Hybrid interferometer system for velocity measurements

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Abstract. The first result of the developed hybrid system for measuring the mass velocity of a matter is presented in the article. It combines two methods, VISAR and PDV, to compensate for their shortcomings. The scheme of the measuring system and the results of the laboratory experiment are shown.

1. Introduction
Knowledge of the dynamic behavior of matter under the high-density energies is critical to obtaining and refining of equations of state. One of the main sources of information is laser interferometry, which makes it possible to measure mass velocity of a shock-loaded matter. One of the systems serving for these purposes is velocity interferometer system for any reflector (VISAR) [1].

VISAR systems have a high spatial and temporal resolution of data, but for stable operation, a reflective surface is required, which makes it impossible to detect impact dusting and analyze the expansion of particles of a substance. In addition, the variation in the fringe visibility can lead to a difference in the expected velocity from the obtained one, which is solved by adding one or more interferometer constants [2].

Another system solves the same problem is photonic Doppler velocimeter (PDV). PDV system is a fiber optic Michelson interferometer [3]. An important distinguishing feature of this system from various systems is a direct measurement of the beat frequency during the entire experiment. This allows to observe dusting or scattering of the substance. However, the requirements for measuring equipment are very high, since it is necessary to detect beat frequencies above GHz.

Based on this, it seems possible to use two techniques at the same time, which allows you to use their advantages simultaneously.

2. Principles of fiber optic hybrid system
As in the original scheme, the principle of the fiber optic VISAR is based on creating a time delay in one of the arms of the interferometer. The interferometer is formed by 1x2 and 3x3 splitters [4]. At the input of the 3x3 splitter, the radiation reflected from the object is supplied by the 1x2 splitter. A fiber of length \( \Delta L \) was added to one of the arms, which sets the time delay of the signal. The interferometer constant \( K \) is defined as follows:

\[
K = \frac{\lambda c}{2n_0\Delta L},
\]

where \( \lambda \) is the wavelength of the radiation source, \( n_0 \) is the refractive index of the optical fiber. Depending on the range of measured velocities, it is not a difficult task to select and set the necessary interferometer constant. Using a 3x3 splitter also changes the approach to data processing.
Prior to this, in VISAR systems, the phase difference was 90°, and the phase displacement 3x3 is 120°, which also allows to determine the direction of movement of the object[5].

To obtain the interference signal of the PDV system, laser radiation is supplied to one arm of the splitter 1x2, and to the other reflected from a moving object. Denoting the laser frequency \( f_L \), and the frequency of the reflected radiation \( f_r \), the beat frequency \( f_b \) will take the form:

\[
f_b = f_r + f_L = 2(v/c)f_L,
\]

the expression of velocity:

\[
v = (\lambda/2)f_b.
\]

3. Description

The aim of this work is to refine the results of shock wave loading experiments using two measurement techniques simultaneously. A diagram of a fiber measuring system is shown in Figure 1. A fiber laser is used as a radiation source of 1550 nm, the radiation of which is divided into a reference one for the PDV system and a probe one. Using a circulator and a grin lens, radiation is supplied and collected from the object under study, then the reflected radiation is amplified and filtered through the laser wavelength. The radiation collected from the object is also separated - the part is directed to form a PDV signal, the other in fiber optic VISAR. The interference signals of both systems are recorded by photodetectors, the signals of which are recorded by an oscilloscope.

![Figure 1. Fiber optic hybrid system design.](image)

4. Experimental setup

The measuring system uses a laser with a working wavelength of \( \lambda = 1550 \) nm, 1x2 90-10 and 50-50 fiberoptic splitters that register photodetectors with a 10 GHz bandwidth, an oscilloscope with a 4 GHz bandwidth and a 20 GHz sampling frequency.
To test the hybrid system in laboratory conditions, the circuit that shown in Figure 2 was created. For ease of adjustment, a grin lens and the observed object, which is an aluminum plate, are mounted on an adjustable stand.

5. Experimental results

Several experiments were conducted with various targets. The velocity of the impactor was up to 200 m/s. The results of one of them are presented in Figure 3. The observed object is not destroyed and the reflective surface is preserved, which increases the effective recording time. From the obtained data, it is possible to determine the moment of impact and the further propagation of plastic deformation of the sample. The results of both diagnostic systems are in good agreement for 150 μs; a further difference between the fiber optic VISAR data is due to the small amplitude of the signals. VISAR data has better time resolution and allows to measure variation in velocity even on such small velocity scales. PDV data has better sensitivity and record length.
6. Conclusion
The first results of laboratory experiments obtained using the developed hybrid system are presented, in which two of the most common methods for measuring the mass velocity of a substance are implemented. The tests performed demonstrate the ability of this solution to perform accurate velocity measurements of surfaces of any type. In the future, it is planned to use this development in experiments of a higher range of velocity.

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