The use of the modernized high-aperture shearing interferometer for visualization of flows

THE USE OF THE MODERNIZED HIGH-APERTURE SHEARING INTERFEROMETER FOR VISUALIZATION OF FLOWS

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KEYWORDS:
Main subjects: flow visualization
Fluid: subsonic and supersonic jets
Visualization method(s): shear interferometry,
Other keywords: light sources, coherence

ABSTRACT: *The high aperture shear interferometer is presented. Due to the use of synthesized coherence elements, it was possible to remove the limitation on the size of the light source, which allowed to get rid of the slit diaphragm. The pictures of visualization of plane subsonic and supersonic jets are given. This method will be especially in demand in the visualization of fast processes, where the illumination of a phase object is most necessary.*

1 Introduction

To date, a number of publications have appeared on the possibility of allocating optical inhomogeneities in the cross-section of a light beam probing a gas medium [1]. They talk about the prospects of using the method of synthesized coherence, which was previously used in astronomy to detect exoplanets [2], to visualization of gas-dynamic flows. In these publications, we are talking about the synthesized coherence of the light source, which can be locally created in a particular section of the light beam probing the inhomogeneity region. In this case, the interference pattern recorded by the system will characterize the local inhomogeneity in the cross-section, rather than represent the integral inhomogeneity throughout the beam, as it was before. It should be noted that all experiments on the implementation of this principle were carried out in the laboratory under atmospheric air density and single – pass scheme (light source on the one hand, the receiver-on the other). Under these conditions, it was possible to achieve localization of phase inhomogeneity within 20 cm, which is clearly insufficient for gas-dynamic studies on aerodynamic stands. So far, the method of synthesized coherence has not reached the level required to highlight the inhomogeneity of the flow in the required section (order of at least 1 cm) of the tested model. However, the elements of the method of synthesized coherence, implemented in the illuminator of the shear interferometer, allowed to obtain an interference pattern without a slit diaphragm, which significantly expanded the possibility of high-speed recording of the observed process due to the increase in the luminous flux of the illuminator by using a wide light source.

The problem of illumination of the measuring volume in shadow and interference devices used for visualization of gas-dynamic flows is particularly acute when registering fast-flowing processes. If we limit ourselves to continuous light sources that do not require synchronization with the recording system and therefore require minimal adaptation, laser sources provide the greatest illumination to date. For Fig. 1 the process of shot from an air gun (4 consecutive frames), registered with the help of a shadow device IAB-455, was presented, a laser with a power of 1 W was used as an illuminator (Fig. 2).

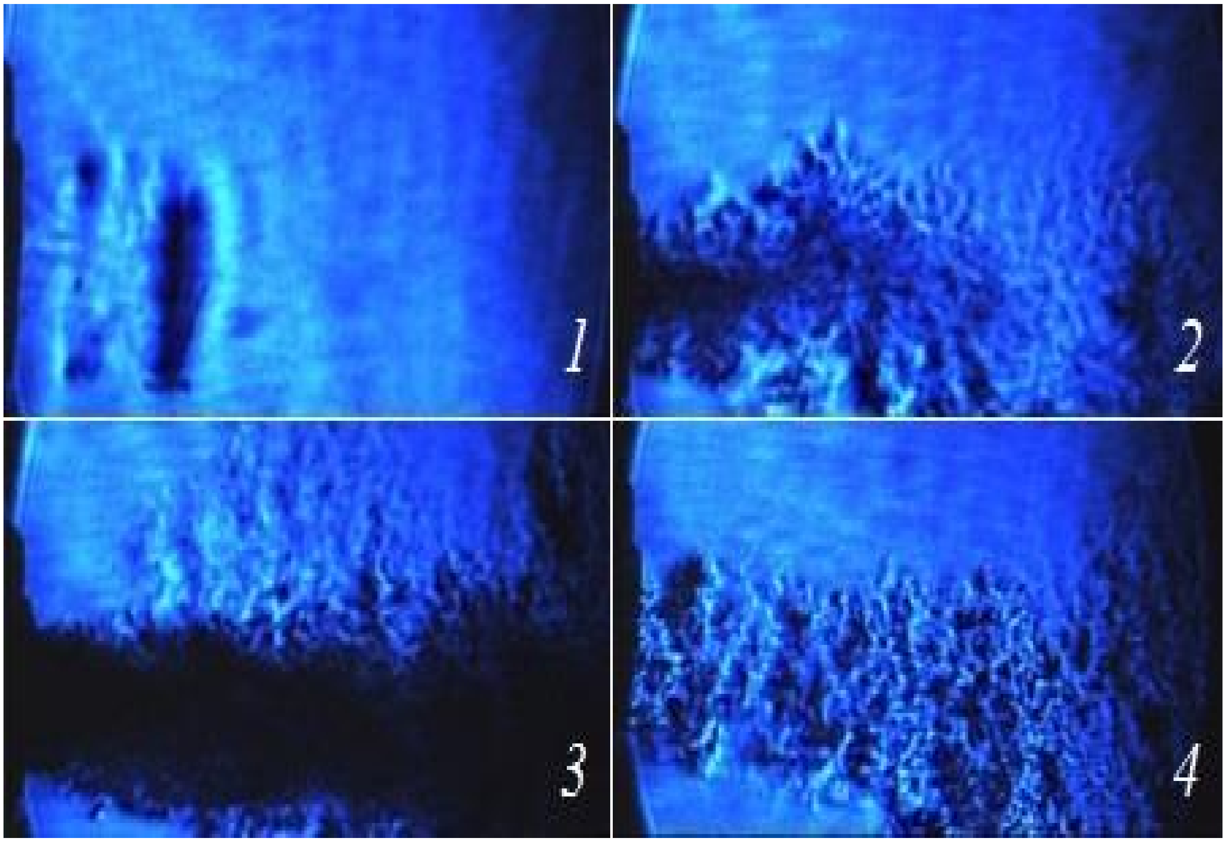
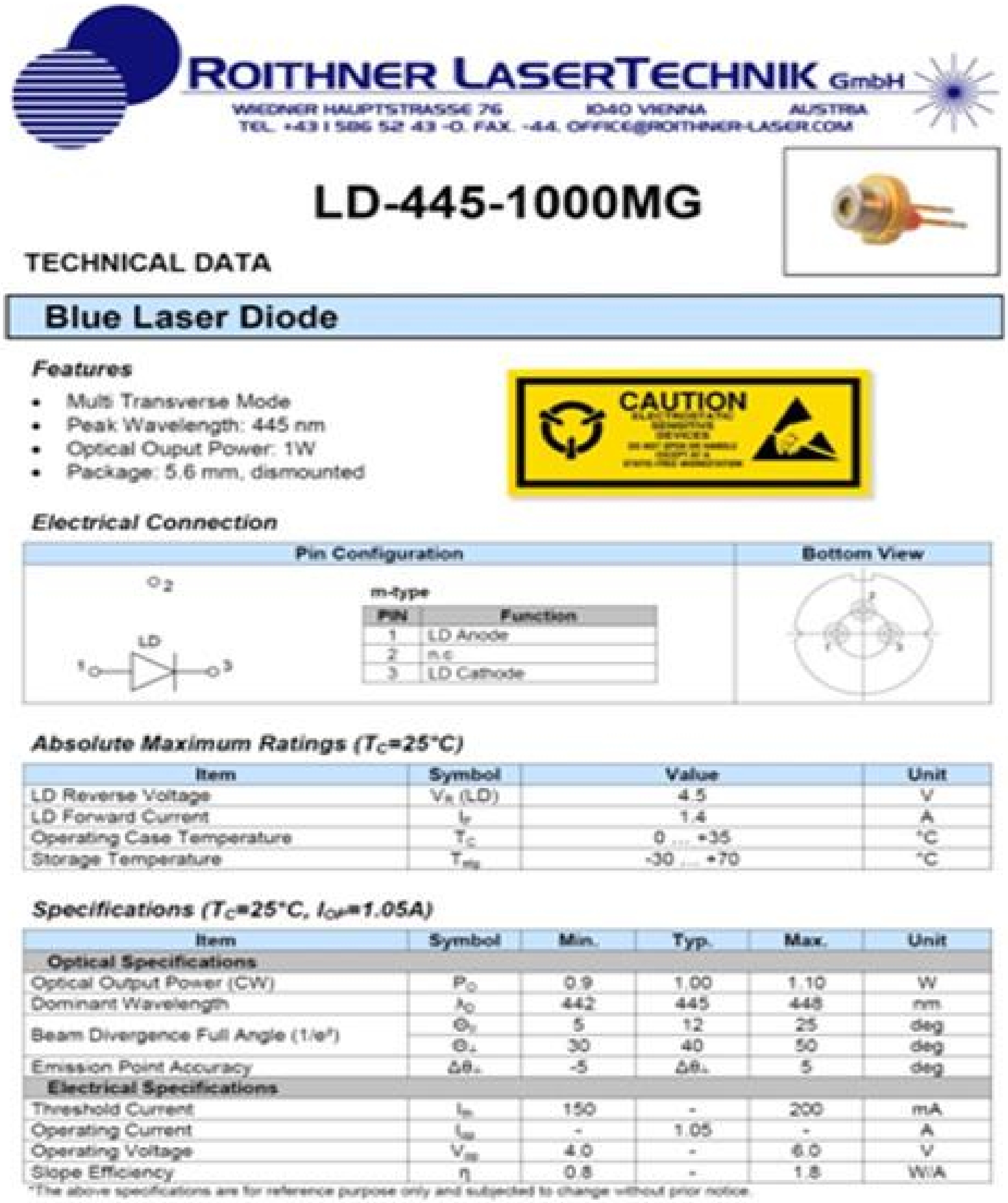


Figure 1



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LD-445-1000MG

TECHNICAL DATA

Blue Laser Diode

Features

- Multi Transverse Mode
- Peak Wavelength: 445 nm
- Optical Ouput Power: 1W
- Package: 5.6 mm, dismounted

Electrical Connection

Pin Configuration — m-type

PIN	Function
1	LD Anode
2	n.c
3	LD Cathode

Bottom View

Absolute Maximum Ratings (T_C=25°C)

Item	Symbol	Value	Unit
LD Reverse Voltage	V_R (LD)	4.5	V
LD Forward Current	I_F	1.4	A
Operating Case Temperature	T_C	0 ... +35	°C
Storage Temperature	T_{stg}	-30 ... +70	°C

Specifications (T_C=25°C, I_{OP}=1.05A)

Item	Symbol	Min.	Typ.	Max.	Unit
Optical Specifications					
Optical Output Power (CW)	P_O	0.9	1.00	1.10	W
Dominant Wavelength	λ_D	442	445	448	nm
Beam Divergence Full Angle (1/e²)	$\Theta_{//}$	5	12	25	deg
	$\Theta_{\perp}$	30	40	50	deg
Emission Point Accuracy	$\Delta\theta_{\perp}$	-5	$\Delta\theta_{\perp}$	5	deg
Electrical Specifications					
Threshold Current	I_{th}	150	-	200	mA
Operating Current	I_{op}	-	1.05	-	A
Operating Voltage	V_{op}	4.0	-	6.0	V
Slope Efficiency	η	0.8	-	1.8	W/A

*The above specifications are for reference purpose only and subjected to change without prior notice.

Figure 2

This laser (LD-445-1000MG) has a low coherence, which has a positive effect on the quality of the picture, but the need for a slit diaphragm does not allow the full use of all the available light flux.

2. System description and results

Organization "Rosinterf" together with TSAGI has developed a basic two-pass interferometric system based on a IAB-451 collimator and IT183 interferometer with testing light wave synthesized coherence. Optical scheme of the system is presented on Fig. 3.Interferometer schematicis presented on Fig. 4/ Aerodynamic stand appearance is shown on Fig. 5, 6.

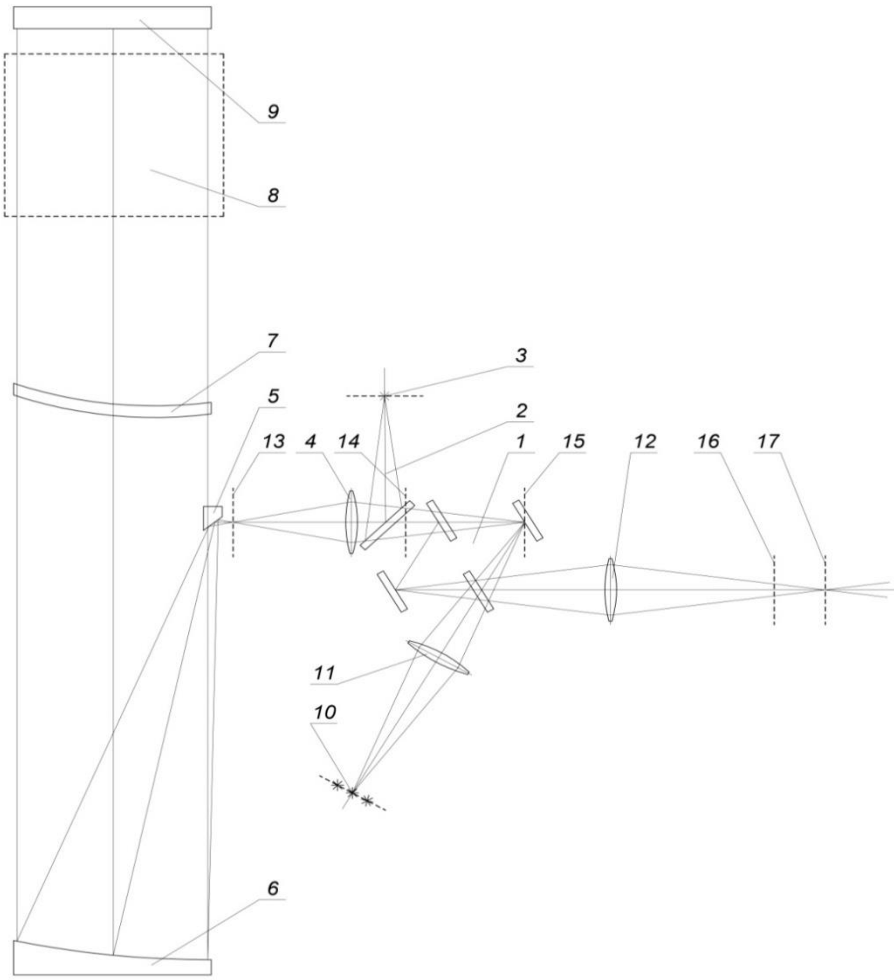


Figure 3

1. Zander-Mach typeIT183 interferometer.
2. Zabelin layout light source.
3. A point monochromatic light source, a laser diode (λ=650 nm).
4. Mate lens "Zenitar".
5. Turning mirror from IAB-451collimator.
6. Off-axis spherical mirror from IAB-451 collimator.
7 Optical compensator from IAB-451collimator.
8. The area of visualization.
9. The reference mirror.
10. Wide size visible spectrum light source, white LED.
11. White source pairing lens.
12. Recorder lens.

13. IAB-451collimator focal plane.
14. Reference mirror intermediate image plane.
15. Light source intermediate image plane.
16. Reference mirror image plane, camera position.
17. Light source image plane.

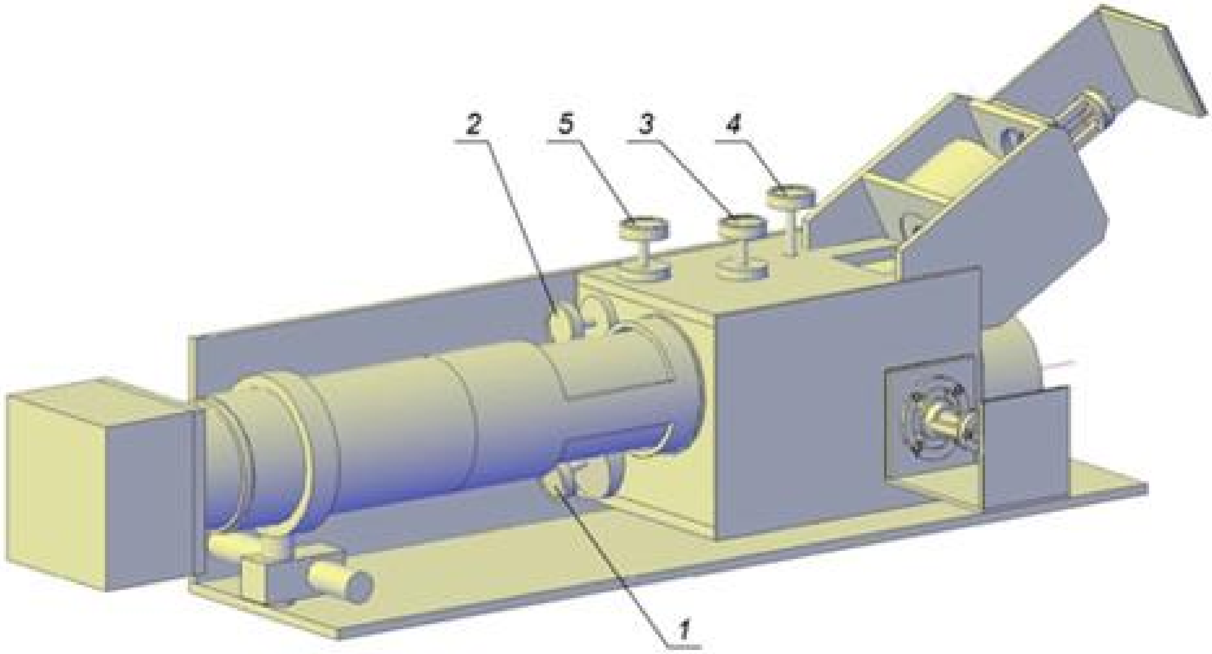


Figure 4

1. Horizontal shear adjustment handle. It adjusts the horizontal shear between the interfering light waves in the image plane.
2. Vertical shear adjustment. It adjusts the vertical shear between the interfering light waves in the image plane.
3. Horizontal fringe adjustment handle. It adjusts horizontal fringe width and vertical fringe inclination.
4. Vertical fringe adjustment handle. It adjusts vertical fringe width and horizontal fringe inclination.
5. Optical path difference adjustment handle. It adjusts shear fringe order in both directions.

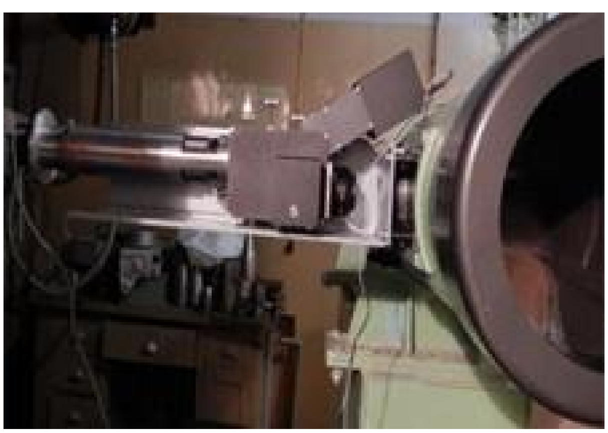
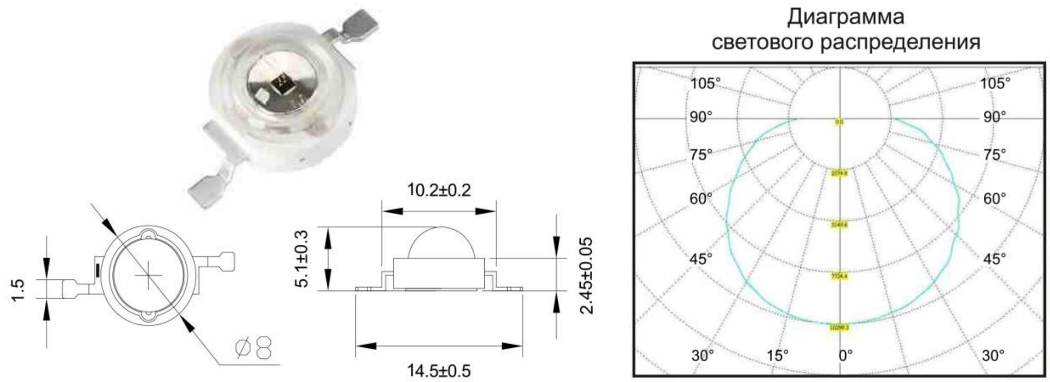


Figure 5
Collimator and interferometer

Figure 6
Flat mirror

The system used two light sources-a monochrome laser source (λ = 650 nm) and a white led with a luminous body of 6 mm in diameter (Fig. 7). The results of imaging tests flat supersonic jet flowing into the low pressure area presented at Fig. 8 and 9.



Артикул	MSD-001C/ MSD-001N/ MSD-001W/ MSD-001O/ MSD-001Y/ MSD-001R/ MSD-001G/ MSD-001B/ MSD-001PI/ MSD-001P
Угол свечения,°	120
Световой поток, Lm	100-110/ 100-110/ 100-110/ 40-50/ 40-50/ 30-40/ 70-90/ 20-30/ 70-80/ 80-90
Напряжение питания, V	3,2-3,4/ 3,2-3,4/ 3,2-3,4/ 2,2-2,4/ 2,2-2,4/ 2,2-2,4/ 3,2-3,4/ 3,2-3,4/ 3,2-3,4/ 3,2-3,4
Номинальный ток, mA	350
Потребляемая мощность, W	1
Кол-во светодиодов	1
Цвет	Белый холодный (CW) / Белый нейтральный (NW) / Белый теплый (WW)/ Оранжевый/ Желтый/ Красный/ Зеленый/ Синий/ Розовый/ Фиолетовый
Температура свечения, К	6000-6500/ 4000-4500/ 2700-3000/ 595-605nm/ 585-595 nm/ 630-640nm/ 520-530nm/ 440-460nm/ - / 390-400nm
Тип светодиодов	Epistar
Габариты, мм	L14,5 B 8 H 5,1
Производитель	Тайвань
Вес товара, кг	0,001

Figure 7

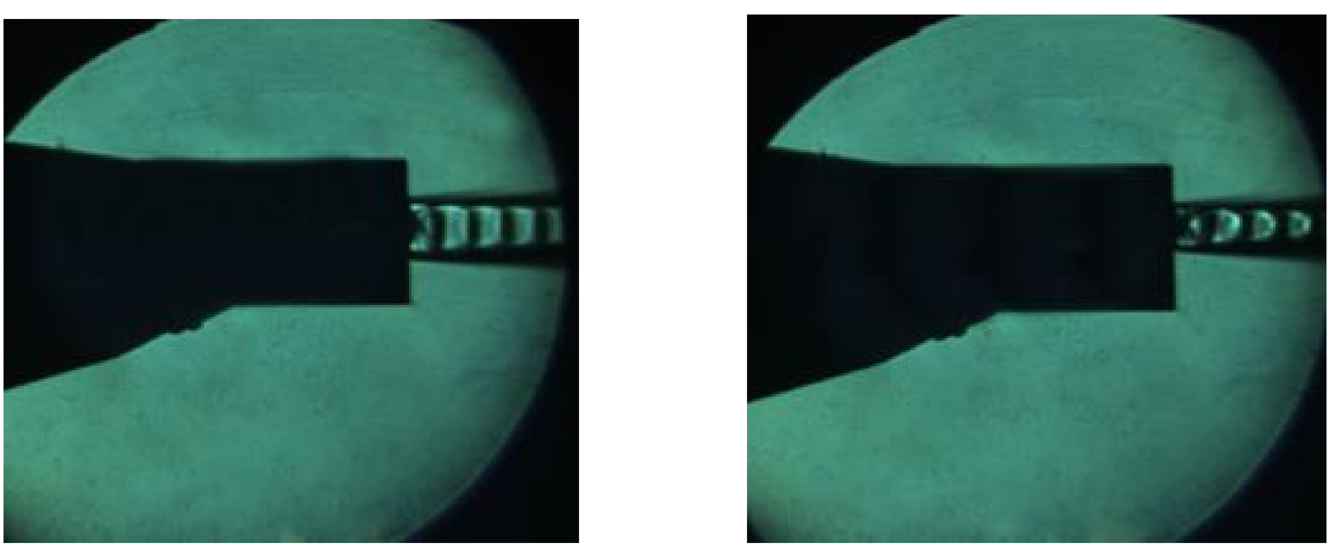


Figure 8
Flat supersonic jet into the flooded space

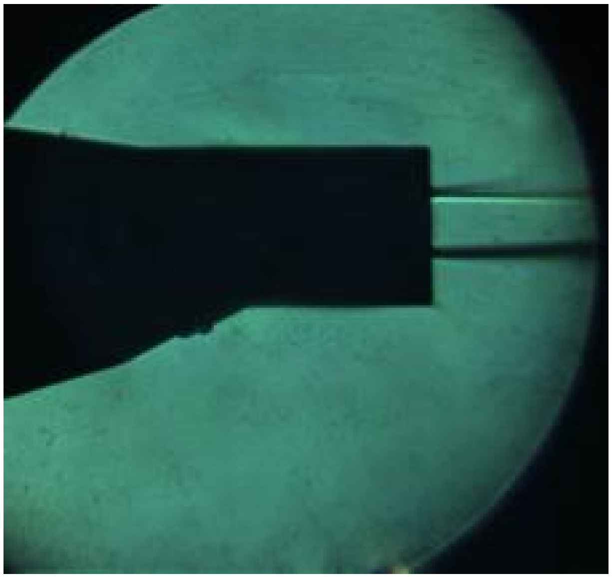


Figure 9
Subsonic jet flow

3. Summary

The presented results demonstrate the possibility of gas-dynamic flows visualization in the interferometric system without the slit diaphragm. The slit diaphragm absence increases test medium luminosity by several orders of magnitude. This approach has great potential for visualization of fast flows.

4. References

[1] V. N. Shekhtman, A. Y. Rodionov, Shear interferometric method of investigation of spatial distribution of optical inhomogeneities in spatially extended phase objects, *Optical journal*, No. 4, 2015, St. Petersburg.

[2] A. F. Tavrov, *Application of optical coherence*, textbook, Publishing house of MPEI, 2012.