The Los Angeles Physics Teachers Alliance Group (LAPTAG)
Plasma Physics Experiments 2002

Principal Investigator: Walter Gekelman, Dept. of Physics, University of California, Los Angeles

Abstract

More than two years ago a group of teachers from the Los Angeles Physics Teachers Alliance Group (LAPTAG), Prof. Walter Gekelman, and Dr. Pat Pribyl completed construction of the first high-school plasma laboratory in the country. High-school teachers and their students use the laboratory for plasma physics research projects. Since then DOE has generously given support to a PC for data acquisition and a computer interface, which is used to precisely control probe motion. The lab has operated successfully since then and the high school students have presented results at the APS-DPP meeting in Oct 2001. The resources requested in this is a fiber optic based spectrometer so the plasma experiments can be expanded to study line radiation.

Background/Proposal

We propose to augment an existing DOE research grant (award number DE-FG03-00ER54598) for the purpose of continuing a high-school project in plasma physics. In a dedicated room in our laboratory, we constructed a small device powered by a helicon source for the use of high-school students in research projects. Most of the machine was constructed from spare parts donated by a local aerospace and information science contractor (TRW) as well as a military association. Some other parts (e.g., an industrial RF source and a turbo pump with controller) were purchased inexpensively from a financially unsuccessful plasma processing company. Most of the diagnostic equipment (waveform generator, digital scope, and signal amplifiers) is borrowed from the LAPD laboratory. The DOE supplement, which built the lab over a year ago, was for $15K (1/3 of which were for teachers salaries) and we estimate that the machine is worth about $50K.

The students were able to get extra credit for their participation in the project, but more importantly, were introduced to the study of plasma physics in a university setting. High school physics teachers, a subset of LAPTAG, constructed the machine, wrote the laboratory manual, and directly supervised the students during their laboratory time. Professor Walter Gekelman, who is the LAPTAG faculty advisor, gave additional lectures and devised new experiments.

Los Angeles Physics Teachers Alliance Group (LAPTAG)

Nearly nine years ago LAPTAG was created so that universities could interact with local high schools to strengthen science education. The organization now has about sixty members in 32 institutions. Institutions of higher education involved in LAPTAG include Santa Monica College, University of California, Los Angeles (UCLA), and University of Southern California. Some of the most active high-schools include: Camarillo High School, Royal High School, Birmingham High, Louisville, Monroe High

School, Van Nuys High School, Grant High, Westridge School, Crossroads School, Crenshaw High School, Westchester High, San Marino High School, Narbonne High School, Mayfair High School, New Roads Schhool and University High. Many in the group have been in education for decades and have developed innovative curricula and effective demonstration materials. LAPTAG is dedicated to science and to the goal of broadening the educational experience in their schools. The LAPTAG group is strongly supported by the UCLA administrations and by the participating high schools and colleges.

During the first year, tours were arranged for high-school teachers and their students to several university laboratories, seminars were conducted, high-school classes visited universities, and members engaged in numerous discussions about the educational process. Since then, we have instituted a seismology study program involving eleven high schools. Each of the participating schools received a seismometer, which was interfaced to a computer. They record seismic events and then place their data on the internet. The University of California Office of the President has supported this research at a level of about $5000 for two years. LAPTAG presented these two years ago in six posters, at the March American Physical Society Condensed Matter annual meeting in Los Angeles, and early this year in the American Physical Society-AAPT (American Association of Physics teachers) winter meeting in Anaheim, California.

This year LAPTAG has had a number of successes. We presented five posters (abstracts attached) at the American Physical Society Division of Plasma Physics annual meeting in Long Beach (Oct. 29-Nov. 2). The Los Angeles Times did a full-page story on the Basic Plasma User Facility (April 8, 2001, article attached) and mentioned this outreach program. Walter Gekelman presented an invited talk at this APS-DPP meeting on Laptag and science education. One of the high school teachers (Richard Buck, Louisville School for Girls, Woodland Hills, Ca) just won an excellence in teaching award from Amgen based on the plasma work with his students. Finally Walter Gekelman has been invited to give a seminar at Physics Department Chair Conference, from June 8, 2002, in College Park Maryland. The theme of the conference is "Shaping the physics agenda for the next decade."

The Machine and Present Experiments

Presently, we have a meter long vacuum chamber with a roughing pump as well as vacuum plumbing an ionization gauge controller and thermocouple

Figure 1. The LAPTAG plasma helicon source. The plasma is safe, reliable and easy to turn on and make measurements in.

We have a 400 L s^{-1} turbo-pump, which gives the device a base pressure of ~$3x10^{-7}$ Torr. A helicon source creates the Ar or He plasma of density ~10^{10} cm^{-3}. A helicon source is a durable and safe methodology, able to operate at low voltages at modest power levels. Since inexperienced high-school students use the machine, safety is a prime consideration. In an award from DOE in 2001 we purchased a PC for data acquisition, put Labview on it to control a 4 channel 100 Mhz digitizer and built a stepper motor probe drive system. In this proposal, we ask for funding for a new experiment to be placed on the device. The heart of this is a fiber optics based spectrometer, which will be driven by the LAPTAG computer. It will display the entire visible spectrum of neutral and ion lines in the plasma. We will use this to introduce a new experiment on the nature of light, line emission and atomic physics. It may also be possible to use this as a diagnostic for plasma properties.

The Los Angeles Unified school district is mandated to bring internet access to all the high schools in Los Angeles, and all participating LAPTAG schools are connected to the internet. LAPTAG has its own website (http://coke.physics.ucla.edu/laptag) with a section devoted to the plasma lab as well as an FTP site. Now that the laboratory has digital data acquisition, the schools can put their experimental results on the web and it may be possible to have remote high schools participate in experiments over the internet network.

The High School Lab and Course

Thus far, about 30 students from five Los Angeles high schools have taken advantage of the LAPTAG plasma lab. Although it is in a state of constant revision and improvement, we believe it is a success. We carefully planned the plasma lab so that it may be integrated into the existing science curriculum. We will also design modules that could supplement what is taught in Advanced Placement Physics courses. The laboratory is a great source of general science subject material, as well as plasma physics. Some of the questions and topics the young students can address include:

Vacuum system technology. How is most of the air in a chamber removed? What are all the components in a vacuum system? How is low pressure measured?

Use of measurement equipment. How do oscilloscopes and tone burst waveform generators work? How are they set up and used in a laboratory?

Plasma sources. How does the helicon system plasma source work? How are plasmas used to physics?

Electricity. What does an electric potential mean? How is electricity measured in a plasma?

Probes. How are Langmuir probes used to measure density and electron temperature in a plasma?

Wavelength and velocity. The detector on the machine has the potential to measure ion acoustic wave phase velocity by examining the phase shift of the wave. The experiment introduces the concept of phase and its relationship to wavelength and frequency (see Figure 2 below).

The propagation of a sound wave in plasma. Ion acoustic waves move at speeds about ten times faster than regular sound waves in air. We have set up an experiment using ultrasound pulses in air and a grid in the plasma to launch both these waves as tone bursts and compare the difference between them. When the lab is digitized, a direct comparison will be possible. Additionally, by moving the probe over large distances we can measure the group velocity of the wave. A measurement of wave propagation from LAPTAG experimental data is illustrated in figure 2.

Note the subjects listed above can be taught on many levels. For example, the method in which helicon sources make plasma is a subject of debate among many researchers. However we feel confident that the key elements in these topics can be put into a form that is understandable to high-school science students. Additionally, we would like to attract more students and schools to the LAPD laboratory and are encouraged by the support of the Los Angeles Unified school district. We also plan to conduct regular tours of the LAPD facility. These will be accompanied by lectures given by Professor Gekelman, his staff, and high-school teachers. The latest series of lectures was given in March 2002 on three successive Saturdays.

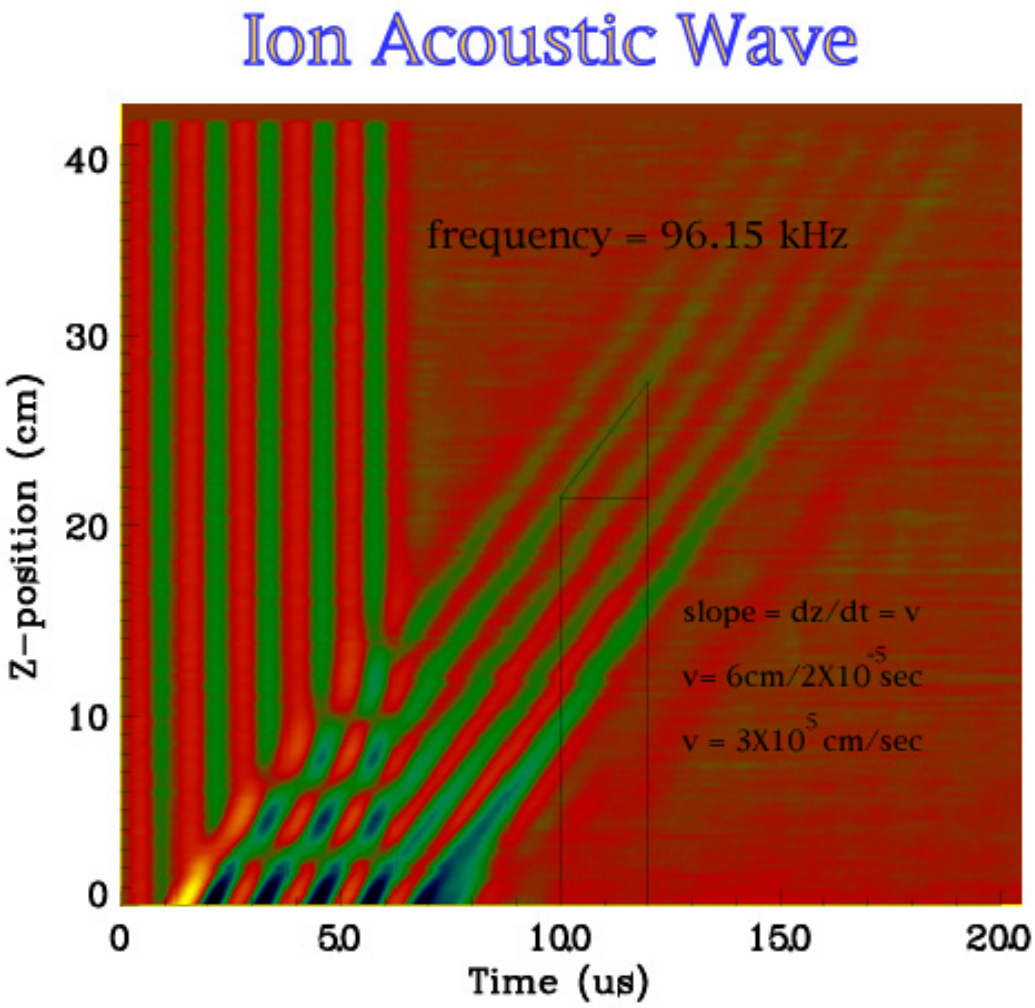

Figure 2. The propagation of an ion acoustic wave in the Laptag device. A five-cycle tone burst was launched. The wave was measured with a Langmuir probe, which collected ion saturation current. It was in an Ar plasma with base pressure 4X10-^{4} Torr. Tracking the peaks yields a wave speed of 3.0X10^{5} cm/sec. This data was acquired and analyzed by High School students from the Crossroads School, University High School, The New Roads School and Lousiville High. The vertical signal is direct electromagnetic pickup

The New Experiment:

We wish to use the equipment money to purchase a Fiber Optic Spectrometer from Ocean Engineering. This is a wonderful instrument, which uses light from a fiber and a small diffraction grating held next to a glass port on the machine. The instrument creates a spectrum of the visible atomic and ionic lines. The range of the instrument is 200-850 nm. The machine is easily interfaced to the PC, which is now a permanent part of the LAPTAG laboratory. The students will be able to record the line radiation from the plasma and compare it to tables of neutral and ion lines. The will also be able to point it at other light sources and learn about continuous and absorption spectra as well. We will the give a series of lectures on how light is generated and relate that to the atomic

physics they are learning in high school. We will also teach the dependence on line radiaition in the plasma on plasma parameters and the possibility (of course model dependent) of using it as a diagnostic. We will try to use the line intensity ratios of the neutrals I (728.1 nm/ I (706.5 nm) to determine the average line of sight plasma density and I (667.8 nm/ I (728.1. nm) to determine the plasma temperature. These will be compared to data from the ion acoustic wave experiment. The tehory concerning the use of these spectral lines in this measurement will be included in the next version of our laboratory manual.

Budget and Justification

Student Salary: 3 months for $7.00/hr. 2000.00

This will be funding for several high-school students. They must have passed the lab course successfully and be highly motivated. They will help construct the probe drive system and help program it using the computer language Labview. They will also serve as mentors and role models for other summer students taking the lab.

Supplies and expenses. $ 1,000.00

Acquisition associated with the experiment, paper for laser printer, parking fees, mail, and phone, printing lab manuals.

Ocean Optics Computer based spectrometer: $3,000.00

This is a very simple to use spectrometer that may be connected to the existing PC (which DOE funded last year). All the software for running the spectrometer is included. The spectra can be saved as files and sent to the various schools or to a laser printer in the high school plasma lab. A quote for the spectrometer is attached.

Total **$ 15,000**

Start date June 1, 2002.

We wish to augment an existing DOE/NSF grant (Award number DE-FG03-98ER54494) with the above funds to carry out this project.

Supplemental Abstracts and Newspaper Article

APS Abstracts October 2001

Abstract(1)

LAPTAG: **L**os **A**ngeles **P**hysics **T**eachers **A**lliance **G**roup and the UCLA Basic Plasma User Facility. W. Gekelman, Department of Physics and Astronomy, University of California, Los Angeles*

LAPTAG was founded in 1993 during a meeting sponsored by the APS, which encouraged high schools and Universities to form alliances. There are currently about twenty high schools, several community colleges and two Universities (UCLA and USC) involved. At first LAPTAG organized tours of laboratories at UCLA, USC, JPL, General Atomics and the Mt. Wilson Observatory and had meetings in which issues on curricula were discussed. It became obvious after awhile that in order for the group to last that projects were necessary. An early project involved having the high school faculty and students create Websites for most of the schools. This was before most the schools could afford Internet connections and Web authoring tools did not exist. Then with funding from the UC Office of the President, a seismology project was initiated and ten schools received seismometers. There were lectures by geologists and staff members of the Southern California Earthquake center; results were reported on the Web. In the spring of 1999 LAPTAG gave seven posters at the Condensed Matter APS meeting in Los Angeles. A web based astronomy course was created and high school students controlled the Mount Wilson telescope remotely and studied a variable star. Our latest project, funded by the Department of Energy resulted in the construction of a plasma lab dedicated to LAPTAG. The lab has equipment that is used by practicing plasma physicists (tone-burst generators, digital scopes, digital data acquisition and computerized probe drives) as well as software (LabView, PVwave). The high school students and teachers built the machine and all the associated diagnostics. Examples of the experiments will be given, however it is not a cookbook lab. As new experiments are introduced the same difficulties we all face must be overcome; the students take part in this.

The LAPD laboratory is now a National User Facility and LAPTAG is a key component of its outreach program. We have met with the director of science for the Los Angeles Unified School district, and others, to muster resources to allow many more schools to participate. This and plans for other programs such as the Integration of Art and Science, will be presented.

* Work supported by the Department of Energy, UCLA and UCOP.

Abstract (2)

Construction of a High School Plasma Laboratory.* M. Buck, Chaminade High School, J. Wise, New Roads H.S. , B. Baker, University H.S., J. Altounji, Sylmar H. S., R. Buck, Louisville H.S., C. Spahn, Monroe H.S., W. Gekelman, UCLA, P. Pribyl, UCLA.

Members of LAPTAG have constructed a laboratory plasma device for use by high school students. Currently students are using the device to do experiments to measure the velocity of ion acoustic waves The plasma is contained in a 0.25 m^3 chamber that is initially evacuated by a turbo vacuum pump to $\approx 10^{-7}$ Torr. It is produced by a Helicon source which is comprised of a 250 watt 13.6 MHz RF

power supply, a double loop antenna on the outside of a glass section surrounded by solenoidal magnets. The magnetic field in the source can be as much as 100 Gauss. A steady state plasma then streams into an unmagnetized experimental. Data is taken by means of a Langmuir probe connected to a 175 MHz digital oscilloscope. Current upgrades of the device include automating the motion of Langmuir probe with a computer driven stepper motor and the use of digitizers and computers to facilitate data acquisition. The high school teachers and students are directly involved in the machine upgrade. They have already constructed the probe drive and will write LABVIEW based software to control it as well as the data acquisition. Other diagnostics such as energy analyzers and a monochrometer will be installed shortly.

- Work supported by the U.S Department of Energy. Some equipment has been donated by TRW systems, Redondo Beach.

ABSTRACT (3)

LAPTAG, Encouraging High School students to Consider Physics Related Careers

Authors: W.Layton, UCLA., W.Gekelman, UCLA, J.Wise New Roads H.S., N.Rodriguez, SMCC, S.Cooperman, Milken H.S., R.Griffen, Campbell Hall H.S., J.Altonji, Sylmar H.S., F. Carrington, Grant H.S., B. Coutts,VanNuys H.S., K. Coutts, Royal H.S.*

The Los Angeles Physics Teachers Alliance Group (LAPTAG) represents high school physics teachers from the entire Los Angeles area. It was formed in 1993 Over the years between twenty and thirty schools have participated. Our Website is at http://coke.physics.ucla.edu/laptag and web service is provided to schools without servers or Internet access. LAPTAG encourages communication between high school and college/university physics teachers by providing regular meetings, tours of laboratories at UCLA and other institutions, and discussion of curricular issues. LAPTAG also provides unique opportunities for student involvement in research projects. Our first project was a distributed seismometer experiment in which ten schools received seismometers. LAPTAG provided a Web based astronomy class in which studied a variable star. During the past three years, we have constructed a plasma device and developed a high school plasma curriculum. These laboratory experiences engage science students and encourage them to enter physics related careers.

*Funded by: University of California Office of the President and the Department of Energy

Abstract (4)

Characteristics of the LAPTAG high school Plasma , P. Hsu, Compton H.S., B. Baker, University H.S., J. Wise, New Roads H.S., M. Buck Chaminade H.S., R. Buck, Louisvillle H.S., W. Gekelman, UCLA*

In 1999, a group of high school teachers in the Los Angeles Physics Teachers Alliance Group (LAPTAG) successfully constructed a plasma device for high school research. Since then groups of high school students have collected data to characterize the plasma. The plasma has a helicon

source which produces an Argon plasma that streams into an unmagnetized chamber. The plasma density is obtained from the ion saturation current to a Langmuir probe, $I = ne\sqrt{\frac{kT_e}{M_I}}A$, where A is the probe area. In our plasma Te>>Ti. In these experiments the plasma density is $n \approx 10^9 - 10^{10}$ cm^{-3}. The electron temperature is measured from the dispersion of ion acoustic waves, discussed in another poster in this session. The plasma potential is measured by sweeping the Langmuir characteristic curve. We will present data on the spatial distribution of the plasma potential and discuss the radial electric field in the device. Measurements of the plasma production as the RF source power and background gas pressure are changed will be presented as well. Using these measurements we have generated a list of possible future experiments the device may be used for.

*Work supported by the U.S. Department of Energy.

Abstract (5)

Ion Acoustic Waves, A High School Plasma Experiment. R. Buck, Louisville H.S, J. Wise, New Roads H.S., N. Gibson, Crossroads H.S., , M. Buck, Chaminade, H.S., W. Gekelman, UCLA, E. Wetzel. Louisville H.S., C. Wetzel, Loyola H.S., C. Moynihan, Cal Tech,.

Over the last three the Los Angeles Physics Teachers Alliance Group (LAPTAG) has built a plasma device and designed experiments for high school students to learn about plasma properties and behavior. One of the first experiments performed by small student groups (two to three students at a time) is to create ion acoustic wave tonebursts in an Argon plasma, measure the wavelength and frequency of the wave and thereby calculate the velocity of the wave. A grid antenna immersed in the plasma, which is pulsed by a function generator, creates the waves. Measurements are made using a Langmuir probe and read out on a digital oscilloscope. From this information students calculate values such as the temperature of the plasma, the plasma density and percent ionization of the plasma. In order to do these experiments students must understand what plasma is, how plasma can be created using a helicon source, how to use an oscilloscope and many other aspects of the plasma chamber involved in the experiment. Other experiments are currently being done on the device and still others are being designed. For more information visit the LAPTAG website (http://coke.physics.ucla.edu/laptag).

Abstract (6)

Using Plasma Physics to Enhance the High School Physics Curriculum

J. A Wise, New Roads H.S., M. Buck, Chaminade H.S., W. Gekelman, UCLA, R. Buck, Louisville H.S., C. Spahn, Monroe H.S., C. Walker, Louisville H.S., B. Layton, UCLA*

Faculty and student members of the Los Angeles Physics Teachers Alliance Group (LAPTAG) have constructed a plasma machine on the ULCA. Dr. Gekelman, the faculty advisor, provides information and materials on plasma physics via the Web and lectures to high school faculty and students. Faculty members then transfer the information to students at their respective schools and schedule time for experiments on the machine. A lab manual and curricular materials suitable for high school students is being developed using a lab based, discovery approach. The manual is available as a pdf document on the LAPTAG website (http://coke.physics.ucla.edu/laptag/plasma_exp.dir/laptag_plasma.htm)

Introducing plasma physics into the high school curriculum provides a 20th century application of classical physics concepts that support and motivate student interest in physics. Students from LAPTAG schools use state-of-the-art computers, software, and equipment to perform developed labs and to design experiments of their own. Collaboration exists between students and faculty from different schools and the university. Learning physics concepts takes place in the context of a "science community" that realistically demonstrates the scientific process to students.

*Funding has been provided by the U.S Department of Energy.