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SCIENTIFIC SESSIONS OF THE DIVISION OF GENERAL PHYSICS AND ASTRONOMY OF THE USSR ACADEMY OF SCIENCES, DEVOTED TO LENIN'S 100-th BIRTHDAY

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A scientific session of the Division of General Physics and Astronomy of the USSR Academy of Sciences, jointly with the Radiotechnical Institute of the USSR Academy of Sciences, was held on 25 March 1970 in the conference hall of the Radiotechnical Institute of the USSR Academy of Sciences. The following papers were delivered:

1. A. L. Mints. Lenin and the Founding of Soviet Radio Electronics.
2. M. V. Samokhin. Convective Motion of a Plasma in a Quiet Magnetosphere, Its Causes, and Its Geophysical Consequences.
3. A. D. Vlasov. Methods of Increasing the Proton Current at the Output of a Linear Accelerator.
4. M. L. Levin. Formation of a Ring of Relativistic Electrons with the Aid of Axial Injection.
5. G. V. Voskresenskiĭ and V. N. Kurdyumov, Radiative Losses of Electron Storage Rings in Inhomogeneous Structures.
6. M. G. Nikulin. Dynamic Stabilization of Plasma Pinches.

We publish below brief summaries of the delivered papers.

M. V. Samokhin. Convective Motion of a Plasma in a Quiet Magnetosphere, Its Causes, and Its Geophysical Consequences.

According to present-day notions, the boundary of the magnetosphere is the limiting case of a tangential discontinuity, characterized by the fact that the plasma density inside the cavity is negligibly small, and there is no magnetic field outside the cavity.

The author presents a more general definition of the boundary of the magnetosphere from the point of view of a continuous medium. The equilibrium of the boundary of the forbidden band is considered for different equations of the continuous medium, namely the equations of hydrodynamics, gasdynamics, quasihydrodynamics with straight magnetic force lines perpendicular to the plane of flow, and magnetohydrodynamics in the case when $v_{\parallel} = 0$, where $v_{\parallel}$ is the velocity of the plasma along the magnetic field. It is shown that in the case of a tangential discontinuity the existence of motion of matter inside the forbidden band is a condition for the equilibrium of the separation boundary, and the frontal points of the external and internal regions of the flow coincide. The velocity of the flow inside the forbidden band is equal to zero only in the case when the total pressure (gas and magnetic) does not vary along the boundary. Power series are used to determine the structure of the plasma flow in the vicinity of the frontal points inside the magnetosphere and the plasmosphere. A comparison of the corresponding calculations of the current systems S_p^q and S_q^o in the vicinity of the projections of the frontal points of the magnetopause and plasmopause in the ionosphere with the experimental data offers evidence of satisfactory agreement between the directions of the currents, the slopes of the streamlines, and the distance in latitude between them at a given total current flowing between them; this makes it possible to assume that the source of the unperturbed middle- and low-latitude geomagnetic variations is the "residual" convective motion inside the plasmopause, caused by the solar wind.

A. D. Vlasov. Methods of Increasing the Proton Current at the Output of a Linear Accelerator

The paper is devoted to a review of work on estimating proton currents attainable in a linear accelerator under different injection and acceleration regimes, and also to the choice of the most promising regimes.

At the present time, proton pulse currents on the order of 140 mA have been attained in Soviet and foreign linear accelerators. The requirements of physical experiments are already two or three times larger, and in the future the requirements will increase even more. The attainable currents are limited principally by the longitudinal repulsion of the proper charge of the accelerated plasmoids.

An investigation of this problem was initiated at the Radiotechnical Institute of the USSR Academy of Sciences about ten years ago. In 1960, an expression was obtained for the proton current in the regime of shaped stable plasmoids represented approximately as uniformly charged ellipsoids. Two years later, a paper appeared in which the current was estimated numerically on the basis of another, cylindrical approximation of the plasmoids, identical in essence with the well-known disc model. Later on it became possible to consider cylindrical plasmoids also analytically, and the results, including the expression for the current, coincided with the results of the ellipsoidal approximation. The calculated currents exceeded somewhat those actually obtained.

It was necessary to seek other, more effective regimes. In 1967 and 1968 there appeared two papers, in which numerical methods were used to consider cases of injection of denser and longer bunches, and also of a continuous beam. In spite of the loss of particles during the course of the shaping of the bunches, the currents increased in this case to 200–700 mA.

In 1969, the regime of indifferent equilibrium of the bunches was investigated and the maximum attainable currents without particle loss were estimated. These currents are on the average twice as large as in the previously considered stable bunches.

The results offered evidence of a rapid increase of the current with increasing equilibrium phase. When the latter increased from the usual values 35–45° to 85–90°, the current increased to 6–10 A. However, the preliminary bunching necessary to obtain indifferent equilibrium is quite difficult to accomplish. In addition, the increased equilibrium phase shifts can be allowed only in limited regions of the accelerator.

An accelerator was therefore considered with an equilibrium phase shift equal to 85–90° at the beginning and then decreasing gradually. The investigation has shown that the admissible decrease of the equilibrium phase shifts along the accelerator is limited from below by a certain limiting curve. In the case of injection of the continuous beam, other accelerator parameters remaining the same, the proton currents do not exceed 1 A. Preliminary bunching into constant-density bunches makes it possible to increase the currents attainable in the considered examples to 3 A. The attainment of such currents is perfectly realistic.

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[3]A. Faltens, Symp. Electr. Ring Acceler., Berkeley, USA, 1968, p. 363.
[4]J. D. Lawson, Rutherford Lab. Memor., RHEL/M144, 1968.
[5]E. D. Courant, Proceedings of All-Union Conference on Accelerators, Moscow, 1968.

G. V. Voskresenskiĭ and V. N. Kurdyumov. Radiative Losses of Electron Rings in Inhomogeneous Structures

The calculation of radiative losses accompanying the motion of electron rings in inhomogeneous structures, for example when passing through junctions of waveguides with different cross sections, resonators of the accelerating system, etc., is of interest in connection with the development of the collective method of ion acceleration. In practice, the most important aspect of this calculation is a clarification of the dependence of the total loss to radiation on the kinetic energy of the source. However, the sought equation for the losses turns out to be different and to depend essentially on the model assumptions used by the different authors. The present paper considers critically certain models which make it possible to obtain an approximate estimate of the losses: 1) excitation of a completely closed resonator [1,2]; 2) geometrical-optics calculation[3]; 3) the Lawson diffraction model[4]; 4) calculation in the Kirchhoff approximation[5]. The shortcomings inherent in approximate calculation methods require a rigorous electrodynamic calculation of the radiation in a single resonator with connecting waveguides. The paper presents the results of a solution of the electrodynamic boundary-value problem for such a region. The problem, reduced to an infinite system of linear algebraic equations for the coefficients of excitation of the eigenwaves in the connecting waveguides, is solved by numerical methods. The spectral distribution of the losses is calculated. The solution is different qualitatively in different frequency regions. In the low-frequency band there is excited a denumerable number of discrete harmonics, analogous to the modes of a closed cavity. In the region of high frequencies, a continuous radiation spectrum is generated. The spectrum broadens with increasing source energy, leading to a linear dependence of the loss on the energy for ultrarelativistic electron rings. The rapid growth of the losses with the energy imposes stringent requirements on the choice of the accelerating system for high-energy electron-ring accelerators.

M. G. Nikulin. Dynamic Stabilization of Plasma Pinches

The paper considers different schemes for high-frequency dynamic stabilization of a current-carrying plasma pinch against long-wave flexural perturbations. The flexural instability of the pinch with direct current, in the absence of an external longitudinal field, can be suppressed, as is well known, by a well-conducting jacket located close enough to the surface of the pinch. In systems with large degrees of plasma compression, where this stabilization method is not effective, and also in systems without a conducting jacket, the suppression of long-wave deflections of the pinch can be realized by means of the standing or rotating high-frequency quadrupole magnetic field. To stabilize a pinch with alternating current, one can use either a constant or a high-frequency quadrupole field.

In systems with an external longitudinal field, the changeover from a direct current to a high-frequency alternating current makes it possible to weaken greatly the limitation imposed on the value of the current by the condition that the pinch be stable against long-wave helical perturbations. Consequently, an alternating longitudinal current in conjunction with a transverse high-frequency magnetic field can be used for equilibrium containment of an annular θ pinch, and in conjunction with a conducting jacket or a quadrupole magnetic field that adds an additional margin of stability to the plasma pinch against long-wave perturbations, it is possible to suppress the unstable Shafranov-Kruskal mode of a pinch with direct current or the unstable Haas-Wesson mode of a corrugated θ pinch.

The paper also considers the effect of parametric buildup of natural oscillations of the plasma pinch under the influence of high-frequency magnetic fields. Possible methods of eliminating this effect are considered.

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