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VISAR: Some Things You Should Know

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Abstract

VISAR performance can be improved while reducing cost, set up time, and required operator skill. Simple features that increase laser light efficiency, improve signal-to-noise ratio, reduce the number of data channels, greatly simplify data reduction, ease VISAR adjustments, and reduce laser wear and tear are discussed. These features were collected, developed, tried, and proven over the last few years and several hundred VISAR shots.

Introduction

Although any VISAR can measure velocity, its true value depends upon how well it acquires data compared to the cost, effort, and assets required for its use. Versatility and ability to measure velocities under adverse conditions, as well as simplicity and low cost can easily be achieved in the same instrument.

This paper is a brief description of features that have proved useful in our VISAR since 1976. I have selected for discussion those features most ignored by VISAR builders and users. It is surprising that most of the best alternatives are the least expensive.

It is assumed that everyone is familiar with VISAR; therefore, no detailed discussion of VISAR will be presented here. The two data channel method discussed here logically precedes another paper, "VISAR: 2½ Minutes For Data Reduction," to be presented in Session 4.

Ideas presented here can be grouped into four categories: VISAR optical system design, data signals and recording, data reduction, or miscellaneous. Except for optical system design features, they can easily be incorporated into existing systems.

VISAR optical system

Push-pull photodetector design

Figure 1 shows a conventional VISAR[1] interferometer with an intensity monitor and two data detectors. In this design, three signals are needed for data reduction; however, only the two data detectors obtain velocity information. Moreover, one recombined beam from the interferometer is not used. Thus, only about one-third of the available light produces signal containing velocity information.

In the design of Figure 2, two more data detectors are added, but the monitor is deleted.[2] Here all light, except for transmission and reflection losses, produces signals that contain velocity information. Thus, the useful signal is approximately triple that of Figure 1.

In practice, the four signals of Figure 2 are usually not recorded separately. Instead, the conjugate signals from opposite sides of the interferometer are subtracted electronically before recording. This provides several benefits. Optical or electrical noise common to both signals is cancelled while the signal amplitude is doubled. Furthermore, only two data channels are needed. Also, the signals are of the proper form to use the simple arctangent data reduction algorithm to be discussed later.

Although this design does require a modified VISAR, it provides important advantages. The relative importance of the increased signal, reduced sensitivity to optical noise from target self-light, or reduced sensitivity to strong electromagnetic interference depends upon the VISAR application. Any one of the three could be paramount in a given experiment.

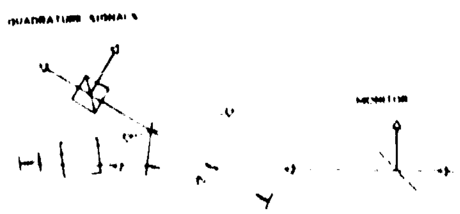

Figure 1. Schematic of conventional VISAR with three signals required for data analysis.

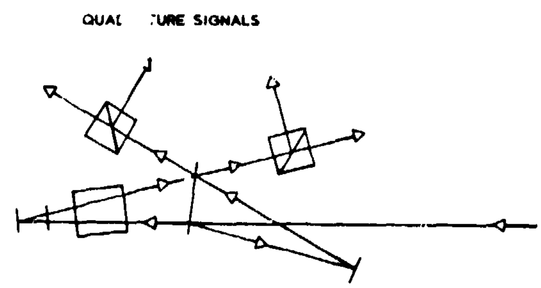

Figure 2. Schematic of push-pull VISAR with outputs that are subtracted to give two signals.

Polarizing beamsplitter for dividing light

Because it is necessary to operate two VISARs together on some experiments to account for lost fringes, light is often split between two interferometers. This is usually done with an ordinary 50/50 beamsplitter.

To prevent the possibility of time dependent polarization changes from affecting the quadrature-coded data signals unequally, it is necessary to polarize light ahead of a VISAR interferometer. The input polarization should be oriented halfway between the orientations of the two data polarizations to ensure equal signal strengths. But using a 50/50 beamsplitter before the polarizer wastes approximately half the light.

By using the polarizing beamsplitter and mirror arrangement of Figure 3, it is possible to simultaneously split the light equally between two interferometers, provide the proper polarization, and not waste light. This small change could effectively double the laser power in many existing VISAR systems.

Light efficiency and signal-to-noise improvements enable the use of higher f number optical components. One beneficial effect of this is to reduce aperture broadening of the doppler spectrum collected. This broadening is caused by the angular dependence of the doppler shift over a finite collection angle.

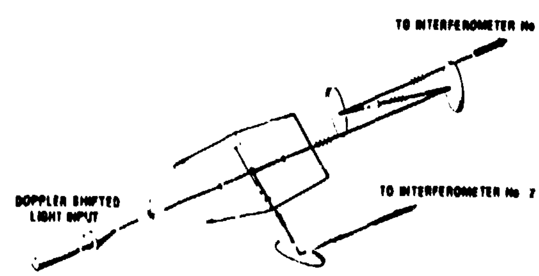

Figure 3. Polarizing beamsplitter and mirror arrangement to split, polarize, and properly orient input to two VISAR interferometers.

Translate the etalon mirror only!

Figures 1 and 2 show VISAR interferometers with a glass etalon in one leg. It is necessary to change this etalon and the location of one mirror to adjust the VISAR fringe constant.

A linear translator is usually provided to allow for equalizing beamsplitter-to-mirror path lengths after etalon changes. In principle, either mirror can be translated.

However, it is much better to translate the mirror in the same leg as the etalon. This allows the other mirror to be fixed. Thus, with the beamsplitter, it can provide a permanent reference for the optical axis through the interferometer.

If the mirror opposite the etalon is translated, etalon changes affect both legs of the interferometer. This changes both the optical axis and the angle for recombination at the beamsplitter. Because the photodetector apertures are fixed, they will no longer be on coincident optical axes. This will cause light distribution changes between photodetectors to be misinterpeted as velocity changes. Thus, etalon changes necessitate tedious realignment of mirrors, beamsplitters, apertures, etc.

Data signals and recording

Recording data with two channels

The push-pull photodetector design of Figure 2 is not necessary to enable the use of two channel data recording. If the monitor of Figure 1 is subtracted from each of the data signals, it can be eliminated.[3]

Although the resulting signals do not have increased amplitude as in the push-pull design, some benefits are still obtained.

Only two data recording devices instead of three are needed. This could be significant, especially if changing from oscilloscopes to digitizers. For example, one R7912AD digitizer costs approximately the same as the whole VISAR optical system. Or, a single two channel digitizer could suffice for recording VISAR data.

Another benefit realized when using two data channels is greatly simplified setup. By using an X-Y (or Lissajous) oscilloscope display of both fringe signals, it is simple to equalize amplifier gains and to adjust the interferometer retardation plate to obtain perfect quadrature. This is done during setup with a piezoelectric translator moving one interferometer mirror to provide fringe motion. Correct adjustment is obtained when a perfect circle is produced on the oscilloscope.

Finally, data reduction using two data channels is greatly simplified. This is the most important reason for using two channels.

Data format and error discussion

VISAR raw data is usually recorded by oscilloscope cameras or waveform digitizers. In either case, several constants are needed before data reduction can be done. Also, precise time registration between all data must be provided.

By recording the laser turn-on generated by a fast Pockel's cell on traces just before the start of data, it is possible to get zero light level and, in most cases, precise time synchronization of multiple traces.

The addition of time fiducials before and after each signal provides more than redundancy. First, time calibration can be verified from the raw data. Furthermore, the valid data interval can be located automatically. Finally, sequential traces can be registered in time to each other.

Figure 4 shows a VISAR record obtained using two data channels and an oscilloscope camera. Each data trace contains the laser turn-on, a time fiducial, velocity data, and a fiducial just before the end of the trace. Offset below each trace is the time calibration signal.

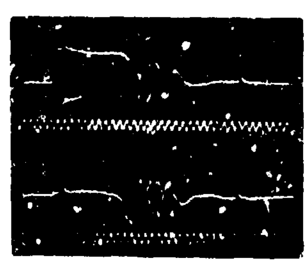

Figure 4. Complete VISAR record showing two signals obtained by electronic subtraction, zero light level before Pockel's cell turn-on, time fiducials and time calibration marks offset below signals.

In this format, a single film contains most information for data reduction except the fringe constant and the time mark interval. Both are time independent.

Although the amplitude ratio of the two signals is not self-contained in the record, it is set to 1.0 during VISAR setup. Also it is quite stable even over a period of days. Moreover, data reduction is relatively insensitive to modest changes in this ratio, especially when many fringes are present.

Almost the same is true for the phase angle; it is set to 90° during setup, it is very stable, and data reduction is quite insensitive to modest changes in it.

Furthermore, over several fringes, it is probable for errors in any or all of the above constants to average to zero. This is because the effect of these errors is to superimpose onto the velocity, a small oscillating error. For an integral of the velocity, like the position vs time curve, errors can average approximately to zero over each fringe. Thus VISAR signals are relatively immune to experimental errors.

Arctangent data reduction

This data reduction method[3] is usable in VISARs where data are recorded with two channels. It complements a graphical diagnostic to simplify data analysis. It has been used for several years in two systems; one for manually read oscilloscope photographs and another with computerized data acquisition. It will be discussed in the Session 4 paper, "VISAR: 2½ Minutes for Data Reduction."

Miscellaneous

VISAR fringe constant accuracy

The accuracy of VISAR measurements depends upon an accurate determination of the interferometer time delay that gives rise to the fringe constant. A two-stage procedure[4] using white light interference from a mercury source, then an incandescent lamp, can be used to make a very precise determination of the zero delay position. All fringe constants can then be based on this zero position.

VISAR sequencer

For the past six years, our VISAR has made use of a microprocessor-based sequencer to perform check list, repetition, and firing chores. It verifies proper firing conditions, then gates, triggers, and switches in the proper sequence to acquire velocity signals and calibration data. This provides several benefits.

It allows the laser to idle at just above lasing threshold, except when gated to higher power by the sequencer. Thus, plasma tube life and also laser safety are greatly enhanced.

It helps maximize accuracy by acquiring calibration within milliseconds after velocity signals are recorded. Also, it greatly reduces the time, effort, and skill required to fire VISAR tests.

Although rapid test-firing is not always necessary, two operators working together have fired a series of 31 VISAR shots in 40 min on this system. This demonstrates that VISAR could be applied to production measurements if necessary.

In another example, we helped two visitors (who were not familiar with this VISAR) fire 54 shots in approximately one day of firing. All shots gave usable data. We feel this further demonstrates simplicity of VISAR system operation.

Optical fiducial pulser

It is easily possible to generate simultaneous ~10-ns-wide optical pulses. We do this by connecting a series string of small, light-emitting diodes to a single avalanche transistor pulser. Light is coupled to VISAR photomultipliers using light pipe. (Our pulser is 2 x 3 x 5 cm, and has 12 optical outputs and one electrical output.)

With equal length light pipes, this provides simultaneous optical fiducials to eight photomultipliers on our dual VISAR. In addition to the time signals this system produces, it provides a double check on proper photomultiplier operation just nanoseconds before and after velocity signals. It also provides a simple transient response test for the complete signal path from photocathodes to digital data file in the computer. This has been useful to help locate intermittent faults in signal cables; especially at connections, relays, and terminations.

Although the optical fiducials are used for day-to-day synchronization of VISAR data signals, the fast turn-on of the laser is a better timing fiducial because the actual path for signals is used. Therefore, it was used to check out the light emitting diode system at initial setup.

Note that the optical fiducial system must be used, in general, for VISAR shots instead of the laser turn-on. This is because of the random interferometer phase at laser turn-on time. If either data signal is at 90° or 270°, then no output will be present in that signal to provide timing synchronization.

Use the Pockel's cell waste beam

A laser spectrum analyzer can be permanently mounted to receive the laser Pockel's cell waste beam. Because this beam is reflected to one side of the laser axis, it is simple to mount a suitable attenuator and spectrum analyzer in this location. Thus, the laser spectrum can conveniently be observed at any time except for when the Pockel's cell is gated on.

Conclusion

Importance of features discussed are illustrated in Figure 5. Advantageous use of a sequencer, proper translator, optical fiducials, laser spectrum analyzer, and precise fringe constant also enhance VISAR value.

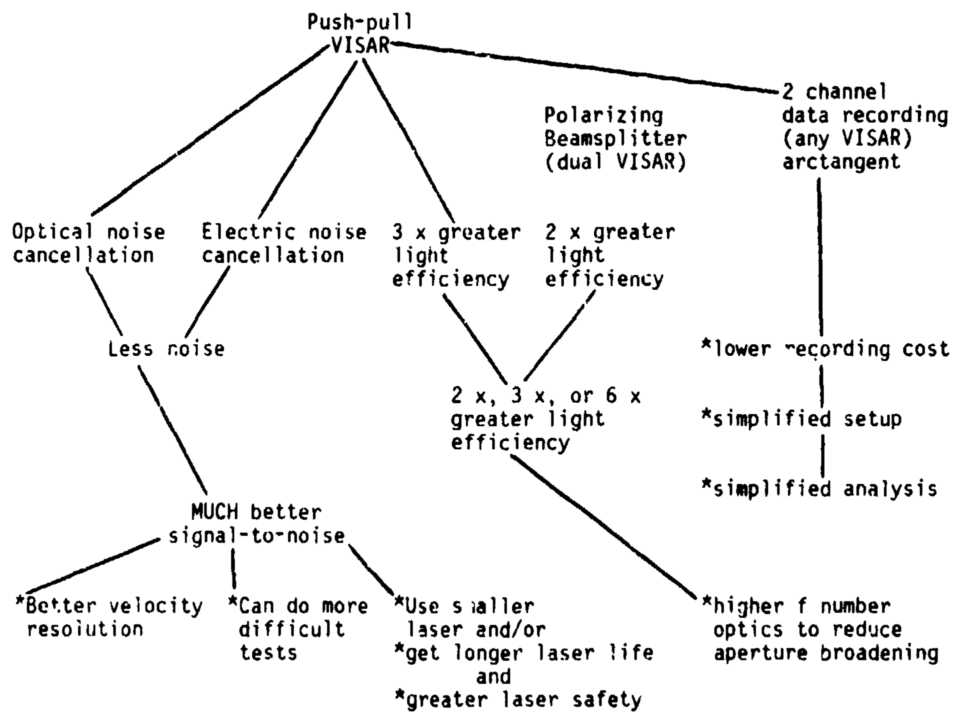

Figure 5. Diagram illustrating benefits of VISAR features

Acknowledgments

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References

1. Barker, L. M. and Hollenback, R. E., "Laser Interferometer for Measuring High Velocities of Any Reflecting Surface," Journal of Applied Physics, 43, 4669. 1972.
2. Hemsing, W. F., "Velocity Sensing Interferometer (VISAR) Modification," Review of Scientific Instruments, 50 (1), January 1979.
3. Amery, B. T., "Wide Range Velocity Interferometer," Sixth Symposium on Detonation (Office of Naval Research, Department of the Navy, Arlington, VA, 1976), p. 215. August 24-27, 1976.
4. Isbell, W. M., private communication, 1978.