Analyzer of charged particles based on the electrostatic quadrupole-cylindrical field in the «axis-ring» focusing regime

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The potential of a multipole-cylindrical field based on a superposition of fields of the cylindrical type mirror and a various order circular multipole has the following form:

$$U(r,z) = \mu \ln r + U_m(r,z)$$

where U_m is circular multipole, μ is coefficient specifying the weight contribution of the cylindrical field.

The connection of multipole components of various orders **(quadrupole, hexapole, sextupole, etc.)** to the base cylindrical field leads to the synthesis of a wide class of various axially-symmetrical fields, among which can be found variants of mirror analyzer designs with improved angular focusing quality.

The work is devoted to the calculation of the focusing properties of an axially-symmetrical electrostatic quadrupole-cylindrical mirror energy analyzer of charged particles and the search of new angular focusing regimes.

The calculation of the structures of electrostatic quadrupole-cylindrical fields synthesized based on the sum of the base cylindrical field and axially-symmetrical cylindrical quadrupoles of various types is given earlier. Equipotential portraits of quadrupole-cylindrical fields of various types are presented.

The analysis of the obtained equipotential portraits of quadrupole-cylindrical fields is carried out. **It is established that an electron mirror based on quadrupole-cylindrical field, potential which is equal to**

$$U_q(r,z) = U_0\left(\mu + z\right)\ln r$$

more accessible for analytical research of its electron-optical properties and for construction high luminosity energy analyzer based on it.

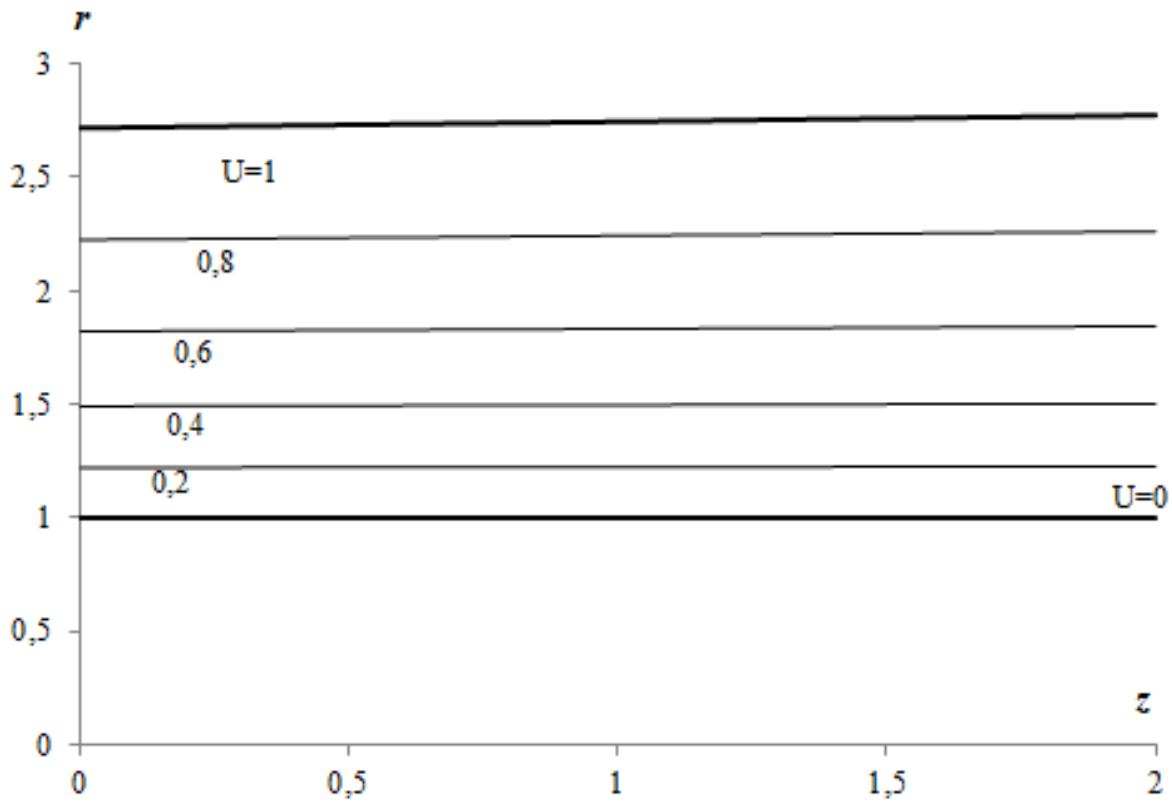
It is noted that the quadrupole-cylindrical field at the value coincides with the well-known Wannberg field, proposed for the development of a device operating in the spectrograph mode.

The potential of the Wannberg field in the coordinate system *r, z* is described by the following expression

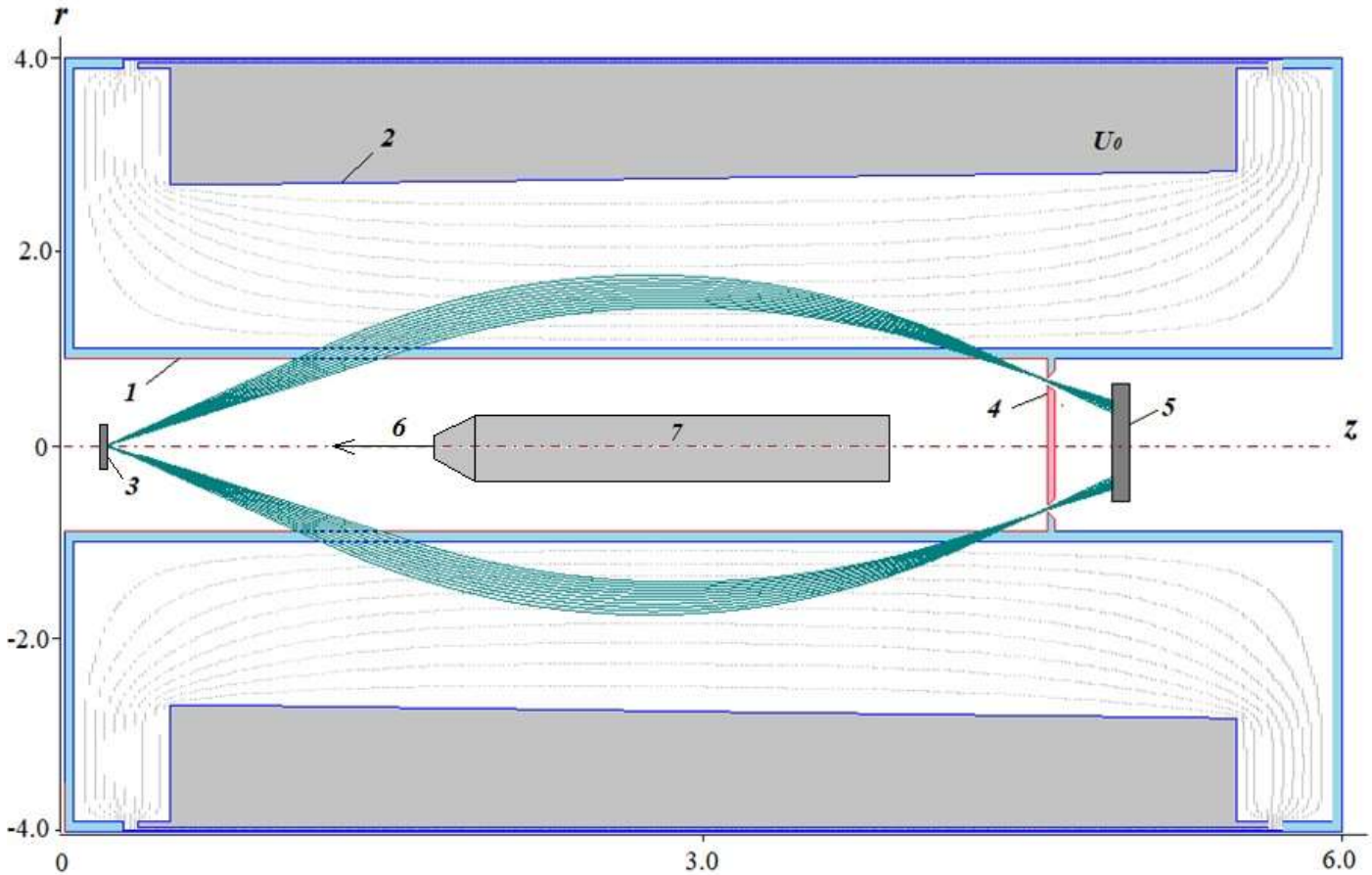
$$U = \frac{V}{\ln\left(r_1/r_o\right)}\left(1 + Az\right)\ln\frac{r}{r_o}$$

where is a small dimensionless parameter.

The profile of the outer electrode is determined from the calculation of equipotential lines in a quadrupole-cylindrical field.



Equipotential lines in the electrostatic quadrupole-cylindrical field at a values of parameters A=-0.01 and μ=1

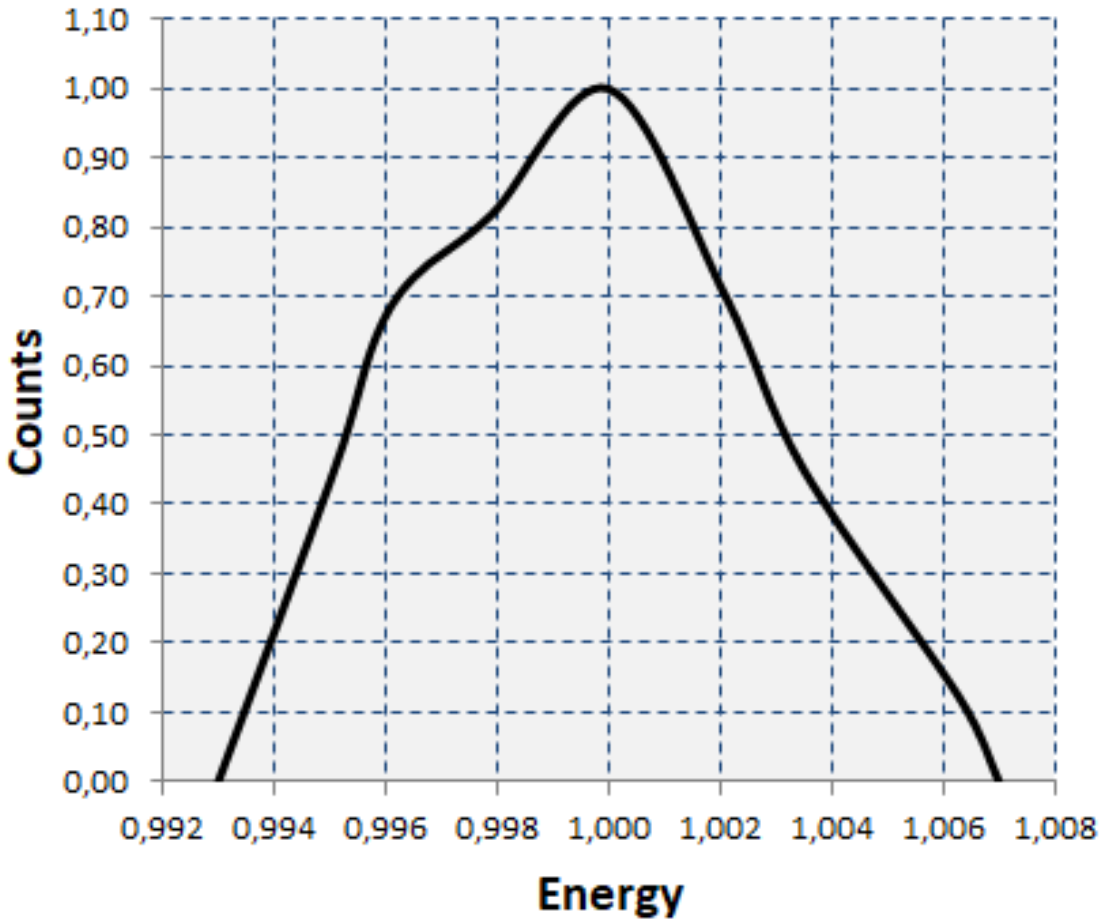


Scheme of a longitudinal section of the axially-symmetrical energy analyzer based on quadrupole-cylindrical field ("axis-ring" focusing regime) at value of parameter *A* = - 0.01:

1 is cylindrical electrode, 2 is outer electrode, 3 is sample with a point source of particles, 4 is exit diaphragm, 5 is detector, 6 is primary electrons, 7 is electron gun.

Table 1. Focusing properties of an energy analyzer based on an electrostatic quadrupole - cylindrical field at A = - 0.01.

Type of focusing	«axis-ring»
Focusing order	2
Center angle of focusing	36.6°
Xfoc coordinate of the focal point	4,6
Yfoc coordinate of the focal point	0,7
Reflection parameter, P	1



The instrumental function of axially-symmetrical energy analyzer based on quadrupole-cylindrical field for a point source case.

Modeling of the electron-optical scheme showed the possibility of achieving “axis-ring” type second-order focusing of charged particles.

Results of calculation the focusing properties of energy analyzer based on a quadrupole-cylindrical field are obtained. The design of a quadrupole-cylindrical mirror is proposed, which has higher corpuscular-optical parameters compared to the classical cylindrical mirror.

On the basis of quadrupole-cylindrical fields, energy analyzers can be built that provide operating regimes in conditions of high resolution.