Experimental investigation of vortex wake/crossing shock waves interaction

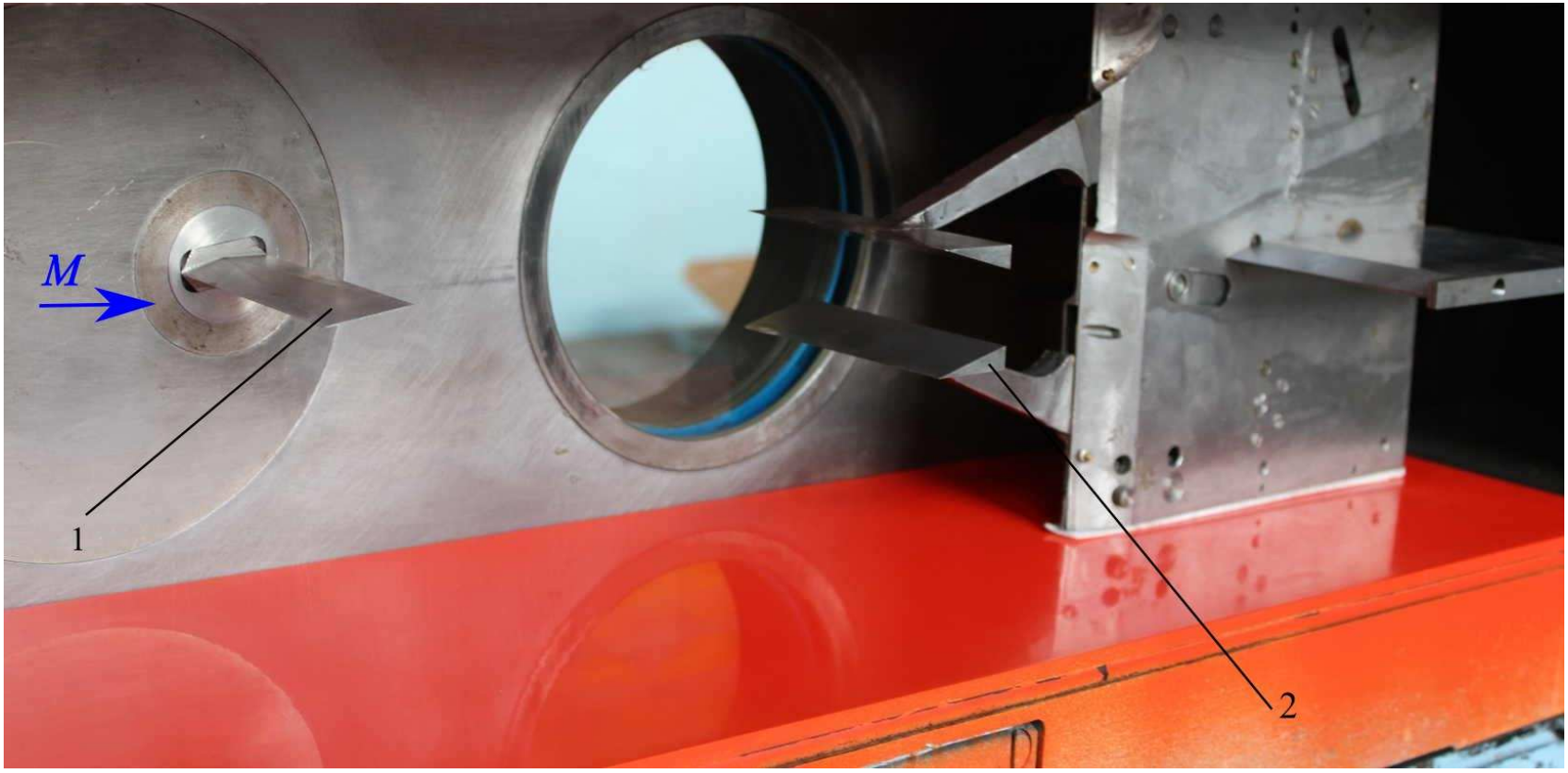
A.M. Shevchenko, M.P. Golubev, A.M. Kharitonov,
A.A. Pavlov, Al.A. Pavlov, A.S. Shmakov

Khristianovich Institute of Theoretical and Applied Mechanics SB RAS, Novovsibirsk

Introduction

- Wake vortex interaction with shock waves about 40 years remains one of the most important problems of gas dynamics, beginning with the pioneering work by Zatoloka et. al., 1975. The problem is of great practical importance, for instance due with the possibility of entering vortex core in the air intake.
- The present study is an extension of our previous investigations of the interaction of a wake vortex with a bow shock wave in front of the cylinder and with an oblique shock wave which are reported earlier.
- The main goal of the present study is a determination of various regimes during the interaction of the wing-tip vortex wake with crossing shock waves generated by two wedges with a novel optical technique.

Description of Experiments



Supersonic wind tunnel T-325 of ITAM SB RAS.
1 – unswept semispan slender wing with sharp leading and trailing edges, chord of 30 mm.
2 – system of couple counter wedges with a sharp edges

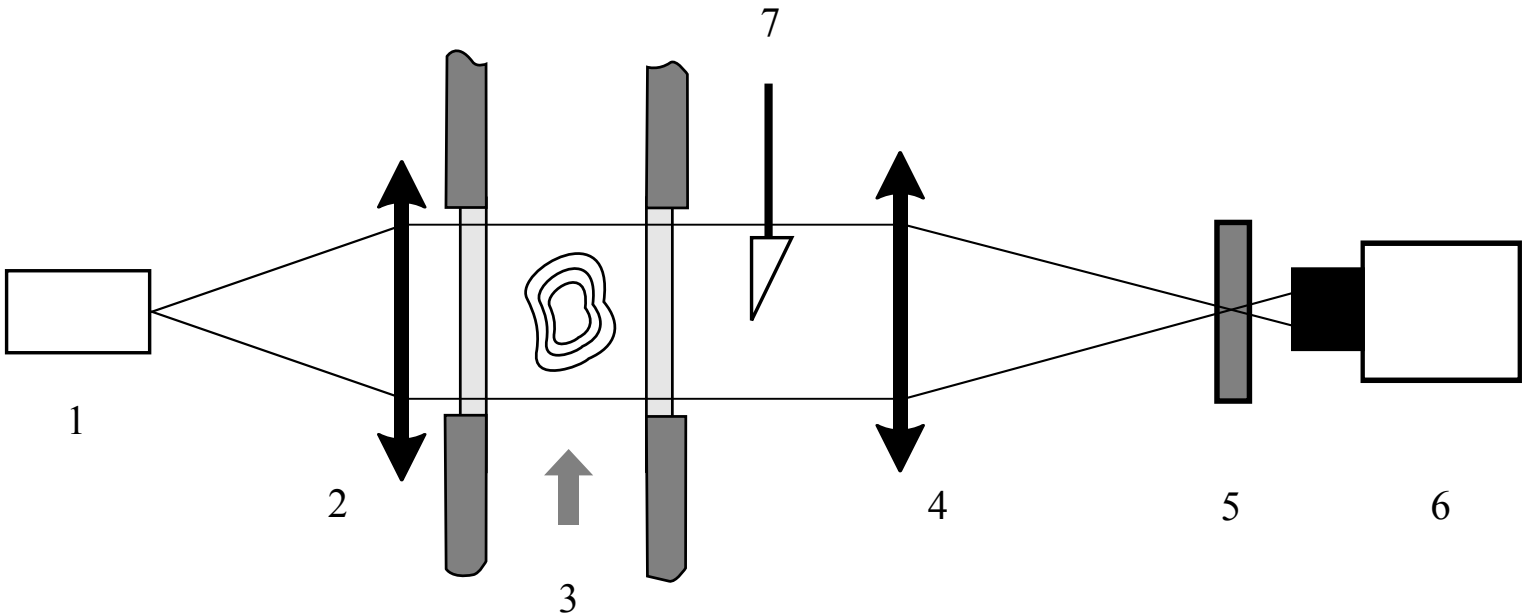
Experimental Conditions

- Mach number of 3
- Wing angles of attack up to 6 deg.
- The angle of deflection of the flow at each of the wedges ranged 14-27 degrees, thereby implementing regular (RR) and Mach (MR) reflections.

To predict the flowfield without the wing wake we use

1. Ivanov, M.S., Markelov, G.N., Kudryavtsev, A.N., Gimelshein, S.F.: Numerical Analysis of Shock Wave Reflection Transition in Steady Flows AIAA Journal. **36**:11 (1998)
2. Ivanov, M.S., Kudryavtsev, A.N., Nikiforov, S.B., Khotyanovsky, D.V.: Transition between regular and Mach reflection of shock waves : new numerical and experimental results. Aeromechanics and gasdynamics (in Russian). **3**, 3–12 (2002)

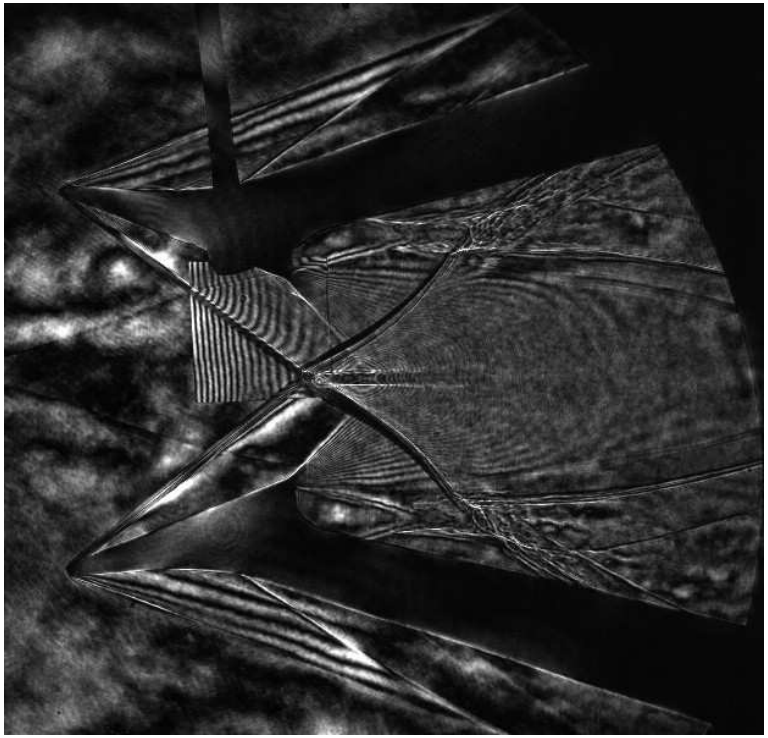
Saturation Absorption Adaptive Visualizing Transparency (SA AVT) technique

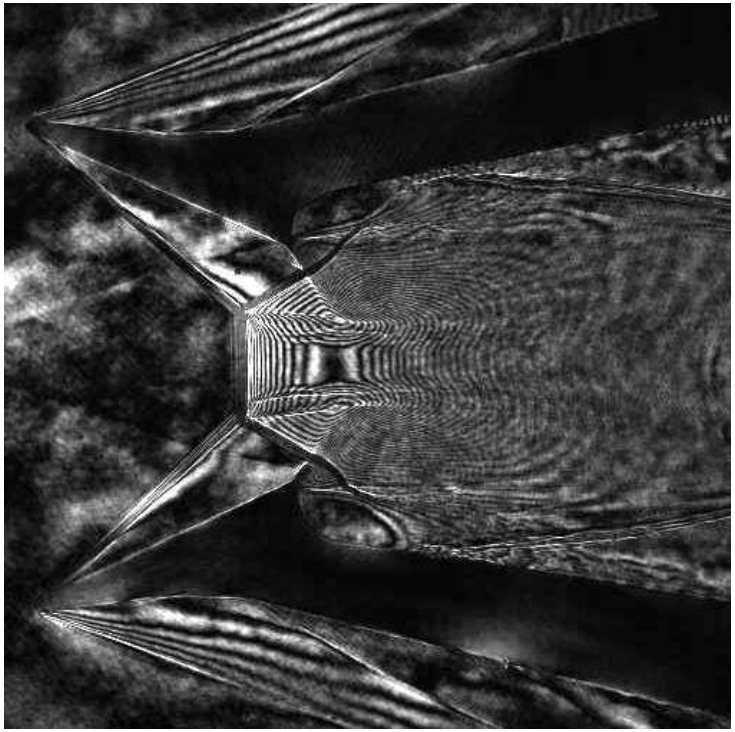


Laser light source 1 (532 nm) and collimator 2 are used to produce a probing beam. Passing through the test section of the wind tunnel 3 the beam is focused by a lens 4.
SA AVT 5 is placed in the focal plane of the lens similar to a classical cutoff (Fuko's blade).
A camera 6 serves to image recording. If necessary a glass wedge 7 is applied to convert infinite fringes to finite ones.

- SA AVT is a further development of AVT schlieren-type method.
  1. Pavlov, A.A., Pavlov, Al.A., Golubev, M.P.: Some Aspects of a Schlieren Technique Sensitivity Increasing. ISALTFM, Lisbon, 09–12 July, 2012, paper 314.
  2. Pavlov, A.A., Pavlov, Al.A., Golubev, M.P.: On schlieren methods with use of self-induced Zernike filters based on saturable absorption effect. Vestnik NSU. Series: Physics, 2014, No. 1 (in Russian).
- SA AVT Zernike-type filter represents a thin layer made of translucent substance which is placed in the focal plane of the receiving lens of a schlieren system.
- Advantages:
  1. SA AVT allows to receive images similar to infinite width fringe interferograms, almost completely to exclude the influence of vibrations of optical elements.
  2. If it is needed during an experiment the infinite-fringe interferograms can be easily transferred to finite-fringe ones.

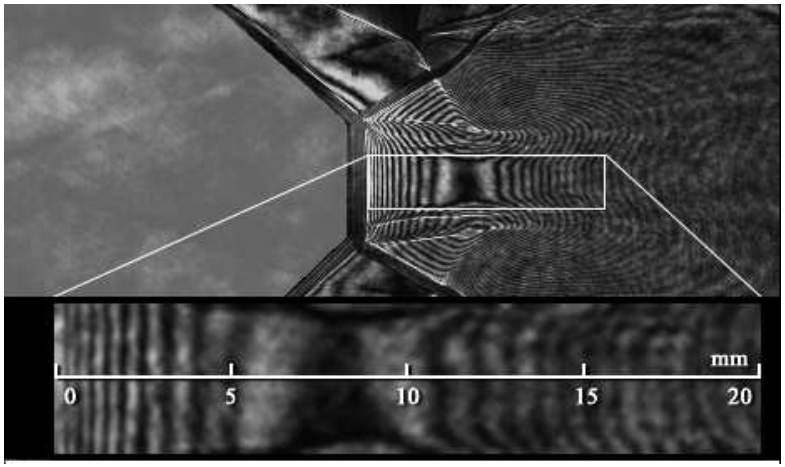
Experimental Results. Flowfield without the vortex



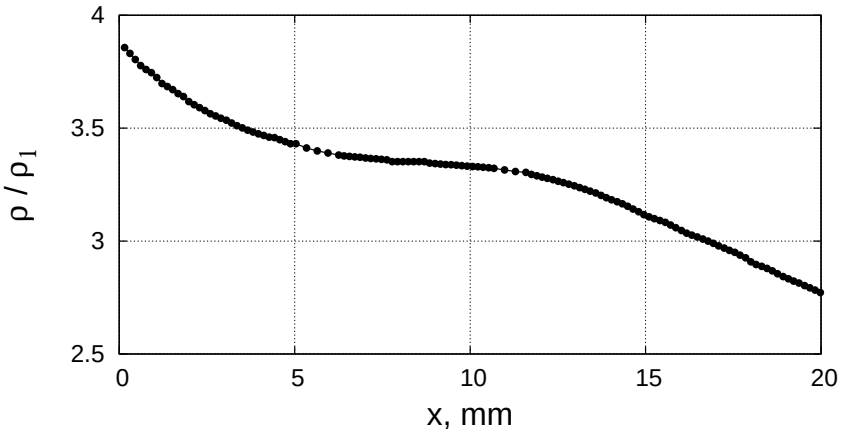


Left image shows the region which is transferred into the finite–fringe interferograms using the optical wedge.

Density estimation



(a)

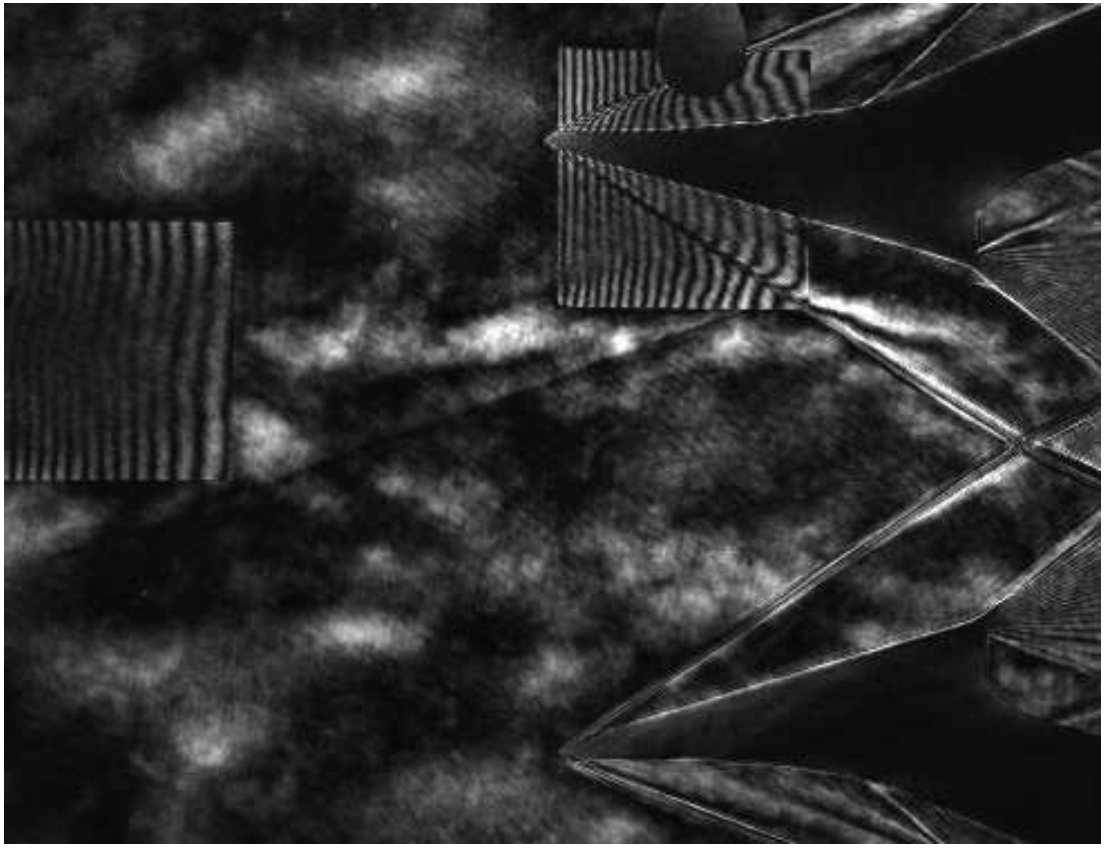


(b)

Interferogram processing has been performed in paraxial approach for 2D flow assumption (i.e. density does not change along the optical path, and the path itself – is a straight line).

The relations for normal shock wave were used to estimate a density behind of the Mach stem.

Vortex wake/RR interaction

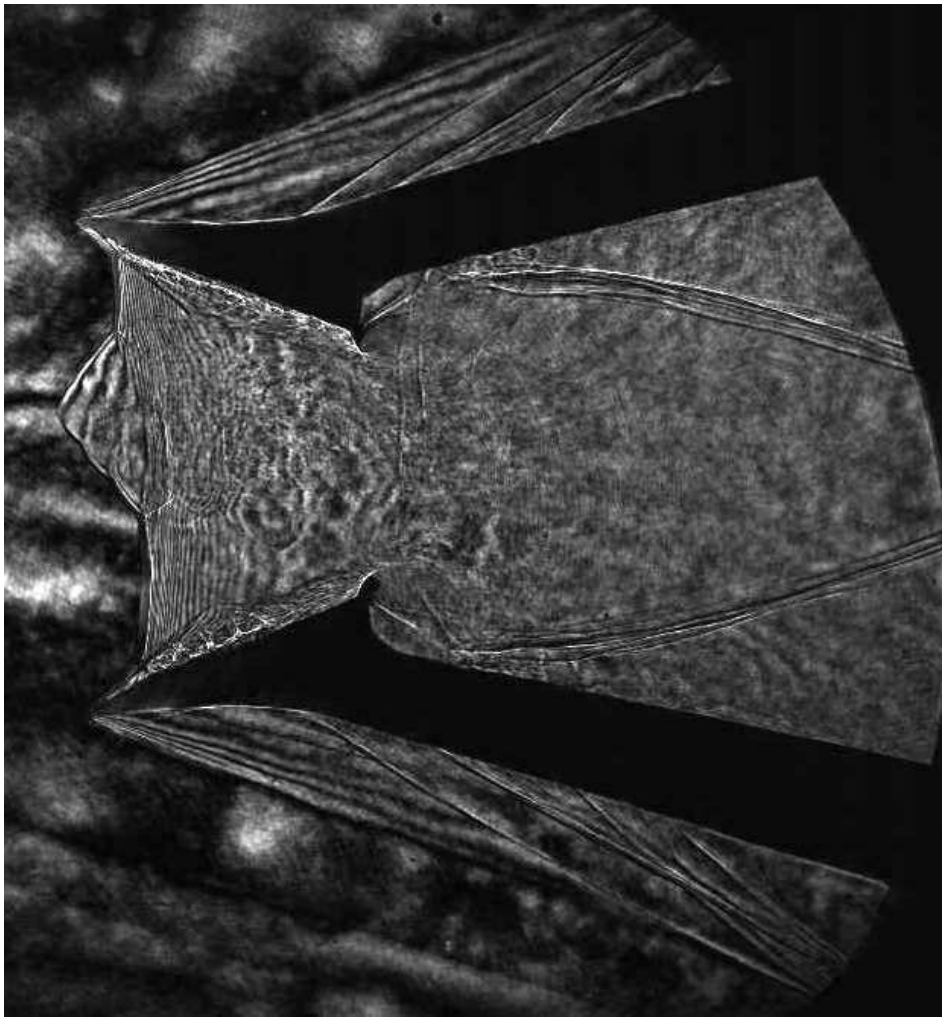


Infinite–fringe interferogram, and two regions of which are transferred into the finite–fringe interferograms using the optical wedges.

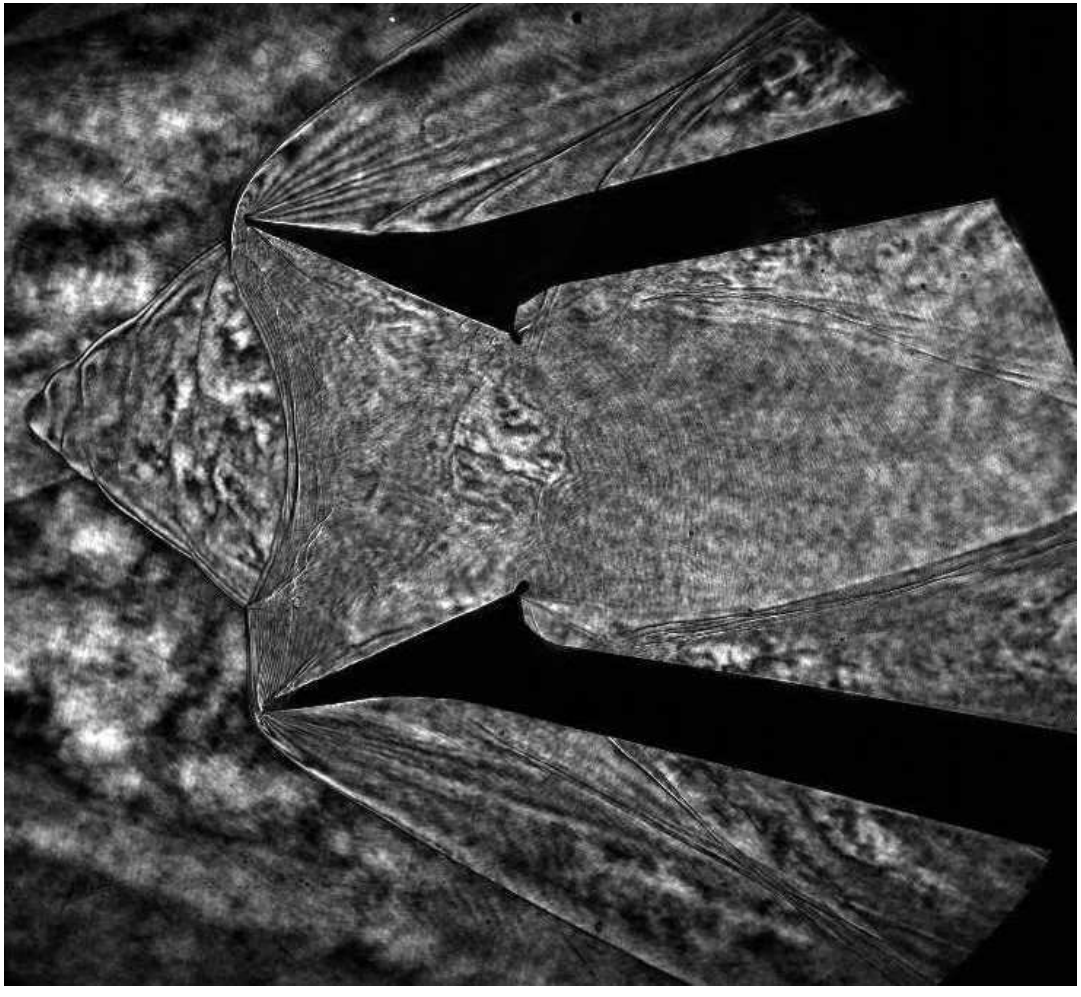
Vortex wake/MR interaction

Interaction at $\alpha = 4$ deg.

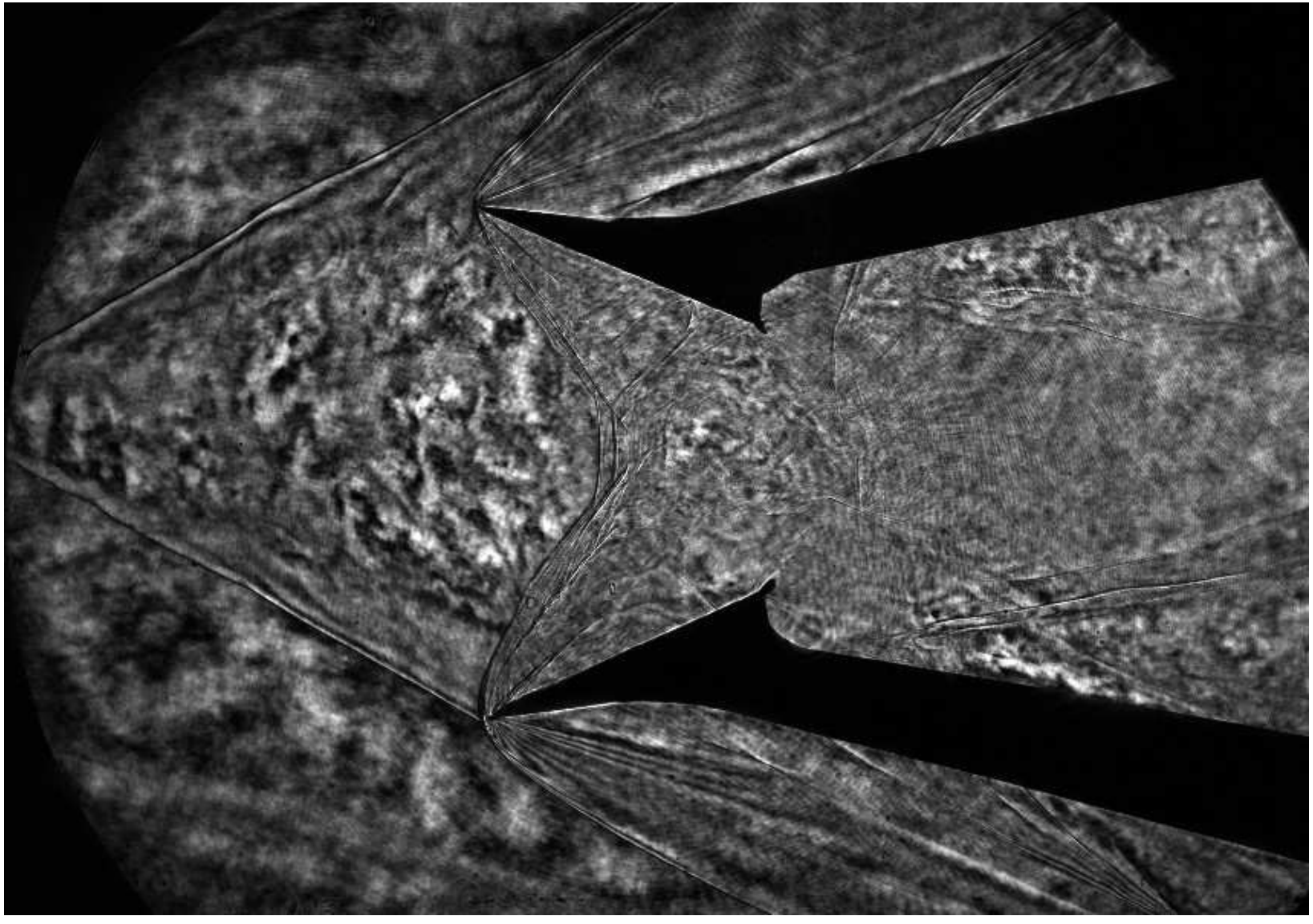
Vortex wake/MR interaction



Interaction at $\alpha = 4$ deg.



Interaction at $\alpha = 4$ deg.



Interaction at $\alpha = 6$ deg.

Conclusion

- Various regimes during the interaction of the wing-tip vortex wake with crossing shock waves generated by two wedges were examined with the novel optical technique.
- Wing tip vortex interaction in the case of RR shock waves system refers to the so-called weak type. Vortex core passes through a system of shock waves without the vortex burst and formation of circulation zones.
- The interference of the wake vortex with MR shock waves system leads to destruction of the vortex core. Various modes of interaction are similar to those observed in the interaction of wake vortices with the bow shock in front of the cylinder.
- In paraxial approach for 2D flow assumption an experimental estimation of the density distribution along the "virtual nozzle" is first obtained experimentally.

Acknowledgements

The work was supported by RFBR projects
12-01-00806 and 15-01-08575.

Thank you for your attention!