



## New Electron Conversion Lines from Existing $\Gamma$ -Transitions In $^{160}\text{Dy}$

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### Abstract

Three photo plates derived with spectrograph LNP JINR with constant magnetic field [1] have been investigated using the Microscope Automatic Scanning MAS [2]. Electron internal conversion (ICE) spectrograms of two erbium (Er P-2, Er P-8) and one Ho fractions has been measured. More detailed analysis gave us the possibility to obtain some new lines (see table) in addition to many earlier existing lines in  $^{160}\text{Dy}$  [3]. For that investigations it is necessary to increase the speed with which microscopic objects are measured are described. These efforts include the modernization of the MAS automatic scanning microscope and the development of programs to reach an initial point and for carrying out automatic point-to-point linear transitions with a specified step. The error in realizing a transition to a given point with specified coordinates is shown to amount to  $1\ \mu\text{m}$ .

**Keywords:** internal conversion electrons, spectra, photographic emulsion plates, magnetic spectrographs, microscope complexes, automatic linear scanning.

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## Introduction

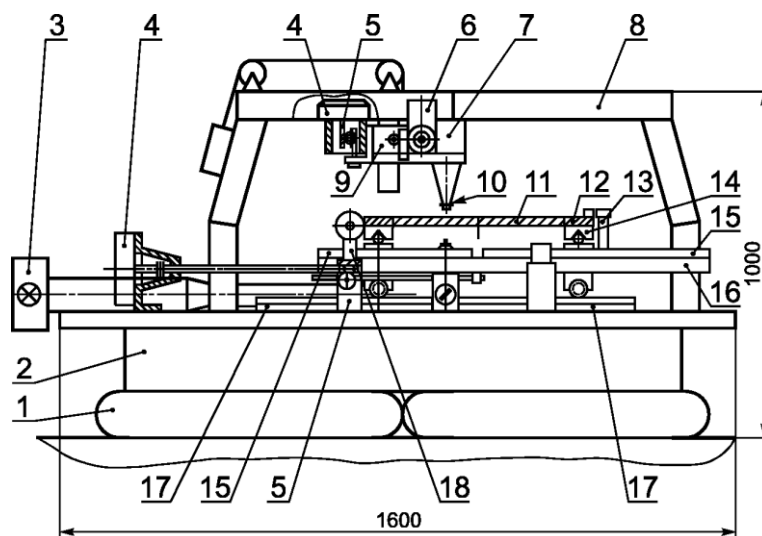
Further intensification of studies of the spectra of internal conversion electrons is planned in view of the increasing number of studies on the creation of an international database, the foundations of which were constructed and more than ten scientific centers are now participating in this research [3].

One of the problems that arise in studying photographic plates containing the spectra of internal conversion electrons is that these plates have a length greater than 400 mm, which entails, at the least, a digitized scale. There are two such microscope complexes in Russia today, the PAVIKOM-1 unit at the Lebedev Institute of Physics of the Russian Academy of Sciences [4] and the MAS unit at the Alikhanov Institute of Theoretical and Experimental Physics, which until now has functioned in a semi-automatic regime and has been described in sufficient detail in [2,5,6]. Below, the degree of automation that has been realized so far in the MAS unit, when operator participation is reduced to a minimum, is considered.

Fig. 1 presents the scheme of the MAS unit, a device designed for scanning and measurement of nuclear emulsions and other transparent subjects with maximum dimension  $400 \times 400$  mm with respect to the X and Y coordinates. (The vertical scale is 50 mm.) All the functional elements of the unit are situated on a common base, a bench plate 2 measuring  $1000 \times 1600 \times 240$  mm and weighing 800 kg. The plate is mounted on air cushions 1 in order to dampen vibrations in the base and ground. Precision vee-slides 14 and 15 along which the horizontal carriages travel are attached to the plate. A microscope stage used for the photographic plate is mounted on the carriage. The plane of the stage is formed of transparent glass 11 measuring  $420 \times 420 \times 8$  mm on which the photographic plate is mounted by means of a vacuum clamp. Vertical movement is realized by means of a carriage 9 that contains the microscope's detachable objective 10 and a camera 7 with attached CCD array. The camera reads the image and transmits it to a computer.

Diffraction grating rules manufactured for computer-controlled machine tools are used to record the displacement coordinates of the microscope carriages.

The diffraction gratings are in the form of two glass rules with lines superposed on the rules in  $4 \mu\text{m}$  steps. Rules that have been joined together are placed between the four light photodiodes. A diffraction pattern consisting of more bands is formed as light passes through the rules. Once one of the plates moves ahead of the other plate, the dark and light zone read by the photodiodes. The photodiodes are adjusted and are switched so that they generate two pairs of pulses shifted by a quarter period at the output. Count pulses the relative duration of which corresponds to a displacement of one micrometer are formed from the pulse fronts. The count pulses are fed to a binary reversible counter the operation of which in addition and subtraction is determined by the shift in the phases of the pulse pairs from the photodiodes.



4) electric motors for vertical and horizontal motion provided with worm-screw pairs;



5) friction node; 6) unit used to adjust the movement of the Z carriage; 7) television camera; 8) steel frame for mounting of Z carriage; 9) vertical carriage (Z carriage); 10) objective to produce effective image in television camera CCD array; 11) 460 x 460 x 5 mm glass plate and grooves for vacuum clamping of objects being measured; 12) X carriage (microscope stage); 13) converter of linear displacements of X carriage; 14) vee-slides of X carriage; 15) vee-slides of Y carriage; 16) Y carriage; 17) rectangular prisms along which Y carriage travels; 18) bearing assemblies responsible for movement of Y carriage.

The microscope is tested by means of repeated automatic departure to the coordinates of specially created datum marks which may be observed visually on the microscope monitor. The precision of the reading of the microscope's digitized television image depends on the magnification ratio of the objective and in the present problem had an error of 3  $\mu\text{m}$ . The maximal error of the departure to a datum mark did not exceed 1  $\mu\text{m}$ .

Repeated departure from a previously selected arbitrary point to a distance of several centimeters was performed in different directions followed by a return to a point with the same coordinates in order to check that the coordinate counters are functioning correctly. Continuous observation of the coordinates of this point was performed by means of the microscope. It turned out that each time the system returns to the initial point with error 1  $\mu\text{m}$ , i.e., the system returned to a point the coordinates of which were at a distance of no more than 1  $\mu\text{m}$  from the initial point.

The image of the object may be observed both on the control monitor as well as in digitized form on the screen of a personal computer. The unit makes it possible to obtain information from objects that are being considered in both an automatic and in a semi-automatic mode. The computer software plays a very important role, serving to control the unit, both for the purpose of solving general problems that arise in the measurement of objects as well as in concrete problems for a given experiment.

When scanning photographic plates, it is necessary that the microscope objective point at a given point of the photographic plate at a given distance from the photosensitive layer so as to assure a required degree of focusing. The image created by the objective is focused on a CCD array with 256 gradations of brightness. In addition, the flat surface of a CCD array must be parallel to the plane of the photosensitive layer. The movement of the microscope objective over the photographic plate is determined by the two coordinates X and Y, and vertical movement by the Z coordinate. Movement along the X and Y coordinates occurs in the course of the travel of the corresponding carriages. The displacement error with respect to all the coordinates is determined by the diffraction grating and amounts to 1  $\mu\text{m}$ .

Control of motion in each of the three directions is realized by means of sensors that read information from the diffraction gratings, the signals from which are summed in reversible counters. The sensors determine the values of the coordinates with error up to 1  $\mu\text{m}$ . Control of the engines and readout of the indications is performed by means of a personal computer through the KAMAK system. Conversational interaction with the computer and the algorithm that determines travel with respect to each of the three coordinates with a transition to a given point are determined by the corresponding program.

Algorithm of Program for Control of the Motion of the Microscope Carriages, let us consider the basics of the operation of the algorithm used to attain a given point with error up to 1  $\mu\text{m}$ . We specify the motion separately with respect to each of the coordinates. Motion control is achieved through control of the rate of rotation of the engine. With each of the coordinates X, Y, and Z there is associated its own register in which is stored an integer equal to the value of the coordinate with error up to 1  $\mu\text{m}$ . The program makes it possible to compute the contents of these registers at any time as well as turn the engines that control the motion of the carriages on and off and to control their speeds over a broad range. The objective of the program is to assign values to the coordinates X, Y, and Z equal to specified values when the engine is turned on or off. The algorithm is based on the fact that in the course of traveling in the direction of a given coordinate the engine turns off after passing the value of this coordinate.

Attainment of a given coordinate is initially achieved with a low precision, though at a high rate. Once a short distance remains before a given value of the coordinate is reached, a lower value of the coordinate is set. If



less than 1 mm remains before the given coordinate, the least of all possible speeds is set. Next, an exact transition to a given coordinate occurs iteratively. As soon as a given coordinate has been passed, the engine stops and it is necessary to wait for complete cessation of motion due to inertia. Motion then begins anew at the same minimal speed in the direction of the given coordinate. The motor again turns off after passing the given coordinate and it is again necessary to wait for the motion to cease completely. This operation is repeated several times. Each time the distance decrease to the given coordinate decreases. After a succeeding halt in motion, the distance to the given coordinate becomes less than 1  $\mu\text{m}$ , at which point the process of movement to the given coordinate halts.

The convergence of the process may be explained by the fact that on the concluding stages motion occurs over short distances and in brief periods of time during which the speed is not able to reach its pre-set value. In subsequent iterations, the speed becomes significantly less than the preset rate due to the short time run. Thus, the speed one iteration to the next decreases significantly, which makes it possible to move to a given coordinate with error up to 1  $\mu\text{m}$ . It may happen that at low speeds the engine may turn over. In this case, the engine control algorithm enables an abrupt escape from the current coordinates at a high speed and for a short distance, after which the basic algorithm is again implemented.

The criterion according to which the program is functioning correctly is that at the conclusion of a movement the values of the X, Y, and Z registers are equal to the required values.

Besides the ability to reach a point possessing specified coordinates, the program also makes it possible to correct the coordinates manually by means of track balls and to also input additional coordinates that have been shifted or rotated relative to the basic coordinates. Moreover, linear scanning in a specified direction may be performed between two points with a specified step in an automatic mode. Linear scanning and a transition to a given point may be realized in both the basic as well as in new local coordinates.

The program is written in Pascal and is designed to be run in an MS-DOS mode for effective control of the equipment. The program uses additional program inserts written in Assembler. This additional software makes it possible for the personal computer to interact with the KAMAK circuit board. Studies are now under way on find out how to modify the program to function in a Windows-type operating system in MS-DOS emulation mode.

The procedure of automatic scanning that has been described here makes it possible to greatly facilitate the operator's work and accelerates the scanning process approximately ten-fold by comparison with a semi-automatic mode. In the case of small linear movements, the time it takes to travel to a succeeding point is ten times greater.

A bias lighting scheme that utilizes modern bright light diodes has been used to improve the system used to illuminate the image. The new scheme improves the uniformity of the image.

If it is necessary to increase the response in order to travel to a point with specific coordinates, it would probably best to adopt personal computers with greater operational speed.

Our results are presented in table 1.



Table 1. Electron internal conversion (ICE) spectrograms of two erbium (Er P-2, Er P-8) and one Ho fractions

$E_r$ ( $\Delta E_r$ ) [3] (keV)	$I_r(\Delta I_r)$ [3] (rel. units)	$I_k$ [this paper] (rel. units)
673.09(7)	2.7(3)	< 0.015
748.8(1)	4.5(3)	< 0.05
791.5(2)}	4(1)}	} < 0.04
792.0(2)}	3.0(5)}	}
828.13(15)	3.2(4)	< 0.046
986.15(11)	2.63(12)	< 0.001
987.9(11)	3.64(17)	< 0.001
989.75(5)	7.7(3)	< 0.002
994.76(13)	4.0(5)	< 0.002
1058.25(4)	2.96(15)	< 0.01
1067.9(1)	3.5(4)	< 0.01
1077.25(6)	3.6(4)	< 0.01
1083.70(5)	3.6(5)	< 0.006
1091.1(3)	3.6(5)	< 0.005
1102.60(4)	9.3(4)	< 0.01
1111.11(18)	2.7(6)	< 0.005
1208.28(12)	3.2(2)	< 0.005
1211.71(6)	2.9(2)	< 0.004
1754.32(8)	1.25(8)	< 0.004
1871.5(2)	1.58(8)	< 0.002

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