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PROBLEMS OF TRANSMITTING A HIGH INTENSITY PRIMARY H^+ ION BEAM IN THE LAMB SHIFT SOURCE

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ABSTRACT

This article summarizes experimental facts about the formation of high intensity H^+ ion beam, observed in the course of development of a high intensity Lamb shift source. Various curious observations can be understood in terms of a beam plasma which is deficient in swarm electrons.

Technical difficulty of getting high intensity output of polarized ions in the Lamb shift source seems to be mostly connected with the problem of formation of high intensity primary H^+ ion beam transmitted through a long path. This problem has been investigated extensively at the tandem laboratory of Kyushu University.

In the system we developed, the diameter of extracted ion beam was taken very large (40 mm) for the technical reason of getting a rather high beam current of several tens to 100 mA. For introducing this wide ion beam into the Cs-cell various arrangements have been tested. The simplest way was to put the Cs-cell just behind the extraction grid. With this arrangement, however, we could not get a high intensity output of polarized ions. This result is probably due to the quenching of H(2s) atoms effected by the atomic field of Cs ions which are generated in the Cs-cell with a very high density.**

In the system finally adopted a magnetic lens is used between the extraction grid and the Cs-cell. Normally a factor of two increase of the

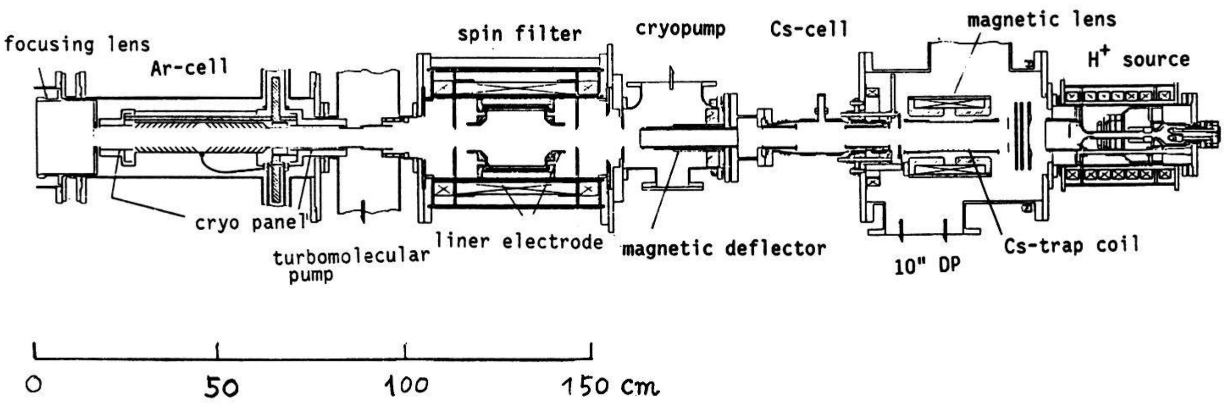

Fig.1 Lamb shift source of the Kyushu Univ. Tandem Laboratory

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**This point is discussed in another paper presented to this workshop.

output polarized ion current can be obtained by using this lens with a weak strength. The whole arrangement of the present Lamb shift source is shown in Fig. 1. This source has given the highest output intensity of polarized ion beam (∿3μA at P=80% for $\vec{H}^-$) among the existing Lamb shift sources, but the fraction of effective H^+ intensity extracted from the primary positive ion source is of a few percent.** This low efficiency is mostly due to a poor optical property of the extraction grid system, as shown in another paper submitted to this workshop. This point will be greatly improved if a proposed design of the extraction grid in this paper is used.

Problems of the primary H^+ ion source and the extraction grid are described in other papers presented to this workshop. Problems proper to the beam transmission through a long path will be treated in this paper.

With a long beam path in the present source, stringent requirement is put on both the beam extraction and the space charge neutralization. Allowable beam divergence for the primary H^+ ion beam is about 0.4° at half angle. This is not attained with the present system, so only roughly a quarter of beam passing through the Cs-cell is accepted by the Ar-cell.

Degree of space charge neutralization must be better than 99.9% in order to avoid beam broadening of 0.5° at half angle. Of course the Cs-cell itself is a very efficient source of low energy electrons but it is far from the extraction grid, so an extra electron source near the extraction grid is indispensable. For this purpose hot tungsten filaments are installed, crossing the beam, as close as possible to the extraction grid. This location is necessitated for production of a high intensity ion beam. Use of several filaments in parallel is required since only very limited section of each filament of which potential coincides with that of ion beam plasma, can be effective to supply low energy electrons.

In our present system, secondary electron emission from metal walls at various places along the beam path takes an important role for space change neutralization. A helical coil, surrounding the beam, which is set inside the magnetic lens, being cooled by circulating freon, acts as an effective secondary electron emitter when cesium is deposited on its surface. A similar cold trap for cesium vapor is also installed at the exit portion of the Cs-cell.

An interesting observation on the present beam system is that at the start of beam production in daily use a high intensity ion beam can be obtained without hot filaments and/or the magnetic lens. Use of these devices even reduces the beam intensity. But this situation can not last long. Beam intensity goes down gradually and finally use of the hot filaments and the magnetic lens becomes necessary.

It is clear that occurence of this phenomena is not due to the outgas because no effect occurs if the residual gas pressure is increased by supplying a gas to the drift beam region in the equilibrium state. Thus we imagine that this transient effect is caused by secondary electron emission from the contaminated metal surfaces at the initial condition. We see that the secondary electron emitter is much more effective than the hot filament as a space charge neutralizer, and that the main function of the magnetic lens is to compensate the beam for broadening due to incomplete space charge neutralization. Unfortunately it seems to be difficult to keep this activity for a long time in the present system.

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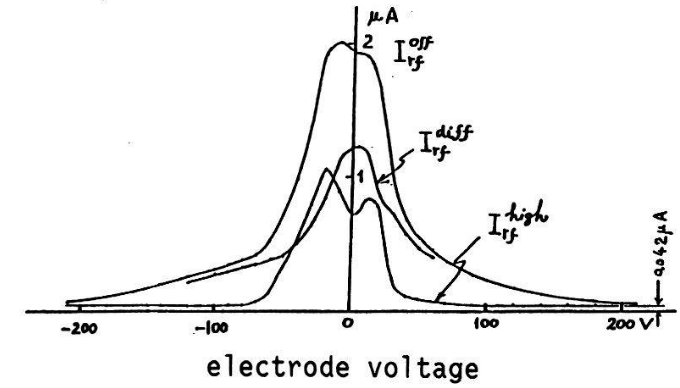
*See an article presented in this workshop by Dr. Schiemenz.

Another point to be mentioned is concerned with the charged-particle deflector. Fig.2 shows a result of an experiment made for comparing performance of the electrostatic and magnetic deflectors. Both types of deflector of the same length were installed, being combined with each other, inside the deflector chamber and tested one by one with the same incident beam condition. It is found that the magnetic deflector gives several times higher intensity of the polarizable output current I_{rf}^{diff} ($\equiv I_{rf}^{off} - I_{rf}^{high}$) than the electrostatic deflector when the both deflectors are used with the strength enough to depress the charged particle background in each case. In both cases saturated currents of background (I_{rf}^{high}) obtained with enough strength of the deflectors is proportional to the intensity of components which passes through the deflector as neutral particles. This magnitude is considered to be a good measure of the effective incident beam current to the Cs-cell. Difference of a factor of four of this quantity can be seen for both types of deflector. This large difference can be reasonably understood considering that the electrostatic deflector always robs the ion beam plasma of swarm electrons, but the magnetic deflector repels electrons back to the beam. Thus we see that loss of electrons at the deflector which is located after the Cs-cell causes strong fading of the primary ion beam incident to the Cs-cell.

a) electrostatic deflector



b) magnetic deflector

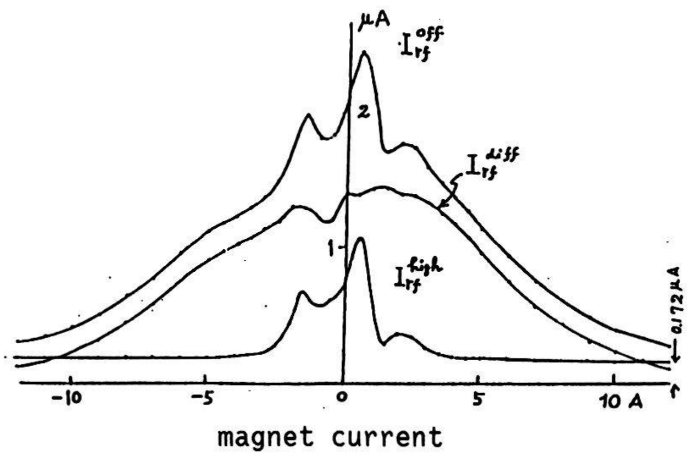
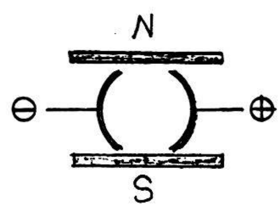


Fig.2 Comparison of (a) electrostatic and (b) magnetic deflectors. I_{rf}^{off} and I_{rf}^{high} are the Lambshift source output current, obtained with the spin filter rf power of off and high, respectively. I_{rf}^{diff} ($= I_{rf}^{off} - I_{rf}^{high}$) is nearly equal to a polarizable output intensity including both spin states.



Stability of the high intensity ion beam of 500 eV depends strongly on the surrounding wall potential. For maximizing the intensity and polarization of the Lamb shift source output, it is necessary to adjust the potentials at various portions independently with an accuracy of less than one volt. In particular the potential of the magnetic deflector, where the H^+ ion beam is terminated, needs a careful adjustment. If this potential is several volts off the optimum value, anomalous increase of the background component occurs. This effect can be explained in the following way: If the wall potential of the deflector is set too low, electrons neutralizing the space charge are repelled and the H^+ ion beam gets divergence at the entrance of the deflector. This causes, in turns, convergence of H ions produced in the Cs-cell (Hc^-) and contributes larger intensity of H^- ions to the background. On the other hand if the wall potential of the deflector is set too high, swarm electrons are lost to the wall, causing spreading of the primary H^+ ion beam. Again this situation results in the increase of H^- background.