Fifth General Conference of the Balkan Physical Union
BPU-5

Vrnjačka Banja, Serbia and Montenegro, August 25-29, 2003

Editors: S. Jokić, I. Milošević,
A. Balaž, Z. Nikolić

Book of Abstracts

Serbian Physical Society
Belgrade, 2003

SP04-014

THE INVESTIGATION OF FOCAL PROPERTIES OF FOUR-CYLINDER ELECTROSTATIC LENSES BY SIMULATIONS IN THE "SIMION" PROGRAM

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ABSTRACT

By using the electron trace simulation program "SIMION" and additional programming, the focal properties of four-cylinder electrostatic lens with A/D = 1 and G/D = 0.05 were investigated. The required relationships that must be maintained between the variable voltage ratios of the lens to keep the position of the image of a fixed object constant were determined. The use of the lens for beam energy scanning was investigated. Some of the calculated results were checked according to the experimental measurements.

Keywords: electrostatic lens, trace simulation, focal properties, SIMION

1. Introduction

The cylindrical electrostatic lenses have been widely used in electron spectroscopy and a large amount of data exists on the electron optical properties of such lenses. However, multi-electrode lenses, which allow controlling of many independent optical parameters and are expected to be more flexible, have been studied less often than two- and three-electrode lenses. The detailed calculations of a four-element lens properties by applying charge-density method have been published by Martinez and Sancho [1] and Martinez *et al* [2]. Only results for the lens with A/D = 0.5 and G/D = 0.1 (where G is the gap between the cylinders, A is the spacing between the mid points of the gaps and D is the diameter of the cylinders) have been presented. Very recently, a four element zoom lens has been used for the low energy electron-molecule scattering experiments [3], where electrode voltages were tuned (according to the former calculations [2]) to provide constant both image position and linear magnification.

In this contribution we present the preliminary results of a detailed investigation of the non-standard type of four-element electrostatic lens with A/D = 1 and G/D = 0.05. The electron optical lens properties were obtained by using of the program SIMION [4]. Also, we made additional programs that allowed continual changing of the starting parameters and the potentials of the electrodes, as well as collecting a large amount of data. The present method has been already reported earlier [5], [6].

2. The comparison of the present calculations with previous results

In order to test the present method, we have calculated the focal properties of the four-element lens with A/D = 0.5 and G/D = 0.1, which was investigated by Martinez *et al* [1], [2]. A few of the obtained results are compared to the previous ones in figure 1, namely for the image (object) focal length (figure 1a), spherical aberration coefficient (1b) and relationships that must be maintained when either image position (1c) or magnification (1d) are constant. It could be seen that a very good agreement with the previous data was achieved.

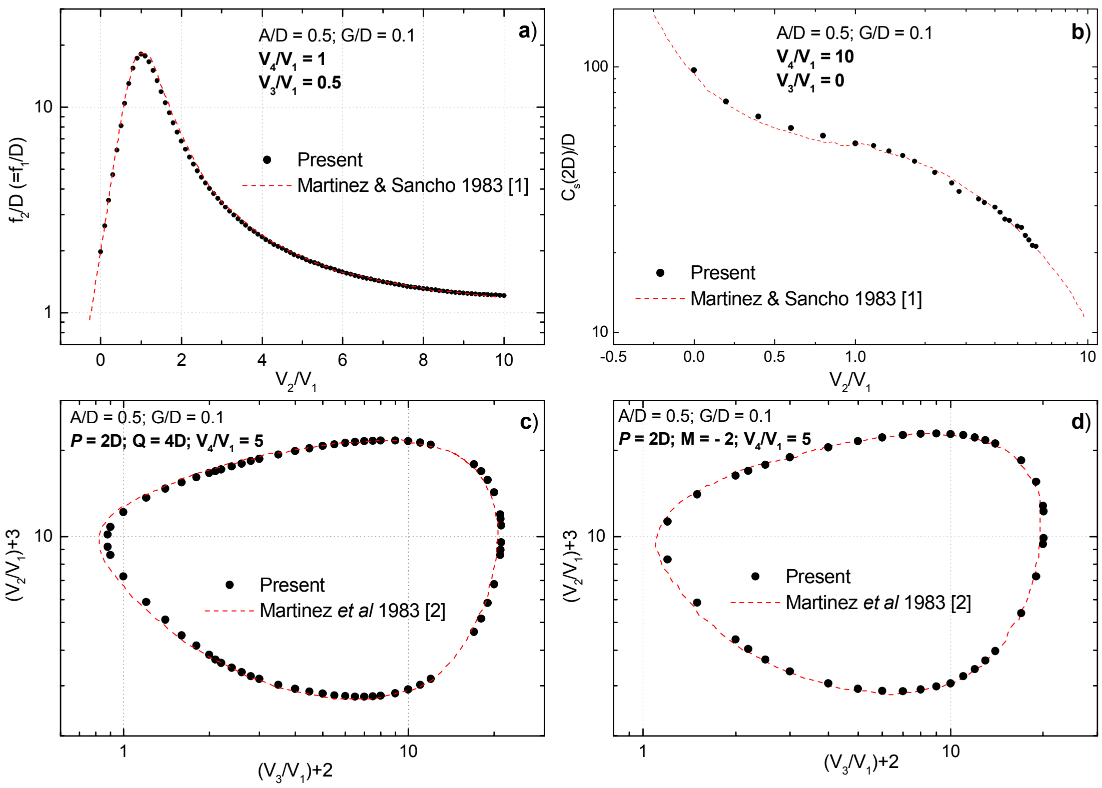

Fig. 1. *The comparison of present calculated focal properties of the lens with A/D = 0.5 and G/D = 0.1 with previous data. Note that the horizontal scale in figure 1b is logarithmic for $V_2/V_1 > 1$ and linear for $V_2/V_1 < 1$.*

3. Electron-optical properties of the four-element lens with A/D = 1 and G/D = 0.05

The object and image distances P and Q, the focal lengths f_1 and f_2, the mid-focal lengths F_1 and F_2, and image linear and angular magnifications M and M_a are related through the expressions (e. g. Granneman and Van Der Wiel [7]),

$$M = -\frac{f_1}{P - F_1} = -\frac{Q - F_2}{f_2}; \qquad f_2 = \sqrt{\frac{V_4}{V_1}} f_1; \qquad M_a = \sqrt{\frac{V_1}{V_4}} M^{-1},$$

where V_1, V_2, V_3 and V_4 are the electrode potentials. Hence, for a given potential ratios, only three independent parameters, for example Q,, F_2 and f_2, need to be calculated. We have obtained Q/D, F_2/D and f_2/D as a function of V_2/V_1 for different fixed ratios V_3/V_1 = 0, 0.5, 1, 2 and 5; and different fixed ratios V_4/V_1 = 1, 2, 5 and 10. Due to the limitation of space, only the results for V_4/V_1 = 5 are presented in this contribution (figure 2). Furthermore, the relationships that must be maintained between V_2/V_1 and V_3/V_1 when P, V_4/V_1 and Q are constant were obtained. In figure 3, these “zoom curves” are presented for $V_4/V_1 = 5$, $P = 2D$ and 5.6D, and for $Q = 2D$, 4D and infinitive. One could see that present lens (A/D = 1 and G/D = 0.05) allows preserving constant image position Q over higher voltages ratios than the lens investigated by Martinez *et al* [2] (A/D = 0.5 and G/D = 0.1). However, the latter lens posses much flatter zoom curves. It should be pointed out that four-element lens allows two different parameters, such as both the image position Q and linear magnification M, to be kept constant while the energy ratios is varied. In this contributions, however, only the constant object position will be considered, although the present method allows very simple calculation of both zoom curves.

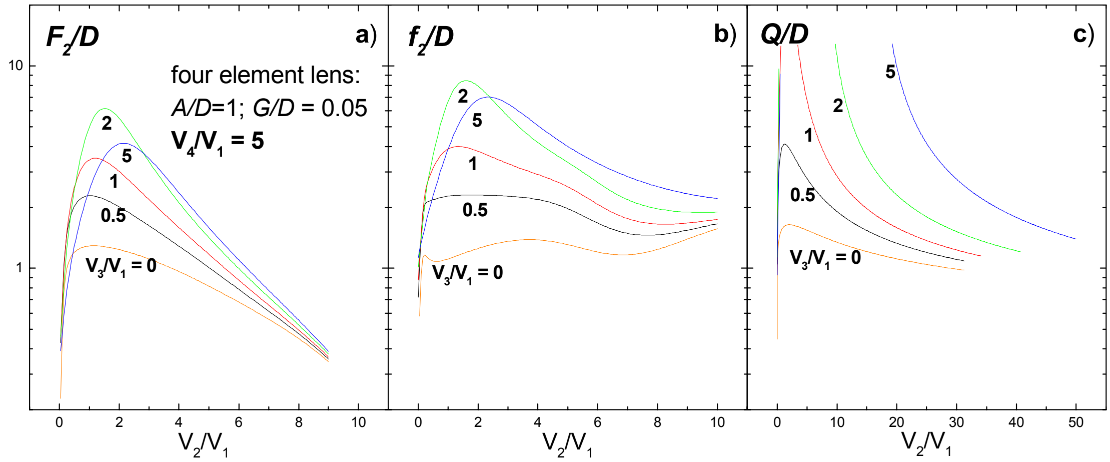

Fig. 2. *The image mid-focal length F_2/D, image focal length f_2/D and image position Q/D as a function of V_2/V_1. The numbers on the curves indicate the values of V_3/V_1.*

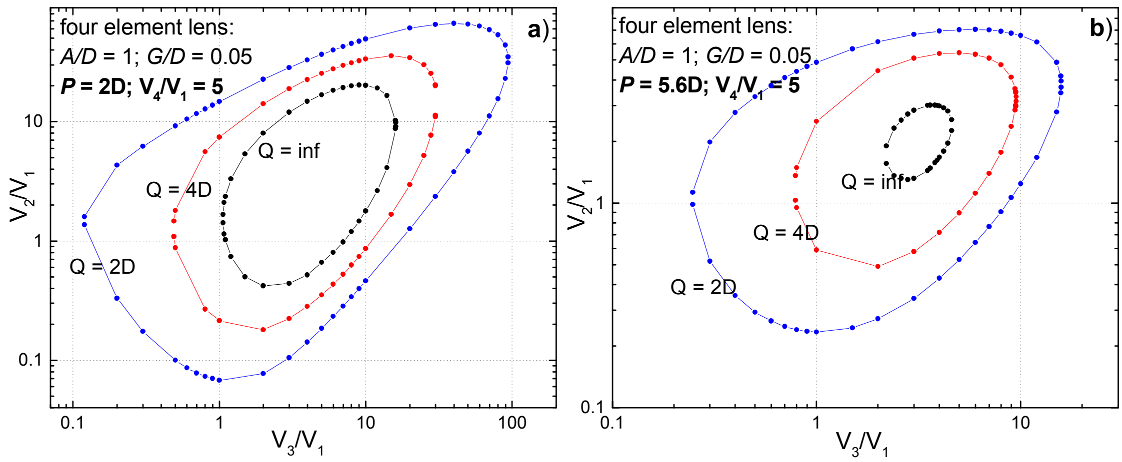

Fig. 3. *The relationships that must be maintained between V_2/V_1 and V_3/V_1 when P, V_4/V_1 and Q are constant (the values are given on the picture).*

4. The application of the lens for energy dependent measurements

We have measured differential cross sections (DCSs) for elastic electron-argon scattering as a function of incident electron energy, in the range of 90-150 eV, at various fixed scattering angles. In order to obtain accurate DCSs, the most important energy dependent factors (electron beam current, analyser lens transmission and detection efficiency) were keeping constant. For the applied incident electron energy, the electrode voltages of both the electron gun and analyser lens were tuned to provide constant beam current and transmission. The investigation of the analyser lens transmission function for the appropriate experimental conditions has been reported earlier as well [5]. It was found to be constant over the energy range from 90 to 150 eV. Moreover, in present contribution the obtained relative energy dependent DCSs are compared to the previous results. In figure 4, it could be seen a perfect agreement of the present relative curves at 70° and 100° with the available previous results. Because only the *shape* of the energy dependent DCS is of interest, all curves are normalized to the same value at 100 eV.

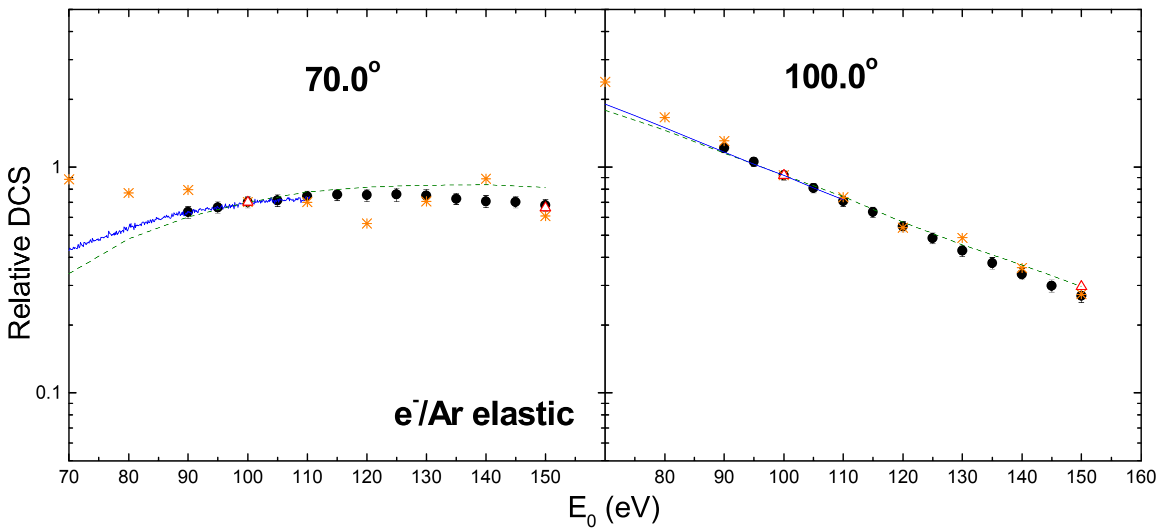

Fig. 4. *Relative energy dependent DCSs for elastic e^-/Ar scattering at scattering angles of 70° and 100°, normalized to the same value at 100 eV: present,* ●*; Williams and Willis, JPB **8**, 1670 (1975),* △*; Vušković and Kurepa, JPB **9**, 837 (1976),* **; Cvejanović and Crowe JPB **30**, 2873 (1997),* —*; Fon et al (theory), JPB **16**, 307 (1983),* – –.

Conclusion

The focal properties of four-element electrostatic lenses have been investigated by simulations in program SIMION. For the lens with *A/D* = 0.5 and *G/D* = 0.1, a very good agreement with the previous data [1], [2] has been achieved. For the first time, the detailed investigation of focal properties of the four-element lens with *A/D* = 1 and *G/D* = 0.05 have been performed. The conditions for constant lens transmission function while scanning the electron energy were considered. For the high impact energies of 90-150 eV, as a check of the constant transmission, the experimentally obtained relative energy dependent DCSs for elastic e^-/Ar scattering at 70° and 100° were compared to the previous data.

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CIP - Katalogizacija u publikaciji
Narodna biblioteka Srbije, Beograd

53(048)

GENERAL Conference of the Balkan Physical Union (5; 2003; Vrnjačka Banja)
Book of Abstract / 5th General Conference of the Balkan Physical Union (BPU-5), Vrnjačka Banja, Serbian and Montenegro, 25-29 August 2003; [editors Stevan Jokić... et al.]. - Belgrade: MST Gajić). - XXIX, 435 str.; 24 cm

Tiraž 800. - Registar

ISBN 86-902537-3-4
1. Dop. nasl. 2. Jokić Stevan
a) Fizika - Bibliografije, referativne
COBISS. SR-ID 107686156