DYNAMIC POSITRONIC BUNCH IN SURKO TRAP OF LEPTA FACILITY

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Abstract

On base of solution of dynamic equations of motion is presented the explanation of effect of influence "rotating wall" electric field the positron bunch in Surko trap, being one of the elements of LEPTA facility.

INTRODUCTION

Facility LEPTA is created in JINR for production of atoms positronium [1]. Work goes for present-day day on increase of density and monochromaticity positron bunch. In these purposes are improved the separate sections of installation, goes selecting the optimum parameters of handling positron bunch. One of the significant elements of LEPTA is positron trap for accumulation of positrons. Working the trap is founded in noted experimental compression and stability positron bunch in rotating wall electric field. Effect strong depend on direction of rotation and frequency for the longitudinal magnetic field. Originally this effect "rotating wall" (RW) field was is discovered in experiments on accumulation ions Mg^+ [2]. Then similar results there were are received and for positron, electron, antiproton (Hbar production in ATHENA project) plasmas [3,4,5]. The direction of rotation RW field at accumulation coincided with a direction of particles drift in crossed the magnetic field and the space charge electric field. The made experiments [6] with electrons have fixed optimum operating modes of Surko trap with a rotating wall, however the mechanism of influence of RW field was necessary for finding.

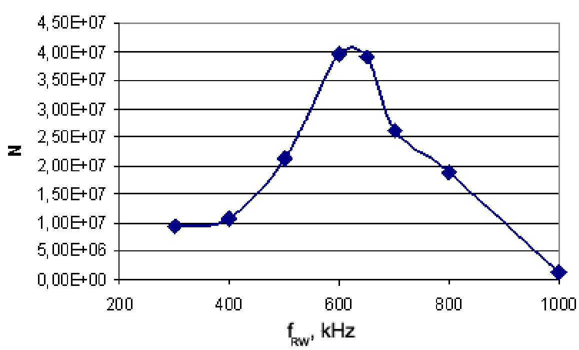

Figure 1: Dependence of number of particles in a bunch from frequency RW field.

In particular it has been noticed, that there is a certain resonant frequency of the RW field at which there is an essential increase in life time. Results of electron (positron) accumulation in the trap are presented in Fig. 1.

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Accurately expressed resonance is visible at RW frequency $f_{RW} \approx 650$ kHz. Similar resonances have been noted in works [2]-[5]. However, in difference of these works effective accumulation of particles [6] occurred at an opposite direction rotation RW-field.

SOLUTION OF DYNAMIC EQUATIONS

In this work of approach there was is dynamic equation of moving the positron in the following conditions (see Fig. 2):

- Longitudinal magnetic field $\mathbf{B}$;
- Rotating electric field $\mathbf{E}_\omega$;
- Electric field of space charge positron bunch $\mathbf{E}_\mathbf{R}$;
- Longitudinal motion of the trapped particle
- Collisions with molecules of buffer gas.

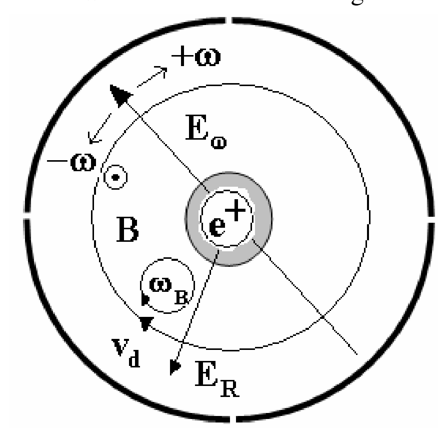

Figure 2: Positron bunch in Surko trap. Transverse positron motion.

At the theoretical analysis of the reasons of occurrence there is nobody a resonance in behavior of the bunch at a certain direction and frequency of rotation of a field there was a following problem - all frequencies concerning data of a problem had essentially various values. For example, at [6] longitudinal field, typical in experiment, concentration of particles $n \approx 0.5 \cdot 10^8 \quad cm^{-3}$, cyclotron frequency is equal to a room temperature $\omega_B = 2.10989 \cdot 10^{10} Hz$, plasma frequency $\omega_p = 1.89 \cdot 10^8 Hz$, and resonant frequency of rotation of field $\omega_{res} = 2\pi \cdot 650 \quad kHz$. Collisions of positrons with molecules of buffer gas (nitrogen [6]) pays off as

$$f_{col} = \sigma \upsilon_{lon} n_N ,$$

where n_N - concentration of molecules, σ - section of inelastic processes of excitation of rotary oscillatory fashions at collision of positrons with molecules of buffer gas, υ_{lon} - longitudinal speed of positrons in the bunch. At energy of positrons of an order 1 eV, pressure of buffer gas in trap $\approx 3\cdot 10^{-4}$ Pa frequency of collisions of positrons with molecules of buffer gas makes size $f_{col} = 200 \div 700$ Hz.

Beginning of one-partial approach, having separated longitudinal and cross-section (in relation to a magnetic field direction) movement of particles in the bunch. Within the limits of approach the equation of movement of a charge in following fields and conditions has been solved: a longitudinal magnetic field (axis Z, an axis of symmetry of the plasma bunch) and rotating electric field $\mathbf{E}_\omega$ (~0.05 V/cm) in plane X0Y with frequency ω_{RW} ; at additional imposing of a field of space charge $\mathbf{E}_R$ in plane X0Y; in the presence of the force of a friction operating on charges owing to inelastic collisions. The movement equation solved in plane X0Y. The field of the space charge got out at uniform distribution of charges on the bunch. The equation of movement of a particle in a case looks like

$$\ddot{\xi} + i\omega_B\dot{\xi} - \eta\xi = \varepsilon e^{-i\omega t},$$

where $\varepsilon = \frac{e}{m}E_\omega$, $\xi = x + iy$, x, y - coordinates of the positron of charge e and weights m, E_ω - intensity of a rotating field. Here $\eta = 2\pi\frac{e^2 n}{m}$ characterizes a field of the space charge with concentration n and intensity $E_R = 2\pi ner$, where $r = \sqrt{x^2 + y^2}$. We will notice that $\eta = \omega_p^2/2$. From the decision analysis it became clear, that electric field of the space charge creates the drift which direction depends on a sign on charges in the bunch, a rotation trajectory - a circle which centre is axis Z. The radius of rotation without **E** would be defined only by a point injection x_0, y_0. The trajectory in the field of the space charge twists in a direction larmor rotations in independence of a charge sign. The magnetic field leads to fast rotation on larmor to mugs of small radius, a field of the space charge - to slower drift movement on a circle of the big radius R_E with frequency

$$f_E = \frac{w_R}{2p} = \frac{u_R}{2pr} = \frac{cE_R}{2prB} = \frac{cne}{B}.$$

Field of a rotating wall to faster rotation with radius R. Imposing of all these movements gives difficult enough picture of movement of particles in a clot. It has been found, that the kind of a trajectory and speed of particles resonance depend on RW frequency of rotation. In case $f_E = f_{RW}$ and the rotation direction coincides with a direction of drift of a trajectory represent braided and untwisted spirals. This resonance is obvious from presented above the equations. The equation of movement has resonant character in relation to the frequencies which are roots of the equation

$$\omega = \frac{\omega_B}{2}\left(1 \pm \sqrt{1 - \frac{2\omega_p^2}{\omega_B^2}}\right).$$

One of equation roots in non-Brillion a density limit corresponds above presented drift frequency $\omega = 2\pi f_E$. The second root - cyclotron frequency of rotation ω_B.

It has been noticed, that longitudinal frequency of movement of positrons in this bunch also has coincidence to RW frequency:

$$f^{res}_{RW} \approx T^{-1}_{long}.$$

In experiments on accumulation of positrons and electrons [7] some resonances on frequencies have been noted. Besides “slipping” of RW frequency concerning frequency of drift movement has been noted. For an explanation of this effect it is possible to use the theory of electro-mechanical wave TG in cylinder column plasma [8]. According to this theories the column plasma has own modes and resonances, defined from condition

$$f^{TG}_{RW} = m_\theta f_E \pm \frac{1}{p_{m_\theta m_z}}\frac{\omega_p}{2\pi}\frac{R}{L}\pi m_Z$$

where R, L - radius and length positron bunch, $p_{m_\theta m_z}$ - m_z -zero of m_θ -Bessel function. Herewith if RW rotation in particle drift direction, that $m_\theta = 1$, if RW rotation in the direction opposite to particle drift, that $m_\theta = -1$. Thereby, own frequencies the bunch can have resonance value in passage (see Fig. 3).

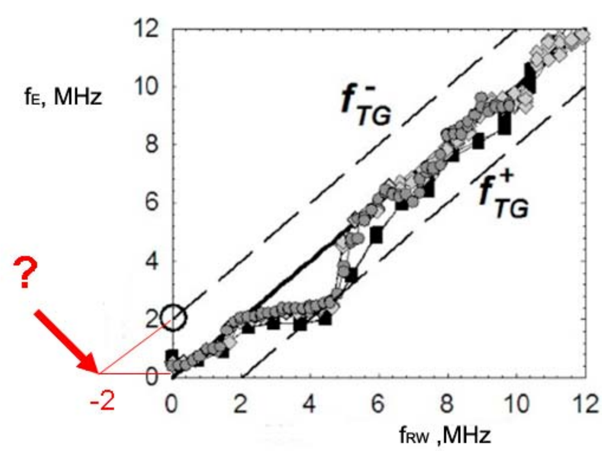

Figure 3: TG-modes in column plasma bunch in Surko trap.

Under low density for RW frequency negative values are possible. This, maybe, exist in experiments [6]. Obviously that for check of this hypothesis necessary to conduct the new experiments. Define dynamics of the dispersion in distribution of the positron density in the accumulation process. It is necessary to realize mechanism the effectively compressed positron bunch.

SUMMARY AND DISCUSSION

We have presented results and offer for discussion:

- Tracks (in transverse plane) and velocities of positrons in the trap were calculated for parameters of the trap of the LEPTA facility. RW rotation resonance of the frequency was defined. Было определено, что при накоплении RW frequency должна быть близка к частоте дрейфа. There is determined that at accumulation RW frequency must be close to the drift frequency.
- It has been noticed, that longitudinal frequency of movement of positrons in this bunch also has coincidence to RW frequency.
- Numerical simulation of particle motion in the trap was realized.
- Electro-mechanical TG modes and resonances in the positron bunch were defined.
- Proposal for new experiments in the Surko trap for positrons was suggested. This required do for optimization of process of accumulation of particles in Surko trap and detailed of mechanism the compressed the positron bunch.

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