PLASMA ASSISTED COMBUSTION OF PARAFFINS

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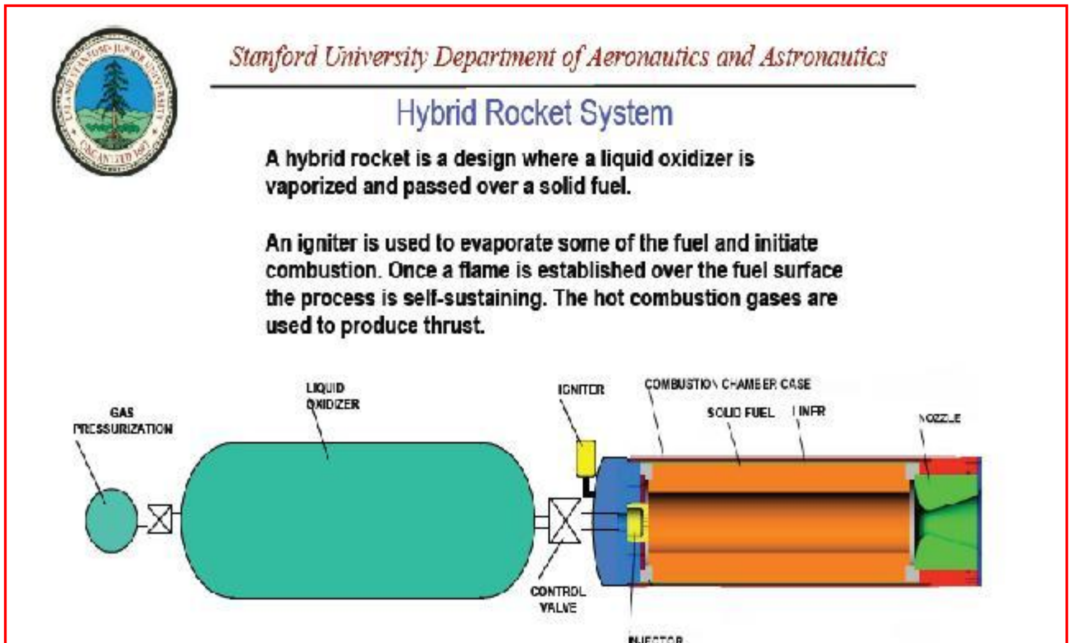
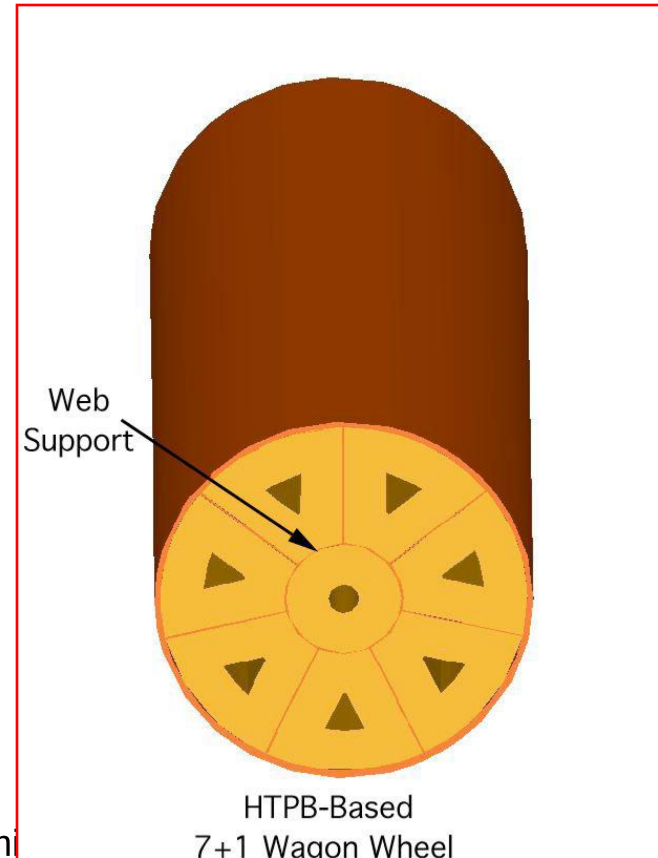
Hybrid Rocket Engine

[*Stanford University Department of Aeronautics and Astronautics]*

The hybrid design concept has been known for more than 50 years. Small Hybrid rocket motors built to military specifications were used in target drone programs between 1968 and 1983 (Sandpiper, Hast, Firebolt). The fuel used was Hydroxyl-Terminated-Polybutadiene (HTPB).





Motivation

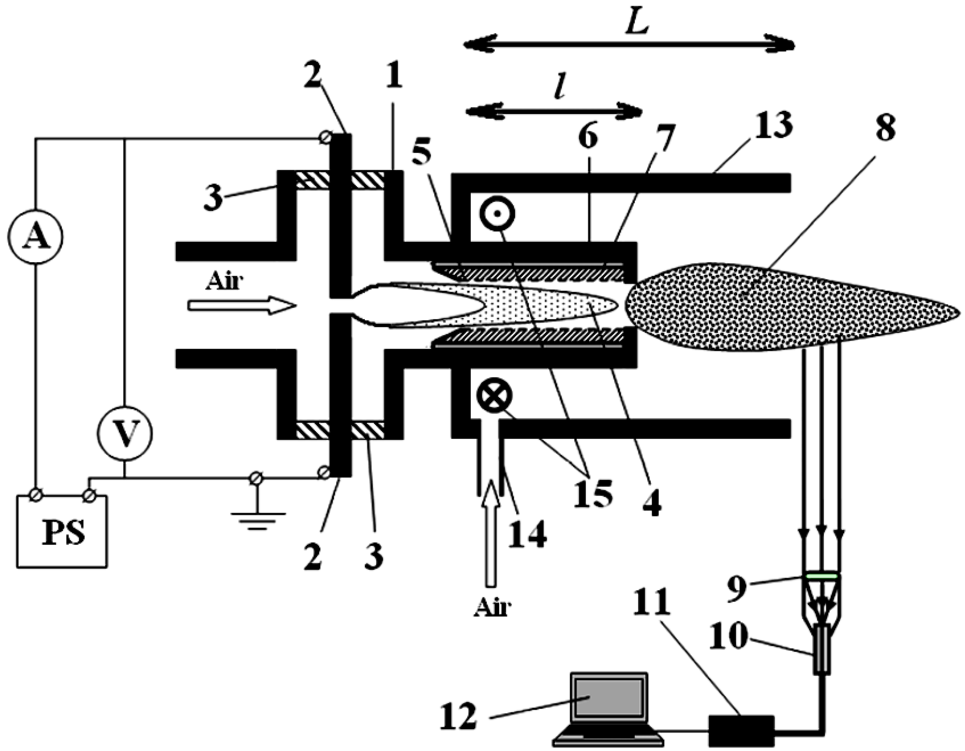
Ideal hybryd Fuell is wax. The general advantages of paraffin as a green fuel are high caloricity, ecological compatibility, safety of keeping and high chemical inertness to external factors, etc.

***[Michel A.Dornheim: Aviation week and space technology. -2003.-3.-P.52-54*].**

Plasma assisted combustion of these alternative fuells for reduction of influence of their structure by process of combustion.

[Chernyak V.Ya., Nedybaliuk O.A., Bulletin of the American Physical Society, 2010, volume 55, No 7, P. 71].

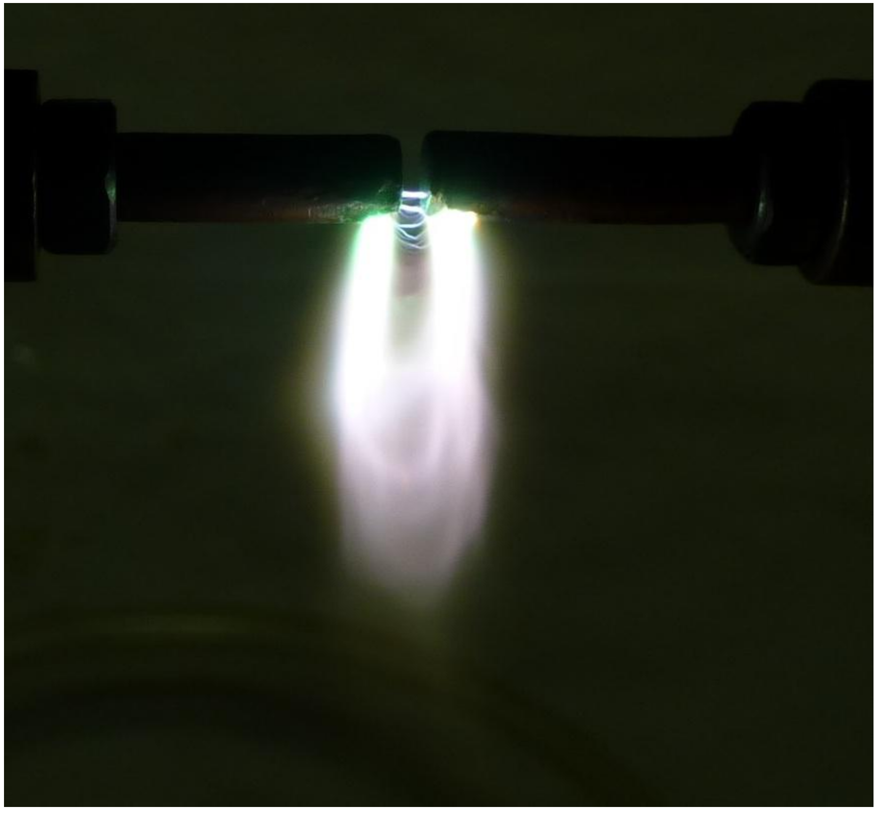
SCHEME OF THE PLASMA-DYNAMIC SYSTEM WITH TRANSVERSAL ARC



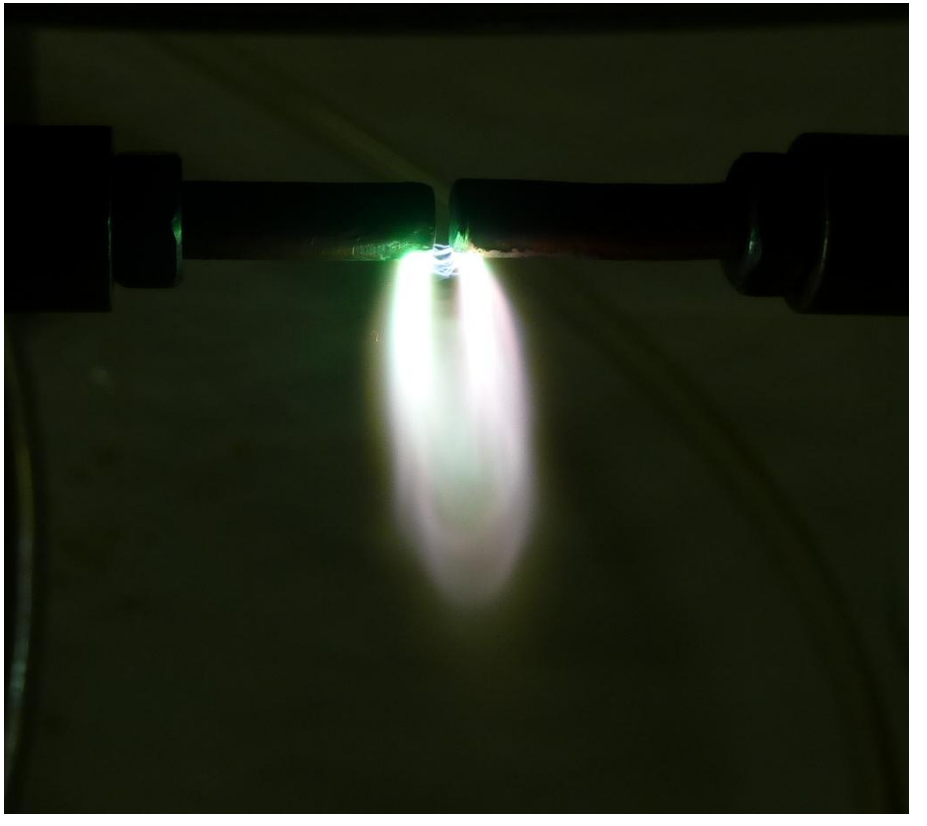
1 – steel chamber;2 – copper electrodes;3 – dielectric tube plug; 4 – plasma torch;5– stainless steel cylinder;6 – paraffin cylinder; 7 – cylinder net;8 –torch; 9 – focusing lens; 10 - optical fiber; 11 – Spectrometer "Solar-TII"; 12 – computer; 13 – cumbustion chamber; 14 –air flow; 15 - holes.

Photo of the transversal arc in air flow and in flow of air / ethanol mixture

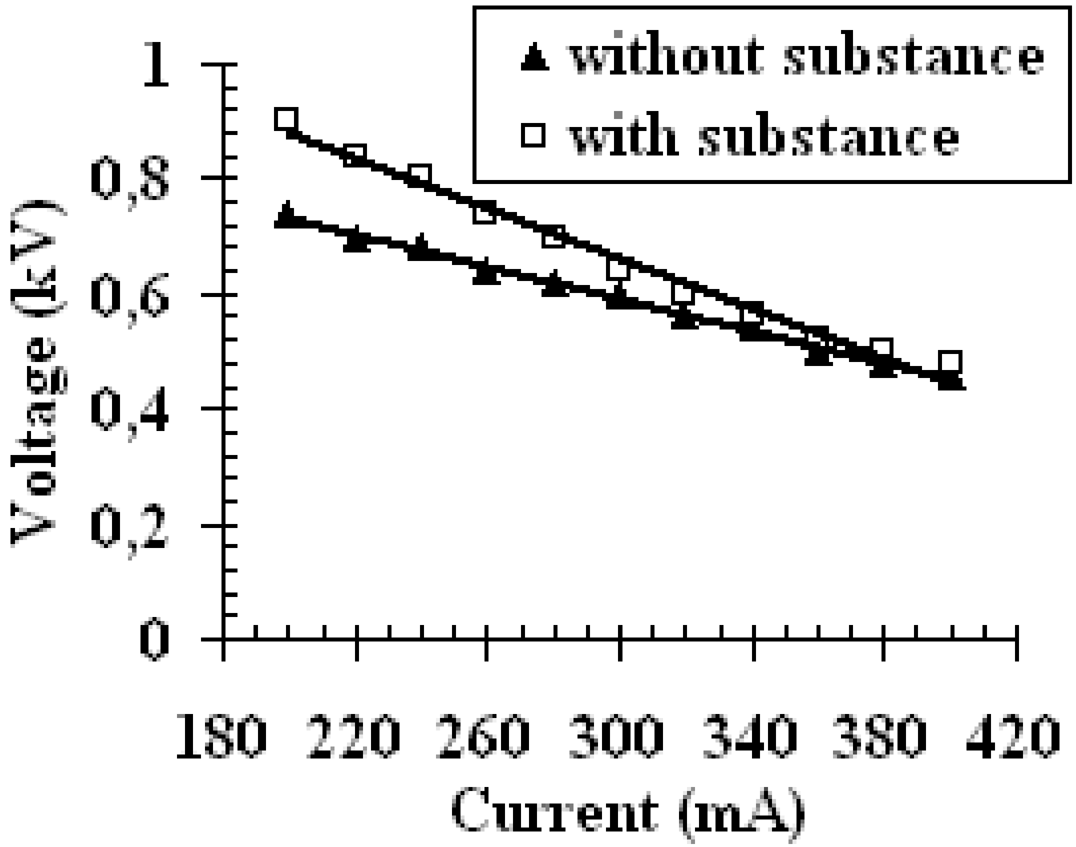
Air / ethanol mixture. I = 400 mA, U = 0,6 kV, G = 75 cm^3/s



Air. I = 400 mA, U = 0,6 kV, G = 75 cm^3/s

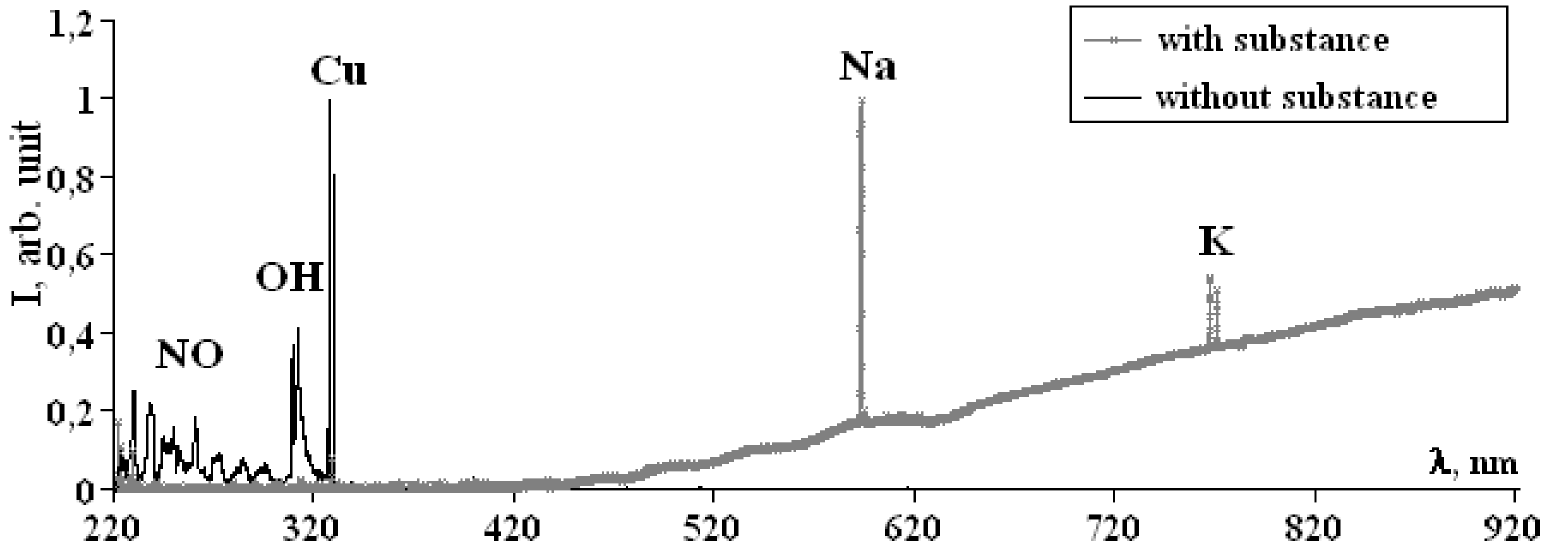


The voltage-current characteristics of transversal arc



THE TYPICAL EMISSIN SPECTRA OF PLASMA TORCH AND FLAME

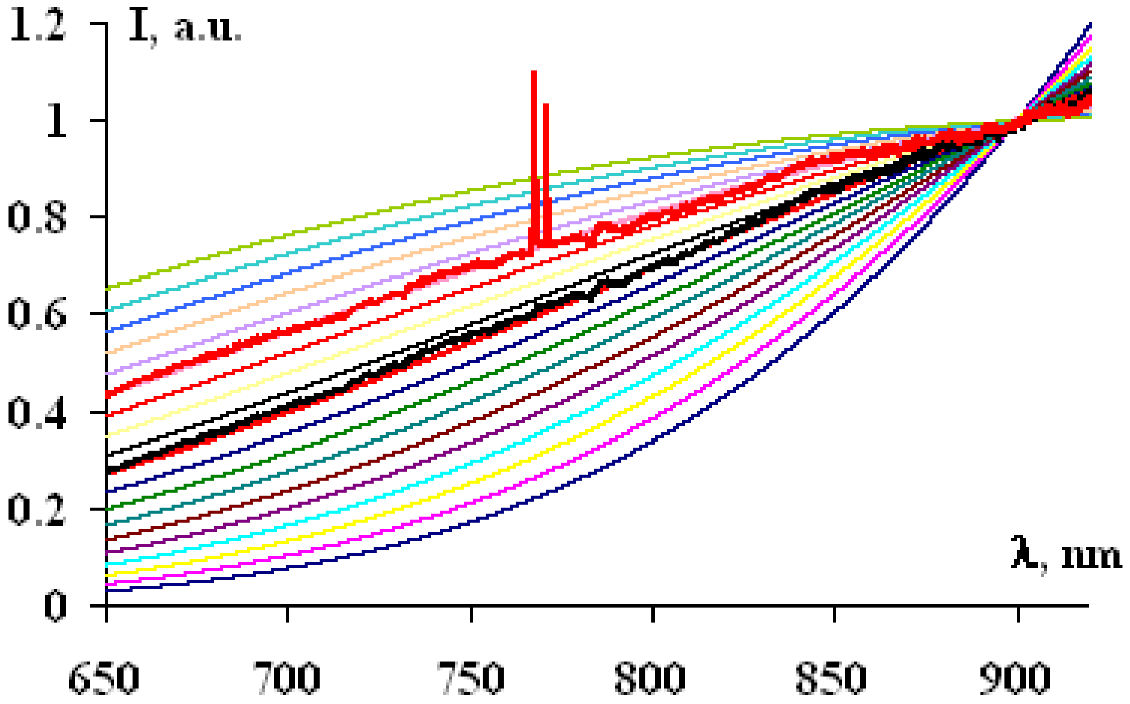
G = 55 cm^3/s; I = 300 mA; U = 0,6 kV



Ratio of fuel (stearin) energy to energy that was inputted to electrical discharge ~ 100

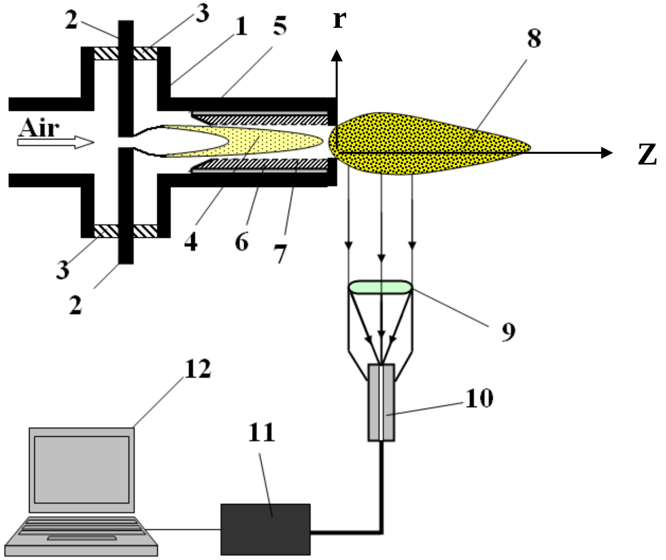
THE TYPICAL EMISSIN SPECTRA OF PLASMA TORCH AND CANDLE

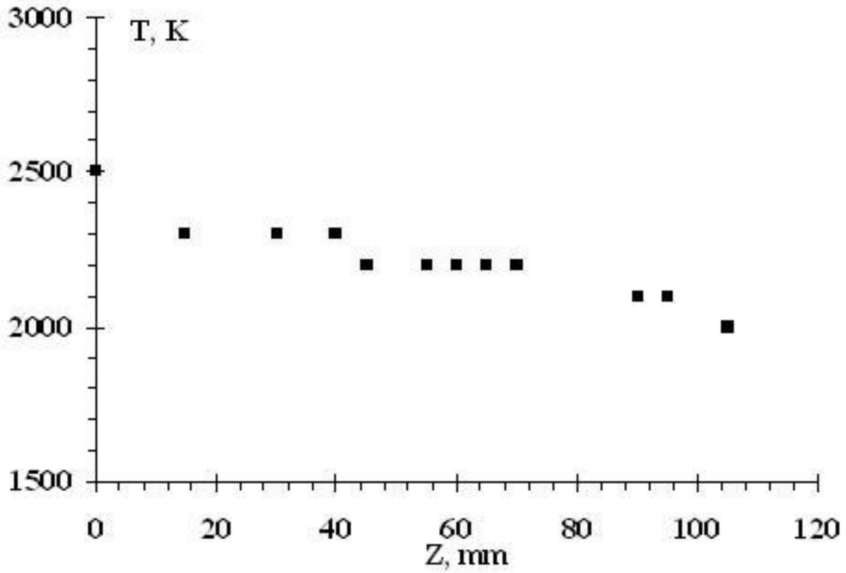
T_{candle}=2100±100 K, T_{PASC}=2500±100 K



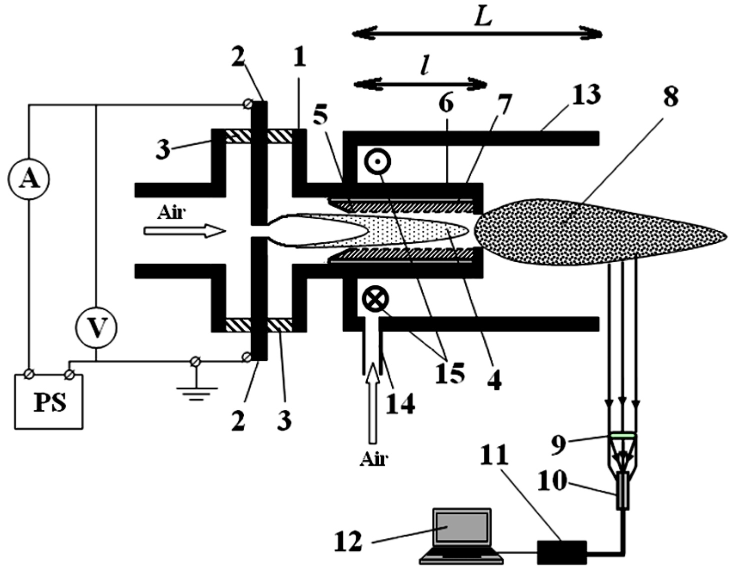
The plasma support by of burning increases temperature of a stearin flame in air ~ TPASC = 300 K (Tcandle = 2100±100 K)

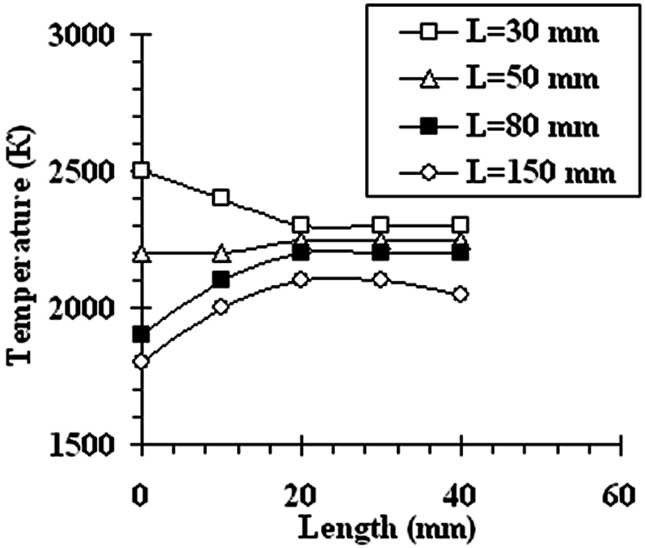
AXIAL DISTRIBUTION OF TEMPERATURE IN FLAME WITHOUT COMBUSTION CHAMBER





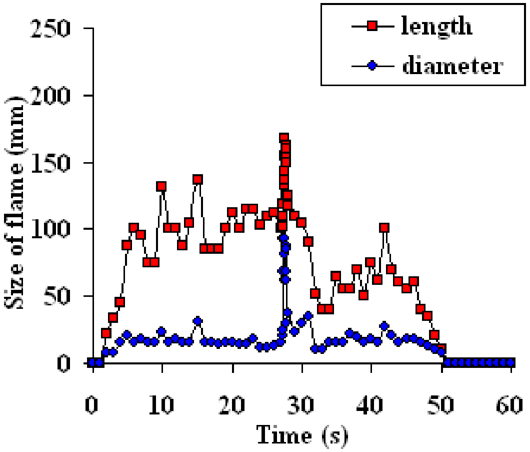
AXIAL DISTRIBUTION OF TEMPERATURE IN FLAME OUTLET OF COMBUSTION CHAMBER



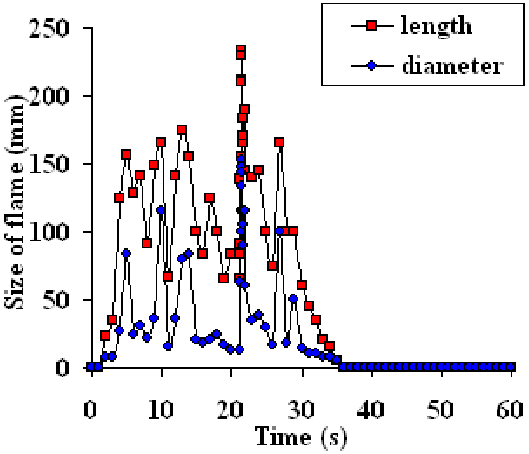


DEPENDENCE OF FLAME SIZE FROM TIME OF PLASMA ASSISTED COMBUSTION OF $C_{18}H_{38}$ AND $C_{22}H_{46}$

$C_{18}H_{38}$



$C_{22}H_{46}$



ROTATED GLIDING ARC

[Chernyak V. Gas discharge plasma in dynamics system as a noneqilibrium plasma sources// Proc. 3rd Czech-Russian Seminar on Electrophysical and Thermophysical Processes in Low-temperature Plasma, Brno, 1999, Nov. 16-19, P.94-99].

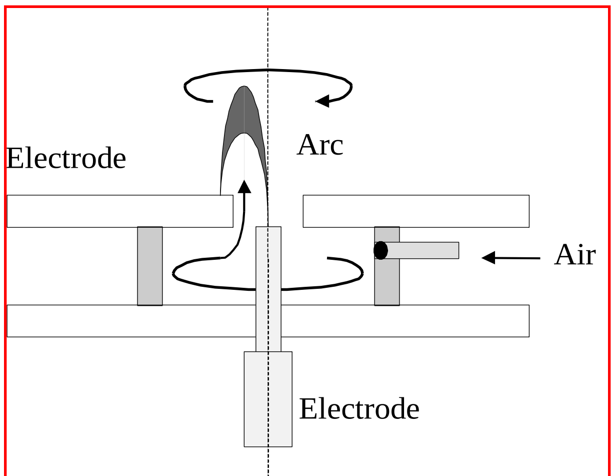


Fig. 1

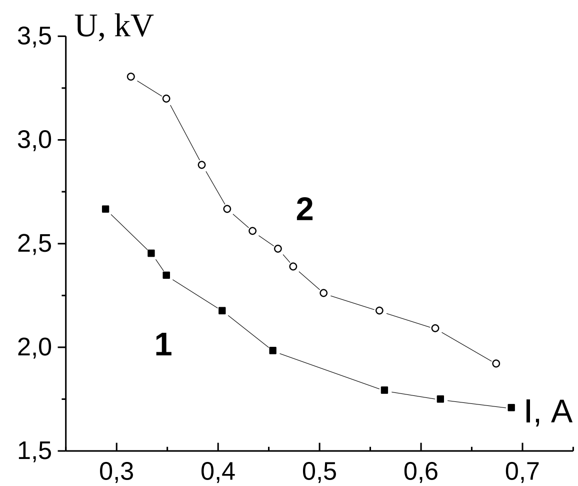


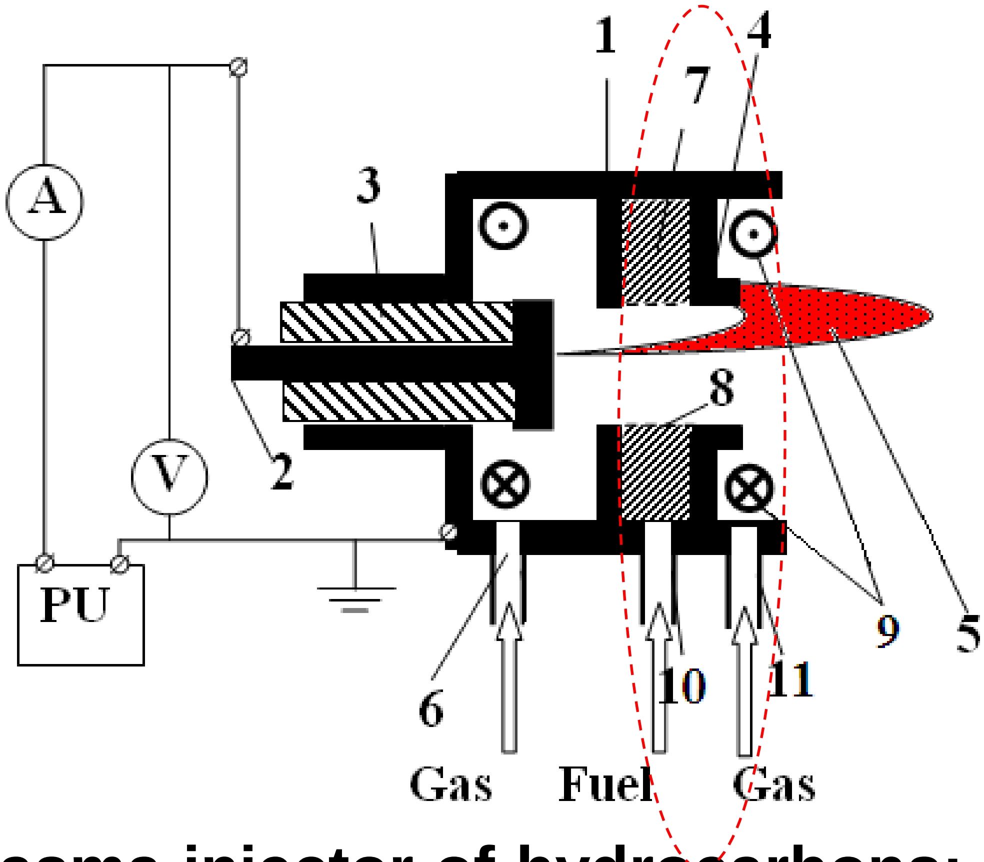
Fig. 2

Fig. 1 RGArc.

Fig. 2 . The volt-ampere characteristics of RGArc: 1 - air flow ~ 0,15 l/s), 2 - air flow ~ 0,2 l/s.

SYSTEM WITH ROTATIONAL GLIDING ARC

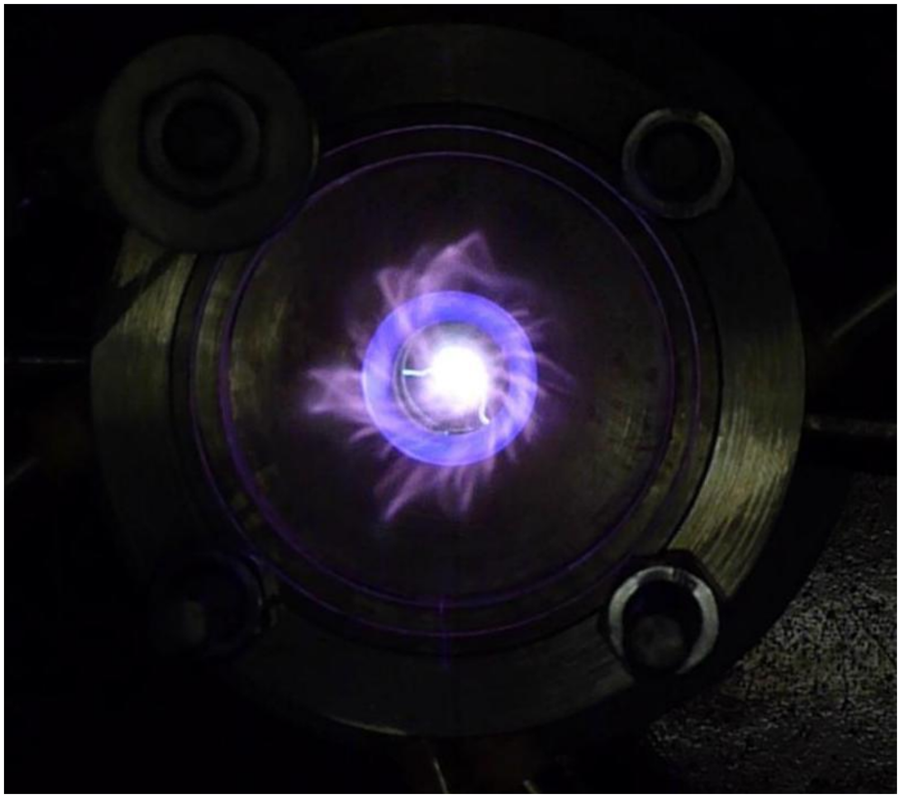
PLASMA INJECTOR OF HYDROCARBONS WITH HIGH VISCOSITY

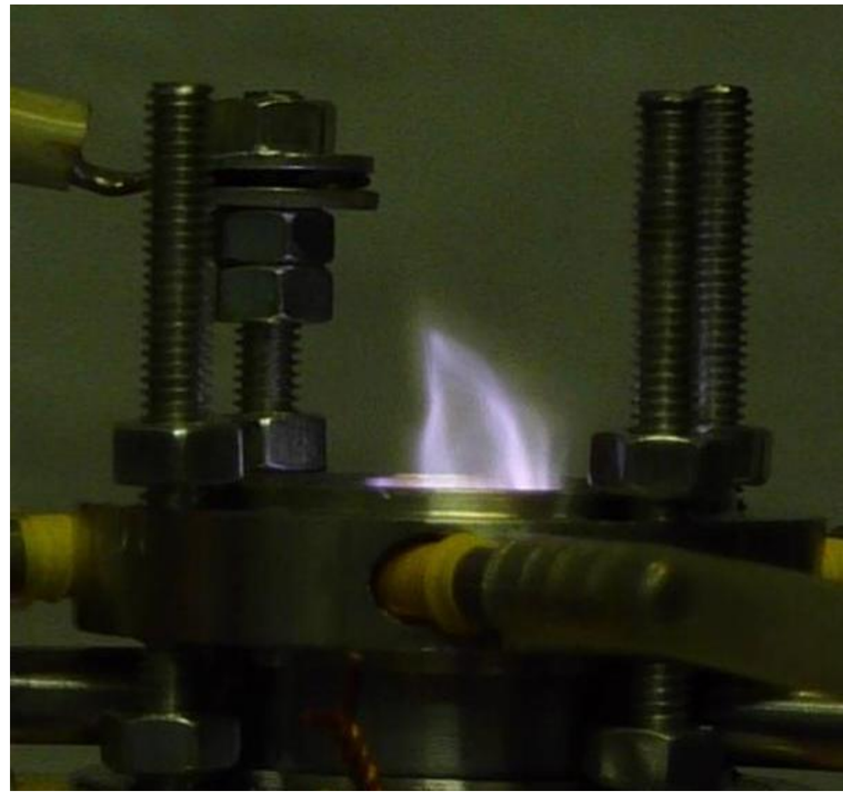


1 – plasma injector of hydrocarbons; 2,4 – electrodes; 3 – insulator; 5 – plasma jet; 6 – input gas; 7 – hydrocarbons; 8 – grid; 9 – gas flow; 10 – input fuel; 11 – additional gas; 12 – reaction chamber; 13 – flame.

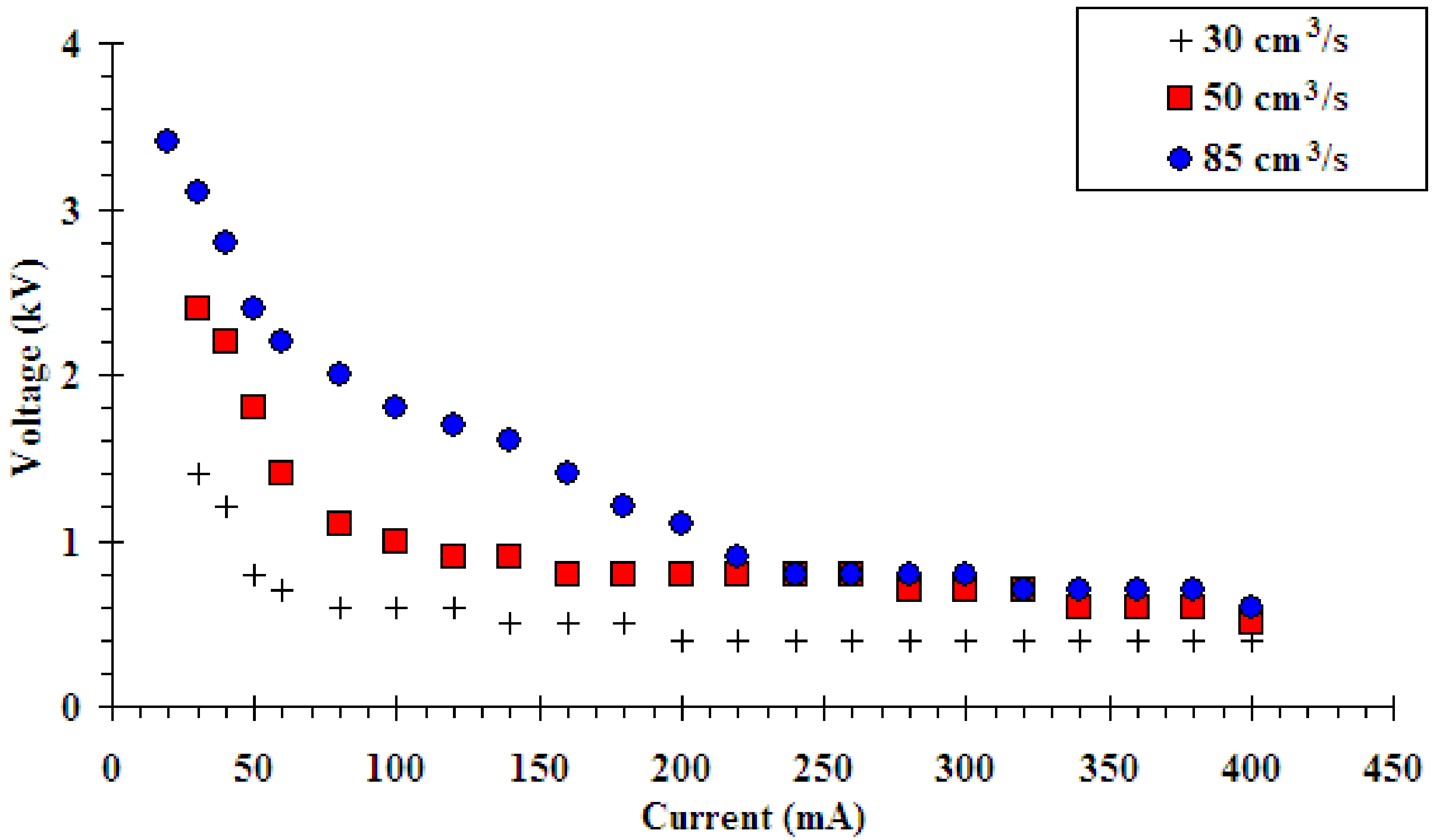
PHOTO OF ROTATIONAL GLIDING ARC

Air flow – 400 cm^3/s, Current – 300 mA, Voltage – 1 kV

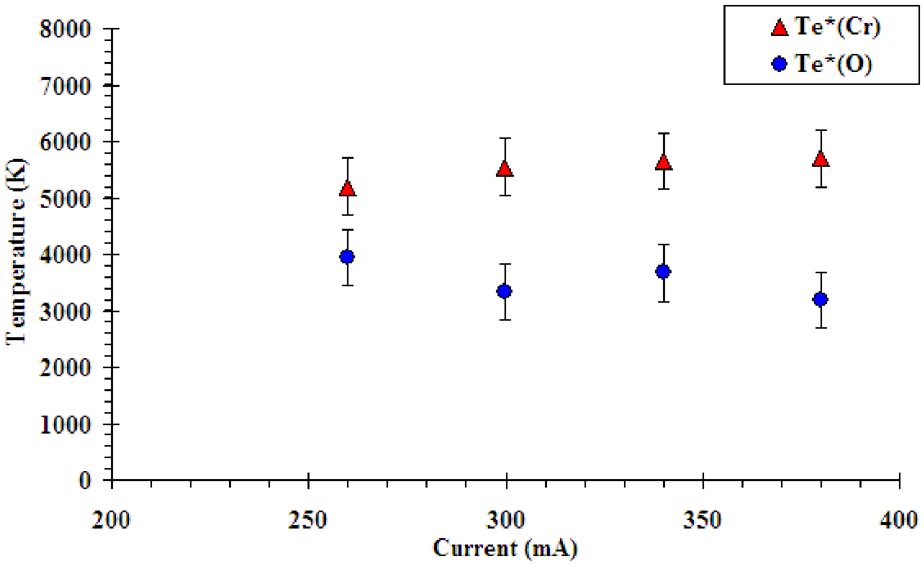


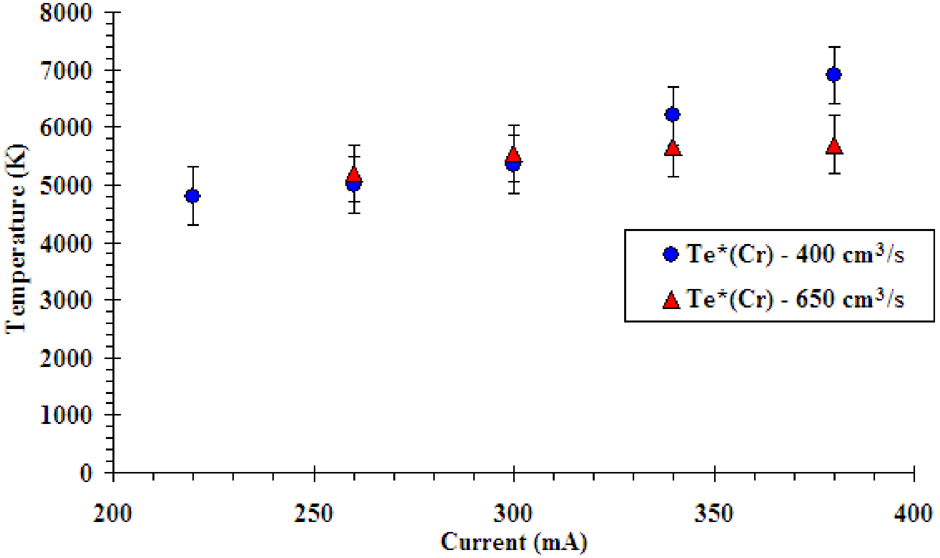


CURRENT-VOLTAGE CHARACTERISTIC OF ROTATIONAL GLIDING ARC



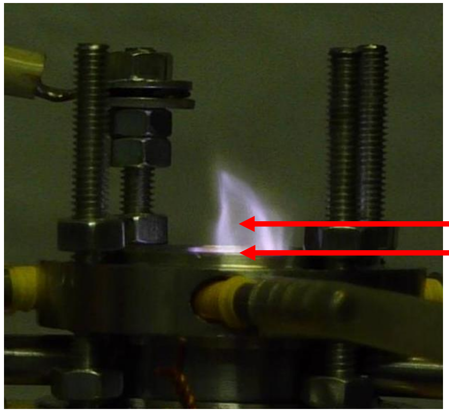
TEMPERATURE POPULATION OF EXCITED ELECTRONIC LEVELS





h = 5 mm, Air flow – 650 cm³/s

h = 5 mm



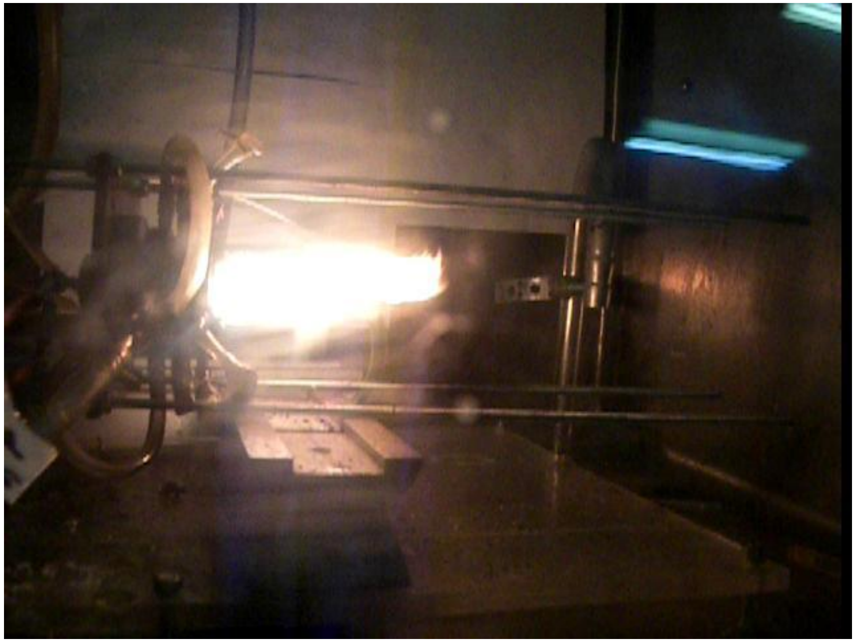
h = 5 mm

h = 0 mm

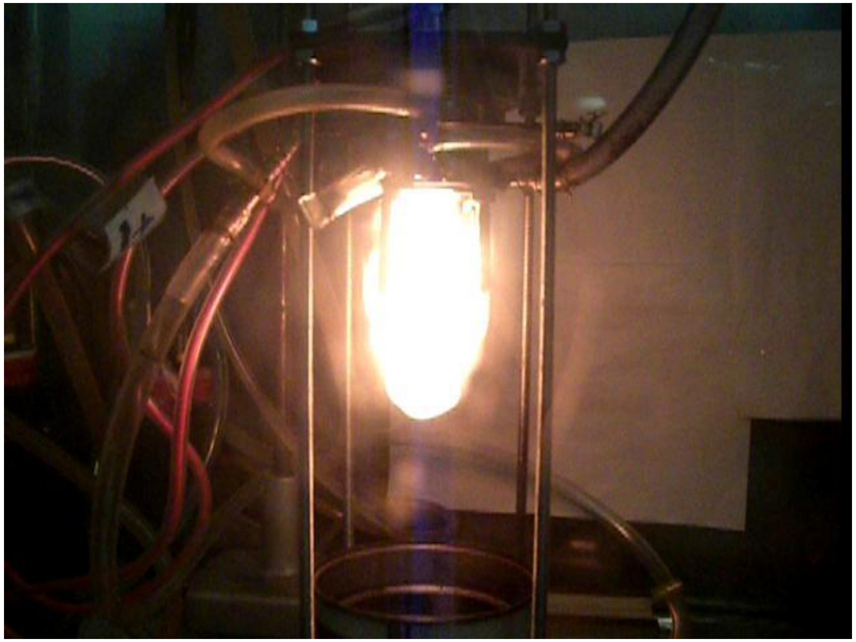
PHOTO OF PLASMA INJECTOR

Air flow – 50 cm^3/s, Additional air flow – 330 cm^3/s, Current – 200 mA, Voltage – 0,6 kV

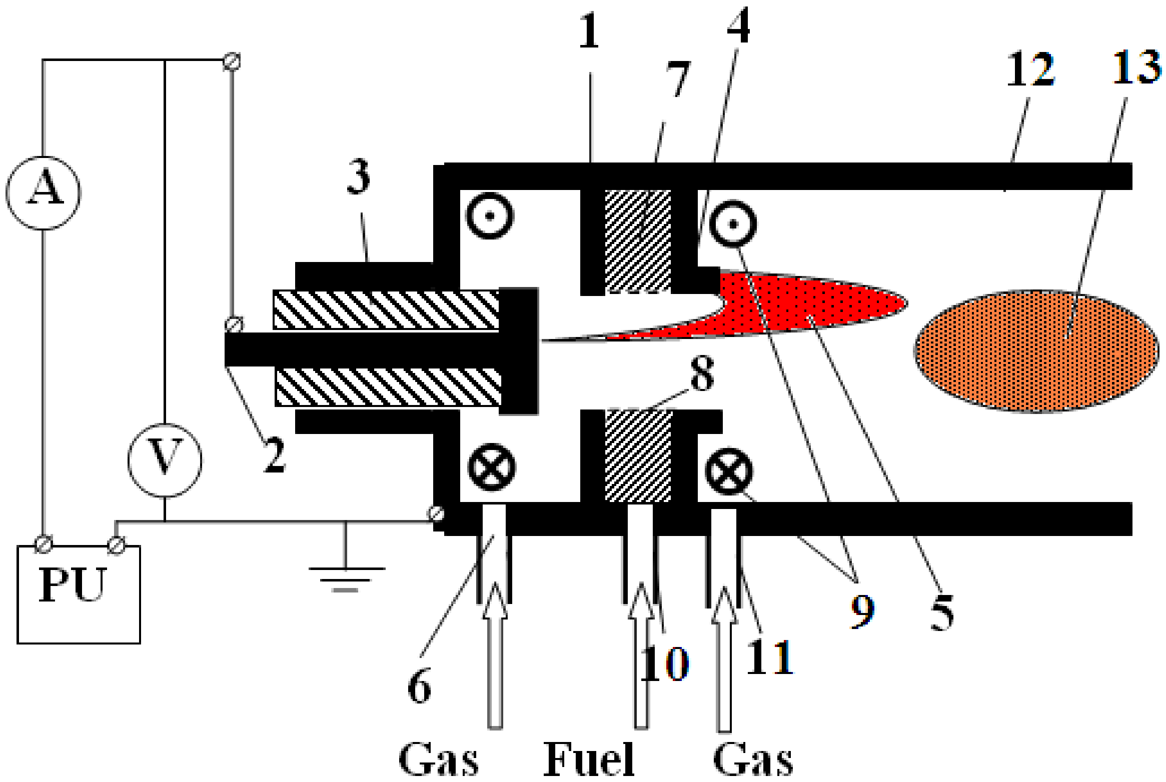
horizontally



vertically

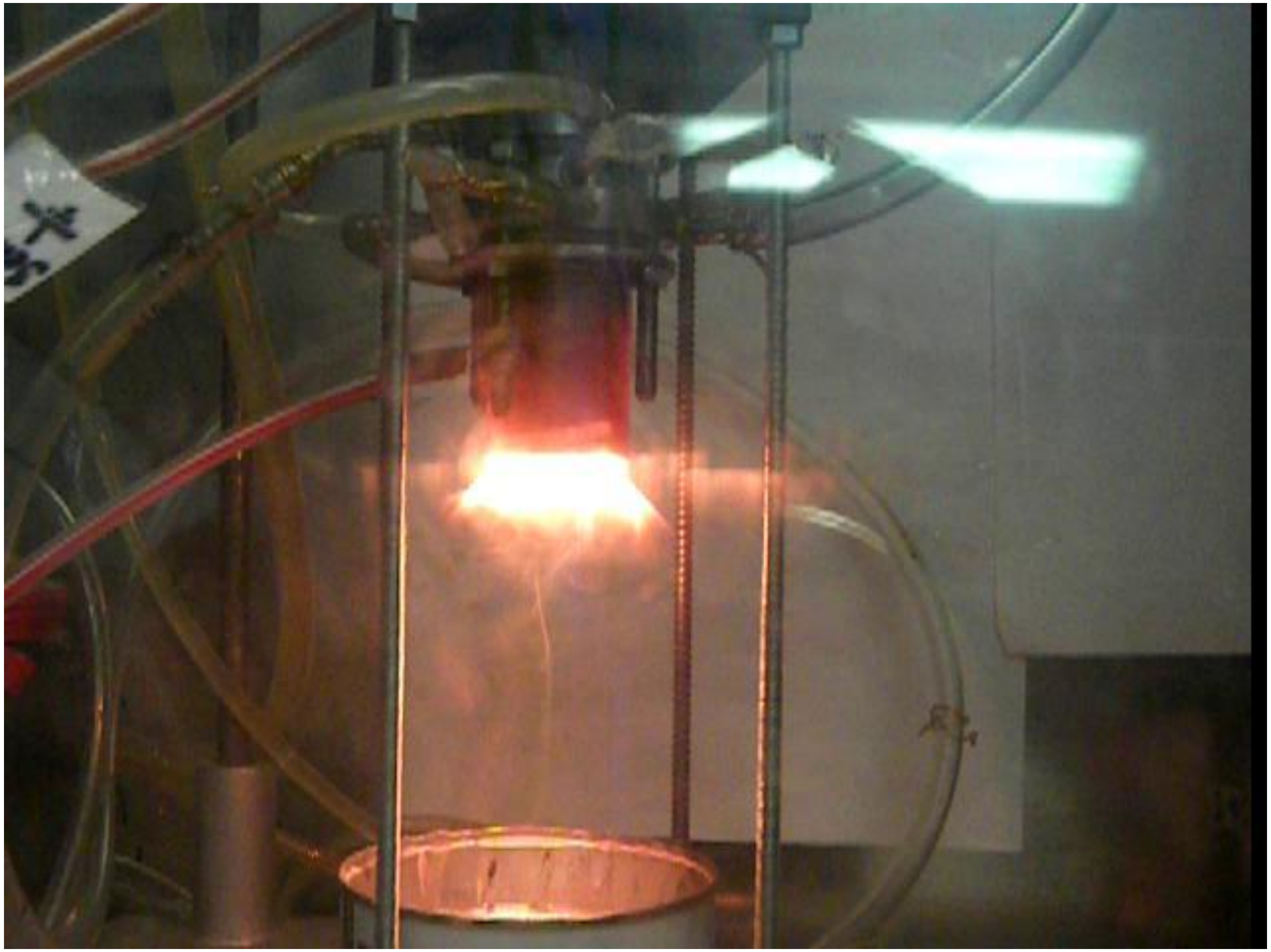


COMBUSTION CHAMBER

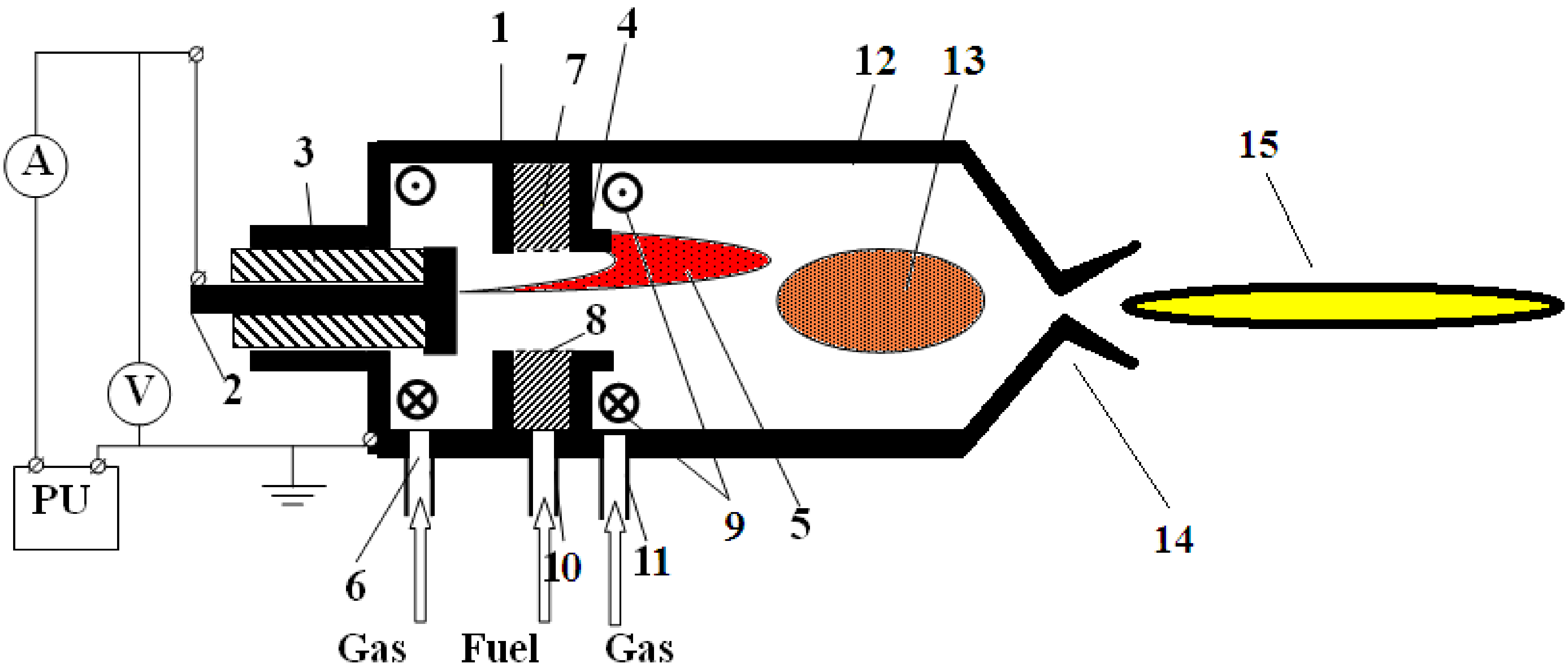


1 – plasma injector of hydrocarbons; 2,4 – electrodes; 3 – insulator; 5 – plasma jet; 6 – input gas; 7 – hydrocarbons; 8 – grid; 9 – gas flow; 10 – input fuel; 11 – additional gas; 12 – reaction chamber; 13 – flame.

PHOTO OF COMBUSTION CHAMBER

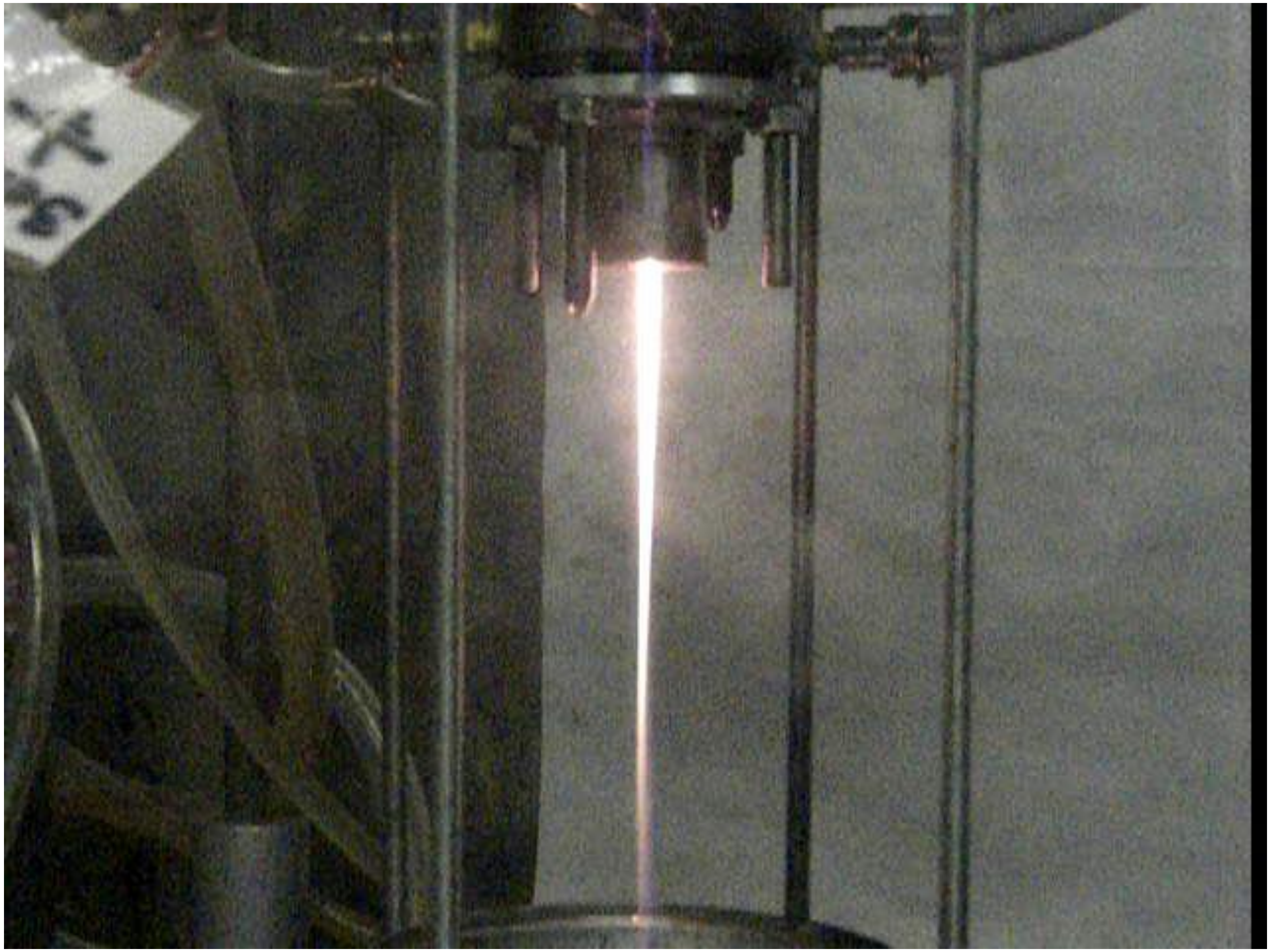


NOZZLE



1 – plasma injector of hydrocarbons; 2,4 – electrodes; 3 – insulator; 5 – plasma jet; 6 – input gas; 7 – hydrocarbons; 8 – grid; 9 – gas flow; 10 – input fuel; 11 – additional gas; 12 – reaction chamber; 13 – flame; 14 – nozzle; 15 – flame torch.

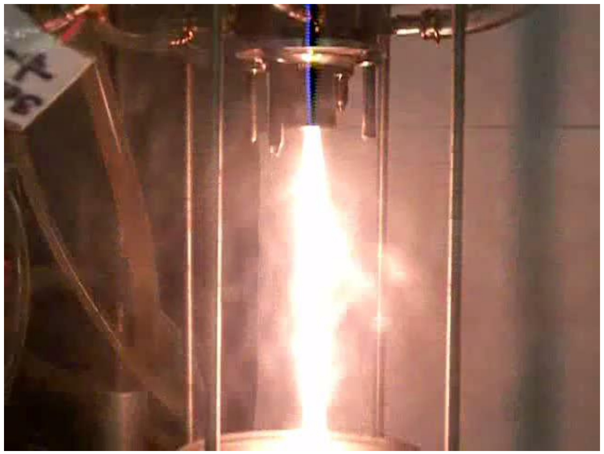
PHOTO OF FLAME TORCH



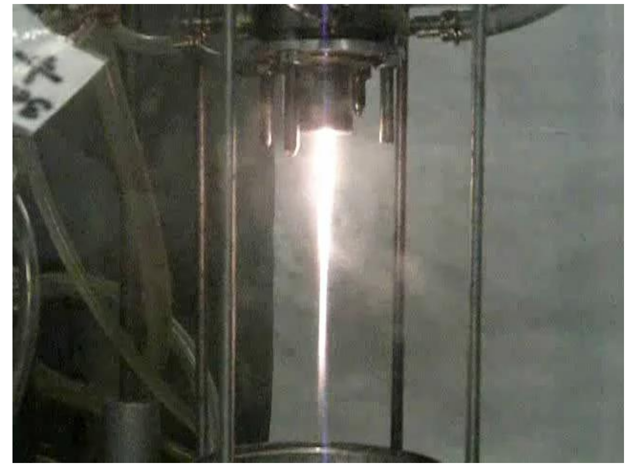
VIDEO

Current – 300 mA

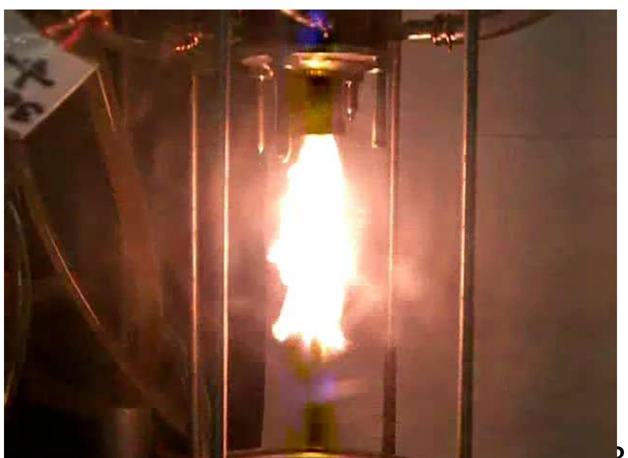
Air flow – 30 cm^3/s, U = 0,4 kV



Air flow – 50 cm^3/s, U = 0,4 kV

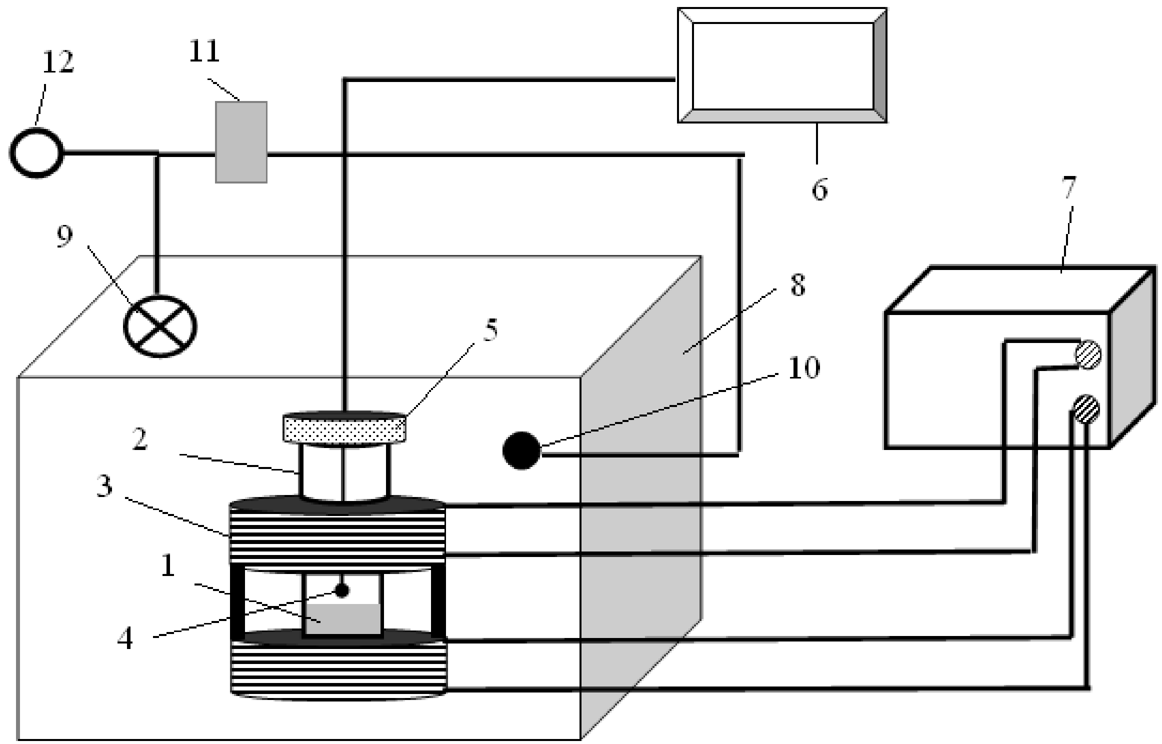


Air flow – 65 cm^3/s, U = 0,6 kV



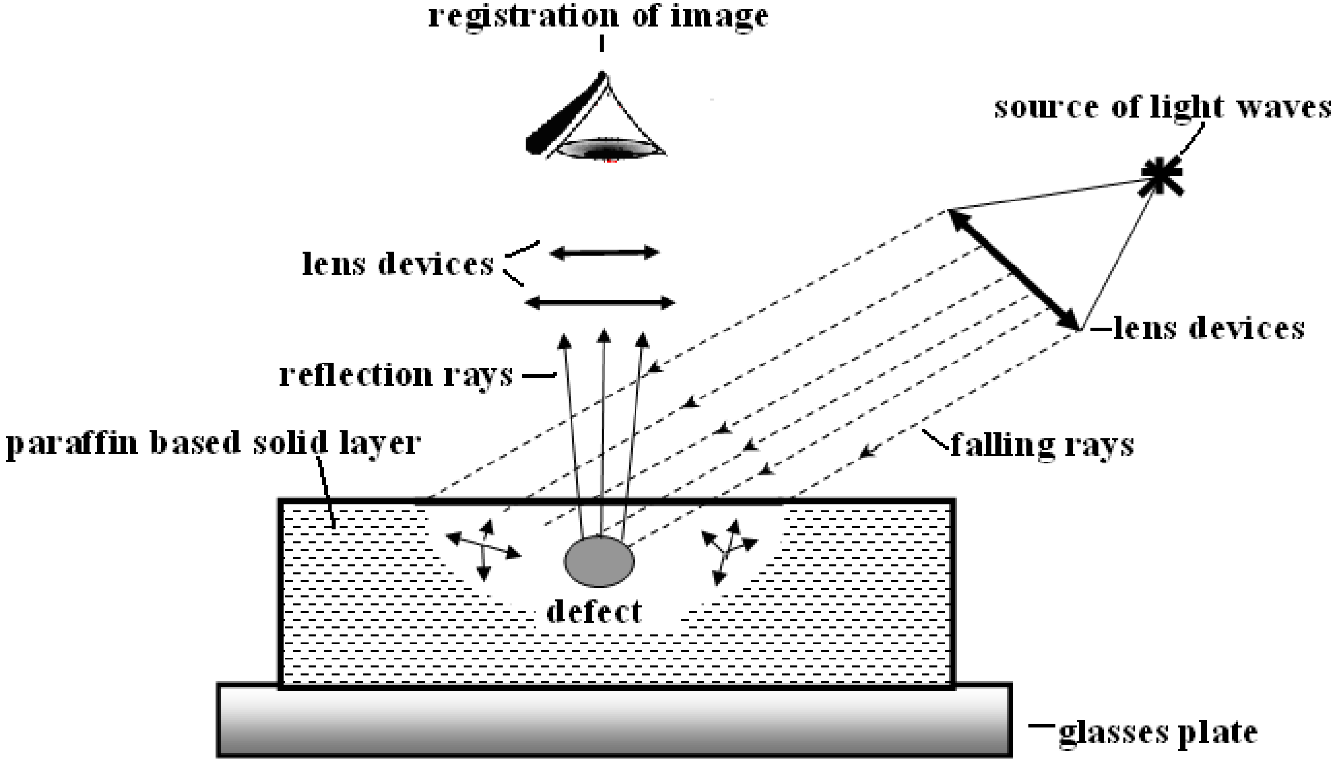
Air flow – 85 cm^3/s, U = 0,6 kV

Magnetic pretreatment of stearin

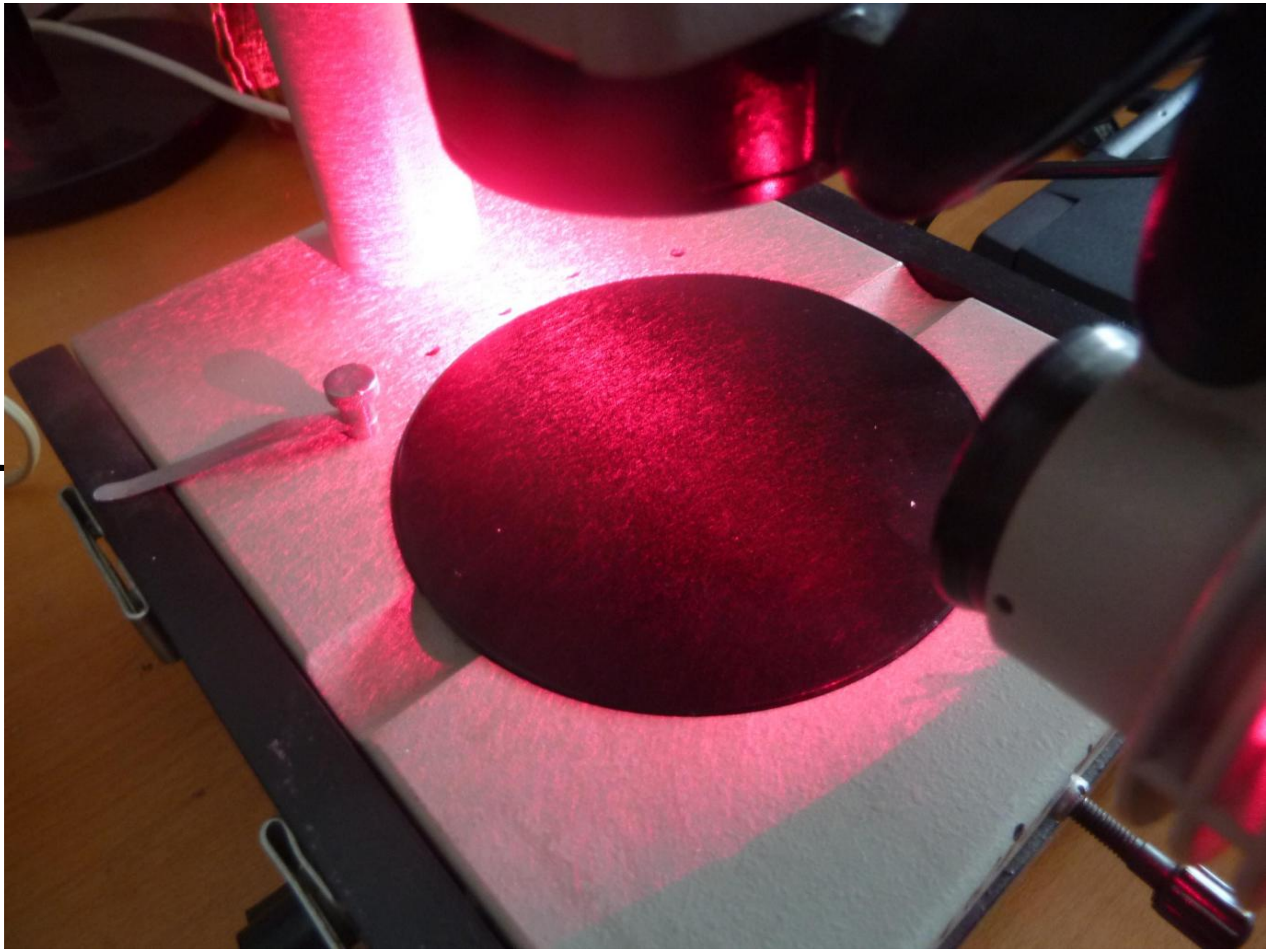


1 - stearin, 2 - cell, 3 - Helmholtz coils, 4 - thermal sensor, 5 - cell holder, 6-PC, 7 - Power Supply D15-10-01A, 8 - thermostat, 9 –heater (glow lamp), 10 - thermal sensor, 11 -heat controller.

Paraffin in and out of magnetic field



Microscope (x14) and red laser

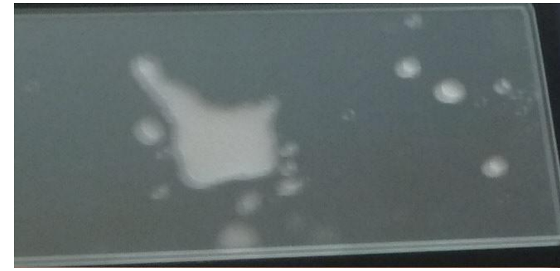


Droplet of stearin

(0 A)

(0,5 A)

(1 A)

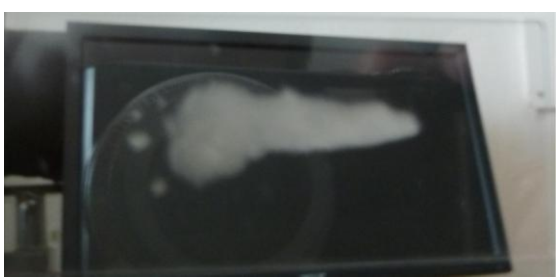


(1,5 A)

(2 A)

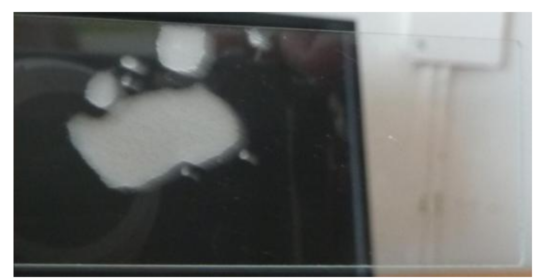
(2,5 A)

(3 A)

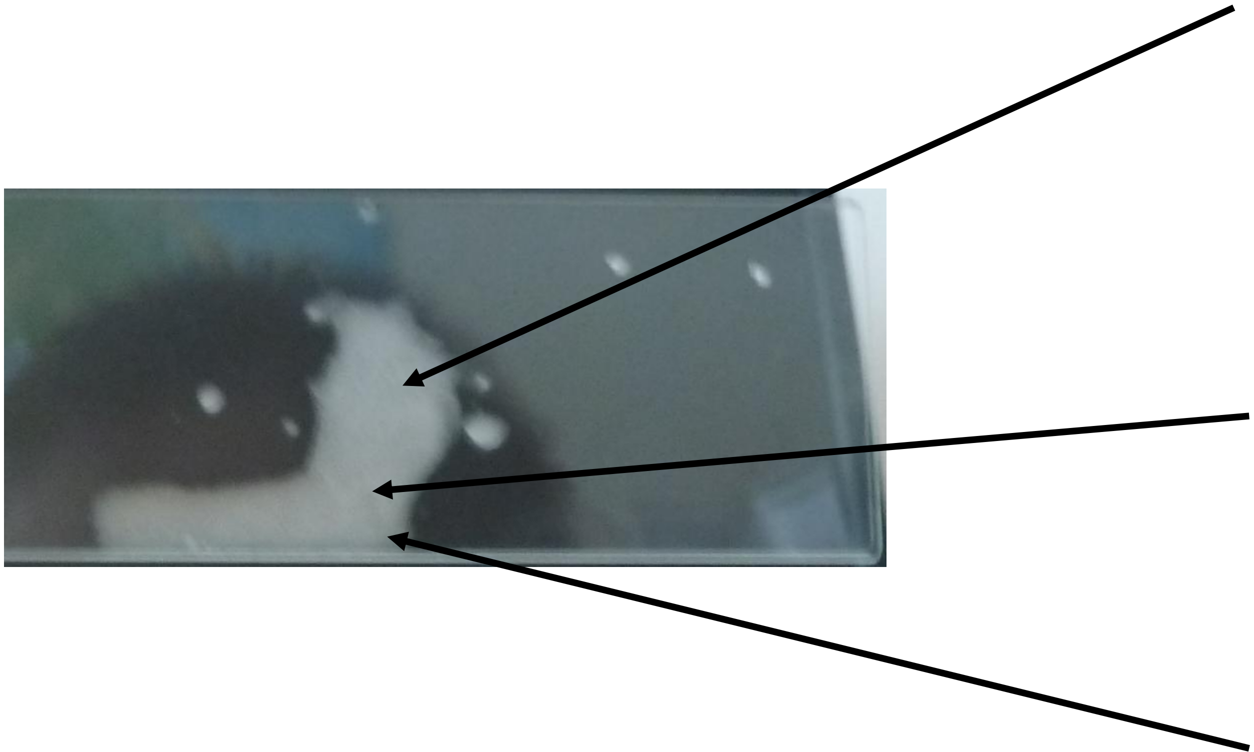


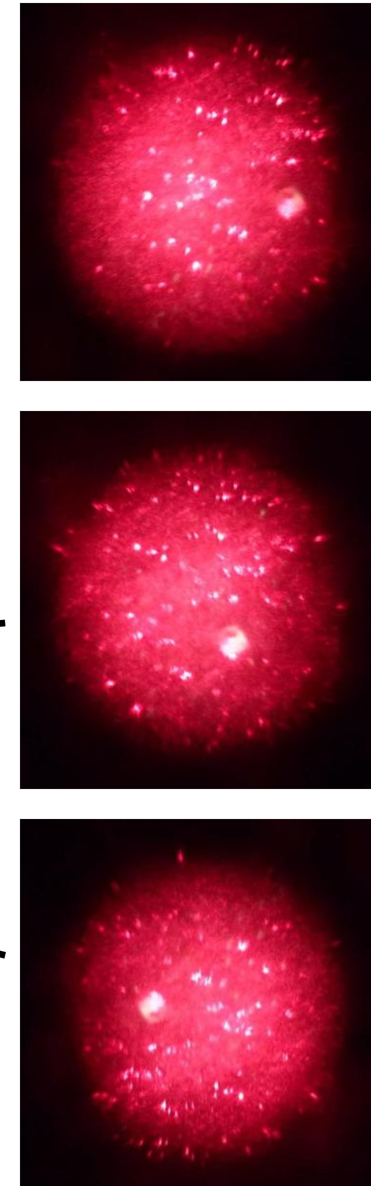
(3,5 A)

(4 A)

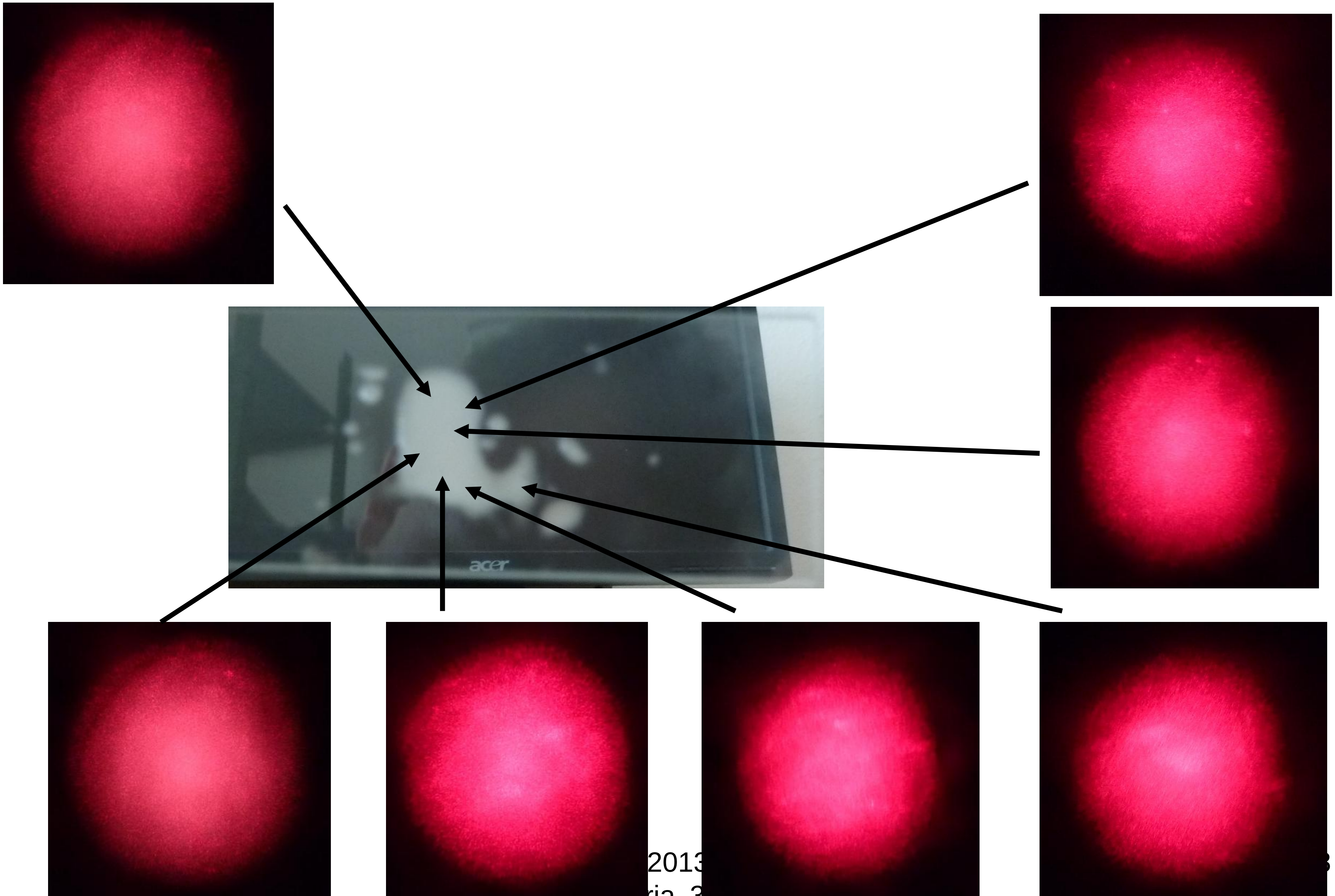


Without magnetic field

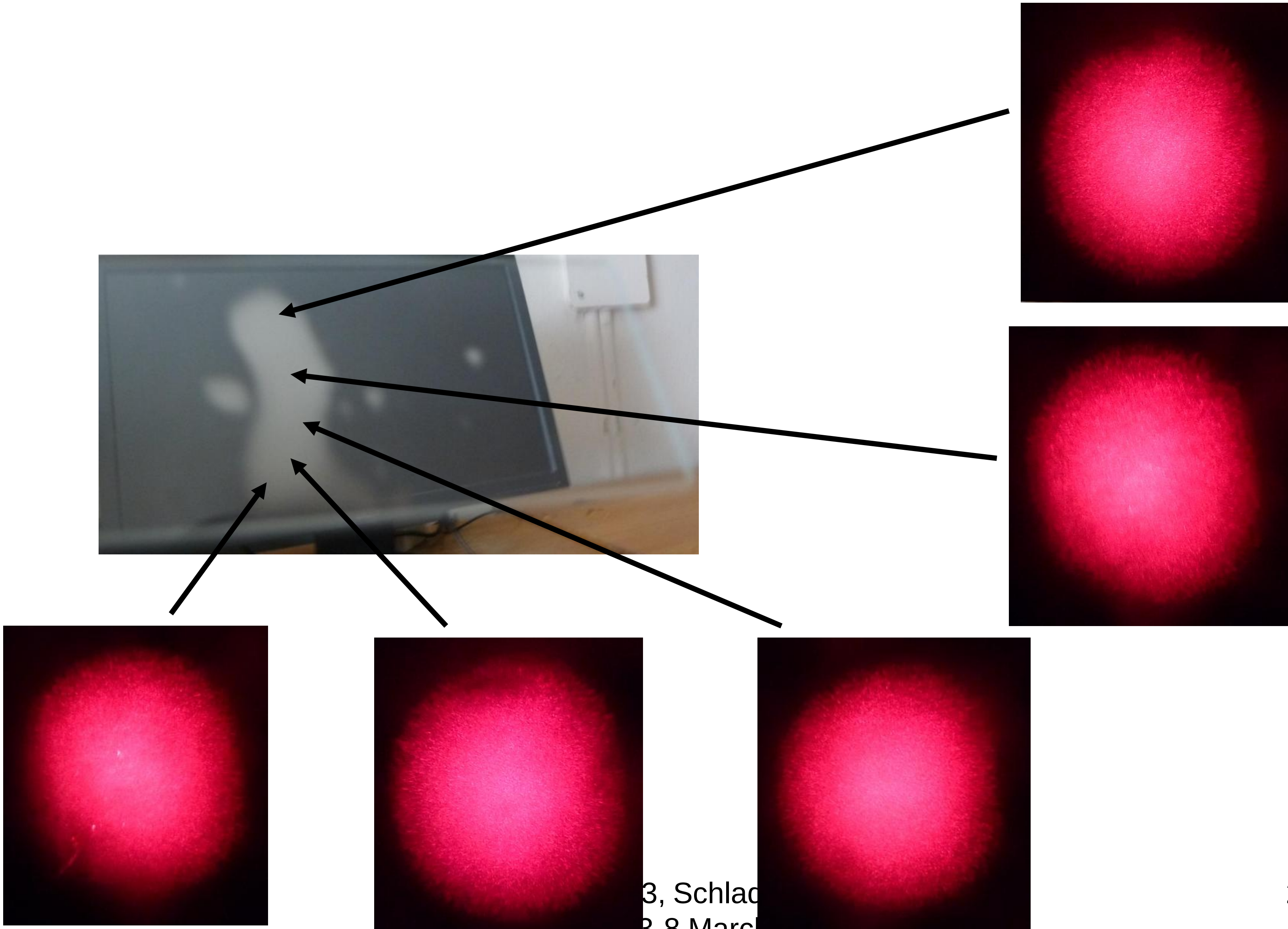




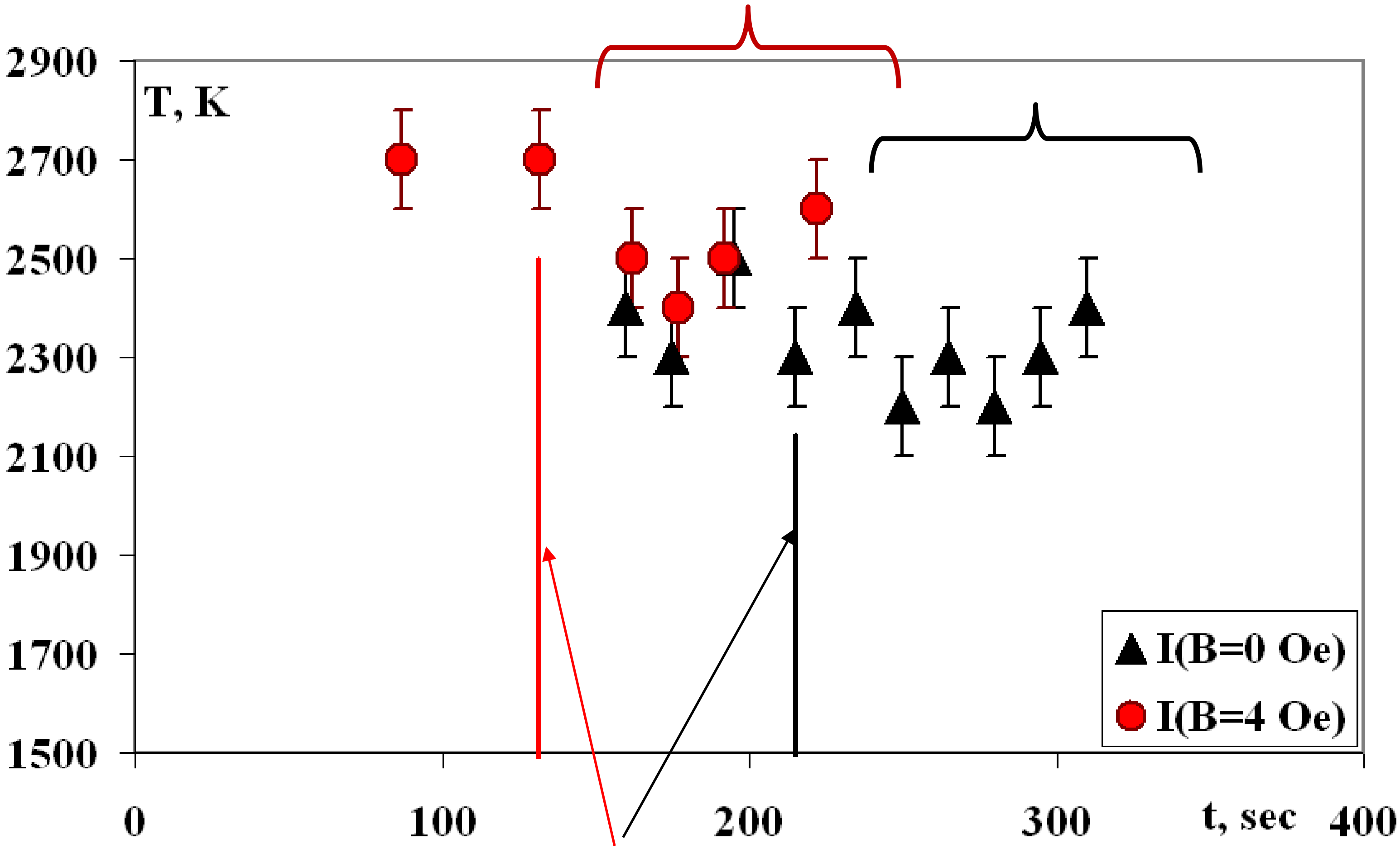
Magnetic field (0,5 A)



Magnetic field (1,5 A)

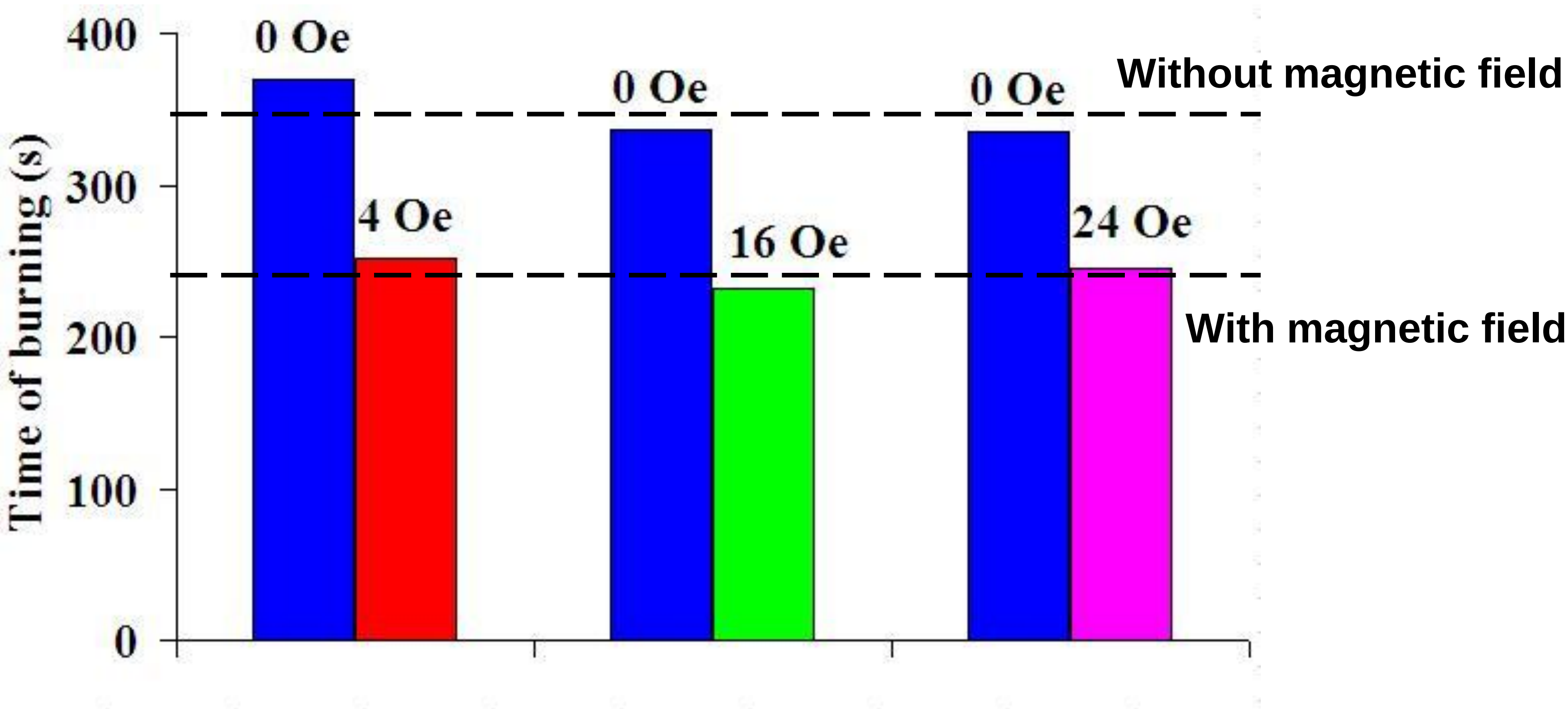


Time stable combustion



Start stable combustion

Plasma assisted combustion of paraffin



G = 50 cm^3/s; Additional air - 200 cm^3/s; I = 300 mA; U = 0.4 kV

CONCLUSIONS

- **A unique plasma injector based on the discharge with rotational gliding arc was designed and its effective using in systems of spraying and burning of viscous fuel (paraffin) was shown.**

- **During investigation of the paraffin burning process stimulated by transversal arc plasma effective management of burning paraffin (bad ignition of high-calorie carbohydrates) was showed. The ratio about 100/1 of energy that is released during fuel complete combustion to the energy inputted in the plasma generation was realized when using plasma.**

- **Pretreatment of paraffin by magnetic field leads to increased speed of his combustion**

THANK YOU FOR ATTENTION!!!