Development of VISAR at CLF

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Introduction

Velocity Interferometer System for Any Reflector (VISAR) is an optical device to detect the velocity of a moving, illuminated object. The special ability of the device to produce an optical interference pattern, even in the presence of a wide-angle, diffuse illumination of light, renders it an important plasma diagnostic for studying the velocity of targets subjected to high power laser irradiation. The device has been known [1,2] to the science-community for decades for application in the field of laser induced shock wave and equation-of-state studies.

Though the CLF caters for most of the experimental diagnostic requirements for its user community, a VISAR system has not been available. The present article will briefly demonstrate the development of hardware and software for a VISAR in the CLF.

Hardware description

The overall VISAR system consists of an interferometer bed, an optical arrangement for illuminating a target and collecting reflected light into the interferometer bed, and a fringe recording system (a streak camera to record the temporal changes in fringes). The light delivery system and detection are mainly two variable operational processes, which are independent from the VISAR itself. The guiding factors for these two processes are the target image relaying, the image magnification and image resolution. The present article will describe only the VISAR interferometer bed and its accessories (figure 1). The VISAR bed includes an interferometer, an alignment laser, a nearly collimated white light source and an imaging system with a CCD on the same breadboard. The advantage of this design is that it occupies less overall space due to the integration of internal light sources white light fringe alignment. This increases the stability of operation and reduces the overall instrument size.

The interferometer consists of two arms, each containing a 100% mirror (1”) and a 50%-50% beam splitter (1”), in a Mach-Zehnder configuration. The input light is split into two beams by the first beam splitter; the transmitted and reflected beams, after full reflection from the two end mirrors, meet the second (output) beam splitter and produce an interference pattern on its surface. The CCD lens is set to sharply focus the surface of the output beam splitter. The green (527 nm) alignment laser is used to centre and align the optics using crosswire fixtures. The equalisation of arm lengths has been done by using a nearly collimated white light source and moving the mirror of one arm on a motorised translation stage until a bright white light fringe is produced (figure 2). A combination of

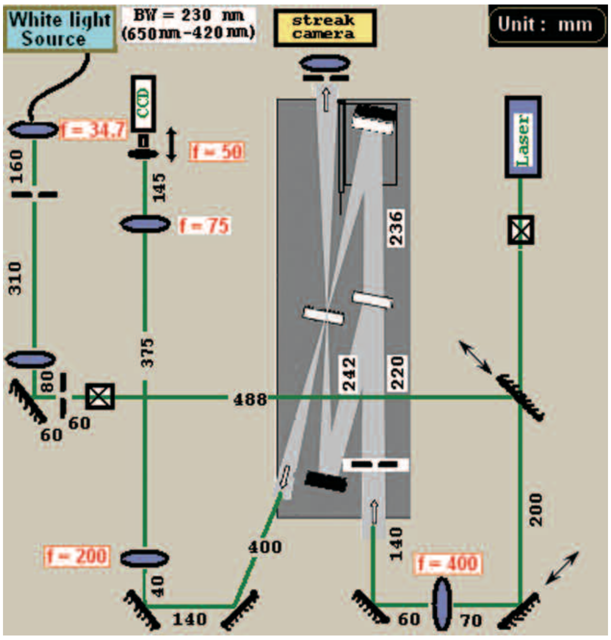

Figure 1. Schematic set-up for the VISAR bed.

lenses is used to image a cross-wire (in the path of white light) to the plane of output beam splitter and another set of lenses relays the magnified image of the cross-wire from the output beam splitter to the CCD. For velocity measurement, a variable thickness stack of 2” AR coated parallel windows (etalons) are used before the motorised mirror to provide appropriate physical beam path difference between the two arms of the interferometer without changing the geometric paths.

Software description

A program written in MATLAB has been developed to analyse the velocity profile from the raw interferometric data of the VISAR. The program first reads the raw VISAR data (the CCD image of the streaked interference pattern) into an array. Subsequently, it performs a one dimensional Fourier Transform on the data with points equal to the number of columns in the array. The Fourier transformed data is shifted on the frequency axis to have the zero-frequency component in the middle of the spectrum. The central frequency component (dc component) is the background intensity and the negative frequency component is just a replica of the signal appearing at the positive frequencies. The signal is filtered by forcing the values of the dc and the negative frequency components to zero. Next, an inverse Fourier transform is performed on the filtered signal after undoing the effect of

Figure 2. White light fringe pattern.

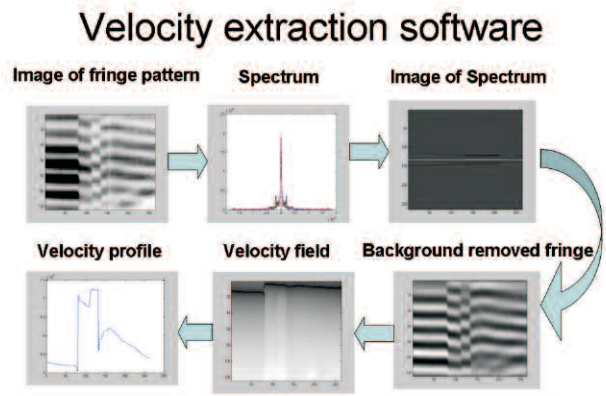

Figure 3. Velocity extraction software scheme.

frequency shifting. The process is followed by phase retrieval through phase determination and unwrapping. The velocity-per-fringe (VPF)[3] is computed from the known values of the etalon parameters (thickness and refractive index) and the working wavelength. The velocity field is constructed by multiplying the VPF by the phase angles normalized to 2π. Finally, the temporal velocity profile of the object is found by taking a scan of all velocity columns for a particular row. Figure 3 is an illustrative example of how the velocity profile is generated from VISAR interferogram data (published raw data has been used for simulation). The velocity derivation from the interference data described here follows the same methodology of P.M. Celiers *et al*[3]. Background phase correction is performed by finding the phase angle from a background fringe image.

Conclusions

A VISAR instrument has been developed in the CLF with an *in situ* alignment facility using a nearly collimated white light source. In future, another VISAR bed will be developed for vertical integration with the first one in a semi-mobile workstation. The software developed to analyze the velocity is in fair agreement with the results of standard software (IDL) in use. The in-house development of the device has proven to be very cost-effective as compared with the purchase of a commercially available turn-key system.

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