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STUDIES ON A SIDENIUS /DANFYSIK-911/ ION SOURCE

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BUDAPEST

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ABSTRACT

The experience gained from the installation of a Danfysik-911 ion source /bought in 1971/ is reported. A modification in the extracting system has enabled a doubled starting current /e.g. 23-25 μA B^{11}/ to be obtained. Emittance diagram of the source and mass spectrum of the ion beam are presented.

АННОТАЦИЯ

В работе обобщается опыт, полученный при пуске в эксплуатацию источника ионов типа Danfysik-911, купленный в 1971 году. Изменением системы вытягивания удалось получить ток, в два раза больше, чем в оригинальной системе./например, 23-25 мка B^{11}/. Была снята диаграмма эмиттанции источника, а также масс-спектр полученного ионного пучка.

KIVONAT

1971-ben vásároltunk egy Danfysik-911 tipusu ionforrást. Cikkünkben összefoglaljuk a forrás üzembehelyezésénél szerzett tapasztalatokat. A kiszivó rendszer megváltoztatásával sikerült a kezdeti áram kétszeresét /pl. 23-25 μA B^{11}/ elérnünk. Felvettük a forrás emittancia diagramját, valamint a szolgáltatott ionnyaláb tömegspektrumot.

In 1971, on surveying our scientific tasks, the development of a heavy-ion source seemed to be necessary. Earlier, ion sources of this kind were not used; various versions of RF ion source generally being used. In the circumstances the main possibility thought to be suitable and having two distinct advantages was:

1./ To buy an ion source which could be applied for all possibile purposes and which could be fitted to each accelerator of our institute thus enabling time and money to be saved;

2./ With such a source and experience gained from it, we could start to develop our own heavy-ion source.

We took stock of the situation of the ion source market and chose the Danfysik-911-type ion source constructed originally by G. Sidenius. This is a so-called hollow cathode ion source with the ability to work at high temperatures and to produce ions of practically all the elements of the periodical system. This equipment is small in size, with a not too high /about 2oo W/ power consuption. The firm uses the source primarily in ion implanters.

I.

Having the source and power supplies we started to reproduce the parameters given by Danfysik. A stand /Fig.1/ was assembled enabling the current and mass spectrum of the source to be checked. The geometry of the extraction part of ion source was identical with that offered by the firm /Fig.2/. To focus the beam we used a three-electrode-einzel lens which was - similarly to the analysing magnet - originally constructed for other purposes. A block diagram of the electrical circuit is shown in Fig.3.

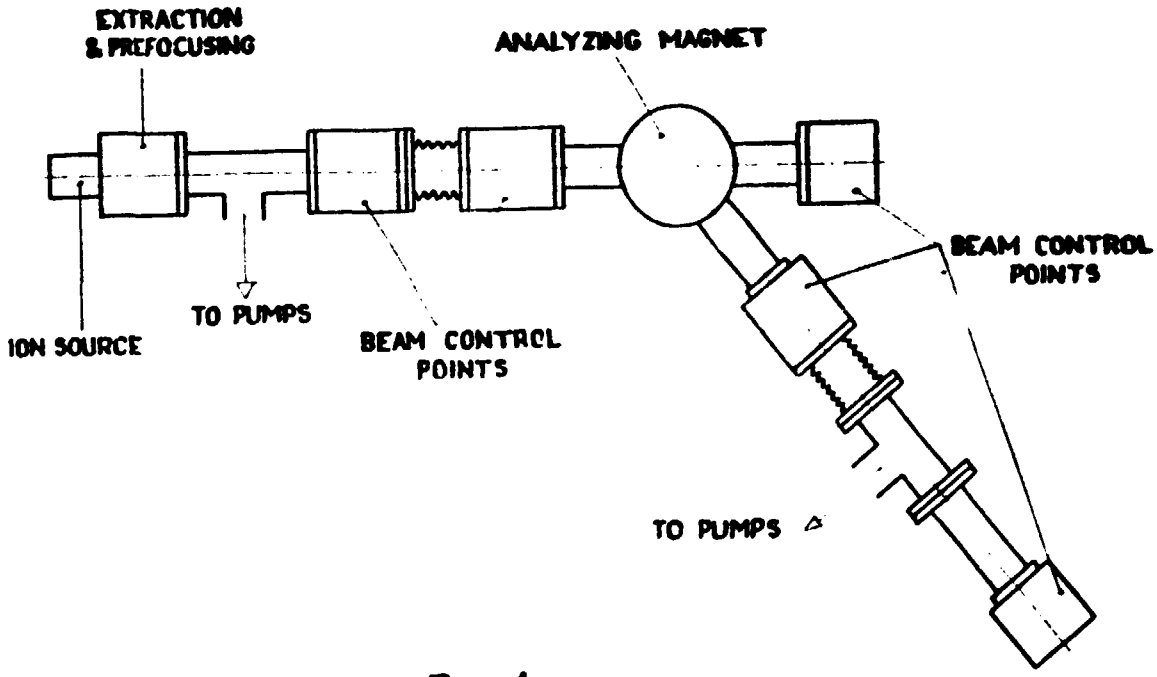

Fig. 1.

At the beginning we only wished to reproduce currents which may found in the catalogues. Such gases were used as in normal operation ie. Ar and He. The first results are given in Figs 4 and 5. The currents were measured at the beam control point situated just after the first pump connection. The values reached were only 25-30% of the currents given by the firm.

Having investigated the reasons for the small currents we found two basic problems:

1./ The housing and inner part of the source holding the discharge chamber were inaccurately fitted in this case; the fitting surface not being long enough to ensure the correct coaxial localisation.

2./ Discharges can take place outside the discharge chamber forming a shunt and as a result only a part of the total power supplies the useful discharge.

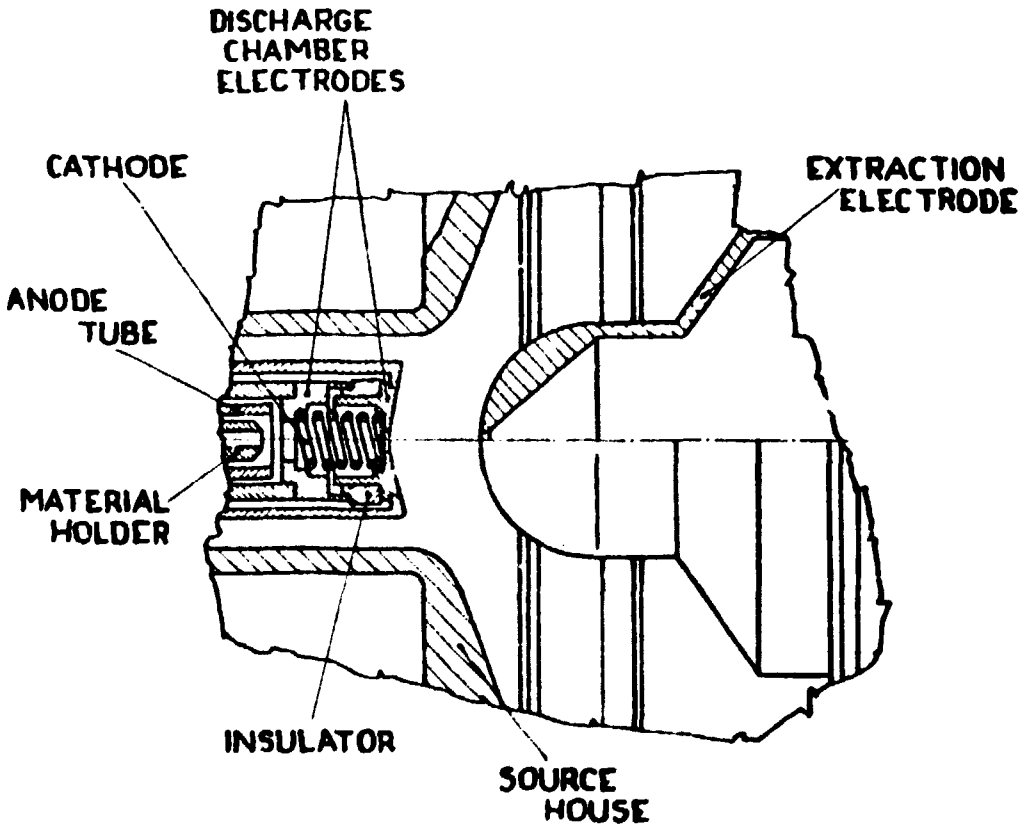
DISCHARGE
CHAMBER
ELECTRODES
CATHODE
EXTRACTION
ELECTRODE
ANODE
TUBE
MATERIAL
HOLDER
INSULATOR
SOURCE
HOUSE

Fig. 2.

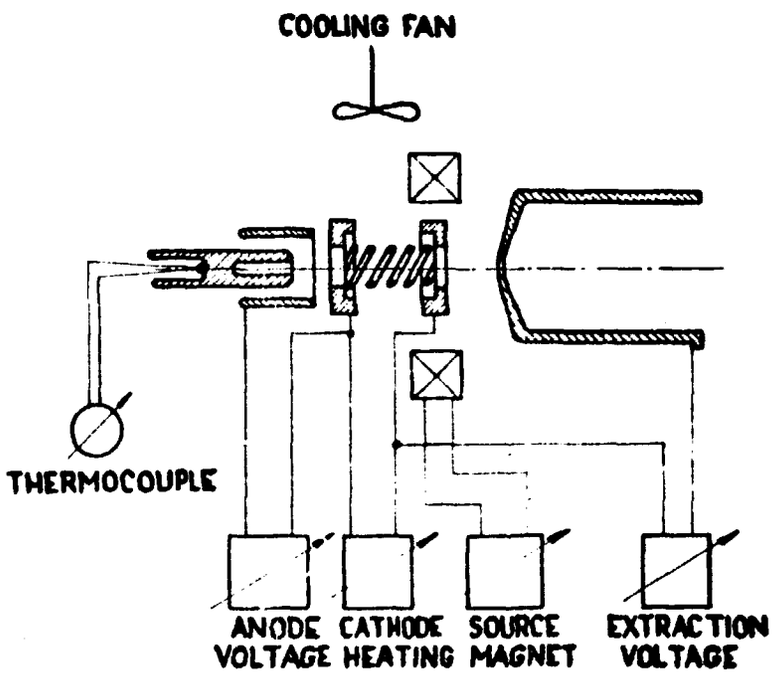

Fig. 3.

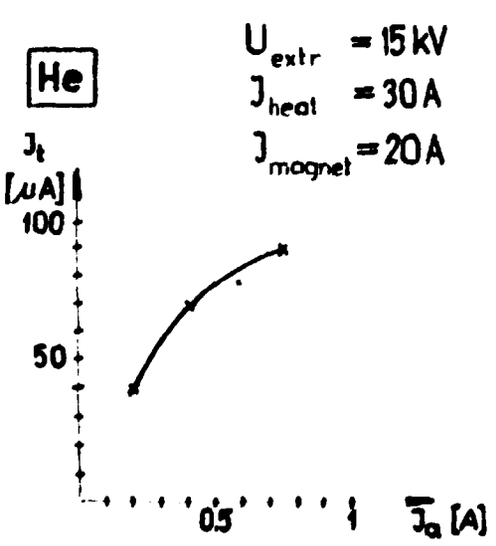

Fig. 4.

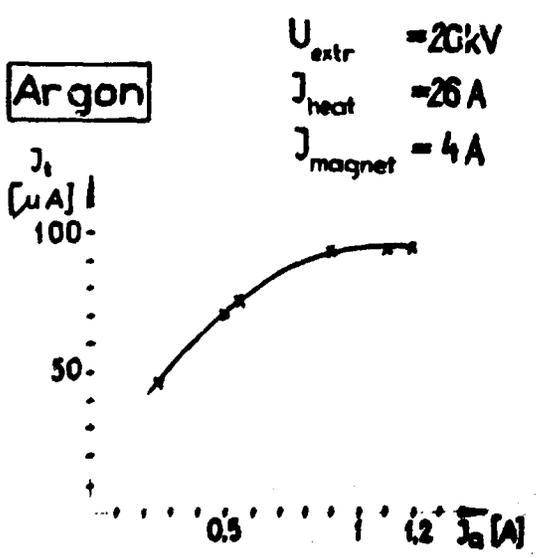

Fig.5.

The first problem could be quickly solved by turning and enlarging the fitting rings on a lathe. The second problem was eliminated by a more accurate assembling of the inner part, as where the anode is coaxial with the wall there is no side discharge. Having solved the above mentioned problems, it was possibile to investigate why we were unable to get the ion currents promised by the firm.

II.

Having rechecked the assembly shown in Fig.2, it seemed that the shape of the extraction hole and source housing was not sufficiently well fitted to the dome-shaped extraction electrode. The electrostatic field in this area is not enough strong to focus the beam into the hole of the extracting electrode and it was for this reason that the current was rather small. The shape of this part of the source suggested that a 150°-bevel-angle Pierce geometry be formed /Fig.6/.

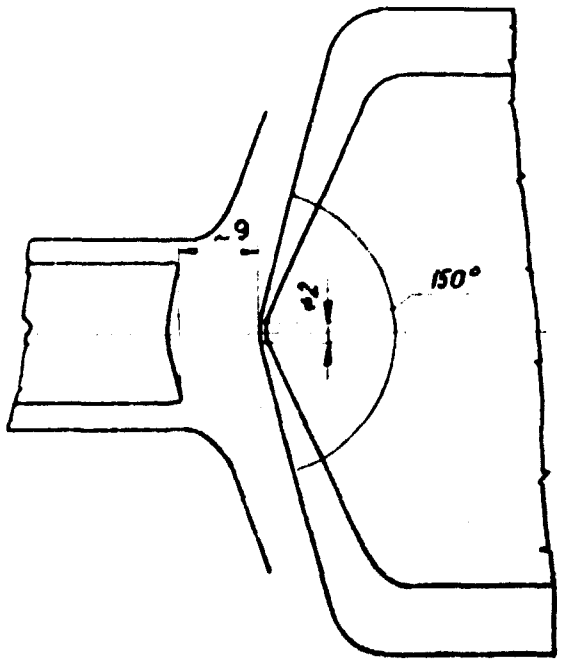

Fig.6.

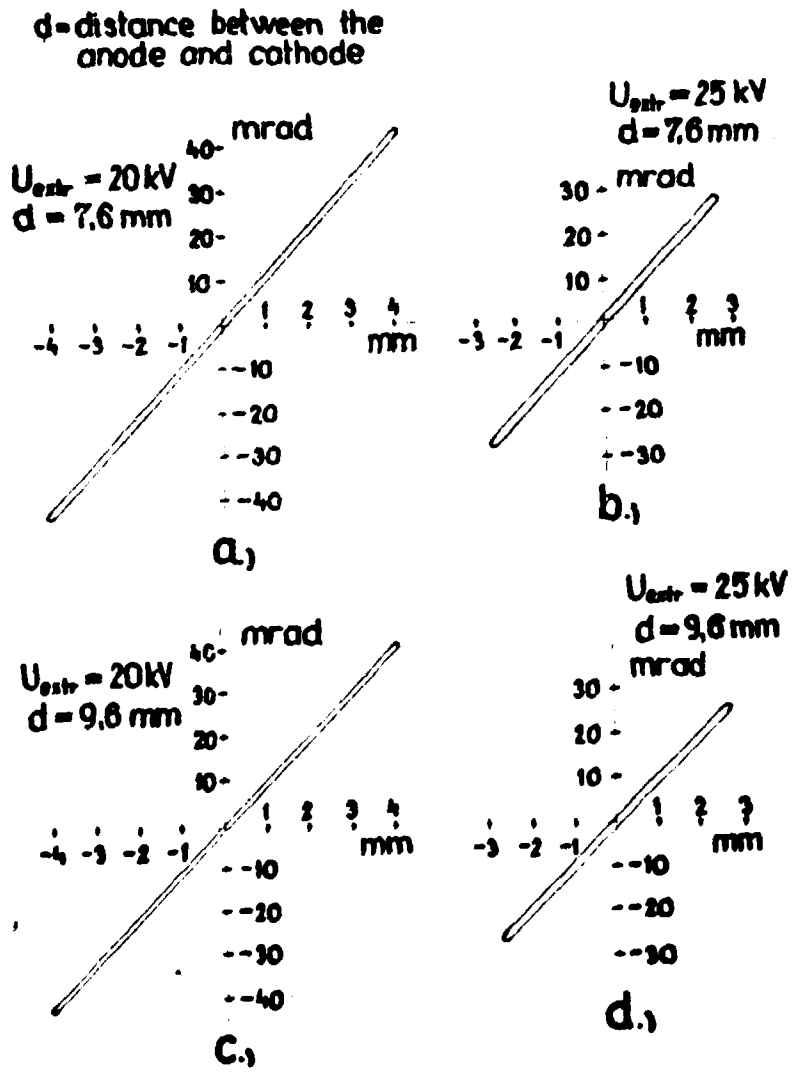
d - distance between the anode and cathode
U_{extr} = 20 kV
d = 7,6 mm
mrad
mm
a.)
U_{extr} = 25 kV
d = 7,6 mm
mrad
mm
b.)
U_{extr} = 20 kV
d = 9,6 mm
mrad
mm
c.)
U_{extr} = 25 kV
d = 9,6 mm
mrad
mm
d.)

Fig. 7.

The measurement was repeated with the new geometry and thereafter we measured the emittance diagram of the source. At the same time, because the source was initially recommended for ion-implantation with boron and phosphorus, we changed the gas used from He and Ar to BF_3 in the hope that the results would be better.
In the case of the Pierce geometry it was found that our einsel lens was not sufficiently well fitted to the source and extraction system, the cross-over of the beam was not located according to our calculations and previous measurements. The emittance measurements were therefore repeated. Diagrams are shown in Fig.7. It can be seen that the emittance does not strongly depend on the distance between the exit hole and extraction electrode but the bevel-angle of the beam is rather large, a fact which must be taken into account during the construction of the focusing lens. We also measured the whole current which was in accordance with the rates given in catalogues /Fig.8/.

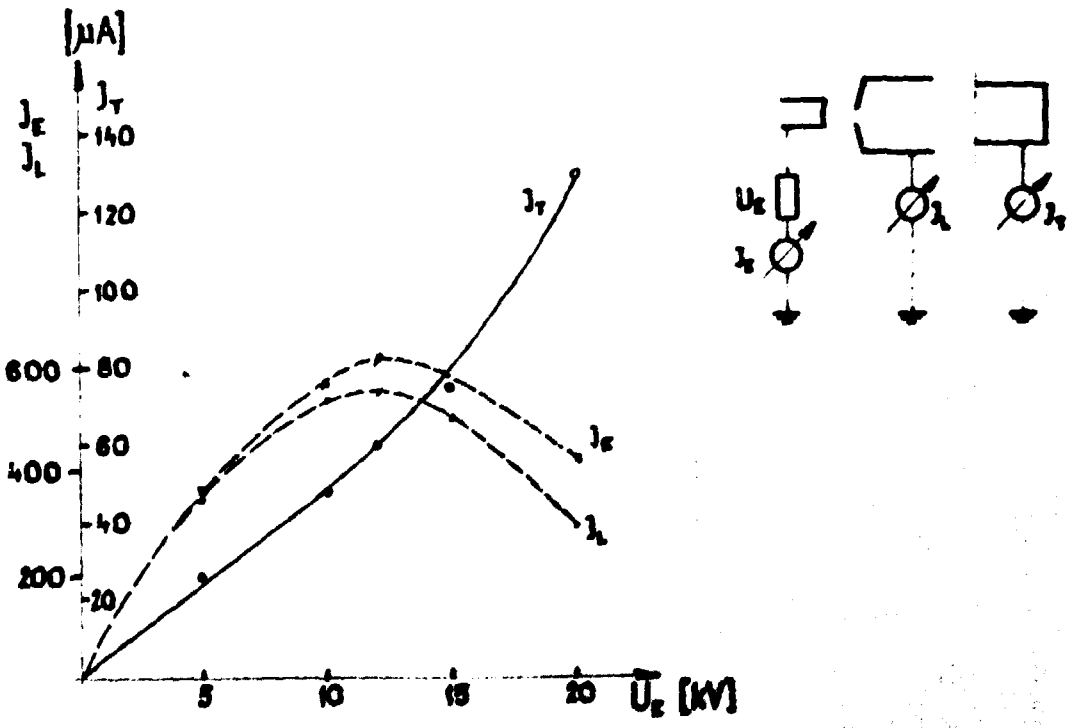

Fig. 8.

We should have liked to reproduce the mass-spectra too. The magnet we used for this had the following parameters: radius 5oo mm, gap 3o mm, magnetic field 45oo Gauss max, stability of the magnetic fiedl better than $1o^{-4}$. The poles have Rogowsky-shaped pole profiles. The new set-up is shown in Fig.9.
With this arragement it was possibile to obtain a current* of some 23-25 μA B^{11}. The working parameters of source met the specifications. We think the shape of the extraction electrode used here to be better than the one previously suggested in the sketch of Danfysik.
The following good working parameters were obtained:

I_{heat}	U_{heat}	I_{anode}	U_{anode}	p_{source}	$U_{extr.}$	$I^{B^{11}}$
23A	6,2V	1,95A	42V	o,2Torr	2oKV	23 μA

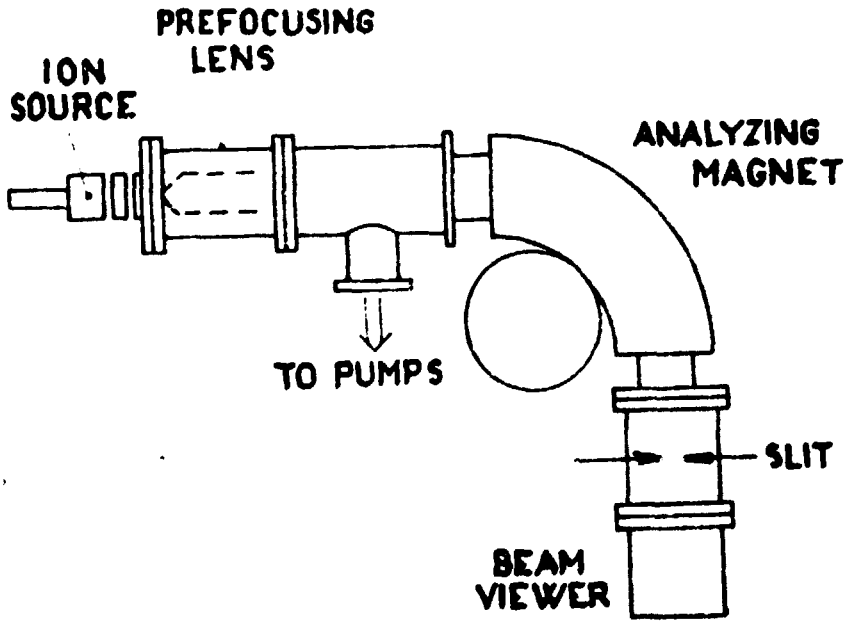

Fig. 9.

* All the currents were measured after the analyzing magnet applying a suppressing field against the secondary electrons.

GAS: BF_3

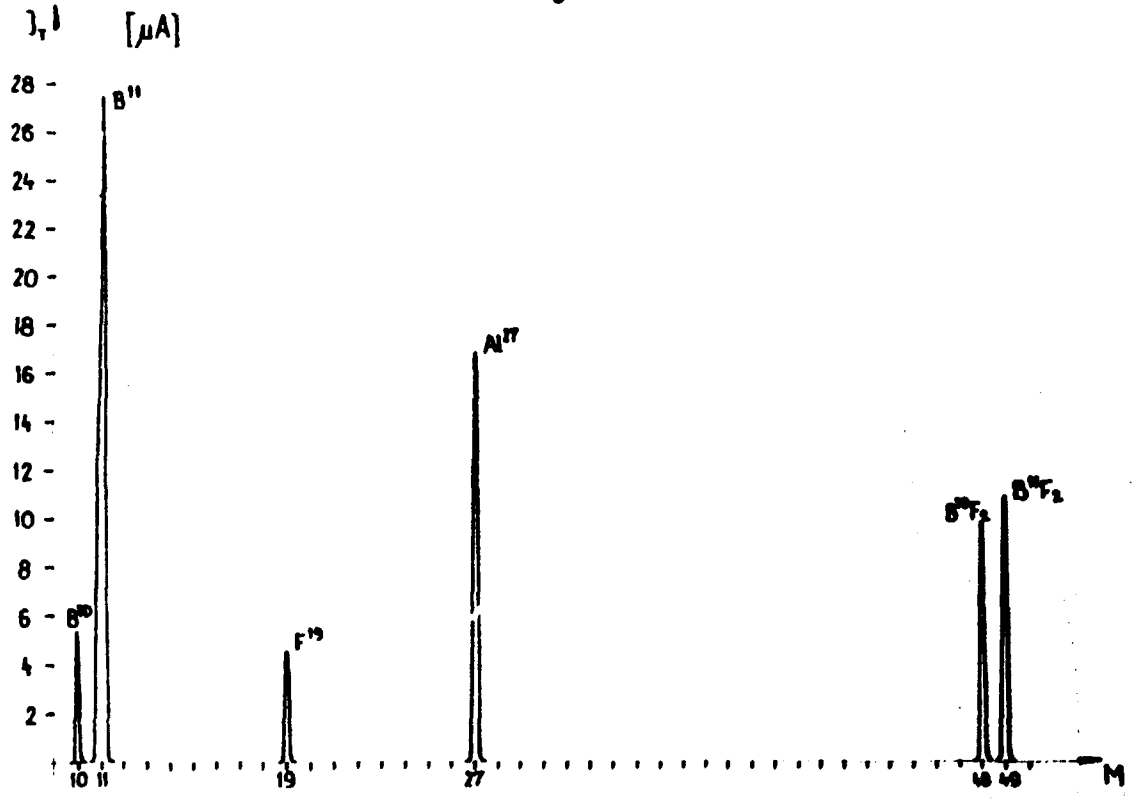

Fig. 10.

We measured the mass spectrum of the beam /Fig.1o/. This spectrum meets the expectations; the Al line is due to the alumina insulators which we applied instead of the boron nitride insulators. /Of course, we had some N and O too, but in very small quantities, see Fig.11/. We also investigated the lifetime of the source, i.e. how long it operates without the need for changing the cathode or cleaning the source inside. It was found that cleanliness plays a very important role. A thin layer arises on the walls of the ion source - also in the case of noble gases - which may cause sparks and short circuits between the anode and cathode. In the case of corrosive gases such as BF_3 this factor must strongly be taken into account, however, it is mainly the presence of humidity - even in very small quantities - that is highly corrosive.

For production of ions of materials having high melting points it is recommended in the literature to use their chlorides. This was attempted starting with BCl_3. Our results - if they could be called results - were negative. The upper and lower electrodes of the

discharge chamber /see Fig.2/ were corroded after a few minutes work. This could happen in spite of our meticulous care in putting the system together. The balloon and tube between the balloon and ion source was pumped for several hours at a temperature of over 1oo°C. The balloon was filled with BCl_3 under a vacuum of about $1o^{-5}$ Torr and the control measurements of vacuum did not show any leak or presence of water vapour in the system. Electrodes of different materials, such as W, Mo, Ta, SS were tried with no success. With no more time at our disposal we had no wish to continue the corrosion studies but we have to remark there could be very considerable corrosion if chlorides are used. Not having such intensive corrosion as mentioned above, the cathode of the source has normally a lifetime of about 4o-5o hours. After that time the cathode wire becomes very thin and is no longer adequate. After 4o-5o working hours it is necessary to clean the source if analyzed currents of about their maxima are required. If the source is used under difficalt conditions - for example in a pressurized Van de Graaff accelerator - it is suggested to work at reduced parameters and power - first of all with reduced heating voltage and current - thereby enabling longer source-lifetime.

This source is also suggested for ions of solid materials. We wished to check its functioning in such cases too. As, according to the catalogues, it is very easy to obtain phosphorus ions, we commenced with this. The material holder of the source was filled with red phosphorus and pumped till we had no adsorbed air and humidity. In this version of 911-type ion source there is no need to heat the material separately, this can be done by the discharge itself. To find definite temperature one can move the holder from outside /see Fig.2/. After a series of experiments we observed that in the case of materials easily evaporable the temperature as well as the rate of evaporation is very sensitive to the position of the holder. Namely either the evaporation does not start or it happens so quickly that the material from the tiny chamber /1,5 mm dia and 5 mm long/ can evaporate during 1o-2o sec. A bigger chamber has been made /2 mm dia and 15 mm long/ but it was not possible to reach a longer working time in the case of phosphorus.

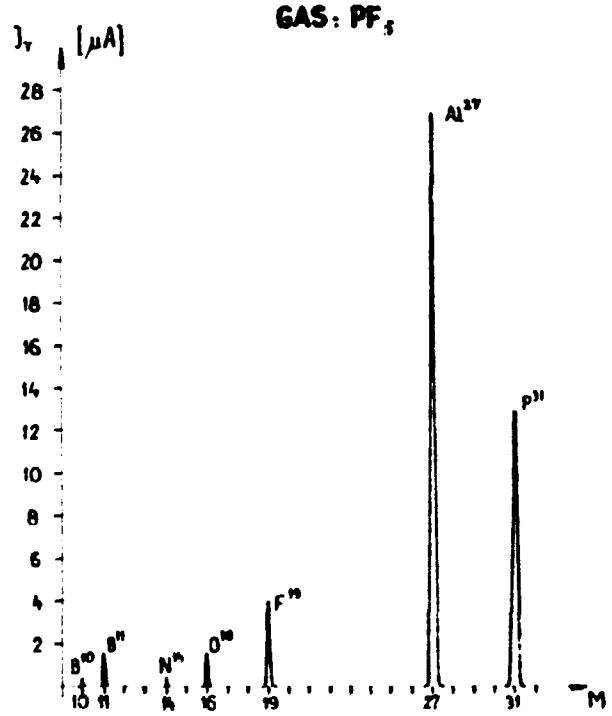

Fig. 11.

According to our well-founded experiences in the case of BF_3, PF_5 was applied and no problems occurred and some 40-50 μA current was obtained at the same parameters as for boron. The gases BF_3 and PF_5 were conducted through the same tube. This explains the boron lines originating adsorbed BF_3 on several places of the source and the tube.

Summarizing: In our view the Danfysik 911-Type ion source appears to be suitable for producing ions of gaseous materials. Its working time /without cleaning and maintenance/ is long enough for convenient use, possibly reaching a few times 10 hours even in the case of corrosive gases. If one wishes to get ions from chlorides, one has to work very carefully. Our efforts in that case achieved no results. Similar care is recommended in the case of solid materials too, because heating the materials directly by the discharge is a very good idea but it is very sensitive to the position of the material holder.

Kiadja a Központi Fizikai Kutató Intézet
Felelős kiadó: Kiss Dezső igazgatóhelyettes
Szakmai lektor: Vályi László
Nyelvi lektor : N. Shenker
Példányszám: 240. Törzsszám: 74-10.138
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