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ANALYZERS ON THE CLASSICAL FIELDS BASIS FOR ELECTRON SPECTROSCOPY

A.O. Saulebekov, S.E.Sakipova, S.N. Assylbekova, Zh.T. Kambarova, A.T. Makhabaeva

Karaganda State University named after E.A.Buketov, Universitetsckaya St. 28, Karaganda, 100028, Kazakhstan,
saulebekov@mail.ru

Energy analysis of the charged particles fluxes as an effective method of solid body's surface research demands the existing systems modernization or creations of qualitatively new ones. The purpose of the given work is developing out energy analyzers with high electron-optical parameters and wide functionality based on the classical fields.

The schemes consisting of a cylindrical mirror and a spherical mirror with internal and external reflection of the charged particles beam have been considered earlier separately. It is established, that the formulas describing these systems differ only by the signs at the separate components. It gives the chance to describe all system mathematically uniformly. At the conditions of angular focusing of the second order the ratios between the mirrors parameters have been received. Three parameters are free, and some practical advantages can be achieved by variations of them.

Keywords: charged particles fluxes, cylindrical mirror, spherical mirror, angular focusing.

Introduction

The electron-optical characteristics of the electrostatic mirrors of cylinder (CM) and spherical (SM) types are studied enougth well [1,2], and the mirrors of such types are widely used for energy analyses of the charged particles fluxes. The system of consequently arranged CM and SM has extra free parameters respectively to the single mirrors, which can be used to improve chracteristics a combined energy analyzer and to wide its functionalities.

In the present work the systems of SM and CM are considered in two variants: with internal and external reflection of the charged particles beam from CM, and at this in the both cases the procedure of uniform mathematical description are done. The internal and external reflection mean penetration into the area of the deflecting field and leaving it via the internal or external spherical electrodes.The simulation method is given in the works [1,2], the notations of the quantities used in the mentioned works have been preserved.

Among the large number of the schemes SM + CM types the only have been chozen in which a point source, placed on an axis of symmetry, at the condition of the second order focusing forms a dot's image.

To search number of the schemes SM+CM it should vary the values of the free parameters, such those the next three ones have been chosen - the angles of declination of an axis trajectory to an axis of system, and an angle coordinate of a cross point of the axis trajectory with the spherical electrode at the input of the deflecting field .The equation, which meets the request of angle focusing of the second order, was solving in respect with the CM reflection parameter.

The parameters and the fields of electron-optical systems application

Let's consider the schemes of SM+CM with internal reflection of a beam from SM, those have practical interest. It was found that the image of a dot source, maintained on SM axis of symmetry, at the regime of angle focusing is a ring image, the last complicates registration practically. In the system SM+CM that restriction is overcome.

In fig.1 is shown a scheme, where the main dispersive element is SM with internal reflection, and a comparatively small by size CM corrects the image of SM, transforming the ring image into the dot one. At such approach the angle focusing of the second order of the type"axis-axis "is provided for whole system.

Let's reproduce computation data of the characteristic for the scheme given in fig.1: the inclination angles of axial trajectory to system's axis $\alpha = 30^0$ and $\alpha_1 = 60^0$, the angular coordinates of axial trajectory and internal electrodes crossing points $\chi_1 = 10^0$ and $\chi_2 = 80^0$, the reflection parameters of the spherical and cylindrical mirrors S=1.290 and p=0.591; the ratio of the external spherical mirror radius to one of the internal cylindrical cylinder $\mu = 6.517$, the linear dispersion on energy D=-29.431, the coefficient of linear longitudinal elongation $\Gamma_{np} = 5.748$, the maximal values of the radial toward going of axial trajectory to the field of SM and CM $R_m = 1.360R$ and $r_m = 1.4187$ (R - a radius of external electrode of SM). If at the exit of source the beam's angular opening is ± 4, that the relative spreading of image due to angular cubic aberration is not more then $(\Delta l / l) = 0.0004$.

The scheme given in fig.1 is characterized by comparatively high dispersion $D = -4.51R$, the small value of angular aberration, alongside that the longitudinal elongation of system is enough great. The scheme can be effective used for the sources of small size in the cases when the product of a size of source by longitudinal elongation $\rho \cdot \Gamma_{np}$ is less or equal to width of a gap, for example, in the microprobe electron microscopy.

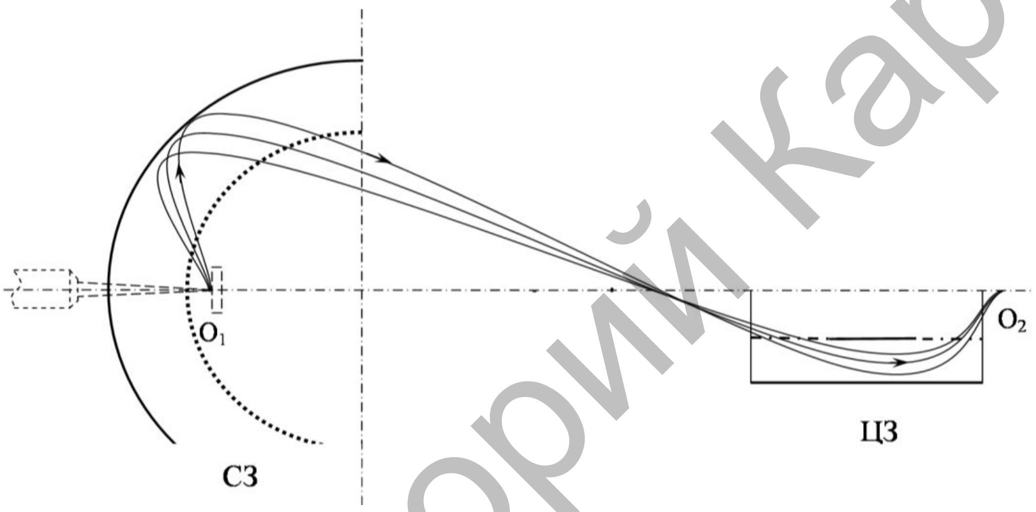

Fig.1. The scheme of SM+CM corrects an image, providing focusing of the type "axis-axis"

In fig.1 and further in the next figures the dot-lines show the contours of a tested sample and a sources of primary excitation of secondary electrons.

The specific particularity of the scheme SM+CM, shown in fig.2, consists in that the source O_1 is taken out of the area of internal spherical electrode of SM, the intermediate image is the reduced one, and for the whole given scheme $\Gamma_{np} < 1$ is valid.

The calculations becomes more simply, if at the plane of system's intermediate image the focuses of the second order of SM and CM coincide. At this, the number of the system's free parameters reduces to two, and it is convenient as such parameters to take the values of α and α_1 $(\alpha < \alpha_1)$. The characteristics of the system calculates in the next consequence: find the parameters of SM at the regime of angular focusing of the second order with help of the formulas [1]; take the angle α_1, as an input characteristic for CM calculation, because it at the regime of angular focusing of the second order connects with the deflection parameter p by the ratio, given in the work [3].

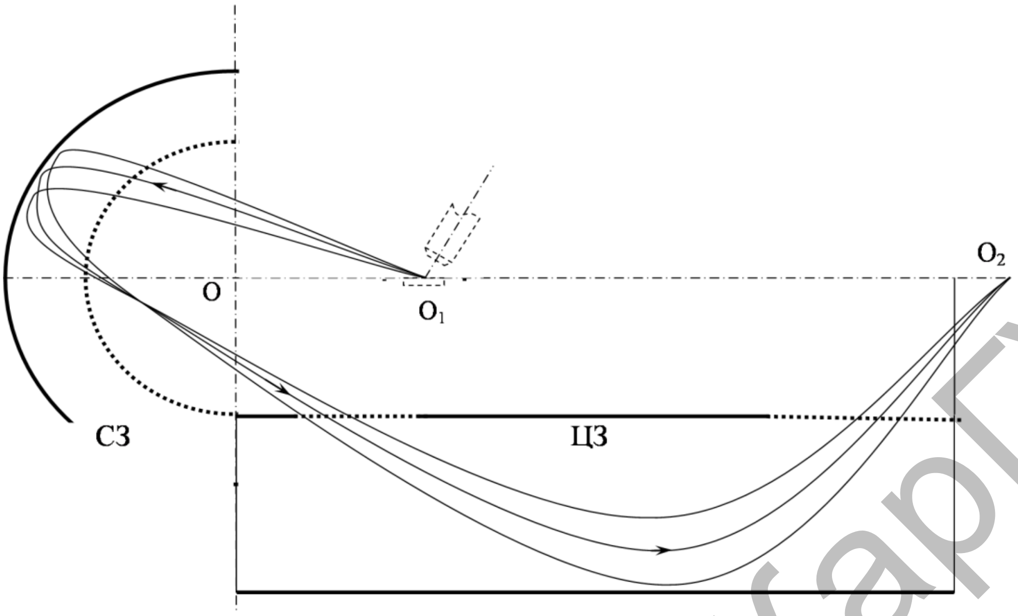

Fig.2. Scheme of SM+CM, in which the linear reduction of a source‘s image is achieved

Calculated p, we find μ, and then the rest of the parameters for CM and for the whole system SM+CM. The calculated characteristics of the scheme given in fig.2, in the case when $\alpha = 20^0$, $\alpha_1 = 42.29^0$ are the next: $\chi_1 = 54.66^0$, $\chi_2 = 7.63^0$, $s = 1.3984$, $p = 0.7695$, $\mu = 1.040$, $l = 5.2417$, $D = 4.7318$, $\Gamma_{np} = 0.2244$, $R_m = 1.4307R$, $r_m = 1.8078$. All linear sizes are expressed in the fraction of internal cylinder electrode‘s radius.

If initial opening of a beam is $\Delta\alpha = \pm 2^0$, then after passing SM the angular opening increases to $\Delta\alpha_1 = \pm 5^0$, at this the image relative spreading due to the cubic angular aberration is not more then $(\Delta l)/l = 0.0005$. The scheme of SM+CM (fig.2) is characterized by high quality of angular focusing, ordinary for SM and CM dispersion on energy, and what is remarkable, the small coefficient of longitudinal elongation. The first stage of a system consist in that: the SM forms a reduced image of source in the intermediate focus of the system, which then with init longitudinal elongation is transited to CM focus. The scheme can be recommended for working out of photoelectron spectrometer or Auger-spectrometer with enlarged area of scanning**.**

Among the schemes SM+CM, characterizing by the large value of α, let’s separate the case when $\alpha = 90^0$ (fig.3). From the analyses of the received data follows, that in this case the SM transits to the achromatic mode of the angular focusing of the second order and transforms the image of a dot source, arranged on the axis of symmetry, into a ring of radius $\delta = \mu \cos\alpha_1 \cos\chi_1$. The received formulas meet the requests of zero equality of a single CM angular aberrations coefficients of the first and second order ‚that focusing by the scheme of type” ring-axis” , having a ring source of radius δ [3]. Thus, at $\alpha = 90^0$ it follows that the system consists of two SM and CM independently focusing at the second order on a divergence angle and having common intermediate focus of ring shape. Calculating a system’s parameters, we must firstly choose value of δ, then to determine the deflection parameter p and the angle α_1, and after all to choose value of angle χ_1 and determine μ, and only then the rest characteristics .

The linear dispersion on energy of SM is equal to zero, therefore the linear dispersion on energy of the system D equals to the dispersion of CM. The longitudinal linear magnification is $\Gamma = (\sin\alpha_1)^{-1}$, the angular magnification is equal to $d\alpha_1 / d\alpha = 1$, and the angular cubic aberration of the system is equal to $A_{Ш} = A_{Ш}^{СЗ} + A_{Ш}^{ЦЗ}$.

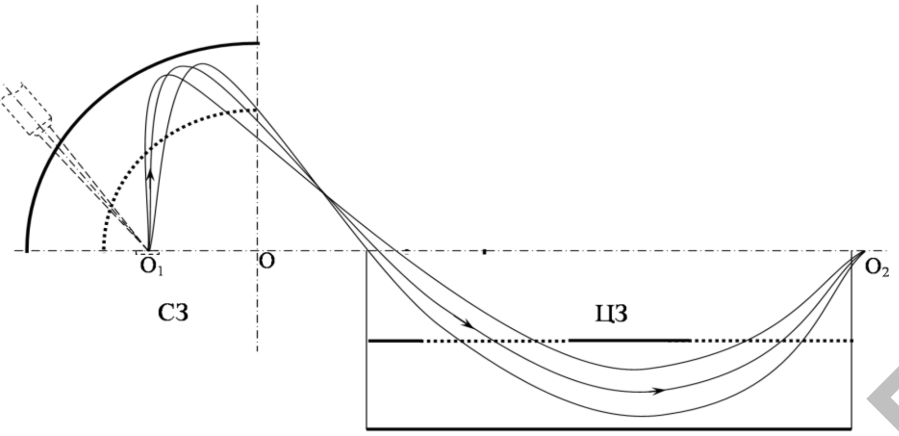

Fig.3. The scheme of SM+CM $\alpha = 90^0$, where the choice on polar angle is realized

Let's give the list of the system's calculated data for the case $\delta = 1$. The solution of the given equation is $p = 0.86910$, $\alpha_1 = 44.344^0$; if we choose $\chi = 55^0$, then $\mu = 2.4378$, $\chi_2 = 79.34^0$, $\chi_1 = 24{,}34^0$, $s = 2.5073$, $D = 8.1230$, $\Gamma_{np} = 1.4307$, $l = 10.684$, $1_{ЦЗ} = 8.3100$, $R_m = 1.1796R$, $r_m = 2.1283$. The scheme is convenient for photoelectron spectroscopy with energy angular resolution.

Let us consider the schemes of SM and CM with external reflection of the charged particle beam. A point source O_1 is placed on the symmetry axis near the surface of external spherical electrode. The electron optical characteristics of the numerical schemes of such type system are calculated by the received formulas preserving the low sing at the places having two sings. At the conditions of the second order angular focusing the three parameters are free, and as such parameters the next ones α , $\mu > 1$ and $\Delta = \mu[\cos\chi_1 - 1 + ctg\alpha \sin\chi_1]$ are convenient.

The given scheme (fig.4) is characterized by absolute small coefficient of longitudinal elongation $|\Gamma_{np}| < 1$ .We give the numerical data about the parameters of the system SM+CM at one of the possible regimes of the second order angular focusing: $\mu = 1.6$, $\alpha = 10^0$, $\alpha_1 = 43.634^0$, $\chi_1 = 8^0$, $\chi_2 = 24{,}634^0$, $p = 0.7656$, $s = 1.9149$, $\Delta = 1.2473$, $l = 6.7222$, $1_{ЦЗ} = 5.9922$, $r_m = 1.7970$, $R_m = 0.8164$, $D = 5.1388$, $\Gamma_{np} = -0.0644$, $d\alpha_1 / d\alpha = 3.983$. At angular divergence of beam $\Delta\alpha = \pm 0.54^0$ the angular cubic aberration is $\Delta = 0.0180$. The scheme SM+CM (fig.4), in which the source is placed at the point O_1, an exiting element and a sample are arranged in the position 1, can be useful for the purposes of **Auger –spectroscopy of the solid rough surfaces .**

It is known that the comparatively large angle of secondary electrons choice ($\alpha = 42.3^0$) in traditionally used CM limits the depth of the Auger - micro probing of the cavities of solids rough surfaces. The particularities of the SM+CM scheme consists in that the charged particles fluxes(secondary electrons), entering SM , leave it at small angle of choice α . If α belongs the range 10-15^0, the depth of the probed by the method of Auger- electron spectroscopy increases in several times. The small longitudinal magnification of a system provides focusing in the wide range of the cavities depths and heights of asperities of solids rough surfaces.

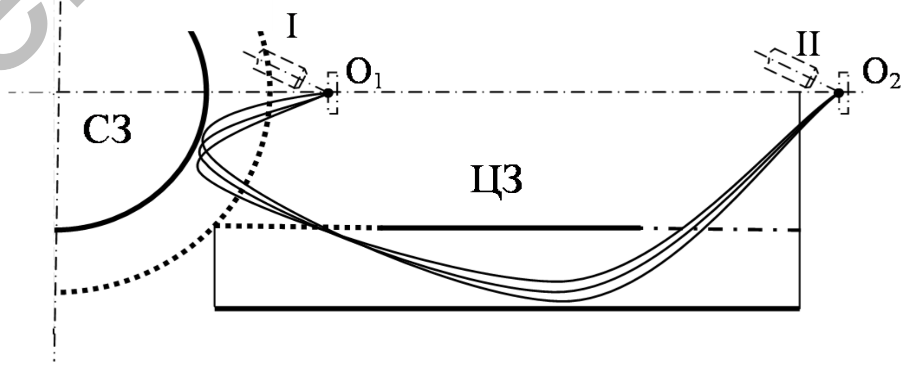

Fig.4. The scheme on the base of CM and SM with external reflection of beam

Let’s consider the inverted scheme CM+SM (fig.4), which is differ from one considered previously in that a source and its image have changed by the places : the source is placed at the point O_2, and the image now takes the place $O_{1,}$ the exiting element and the sample are arranged to the position II. Due to the property of trajectory reversibility of the charged particles having the same energy, the angular focusing in the system CM+SM occurs at the same parameters as in the system SM+CM; the coefficients of linear and angular magnification change the values of them on the inverse ones. The linear dispersion on energy does not posses the property of reversibility, and depends on order of mirrors sequence. At transition to the inverted scheme CM+SM some of the parameters from the computed data in the system SM+CM (fig.4) for the case $\mu = 1.6$, $\alpha = 10^0$, $\alpha_1 = 42.643^0$ keep the own values. There are three exceptive parameters, those become equal to $\Gamma_{пр} = 15.6$, $d\alpha_1 / d\alpha = 0.2513$, $D = 79.84$. If the source is so small, that the product of its size by linear magnification is not more then the width of the output diaphragm, then providing large dispersion in the inverted scheme CM+SM the great energy resolution is achieved. Supplying a standard raster Auger-spectrometer, built on the base of CM, by a SM, it is possible to construct on mentioned above base, an extra channel of measurement, which lets to fix the Auger-electrons spectra of great energy resolution at some definite dots of the scanned part of surface, and by the peaks’ shape find the chemical bond of the elements.

The SM+CM scheme (fig.4) with external reflection of the charged particles beam is used for energy analyses creation to analyze solid’s surface. On the base of the system with reverse reflection the analyzer of double filter type is constructed. In it by reducing of the potential barrier it was luck to improve theoretical resolution to 1% [4], which is a very great achievement for the energy analyzers of such types.

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