STUDIES ON ECR4 FOR THE CERN ION PROGRAMME

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Abstract

The CERN heavy ion community, and some other high energy physics experiments, are starting to demand other ions, both heavy and light, in addition to the traditional lead ions. Studies of the behaviour of the afterglow for different operation modes of the ECR4 at CERN have been continued to try to understand the differences between pulsed afterglow and continuous operation, and their effect on ion yield and beam reproducibility. The progress in adapting the source and ion beam characteristics to meet the new demands will be presented, as will new information on voltage holding problems in the extraction.

I Introduction

Besides the normal lead operation scheduled for 2002, it is necessary to prepare several new types of beam for physics experiments in the CERN Super Proton Synchrotron (SPS) and to anticipate requests that could arise in the Large Hadron Collider (LHC) era. The preparation of a He^{1+} beam and the first trials of an indium beam are given here. Although the lead beam has been in demand for Ion Induced Desorption Studies [1] in test vacuum chambers, free time has been used to test new ideas and modifications. Some experiments on the afterglow and a study of the extraction system are also reported.

II. He^{1+} operation

A muon production experiment requested an α–particle beam. Because of the configuration of the CERN PS Booster (PSB) this requires a He^{1+} beam, (similar acceleration parameters to the Pb^{53+} beam) from the linac which would be stripped after the PSB. Because of the strictly fixed injection energy of 2.5 keV/u into the Radio Frequency Quadrupole (RFQ) the extraction voltage of the source should have been 10 kV for He^{1+}. Experimentally, a slightly higher voltage (10.8 kV) gave more intensity at the end of the linac.

For 500 eμA at the entrance of the RFQ, there was 270 eμA at exit of the RFQ and 160 eμA at the end of the linac at 4.2 MeV/u. The high losses can be attributed to the limits of the accelerating structure and emittance problems. To obtain the above results, the same extraction gap as for standard lead operation was used, but when this gap was reduced by a factor 2 to give an extraction field strength comparable to nominal lead operation, the current was ~40% lower and unstable, with a sawtooth structure.

III. Indium operation

In 2003 a SPS fixed target physics run with indium is scheduled. Although the initial request was for silver (most common isotope ^{107}Ag, 53%) the strict energy acceptance of the PSB would have required the use of pure silver isotopes. Indium, being virtually mono-isotopic, readily available and having a vapour pressure curve between silver and lead seemed more suitable. A test was initiated in the linac using metallic indium with the standard micro-oven (Figure 1) evaporating the metal vapour into the ion source oxygen plasma.

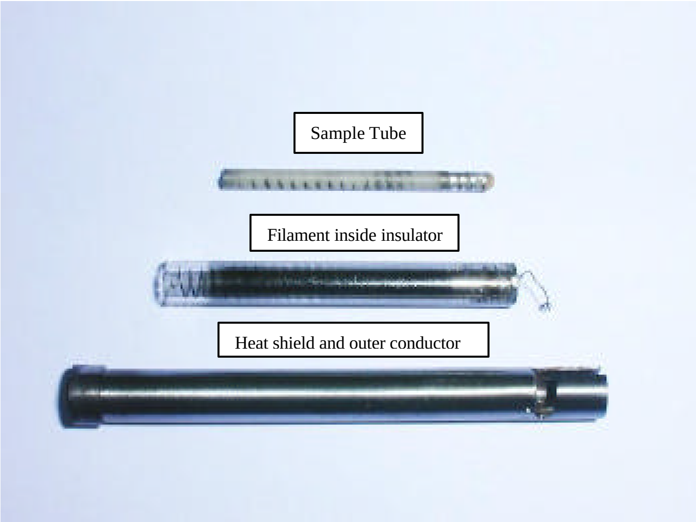

FIG. 1 The oven used for lead or indium.

If it is assumed that the vapor pressure of indium in the plasma chamber should be comparable to that of lead, then a temperature of around 650 °C (melting point 156.6 °C) is needed. At this temperature the indium is very liquid, easily flowing out of the sample tube. As liquid indium wets quartz and ceramics, short-circuits occurred in the heater filament. Closing the sample tube with a leaky plug of molybdenum alleviated the problem. However, if the oven power was maintained constant (instead of the voltage as is usual), the oven could maintain temperature, even with partial short-circuits. The necessary modifications to heat the oven under power control should be available for the next test.

With up to 80 eμA of In^{21+} out of the RFQ and accelerated through the linac to 4.2 MeV/u, approximately 25 eμA of In^{37+} was obtained after the stripper foil without optimising the linac parameters (over and above a simple scaling). It was of interest to note that the optimum charge state for linac operation (In^{15+} which is very similar to Pb^{27+}) proved difficult to produce in any quantity as is shown in a typical charge state distribution (Figure 2) whereas 21+ could be readily maximised. This could possibly be due to a too high plasma temperature and a poor yield for this charge state in afterglow mode. No attempt was made in the time available to experiment with the "normal" pulsed mode of operation.

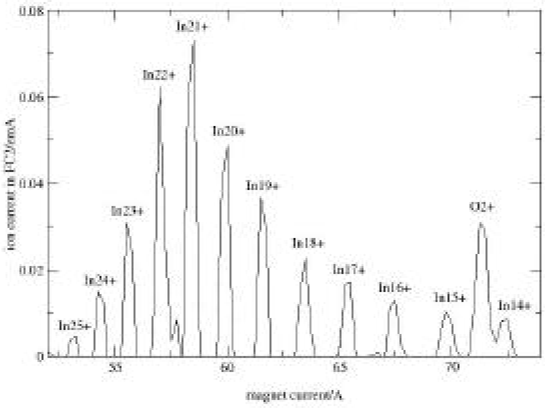

FIG. 2 Indium charge state distribution (2.5 keV/u).

Overall, the long-term stability would not be satisfactory for operation. The source has to be reoptimised several times per day, as compared to one or two times per week for lead operation. Considerable care was needed to maintain the oven power constant. Improvement of the stability will be the main objective in the next series of tests. Two possible solutions will be tried to improve stability: firstly to modify the present, simple, voltage control of the oven heating to a constant power controller; and secondly to investigate the use of indium oxide instead of metallic indium, possibly with a support gas other than oxygen.

Additionally, for operation it would probably take around 24 hours to change the oven and to come back to a stable and intense beam (~4 hours in the case of lead) mainly due to the care needed to avoid overheating the sample tube. This could become an important consideration since the consumption of indium (15-20 mg/day) was somewhat higher than that of lead (4-8 mg/day) during these tests.

IV. New investigations on the afterglow effect

The flexibility of the source timing system enabled some experiments to be carried out with lead beams in afterglow mode to investigate the effects of plasma heating times. As these tests required the source timing to be asynchronous with respect to the linac, beam intensities could only be measured at a Faraday cup (FC2) in the dc injection line [3]

TABLE 1. Effect of heating time (Pb $^{27+}$)

RF pulse length ms.	ion current in FC2 eμA.
50 (standard)	56
40	52
30	32
20	12

Initially, for a given source setting the length of the microwave pulse (i.e. plasma heating) was varied whilst maintaining the standard source pulse repetition rate of 10 Hz. Table 1 shows the variation of current with heating time which is a demonstration of the breeding time of the chosen charge state. Figure 3 shows the Faraday cup signals at 10 and 40Hz.

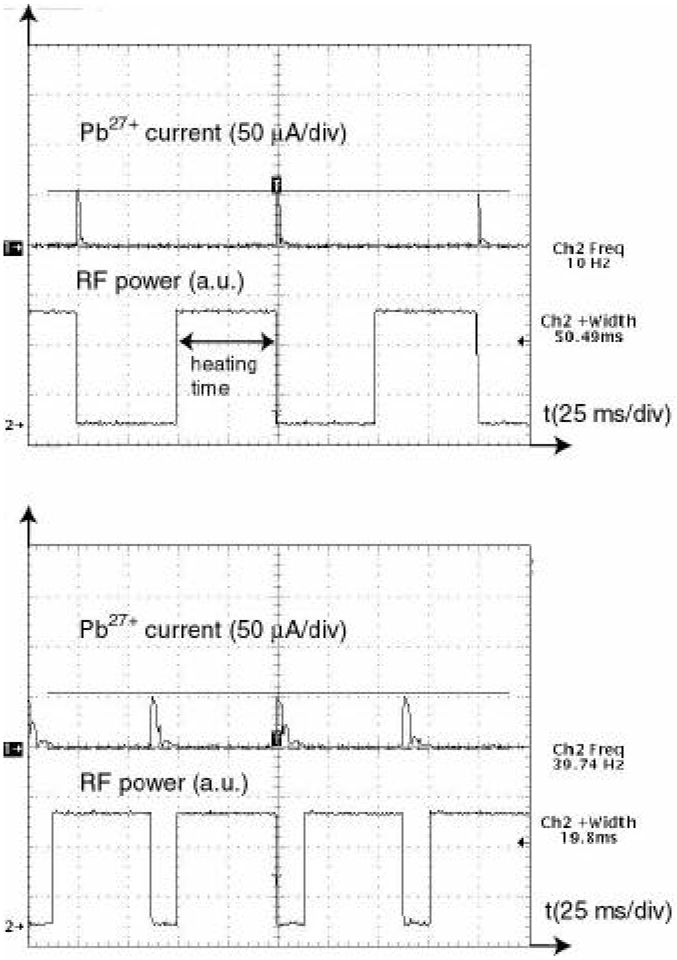

FIG 3. Effect of heating time and repetition rate for Pb $^{27+}$. Upper trace, beam current, lower trace RF power. Repetition rate is indicated by Ch2 Frequency.

However, if the repetition rate for the 20 ms heating was increased, the peak current at FC2 rose until at 40 Hz it reached 48 eμA. There are two possible explanations. Firstly, at the instant the RF is switched on, electrons that remain trapped in the magnetic field in the plasma chamber create an initial electron component in the plasma which leads to a shorter breeding time for the desired charge state [3]. Alternatively, together with the electrons, there are still ions in the plasma chamber (the afterglow plasma has not completely decayed) that help create a new plasma with the next microwave pulse and thus reduce the breeding time. VUV or X-ray measurements of the characteristic lines of ions between the heating pulses could indicate which explanation is correct.

Changing the RF repetition rate on a O^{2+} beam shows a smooth transition between real pulsed operation and quasi constant beam as can be seen in figure 4 where the repetition rate varies from about 3 Hz at the top to 10 Hz at the bottom. The afterglow is most intense at an intermediate frequency.

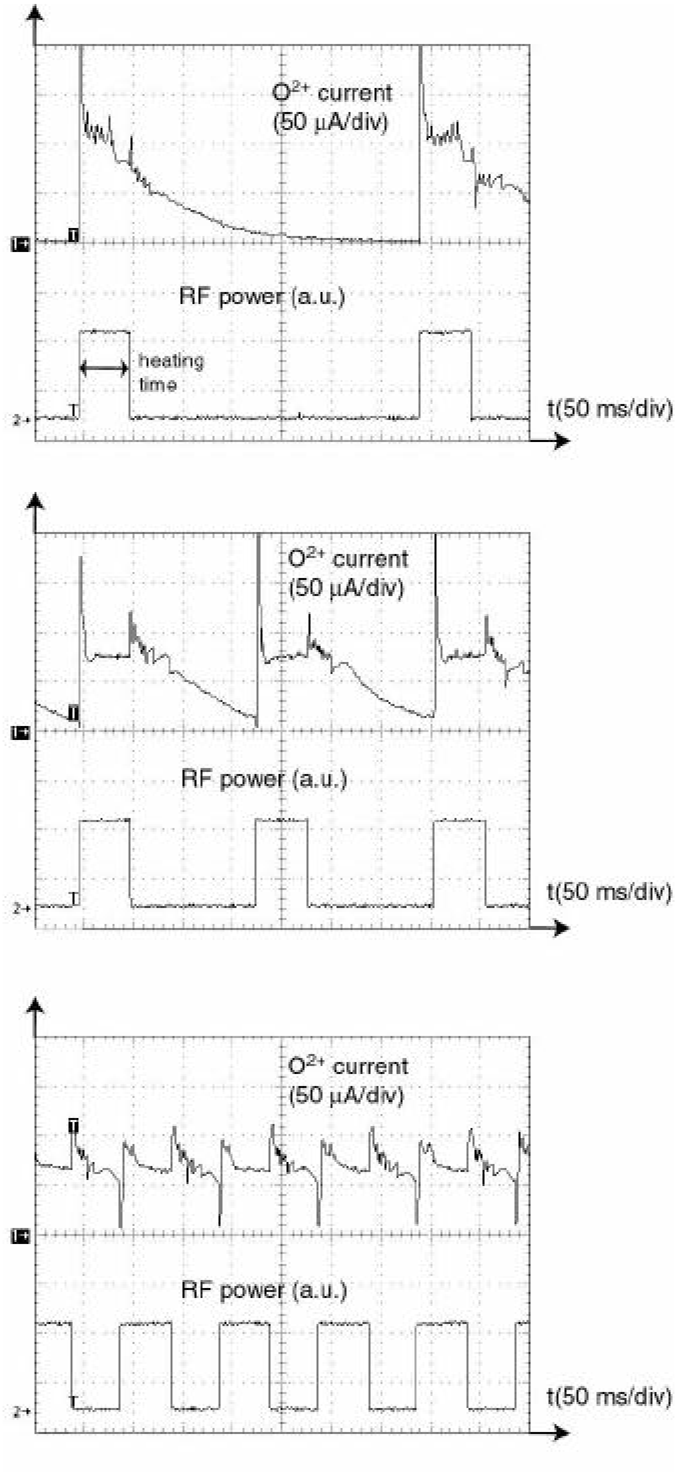

FIG 4. Repetition rate effects for O^{2+}. The beam current zero is marked by the black boxed numbers.

V. Solution of the voltage holding problem

The ECR4 uses a simple two electrode extraction system and an axially adjustable extraction mechanism was designed. With the desire to simplify the manufacture of the grounded electrode a smooth puller was produced [4]. Unfortunately this gave extreme voltage holding problems with high leakage currents (several mA) with magnetic field in the extraction gap and independent of the presence of plasma but unrelated to the distance between puller and plasma electrode. The discharge is believed to originate in low field areas between the cylindrical part of the puller and the main ceramic insulator. This problem was finally solved by adding a small "geometrical perturbation" (a lip), as in the original design, to the smooth puller about 1 cm. from the ground plane.

VI. Outlook

Apart from the continuing effort to improve the yield of lead ions from the ECRIS, it is evident that an effort will be needed to understand the limitations of the source in producing high intensities of light and medium mass ions [5]. This will become important in the LHC era in defining the number of ion sources and injectors that will be needed to satisfy the experimental physics requirements.

References

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