MODIFIED He ION SOURCE USING Cs VAPOR CHARGE EXCHANGE*

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Summary

Earlier versions of the He^- source suffered from cesium metal collecting on insulators and entering the r. f. source. A single acceleration gap is used to reduce the number of insulators requiring protection and additional shielding of the remaining insulators is provided. The new version also uses a gridded focusing element. Additional baffling and smaller entrance and exit apertures for the exchange canal have eliminated the flow of cesium vapor into the r. f. source. A further modification to produce higher current adds an einsel lens between the r. f. source and the exchange canal.

* Work supported in part by the U. S. Atomic Energy Commission.

Introduction

The efficient generation of He^- beams is of interest for the production of energetic alpha particles in tandem Van de Graaff accelerators. Production of beams greater than a hundred nanoamps is difficult using the duoplasmatron source supplied with the tandem. In the conventional arrangement, a He^+ beam is extracted from the duo-plasmatron, accelerated through approximately 40 kv, and then charge exchanged on hydrogen gas. The exchange efficiency for this process is only about 10^{-5}.[1] Charge exchange on cesium vapor has a much higher cross section[2] and the source described in this paper takes advantage of this fact to produce beams of approximately 2 μa. The exchange efficiency in this case is one to two percent. Earlier versions of our source suffered from build-up of metallic cesium on insulators and from lower output currents.[3]

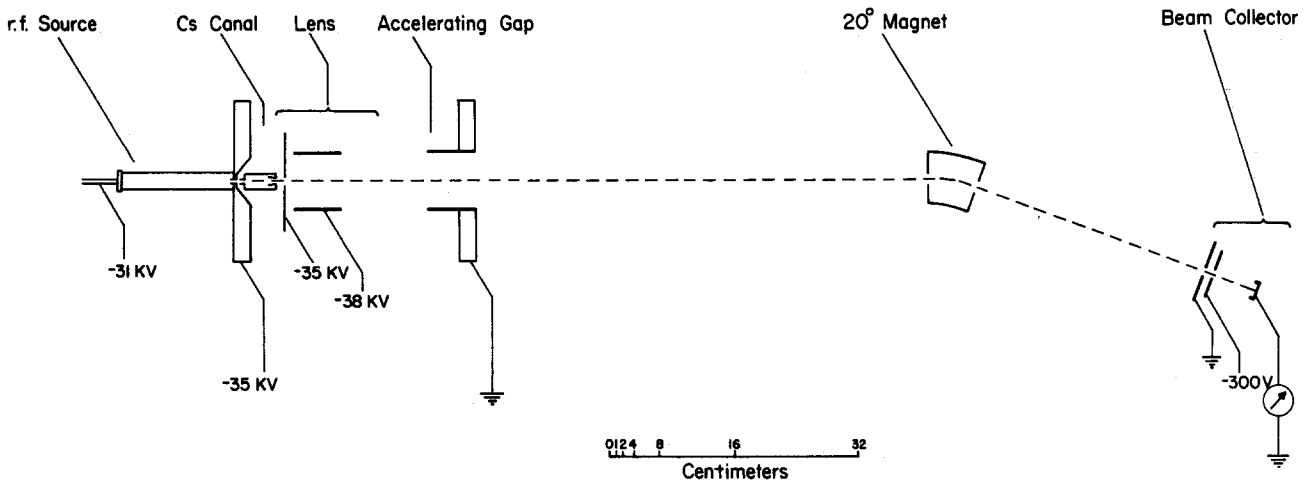

Fig. 1. Arrangement used to test the He^- source.

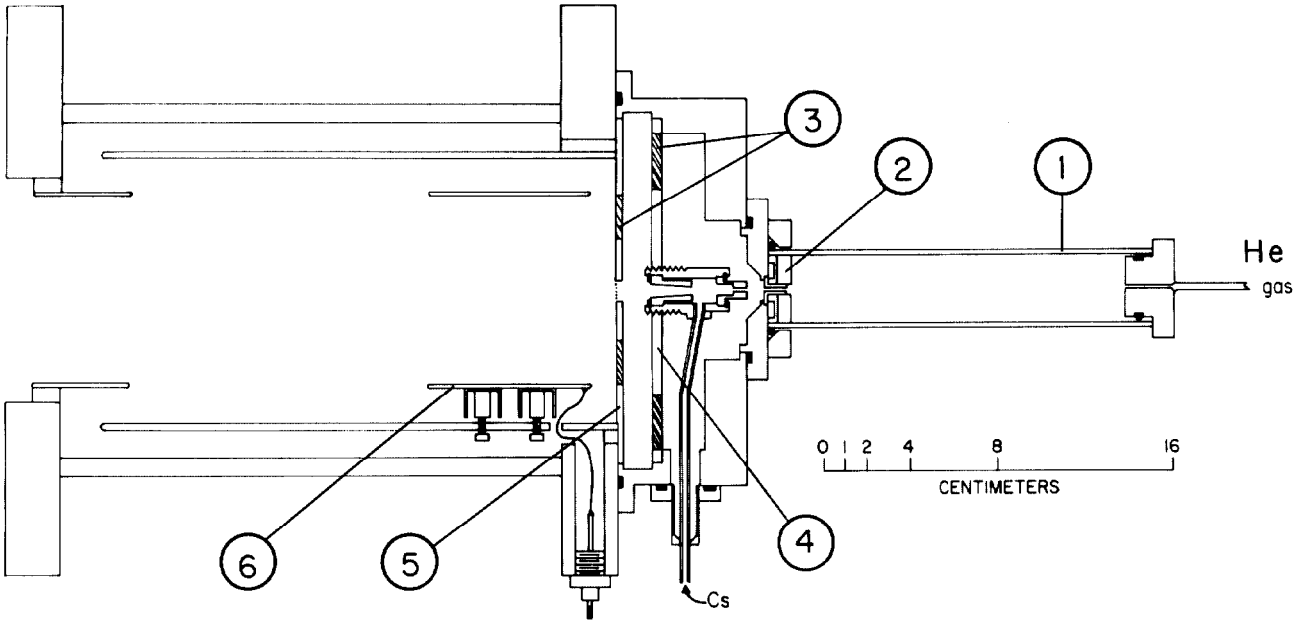

Fig. 2. Detail of the source assembly. (1) quartz discharge bottle, (2) quarts insulating disc, (3) pump-out holes, (4) stainless steel exchange canal support, (5) stainless steel baffel to limit Cs flow, (6) lens electrode.

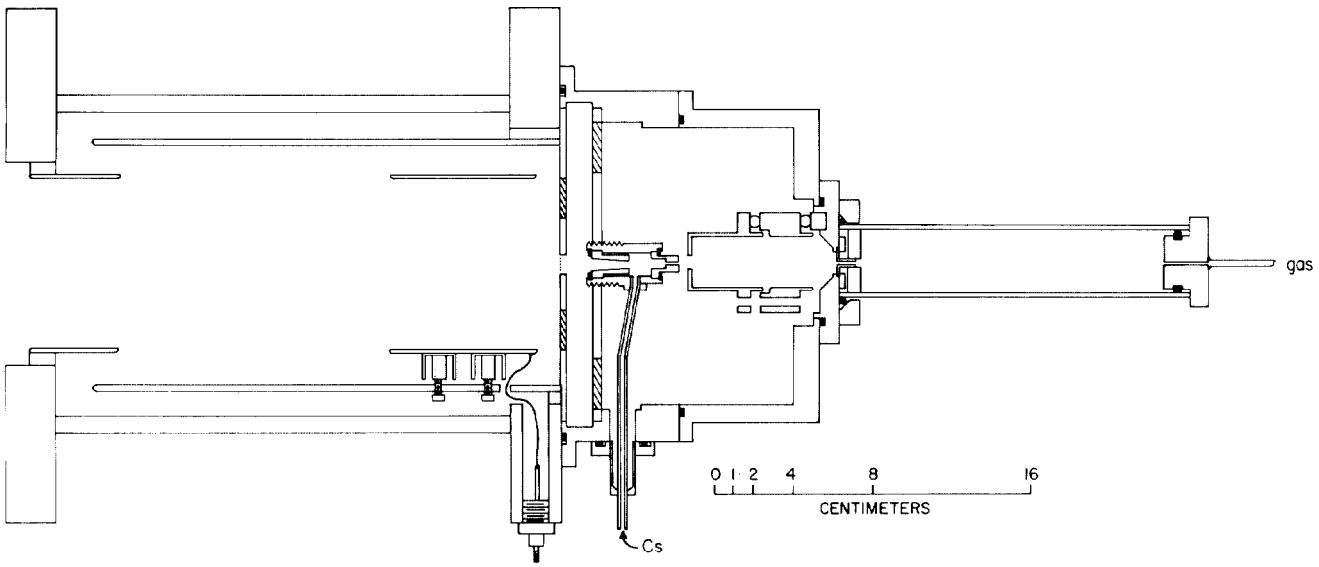

Fig. 3. Representation of modifications being made to source of Figure 2 to increase the yield.

System Description

Figure 1 illustrates schematically the arrangement used to test the source. The source is located approximately 1.2 meters from an analyzing magnet, with a slit system and collector cup about 50 cm beyond that. Four keV He^+ ions are produced by an r.f. source and allowed to drift through an exchange canal supplied with cesium vapor. The cesium vapor is generated in an external oven maintained at a temperature of about 200°C and metered into the exchange canal through an all stainless steel bellows valve. Iron-constanstan thermocouples monitor the temperature of the exchange canal, its feeder tube, and the oven, and provision is made for separately controlling their temperatures.

It has been found that the most satisfactory way to maintain a stable output is to first open the valve fully, thereby permitting excess cesium to flow into the canal from the oven. The cesium vapor density is then controlled by varying the temperature of the exchange canal. If the temperature of the canal deviates from optimum by more than approximately ±5°C, a significant decrease in output current is observed. The optimum temperature for our exchange canal was found to be about 125°C. Cesium consumption for this source is such that one gram of cesium is sufficient for approximately 30 hours of running time.

The mechanism responsible for the production of He^- by charge exchange on cesium vapor has been proposed as follows by Donnally:[2] The only He^- state which does not undergo autoionization is the (1s, 2s, 2p) $^4P_{5/2}$ state.[4] The He^+ - Cs collision leaving the He° in the (1s, 2s) metastable state is almost resonant, and hence is presumably the dominant reaction. In a second collision, metastable (1s, 2s) He° picks up an electron in the 2P orbital to form the He^- ion. We observe, in support of this, that even a trace of cesium vapor first causes almost 100% conversion of He^+ to He°, but only after the cesium vapor pressure has been raised considerably does the production of He^- occur. If the cesium pressure is further increased, the yield of He^- decreases, probably because of the increasing importance of triple collisions.

Figure 2 is a drawing of the source assembly. A quartz bottle, (1), is used to contain the plasma generated in the helium gas by an Ortec r.f. oscillator. The oscillator is capactively coupled to the source in the conventional manner. The usual base insulator and saphire sleeve found on an r.f. source have been replaced by a single 1/4" thick quartz disc, (2), cemented to the quartz bottle. A hole the size of the outside diameter of the extractor is drilled in the disc and the extractor is recessed therein. This arrangement is much more rugged than the conventional one making it essentially impossible to fracture the quartz around the extractor by sparking.

A magnet coil is placed around the source bottle near the base plate. A cold rolled steel or magnetic stainless steel extractor canal is used and the He^+ beam is extracted through it by a 4 to 5 kv probe voltage. The use of ferromagnetic extractor increases the yield of He^+ from the source, apparently by increasing the magnetic flux in the immediate vicinity of the extractor tip and hence the plasma density at that point. Leads for the canal heater and thermocouples are brought in through feedthroughs which are not shown on this view.

The cesium vapor is passed into the canal through a thin walled stainless steel feedthrough which provides the necessary thermal isolation between the cesium feeder tube and the source base. Staggered pump-out holes, (3), are provided in the stainless steel plate which supports the cesium canal, (4), and in the plate which provides a cesium baffle, (5).

A lens electrode, (6), is provided, with its insulators shielded by aluminum cups. To prevent the beam aperture in plate (5) from introducing large aberations in the lens, a grid of 0.0125 mm tungsten wires spaced 0.5 mm apart is spot welded across the aperture. This grid provides an equipotential surface which appears as a plane facing the lens element.

Insulation for the accelerating gap is provided by a 15 cm diameter, 22.5 cm long section of "Pyrex" glass drainline. The flanges used for clamping it to our end plates were omitted from the drawing for the sake of simplicity. A single acceleration gap is used to simplify the problem of shielding the insulation (i.e. the glass) from cesium deposits. The reentrant construction provides very good shielding of the glass and the problem of metallic cesium buildup on the insulators seems to have been eliminated. Our acceleration arrangement provides a number of advantages: 1) low pumping impedance; 2) a small vacuum gap; 3) a large insulating area shielded from direct flow of cesium

vapor; and 4) simplified beam optics.

A steady beam of 2 μa of He^- is normally obtained from this source with 3.5 μa having been observed. Tests have been made with the source on the University of Wisconsin tandem accelerator and good transmission was observed.

We are in the process of testing a further modification of this source to provide even higher currents. The modification, shown in figure 3, consists of adding an einsel lens between the r.f. source and the exchange canal to utilize a larger solid angle of the He^+ beam from the probe canal. Preliminary tests have produced a steady beam of 3.5 μa. When the optics are corrected to fully utilize the available He^+ beam, approximately 10 μa of He^- current should be obtained.

References

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