CASPER 2010 RET (Research Experience for Teachers) at Baylor University, Waco, Texas

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Abstract

The 2010 RET Program at Baylor University has had some unexpected but rewarding adjustments. The experience of needing to be flexible and adjust the scope of the project for the time frame of the summer became evident after the first week. The institute has also included lectures on assorted cutting-edge topics and discussions with educational experts ranging from the “Gear Up” educational grant for the Waco ISD, the Baylor Physics Circus program and discussions with fellow RET participants from Ohio and Virginia.

Introduction

The Research Experience for Teachers at Baylor University has afforded an excellent opportunity to further educational experience and to participate in a "hands on" learning experience in a state of the art laboratory, CASPER.

Part of the motivation to apply for the RET program this year was the possible option of working in the High Velocity Impact Lab. Unfortunately, both gas guns were either in the renovation stage or construction stage. As a result, Dr. Steve Rapp and I worked with researcher Jorge Carmona Reyes in the Dusty Plasma Lab.

1. The Research Segment of the Program

1.1 Gold particle research Group and Project objective

Research was in progress on arrival to find estimates of the force values experienced by 8.9 micron gold particles in argon plasma. Our goal at the beginning of the institute was to focus on forces between particles, laser induced forces, drag forces, boundary forces and equilibrium forces.

After the first week of working with analysis software JPIV and Mat Lab PIV our efforts and focus were narrowed to find the velocity and acceleration experienced by gold and melamine formaldehyde particles induced by the diode lasers at 640 nm wavelength, 80 mW and the YAG laser at 532 nm wavelength, 0.25-3 W.

1.2 Data collection process

Different sized clouds of gold and melamine formaldehyde particles, 8.9 micron, were examined in the cell. Sizes of these clouds ranged from a single particle to multilayered one hundred plus particle clouds. The initial data collection method was constant illumination of the particles by the diode laser for long periods of time and taking top and side view pictures every ten minutes. The second method of data collection involved illuminating the particles with the diode laser and alternating YAG laser burst for either five or ten seconds. Top and side view pictures along with electronic data were taken. The frame rate used was sixty frames per second. Six hundred pictures were taken in the initial diode laser sequence and two thousand pictures taken during the YAG laser portion of the experiment .

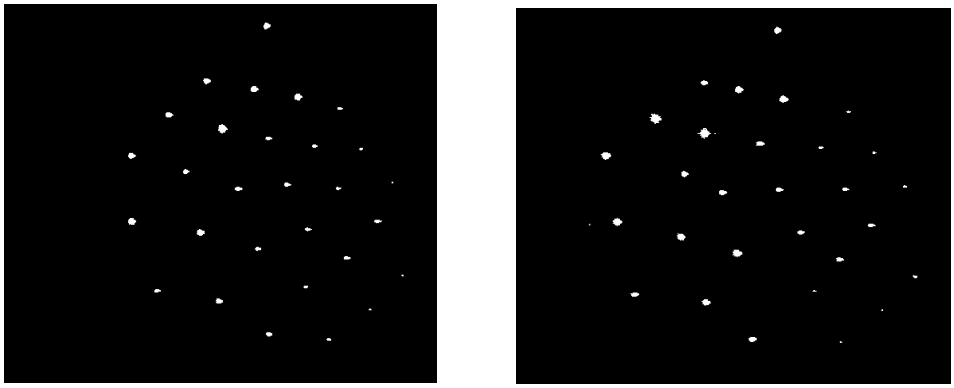

Figure 1: Top View pictures of a gold particle cloud taken during a YAG laser burst. One half second interval between frames

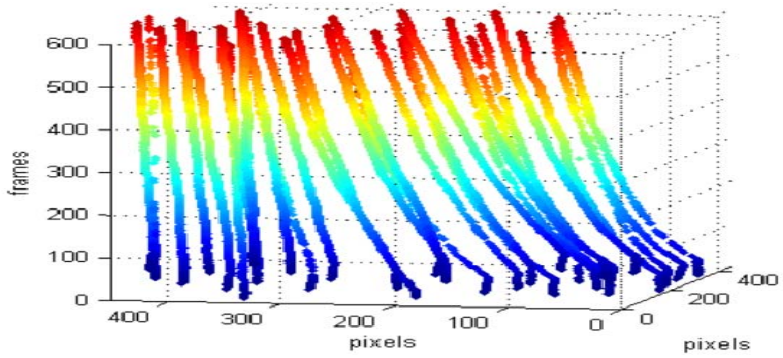

Figure 2: Particle positions stacked to show movement of particles during a sequence of 600 pictures taken during the first 10 second period during YAG laser experiment

1.3 Noise removal software

Issues with noise due to reflection from the cell walls and changes when the YAG laser engaged made it necessary to apply a MatLab program to filter the picture sequences. Our adviser provided the needed software and instruction on its use.

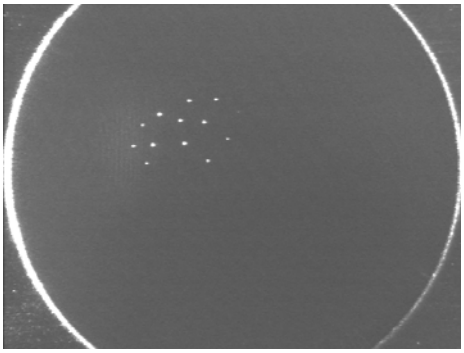

Figure 3: Non filtered frame

1.4 Choice of Software Analysis Program. (Particle Image Velocimetry PIV)

Dr. Steve Rapp and I were given the task of working with a freeware program called JPIV. The objective was to find and adjust pre made software that would compare picture frames taken at a known time difference and would calculate the velocity in pixels per second of the cloud flow. With this information and a distance grid of the cell plate an acceleration rate could be estimated.

There were issues with the JPIV package as it lacked sufficient documentation, examples, (one with coffee in a cup) location of software libraries for the main program to access, filter combination usage and computer setup characteristics.

The project director decided that instead of dealing with these issues to use the MatLab equivalent. The sample from JPIV was later helpful in understanding the location process of the particles for dimensional aspects of the pictures. The JPIV program does have an advantage for classroom use in that it is freeware with Java code available.

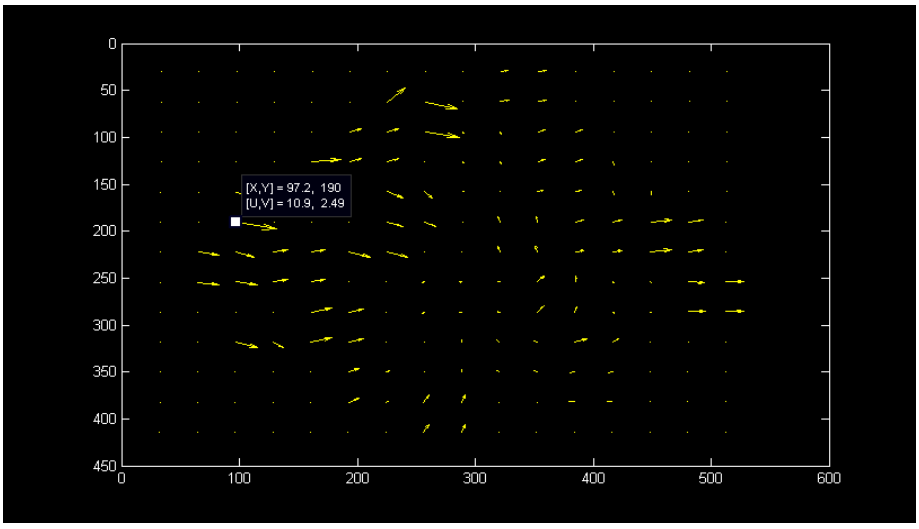

Figure 4: MatLab PIV output, X and Y are pixel positions. U and V are Horizontal and Vertical velocities in pixels per second

1.4.1 MatLab Particle Image Velocimetry (PIV)

The MatLab PIV program separates two pictures into smaller segments called interrogation windows. The preferred window is a square, 32 by 32 pixels. Other square options were available along with user defined polynomials. Each window of each picture is compared to each window of the other picture using a cross correlation function. (Frequency domain, FFT)

Although the PIV software gives multiple pass options that will create smaller windows on each pass, the single pass option was used. Our choice was based on lengthy computing time and computer memory space issues. A cropping tool in the software was used that allowed areas not of interest to be ignored. The program requires a defined shape for individual particles prior to processing. Of the options available a circle shape was usedwhen defining particle pixel location and size.

To get reasonable results, the pictures overlaid needed to show a change in position of the particles. We compared pictures and settled on using one half second. (30 frame jumps)

The software result compares and assigns a horizontal and vertical velocity vector to each pixel. Built in or user defined filters (low and high pass) adjust the results to eliminate outliners for the visual display.(see Figure 4) The position of the pixel, (X,Y), the horizontal, U, vertical, V, and resultant velocity are saved in a spreadsheet in units of pixels per second.

When put in an overlay with the particle pictures (Figure 5) both the flow direction and velocity characteristics of individual particles can be shown. For individual particles there were multiple adjoining pixel vectors that matched in velocity components.

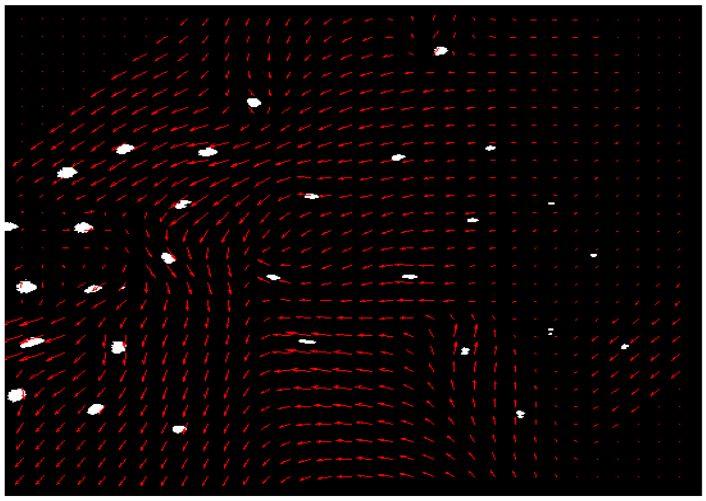

Figure 5: Overlay of the PIV vector output with the overlay of individual pictures.

1.5 Experiments Results

Melamine Formaldehyde

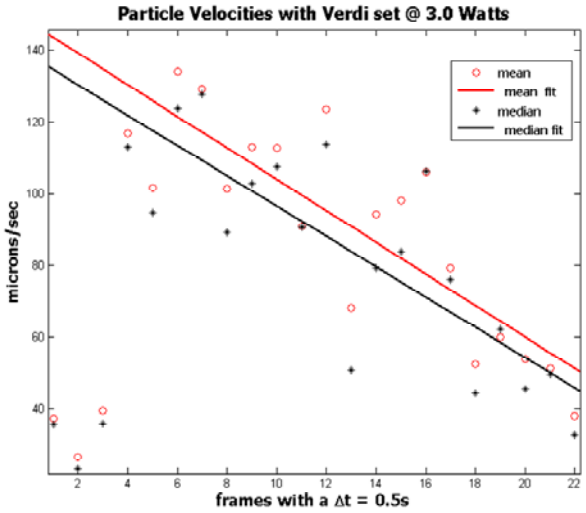

Figure 6: Graphic results of melamine formaldehyde particles

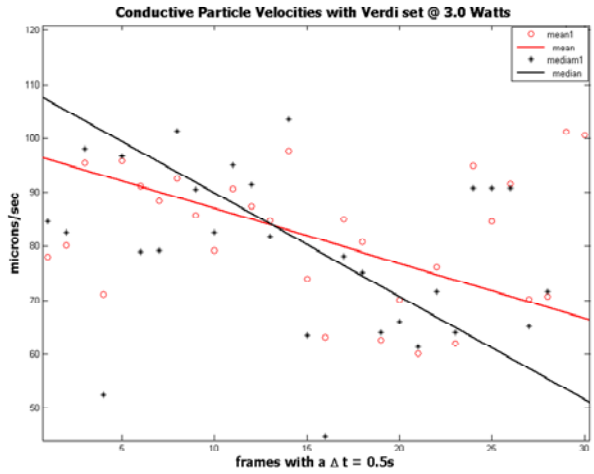

Figure 7: Graphic results of conductive particles

Initial results of both gold and melamine formaldehyde were graphed and a linear fit was used to estimate change in average cloud velocities when the YAG laser was in use. (Figure 6 and 7) More data sequences need to be processed in this fashion to see if consistency occurs at the different power settings of the laser.

Little if any reaction over the two hour experiments with the diode laser showed any change in position contrary to work completed last year.

The MatLab PIV software has been successfully adapted to complete the analysis in finding the velocities of groups of particles. With a distance reference grid of the cell plate, average acceleration and laser force can be calculated on the 8.9um particle clouds.

1.6 Future work suggestions

Hopefully the data collected during the institute can be used in the overall goal of finding experimental force values. Different sized cutouts on the lower plate might be used along with higher speed camera rates. Other software options should be considered for individual particle flow characteristics. (example: PTV or Particle Tracking Velocimetry)

2. Lecture and Discussion Sessions.

2. 1 *Lecture sessions*

Each Wednesday members of the summer institute gathered at the Baylor Science Building for a luncheon and lecture based on the expertise of invited Baylor staff members. Talks included the preparation of scientific papers and presentations, physics in everyday situations, also small satellite makeup and preparation.

2.2 Educational discussions with other teachers and Baylor staff.

The three teachers in the RET program met and discussed particular issues they are dealing with at there schools. Participants this year work in Ohio, Virginia and Massachusetts. Points of view about the “No Child Left Behind” program, federal stimulus funding usage, and many like programs were expressed.

The RETs and REUs were invited to take a guided tour of the Texas University Science facility in Dallas. One impressive stop on the tour was their modern nano technology lab. A picnic and night out at the Baylor observatory was another activity provided during the institute.

Ms. Cindy Fernandez, one of the Baylor’s directors of “Gear Up”, was available for discussion on details about Baylor University’s federal educational grant. The grant’s purpose is to study and help improve the performance of students from the Waco School District. This federal grant is the second largest every given to a college or university and is matched with money from the state of Texas.

Dr. Hyde and Dr. Matthews held meetings to discuss the week’s work and objectives along with a Friday afternoon meeting for updates on the progress for that week.

3. Conclusion of the Research Teacher Experience 2010 at Baylor University.

This summer has been a unique research experience at CASPER HIDPL. This summer has turned out differently from what I envisioned but understand that flexibility is part of a working lab. The opportunity to see the interactions of the personnel, communication between the lab technicians and experimental investigators, the need for teamwork and

cooperation has been enlightening experience. Having the opportunity to converse with undergraduate science majors and exceptional high school students has been valuable for future reference.

The MatLab version of PIV software has been adapted for assessing velocities of particle clouds in a plasma environment. Velocities of conductive and nonconductive particle clouds have been computed for limited powers.

The JPIV freeware was investigated along with discussions of how to possibly implement this software into high school courses.

Acknowledgements

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Suggested articles

J Westerweel, “Fundamentals of digital particle image velocimetry” Laboratory for Aero & Hydrodynamics, Delft University of Technology, Rotterdamseweg 145, 2628 AL Delft, The Netherlands Received 28 May 1997, accepted for publication 27 August 1997.

J. Westerweel, “What is PIV” Delft University of Technology.

R. J. Adrian, “Twenty years of particle image velocimetry” Experiments in Fluids (2005) 39: 159–169 DOI 10.1007/s00348-005-0991-7.

G. M. Que, J. Pakleza, T. A. Kowalewski, “Particle image velocimetry with optical flow”, Experiments in Fluids,(1998) 177Ð189 (Springer-Verlag 1998).

Ajay K. Prasad, “Particle image velocimetry” Department of Mechanical Engineering, University of Delaware, Newark, DE 19716-3140, USA.

Peter Vennemann, “JPIV Particle Image Velocimetry” Copyright (C) 2008.