

PAPER • OPEN ACCESS

Modeling of electrostatic decapole-cylindrical mirror analyzer

To cite this article: Zh T Kambarova *et al* 2017 *IOP Conf. Ser.: Mater. Sci. Eng.* **168** 012078

View the [article online](#) for updates and enhancements.

Related content

- [Cylindrical Mirror Analyzer for Measuring Energy Spectrum of Photostimulated Exoelectrons](#)
Shigeyuki Yamamoto, Hiroshi Yokogawa and Hiroshi Hashimoto
- [STUDY OF EXOTIC WEAKLY BOUND NUCLEI USING MAGNETIC ANALYZER MAVR](#)
V.A. Maslov, V.I. Kazacha, I.V. Kolesov et al.
- ["AN IMPROVED ASTRONOMICAL MIRROR"](#)
J. E. Keeler

Репозиторий КарГУ

Modeling of electrostatic decapole-cylindrical mirror analyzer

Zh T Kambarova¹, A O Saulebekov² and D A Saulebekova³

¹ Ye.A. Buketov Karaganda State University, Universitetskaya str. 28, Karaganda 100028, Kazakhstan

² Lomonosov Moscow State University, Kazakhstan branch, Kazhimukan str.11, Astana 010010, Kazakhstan

³Nazarbayev University, Kabanbay Batyr Ave. 53, Astana 010000, Kazakhstan

E-mail: saulebekov@mail.ru

Abstract. Numerical modeling of electron-optical scheme of electrostatic decapole-cylindrical mirror energy analyzer has been carried out. Trajectory analysis of the charged particles motion in decapole-cylindrical field has been conducted. Two regimes of second-order angular focusing (“ring-ring” and “axis-ring” types) were found. Focusing properties of decapole-cylindrical analyzer in second-order angular focusing regime for different types of focusing were calculated. Instrument functions were obtained; energy resolution and luminosity of device were estimated.

1. Introduction

The mathematical method of construction a new class of multipole-cylindrical fields on the basis of the superposition of cylindrical and circular multipole fields, which proposed in [1-2], opens up the prospects to develop new effective systems of energy analysis. Based on this method, the wide range of various potential fields, of practical interest for development of new schemes analyzers with improved characteristics, was calculated. The calculation and analysis of potential properties of synthesized hexapole-cylindrical fields have allowed defining new schemes of mirror energy analyzers having broader functional capabilities compared with the cylindrical mirror [3-4].

The purpose of this work is a numerical modeling of electron-optical scheme of decapole-cylindrical energy analyzer of charged particles beams.

2. Description of decapole-cylindrical analyzer scheme

The scheme of the electrostatic mirror analyzer having the deflecting field which is the result of the superposition of cylindrical field and circular cylinder decapole, was studied in the present work.

$$U(\rho, z) = \mu \ln(1 + \rho) + \gamma U_d(\rho, z), \quad (1)$$

where $\mu \ln(1 + \rho)$ is the cylindrical field, μ is the coefficient that specifies the weight contribution of the cylindrical field, $U_d(\rho, z) = \rho z^4 - 2\rho^3 z^2 + \frac{1}{2}\rho^2$ is the cylindrical decapole, γ is the weight contribution of the circular decapole.

The scheme of mirror energy analyzer with decapole-cylindrical field (1) is shown in Fig.1, and contributions of cylindrical field and decapole are respectively $\mu=1$, $\gamma = -1/100$. It shows emerging of the axial trajectory of the particles beam from A ring source.

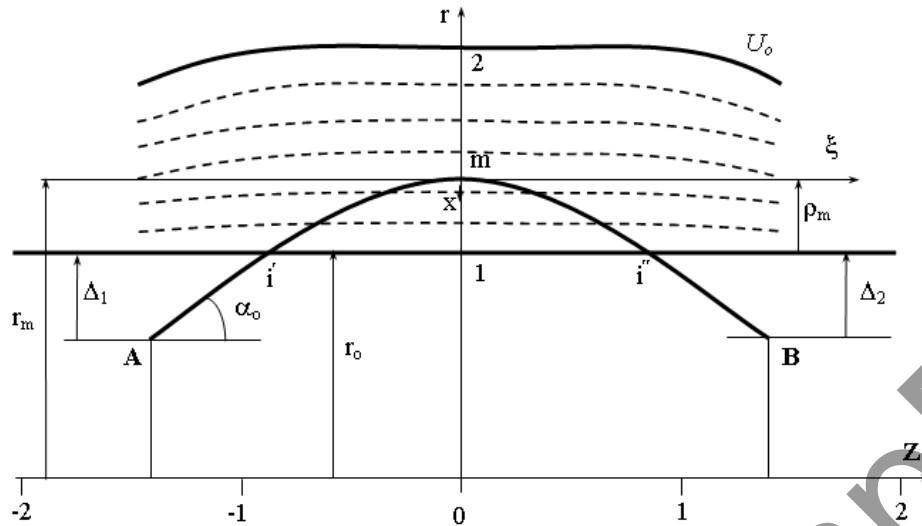


Figure 1. Scheme of energy analyzer based on the decapole-cylindrical field. A is the source of charged particles beam, B is the receiver, i' is the enter ring slit, i'' - the exit ring slit.

Because of the small contribution of circular field, the distribution of equipotential lines of decapole-cylindrical field, having small deviation from the straight line, is similar to one of equipotential lines of cylindrical field. The field is formed in the space between the two axial-symmetrical coaxial electrodes. The inner electrode of cylindrical shape (radius r_0) is at ground potential, the outer electrode having the curved profile is fed by deflecting potential U_0 . At a certain ratio of geometrical and energy parameters of the analyzer, a charged particles beam coming from A ring source is reflected by the mirror field and focuses to B ring image.

3. Modeling of electron-optical scheme of mirror decapole-cylindrical energy analyzer

Numerical modeling of electron-optical scheme of energy analyzer based on the decapole-cylindrical field has been carried out in the work. The "Focus" numerical program of modeling axially-symmetrical corpuscular-optical systems was used to model the proposed energy analyzer [5]. Profile of outer electrode was defined on the basis of calculation equipotential lines in decapole-cylindrical field by using MathCAD program.

Fig.2 shows the scheme of second-order angular focusing regime of the "ring-ring" type in decapole-cylindrical analyzer with $\mu = 1$, $\gamma = -1/100$. The total length of the electron-optical system is 11.4. The potential of the outer electrode (2) having curved profile is 1. The radius of the inner cylindrical electrode (1) is equal to 4.2. The inner cylindrical electrode is at zero potential. The ratio of the energy of charged particle and the potential of the electrode is $E/V = 1$. The position of the source is $x = 1.1$; $y = 2.9$. The change step of the initial launch angle of particles change is 2° . All dimensions are expressed in standard units.

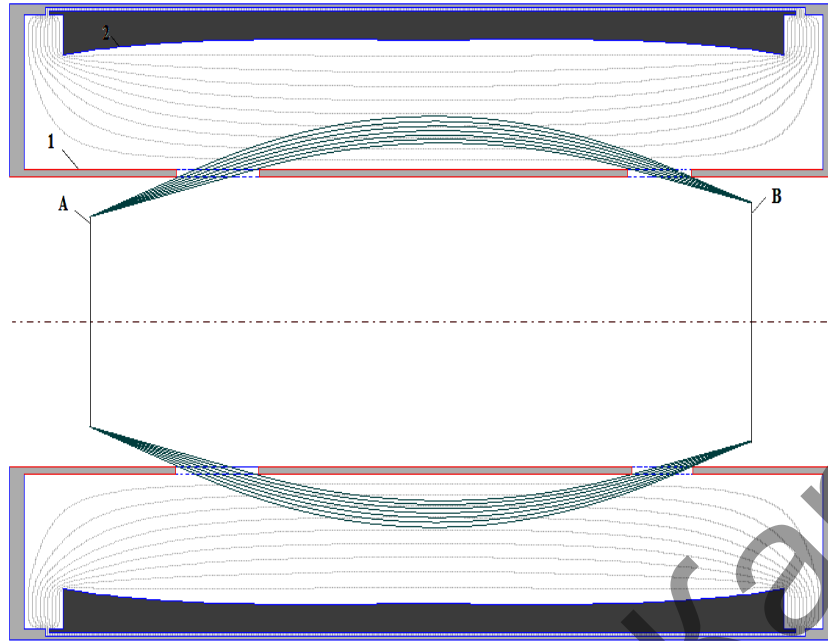


Figure 2. The scheme of the second-order angular focusing regime of the “ring-ring” type in decapole-cylindrical analyzer with $\mu = 1$, $\gamma = -1/100$. A is ring source, B is ring image, 1 - cylindrical electrode, 2 - outer deflecting electrode having curved profile.

According to Fig.2, the particles from A thin ring source in the range of polar angles from 30 to 42° are emitted and deflected from decapole-cylindrical field under the action of potential of external electrode having curved profile (2), and then focused to the B ring image. A ring source and its B image are located in the region of inner cylindrical electrode. Thus, the second-order angular focusing regime of the “ring-ring” type is performed in the system. From calculations of focusing properties it was found that the second-order angular focusing regime with the central angle of 34.885° was realized in the electron-optical system for a wide range of change of enter angles (30 - 42°).

To calculate the instrumental function of decapole-cylindrical analyzer in the second-order angular focusing regime of the “ring-ring” type, the particles were launched from the ring source in the ranges of initial angles 30 - 42° and initial energies 0.94 - 1.06 . Fig.3 shows the instrumental function of decapole-cylindrical analyzer with $\mu=1$ and $\gamma = -1/100$ for angular focusing regime of the “ring-ring” type. Relative energy resolution on half-height of instrumental function is 1% with $0,1R_{in}$ output aperture radius, and luminosity is $\Omega/2\pi=12\%$.

It also has been found that the second-order angular focusing regime of the “axis-ring” type was performed in the electron-optical system of decapole-cylindrical analyzer. In this case, the distance from the investigated sample to the analyzer is $z = 3.6$. This scheme of angular focusing provides the “sample-analyzer” long focal length.

Fig.4 shows the scheme of the second-order angular focusing regime of the “axis-ring” type in decapole-cylindrical analyzer. The interval of initial launched angles of charged particles is from 34° to 42° . The ratio of the energy of a charged particle and the potential of the electrode is $E / V = 1.3$. The position of the point source is defined by $x = 0$; $y = 0$. The change step of the entry angle of particles is 1° . The electron gun is located in the region of inner cylindrical electrode.

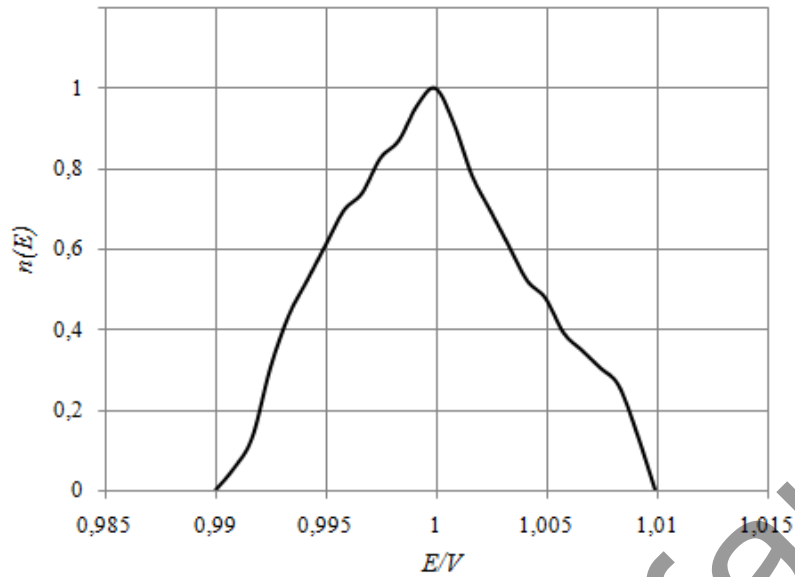


Figure 3. The instrumental function of decapole-cylindrical analyzer in angular focusing regime of the “ring-ring” type at $\mu = 1$, $\gamma = -1/100$.

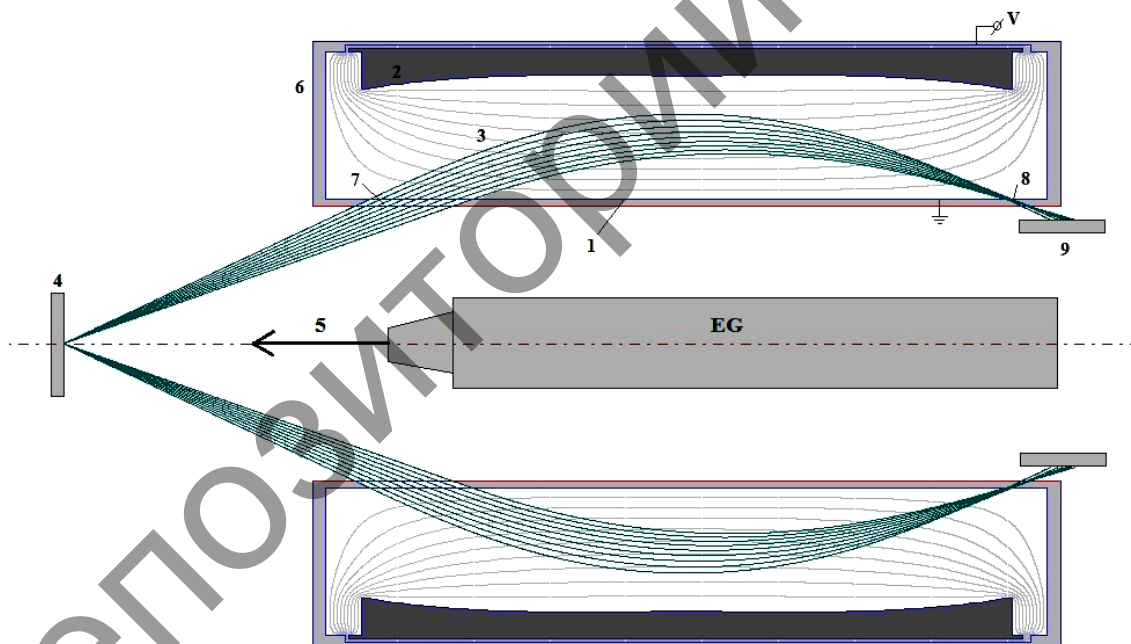


Figure 4. The scheme of the second-order angular focusing regime of the “axis-ring” type in decapole-cylindrical analyzer at $\mu = 1$, $\gamma = -1/100$. 1 - cylindrical electrode, 2 – outer electrode having curved profile, 3 - secondary electrons, 4 – investigated sample, 5 - primary electrons, 6 - magnetic screen, 7 and 8 – enter and exit slits, 9 – detector, EG - electron gun.

According to Fig.4, the secondary electrons (3) emitted by the action of the primary radiation (5) from the surface of the investigated sample (4), entered into the region of the analyzing decapole-cylindrical field through the enter slit (7), then reflected from the outer deflection electrode (2), and focused to the ring image on the surface of the inner cylindrical electrode (1). Next, they pass through the exit slit (8), and registered by the detector (9). This scheme with internal electron gun has a long focal distance from the investigated sample to the analyzer.

For instrumental function calculation a diaphragm is placed on the surface of the inner cylindrical electrode. The range of initial launch angle of particles is $34-42^\circ$, the range of initial energies (or rather E/V) 1.287-1.313. Fig.5 shows the instrumental function of electron-optical scheme of decapole-cylindrical analyzer for the case of the angular focusing regime of the “axis-ring” type. Relative energy resolution on half-height of instrumental function of analyzer is 0.8% with $0.024R_{in}$ output aperture radius, luminosity is $\Omega/2\pi=8.6\%$.

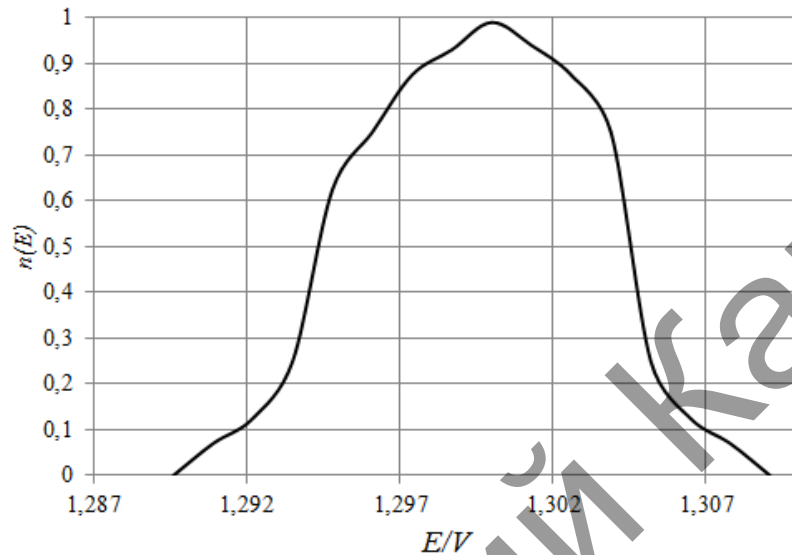


Figure 5. The instrumental function of decapole-cylindrical analyzer in angular focusing regime of the “axis-ring” type at $\mu = 1$, $\gamma = -1/100$.

The table 1 shows results of calculations of focusing properties of decapole-cylindrical analyzer at $\mu=1$, $\gamma = -1/100$ for different types of second-order angular focusing.

Table 1. Focusing properties of decapole-cylindrical analyzer with $\mu = 1$, $\gamma = -1/100$ for different types of the second-order angular focusing.

Focusing type	«ring-ring»	«axis-ring»
Focusing order	2	2
Central angle of focusing	34.8850	34.70
X coordinate of focusing	10.41	17.415
Y coordinate of focusing	3.165	4
Reflection parameter	1	0.99

4. Conclusions

The numerical model of the electron-optical scheme of decapole-cylindrical analyzer with $\mu = 1$, $\gamma = -1/100$ has been obtained. Instrumental functions of analyzer for second-order angular focusing regimes of “ring-ring” and “axis-ring” types were calculated. Focusing properties of decapole-cylindrical analyzer for second-order angular focusing regimes of “ring-ring” and “axis-ring” types were determined by numerical calculations. It was established that on the basis of decapole-cylindrical field the high-aperture energy analyzers with second-order angular focusing can be built. Practical realizable scheme of the angular focusing regime of the “axis-ring” type with the long focusing distance makes it possible to use it as a dispersing element in the system for a local elementary analysis of micro- and nanometer scale regions.

Acknowledgements

This work was supported by the grant GF4-0815 of the Ministry of Education and Science of the Republic of Kazakhstan.

References

- [1] Zashkvara V V and Tyndyk N N 1991 Axial-symmetrical multipoles, their application *Zh.Tech.Phys.* **61(4)** 148-157
- [2] Zashkvara V V and Tyndyk N N 1996 Potential fields based on circular multipole series *Nuclear Instrum. and Meth.* **A370** 452-460
- [3] Ashimbaeva B U, Chokin K Sh and Saulebekov A O 2005 Focusing Properties of a mirror analyzer with hexapole cylindrical field *J. of Electron Spectroscopy and Related Phenomena* **143** 29-32
- [4] Ashimbaeva B U, Chokin K Sh, Saulebekov A O and Kambarova Zh T 2012 Modeling of electron-optical scheme of the analyzer with hexapole cylindrical field *Prikladnaya fizika* **2** 45-48
- [5] Gurov V S, Saulebekov A O and Trubitsyn A A 2015 *Advances in imaging and electron physics. Analytical, Approximate-Analytical and Numerical Methods in the Design of Energy Analyzers* (Editor-in-chief Peter W. Hawkes CEMES-CNRS Toulouse, France. - Academic Press is an imprint of Elsevier) **192** 205