Appl. Phys. B 56, 123–129 (1993)

Applied Physics B Photophysics and Laser Chemistry

Enhancement of the Reflectron TOF Focusing Energy Range

E. V. Moskovets

Institute of Spectroscopy, Russian Academy of Sciences, 142092 Troitsk, Moscow region, Russia
(Fax: +7-095/334-0886, e-mail: lls@isan.msk.su; mev@pczz.msk.su)

Received 7 September 1992/Accepted 17 September 1992

Abstract. The requirements for the geometrical dimensions and ion packet deflection angles to achieve a maximum resolution of the mass-reflection with a field-free gap introduced between its decelerating and reflecting gaps are considered. The results obtained demonstrate the capability of the device proposed to make TOF analysis of the ion packets with large ion energy spread. It is also shown that, if by some reasons, the energy range of the ions entering the routine reflection can be predetermined, the regime with slightly detuned deceleration voltage is preferable, as it provides better mass resolution.

PACS: 82.80.Ms

Since its invention the mass-reflectron [1, 2] is successfully used as a tool for high resolution mass analysis of ions produced by the action of laser radiation on molecules in the gas phase or on a surface [3, 4]. The principle of the reflectron is that the TOF spread of ions with different kinetic energies escaping simultaneously from one and the same plane (acquired by the ions during their passage through a field-free region) is compensated by related variation of the time of flight of these ions through the decelerating and reflecting gaps. Thus, despite their different initial energies, all the ions of one and the same mass-to-charge ratio escaping simultaneously from one and the same plane of the field-free region are able to cover one and the same field-free drift path at the same time. So, the width of the ion packets characterized by a moderate spread of ion kinetic energies at the registration plane will be almost the same as it was at the exit of an ion source.

The high mass resolution as well as some operation options available with the reflectron allow good background suppression [5]. This property of the reflectron holds much promise in its successful application to trace analysis of organic molecules both in large volume under analysis [6] and under the conditions of substantial background noise.

The new operation mode of the routine reflectron [7] allows to increase the reflectron resolution in TOF analyses of ions desorbed from surfaces by short desorbing/ionizing pulses [8]. This new operation mode can also be successfully used in investigations of materials by means of pulsed field or laser-assisted field evaporation from a tip apex [9].

In a number of its applications the reflectron operates in conjunction with the Wiley-McLaren acceleration system (WMAS) [10]. The most useful mode of such a conjunction is when the entrance slit of the reflectron coincides with the TOF focusing plane of the WMAS [2]. The WMAS is capable of time-of-flight focusing of ion produced at distant points of the ejecting gap of WMAS. As these points differ in their electric potentials, one can expect a rather large ion energy spread in the focused ion packet coming to the reflectron entrance slit. Under these conditions one has to provide that the reflection compensates this energy spread for attaining a high mass-resolution. It has been shown in [2] that an appropriate deviation of the voltage applied across the deceleration gap can lead to an enhancement of the energy range of an effective TOF focusing in the reflectron. At the same time this change in the reflectron operation can cause some decrease in the reflectron resolution under the condition where ion packets of minor energy spread are analyzed. In the present work the dependence of the reflectron resolution on the given ion-energy spread (when the resolution is restricted only by that spread) has been found.

Further improvement of the TOF mass-spectrometer based on the principle of ion step deceleration and reflection is also proposed. It is shown that the introduction of an extra narrow field-free gap between the decelerating and reflecting gaps of the reflecting system gives rise to an enhancement of an effective TOF focusing energy range of the reflectron and, hence, under some conditions, can improve its resolution. The influence on the ultimate mass resolution of the ion scattering on wires of reflectron grids is compared with routine reflectron and with gap reflectron operation.

1 Theory

The electron optical system that performs the third-order energy focusing of the time of flight of ions can be realized

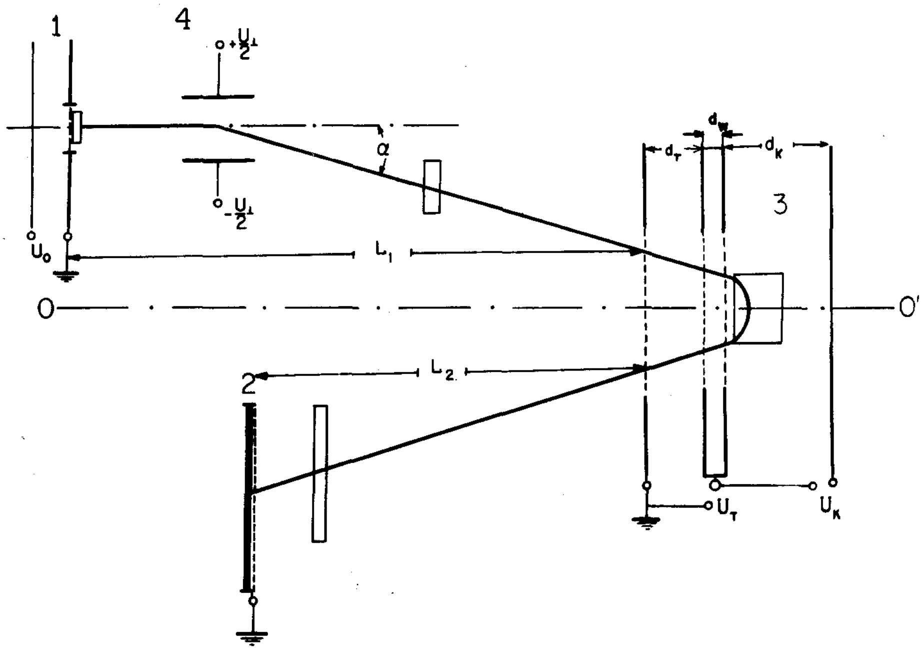

Fig. 1. Schematic diagram of the mass-reflectron with field-free gap: 1: extracting and accelerating electrodes system; 2: detection unit; 3: reflection system; 4: deflection system; α: angle between the direction of an ion packet mean velocity and reflectron axis 00′

by introducing a field-free gap between the decelerating and reflecting gaps of a routine reflectron (Fig. 1). Following [2], let the average energy of ions in the ion packet after its acceleration in the ion source be U_0 and the energy of the ions under analysis be U. Let us take into consideration here a one dimensional case, viz. we shall consider further U and U_0 as corresponding projections of the ion kinetic energies on the reflectron principal axis 00′. We introduce the parameter $k = U/U_0$ and denote the total length of the field-free drift of ions by $L = L_1 + L_2$, the deceleration gap width d_T, the field-free gap width d_w, and the reflecting gap width d_K. The corresponding field strengths in the decelerating and reflecting gaps are $E_T = U_T/d_T$ and $E_K = U_K/d_K$. In that case, the time of flight t of an ion with its energy U at the exit plane of the ion source is as follows:

$$t = CF(k) \tag{1a}$$

with

$$C = \frac{4d_K}{\sqrt{2U_0/M}} \frac{U_0}{U_K}, \tag{1b}$$

$$F = \frac{A_1}{\sqrt{k}} + \frac{A_1 w}{\sqrt{k-p}} + nA_1(\sqrt{k} - \sqrt{k-p}) + \sqrt{k-p}, \tag{1c}$$

where

$$A_1 = \frac{L}{4d_K} \frac{U_K}{U_0}, \tag{1d}$$

$$n = \frac{4d_T}{L} \frac{U_0}{U_T}, \tag{1e}$$

$$p = \frac{U_T}{U_0}, \tag{1f}$$

$$w = \frac{2d_w}{L}. \tag{1g}$$

The condition for the time-of-flight focusing of the ions differing in initial energy is

$$\left(\frac{\partial^m F}{\partial k^m}\right)_{k=1} = 0, \qquad m = 1, 2, 3 \ldots. \tag{2}$$

Taking the appropriate derivatives, we can obtain the following system of equations:

$$\left.\begin{aligned}
(1-p)(1-nA_1) &= A_1 w + A_1(1-p)^{3/2}(1-n), \\
(1-p)(1-nA_1) &= 3A_1 w + A_1(1-p)^{5/2}(1-n), \\
(1-p)(1-nA_1) &= 5A_1 w + A_1(1-p)^{7/2}(1-n), \\
&\cdots\cdots\cdots \\
(1-p)(1-nA_1)& \\
&= (2m-1)A_1 w + A_1(1-p)^{\frac{(2m+1)}{2}}(1-n),
\end{aligned}\right\}$$

with

$m = 1, 2, 3 \ldots$.

We should note here that there are no four equations in the system that can be solved simultaneously to yield a general solution. So, solving this system can not help us to find all the four parameters n, p, w, and A_1 at once. Let us find p, w, and A_1, and leave n as a free parameter. Solving simultaneously the first, the second and the third equations of (3), i.e., equating to zero the first, the second and the third derivatives of the time of flight with respect to the reflectron principle axis projection of the ion kinetic energy, we have, after simple manipulations:

$$p = \frac{4}{5-n}, \tag{4a}$$

$$w = (1-p)^{5/2}, \tag{4b}$$

$$A_1 = \frac{1}{n + (1-p)^{3/2}(6-n)}. \tag{4c}$$

From the relations (1e) and (4a) it can be found that

$$n = \frac{5d_T/L}{1+2d_T/L}\,, \tag{5a}$$

$$U_T = \frac{4}{5}\left(\frac{1+2d_T/L}{1+d_T/L}\right)U_0\,. \tag{5b}$$

Thus, if the ratio d_T/L is specified, the retarding potential U_T can be found from (5b). Then, after calculating n and A_1 we can find the field strength E_K in the reflecting gap. The lowest limit of the permissible value for the parameter U_K/U_0 can be determined from the following inequality:

$$U_T + U_K > U_0\,. \tag{6}$$

From here we get

$$U_K > \frac{1}{5}(1-3d_T/L)U_0\,. \tag{7}$$

It follows from (1d) and the above expression, that

$$\frac{d_K}{L} > \frac{1}{20A_1}(1-3d_T/L)\,. \tag{8}$$

The given inequalities define necessary conditions which must be fulfilled in any design of the reflectron under consideration. It will be further demonstrated that the reflectron of the given type can effectively realize the TOF focusing only when the ion energy spread is no more than 25–30% of the average energy of the ions in the ion packet. So, as it usually happens in practical mass-analysis, one need not detect the ions with kinetic energies far beyond the reflectron energy range. Therefore, to restrict the reflecting system's size we recommend to choose the parameters which satisfy the following inequalities:

$$U_K > 1.15U_0 - 0.8\left(\frac{1+2d_T/L}{1+d_T/L}\right)U_0 = \frac{7}{20}\left(1-\frac{9}{7}d_T/L\right)U_0\,, \tag{9a}$$

$$d_K/L > \frac{7}{80A_1}\left(1-\frac{9}{7}d_T/L\right)\,. \tag{9b}$$

Furthermore, the following circumstances must be taken into consideration, viz. the potential U_T must be not larger than the minimum ion energy U_{min} in the packet

$$U_T < U_{min}\,. \tag{10}$$

By analogy with the previous considerations we define the following necessary condition

$$U_T < U_0\,. \tag{11}$$

One can find from here the upper theoretical limit of the d_T/L value:

$$d_T/L < \frac{1}{3}\,. \tag{12}$$

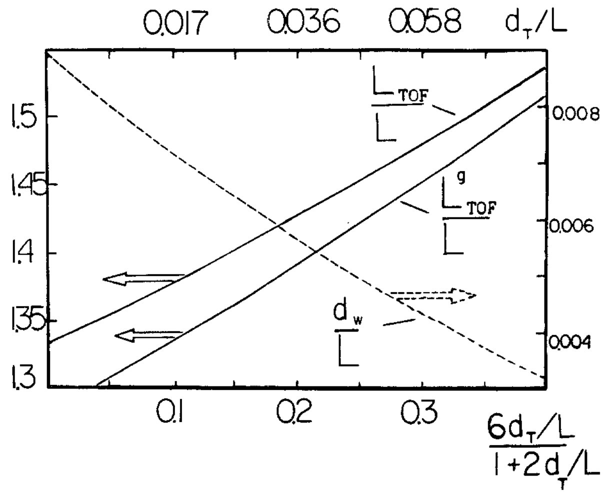

Fig. 2. The dependence of the relative field-free gap value (d_w/L), the equivalent relative lengths of the routine reflectron (L_{TOF}) and that with the gap (L^g_{TOF}) calculated for various d_T/L parameters. The absciss axis is scaled in $n = (6d_T/L)/(1+2d_T/L)$ calculated for the routine reflectron

Taking into account the practical upper limit of the reflectron energy range $U_0 - U_{min} \le 0.15U_0$, we can write the following inequality

$$U_T < 0.85U_0\,. \tag{13}$$

It follows from the said and from (5b) that in a number of practical cases the d_T/L value should be restricted more severely to

$$d_T/L < \frac{1}{15}\;: \tag{14}$$

Note that the upper limit of d_K/L value is defined by us rather arbitrarily. If the energy range of the ions under analysis is large, this upper limit can be raised to any appropriate distance. Yet, one should keep in mind when making a mass-analysis that the reflectron focusing properties vanish dramatically when the ion energy deviates more than approximately 15% from the average one.

By analogy with what was done in [2], we can define the equivalent TOF drift length L^g_{TOF} of the reflectron of the given type. Using (1a) and (1b) we obtain

$$L^g_{TOF} = L\left[1+n(1-\sqrt{1-p})+\frac{w}{\sqrt{1-p}}+\frac{1}{A_1}\sqrt{1-p}\right]. \tag{15}$$

Figure 2 presents the dependence of the L^g_{TOF} and $w/2$ values on d_T/L. One can also find there the similar dependences of the L_{TOF} for the routine reflectron.

2 The detuning of the Reflecting System Potential as a Tool for an Extra Enhancement of the Reflectron Energy Range

If the potentials U_T and U_K are stable but their values differ from optimal ones, this causes the mass-reflectron to be misaligned. Let the potential U_T differ slightly from the optimal one U^0_T so that $|(U_T - U^0_T)/U_0| \ll 1$. Find the deviation Δt of the time of flight of the ion with its energy kU_0 in the misaligned reflectron from that in the reflectron with normal parameters. We note here, that in accordance with their definitions, only parameters p and n depend on U_T. After taking the first derivative of t with respect to U we can get

$$\Delta t = \frac{L}{\sqrt{2U_0/M}} \left\{ -n_0 [\sqrt{k} - \sqrt{k - p(n_0)}] + \frac{n_0 p(n_0)}{2\sqrt{k - p(n_0)}} + \frac{w(n_0) p(n_0)}{2\sqrt{k - p(n_0)}\,[k - p(n_0)]} - \frac{1}{A_1(n_0)} \frac{p(n_0)}{2\sqrt{k - p(n_0)}} \right\} \frac{\Delta U_T}{U_T^0}, \tag{16}$$

where $p(n_0)$, $w(n_0)$, and $A_1(n_0)$ are the optimal values of the parameters p, w, and A_1 calculated from (4a–c) for the given n_0 and, hence, the given value of d_T/L. From the above expression one can find the dependence of the value of the time of flight deviation for the reflectron of the given length L on the U_T value. Varying the U_T in a narrow range near U_T^0 and simultaneously registering the deviation $\Delta t(U_T - U_T^0)$ for the ions with their energy U_0 (for this purpose ion packets of very narrow energy range can be used), one can find the value in curly brackets of (16). From the value obtained the value of the parameter n_0 can be found for the reflectron under investigation. Further, if n_0 is known, this procedure can help us to find experimentally the value of d_T/L without measuring it in the usual way.

Let t_m be the time of flight of the ions of energy U_0 in the misaligned routine reflectron. Substituting U_T instead of U_T^0 (calculated from the given d_T/L values) into the expressions analogous to (1a–f) [2], we can find the dependence of the relative time of flight of the ions with energy U $\Delta t/t = [t(U) - t_m]/t_m$ on the relative energy deviation $(U - U_0)/U_0$ of the ions passing through the routine reflectron with detuned deceleration potential U_T. Figure 3a presents curves of relative variations in the ion time of flight through the mass-reflectron with different values of deviation ΔU_T of the first-grid potential from the optimal U_T^0 value. Attention must be drawn to the regime with $\Delta U_T < 0$. The matter is that the reflectron resolution by many reasons (the main among them is the ion scattering on the grid wires) can be limited to the value of 10,000. Therefore, this regime appears to be more preferable because the conditions of the TOF focusing in this case are valid for a larger energy spread. Figure 3b presents the analogous curves calculated for the reflectron with the field-free gap.

The reflectron mass-resolution can be calculated from the relation $R = t/2\Delta t_{max}$, where Δt_{max} is the time difference between the two maxima of the curves in Fig. 3a. The procedure of finding an energy spread $\Delta U(\Delta U_T)$ corresponding to a given resolution R can be understood from the same picture.

The upper-limit dependence of the resolution of both reflectrons on the chosen energy spread is shown in Fig. 4

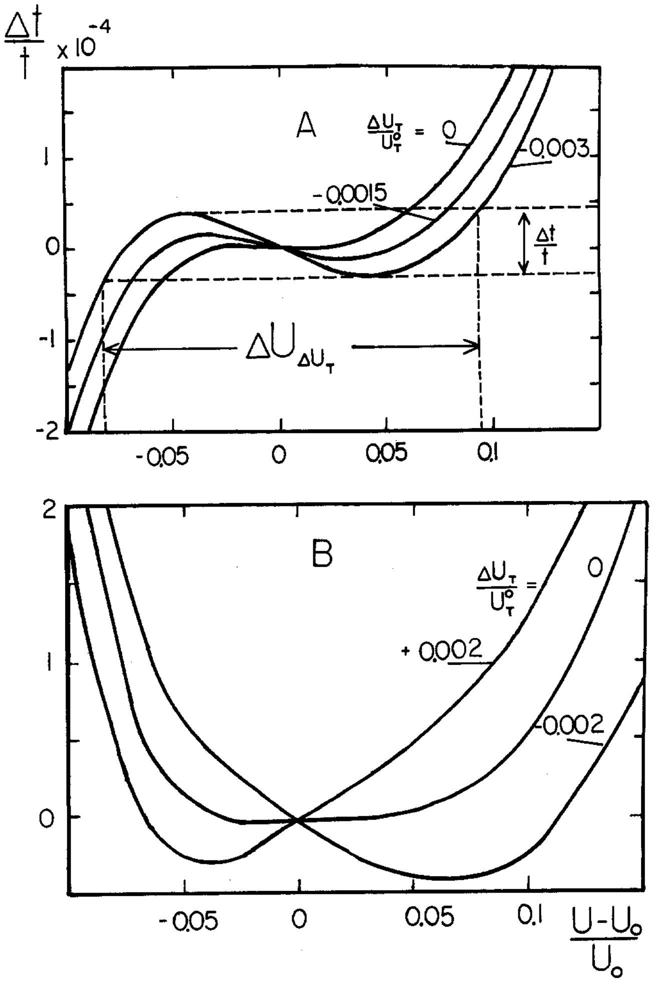

Fig. 3. The dependence of the relative time of flight of ions in the routine reflectron **A** and in that with the gap **B** under the conditions where the value of U_T in both reflectrons is slightly detuned from calculated value $U_T^0 (\Delta U_T / U_T^0 \ll 1)$

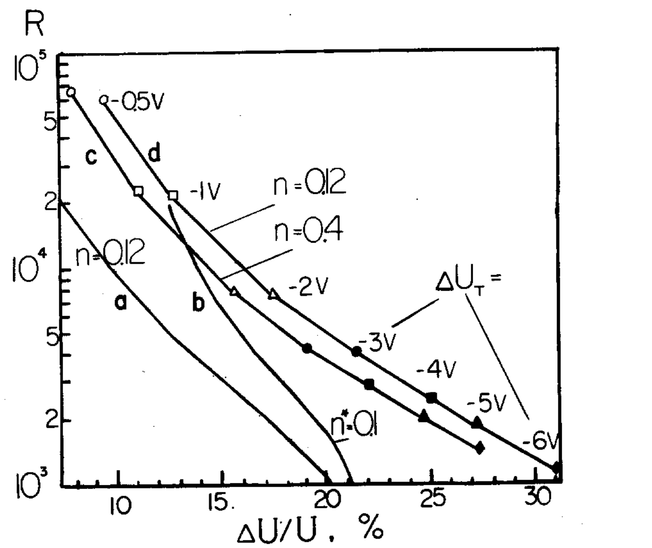

Fig. 4. The upper limit of the resolution of the routine reflectron *(a, c, d)* and that with the gap *(b)* as a function of the chosen energy range calculated for different d_T/L values. An extra deposit of the ion scattering on the reflectron grids to the total reflectron resolution is neglected. The curves *a*, *b* are referred to the ideally ($U_T = U_T^0$) adjusted routine reflectron *(a)* and that with the field-free gap *(b)*, whereas curves *c* and *d* are referred to the routine two-grid reflectron of various d_T/L values with the first grid potentials detuned from the ideal ones. The value of detuning ($U_T - U_T^0$) at a given resolution is equal for *c* and *d* curves

for different values of d_T/L. The ΔU_T values pointed out in Fig. 4, calculated with respect to U_T^0 – the latter are calculated from given d_T/L and U_0 – are assumed to be 1000 V. Also, it should be noted that the one-dimensional case is considered here, i.e. $\alpha = 0$. The value of parameter n^* (referred to the reflectron with the gap) is calculated in accordance with (5a), while the parameter n (introduced to calculate the resolution and energy range of the routine reflectron) is defined by the expression $n = (6d_T/L)/(1 + 2d_T/L)$, taken from [2].

3 Reflectron Resolution Defined by Ion Scattering on the Grids

As it can be derived from (14), the value of the parameter n may be chosen in the region $0 < n < 0.4$. Also, there exists an extra restriction on the lowest value of n which depends on the resolution to be attained. As it is demonstrated in [11], the upper limit of the resolution also depends on the parameters of the grids used to set up homogeneous fields. If the reflectron grids are mounted very close to each other, i.e. when the value of the ratio d_T/L is too small ($d_T/L \ll 1$), the gradient of the electrostatic field near the grid wires will be rather high and the ions will be effectively scattered. If the wire diameter is considered to be small with respect to the mesh size of the grids used, one can neglect a geometric scattering of the ions on the wires themselves. Correcting the results obtained in [11], we can write

$$\frac{\overline{\Delta t_i}}{t} = \left(\frac{V_\perp}{V_\parallel}\right)_i \frac{E_i a}{4\sqrt{3}} \left|\frac{\partial t_{i-d}(U_\parallel)}{\partial U_\parallel}\right| \frac{1}{\gamma L\sqrt{M/2U_\parallel}} . \quad (17)$$

Here $\overline{\Delta t_i}$ stands for the averaged time deviation of the ions evenly distributed over the cross section of the ion beam moving through a reflection grid with the mesh size a that appears after the i^{th} passage of the ions through the reflection grid. Further, the ion velocity component parallel to the reflectron's $00'$ axis is denoted by $v_\parallel$, and $v_\perp$ is the velocity component perpendicular to the axis. Then E_i is the absolute value of the difference between the field strength in the gap under consideration and the field strength in the space from where the ion has come in; $U_\parallel$ is the $00'$-axis projection of the average ion kinetic energy, t_{i-d} is the time of flight of the ion with its energy $U_\parallel$ from the i^{th} grid to the detection plane. The value of the parameter γ is equal to the ratio of the equivalent TOF length L^g_{TOF} to the field-free drift length L and can be found from (15). Let us calculate the average time deviation for the first passage through the first grid. Taking into account the oblique incidence of the ion beam on the reflecting plane, the above expression with due regard to (1a–f) can be reduced to

$$\frac{\overline{\Delta t_1}}{t} = \frac{1}{8\sqrt{3}}\left(\frac{v_\perp}{v_\parallel}\right)_1 \frac{U_T a}{U\gamma d_T}\left[\frac{L_2}{L} + n\left(\frac{1}{\sqrt{1-p}} - 1\right) + \frac{w}{(1-p)^{3/2}} - \frac{1}{A_1\sqrt{1-p}}\right], \quad (18)$$

Here $\overline{\Delta t_1}$ denotes the averaged spread of the time of flight t of ions escaped from the ion source, which passed through the whole reflectron and reached the detection plane that appears after the first passage of ions through the first grid. Each passage of the ion beam through the grid under analysis is considered to be independent of passages through the other grids in the approach developed. So, the calculate $\overline{\Delta t_1}/t$, one can consider the other passages as ideal ones. This approach is not almost true as it does not account a partitial compensation of the time-of-flight spread caused by an ion scattering on the i^{th} grid during the ion packets scattering on the $(i+1)^{\text{th}}$ grid. Yet, it may be demonstrated, the final result of the enhanced approach deviates a little from the developed one.

Now we find the averaged spread $\overline{\Delta t_2}$ for the next scattering. Taking into account the ion deceleration in the first gap and, hence, the change in the corresponding angle of departure of the decelerated ion beam, we find

$$\frac{\overline{\Delta t_2}}{t} = \frac{1}{8\sqrt{3}}\left(\frac{v_\perp}{v_\parallel}\right)_2 \frac{U_T a}{U\gamma d_T}\left|\left[\frac{L_2}{L} + \frac{n}{2}\left(\frac{1}{\sqrt{1-p}} - 1\right) + \frac{w}{(1-p)^{3/2}} - \frac{1}{A_1\sqrt{1-p}}\right]\right|, \quad (19)$$

where the sign $|\ldots|$ means the absolute value of the quantity and

$$\left(\frac{v_\perp}{v_\parallel}\right)_2 = \left(\frac{v_\perp}{v_\parallel}\right)_1 \frac{1}{\sqrt{1-p}} . \quad (20)$$

By analogy with the above consideration we can find the spreads $\overline{\Delta t_3}/t$ and $\overline{\Delta t_4}/t$ appearing as a result of ion scattering after corresponding passages of the ion packet through the third grid

$$\frac{\overline{\Delta t_3}}{t} = \frac{1}{8\sqrt{3}}\left(\frac{v_\perp}{v_\parallel}\right)_3 \frac{U_K a}{U\gamma d_K}\left|\left[\frac{L_2}{L} + \frac{n}{2}\left(\frac{1}{\sqrt{1-p}} - 1\right) + \frac{w}{2(1-p)^{3/2}} - \frac{1}{A_1\sqrt{1-p}}\right]\right|, \quad (21)$$

$$\frac{\overline{\Delta t_4}}{t} = \frac{1}{8\sqrt{3}}\left(\frac{v_\perp}{v_\parallel}\right)_4 \frac{U_K a}{U\gamma d_K}\left|\left[\frac{L_2}{L} + \frac{n}{2}\left(\frac{1}{\sqrt{1-p}} - 1\right) + \frac{w}{2(1-p)^{3/2}}\right]\right|, \quad (22)$$

where

$$\left(\frac{v_\perp}{v_\parallel}\right)_4 = \left(\frac{v_\perp}{v_\parallel}\right) = \left(\frac{v_\perp}{v_\parallel}\right)_2 .$$

Further, the second passage through the second grid gives

$$\frac{\overline{\Delta t_5}}{t} = \frac{1}{8\sqrt{3}}\left(\frac{v_\perp}{v_\parallel}\right)_2 \frac{U_T a}{U_0\gamma d_T} \times \left[\frac{L_2}{L} + \frac{n}{2}\left(\frac{1}{\sqrt{1-p}} - 1\right)\right] . \quad (23)$$

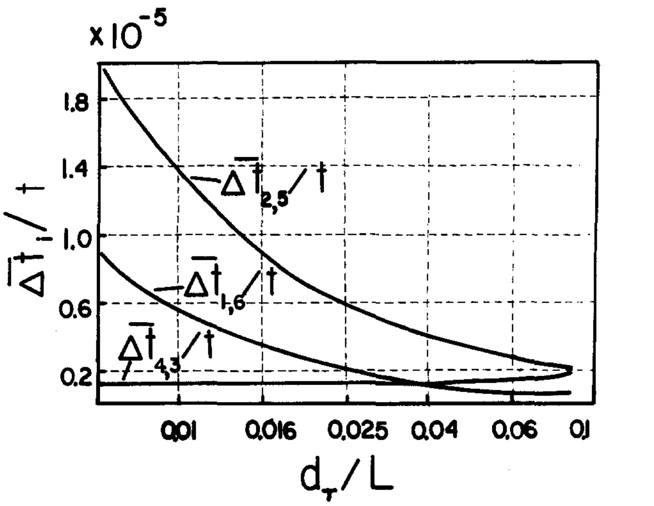

Fig. 5. The relative spread $\overline{\Delta t_i}/t$ caused by an ion scattering on the i^{th} grid of the reflectron with field-free gap as a functio of d_T/L parameter (Mesh size of grids $a = 200\,\mu$, $L_1 = L_2 = L/2 = 100\,\text{cm}$)

Finally, the second passage through the first grid gives

$$\frac{\overline{\Delta t_6}}{t} = \frac{1}{8\sqrt{3}} \left(\frac{v_\perp}{v_\parallel}\right)_1 \frac{U_T a}{U_0 \gamma d_T} \frac{L_2}{L} . \tag{24}$$

Figure 5 depicts the contribution $\overline{\Delta t_i}$ of each of the grids to the total averaged deviation $\overline{\Delta t}$ of the time of flight t calculated for a grid mesh size $a = 200\,\mu\text{m}$ and under conditions, where $L_1 = L_2 = L/2 = 100\,\text{cm}$. The diameter of the grid wires is considered here to be negligible. As it was pointed out in [11], the reflectron resolution restricted by the ion scattering on the grids can be calculated from the relation

$$R_{\text{grid}} = \frac{1}{4} \frac{t}{\overline{\Delta t}} . \tag{25}$$

Figure 6 presents the dependence of the mass-reflectron resolution on the parameter d_T/L when the resolution is restricted only by the ion scattering on the three-grid reflecting system. It is assumed here that $L_1 = L_2 = L/2 = 100\,\text{cm}$ and mesh size of all the grids $a = 200\,\mu\text{m}$.

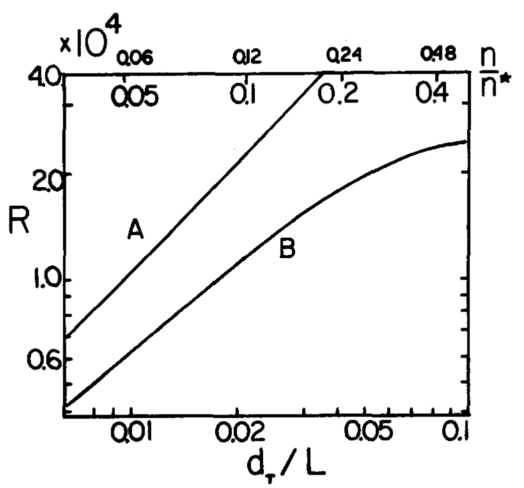

Fig. 6. The dependence of the mass-reflectron resolution on the parameter d_T/L under conditions where the resolution is restricted only by the ion scattering on two grids of the routine reflectron *(A)* and three-grid reflectron with the field-free gap *(B)* (Mesh size of all grids $200\,\mu\text{m}$, $\tan\alpha = 0.025$, $L_1 = L_2 = L/2 = 100\,\text{cm}$)

Thus, to attain a high resolution ($\geq 10{,}000$) for typical angles 1°–3° between the ion beam direction and reflectron $00'$-axis, it is essential to use grids with a mesh size about $200\,\mu\text{m}$ or less. Since the wire diameter is usually about 15–$20\,\mu\text{m}$, the transmission of such reflectrons can not exceed 50–60%.

When the ion beam diameter inside the reflecting system increases so that particular ions traverse the close vicinity of edges of shielding rings, an extra TOF spread appears. To our regret, the analytical expressions of TOF spread obtained for this case are not simply enough and claims the definition of the geometry of the edge of the inner ring. To study the problem thoroughly one can use the results of special computer calculations obtained in [12]. One can avoid this problem in experimental use of the reflectron by choosing the shielding ring's inner diameters 2–3 cm larger than the expected diameter of the ion beam inside the reflecting system. The problem can also be partly solved by making the rings as narrow as it is principally possible.

The electric field inhomogeneity caused by the spread of the distances between the reflectron shielding rings can also result in an extra TOF spread. Using numerical methods developed in [12] one can investigate theoretically how the given spread of the distances between the shielding rings effects the upper limit of the reflection resolution. As was found experimentally, the use of high quality mechanical treatment allows for limiting the given spread to a range of 0.1%. This value seems to be too small to cause any substantial variation of the electric field in the larger part of the reflecting system with plane-parallel metal grids.

4 Conclusions

This work has considered the requirements for the geometrical dimensions and ion packets deflection angles to achieve a maximum resolution of the mass-reflectron with a field-free gap introduced between its decelerating and reflecting gaps. The results obtained demonstrate the capability of the device proposed to make TOF analysis of the ion packets with large ion energy spread.

It is also shown that if, by some reasons, the resolution of routine reflectron can be restricted, the regime with slightly detuned deceleration voltage is preferable as it provides the TOF focusing of ion packets with larger energy spread.

It is found that the spread of the time of flight caused by scattering of the ions on the reflectron grids is 2–2.5 times less in the routine two-grid reflectron than in the three-grids one. It is also demonstrated, that for many practical cases to attain a maximum resolution of the reflectron used it is more convenient to detune the deceleration potential slightly than to try to achieve third-order TOF focusing by introducing an extra grid into the reflectron.

Acknowledgements. The author would like to thank Prof. V. S. Letokhov for his continuous encouragement of this work and helpful discussions.

References

1. B.A. Mamyrin, V.I. Karataev, D.V. Schmikk, V.A. Zagulin: Sov. Phys. – JETP (Engl. Transl.) **37**, 45 (1973)
2. E.V. Moskovets. Appl. Phys. B **53**, 253 (1991)
3. V.S. Letokhov: *Laser Photo-ionization Spectroscopy* (Academic, Orlando 1987)
4. D. Lubman (ed.): *Laser in Mass-Spectrometry* (Oxford Univ. Press, Oxford 1990)
5. A.P.L. Wang, L. Li: Appl. Spectrosc. **45**, 969 (1991)
6. A.P.L. Wang, J.I. Zhang, D.S. Nagra, L. Li: Appl. Spectrosc. **45**, 304 (1991)
7. E.V. Moskovets: Appl. Phys. B **54**, 556 (1992)
8. A. Overberg, M. Karas, U. Bahr, R. Kaufmann, F. Hillenkamp: Rapid Comm. Mass. Spectr. **4**, 293 (1990)
9. M.K. Miller, G.D.W. Smith: *Atom Probe Microanalysis* (Material Research Society, Pittsburg 1992)
10. W.C. Wiley, I.H. McLaren: Rev. Sci. Instrum. **26**, 1150 (1955)
11. T. Bergmann, T.P. Martin, H. Schaber: Rev. Sci. Instrum. **60**, 347 (1989)
12. T. Bergmann, T.P. Martin, H. Schaber: Rev. Sci. Instrum. **61**, 2592 (1990)

Responsible for Advertisements: E. Lückermann, G. Probst, Heidelberger Platz 3, D-1000 Berlin 33, Tel. (0 30) 82 07-0, Telex 01-85411, FAX (0) 30/8207300
Responsible for the Text: H. K. V. Lotsch, Tiergartenstraße 17, D-6900 Heidelberg, Tel. (0) 62 21/48 72 53, Telex 461723, FAX (0) 6221/43982
Printers: Brühlsche Universitätsdruckerei, Giessen

Springer-Verlag GmbH & Co. KG, D-1000 Berlin 33