TWO MODIFICATIONS OF THE MAGNETIC SYSTEM OF A CHARGED-PARTICLE ANALYZER

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Abstract

Full Text

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PHYSICS

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TWO MODIFICATIONS OF THE MAGNETIC SYSTEM OF A CHARGED-PARTICLE ANALYZER

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1. A wide-range spectrograph with double focusing of the second order. Classical charged-particle spectrographs with semicircular radial focusing in a homogeneous magnetic field are widely used ([1]). These simple instruments are limited in luminosity because vertical focusing is absent, and also because of second-order aberrations for radial motion. Recently, calculations were reported ([2]) for a wide-range magnetic analyzer in which the conditions of double focusing and aberration compensation are almost fulfilled. However, the three-section magnetic system of this instrument appears complicated, and calculation of its optical properties is substantially hampered by the absence of geometrical similarity of the central trajectories for particles with different momenta.

Fig. 1. Trajectories in a wide-range spectrograph:
a—horizontal, *b*—vertical (not to scale)

A simpler scheme of a wide-range spectrograph than that proposed in ([2]) is possible. As is seen from Fig. 1, its magnetic system is two-section. In region *I* the intensity of the homogeneous magnetic field is k times smaller than in region *II*; therefore, at the boundary *I*—*II* the particles undergo "edge" vertical focusing. The boundaries of regions of the magnetic field and the focal line located outside the magnetic field are arranged along straight lines intersecting at the point O of source placement. Point O is the projection of the symmetry axis of the system, and this symmetry ensures similarity of the central trajectories for particles with different momenta.

The values of the deflection angles α_1 and α_2 in regions *I* and *II*, and also

Fig. 2. Trajectories in a spectrometer with double focusing: a—horizontal, b—vertical (not to scale)

Figure 2: Fig. 2. Trajectories in a spectrometer with double focusing: a—horizontal, b—vertical (not to scale)

the magnitude of the ratio k, can be chosen so that, at the focal plane, the conditions of double focusing of the first order are fulfilled (independently of particle momentum), as well as the conditions of second-order focusing for motion in the median plane. For example, these conditions are fulfilled if $\alpha_1 = 60^\circ$; $\alpha_2 = 57^\circ 45'$; $k = 2.1135$. The distance from the boundary of the magnetic field to the focal point is $d = 0.9489\rho_1$, where ρ_1 is the radius of deflection in region I; for radial motion the linear magnification is 0.713, for vertical motion 1.69; the resolving power in momentum is $R = p/\Delta p = 1.71\rho_1/\Delta x$, where Δx is the width of the source. In the calculations, ···

formulas of papers (3, 4). The usual assumption of an abrupt change of the field at the sector boundaries was adopted.

2. Spectrometer with double focusing. The use of a radially inhomogeneous magnetic field of the synchrotron type with $n = 0.5$ (5) made it possible to create analyzers with double focusing. The authors of (6) noted that the closer the value of n is to unity, the greater, for a given turning radius ρ, is the resolving power of the sector analyzer. However, in this case double focusing is absent, which reduces the luminosity.

Fig. 2 illustrates a hitherto unused possibility of creating a magnetic spectrometer with double focusing and improved resolution. The angle of rotation α must be greater than 180°, and the value n, lying within the limits $1 > n > 0.81$, is selected for each value of α by means of formulas (3). In contrast to analyzers with $n = 0.5$, for vertical motion there is an intermediate focus at the middle of the magnet (the source and the image are located symmetrically with respect to the sector boundaries; the linear magnifications are equal to unity).

In the particular case $\alpha = 270^\circ$, the value $n = 0.8317$; the distance from the sector boundaries to the source or image is $d = 1.68\rho$; the resolving power is $R = 11.8\rho/\Delta x$, i.e., almost three times greater than for $n = 0.5$.

Fig. 2. Trajectories in a spectrometer with double focusing: *a*—horizontal, *b*—vertical (not to scale)

If, at $\alpha = 270^\circ$, the value $n = 1 - 0.8317 = 0.1683$ is chosen, the conditions of double focusing are preserved, but the intermediate focus is formed not for vertical, but for radial motion. Moreover, in this case the system proves to be dispersionless ($R = 0$), so that the detector simultaneously registers particles that differ substantially in momentum. In the regime $n = 0.1683$, an "interesting" band of momenta can be rapidly detected, and then this band can be examined in detail at $n = 0.8317$, changing the value of n by means of a special "quadrupole" winding.

The geometrical (spherical) aberrations of the spectrometer can be compensated by known methods—by profiling the magnet gap or by curving the sector boundaries. More flexible compensation of aberrations is afforded by means of adjustable "sextupole" magnets installed at the sector boundaries.

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Note: Figure translations are in progress. See original paper for figures.