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GENERAL EXPERIMENTAL TECHNIQUES

A Method for Measuring the Lifetimes of Unstable Ions

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Abstract—A method for measuring the lifetimes of unstable ions using an electrostatic analyzer with the spatial focusing and rotation angles of 360° and 720° is described. A drawing of this analyzer is presented.

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The lifetime of unstable particles is usually determined by measuring the decrease in the intensity of a beam of these particles by means of a detector that moves along this beam. In this case, a sum of exponential dependences is obtained, the number of which corresponds to the number of excited states of the particles. However, if the beam consists of unstable particles in any one state, their lifetime can be determined by merely measuring their number at two arbitrary points of the beam trajectory and time Δt of flight of particles between these points.

Let us assume that unstable particles with lifetime τ are produced at point *0* (Fig. 1), and their quantity is N_0. Then, at the points *1* and *2* on the trajectory of the beam formed from them, the respective numbers of these particles are: $N_1 = N_0\exp(-t_1/\tau)$ and $N_2 = N_0\exp(-t_2/\tau)$, where t_1 and t_2 are the times of their flight from point *0* to points *1* and *2*, respectively, and their ratio is $N_1/N_2 = \exp(\Delta t/\tau)$, where $\Delta t = t_2 - t_1$. Hence, their lifetime τ is

$$\tau = \Delta t/\ln(N_1/N_2).$$

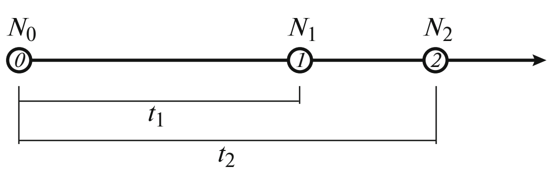

Fig. 1. The trajectory of a beam of unstable particles: (N_0) the number of unstable particles in the place of their production; (N_1, N_2) the number of unstable particles at points *1* and *2* on the beam trajectory; and (t_1, t_2) time of flight of unstable particles from the place of their production to points *1* and *2*, respectively.

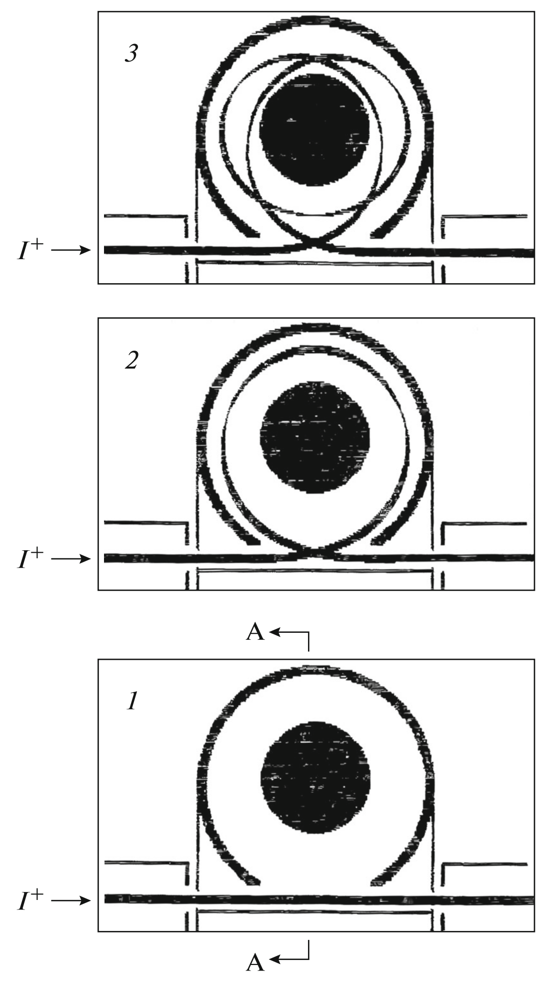

Fig. 2. The trajectories of I^+ positive ions with an energy of 1 keV in the loop at different values of the potential U at the inner electrode of the loop (the other electrodes of the loop are at zero potential) and delay time Δt corresponding to potential U: (*1*) $U = 0$ V, $\Delta t = 0$ μs; (*2*) $U = -1910$ V, $\Delta t = 1.3$ μs; and (*3*) $U = -3000$ V, $\Delta t = 1.9$ μs.

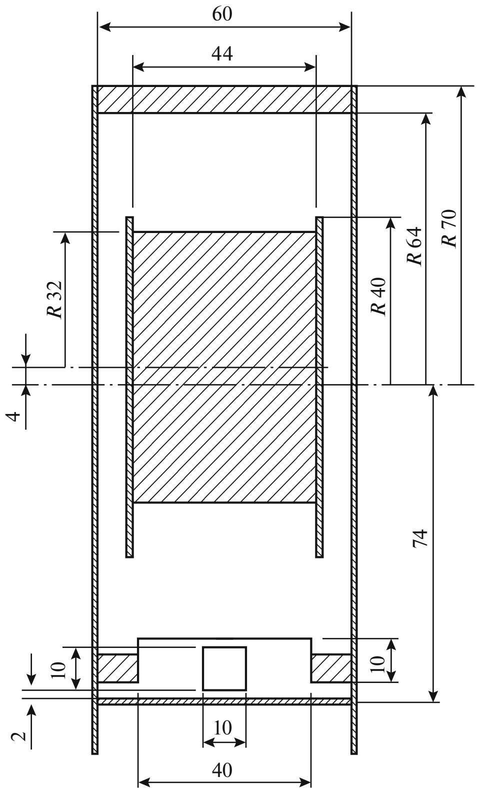

Fig. 3. The cross section of the loop along the arrows A–A (see Fig. 2).

In the case where the unstable particles are ions, the ratio N_1/N_2 and the value of Δt can be obtained using a stationary detector, which facilitates the performance of an experiment. For this purpose, it is sufficient that ions be removed from the beam trajectory and then returned to it after traveling an additional path that specifies the Δt value.

It is convenient to use a "loop" as a system that increases the time of flight of ions from the source to the stationary detector. The loop is an electrostatic analyzer with the spatial focusing and a turning angle of 360°. Figure 2 shows the trajectories of a beam of 1-keV positive ions in such a loop as a function of the negative potential at its internal electrode. We used one of the variants of such a loop to measure the lifetime of a negative deuterium molecular ion D_2^-. The delay time $\Delta t = 1.3$ μs was obtained for a beam of these ions with an energy of 1 keV, which made it possible to determine their lifetime, which was $\tau = 3.5$ μs [1]. It should be noted that Δt can be varied over a wide range by changing the energy of ions in the beam.

Although this version of the loop was developed to solve a specific experimental problem, we believe that it can also be useful in solving other experimental problems. For this purpose, we provide its geometric characteristics and dimensions (Fig. 3)

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