II. ELECTRON OPTICS

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A. ELECTROSTATIC ELECTRON LENSES

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Joint Services Electronics Program (Contract DAAB07-75-C-1346)

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During the past year we have developed and explored an analytic method for expressing the electrical potential as a continuous function of position in a cylindrically symmetric lens. Using this method, we partition the lens into appropriate cells and then select the proper Bessel-Fourier series to express the solution in each cell. Each solution is made to join smoothly to its neighbor along the cell partitions, and to satisfy the outer boundary conditions. By this procedure it is easy to estimate the relative precision and convergence of each solution. Moreover, in contrast to numerical methods, this method affords a high degree of flexibility, in that variation of the lens parameters does not require major changes in the computer program for calculating electron trajectories. Details of this analysis are given elsewhere.[1]

Recent application of this analysis to an einzel lens reveals that significant reduction in spherical aberration can be achieved by a system of three flat, electron-transparent foils (at ground potential and perpendicular to the axis) and two annular rings (one between each of the foils, at potentials V_1 and V_2). In this doublet system a parallel beam, entering a converging lens and exiting a diverging lens, can be brought to a point focus for cone half-angles up to approximately 0.1 radian. It appears that further improvements can be realized by altering the symmetry, as regards the thickness and spacing of the annular rings along the axis and the cross-sectional shapes.

While we intend to explore these possibilities, a practical problem arises, in that it is necessary to calculate first a number of trajectories for a given lens configuration, alter the lens parameters, and then recalculate the trajectories so as to evaluate the properties of the modified lens. Although this procedure is straightforward, it is clumsy and expensive of machine time, since it is often difficult to intuit changes in the lens parameters which will render improved optical performance. Hence, it is highly desirable to develop an analytical method by which one can be guided to the optical properties directly from the potential. We have considered some possibilities for executing a

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JSEP hybrid procedure, partly analytical and partly numerical, which should facilitate the evaluation of the electron optical properties from a given potential, and we expect to report on these in the future.

In parallel with the analysis of flat einzel lenses, we have also been exploring the electron optical properties of lenses bounded by hyperbolic surfaces which generate an interior potential of the form $V(r, z) = Ar^2 + Bz^2$. These systems exhibit optical properties that are superior to those of any of the einzel lenses we have examined thus far, a feature not unexpected in the light of work by previous investigators.[2] However, there arises the practical difficulty of providing curved (electron-transparent) foil bounding surfaces, since the elimination of entrance and exit apertures is essential to the improved optical properties of such a lens. On the basis of recent studies using perturbation methods, it appears that it may be possible to employ flat foils over a very limited and axially centered region of the bounding surfaces without seriously degrading the optical properties. Moreover, small degradations in the optical properties can be offset by altering slightly the shape of the boundaries and by using a converging-diverging doublet system. We intend to explore these systems at length and discuss the results in a subsequent report.

References

1. N. D. Wittels and E. H. Jacobsen, "Bessel-Fourier Series Solutions for Cylindrically Symmetric Electrostatic Lens Potentials," J. Appl. Phys. 47, 2716-2723 (1976).
2. A. Septier, in V. E. Cosslett and R. Barer (Eds.), Advances in Optical and Electron Microscopy, Vol. I (Academic Press, Inc., New York, 1966), p. 204.

B. HIGH-RESOLUTION HIGH-CONTRAST ELECTRON OPTICS: PROGRESS REPORT ON AUGER ELECTRON MICROSCOPE (AEM)

Joint Services Electronics Program (Contract DAAB07-75-C-1346)

John W. Coleman, Michael R. Graham

The assembly of the final AEM is under way, with all major engineering design for the system now completed. The three vacuum systems are under construction: the low-vacuum system is already pumping and the remaining parts of the two other systems are completely designed and on order. The 48 high-voltage feedthroughs have been designed and are also on order. A commercially available suitable image intensification system of the channeltron-array type has been located. Full AEM assembly is on our schedule. We plan to use simulated specimens by September 1976 and real Auger emitting specimens by December 1976.

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attainable in depth profiles of impurities in Si and GaAs. In particular, we are interested in the sharpness of boundaries that isolate low-refractive-index components from high-refractive-index components in integrated optic devices and separate regions of different doping in integrated electronic circuit structures. By studying depth profiles of these materials at levels heretofore unattainable, we shall facilitate device miniaturization, which enhances speed of operation and reliability and reduces cost per function.

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