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ABSTRACT

An ion source with indirect heating and long lifetime was constructed for 1-2 mA currents of heavy ions. The emittances were measured in the xz and yz planes at 30kV extraction voltage.

АННОТАЦИЯ

Был разработан ионный источник с током 1-2 ма для тяжелых ионов. Этот источник, большого времени жизни, имеет косвенный накал. Была измерена характеристика эмиттанции при вытягивающем напряжении 30 кв в плоскостях xz и yz.

KIVONAT

1-2 mA áramerősségű nehéz-ion nyalábok előállítására közvetett fűtésű, hosszú élettartamú ionforrást dolgoztunk ki. Mértük 30 kV kihúzó feszültségnél a forrás emittanciáját az xz és yz síkokban.

The heavy ion sources used in ion-implanters have been developed together with the implanters. Having the task to build up a new ion implanter we also had to construct a new, more suitable source to the new machine.

For several years we have used an arc-discharge-type source [1] which has an intensive beam (10-20 mA P^+), a very long life time of its cathode but the whole construction of the source is rather complicated, the machinery of the spare parts is time-consuming. For the new goal we don't need more than 1-1,5 mA ion current and so there is no need to use the source mentioned before. Even placed the ion-source on high potential we could have a lot of troubles with the power-supply.

There is an other excellent type of the heavy ion sources, the Freeman-sources [2] and its developed variations [3, 4] but according to the literature and other information got personally the lifetime of the cathode is rather short. The possible reason of the short cathode lifetime can be found in the fact that the cathode is directly placed into the discharge. The electrons emitted from the cathode-filament reach the wall of the discharge chamber only under special operating conditions. Normally they run in cycloids-paths along the cathode under the influence of the own magnetic field of the cathode, the outer magnetic field and, naturally, of the anode potential. But there is some potential drop along the cathode-rod which drifts the electrons to the positive end of the filament. Therefore the ionization of the neutral gas is increased at the positive end causing a preferential sputtering of the cathode material [5]. Apart from that disadvantage the Freeman source could be very suitable for our task.

1. THE CONSTRUCTION OF THE ION SOURCE

As it is shown on the Fig. 1 the source has two graphite chambers. In the upper one there are the heating filament and the cathode block. The

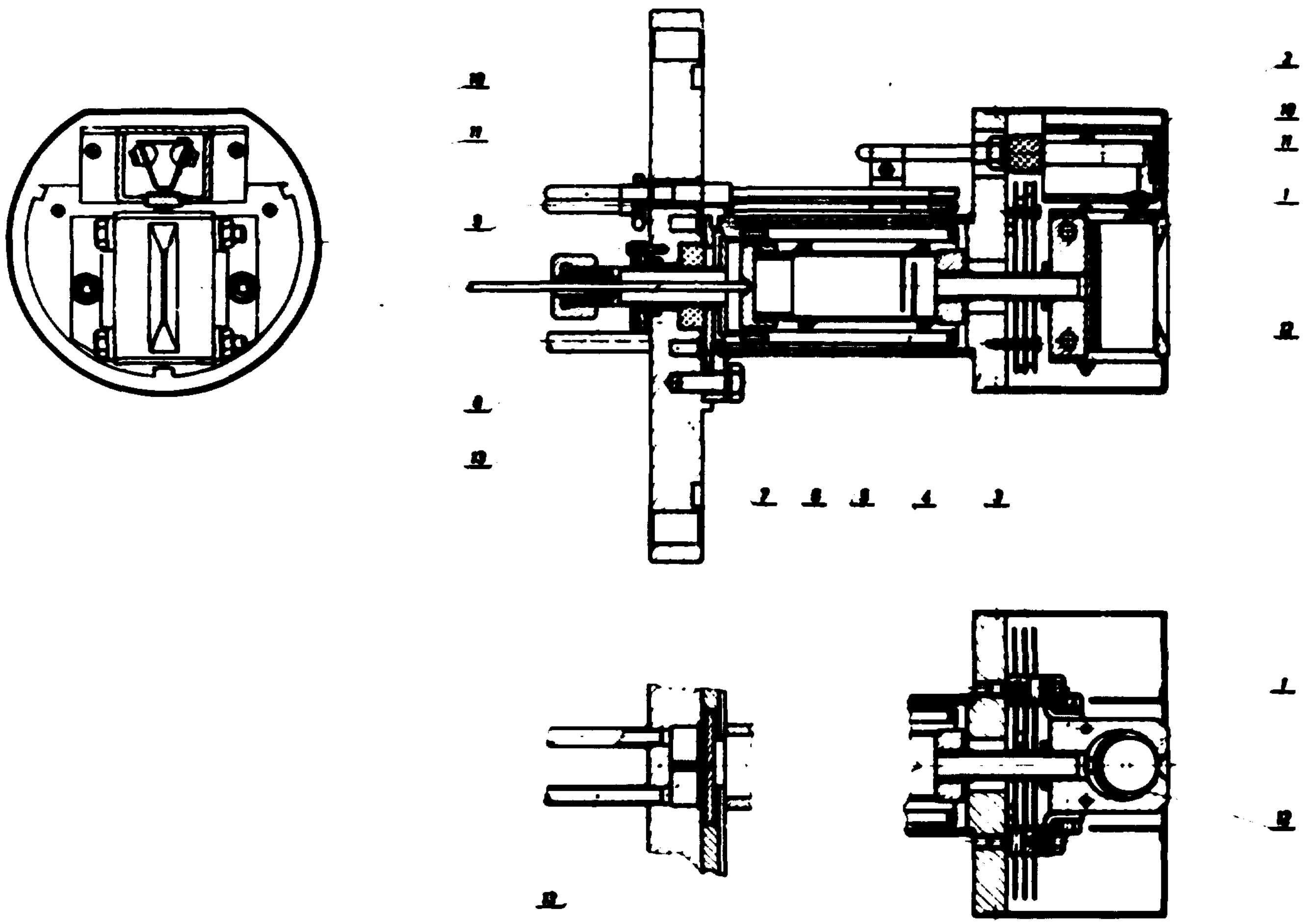

Fig. 1

The construction of the source
1 - Discharge chamber, 2 - High voltage covering, 3 - Heat shielding, 4 - Support, 5 - Oven, 6 - Crucible, 7 - Base plate, 8 - Thermocouple tube, 9 - Feed throughs, 10 - Filament, 11 - Cathode, 12 - Ta chamber, 13 - Water cooling

cathode block - made from a single piece of W - is so positioned in the bottom of the smaller graphite chamber that its emitting surface is in a distance of about 0,3-0,5 mm from the bottom plate of the chamber. On the back side of the cathode block - in a distance of about 1,5-2 mm - a "V" - shaped W filament held by two Ta rods is mounted.

The distance between the filament and cathode block is determined by the shape of the filament and the angle formed by the connecting surfaces of the Ta rods. Both, the shape of the filament and the angle of the rods are formed using a master-piece. A 0,3 mm thick Ta plate is mounted on the negative Ta rod to protect the walls of the small chamber againts electron bombardment.

The discharge chamber is also made of graphite and has two graphite plates for closing on the top and bottom. In the upper plate there is a 6x8 mm^2 hole just in opposite of the emitting face of the cathode block. The ionizing electrons are ejected into the discharge through this diaphragma. The vapours, gases to be ionized are admitted through a small inlet into the discharge chamber. For having the most suitable pressures and pressure -distribution there is a Ta plate between the walls of the graphite chamber and a cylindrical Ta tube which forms the active discharge chamber. Along the line opposite to the extraction slit of the Ta chamber, a set of holes with diameter 1,0 mm was bored. Near the cathode all are in a row, but started in a distance 20 mm from the bottom plate two sets of holes were made.

For materials, which can be vaporized below 500°C a stainless-steel crucible is used. The crucible is connected by a small inlet to the discharge chamber. Two barrier-plates can be found in the crucible for preventing the flow of solid materials into the chamber. The crucible is heated by an oven formed by two coaxial stainless-steel cylinders sealed at one end and isolated at the other end.

The temperature of the crucible is measured and controlled by a thermo-couple.

Using gases as source feed materials the crucible and oven can be replaced by a simple tube having the same diameters as the inlet and the container of the thermo-couple. A remote-controlled, mechanically operated needle-valve is joined the gas conducting tube.

For the better efficiency and the lower temperature there are two measures:

1/ A set of Ta heat-shielding plates are placed between the discharge chamber and the holder-plate and

2/ the end flange of the source which assures the correct adjustment to the optic and vacuum system is cooled by water. The cover of the chambers can also act as a heat shielding.

2. THE FUNCTIONING OF THE SOURCE

Increasing the temperature of the heating filament electrons are emitted and accelerated toward the back side of the cathode block. Being bombarded, the temperature of the cathode also increases, but depending on the number and energy of the bombarding electrons. Naturally, the number of by the cathode emitted - in the discharge chamber ionizing - electrons depends on the temperature of the cathode.

An other accelerating voltage is switched on the cathode-discharge chamber space. This voltage accelcrates the ionizing electrons to an energy which is enough high to ionize the vapours or gases in the chamber.

An additional magnetic field is applied parallel to the axis of the chamber with an intensity of about 100 Gauss. That magnetic field plays a double role: first it makes easier to shoot the electrons through the apperture with less loss and seconds it increases the paths of electrons improving the ionization efficiency.

The indirect heating enables the stabilizing of the discharge working in the arc-region. As it was mentioned above, the temperature of the cathode and so the number of the emitted electrons depends on the intensity and energy of the electron beam bombarding the cathode. To control the energy of the bombardment is relatively easy and having that solution one can also control and stabilize the discharge, too.

3. POWER SUPPLIES, BLOCK-DIAGRAM

The ion source is placed in a high voltage terminal that's why the general power supply of its units is solved by a motor-generator set having an isolating shaft between the two machines.

The block diagram of the power supply units is shown on the Fig. 2. Some additional remarks to that figure: The stabilization circuit of the arc discharge was already mentioned before. There is an other possibility to stabilize the temperature of the oven as well as the crucible. However, generally there is no need to stabilize the crucible temperature in the case of a normal run. All the power supplies are built using semiconductor elements.

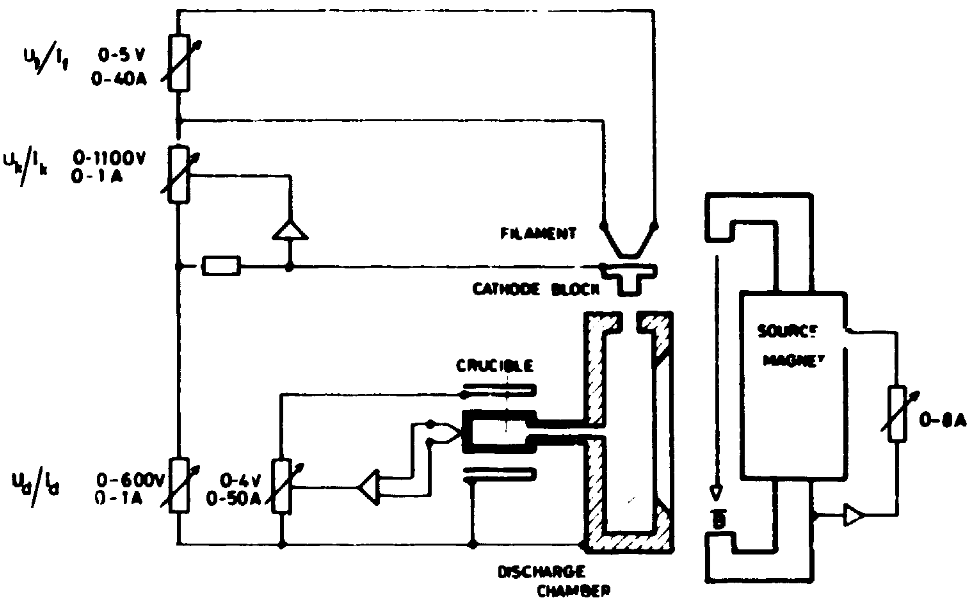

Fig. 2

Block diagram of the power supplies

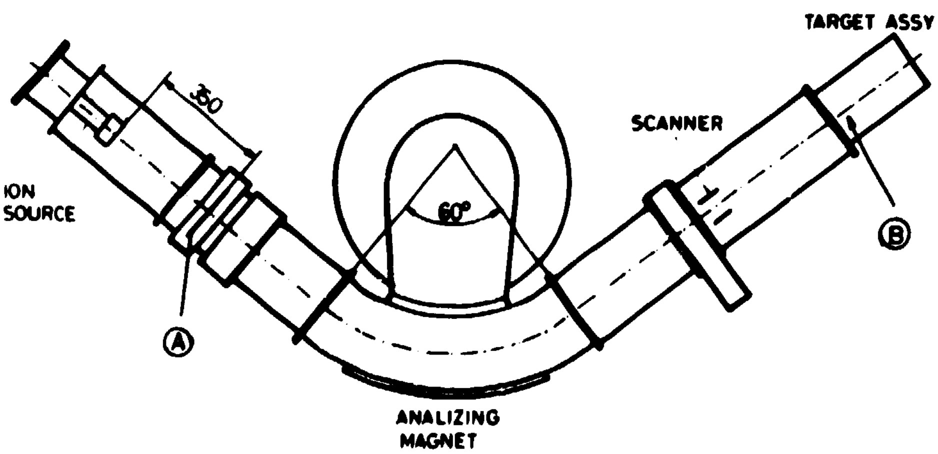

Fig. 3

The sketch of the ILU machine

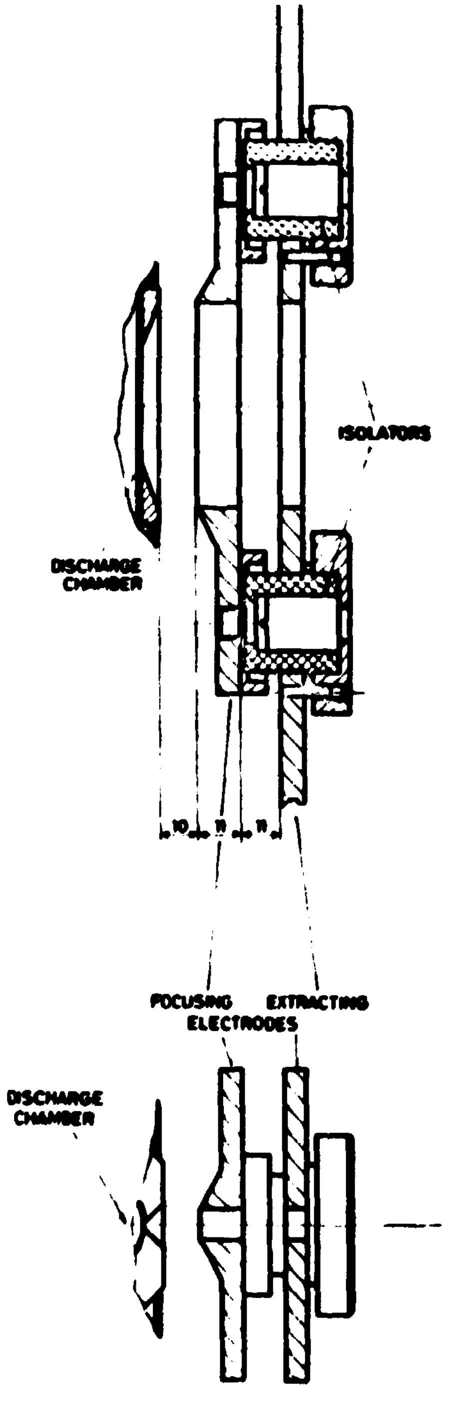

Fig. 4

Extracting-focusing electrode assembly

4. EXPERIMENTAL RESULTS

The new ion source was proved in our mass-separator type ion implanter called ILU-3a [1]. For adjusting the source to that machine we modified it in some respects. Those modifations did not touch the functioning of the source and they only served the correct adjustment. The sketch of the ILU machine is given on the Fig. 3. In the first measurement the total current given by the source was defined. The arrangement of extracting-focusing electrodes used during the whole experiment is shown on the Fig. 4. The extracting voltage applied between the source and earth potencial was 30kV in all cases, the prefocusing voltage varied from 2 to 3 kV.

A measuring electrode of the total current was placed into the system at the point marked on the Figure 3. with A. The distance measured from the earthed electrode of the extraction set-up to that one was 350 mm. A positive voltage about 160 V was switched onto the measuring plate to collect only ions without secondary electrons, as far as it was possible. A total current of 1.95mA of phosphorus ions could be measured with the following parameters: I_f = 35 A, U_k = 900 V, I_k = 500 mA, U_d = 500 V, I_d = 100 mA. /The parameters are in accordance with the block diagram on the Fig. 2./. The temperature of the crucible was 290°C at the point where the thermo-couple touched it. The owerall pressure

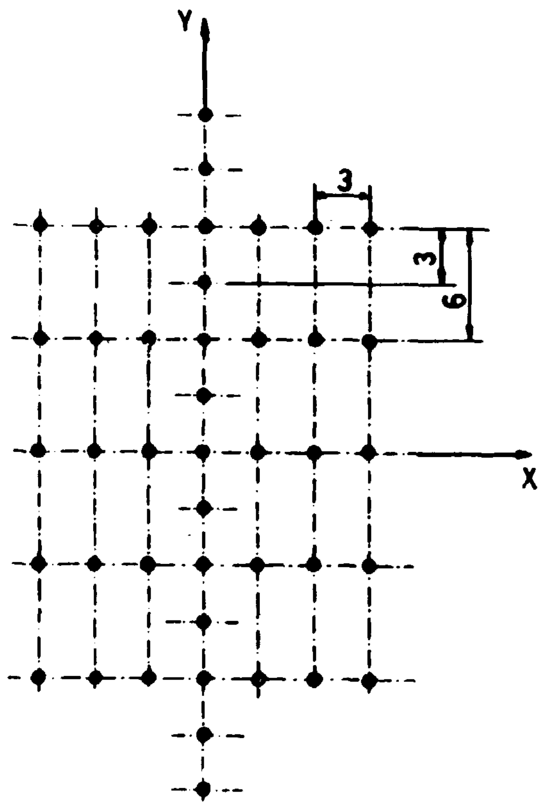

Fig. 5

Holes in the beam defining plate

was 8.10^{-5} Torr in the source vacuum chamber.

Thereafter, the emittance of the source was measured. The beam defining plate having a set of holes with 0,5 mm diameter as it is shown on the Fig. 5 took place in a distance of 150 mm from the earthed electrode of the extraction system. The screen position was the same as it was in the case of the total current measurement. That means we had a 200 mm distance between the beam defining plate and the screen. Stainless-steel and an organic material, called Hostaphan BN-250 /widely used as an excellent isolator in the high voltage transformer technique/ were used on the screen. The evaluation of the emittance was done by the defining of the diameters of the dark spots caused by the impinging ions on the screen. There was no difference in the case of the use of stainless steel as well as the Hostaphan. On the Fig. 6 one can see the emittances measured in the x- and y-planes. According to the figures our beam is practically parallel in the y plane and light diverging in the x one. Using the sweeping of the ILU-machine the distribution of the current in the ion beam was also measured. Under the given conditions that measurement could only be carried out at the point marked B on the Fig. 3 which was in a distance of about 3 m from the ion source. That's why those curves give only preliminary information. At the evaluation of the distributions adjoining to the ion-source parameters and behavior, other effects like the focusing properties of the analyzing magnet and other elements must also be taken into account.

At the same time the analized current was also measured in case of phosphorus at the point B. I_{P31} = 340 µA was found in presence of 160-350 V counterfield. This current is a part of the total one measured at the point A, but one has to think over that the source was not aligned to the optical system and the same effects as it was mentioned in the

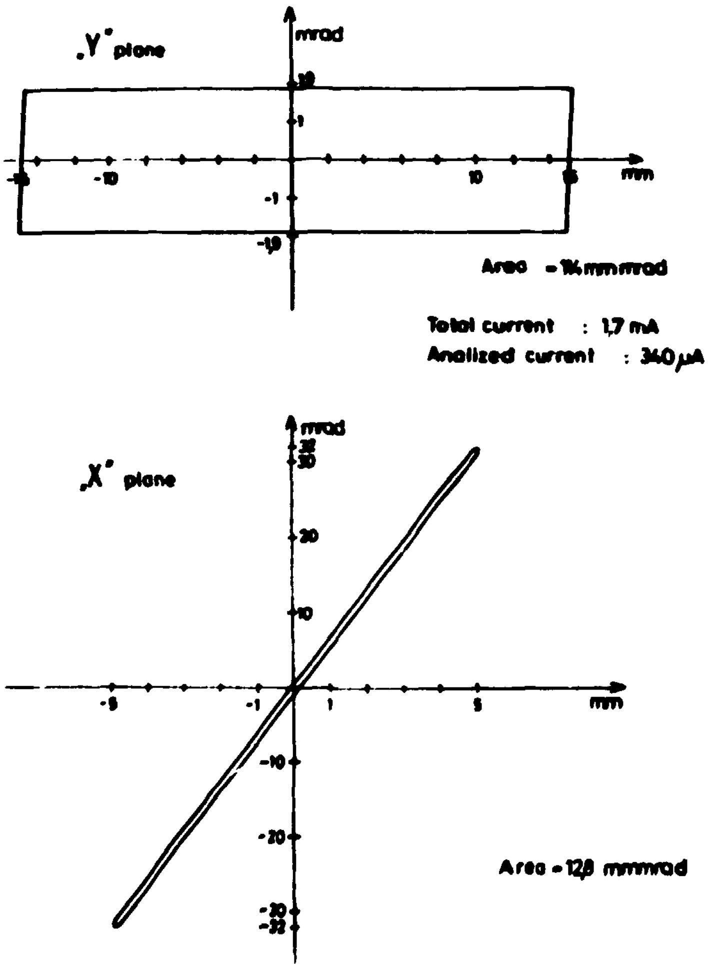

Fig. 6

Emittances

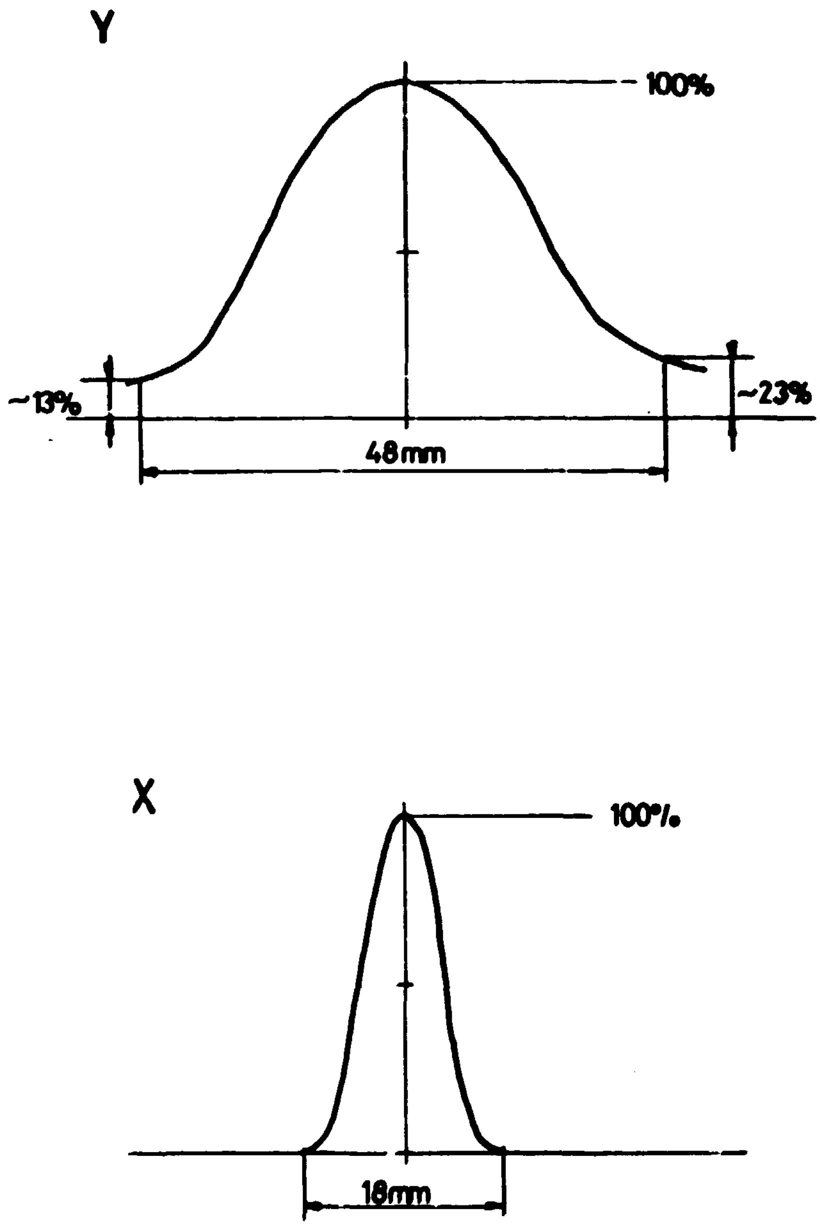

Fig. 7

The current distribution in the beam

Fig. 8

The ion source without high voltage covering

Fig. 9

The ion source with the extraction-focusing electrode assembly case of the current distribution can play an important role in connection of the transmission of the optical system. Having a well aligned and designed machine the analized izotopic beam current of phosphorus can be astimated of about 0,5-1 mA.

On Figures 8-9 the photos of the source are shown. The end flange and the holder tube to be seen on the photos are formed according to the requirements of the ILU-3a implanter in order to carry out the measurements reported above.

According to the life time of the cathode there are no final results. The ion source has worked for more than 100 hours during the period in which the above described measurements were carried out. No change in the emission or other parameters could be observed, so let us assume that the lifetime of the cathode will not be shorter than it was mentioned in the introduction.

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