Available online at www.sciencedirect.com

SCIENCE DIRECT®

Optics & Laser Technology 38 (2006) 152–161

Optics & Laser Technology

www.elsevier.com/locate/optlastec

Precise CCD image analysis for planar laser-induced fluorescence experiments

H. Golnabi

Institute of Water and Energy, Sharif University of Technology, P.O. Box 11365-8639, Tehran, Iran

Received 9 August 2004; received in revised form 16 November 2004; accepted 6 December 2004
Available online 23 February 2005

Abstract

The goal of this paper is to describe essential criteria for image analysis of planar laser-induced fluorescence (PLIF) signals. A new image file conversion method is introduced and some typical illustrative examples showing the potential applications of the method in PLIF experiments are presented. Analysis of row, column, and total pixel counts, and the dark noise related to an image are discussed. Image segmentation, averaging and background correction can be easily done by the reported method. In our analysis it is straightforward to inspect the pixel counts and check for saturation of the camera sensors. It is also feasible to obtain a particular row or column for interpretation and it offers an easy way to check the validity of the captured images. Furthermore, the method offers a sensitive technique to check pulse-to-pulse variation of the excitation laser by using frame-to-frame fluorescence image data comparison, which is more illustrative than power checking by other means. The overall results show that the developed conversion method reported here can be effectively used to obtain more in-depth and quantitative information out of the raw data for the PLIF experiments.
© 2005 Elsevier Ltd. All rights reserved.

Keywords: CCD camera; Image analysis; Laser; Fluorescence signal

1. Introduction

In recent years the PLIF method has found many applications [1] in different areas including measurements in flames [2] and the investigation of mixture formation process in hydrogen engines [3]. Such a technique is often used to study the mixing process in liquid and gas flow experiments. A great variety of studies have focused on the behavior of the turbulent flows. In liquid-phase studies, fluorescent dyes are often used, whereas in gas-phase investigations, the use of fluorescent tracers such as biacetyl and acetone are now common. The probability function of mixed-fluid composition in nonreacting liquid mixing layer has also been studied using the PLIF diagnostics and the influence of forcing on the composition of mixed fluid [4]. PLIF can also be used for quantitative measurements of molecular mixing in gaseous flows. In gas flow experiments, a fluorescent tracer is mixed into one of the two mixing streams and the concentration of the tracer is measured after excitation by a laser sheet. By combined information from fluorescence and phosphorescence signals, the instantaneous quantitative measurement of the molecularly mixed fluid fraction can be obtained. Such a technique has been used in a study of the mixing process in a forced acetone-seeded nitrogen jet discharge into ambient air [5].

Conversion of the raw data into more meaningful results seems to be the main concern of the researchers using the PLIF technique. Some aspects of data acquisition are reported in a recent report by Melton and Lipp [6]. However, the conversion of the image files and the analysis of the raw data resulting from such an experiment is not thoroughly explained in the open

E-mail address: golnabi@sharif.edu

0030-3992/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.optlastec.2004.12.001

literature. The aim of this study is to discuss such processes, which can be useful to all researchers using PLIF as an analytical tool for practical applications. In the report by Melton, some chemical criteria were set out to check the validity of results and to normalize the final fluorescence signals. Some aspects of the PLIF experiments such as the ''integrated intensity'' are well described [6]. For instance, the linearity and the required condition of the fluorescence signal versus the fluorphore concentration are discussed in detail as an ''optically thin'' criterion. The reported paper by Karasso gives a good review for determining whether a given PLIF dye signal provides a linear response [7].

Even though the unprocessed image files captured by the CCD camera are worthwhile to look at directly, a better way is suggested here for data manipulation and interpretation. The inadequacy of the methods presently available and the opportunity to use another program and other methods motivated us to initiate the present study. Among the powerful softwares available, the Matlab program used in this analysis provides a useful approach for data processing and data visualization. Matlab is a powerful computational engine for more complex calculations and adds new features to the analysis and the interpretation of PLIF signals.

Another advantage of this method is that the Matlab images can be exported as JPEG or TIFF files to another program with a greater ability for photo editing. For example, some of the image files are exported as JPEG and using the Microsoft photo editor the brightness and contrast of the captured images can be adjusted for better resolution and recognition. In the photo editor window one can change the brightness and contrast. Some experiments such as capturing pictures of moving gas bubbles in a solution, require a better resolution and higher brightness. So this editor makes it much easier to visualize the images of such bubbles with higher clarity. The details of this article begin with data acquisition and image formation prescription and the conversion of image files to Matlab files in order to present PLIF signals in a more precise way. Some features of the method in image analysis are then presented and at the end some of the captured images are described.

2. Data acquisition

The block diagram of the PLIF experimental arrangement is shown in Fig. 1. It consists of a Nd:YAG laser (Quantel International, model 671C-10), a beam-bending prism, a beam splitter glass, an attenuator cell, a cylindrical rod lens, a CCD camera (REGITA 1300, Quantitative Imaging Corporation, Q IMAGING) a home made flow cell system and the related flow line components, laser power probe and the energy/power

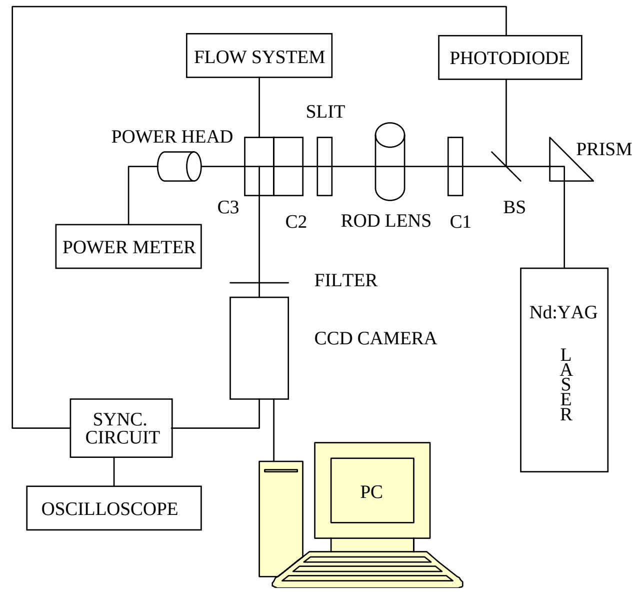

Fig. 1. Block diagram of the experimental arrangement for the PLIF setup.

meter (Scientech, model Mentor MA10). A photodiode, a pulse generator (Global Specialties, model 4001), an amplifier, and a synchronization circuit are used to generate the external electrical trigger pulse for the CCD camera. A long-wavelength pass glass filter (orange, 4 mm thickness) is set in front of the camera lens to move away stray light. A PC is used for camera control and final data processing and presentation.

A 2-pump cart design is used to supply the flows to the rectangular acrylic sample cell (C3), which is mounted so that the flow is enrolled from bottom to top. The flow cell and pumping system provides two reservoirs for the dye and water solutions. With this design switching from dye reservoir to water reservoir is easily possible. A volume of about 2.5 L of liquids is used in each reservoir and the pumping rate is about 1 L/min. A Rhodamine-WT (Rh-WT) concentration of 0.322×10^{-7} M to 2.58×10^{-7} M is used for this study. In order to be optically thin, the dye concentration and laser sheet power must be selected carefully. In a typical trial a PLIF signal resulting pixel count number of approximately 4000 counts out of a possible maximum of 4096 counts (2^{12}) is considered as a large signal.

The single pass Q-switched pulse energy for the fundamental laser line is about 1100 mJ and typical double pass mode-locked 75 mJ. The nominal pulse-to-pulse stability of the mode-locked laser is about $\pm 4\%$. The doubling efficiency for the second harmonic at 532 nm is nominally about 45% of the fundamental mode, which results in a pulse energy of about 495 mJ. In this experiment the exciting power of the laser is controlled by the transmission of the absorber in the attenuation cell. The cylindrical rod lens make a laser

Download English Version:

https://daneshyari.com/en/article/734735

Download Persian Version:

https://daneshyari.com/article/734735

Daneshyari.com