Optical Density Visualization and Abel Reconstruction of Vortex Rings Using Background-Oriented Schlieren

Sznitman, J.* and Rösgen, T.*
* Institute of Fluid Dynamics, ETH Zurich, CH-8092 Zurich, Switzerland.
E-mail: sznitman@ifd.mavt.ethz.ch
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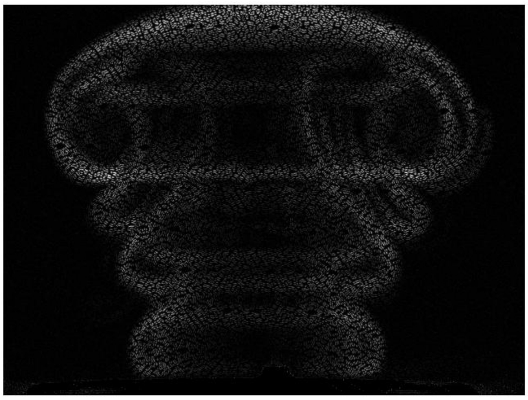
Fig. 1. Schlieren visualization: absolute difference between phase and reference are displayed.

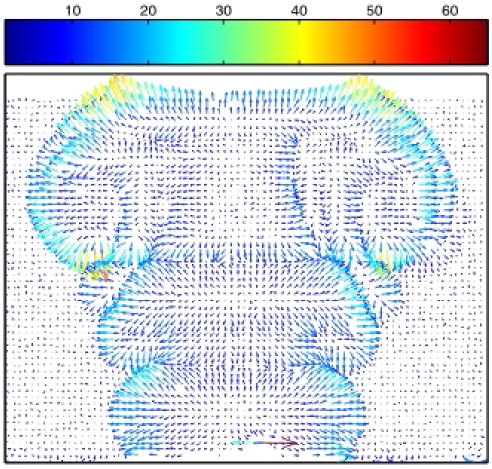

Fig. 2. Vector map of the refractive index gradient (scale in arbitrary units).

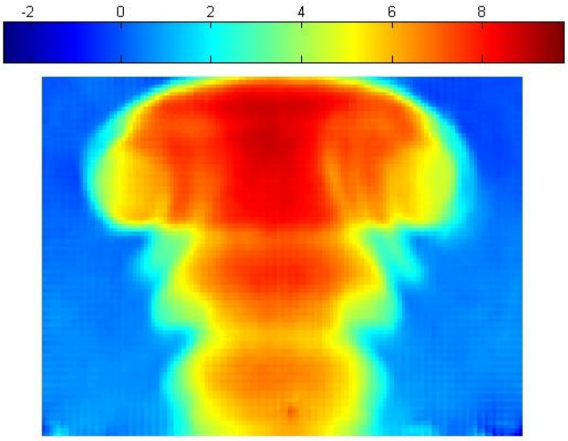

Fig. 3. Vortex ring projected density field (scale in arbitrary units).


Fig. 4. Reconstructed radial profile using the inverse Abel transform.

These figures represent a sequence of visualizations of CO_2-loaded vortex rings generated at the orifice opening of a piston-cylinder apparatus (diameter of orifice opening is 7 cm; *Re* = 36'000; ratio of the piston stroke length to diameter is 0.5 and field of view is 15 x 20 cm). Qualitative Schlieren visualizations are obtained using a Background Oriented Schlieren (BOS) technique (Fig. 1) and a vector map of the gradients of the refractive index is extracted using a PIV algorithm (Fig. 2). The projected density field (Fig. 3) is then obtained by integrating the measured gradient field. Finally, an Abel inverse transform is implemented to reconstruct the true radial vortex ring profiles for enhanced visualization of flow structures such as the recirculating spiral roll-ups and trailing wakes (Fig. 4).

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Laser-Optical Investigation of Stator-Rotor Interaction in a Transonic Turbine

Woisetschläger, J.*, Pecnik, R.*, Göttlich, E.*, Schennach, O.*, Marn, A.*, Sanz, W.* and Heitmeir, F.*

* Institute for Thermal Turbomachinery and Machine Dynamics, Graz University of Technology, Inffeldgasse 25A, A – 8010 Graz, Austria.
E-mail: jakob.woisetschlaeger@tugraz.at, http://www.ttm.tugraz.at

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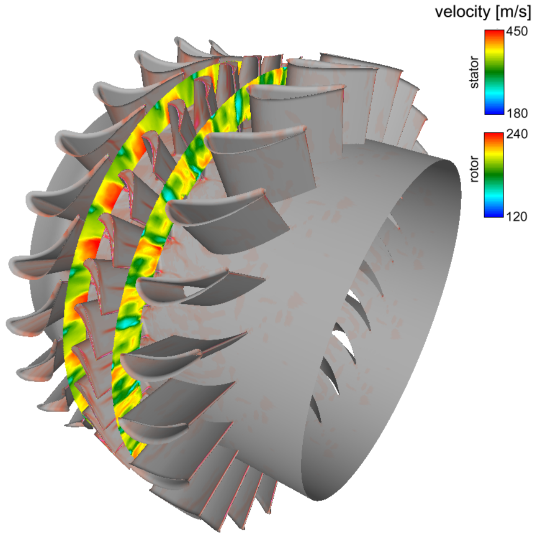
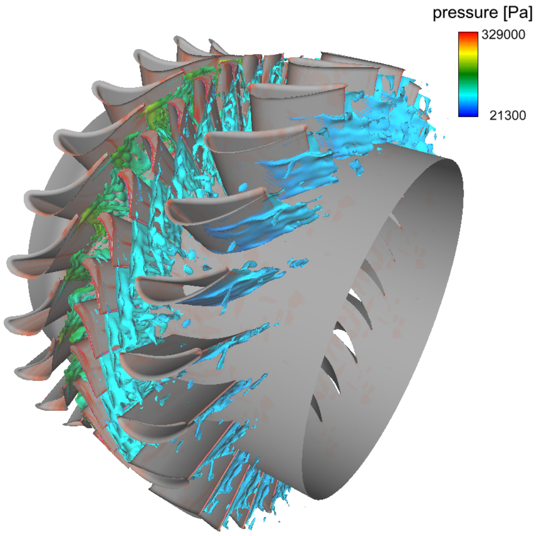
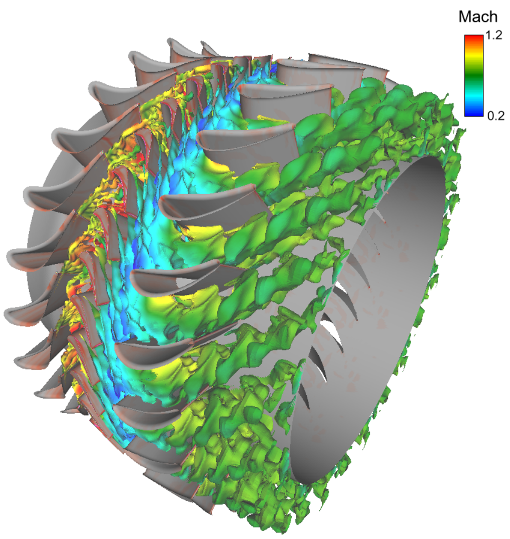


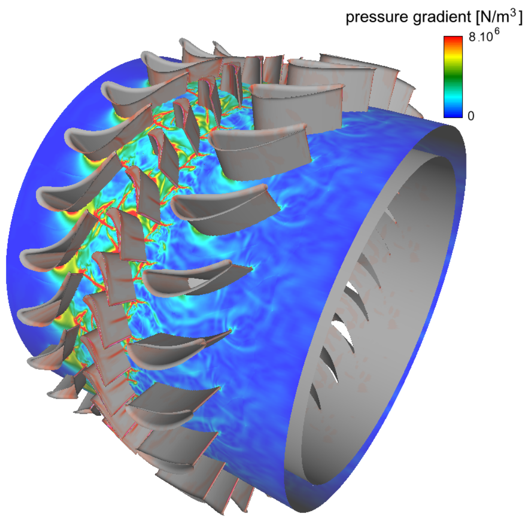
Velocity (LDV, PIV).



Iso surface of vorticity, color shaded by pressure (CFD).



Iso surface of entropy, color shaded by Mach number (CFD).



Pressure gradients (CFD).

These figures show experimental data recorded by laser-optical techniques and numerical data obtained by Computational Fluid Dynamics (CFD), both visualizing the flow through a transonic turbine operating at app. 10600 rpm. While Particle Image Velocimetry (PIV) and Laser Doppler Velocimetry (LDV) record velocity, flow angle and vorticity, CFD presents additional key quantities. Among them are Mach number, pressure, vorticity measuring the strength of secondary flows, entropy related to loss generation, and pressure gradients visualizing shocks.

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Transportation of a Dye in Upstream and Downstream Wakes of the Cylinder in Continuously Stratified Liquid

Chashechkin, Yu. D.* and Mitkin, V. V.*

* Laboratory of Fluid Mechanics, Institute for Problems in Mechanics of the Russian Academy of Sciences, Moscow 119526, prospect Vernadskogo 101/1, Russia

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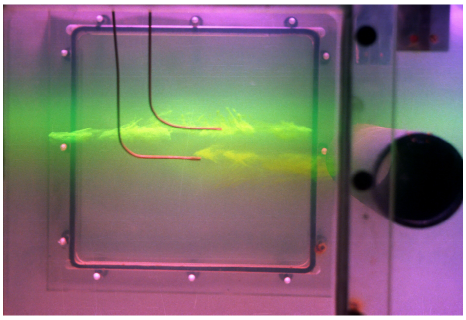
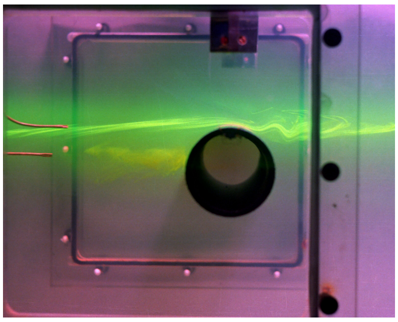
Redistribution of the dye: $D = 7.6$ cm; $T_b = 7.1$ s; $U = 0.24$ cm/s; $\mathrm{Fr} = 0.035$; $\mathrm{Re} = 180$;

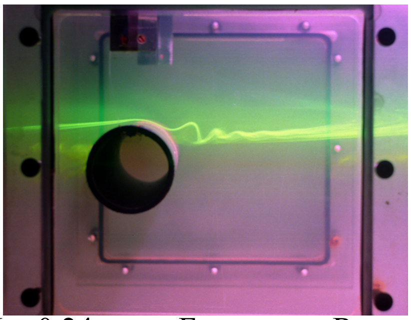


$t = 0$ s

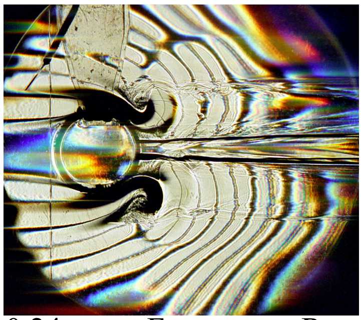


$t = 55$ s

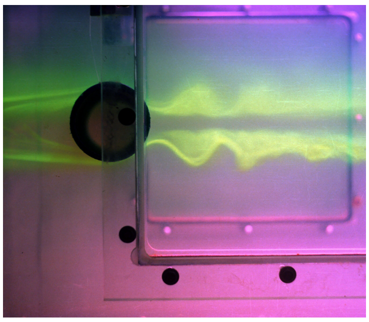
$D = 7.6$ cm; $T_b = 7.1$ s; Dye and schlieren visualization $D = 5.0$ cm; $T_b = 7.4$ s;



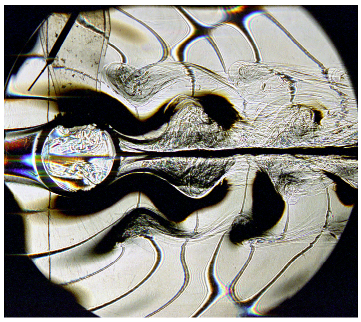
$t = 110$ s



$U = 0.24$ cm/s; $\mathrm{Fr} = 0.035$; $\mathrm{Re} = 180$; $U = 0.24$ cm/s; $\mathrm{Fr} = 0.056$; $\mathrm{Re} = 119$;



$t = 60$ s



$U = 0.69$ cm/s; $\mathrm{Fr} = 0.103$; $\mathrm{Re} = 524$; $U = 0.55$ cm/s; $\mathrm{Fr} = 0.129$; $\mathrm{Re} = 273$;

Evolution of the dye patterns around horizontal cylinder moving from right to left in continuously stratified liquid with buoyancy frequency $N = 2\pi/T_b$. After beginning of the motion part of unchanged cloud of the dye is transported along with the blocked fluid. Part of the dye is accumulated in bright strips coinciding with high-gradient interfaces in schlieren images of the similar undyed flows. U and D are, respectively, velocity and diameter of the cylinder, t is duration of the body motion, $\mathrm{Re} = UD/\nu$ and $\mathrm{Fr} = U/ND$, are Reynolds and internal Froude numbers.

Reference: Chashechkin, Yu. D. and Mitkin, V. V. Soaring interfaces vortices and vortex systems inside the internal waves wake past the horizontally moving cylinder in a continuously stratified fluid, J. of Visualization, 9-3 (2006), 301-308.

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Infrared Based Visualization of Wall Shear Stress Distributions with a High Temporal and Spatial Resolution

Rudolph, I.*, Reyer, M.* and Nitsche, W.*

* Technical University Berlin, Institute of Aeronautics and Astronautics, Marchstr.12, 10587 Berlin, Germany. E-mail: ilka.rudolph@ilr.tu-berlin.de

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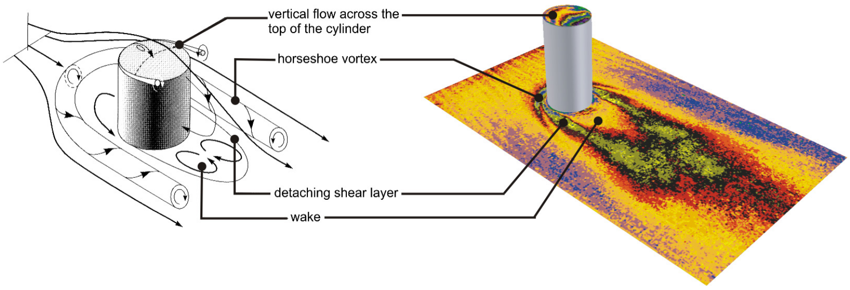

Fig. 1. Characteristic phenomena for the flow around a wall mounted cylinder (left) and temperature difference image from an infrared movie for a Reynolds-Number of $\mathrm{Re}_D = 40000$ (right).

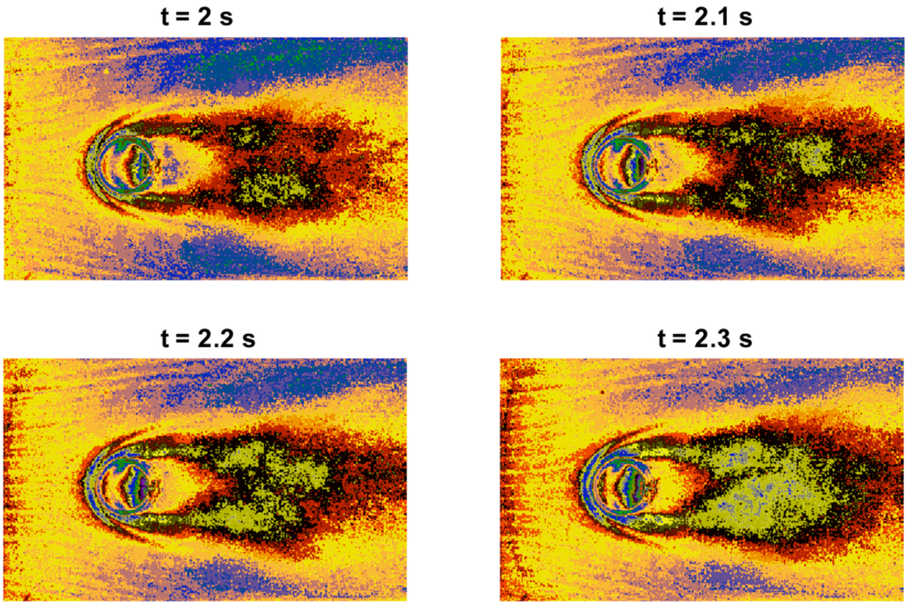

Fig. 2. Sequence of temperature difference images as a qualitative representation of the wall shear stress distribution for four different points in time.

These images are the result of a new infrared based measurement technique which allows the visualization of wall shear stress distributions with a high spatial and temporal resolution*. The experiments were conducted for the flow around a wall mounted cylinder with a height to diameter ratio of H/D = 2 for a Reynolds-Number of $\mathrm{Re}_D = 40000$. The technique is not only able to capture the characteristic flow features displayed in figure 1, but can also visualize the unsteady processes in the wake of the cylinder with a good temporal resolution (Fig. 2)**.

References : *M. Reyer, I. Rudolph and W. Nitsche, Investigations into the Visualization and Quantification of Wall Shear Stress Distributions Using Infrared Thermography, AIAA-Paper 2006-3840, 25th AIAA Aerodynamic Measurement Technology Conference.

**I. Rudolph, M. Reyer and W. Nitsche, Visualization of Time-Dependent Wall Shear Stress Distributions Using Infrared Thermography, ISFV12-30.3, 12th International Symposium on Flow Visualization.

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Schlieren and "Focused" Shadowgraphy Visualization of the Shape and Wake of Single Air Bubbles Freely Rising in Quiescent Water

Heinzel, V.*, Sauter, H.* and Jianu, A.*

* Institute for Reactor Safety, Research Centre Karlsruhe , Postfach 3640, 76021 Karlsruhe, Germany.

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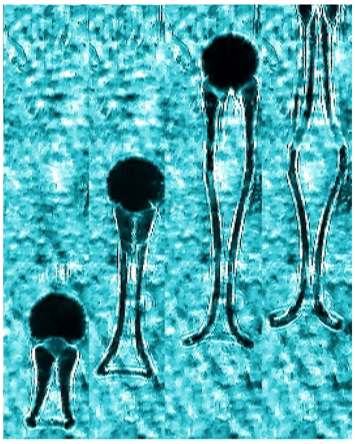

Fig. 1. Wake development shown in temporal sequence.

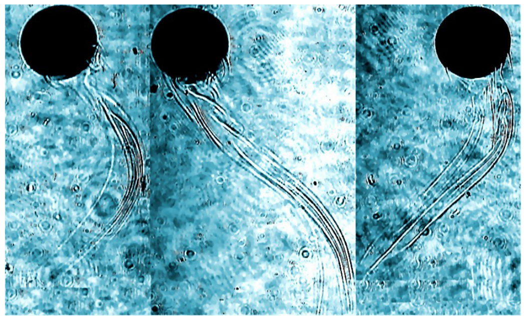

Fig. 2. One-view images of 2.0 mm diameter gas bubbles and wakes (bright-field circular filter in the schlieren cutoff plane).

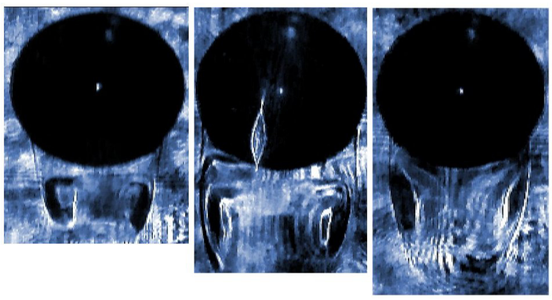

Fig. 3. Images of bubbles and wakes observed by "focused" shadowgraphy.

Fig. 4. Examples of two orthogonal views (a and b) of shape and wake of 0.8 mm diameter bubbles (dark-field circular filters in the schlieren cutoff planes).

Schlieren is a succinct name for gradient disturbances of inhomogeneous transparent media. Schlieren technique allows the visualization of refractive index gradients. "Focused" shadowgraphy (parallel-light shadowgraphy) was performed using a schlieren setup without spatial filtering in the cutoff plane.

Schlieren and "focused" shadowgraphy were used as visualization methods with the aim of giving experimental support to the understanding and numerical modelling of the behaviour of single bubbles freely rising in a quiescent fluid, as well as of the near and far flow field around them.

NaCl-solution, present at the bottom of the test cell, dragged in the wake of the bubble up to the observation area, acted as tracer. As the refractive index of air and water are different, the methods captured the bubble shape as well. Results of bubble and wake one-view imaging are shown in Figs. 1-3. Above all, the observation of very fine hairpin-like wake structures could be performed.

The methods proved also appropriate for the observation of bubble and wake from two orthogonal directions simultaneously, which is mandatory for the validation of 3D simulation codes (Fig. 4).

The experimental visualizations allowed the correlation of the path of single rising bubble with the wake behind it. For a rectilinear path, the wake consisted of a single-threaded axisymmetric wake; after a path instability set in, the bubble movement was either a zigzag or a spiral, double-threaded wakes being observed for both zigzagging and spiralling bubbles.

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Portfolio

Visualization of Space and Fragments of the Installation. Artistic Action "Field of Vision", series "Space Traps"

Ast, Olga*

* Artist, 40 Waterside Plz., 7d, New York, NY 10010, USA.

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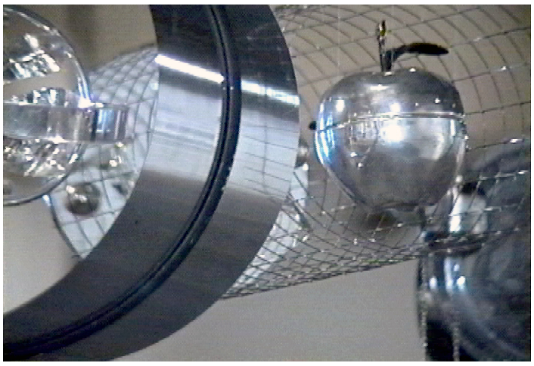

Fig. 1. The Fragment of the *SpaceScope.* Mixed Media: metal, glass and mirror.

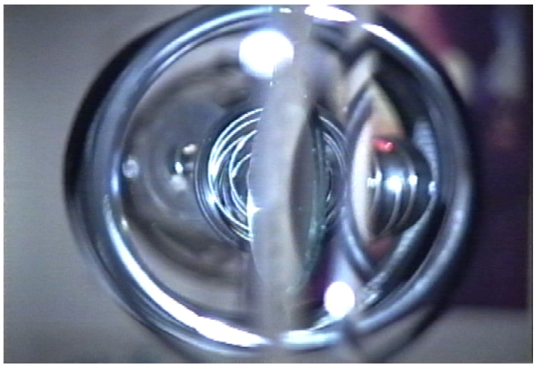

Fig. 2. The Fragment of the *SpaceScope.* Mixed Media: metal, glass and mirror.

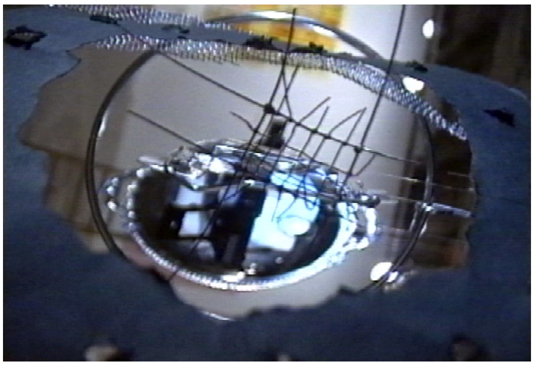

Fig. 3. The Fragment of the *SpaceScope*. Mixed Media: metal, glass and mirror.

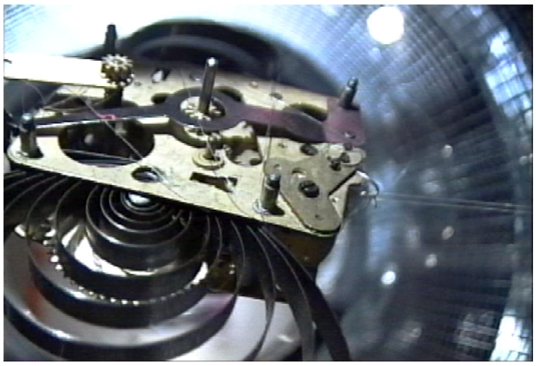

Fig. 4. The Fragment of the *SpaceScope*. Mixed Media: metal, glass and mirror.

My main medium is Space. Most of my works are *Space Traps*. Since early 90s, I have been showing the artistic action "Field of Vision" which consists of the installations "Space TRAP-line," "A Dispersion of Meanings," "Museum Space Trap", among others.

The main body of my work consists of sculptural and installation pieces. I use metal, transparent materials and mirrors in their construction. I also use various ready-made objects and words as substances with semiotic baggage.

Most of my works are boundless and could be seen to develop endlessly because the nature of space is endless. For example, the *Tube Space Trap* (also called the *SpaceScope*) is a see-through structure that consists of a row of transparent, mirrored and holed objects, which are constantly rotating along the direction of the viewer's gaze. This invisible viewer's *gaze axis* is a constructive basic element along which this object could be endlessly prolonged.