# ELECTRON GUN WITH ADIABATIC PLASMA LENS

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*Abstract*

For researches on plasma physics has been designed and constructed the electronic gun with the cold cathode on energy to 300 кэВ. The gun have the parameters: time width of pulses -100 ns, current amplitude - 100 A. The adiabatic plasma lens is developed for transportation and compression of the received electron beam. Results of researches are presented.

## INTRODUCTION

The electron beam with energy in hundreds кэВ is necessary for carrying out researches in the field of plasma physics - studying of formation of Z-pinch [1]. For these purposes the electron beam has to have the following parameters: current amplitude > 100 A, front duration ~ 10 nanoseconds, energy of electrons > 200 keV. The experimental installation is shown on fig. 1. The electron beam is entered through foil into the experimental channel with pressure ~ 1 mbar. The beam size is reduced in the adiabatic plasma and then is injected in the camera for Z-pinch formation. For creation of the required accelerating voltage form was accepted the scheme of the generator on cable lines with use of the double forming line of Blumlein (DFL) and the cable transformer of Lewis [2].

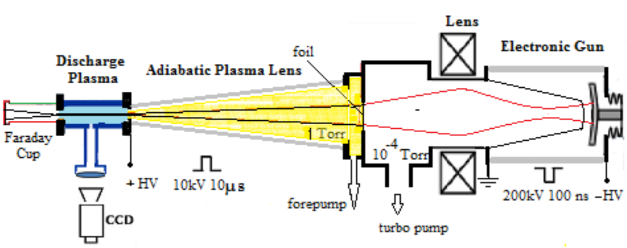


Figure 1: Set up of the adiabatic plasma lens with the ITEP electron gun.

## THE GUN INSTALLATION

The gun installation (fig. 2) consists of actually electron gun with magnetic lens, surveillance camera with the scintillators located in it. Vacuum pumping of an electronic gun is made by the turbomolecular pump, and of plasma part of installation - the roughing-down pump. The appropriate volumes are separated from each other by a mylar film. The desorption emitter was used for reduction of requirements to vacuum. Such long-lasting emitter was developed in ITEP [3]. The gun emitter of an electron beam (fig. 2) is located in the center of a cathode. The desorption emitter represents a set of thin plates of mica and copper. The emitter diameter is 50mm, diameter of a cathode electrode is 110 mm. The gap width is about 50 mm.

Fig. 3 represents simulation results of the electron beam propagation from cathode (C) to adiabatic magnetic lens. Emission current of 100 A and 50 mm cathode-anode gap under voltage of 200 kV were assumed during calculation.

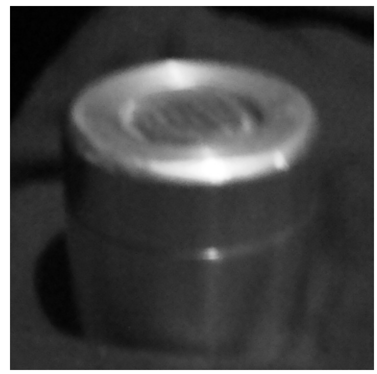

Figure 2: The cathode assemble.

The simulation was performed using numerical code PICSIS-2D [4] based on use of system of the equation of Vlasov-Boltsman with calculation of collisions of particles by Monte-Carlo method. The program enables to calculate a transportation of relativistic charged particles in arbitrary 2D electromagnetic fields taking into account its space charge and self-magnetic field.

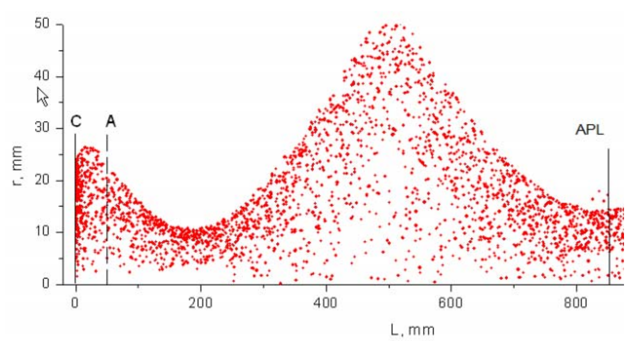


Figure 3: Electron beam propagation; I=100A, U=200kV.

## PULSE MODULATOR

For creation of the accelerating voltage was accepted the scheme (fig. 4) of the generator on cable lines with use of the double forming line of Blumlein (LB) and the cable transformer of Lewis (TL). Generators of this kind were realized [5] and on them voltage about 300 kV impulses were received. For switching of the LB was used by "pseudospark switches" TPI1-10k/50. The forming line was executed from 18 couples 10-meter RC-50 cables. It is loaded from a high-voltage source through $R_h$ resistance. To reduce communication between an exit

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of the transformer of Lewis and the forming line, the last unites to the earth through decoupling inductance of $L_{dec}$. The cable transformer consists of nine 20-meter cables, each of which contain two inductivity decouplings (permalloy and ferrite). For compensation of distortions of a form of an impulse the $L_c$, $C_c$ and $R_c$ elements are entered into the scheme. The control signal is removed from a low-voltage shoulder of $R_d$ of a divider of the accelerating tension.

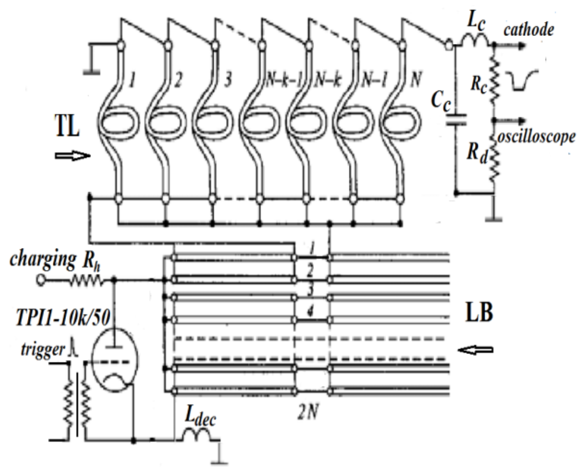

Figure 4: Pulse modulator.

## ELECTRON DIAGNOSTICS

The Kuraray company scintillators are used for obtaining of a beam density distribution. A scintillators luminescence are registered by CCD television cameras. The last together with operating computer are in the iron boxing providing an electromagnetic shielding. Information to the central computer is transferred on optical communication.

An electron beam current was measured by the current transformer which has been built in the transport channel. All measuring systems, as well as start systems, are equipped with fiber-optical devices [1].

Figure 5 shows waveforms of the beam current and DFL voltage pulse at of 25 kV. The peak current of 50 A and the beam time width of 60 nsec.

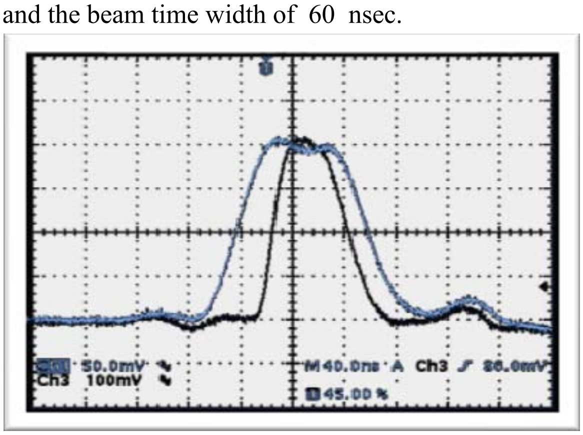


Figure 5: The electron beam current (black curve) and DFL voltage pulse signals.

The measurements of a electron beam energy spectrum on the magnetic analyzer were taken (fig. 6). Width of recession of a spectrum above a maximum is defined by the value of angular dispersion which exceeds 0.01 rad.

Characteristics of an electron beam were close to design values.

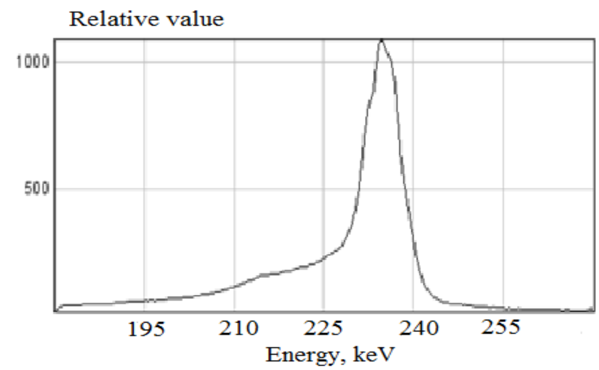

Figure 6: Electron beam energy spectrum for charging voltage 28 kV.

## ADIABATIC PLASMA LENS

Focusing of an charge particle beam in a plasma lens is carried out as follows (fig. 7): the z-discharge plasma current creates an azimuthal magnetic field which focuses a beam passing through the discharge tube. If a discharge tube conic, density of current and a magnetic field increase with reduction of a tube diameter. That plasma z-discharge can be used to reduce the beam size in a way increasing of the focusing strength along the lens [5]. The focusing strength increase reduces the betatron wavelength and at the same time the amplitude of the betatron oscillation and thus results in a reduction of the beam envelope radius. That is different from the traditional "coherent focusing". This of focusing can be achieved by a slow, or ‘adiabatic’.

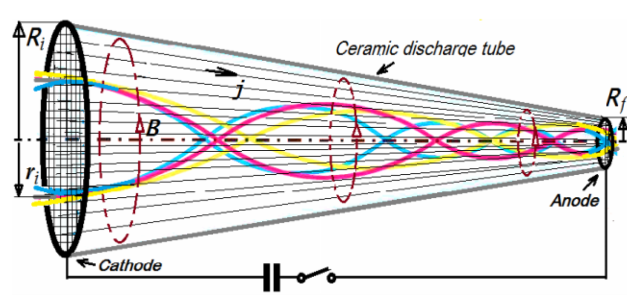


Figure 7: Schematic drawing of the principle and geometry of an adiabatic plasma lens.

Reduction ratio of the final beam radius $r_f$ to the initial beam radius $r_i$ depends on the increase of focusing strength along the lens:

$$r_f / r_i = (R_f / R_i)^{1/2}$$

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where $R_f /Ri$ is the reduction ratio of final to initial diameter of discharge tube. The first studying of an adiabatic plasma lens were performed in Berkeley [6]. The researches were conducted with use of a beam ions $K^+$ of 1.5 MeV energy.

Now research and adjustment works on creation of the adiabatic plasma lens (APL) are carried out. The pulse generator with thyratron TDI1-150/25 as the switchboard on current to 30 kA was created. As current impulse rather long (20 microsec), the discharge current fills all section of a tube, and distribution of the current closely to the uniform where a beam passes. Therefore it is possible the adiabatic formula will correctly define change of the size of a bunch in our lens.

Because of technological problems decided to replace a conic discharge tube with a set of cylindrical tubes. The set of tubes has length of 120 cm and their diameter decreases from 100 to 10 mm. The lens was tested on initial part 60 cm long, where diameter decreases from 100 to 50 mm (see fig. 8).. The steady discharge happens with a pressure less than 0.5 Torr. According to Paschen's curve for the full length lens pressure will need to be reduced to 0.2 Torr.

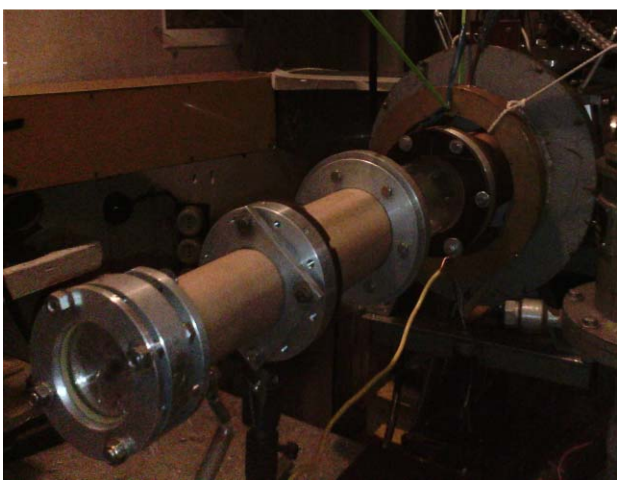

Figure 8: The adiabatic plasma lens (initial part).

The first tests were carried out for a electron beam with energy 200 кэВ and current 30 A. The fig. 9 show a scintillators luminescence for the lens entrance and exit. The corresponding sizes of a beam section are 50 mm and 40 mm. Of course, quality of conducting of a beam leaves to wish much the best, but, nevertheless, the beam size didn't increase on a drift interval 60 cm. Further it allows to hope to achieve the demanded results.

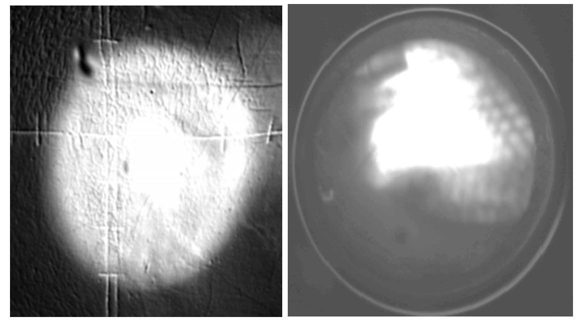

Figure 9: Scintillators luminescence for the lens entrance and exit.

## CONCLUSION

Measurements of parameters of a beam showed their good compliance to projected values. Reliable work of installation speaks about operability of the made technical solutions.

The developed generator for an adiabatic plasma lens provides stable implementation of the plasma discharge.

The carried out tests of an adiabatic plasma lens with an electron beam allow to hope for the successful solution of objectives.

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