ELECTRON OPTICS

SYMPOSIUM IN LONDON

A SYMPOSIUM on "Recent Research in Electron Optics", arranged by the Physical Society, was held during May 15–16 in South Kensington, London, in the Science Museum and in the Physics Department of the Imperial College of Science and Technology. About a hundred and fifty people attended. Of the twenty-two talks delivered, nine were concerned with pure electron optics, and the rest were devoted to a great variety of applications. Nuclear physicists learned about new developments in the design of accelerators and of β-ray spectrometers; electron physicists heard about measurements of quantum losses, scattering experiments, examination of luminescent semi-conductors and plasma oscillations in electron beams. Other talks were concerned with electron microscopy, X-ray production, and applications of electron optics in television and in valve design.

The meeting was opened with a short welcome of the visitors by Prof. R. Whiddington, the president of the Society, and by Dr. O. Klemperer, who had arranged the programme. The first four talks were on electron lenses. G. Liebmann[1] showed that very general practical formulæ can be given for presenting such properties as focal lengths, field distribution, errors, etc., of shielded lenses as functions of the magnetic gap-length, the diameter of the pole pieces and the excitation of the lens. Measured results deviate from these formulæ only when the saturation of the iron becomes substantial. Incipient saturation results in a loss of m.m.f., and at the pole-piece tips it has the effect of an apparent increase in lens dimensions. T. Mulvey[2] discussed the design of the magnetic circuit as the only efficient means of minimizing these saturation effects.

J. Ellis showed pictures and diagrams explaining the design of a large magnetic lens which is used in University College, London, for concentrating fast electrons or positrons from weak sources on to thin foils in order to study differences in scattering of these two kinds of elementary particles.

O. Klemperer[3] directed attention to the importance of line-focus lenses which project parallel rays into a focal line. The practical termination of 'two-dimensional' electrodes without introducing lens errors was mentioned as one of the practical problems. Results of measurements were given for the electrostatic plate lenses, box lenses and lipped lenses, and for the magnetic plate lenses, two-pole and four-pole lenses. Applications of line-focus lenses in a spectrometer, in an electron microscope and in a strong-focusing accelerator were shown in slides.

The following talks dealt with the corrections of aberrations. J. C. Burfoot[4] reported results of his theoretical studies on the possibilities of a correction of electrostatic lenses by abandoning rotational symmetry. He showed pictures of many queer equipotential surfaces which could produce foci without spherical aberration; none of these, however, could easily be applied to the design of practical lens electrodes. G. D. Archard discussed various possibilities of deviations from circular symmetry, leading to astigmatic foci. He demonstrated by means of a large plaster model the classifications of elliptical distortions and of corrugations of the end faces of electrodes or of pole pieces, and he explained the different kinds of magnetic and electrostatic 'stigmator' devices which have been used successfully in electron microscopy for the correction of this asymmetry error. J. E. C. Jennings remarked that every solenoid, even under conditions of best possible circular symmetry, would produce (probably due to the helical nature of the coil) an astigmatic focus. On the other hand, line-focus lenses can easily be obtained by winding the solenoid on to an asymmetric former—for example, of rectangular cross-section.

B. J. Mayo was concerned with the image curvature of electrostatic immersion lenses. Though, theoretically, a completely flat image field cannot be obtained with such lenses, some progress with the reduction of the curvature has been achieved by using first an accelerating lens for converging the pencils towards the axis and then a decelerating lens for focusing the pencils on to the image surface.

In the next section, devoted to the electron gun, M. E. Haine[5] reported his experiments with P. A. Einstein on a three-electrode, high-voltage emission system with a hairpin cathode. Maximum intensities of 10^9 amp./m.^{2} per unit solid angle have been obtained under optimum operating conditions for beams of a Gaussian angular current distribution. For high-beam currents at reduced bias, hollow beams were observed, the formation of which was derived from a marginal emission of electrons with outward radial velocity components running into a strongly converging field deflecting them across the axis. L. Jacob[6] spoke about the emission characteristics of low-energy guns with oxide cathodes. Maxima and minima in the angular distribution of beam current density were thought to be caused by plasma oscillations.

The following two talks dealt with the focusing in accelerators. F. K. Goward gave some information about the strong-focusing synchrotron project. The scheme is essentially based on an alternation of magnetic guide fields of very large positive and negative field index (n) in successive sectors of the orbit. However, the very high n-values and a correspondingly very large orbital radius, as visualized by Livingstone, the originator of the scheme, cannot be realized in practical machines owing to correspondingly minute tolerances for machining and alignment of the pole-pieces[7]; the projected machine has to be built on a more modest scale than was hoped for originally. J. S. Bell[8] discussed the application of the strong-focusing principle to the design of a linear proton accelerator, and recommended the use of electrostatic four-pole lenses which can be operated at relatively modest voltages.

In the following section on electron optics in television tubes and valves, L. S. Allard discussed the requirements for, and the limitations of, electrostatic and magnetic deflectors, especially in connexion with problems introduced by wide-angle scanning. He demonstrated a cathode-ray tube containing a fluorescent screen arranged tangentially to the deflected beam so that the defocusing effects introduced by the deflector could be seen at large deflexion angles. B. Meltzer spoke about certain time-lag phenomena which are most troublesome in the pick-up of rapidly changing scenes by television cameras. These are due to the fact that a mosaic element on the signal plate is not discharged at once after cessation of the illumination, but only after several consecutive scans. The signal lag is found to be the shorter the larger the scanning current that can be concentrated upon the element; hence the limits to the reduction of the lag are set by electron optical conditions. The quality of the focus is known to deteriorate with increasing temperature of the electron beam. Apparently, owing to space-charge interaction, the beam temperature has been found to be much higher and to increase much more rapidly than the temperature of the cathode. C. S. Bull reviewed some applications of electron optics to valves: for example, the focusing by valve grids and the effects of an alignment of these grids. He also discussed the design of thermionic multiplier valves and of counting tubes[9], and he reported some recent attempts to increase the slope in deflexion valves with the help of space charge[10].

In the next section, G. W. Jull described his experiments with a velocity spectrograph with helical axis originally designed by D. Gabor, in which focusing deflexion is effected between cylindrical condenser plates; a change of 1 volt can still be detected at an electron energy of 1 keV. The use of this spectrometer was illustrated by experimental curves showing the small quantum losses which are known to occur at the transmission of electrons through thin foils. R. E. Siday discussed the accuracy of his absolute method for measuring β-ray energies[11], a method which depends on recording the angular rotation of a line image by a solenoidal field of exactly known magnetic potential difference. J. E. C. Jennings[12] gave a short survey of his theoretical and experimental investigations on the deflexion focusing errors of circular magnetic prisms.

Then followed two talks on fine electron foci. V. E. Cosslett[13] discussed the ultimate limits of obtainable current density ($> 10^7$ amp./m.^{2}) when these foci are scaled down to smallest diameters (< 1 micron) by the best available lenses at the greatest possible emission density from a hairpin cathode. These minute foci were shown to be very useful for producing sharp and intense shadow images in the electron point-projector or in the X-ray shadow microscope. W. Ehrenberg explained the use of these fine-electron probes for the investigation of semi-conductors. He showed photographs taken through a microscope from which the depth of penetration of the electrons into a fluorescent transparent solid could be gauged.

J. W. Menter[14] reviewed recent progress of the direct electron optical method for examination of solid surfaces. An electron beam of 50–100 keV. reflected at an angle of a few degrees from a specimen passes through the objective and projector lens of a highly magnifying electron microscope. Maximum intensity of reflexion occurs apparently at the glancing angle. The reflected beam consists of inelastically scattered electrons which have suffered losses of the order of 100 eV. Slides of excellent microscope photographs were shown in which the resolution in some cases reached about 100 A.

G. Liebmann showed slides and explained the design of the large resistor-network analogue which he has built up in the laboratories of Associated Electrical Industries at Aldermaston. This network is being used now to a great extent for solving electron optical problems—for example, for the determination of field distributions in electrostatic and magnetic lenses, especially when these are loaded by space charge.

Finally, P. A. Sturrock, speaking on some prevalent misconceptions in electron optics, directed attention to the confusion which surrounds some formulæ for focal length of electrostatic lenses. He also discussed the necessity for a clear distinction between dispersion and chromatic aberration of systems with curvilinear axis such as the semi-circular deflexion spectrometer.

Many of the items in this meeting were already known to the experts in the particular subject. However, the contents of the talks were always concerned with very recent developments—often still of controversial nature. For this reason the discussion was vivid throughout, and it was not difficult to establish contact between workers in widely diverging fields who were all joined by a common interest in electron optics.

O. KLEMPERER

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THE SCIENTIST'S RESPONSIBILITIES*

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It is fashionable among critics and broadcasters nowadays to speak patronizingly and almost contemptuously of the great rationalists of the nineteenth century—one thinks first of T. H. Huxley—who believed that the advance of our understanding of Nature opened to mankind a great prospect of material and ethical improvement. It is maintained that this was a delusion, and more compromising views about the nature and function of science are aired. The critics have not noticed that the intellectual giants, who were at work during the nineteenth century in the most advanced country in the world, have only in recent years achieved world-wide recognition. They believed that human troubles were to be overcome by human ingenuity rather than endured while blaming or accepting the 'will of God'. Just because here in Britain we have not achieved progress commensurate with what these prophets expected, we fail to see what a revolution there has been in the attitude of the millions of the depressed peoples of the world, and that it is to a great extent their unwillingness to go on accepting fatalistically their various troubles that has had effects on our own economic position and self-assurance. The change in the terms of our trade, consequent on a greater inclination by other nations to industrialize themselves and to eat more of the food they produce themselves, is for us the long-term background of

* Substance of an address given at the National Conference of "Science for Peace" in London on March 14.