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MODELING OF ELECTROSTATIC COLLIMATOR OF CHARGED PARTICLES BEAMS ON THE BASIS OF SPHERICAL MIRROR

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The modeling of the collimator of charged particles beams on the basis electrostatic spherical mirror was carried out. The conditions of collimation in the spherical mirror at the external reflection of charged particle beams were defined. The electrostatic spherical mirror in the external reflection regime of charged particle beams can be used as the collimator. The spherical mirror provides high quality of beams collimating and can be used an additional element in various devices. Calculation of electron-optical scheme was carried out by the "Focus" modeling program of axially-symmetrical systems of corpuscular optics with an arbitrary geometry of the electrodes.

Keywords: collimator of charged particles beams, electrostatic field, the spherical mirror, parallel beams.

Introduction

One of functions of electron - optical elements of practical interest is the collimation of charged particles beams. In this work the collimating problem of charged particles beams was considered. In the corpuscular optics, this problem allows to sudden reduce the intensity loss at transport of charged particle beams and technically implemented by means of electrostatic lenses and mirrors.

In the work numerical modeling of the electrostatic collimator for transporting of charged particle beams over long distances without intensity loss was carried out. The collimator is the electrostatic spherical mirror. The collimator makes it possible to obtain parallel beams of charged particles. Parallel beams can be transmitted over long distances and focused on the detector at any point.

The collimator is device, which forming a parallel beam. The collimator is often used to control all kinds of tests and studies of details and assemblies. It is part of a series of devices: spectral, test-measurement, sighting, instruments of communication and signaling, etc. Collimators are often used in accelerators for absorbing of particles with large transverse impulse.

In work [1] the collimating problem of charged particles in spherical mirror with *inner reflection* was considered. Conditions of collimation in spherical mirror were determined. It is shown that the high quality of trajectories parallelism in the beam was achieved in second-order collimation conditions.

Collimating properties of the spherical mirror by methods perturbation theory were studied in work [2]. Collimating conditions of charged particles beams in spherical mirror in *external reflection* were determined. It is shown that the second-order collimation is achieved. Charged particles beam coming from the source and is located on the spherical mirror axis, after the external reflection from the mirror, becomes parallel under certain conditions (Fig.1). According to the approach of perturbation theory, the quality of collimation can be described by order, the value of which is determined by the number of simultaneous vanishing derivatives $\left.\frac{d^n d_1}{dd^n}\right|_{\alpha=\alpha_0} = 0$.

Calculation for collimating regime of charged particles beam at symmetry angle in cylindrical, spherical and hyperbolic electrostatic mirrors was calculated in work [3]. System of successive cylindrical and spherical mirrors, as well as a system of cylindrical and hyperbolic mirror in collimating regime of charged particles at an angle of the system symmetry were considered. It was determined that the angular dispersion in the energy of system of cylindrical and hyperbolic mirrors more than 2 times higher than the angular dispersion of a similar system with a spherical mirror. This allows using it as independently, and as element with high angular dispersion in energy with its subsequent transformation to linear system of cylindrical mirrors.

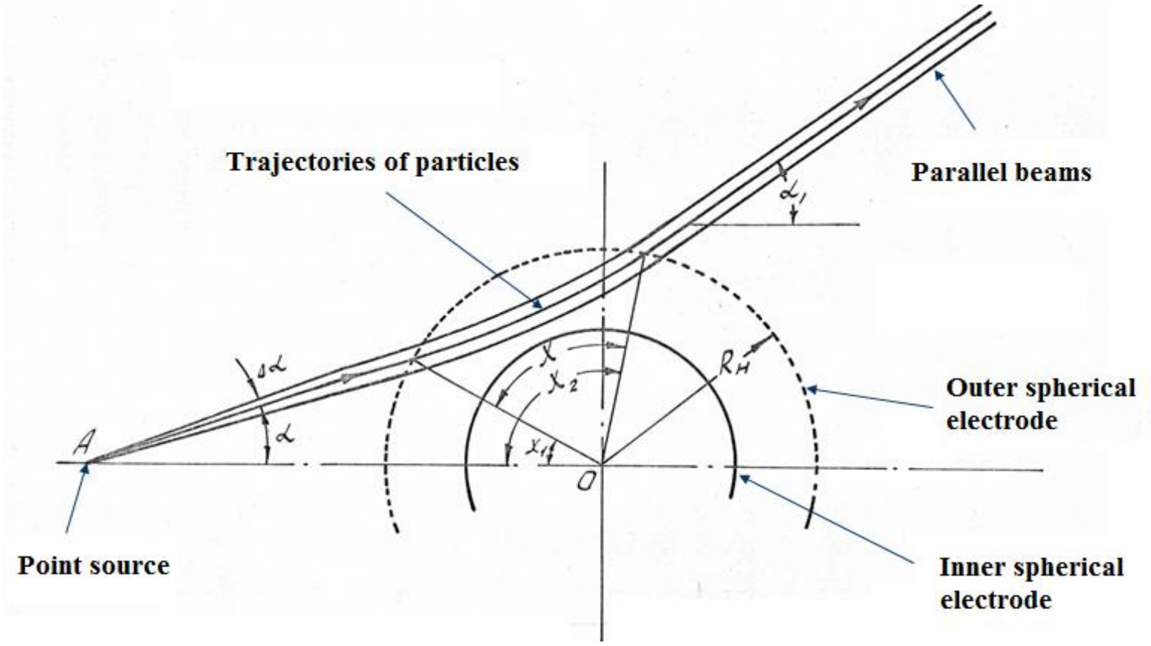

Fig.1. The course of trajectories in the spherical mirror in the collimating regime

The electrostatic spherical mirror formed by two concentric electrodes having forms of spheres. The outer sphere is grounded; retarding potential is served on the inner sphere.

Modeling of electrostatic collimator

The modeling of electron-optical scheme of a spherical mirror was carried out by “Focus” modeling program of axially-symmetrical electron-optical systems in the power regime with constant electric field.

The “Focus” program allows to realize input and modification of design in graphically regime, calculate the potential distribution in the selected area and to conduct the trajectory analysis of the system [4].

Synthesis of electron-optical systems of complex structure, corresponding to specified requirements, impracticable without the preliminary stage of the numerical modeling and analysis. This allows real-time to consider the ten of variants of the desired design of electron-optical system, without the need to create prototypes model. Thus, significantly expanding boundaries of the possible search for the optimal design of electron-optical systems, which allows to estimate its parameters, which are time-consuming to measure or cannot be measured with the required accuracy [5].

Numerical modeling of electron-optical systems traditionally includes parts such as modeling of electrostatic fields and calculation of trajectories of charged particles in these fields. Numerical modeling unlike analytical modeling has several advantages, the main of which is a lower level of idealization of real designs [6].

Fig.2 shows the design of spherical mirror consisting of two concentric electrodes. The total length of the system is 20 (relative units of program). The potential U = 1 is filed on the inner electrode; the external electrode is at ground potential. The external electrode is selected transparent to charged particles as they move into the field of electron-optical system. The radii of inner and outer concentric electrodes selected as R_{in} = 6, R_{out} = 10. The thickness of the electrodes is 0.3.

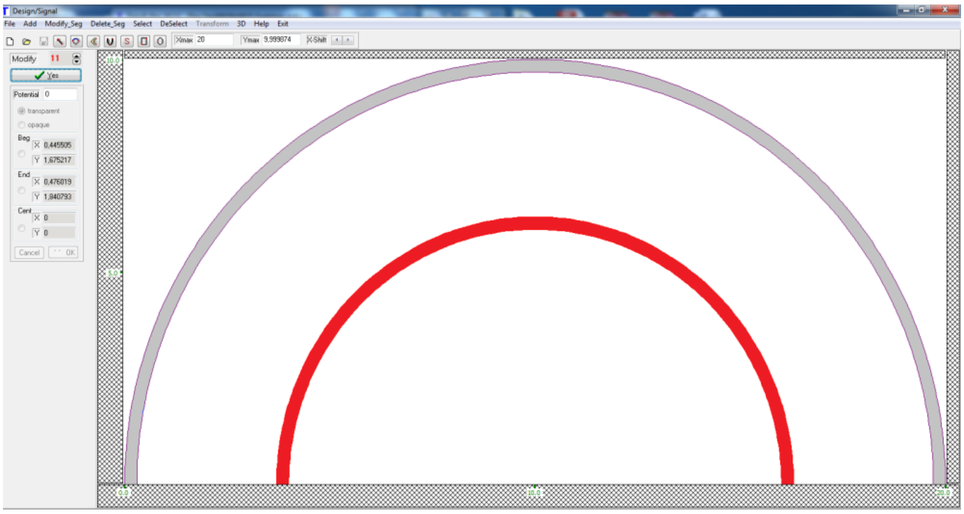

Fig.2. The design of spherical mirror

Fig.3 shows a three-dimensional image of the spherical mirror design. Fig.4 shows the distribution of the field in the electron-optical system of spherical mirror. It made the calculation of values of the potentials at the nodes of the mesh of the partition area and painting the color output of the field at each point of which corresponds to the potential value, the greater the potential, the "warmer" color.

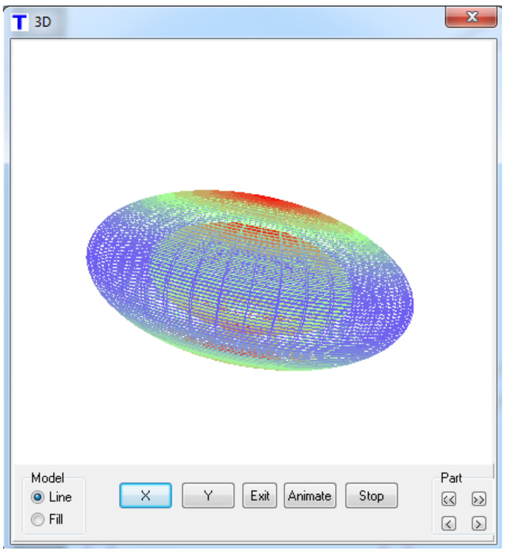

Fig.3. Three-dimensional image of the spherical mirror design

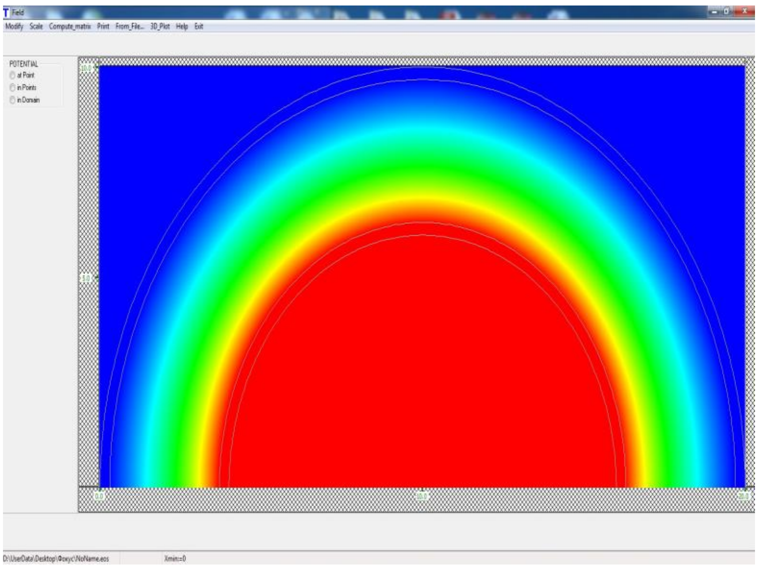

Fig.4. The distribution field function in the spherical mirror

Fig.5 shows set of trajectories of particles with energy E /V = 3, emitted from a point source located on the symmetry axis at a distance of 12.8 from the center of the spherical mirror. The range of entrance angles in spherical mirror is 32^0-42^0. In this figure you can see potential lines of the field of electron-optical system. When calculating a change step of angle was equal to 2^0. Fig. 5 shows that charged particles beam coming from the point source, enters through an external electrode in the spherical mirror field, then after reflection from the field becomes parallel.

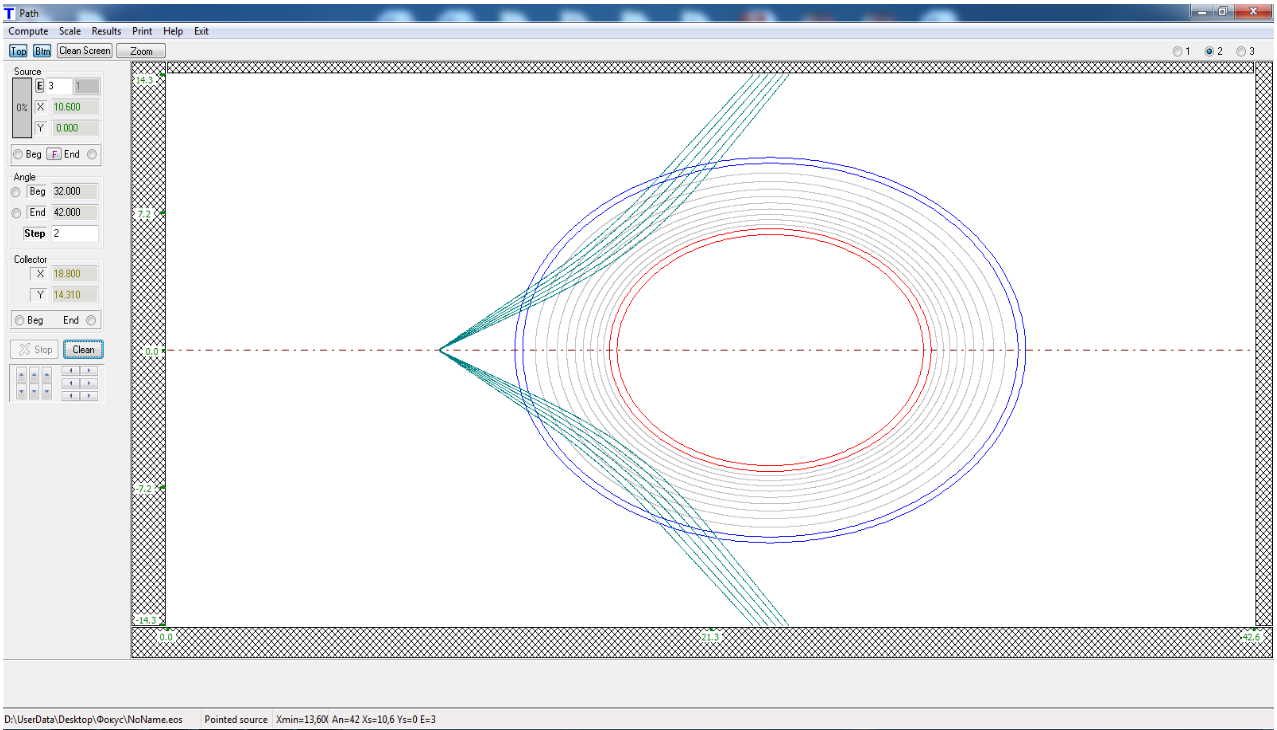

Fig.5. Collimating of charged particles beams in the spherical mirror at external reflection

The angular dispersion in energy of scheme is calculated. Trajectories of charged particles with different initial energies were considered. The angular dispersion in energy is $d\alpha/d\varepsilon = 3.73$. For example, in this regime with the initial spread of the beam $\alpha = 36^0$-39^0, angular divergence of the boundary trajectories from $\alpha = 37^0$ at the output of the mirror is $\Delta\alpha_1\left(-1^0\right) = $-0,04198, $\Delta\alpha_2\left(2^0\right) = -0{,}093091$, and the axial divergence from the central trajectory $\Delta l\left(-1^0\right) = -0{,}018667$, $\Delta l\left(2^0\right) = -0{,}034666$.

Conclusion

The numerical model of the electrostatic collimator on the based spherical mirror was obtained. The calculation of trajectories of charged particles in a numerical form was conducted. Conditions of collimation in the spherical mirror with an external reflection of charged particle beams were determined.

The electrostatic spherical mirror in the external reflection regime of charged particle beams can be used as the collimator. The spherical mirror provides high quality of beams collimating and can be used an additional element in various devices.

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