MECHANISM OF COMPRESSION OF POSITRON CLOUDS IN THE SURKO TRAP OF THE LEPTA FACILITY*

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Abstract

Results from experimental studies of plasma storage in the Surko trap at the LEPTA facility are presented. The number of stored particles is found to increase substantially when using the so-called "rotating wall" (RW) method, in which a transverse rotating electric field generated by a cylindrical segmented electrode cut into four pairs is applied to the positrons storage region.

The conditions of transverse compression of the plasma bunch under the action of the rotating field and buffer gas are studied. The optimal storage parameters are determined for these experimental conditions. Mechanisms of the action of the rotating field and buffer gas on the process of positron clouds storage are presented.

INTRODUCTION

Experiments with antimatter required the development of methods of storage, confinement and manipulate of clouds of antiparticles. For these purposes, generally used a electromagnetic trap. One method of increasing the efficiency of storage: increase in the lifetime of charged clouds inside the trap in a rotating electric field. The effect of «The Rotating Wall» (RW) was detected in experiments on the storage of a plasmoid ions [1]. Then, similar results were obtained for both the electron and positron plasma [2, 3]. The method of the rotating field is used to generate antihydrogen in projects ATHENA/ALPHA [4, 5]. Successful use of this method allowed us to begin the study of the properties of antimatter and exotic atomic and molecular systems. Determining if there is storage of the frequency and the direction of rotation of the field in a plane transverse to the axis of the trap. The dependence of the efficiency savings from RW-field parameters is resonant. There are several mechanisms [6-9] action of the rotating field compression and holding a bunch of charged particles trapped. Until now, the explanation of this phenomenon causes a heated discussion.

THE SURKO TRAP OF THE LEPTA FACILITY

The LEPTA facility [10] is designed for generating high flow orthopositronium opportunity to carry out precision measurements of the characteristics of positronium. In the storage ring can be made of two kinds of particles injection. The electron beam creates an electron gun to clear the circulating electron beam collector exists, positron beam is injected from the source of positrons passing through positron trap. Optimization of the process of accumulation of positrons in the trap is one of the basic conditions of work. This is an open the trap Malmberg-Penning type with a longitudinal magnetic field. Retention of charged particles in the longitudinal direction of the accumulation is carried out by the electrostatic field created by trap electrodes. With the storage of positrons injection from the source (^{22}Na) of a continuous stream necessary to ensure the selection of the energy of motion for the "rolling" in the potential well inside the trap. For these purposes, Surko [11] proposed the use of a buffer gas. Thus modified trap began to wear his name. It is used to the LEPTA facility (see Fig. 1).

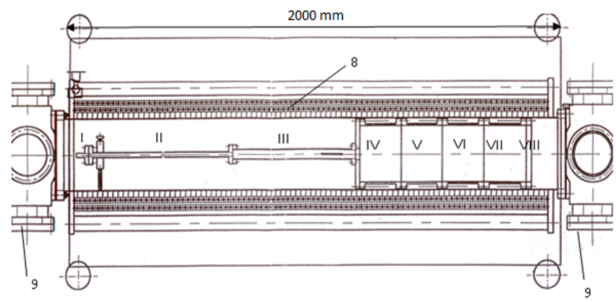

Figure 1: Scheme the Surko traps (longitudinal section). I - VIII - electrodes 8 - solenoid 9 - Vacuum posts.

MECHANISM OF COMPRESSION OF POSITRON CLOUDS

In [12] proposed a mechanism of the effect of a RW-field on the transverse size and lifetime of the storage trapped cloud based 3D model of the dynamics of charged particles. The exteriments datas were presented on research independion frequency of the rotating field with a longitudinal oscillation bounce-frequency, which show the validity of this model. The essence of the proposed mechanism is reduced to the necessity of matching the frequency of the rotating field f_{RW}, frequency magnetron motion of particles in the trap f_{-} and the frequency of the longitudinal oscillations of the bounce f_z :

$$f_{RW} = Nf_{-} = Lf_z \,. \qquad (1)$$

Here N, L — integers. The values of the longitudinal oscillation frequency bounce-determined depth and size of the potential well, retaining particles within the area of accumulation. The values of the magnetron frequency is

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defined as the electrode potential and the space charge accumulated particles. The resonance condition (see Eq. 1) provides a systematic effect of the rotating field, which can reduce the drift of particles to the walls of the trap due to the pressure of the buffer and the residual gas.

EXPERIMENTAL RESULTS: POSITRON STORAGE

In 2013-2014 he was modernized equipment [13] on the LEPTA facility. In particular, as the trapped vacuum stations are installed cryogenic pump and the turbomolecular pump. This allowed to disconnect during storage ion pump, improve almost an order of magnitude (up to 10-9 torr) vacuum inside the base of the trap. In addition to quantitative changes in vacuum conditions and this has led to qualitative changes in the conditions of storage. The adsorption of large organic molecules, which give large cross sections of positron annihilation in the cryopump has significantly raised the lifetime and efficiency of accumulation of positrons. Results were obtained by accumulation of electrons in the trap. Found resonances of storage electrons on the frequency of the rotating field, which agreed well with the calculations (see Eq. 1) for the given parameters.

Experiments were performed to generate the positron annihilation with a detector PMT. Were obtained depending on the number of storage positrons in low-density mode of the frequency of the rotating field (see Fig. 2).

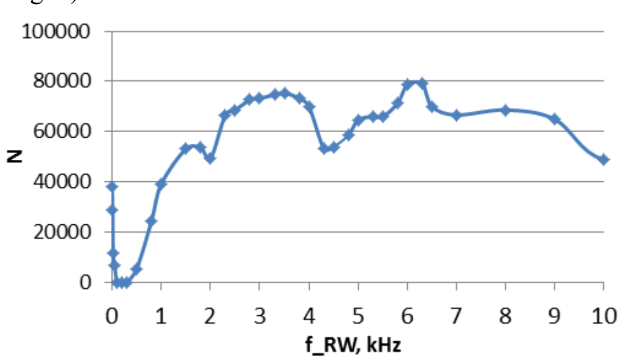

Figure 2: Dependence of the number of positrons in the cloud on the frequency of the rotating field.

Emphasis is placed on the resonances at low frequencies. The dynamics of the accumulation process when turning the rotating field at resonance shows a significant increase in the number of accumulated positrons at low frequencies (see Fig. 3).

With movable collector were obtained transverse size positron clouds when turning the rotating field (see Fig. 4).

Data from these experiments show that the increase in the lifetime and the reduction of the transverse size of the cloud of positrons trapped possible at low frequencies of the rotating field, which are far from the bounce frequency oscillations (about 1 MHz).

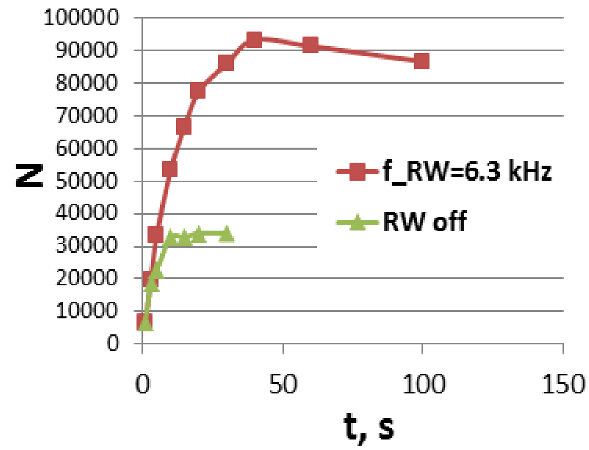

Figure 3: Dependence of the number of positrons in the clouds from the storage time.

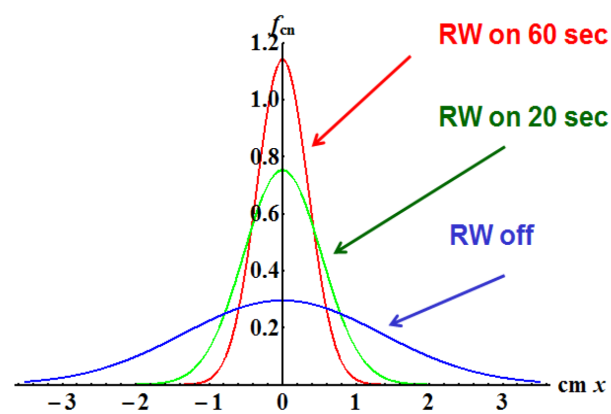

Figure 4: The dependence of the size of the positron cloud working time of the RW field: RW frequency equal 6.3 kHz.

Simultaneously, the frequency of the rotating field does not fall into resonance with the frequency of the magnetron motion of positrons at low densities (about 60 Hz). Moreover, the harmonization of the magnetron frequency with the frequency of the field allows RW under the proposed mechanism to explain the effect of RW-field on the ыещкфпу of positrons. Our hypothesis is that the missing space charge positrons in this case is supplemented with the positive charge of the ions produced in the ionization positrons buffer gas molecules (nitrogen). To test this hypothesis, we need careful measurement of the amount of positive ions in the trap.

CONCLUSION

- «The Rotating Wall» method was studied experimentally at LEPTA injector and a high efficiency of particle storage with RW application has been obtained.
- Optimal the Surko trap parameters have been found.

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- It was found that the RW mechanisms compression of positron clouds were discussed at the LEPTA Trap parameters.
- Methods of optimization of the particle storage and bunch compression in the Surko trap has been obtained.
- Experimental results of positron storage in the LEPTA trap have been presented. A hypothesis about the effect of positive ions on the storage of positrons in the low-density regime.

REFERENCES

[1] X.P. Huang, F. Anderegg, E.M. Hollmann, C.F. Driscoll, and T. M. O'Neil, Phys. Rev. Lett. 78, 875 (1997).
[2] R.G. Greaves and C.M. Surko, Phys. Rev. Lett. 85, 1883 (2000).
[3] J.R. Danielson and C.M. Surko, Phys. Plasmas 13, 055706 (2006).
[4] C. Amole, M.D. Ashkezari, M. Baquero-Ruiz et al., Nature (London) 483, 439 (2012).
[5] N. Kuroda, S. Ulmer, D.J. Murtagh et. al., Nature Commun. 5, 3089 (2014).
[6] J.R. Danielson and C.M. Surko, Phys. Plasmas 13, 055706 (2006).
[7] R.G. Greaves and J.M. Moxom , Phys. Plasmas 15, 072304 (2008).
[8] C.A. Isaac, C.J. Baker, T. Mortensen , D.P. van der Werf, and M. Charlton, Phys. Rev. Lett. 107, 033201 (2011).
[9] C.A. Isaac, Phys. Rev. A. 87, 043415 (2013).
[10] E.V. Akhmanova, M.K. Eseev, A.G. Kobets et. al., Phys. Part. Nucl. Lett. 9, 373 (2012).
[11] C.M. Surko, M. Leventhal, and A. Passner, Phys. Rev. Lett. 62, 901 (1989).
[12] M.K. Eseev, A.G. Kobets, I.N. Meshkov et. al., Plasma Phys. Rep. 39, 787 (2013).
[13] E. Akhmanova, V.M. Drobin, P. Horodek et al., Proceedings this conference.

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