исследователь может увеличить количество датчиков и получить бóльшую статистику и дополнительную информацию.

Заключение

В 2014 году во ВНИИТФ разработан аппаратурный комплекс. Комплекс выполнен на современной элементной базе. В конструкции заложены принципы, позволяющие использовать его для различных исследовательских и технологических задач:

модульность,

цифровая регистрация измерительной информации,

патентованный способ измерения временных интервалов.

Список литературы

1 О.М. Журавлев. Оптические датчики. – Снежинск: Изд-во РФЯЦ-ВНИИТФ, 2006. – 516 с., ил.

2 Методы исследования свойств материалов при интенсивных динамических нагрузках: Монография / Под общ. ред. д-ра физ.-мат. наук М.В. Жерноклетова. – Саров: ФГУП РЯЦ-ВНИИЭФ, 2003. – 403 с.

MULTI-CHANNEL DIGITAL OPTICAL SYSTEM FOR THE RESEARCH OF SHOCK COMPRESSION AND DETONATION

K.S. Boretskikh, D.A. Gribanov, S.M. Dolgikh, A.N. Karzhenkov

RFNC – VNIITF, Snezhinsk, Russia

Introduction

In 2014, RFNC-VNIITF completed development of the multi-channel system to study shock-wave and detonation processes. The multi-channel system can be used to investigate detonation velocity of explosives (HE), flight velocity of flyers, shape of shock and detonation waves, etc. Other areas wherein the multi-channel system can be used are hydrodynamics, burning and so on. It can be also used in the mode of multi-channel counting of pulses. At present, the multi-channel system is used in experiments that traditionally use electrical contact pins and high-speed mirror-scanning photorecorders. Our new multi-channel system is developed to partially substitute high-speed photorecorders in order to update the recording techniques and to improve measurement accuracy.

This paper presents the design of our multi-channel system and also experimental setups that use the multi-channel system.

1 Description of the multi-channel system

1.1 Characteristics of the multi-channel system

The multi-channel system has the following features that precondition its application area:

number of measuring channels – more than 100;

error in measurement of time intervals – ±16 ns at most;

measurement range of time intervals – 200 μs at most;

modularity – possibility to increase the number of measuring channels;

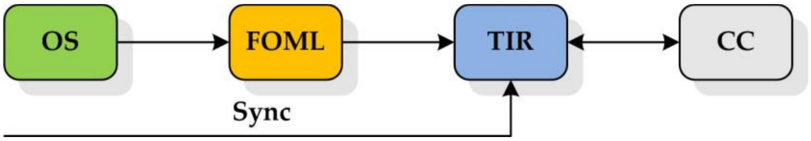
availability of the metrologically certified measurement technique;

availability of diagnostic equipment. RFNC-VNIITF developed a special multi-channel laser pulsed radiation source.

1.2 Design of the multi-channel system

1.2.1 Schematic measurement channel

Schematic measurement path of the multi-channel system is given in figure 1.



OS – optical sensor, FOML – fiber-optic measurement lines, TIR – time interval recorder, CC – control computer.

Figure 1. Schematic measurement channel of the multi-channel system

1.2.2 Optical sensor

The optical sensor – is an optical fiber prepared for emplacement into a measuring unit or onto a test object. As a rule, for measurement results could be repeated and interpreted, the fiber need to be chipped, polished, and placed into the casing. The applied sensors have the following advantages [1]:

- electrical passivity;
- chemical inertness;
- no impact on the test object;
- capability of analog transfer of measured data to considerable distances (of the order of several kilometers depending on a required passband of a measurement system).

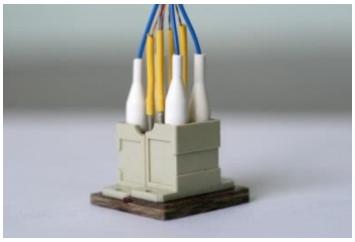


Figure 2. A sample assembly to measure the air shock-wave velocity

Figure 2 gives a simplest assembly intended to measure the air shock-wave velocity. Fiber optic connectors serve as the gages that are placed into adapters. Both elements are standard ones and are serially produced for application in transmission systems.

The multi-channel system can use optic fibers with the core diameter of up to 200 μm.

1.2.3 Fiber-optic measurement lines (FOML)

The fiber-optic measurement line also consists of fiber-optic components (figure 3). A particular configuration of FOML depends on the experimental setup and includes, as a rule, patch-cords (optical cords terminated with the connector on both sides), splitters (multiple sockets that divide the light flux into two and more ones and, vice versa, combine the light flux), and attenuators.

Figure 3 – FOML components

Different configurations of FOML allow different research and diagnostic tasks to be resolved. In particular, it is possible to bend a part of the optical radiation for further registration by other methods, to inject the probing radiation into the measurement channel to check it just prior to the experiment, as well as to attenuate the received signal to match its sensitivity with that of the time interval recorder (TIR).

In the general case, the optical fiber used in the time interval recorder can differ from that one used in the optical sensor. But in order to preserve the measurement data, they would be compatible (in particular, the optical-fiber diameter would not reduce when going from the optical sensor to the time interval recorder).

1.2.4 Time interval recorder (TIR)

The time interval recorder is a digital recorder based on the multilayer printed-circuit board with optical measurement inputs and one input for the sync signal (figure 4). TIR also has an electrical interface connector.

Рисунок 4. Appearance of the time interval recorder

TIR records a digital signal. The measurement result is the time period between the instant when signals arrive at the sync signal input and the instant when they arrive at the measurement inputs. Depending on the experimental setup, the sync signal can be formed either by a device initiating the process (an exploding generator, an ignition device, etc.), or by a sensor placed on the test object.

TIR performance:

- sampling frequency – 1 GHz;
- number of measurement inputs – 8;
- recorded strength of the optical input signal – from 0.2 to 175 μW;
- Error in measurement of the time interval 100 μs – 5 ns.

The patented method of event recording allows measurements during a large period of time (of the order of hours) with the sampling frequency of 1 GHz.

Spectral sensitivity is shown in figure 5.

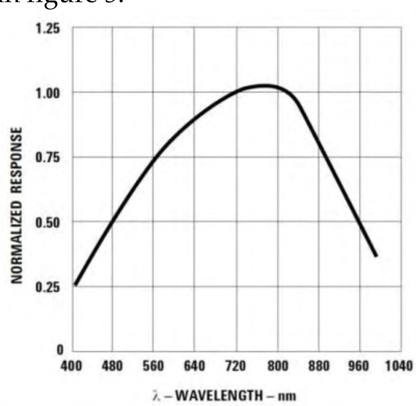


Figure 5. Spectral sensitivity of the time interval recorder (TIR)

A special feature of TIR used in the multi-channel system is three thresholds available in each measurement channel (figure 6).

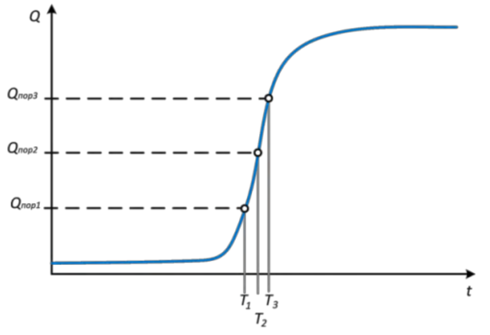


Figure 6. Three thresholds

These three thresholds allow TIR sensitivity to be adjusted depending on the test process, as well as informativity of the experiment to be increased due to additional data on the shape of the measuring signal. In some cases, this provides an investigator with the test object characteristics, say, needed to take a decision whether it is efficient or further experimentation is required. An operator states thresholds in the control program prior to measurements simultaneously for all TIRs in the system.

TIRs are developed and manufactured at RFNC-VNIITF.

Experimental setup

1.3 Recorded physical phenomena

In the general case, one can say that all phenomena accompanied by rather fast changes in the optical wave amplitude can be recorded by the multi-channel system for instance mechanical, electrical, magnetic, and radiation phenomena [1].

RFNC-VNIITF uses the multi-channel system to study shock-wave and detonation processes and to record the following physical phenomena:

- self-luminescence of detonation fronts;
- luminescence of shock-compressed HE, structural materials, and gases;
- luminescence of associated air shock-waves accompanying the initiation and detonation phenomena;
- lightguide core luminescence induced by the pressure pulse when the denotation or shock wave influences the lightguide.

The above phenomena predetermine a number of investigations of both practical and fundamental value.

Below you will find description of several experimental setups [2].

<u>Measurement of detonation velocity (xt-diagram of detonation front movement)</u>

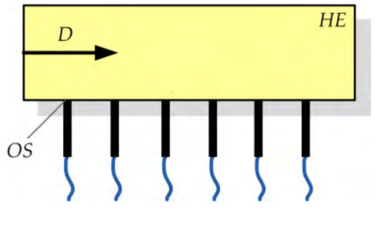


Figure 7. Measurement of detonation velocity

Figure 7 shows the HE cartridge with detonation propagating from its end-face. Optical sensors are positioned normally to the detonation front propagation direction. In the experiment, one records the sequence of the sensors response instants that are indicative of the detonation velocity in HE.

Measurement of shock-wave velocity

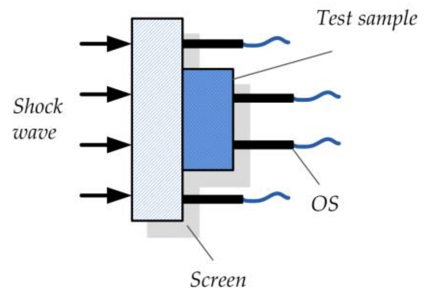


Figure 8. Measurement of shock-wave velocity

The experimental setup shown in figure 8 is used when it is necessary to measure the shock-wave velocity in a matter. The test sample is placed very close to the screen. Sensors are codirectional with the shock-wave. Difference in the response time of sensors placed close to the screen and sensors placed close to the test object indicates the velocity of the shock wave propagation throughout the object.

Measurement of times of the shock-wave arrival into the gap and at the test surface.

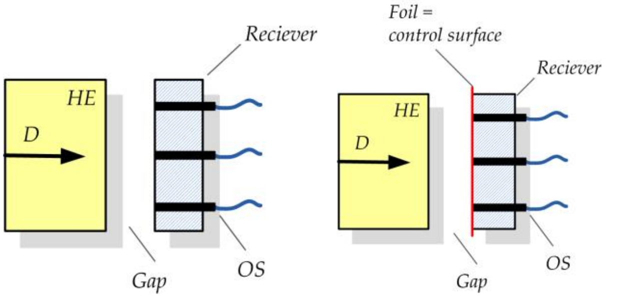


Figure 9. Measurement of times of the shock-wave arrival into the gap and at the test surface

Experimental setups shown in figure 9 enable time instants of the shock-wave arrival at the free surface and at the control surface to be measured. The only difference is that in the second experimental setup the foil shields sensors. The latter variant records the time of the shock-wave arrival at the foil being the control surface.

Measurement of the impactor velocity

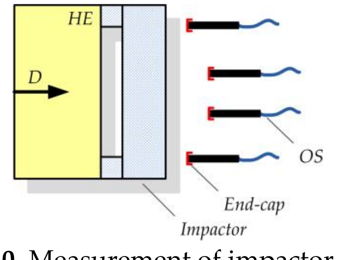


Figure 10. Measurement of impactor velocity

Figure 10 shows the experimental setup that allows the impactor velocity to be measured. Sensors have metal end-caps to cut off the shock-wave luminescence during the impactor movement. The response time of sensors at different positions indicates the impactor flight velocity.

Measurement of the mechanical-system state variation rate (shutter-type sensor)

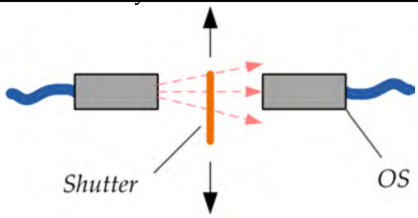


Figure 11. Measurement of the mechanical-system state variation rate

Figure 11 shows the experimental setup that allows the time of the mechanical-system state variation to be measured. The light leaves one fiber and enters another one. The moving shutter stops the light beam or, vice versa, allows it to pass. For instance, the shutter can be connected with the membrane or any other moving object. This is the way to measure the shutter velocity if this shutter is made of a transparent material and a constant-spacing grid is applied thereon.

Certainly, this list of experimental setups cannot be regarded as complete. It just illustrates capabilities of the multi-channel system presented in the paper. And of course, an obvious advantage of the system, i.e. multi-channeling, should be kept in mind. So, an investigator can use more sensors and obtain more data and additional information.

Conclusion

In 2014, RFNC-VNIITF developed the multi-channel system that incorporates the up-to-date hardware components. In order the system could be used for different research and technological tasks, the design of the system is based on the following principles:

modularity,
digital recording of measurement data,
patented time-interval measurement method.

References

1. O.M. Zhuravlev. Optic sensors. – Snezhinsk: Published by RFNC-VNIITF, 2006. – P. 516, illustrations.
2 Methods to study materials properties under high-intensity dynamic loads: Monograph / Edited by M.V. Zhernokletov, Doctor of physics and Mathematics. – Sarov: FSUE “RFNC-VNIIEF”, 2003. – p. 403.