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A source of ion or atom beam with accurately defined energy

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In the paper we propose to show the PIG ion source with axial ion extraction is suitable for formation of ion beams with absolute value of energy known with great accuracy $\pm$1eV. The hydrogen ion source mentioned was developed for the use in corpuscular diagnostics of plasma [1]. The structure of ion source is simple and it can operate some hundreds of hours without repairs. Energy of ions flying through the reflector cathode channel is defined by the potential V_r between reflector cathode and anode. The minimum energy of ions is about 120 eV, total intensity of the ion beam $I(H_1^+, H_2^+, H_3^+) = 45\ \mu A$. Discharge current $I_a = (0,2 - 6)$ mA. magnetic field $B = (400 - 1250)$ G, gas consumption $Q = 0,8\ cm^3$ per hour. Unsymmetrical feeding of the Penning discharge is possible [2] with $V_k \neq V_r$, where V_k is the potential between cathode and anode.

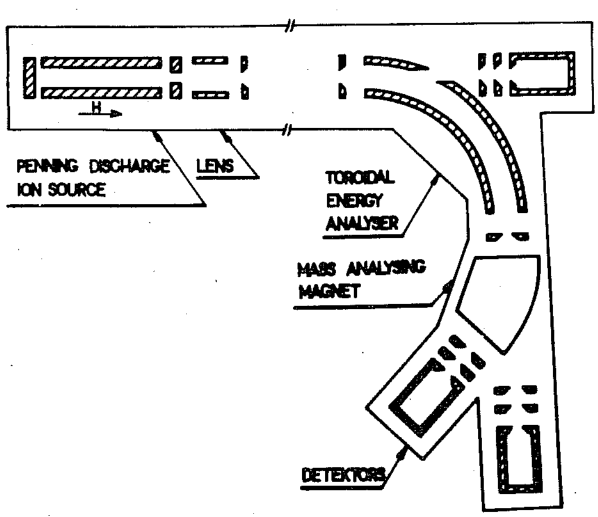

Fig. 1 shows a schematic representation of the apparatus in which the energy of ions was measured.

Energy distribution for ions ejected from the Penning discharge with $V_k > V_r$ is shown in Fig. 2. In the standard ion beam I_1^+ there are positive ions (H_1^+, H_2^+, H_3^+ and residual gas ions) with an energy $E^+ = e(V_r - \Delta V_a)$, where the potential

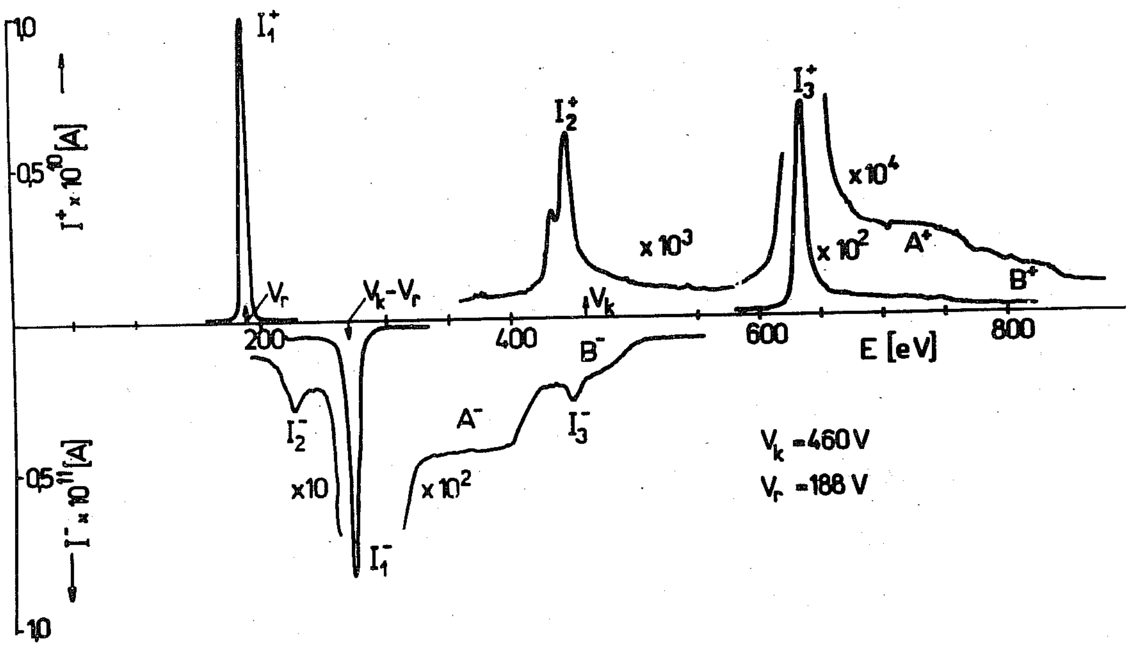

FIG. 2.

fall ΔV_a between the anode and the axis of plasma column varies within (0,5% - 80%)V_r, according to the discharge parameters and the geometrical size of the electrodes. Energy spread E< 6 eV and V_a< 2 V can be reached, when a quiescent Penning discharge burning is held with $\Delta l \ll l$, where Δl is the ion path through the cathode potential fall and l is the distance between the cathodes [1].

In the negative ion beam spectrum we can see the peak I_1^- in which negative ions, namely O^-, OH^- and H^- were detected. These ions are created in the interaction of positive plasma ions with the molecular layer adsorbed at the Al cathode surface [3] with starting energy E_o = 1,5 eV [4]. After acceleration and deceleration in the cathode fall regions, the negative ions leave the discharge tube with the energy $E_1^- = E_o + e(V_k - V_r)$. Passing the discharge tube and vacuum chamber of the apparatus in which a pressure $p < 5.10^{-6}$ Torr is held, negative ions undergo collision processes with gas molecules: the dominant process is single electron loss in which a beam of fast atoms is generated. Passing the vacuum chamber the energetic atoms lose or capture one electron and they are detected as the peaks I_2^+ and I_3^- respectively. The proton beam I_3^+ is created, when negative ions H^- lose two electrons in discharge plasma region. The proton energy in the beam I_3^+ is $E_3 = e(V_k + V_r) - \Delta E_3$, where ΔE_3 implies energy losses associated with the collision processes mentioned.

The beam of negative ions I_2^- contains O^- and H^- with energy $E_2^- < E_1^-$. We suppose these ions to be created in the dissociative collision processes of residual gas molecules with secondary electrons near the cathode.

High energy taile of the beam I_1^- which contains H^- only, could be explained as follows: plasma ions with energy $E \sim eV_k$ fall on the cathode surface and after one or more collisions with lattice atoms they are reflected into the discharge tube. Energy distribution of the reflected ions H^-, produced by dissociation of the primary ions H_2^+ and H_3^+, appears as the regions B^- and A^- respectively. We can also see the specific shape of high energy taile in the beam I_3^+.

The beam of neutral particles is formed by electron attachment, when the beam $I_1^+(H_1^+, H_2^+, H_3^+)$ passes through the charge exchange gas target. Fig. 3 shows mass spectrum of the primary hydrogen ion beam with energy 6 keV (peaks $I_1 - I_6$)

and the secondary ion beam formed after passing the primary ion beam through charge exchange target and stripping target (peaks I_7 - I_{11}). The discharge potential $V_k = V_r = 350$ V.

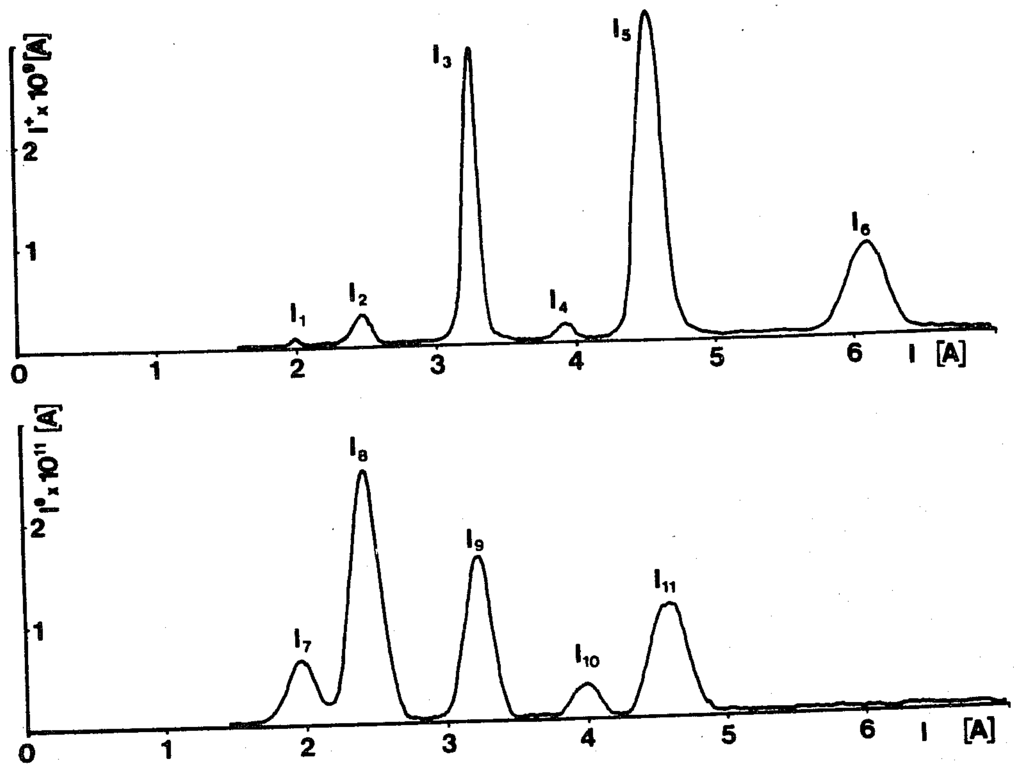

FIG. 3.

The peaks I_3, I_5 and I_6 are the beams of H_1^+, H_2^+ and H_3^+ respectively. The peaks I_1, I_2 and I_4 are formed by ions H_1^+ and H_2^+ produced in dissociative collisions of H_2^+ and H_3^+ with gas molecules.

Ion intensity of I_7 - I_{11} is not in proportion to the density of H_1 and H_2 in the neutral beam between the targets, because the large effectiveness of dissociation processes. Target pressures were typically $p = (4 - 8).10^{-3}$ Torr, charge exchange target containing O_2, stripping target N_2. Energy of hydrogen atoms represented by the beam I_9 is $E^0 = e(V_r - \Delta V_a) + \Delta E - E_e$, where $\Delta E < 1,5$ eV [5] is the exothermic energy and E_e the energy loss due to the internal excitation of the product O_2^+.

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