THEORY AND OPERATION OF A THREE-GATE TIME-OF-FLIGHT VELOCITY ANALYZER

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Time-of-flight (TOF) mass spectrometry is a technique that is gaining renewed attention[1]. A broad range of plasma ion velocities can arise through phenomena (charge exchange, dissociative recombination, etc.) of different exothermicities; or through production of multiply-charged positive ions having an energy equal to charge state x extraction energy. A method to increase the duty cycle without compromising resolution is to increase the repetition frequency (f) and discriminate against alias velocities. This is dorm by including a third grid to the usual "start" and "stop" gates. In the present three-gate realization each gate consists of three meshes. The two outer meshes are hold at ground potential; the center mesh is biased positive torepel positive ions, and biased to ground to open the gate. Tho first gato G_1 initiates an ion packet which travels down the TOF tube with a velocity determined by its mass(m), charge (q), and energy (E). Tho second and third gates G_2 and G_3 are pulsed "open' after a suitable delay time relative to the opening of G_1. Ions having the correct velocity are transmitted by G_3. The gates G_1, G_2, and G_3 are located at distances x = O, L_1 (16.66 cm), and L_2 (18.00 cm), respectively.

One may consider the three-gate TOF velocity analyzer as the superposition of two synchronized two-gate TOF filters. One consists of gates G_1-G_2, and the other of G_1-G_3. Times t_2' and t_3' are tho ion flight times to G_2 and G_3, respectively. The order of harmonic velocities which are passad by G_2 but blocked by G_3 are denoted by p and q. Owing totherepotitive nature of tho gate pulses, the two-gate filter will pass infinite sots of harmonic velocities with transit times given by $L_1/u_p = t_2' - p/f$, and $L_2/v_q = t_3' - q/f$. The harmonic velocities reduce to the principal velocity c_0 by setting $p = q$ = O, so that $c_0 = u_0 = v_0 = L_1/t_2' = L_2/t_3'$.

The rejection of harmonic velocities is shown in Figs. 1 and 2 by comparing a TOF spectrum utilizing a two-gate system, and a second spectrum using three gates. In Fig. 1, a mixture of H_2 and Ar was ionized and tho faster harmonics ($p > 0$) of H_2^+ and Ar^+ detected. These wera eliminated in Fig. 1(b) by the third timing gate. Similarly, shown in Fig. 2 is a case whorein a slower harmonic ($p < 0$) of Ar^+ and Ar^{2+} wero transmitted with two gates [Fig. 2(a)] but only the fundamental (p = O) harmonics of H' and H_2^+ were transmitted by the three gates [Fig. 2(b)].

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References

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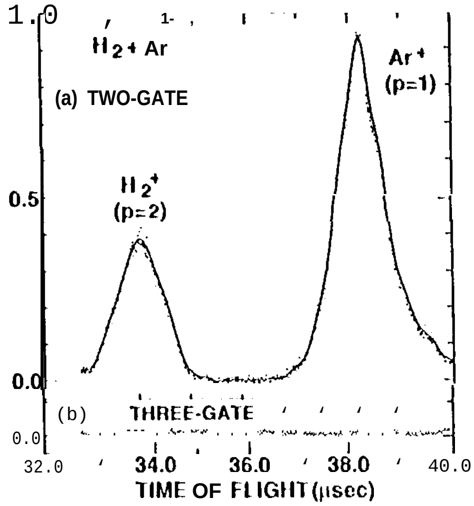

Fig. 1. (a) Two-gate, and (b) corresponding three-gate TOF spectra illustrating rejection of positive alias harmonics. Peaks are labeled by ion and harmonic.

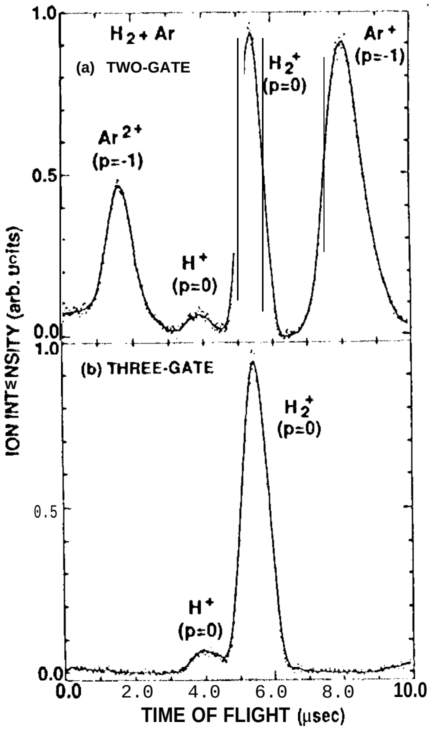

Fig. 2. Transmission of slower (p<O) harmonics in tho two-gate system (a), and their rejection in the three-gate system (b).