

From the past to the future

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Abstract: The evolution of ideas, resulting in ERT and, in particular, to SPT is shortly considered. Large power ERT are described, and also SPT of the second generation, developed jointly with the French firms, possessing with higher efficiency and smaller divergence of jet, than now existing regular models. Attention is paid to the fact, that the controlling of volume electrostatic field and overcoming D.Bohm's dogma about transfers in plasma, having demonstrated in SPT, open enormous space for creation of the plazmodinamics systems for the most different purposes, i.e. «Plazmodinamics Eldorado».

Nomenclature

I	=	electrical current
I	=	specific impulse
F	=	thrust
W	=	power
η	=	efficiency
T_e	=	electron temperature
\vec{H}	=	magnetic induction
τ	=	operation time
α	=	angle of the jet divergence

I. Introduction

The creation of SPT is not only the creation of the technical and important device, this is the destruction of the existing during 50 years error ideas, that it is impossible to create in plasma over-heat (with the classical conductivity) electric field. This error idea has existed from the moment, when in the beginning of the XX century Townsend derived the formula for the classical conductivity across the magnetic field, and a simple experiments did not confirm it for many years. And D.Bom wrote in 40th a formula for the «real» conductivity which sharply conflicted with the classics.

II. Pre-SPT

The astronomy and Ziolkovsky's beautiful books disturbed my imagination still at school, and in 1953y. the first model of the electromagnetic thruster has been created in the town Ludinovo of Kaluga region (where I has taught physics, mechanics and other branches of the science) (figure 1). The bar with dimensions of match-box has been made of the piece of asbestos-cement. Two mutually perpendicular crossed channels, parallel to the wide sides of the bar, have been drilled in it. Two carbon electrodes of diameter ~6mm have been placed into one of these channels. The wide sides of the bar have been placed

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into the lateral magnetic field, and the power supply ($I=50A$) has been connected to the carbon electrodes. When the magnetic field H has been applied and discharge have been turned on, the plasma jet has been escaped from the channel along the ampere force across the line of carbon rods. This experience and the number of other experiments have been stimulated the writing of the paper for the Journal of Experimental and Theoretical Physics (1957, №2). This was the first throughout the world publication, devoted to plasma accelerators. It has aroused the great interest among responsible scientific opinion in USSR and USA. The analysis of the mechanism of the acceleration in these systems and of the role of the volume electrical field have been the principally important elements of this paper.

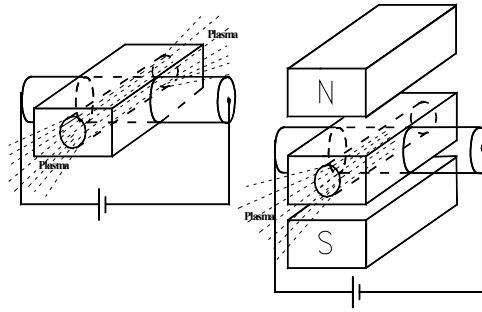


Figure 1. First models.

So I became the inventor of Reliverinum and inductive accelerator.

In a few years I have started to work in the Kurchatov's Institute of the Atomic Energy in the sector of the academician L.A.Artsimovich. Soon after the launching of the first satellite into the Space, on the 2-nd of July of 1959y. Artsimovich has gathered the collaborators, who studied the ions sources and plasma accelerators, and proposed to study the problem of electro-propulsion thrusters. The task of the flight to Mars with the man onto the board has been set: the thruster power 10MW, the specific pulse $I=10000s$, the thrust $F=10kg$. The "ambition" of the task has been explained by that euphoria, which has been caused by the first flight to the Space. Next day I've come to the academician with the idea of magnetic-plasma analogue of Laval's nozzle, which, as the simple theoretical model has showed, had to provide the needed parameters. This proposal has produced the great impression upon Artsimovich, and he has proposed me to organize the experimental group in prof. G.Shepkin's laboratory. The facility for verification of idea in quasystationary mode was created in five months.

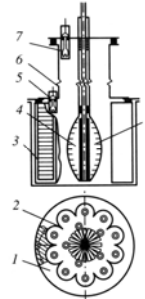


Figure 2. Full-blocked QSPA Kh-50 with 2 transformers:

1 – anode transformer, 2 – current collector, 3 – cracker of the transformer's magnetic system, 4 – cathode transformer, 5 – anode ionization chamber, 6 – drift channel, 7 – entrance ionization chamber, 8 – electron emitter needle.

After a number of experiments it has become clear, that this simple scheme, which was named "co-axial"(co-axial powerful-current accelerator), unexpectedly is not truth due to the near-electrodes processes, caused by Hall's effect. More complicated scheme (QSPA, shown on figure 2) which was successfully realized by me later was here required (look below). Also it has become clear, that in the nearest future there will be no cosmic energetic of 10kW on the board.

III. What is the essence of the fundamental nature of SPT invention?

I have worried with the choice of the alternative thruster during the year. And since 1962y.the scheme, that is in the base of SPT, has become more and more attractive for me. The over-heat volume E-field, created in the channel across to the magnetic field, has been its feature. This scheme has provoked the furious reports from the side of the specialists of the gas discharge: they have accused me in the total ignorance. Only academicians Leontovich and .Artsimovich kept silence at first. Then after the direct experiments in the vacuum chamber they have supported me. The model has been optimized and demonstrated a good performances to 1967y.

Our director, academician A.P.Alexandrov has organized two important deliberations with the constructors of the rocket systems, before only one of them (A.G.Iosifyan) has agreed to install the thruster on the board of the sputnik "Meteor". In the end of 1968y. He has issued the Technical Task onto the thruster plant (equipment) with the parameters: the power $W=400W$, the thrust $F=2g$, the life-time is equal to 100 hours. It was named "EOL" (figure 3). Such thruster plant (wholly, instead of one engine) was created in Institute of Atomic Energy and passed the life time tests there. In May of 1969y. (i.e. in 5 months!) it was passed in EDB «Fakel» for creation of analog, satisfying the requirements of Spaces. The major designer and director of the EDB is «Fakel» R.K.Snarskii, under our scientific leadership, has realized the project. Tests on satellite «Meteor» at the beginning of 1971y were successful. The first thruster plant EOL-1 had the efficiency $\eta\sim 35\%$. The second thruster plant after our recommendations had $\eta\sim 50\%$, i.e. the value, which we have today, except a resource, for which we were then limited to the duration ~ 200 hours. The obtaining of long life-times is the achievement of the «Fakel». The constructive scheme of the main parts remained up to now practically the same, as it was then.

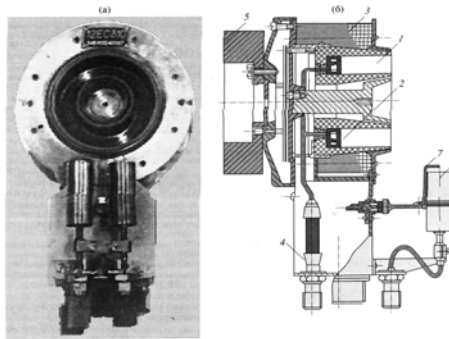


Figure 3. SPT-EOL:
a. original appearance, b. scheme of design (1. discharge chamber, 2. anode gas-distributor, 3. magnetic system, 4. high voltage input, 5. adjusting bracket, 6. cathode-compensator, 7. starting electrode)

IV. The systems with the closed drift

And what is later? The deep study of the physical processes in SPT (near-wall conductivity, Debye layers at high T_e , the role of grad \vec{H} , etc.) and the transfer onto the more powerful thruster have become the main one. We have created SPT with the power $W=30kW$, generating the thrust up to 150g and having the efficiency $\eta\sim 70\%$ in 1976y. This model has operated stationary, and the success has been marked by Kurchatov Honor.

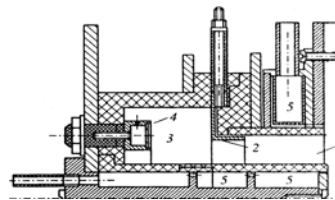


Figure 4. Scheme of the SPT ATON.
1- accelerating channel, 2- anode, 3- buffer chamber, 4 - gas-distributor, 5 - magnetic coils.

Besides, we have created so named two-lenses accelerator, which has been tested in the quasi-stationary mode with $\tau\sim 0,01s$. The experiments have confirmed our hopes onto the opportunity of the creation of the accelerators with the specific pulse $I=100000s$ and the power $W=5MW$.

In 1978y. my research activity has been transferred into MIREA (Moscow Institute of Radio-engineering, Electronics and Automatics) into the laboratory, which was led at first by Prof. L.E. Kalihman, and then (and up to now) – by Prof. A.I. Bugrova. This cooperation was very fruitful. A.I.Bugrova and I succeeded radically to move up in research of kinetics of electron components in SPT. In addition, here, by the contract with French firm SEP, the thruster ATON (figure 4) with the unique characteristics has been created: under the power $W\sim(1\div 2)kW$ he has the efficiency $\eta\sim 67\%$ and the half-angle of the divergence of the going out flow $(\alpha/2)\sim\pm(15)^\circ$. Now, on my proposal, MIREA in co-operation with the French firm SNECMA has developed the next second generation thruster SPT-MAG, which has the low oscillations level, the small half-angle of divergence and the high efficiency.

It is necessary to mention about the work, connected with the creation of QSPA (figure 2). This work has been carried out in 1980th years in the co-operation of 10 leading institutes under my scientific leadership and it has led to the remarkable result: the accelerator of the power $W\sim$ a few GW, which accelerated the hydrogen up to 500km/s under the efficiency $\eta\geq 70\%$, has been created. The scheme of the

coaxial high-current accelerator of 1959y was the underlay of QSPA, but now it was improved taking into account our theoretical researches of flows of plasma with the strong effect of Hall.

V. Conclusion

Possibility of creation of the strong electrostatic fields in a volume of well ionized plasma, shown in SPT, allows to create different plasmadynamics systems, including, transfer of all basic achievements of classic corpuscular optics in plasmaoptics with that principle difference, that these will be the high-current optical systems. One of the actual problems of the plasmaoptics is the creation of separators for the processing of the waste of atom reactors.

A.I.Bugrova, her's employees and I have experimentally demonstrated the efficiency of use of the volume electrostatic fields for plasma confinement. This opens new approaches to the problem of the Controlled Nuclear Fusion.

Truly, one may say, that SPT opened a door in to "Plasmadynamics Eldorado".