/2$) cases are examined.

6. “Search for electron solitary structures,” L.-J. Chen (University of New Hampshire)
   This project is motivated by the ubiquitous observation made on board spacecraft of electrostatic solitary structures known as “electron holes”. The major outstanding questions are related to the generation, dynamics and statistics of phase-space structures of spatial dimension comparable to the Debye length. These features have been investigated by injecting a small suprathermal electron beam into the LAPD plasma and measuring the small structures with novel MEMS microscopic probes that sample the structures at rates much higher than the plasma frequency. The measured scales and amplitudes of these structures are comparable to those derived from observation in the magnetosphere. However, the measured velocities indicate that they are not generated by an instability driven by the initially injected beam. Instead, the solitary structures have the same scales and propagate at the same speed as coherent wave packets and background fluctuations that are identified as electrostatic whistler waves in a strongly Landau damped regime.

7. “Experimental study of Alfvén wave damping processes relevant to the solar corona,” Daniel Wolf Savin, Michael Hahn (Columbia University)
   Shear Alfvén wave damping and heating are studied in the context of explaining heating in solar coronal holes. The waves are launched in magnetic field and density gradients, and their propagation and damping are evaluated in a number of scenarios. Of special interest is the propagation of waves in cross-field density gradients. The gradients are created using grids with variable transparency across B_0 . Another area of study is the reflection of shear Alfvén waves in large magnetic field gradients.

Campaigns

The campaigns are listed as: "campaign title", "campaign leader (affiliation)"; external participants:"name (affiliation)" followed by a description.

1. "Fast-Ion Campaign"
   W. Heidbrink (UCI); participants: M. Van Zeeland (General Atomics), B. Breizman (U.Texas, Austin), H. Boehmer (UCI), I. Furno (Lausanne), F. Jenko (MPI/UCLA), S. Tripathi, S. Vincena, T. Carter (UCLA)
   An ion beam (25 kV , 0.5-3 A) is injected at a variety of pitch angles into the LAPD plasma. The beam, which spirals along the magnetic field, matches the phase velocity of Alfvén waves in the background LAPD plasma. The waves are expected to be generated by Cherenkov emission from the fast ions. The goal is to create an analogue of TAE modes and study them in great detail. The project also has related side studies such as the study of the propagation of shear waves in multiple mirrors. Measurement of transport in velocity and configuration space caused by harmonic heating with compressional Alfvén waves, resonances with shear Alfvén waves, and drift wave turbulence.

   "Study of Ion Transport in Turbulent Plasmas", W. Heidbrink, R. McWilliams, H. Boehmer (Dept. of Physics, University of California, Irvine.)

Continuation of experiments investigating the interaction between fast ions and waves and turbulence in LAPD. A moderate energy (~ 1 keV), low current Lithium ion beam is mounted in the LAPD. The beam provides a source of test ions, whose trajectories spiral around the background magnetic field in an argon or helium plasma. The beam profile is measured with probes as it moves through localized turbulent layers. The layers are generated with antennas. The beam divergence and energy spread are also studied.

2. "Auroral Physics Campaign"
   M. Koepke (West Virginia University); participants: C. Chaston (U.C. Berkeley), D. Knudsen (U. Calgary), Robert Rankin (U. Alberta), S. Vincena, W. Gekelman (UCLA)
   Magnetized plasmas are predicted to support electromagnetic perturbations that are static in a fixed frame if there is uniform background plasma convection. These stationary waves should not be confused with standing waves that oscillate in time with a fixed, spatially varying envelope. Stationary waves have no time variation in the fixed frame. In the drifting frame, there is an apparent time dependence as plasma convects past fixed electromagnetic structures. In this project, an off-axis, fixed channel of electron current (and depleted density) is created in the Large Plasma Device, using a small, heated, oxide-coated electrode at one plasma-column end while the larger plasma column rotates about its cylindrical axis from a radial electric field imposed by a special termination electrode on the same end. A variety of methods is explored to generate $E \times B$ plasma flows in the center of the bulk plasma. These include segmented electrodes, spiral electrodes, emitting electrodes and a biased center conductor.

3. "Radiation-Belt Physics Campaign"
   D. Papadopoulos and T. Antonsen, University of Maryland; participants: U. Inan, T. Bell (Stanford University), S. Sharma, X. Shao (University of Maryland), W. Scales, J. Wang (VA Tech), A. Streltsov (Dartmouth), Y. Wang, W. Gekelman (UCLA).
   The campaign is focused on the interaction of energetic electrons with launched Alfvén and whistler waves. It is motivated by the desire to limit damage to satellites by using these waves to scatter mirror-trapped energetic electrons into the loss cone. Launching shear Alfvén waves of arbitrary polarization was accomplished by constructing an antenna consisting of two perpendicular coils with independent phase-controlled currents. The antenna was found to launch highly collimated, relatively large amplitude shear waves with wave decay resulting mainly from collisional dissipation. The measured radiation patterns of the right-hand mode compared favorably to the predictions of an MHD simulation by the Maryland group. The second antenna studied was a classic short electric dipole. The antenna current and voltage were measured within the dipole, avoiding transmission line effects The real and imaginary parts of the antenna impedance were measured as a function of frequency and time in a decaying, afterglow plasma. A pulsed microwave source constructed for the campaign was used to inject waves at 2.45 GHz into a local magnetic mirror established in the LAPD. The fast electrons vanish when a shear wave, launched by an antenna 5 meters away is switched on. When the wave is shut off the fast electrons reappear and persist until the microwave source is pulsed off.

Publications in refereed journals (funding cycle 2010 - mid 2015)

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11. D. B. Schaeffer, E. T. Everson, A. S. Bondarenko, S. E. Clark, C. G. Constantin, S. Vincena, B. Van Compernolle, S. K. P. Tripathi, D. Winske, W. Gekelman, and C. Niemann, Laser-driven, magnetized quasi-perpendicular collisionless shocks on the Large Plasma Device, Phys. Plasmas 21, 056312 (2014) [http://dx.doi.org/10.1063/1.4876608]

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BaPSF User Group Report

This section is a reformatted copy of the report generated by the BaPSF external user group following their first formal meeting, held April 20-21, 2015 at UCLA.

Position Paper and Recommendations of the User Group at the Basic Plasma Science User Facility at UCLA

I. Introduction

The Basic Plasma Science Facility at UCLA (BaPSF) is a unique and comprehensive research facility providing valuable support and frontier-level scientific opportunities for the plasma sciences. With its suite of plasma devices and extensive particle and wave generation capabilities, it covers a wide range of plasma conditions with excellent diagnostic capabilities that are typically not accessible elsewhere.

The purpose of this facility is expressly to explore under controlled and well-diagnosed conditions the fundamental processes that take place in plasmas ranging from naturally occurring space and geophysical plasmas to high-temperature fusion plasmas and to industrial and medical plasma applications. The facility is available to qualified national and international scientists working in collaboration with an expert BaPSF staff.

The core of the facility is the Large Plasma Device (LAPD). The LAPD is the finest basic plasma research device in the world. It is the culmination of many years of research into plasma sources and plasma confinement schemes. The machine produces a quiescent, highly ionized, 18 meter long plasma in which the ions can be strongly magnetized; the plasma diameter is fifty centimeters. The plasma source is reliable and durable; it permits continuous experimentation for several months. Highly reproducible plasmas are created whose density profiles can be controlled to provide a variety of conditions encountered in naturally occurring plasmas. An important element of the LAPD facility is its flexibility of operation. The broad range of operational conditions permit the investigation of a large class of different phenomena with relative ease.

In addition to the LAPD, the Enormous Toroidal Plasma Device (ETPD), essentially a large former tokamak. What was once a tokamak has been converted into a 1 Hz pulsed plasma device employing a high-emission cathode. It has been brought into preliminary operational status and has the possibility of producing plasmas up to 100 m in length with the possibility of accessing high beta plasma regimes. While this device has been little utilized so far, it has the potential of studying a wide range of natural and fusion-related plasma phenomena.

Finally, several other plasma sources and devices exist within the BaPSF that permit the study of low temperature plasma phenomena relevant to industrial applications and diagnostic development. These devices were devised as spin-offs of the technology developed to support the LAPD functionality, but have provided important scientific tools on their own account. Because of the great commercial value of such low temperature plasmas, there is a growing need for such research tools.

The facility has been well-used since its inception and is supported by a User Group and Scientific Council, who determine the make-up of research projects for the facility. The User Group met in the spring of this year to discuss research opportunities for the BaPSF and to formulate a list of potential facility improvements designed to enable realization of these opportunities. The following is a summary of the consensus of the BaPSF User Group.

II. Recommendations of the BaPSF User Group

The User Group identified three over-arching areas of study for which the BaPSF can serve an important role, which cover in large measure the entire field of plasma sciences. These will be described briefly in the following.

Space Plasma Science

The study of the near-Earth plasmas in the ionosphere and magnetosphere is crucial for maintaining the integrity of global communication and navigation systems. Moreover, the longevity of current space assets and the efficacy of space travel itself require a detailed understanding of the mechanisms that occur within the Earth-plasma system and its interaction with the solar wind. There are many topics under the general notion of space weather that require further study, such as the magnetic reconnection problem, for which the BaPSF has already played an important role. While satellites have provided a wealth of direct information on space plasmas, BaPSF provides a platform for the detailed study of these processes that is unique in its scale and diagnostic capability and serves as an excellent complement to in-situ space data. In addition, certain solar and interstellar plasmas can be studied with scaled conditions that are accessible to BaPSF parameters, including shocks, waves, both linear and nonlinear, and wave-particle interactions.

One area of some practical interest is that of the radiation belts, which present a potentially life-threatening hazard to our space assets and to space travel itself. While it is well-known that wave-particle interactions generated by the solar wind tend to regulate the radiation belt populations, relatively little is known about the details of the processes involved. The LAPD provides a unique platform for reproducing, and measuring, the geometry and dynamics of the belt regions.

Fusion Sciences

Another area where BaPSF plays an important support role is in that of fusion science. For instance, the understanding of edge plasmas and plasma-wall interactions is of particular importance. The LAPD is large enough to create a plasma with distinct core and boundary regions with an unequaled diagnostic environment for studying boundary phenomena. Also, the device is large enough to support many plasma waves of relevance to fusion devices and is particularly well-suited to the study of important nonlinear wave processes and wave-particle interactions. In addition, the LAPD is an excellent device for the study of turbulence and its effect on plasma properties, which remains a key question in fusion plasmas. Moreover, a particularly beneficial opportunity arises to be able to verify large-scale plasma simulations in a situation with relatively simple spatial geometry and comprehensive particle and wave diagnostic capabilities. Finally, the ETPD can provide a unique high-beta plasma environment for the study of this regime, which is highly relevant to fusion.

Low-temperature plasma science

The BaPSF can impact the broad area of low temperature plasmas with its diverse range of plasma sources and comprehensive suite of diagnostics. For instance, it is important to better understand deposition and etching phenomena in detail, which requires a comprehensive determination of particle distribution functions along with an understanding of the associated wave phenomena. The development of micro-probes and sensor arrays at BaPSF enables the study of such processes in unprecedented detail. Other possibilities include plasma medical applications such as those where plasmas can be used to deposit energy within tissue with extreme precision.

As another example of a low temperature plasma suited for study at the BaPSF is that of lightning, where the ETPD comes into play. This device is unique in the world for providing a plasma configuration where many mean-free-paths can be contained within a device that is capable of studying true runaway phenomena, thought to be important in lightning breakdown.

III. Capability Enhancements and Opportunities

The User Group recommends that certain upgrades to the facility be considered with the potential scientific benefits as described below.

1. magnet upgrade - lower collisionality plasma
   The upgrade of the magnetic field in the LAPD would enhance the overall confinement, raise the electron temperature and lead to a lower collisionality plasma. This would enable the study of 3D reconnection and extend the reach of the plasma into the solar wind regime. This would allow for new studies of particle heating and acceleration in both magnetospheric and solar coronal plasmas.

2. cathode upgrade to LaB_6 in LAPD
   The upgrade of the current BaO cathode to LaB6 will produce a denser and hotter plasma for access to new plasma regimes (see above) and will facilitate faster turn-around of machine modifications, leading to a significant increase of machine availability.

3. development of microprobes
   Prelimininary work at the BaPSF has shown the viability of microprobes in measuring the particle distribution functions in exquisite detail. The further development of this technique and deployment in arrays would enable the measurement of wave-particle interactions and turbulence in space and fusion plasmas and enable the study of a wide range of phenomena in low temperature plasmas. Diagnostic development remains a key side benefit of plasma research at the BaPSF.

4. molecular ions/gases
   The addition of specific new ion and molecular gas species into the BaPSF devices would enable the study of a broad range of new phenomena relevant to industrial plasma applications. Bringing the comprehensive diagnostic capability of BaPSF diagnostics and data acquisition systems to bear on such plasmas would have an immediate and profound impact on the field of plasma chemistry. This would even extend to many questions of current interest in the field of astrobiology.

5. relativistic e-beam
   The addition of a relativistic electron beam would add the important capability to make precise measurements of the wave-particle interactions associated with the radiation belts. The current LAPD infrastructure along with the addition of precision beam diagnostics would enable an unprecedented study of belt dynamics in the truest Earth-based plasma configuration to date.

6. ETPD
   Bringing the ETPD into full operation would enable the study of a variety of plasma phenomena that have never been addressed elsewhere. In particular, the high-beta plasma regime could be studied regarding wave phenomena and particle transport in an environment permitting comprehensive diagnostics. The application to fusion plasmas is evident. In addition, plasma propulsion concepts could be studied, including the unresolved issue of plasma detachment from magnetized thrusters. As mentioned above, the study of lightning in this device is a unique opportunity, particularly with regard to the issue of whether runaway electrons play a key role in determining the threshold for lightning events. Moreover, the unique energy sources available at the BaPSF and the diagnostic access of the ETPD provide an excellent opportunity for the study of a wide range of shock phenomena.

IV. Summary

It is clear that the BaPSF fills a special role in the field of plasma physics providing research opportunities for topics ranging from astrophysics to fusion to industrial plasmas. The diverse plasma operating regimes combined with excellent diagnostic capabilities and expert infrastructure support provide a superb environment for studying various plasma phenomena in unparalleled detail. Not to be underestimated is also the possibility of training students and enhancing skills of the plasma science workforce, which is an issue of increasing importance to the national effort.

The BaPSF fills a niche in plasma parameter space that is un-reproduced in most small-scale plasma laboratories, and underrepresented in large-scale research devices worldwide. As the dedicated User Group for this facility, we strongly urge the continued support of the BaPSF, and the enhancement of its research capabilities.