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TO GATCHINA DISCHARGE NATURE

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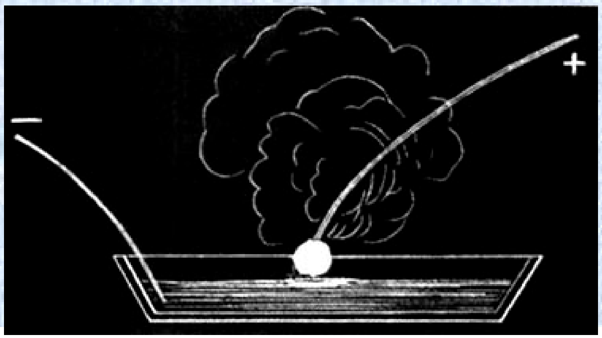
New scientific direction has appeared in 2002 in city of Gatchina near St. Petersburg in the Institute of Nuclear Physics. G. Shabanov has invented a new type of a discharge , so called “Gatchina discharge”. It produced spherical like objects of lifetime ~0.1 s and sizes 12-14 cm.



Plante 1890

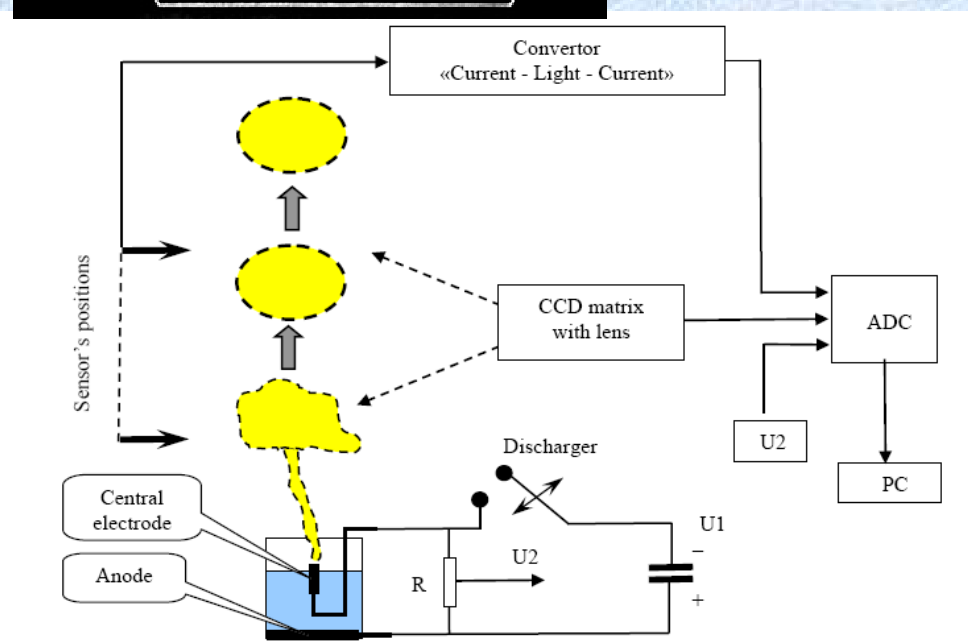


Figure1 - Block-scheme of experimental set-up

G.Shabanov. 2002

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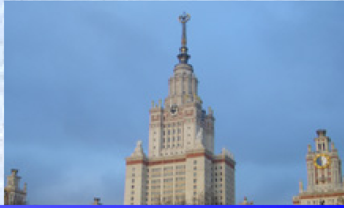

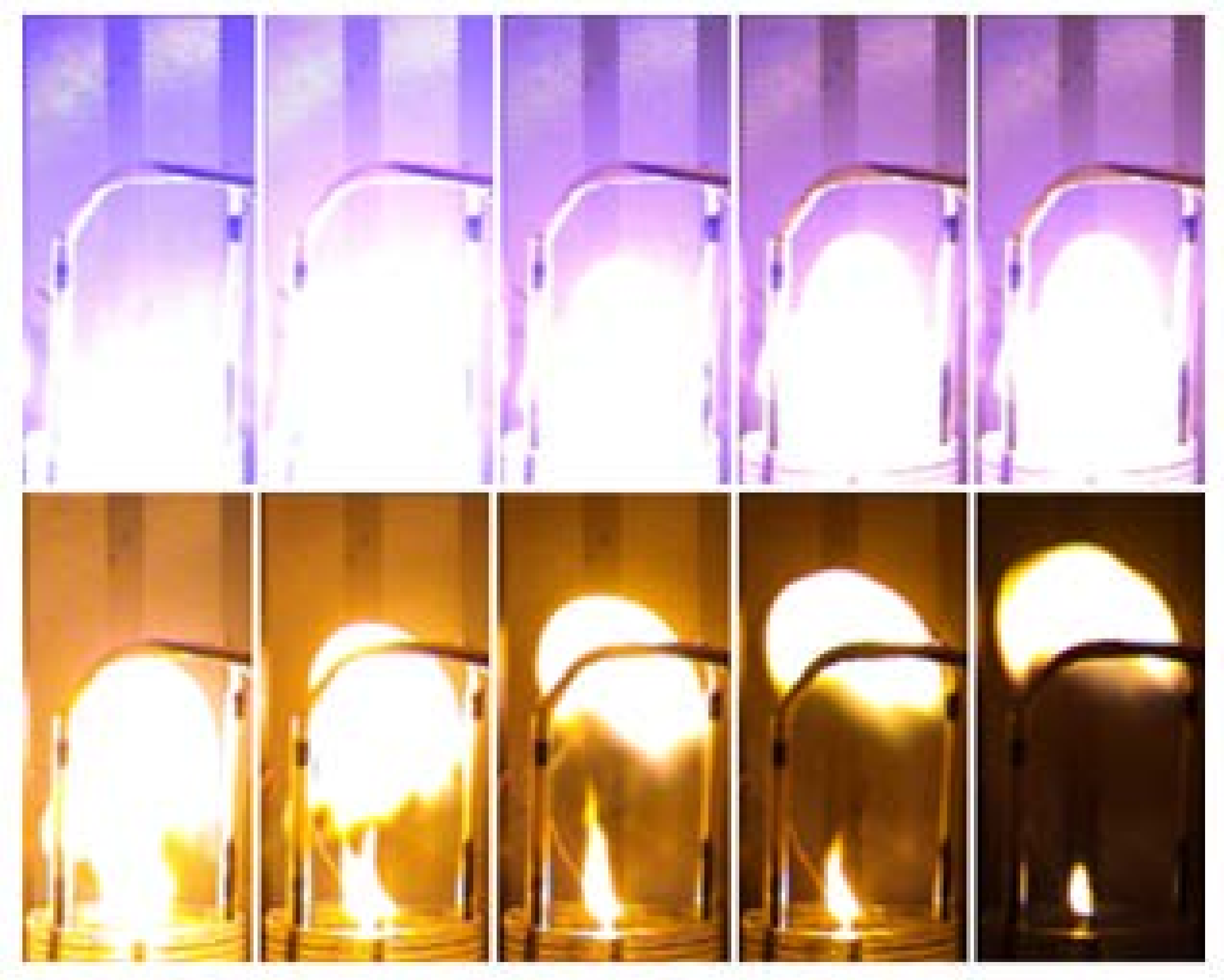

Astafiev A., Emelin S. 2010 Images of the discharge taken with an interval 20ms in the case of electrolytic anode at the initial storage capacitor voltage 5 kV (HNO3).

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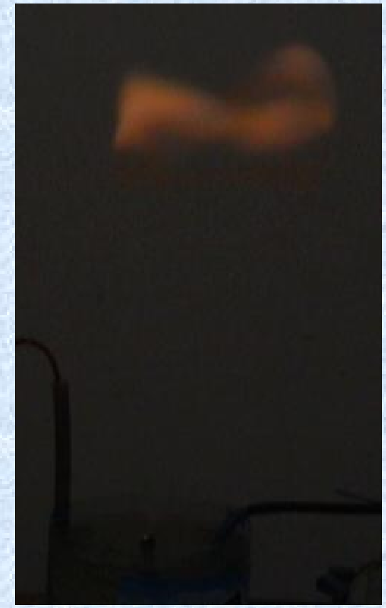

Emelin S.E. 2006

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Theoretical modeling

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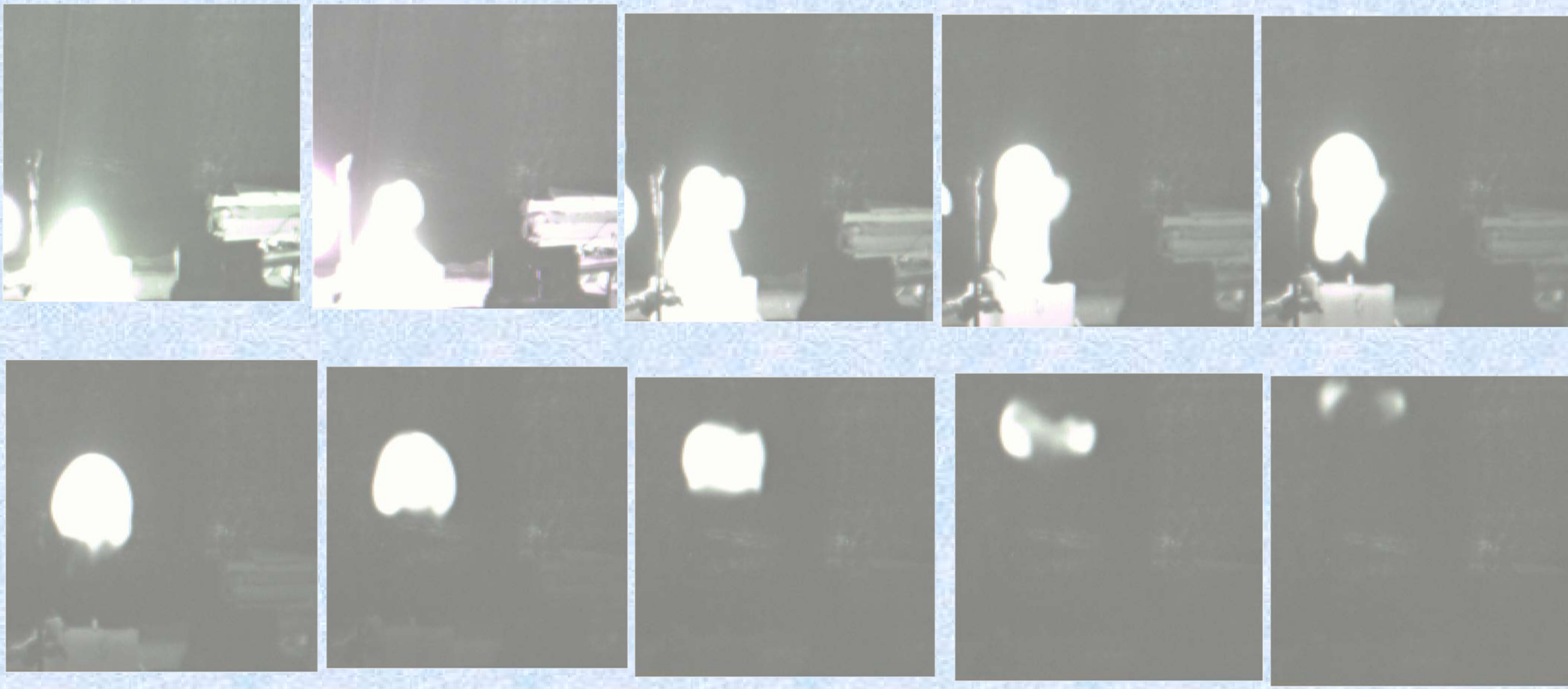
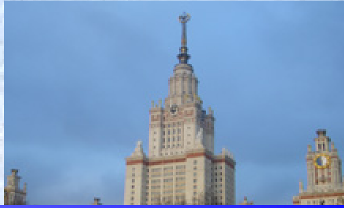


Shabanov G.D. 2004



During processes of energy put in, its part, in a form of a plasma, is released over the upper electrode, and then over it a luminescent sphere, a plasmoid, [of radius up to 6 cm appears. These experimental realizations of spherical-like plasmoids authors connected with realization of natural ball lightning analogous due to their characteristics, such as existence with luminescence from milliseconds to shares of seconds, and 1-2 seconds, as in, and comparable sizes with natural BL. However to the contrary majority of ball lightning observations they rose in air and in the end of their lifetime they transformed in rings.

It was firstly supposed, that these spheres represent cold objects with temperature below 500 **°C**, however the optical measurements of have shown, that the gas temperature in the sphere can reach 1700 **°C** as a result of the chemical reactions (combustion) which are taking place at a stage of discharge realization. In first works temperature measurements inside the objects were not made, so this question stays open, though high temperature inside the sphere could lead to its floatation.

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Experiments on Discharge modeling

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R. Kuz’min, B Shvilkin 2006. MSU, combusting mixtures were specially prepared for producing of spherical and torus structures at discharge realization. Sizes of their objects reached 5-6 cm and lifetime 2-3 s. They were created at an explosion of a thin metallic wire. There was a hole for going out of explosion products. At last stage objects transformed to vortical rings.

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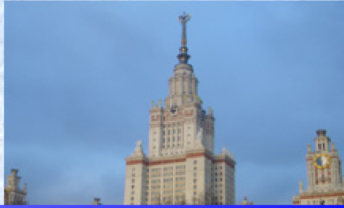


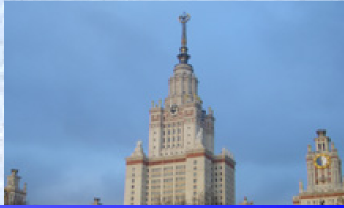
The experimental scheme which we consider for modeling is the following. In the centre of a cup in diameter of 20 **c**m is a tube in diameter of 3-5 mm. From a tube the impulse pushes out a plasma stream of which a luminescent object is formed.

Experiments are carried out at atmospheric pressure and room temperature. It is supposed, that the appearing luminescent plasmoid is a toroidal vortex. The motion of the plasma is mainly defined by air movement; therefore for numerical modeling of the luminescent plasmoid formation process we will use the classical equations of gas dynamics.

We consider therefore Navier-Stokes equations in a form:

$$\frac{\partial \mathbf{U}}{\partial t} + \frac{\partial \mathbf{A}}{\partial r} + \frac{\partial \mathbf{B}}{\partial z} = \mathbf{C}$$

$$\mathbf{U} = \begin{bmatrix} \rho \\ \rho v_r \\ \rho v_z \\ \rho h \end{bmatrix}, \mathbf{A} = \begin{bmatrix} \rho v_r \\ p + \rho v_r^2 \\ \rho v_r v_z \\ \rho v_r h \end{bmatrix}, \mathbf{B} = \begin{bmatrix} \rho v_z \\ \rho v_z v_r \\ p + \rho v_z^2 \\ \rho v_z h \end{bmatrix}, C = \begin{bmatrix} -\rho v_r / r \\ -\rho v_r^2 / r + \nu\left(\partial^2 v_r / \partial r^2 + \partial^2 v_r / \partial z^2\right) \\ -\rho v_r v_z / r + \nu\left(\partial^2 v_z / \partial r^2 + \partial^2 v_z / \partial z^2\right) \\ 0 \end{bmatrix}$$



These equations will be solved in the cylindrical area $r \in [0, R_D]$ $z \in [0, Z_D]$

On the cylinder boundaries we set the following boundary conditions:

$$\left.\frac{\partial v_r}{\partial r}\right|_{r=R_D} = 0, \left.\frac{\partial v_z}{\partial r}\right|_{r=R_D} = 0,$$

$$p\big|_{z=Z_D} = p\big|_{r=R_D} = p_0.$$

$$\left.\frac{\partial v_r}{\partial r}\right|_{z=Z_D} = 0, \left.\frac{\partial v_z}{\partial r}\right|_{z=Z_D} = 0,$$

and the following conditions on the line of axial symmetry

$$v_r(t,0,z) = 0 \quad \frac{\partial v_z}{\partial r}(t,0,z) = 0 \quad \frac{\partial \rho}{\partial r}(t,0,z) = 0 \quad t \geq 0$$

Boundary conditions corresponding to inflow from the tube are chosen the following:

$$v_r\big|_{0<r<R_T, z=0} = 0$$

$$v_z\big|_{0<r<R_T, z=0} = v_{\max} \cdot f(t) \cdot g(r)$$

$$f(t) = (1 - \cos(2\pi t / \Delta t)) / 2, g(r) = (1 + \cos(\pi r / r_0)) / 2.$$

$$T\big|_{0<r<R_T, z=0} = T_{\max}$$

Initial conditions correspond to a motionless air:

$$v_r(0,r,z) = v_z(0,r,z) = 0 \quad p(0,r,z) = p_0 \quad z \in [0, Z_D]$$

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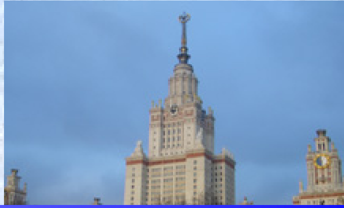

Typical values of parameters are: the radius of the cylinder $\approx$510 cm, the height of the cylinder $\approx$1020 cm, the temperature T ~ 20°**C, Mv = 28·0.785+32·0.215 g/mol** - molar weight of air, P=101325 Pa -the atmospheric pressure, the radius of the tube $\approx$2.5 mm, the height of the tube $\approx$ 5-10 mm, the time of the impulse $\approx$0.01 s.

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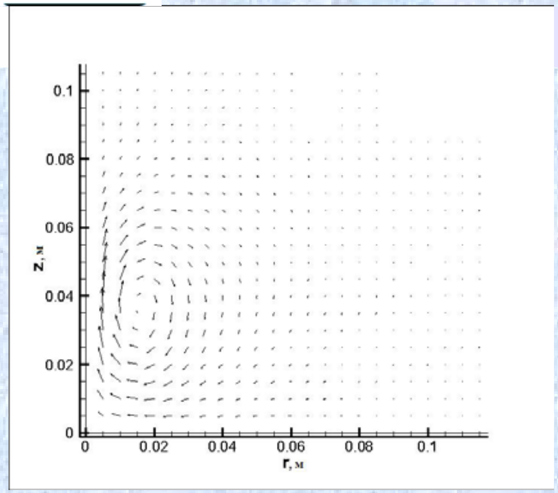
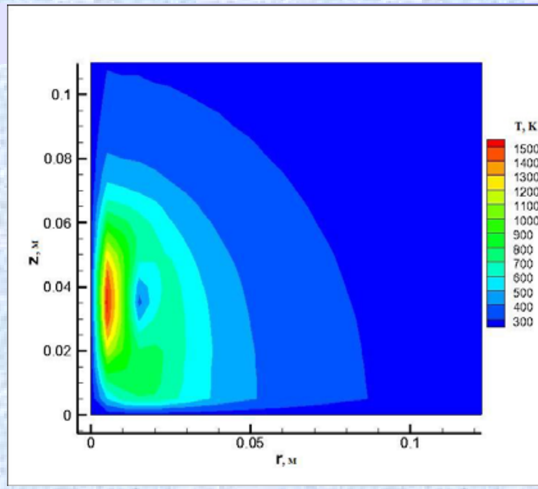
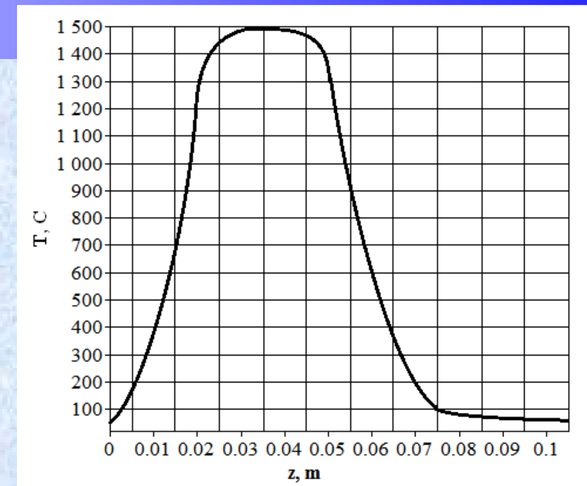


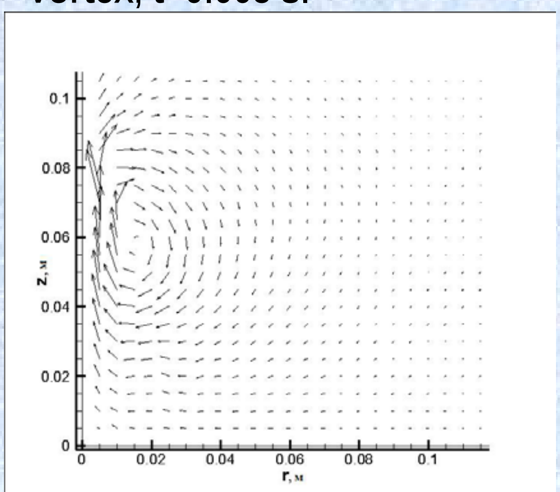
a) Velocity field in the toroidal vortex, t=0.005 s.



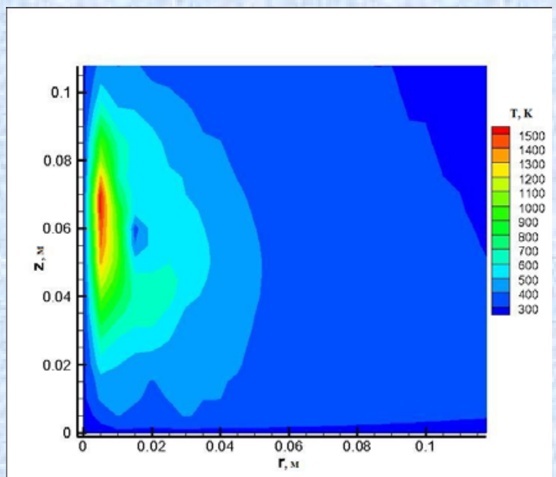
b) Temperature in the toroidal vortex, t=0.005s.



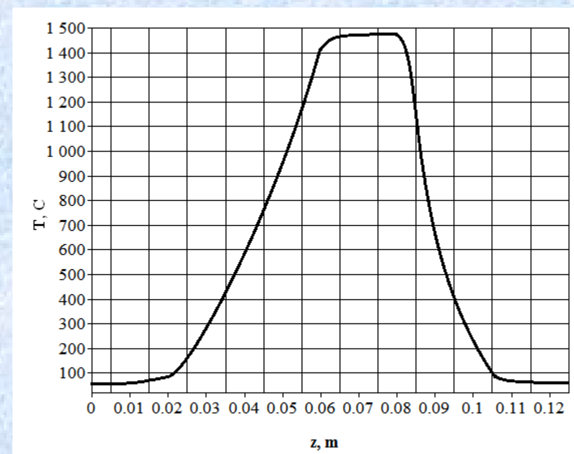
c) Temperature along the symmetry axis in the toroidal vortex, t=0.005s.



a) Velocity field in the toroidal vortex, t=0.07 s.



b) Temperature in the toroidal vortex, t=0.07s.



c) Temperature along the symmetry axis in the toroidal vortex, t=0.07s.

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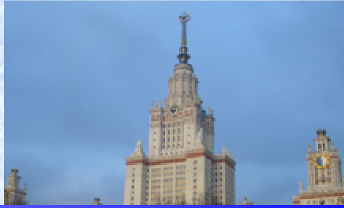
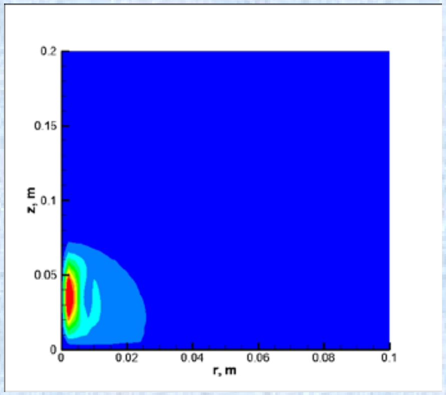
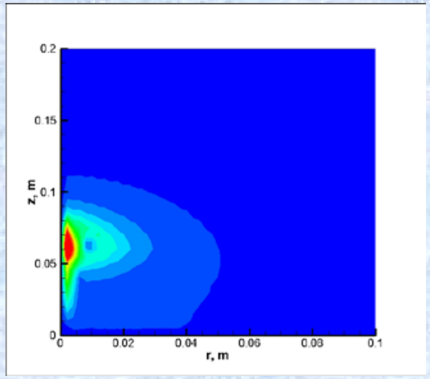
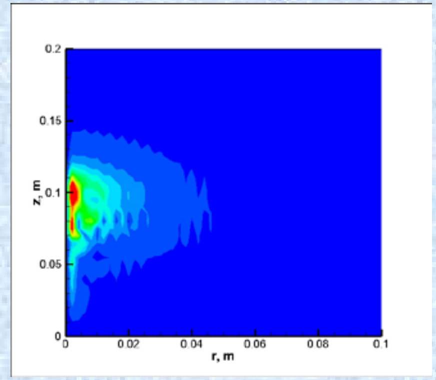




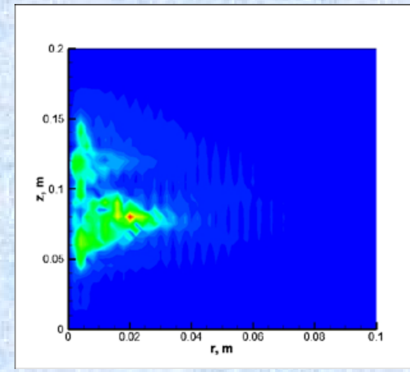
t=0.0001 s



t=0.005 s



t=0.075 s



t=0.1 s

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Conclusions

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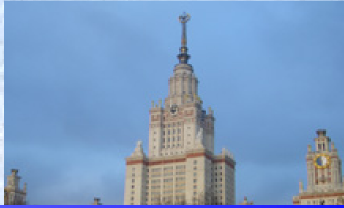
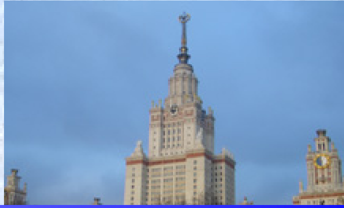


Our calculation shows that in case of the rising stream from the electrode representing a tube one can observe creation of the vortex. Comparison of the numerical and the physical experiments results allows to conclude a sufficient adequacy of the carried out mathematical modeling of the experiment.

Some difference in the sizes of the vortex, generated in the numerical experiment, and the sizes of the luminescent plasmoid in the physical experiment speaks first of all about different moments of time at which the comparison could be made.

In the numerical experiment it corresponds to the time moment of the computation after the stream leaking out, and in the physical - to the photo fixing moment of the luminescent spheroid when it reaches the maximal size. The increase in time of the numerical calculation in future will allow us to define the photographing moment of time. However, it is absolutely clear, that the numerical modeling allows find such moments of the physical process of plasmoids creation and existence which were not known earlier from the experimenters. As an example of it can serve the detection of the toroidal vortex which was born in the tube. Thus, the researches carried out in the work have shown that the mathematical modeling in this case is the effective tool of research of physical experiment. We plan to extend our model taking into consideration a realistic form of heated electrode.

The question of the spheroid luminescence requires development of some combustion model of the erosive particles (from the electrode) in air with addition of water vapor, it will be considered later.



Thank you for attention