Effect of magnetic-field inhomogeneities on the operation of a collisional photionization spectrometer

E. D. Mishchenko, I. L. Rebo, and A. B. Utkin

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The diffusion of particles forming the signal at the side walls of the chamber and at the electrodes established in its electron mirrors is one of essential origins of useless loss of photoelectrons in a collisional photionization spectrometer. We place the spectrometer in a magnetic field parallel to the axis of the mirrors for a prevention of this defect. This field prevents a displacement of charged particles in a transverse direction and also removes electrons of the external photoeffect from the illuminated surfaces. The magnitude of the magnetic field affects the signal very significantly on operation in a spectral region characterized only by elastic collisions of photoelectrons with atoms of the working gas with which the cell is filled. The optimal magnitudes of magnetic fields are 0.5–2 kOe.

In the spectrometers of Refs. 1 and 2 the field under consideration was created by systems of electromagnets. Unfortunately the mass, overall size, and energy composition of such systems is quite large. This significantly limited the application of photionization spectrometers for study of VUV radiation of the sun in outer space. The requirement of high homogeneity of this field in the spectrometer cell is the main origin of the difficulty with the system of formation of the magnetic field. A large number of bent force lines intersecting the electrodes of the mirrors, walls of the ionization cell, and other details of the spectrometer exist in inhomogeneous fields. Loss of electrons moving along the force lines leads to a sharp increase of the useless losses. The use of a microchannel plate (MCP collimator) as the element of the analyzer-detector system is extremely difficult for this same reason. A collimator in fields with poor homogeneity begins to absorb electrons of every energy since the force lines pass through the walls of the MCP channels in this case.

A spectrometer is shown in Fig. 1 that allows us to give up the hard requirements on the homogeneity and to work with a special system of formation of the magnetic field by permanent magnets giving small secondary contributions along the y axis. This became possible owing to the use of electron mirrors of special construction. The two electrodes of each of the mirrors, to one of which (see 1 in Fig. 1) is fed a zero potential and to the other (see 2 in Fig. 1), a retarding potential, are realized in the form of a set of rectangular plate-louvers set at identical distances from one another. The planes of the plates are perpendicular to the x axis. The system of formation of the field at the permanent magnets has, as also the spectrometer itself, a significant extent along the y axis, along which the radiation is introduced. In view of

![Diagram](image_url)

FIG. 1. 1—Screening electrode of the electron mirror; 2—retarding electrode of the electron mirror; 3,4—analysedetector of the system.
this a smallness of the secondary contributions of $H_x$ in comparison with $H$ is attained. The force lines on the magnetic field are bent basically in the $yz$ plane; this bending does not lead to their intersection by the louver system. A significant increase of the useless loss does not occur. As a consequence of the fact that the value of $H$ close to each of the electron mirrors is larger than at the center of the cell, the charged particles moving toward the mirror in the interval between collisions are retarded by this field: the energy associated with the transverse rotation is increased owing to the energy of motion along the force line of the field. This effect known by the name of magnetic stopper is equivalent to an increase of the reflection power of the electron mirrors. Calculations and experiment have indicated that even at minimal working pressures of the gas in the spectrometer cell ($\approx 10^{-7}$ Torr) such effect for our system of formation of the field is insignificant.

The system of formation of the magnetic field represents a configuration of permanent magnets (see Fig. 1): The magnetic field created by the magnets placed above and below is corrected and enhanced by side magnets with magnetizations in the opposite direction. Such configuration allows us to obtain sufficient homogeneity of the magnetic field and to approach the magnetic material itself to the volume of the ionization cell of the spectrometer. In the systems developed, the permanent magnets are strengthened just at the frame of the device and have a total mass of 8.4 kg. Magnets of grade 16BA-190 are used. The two side faces parallel to the $xz$ plane are assembled from 30 magnets 6 cm $\times$ 2 cm $\times$ 1.8 cm each; the front faces parallel to the $yz$ plane, from magnets 4.5 cm $\times$ 2 cm $\times$ 1.8 cm. The rear faces are made up of five magnets; the front, from four: The radiation is introduced into the end in the spectrometer through the remaining space. Apart from the side and end magnets the spectrometer is strengthened above and below along three magnets with dimensions 12 $\times$ 4 $\times$ 1.5 cm, that are magnetized not opposite but along the direction of the $z$ axis is contrast with the remaining magnets.

Graphs of the change of the size of the magnetic field in the ionization cell of the spectrometer are shown in Fig. 1 along three directions: $x$, $y$, $z$. The size of the $x$ component of the magnetic field directed along the propagation of radiation is small in comparison with the total magnitude of the magnetic field ($H_x/H \approx 3\%$ inside the spectrometer cell). As is seen from Fig. 1, the magnetic field obtained is $\approx 620$ Oe.

As a result of experiments on the optimization of the mass of the magnetic material used (ferrite with a density of 4.5 kg/cm$^3$), one more combination system based on permanent magnets similar in terms of its structure to the system shown in Fig. 1 was assembled. This system creates a homogeneous magnetic field $\approx 350$ Oe in a volume of $24 \times 7 \times 4.5$ cm. The mass of the system is 3 kg. The magnitude of the magnetic field created is fully satisfactory from the point of view of efficiency and spectrometer parameters; at the same time the mass of the developed system makes it suitable for use in spectrometers studying the emission of the sun under outer-space conditions.

Thus, a system of formation of the field by permanent magnets giving a stable magnetic field is developed and tested in a photoionization spectrometer. This field has small secondary components along one of the directions perpendicular to the axis of the mirrors. Special constructions of the electron mirrors are developed that allow us to work in this magnetic field.