1.14 Measurements on the anomalous energy spread in a high resolution electron monochromator

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The phenomenon known as anomalous energy spread in electron beams is a common problem in electron microscopy, camera tubes and many types of electron spectrometry. It refers to the increase in the energy spread in dense electron beams and the consequent change in energy distribution.

From thermodynamical reasoning it can be shown that the energy spread only depends upon the absolute temperature of the electron source. However, there is a large body of evidence[1,2] to show that in electron beams this is not the case. Fig. 1 compares schematically the measured energy spread in a beam with that expected from the cathode alone.

In the past ten years it has been discovered experimentally[2] that the energy spread ΔE depends upon the current density and voltage in the following way

$$\Delta E \propto I^n V^m, \text{ where } n = 1,\ 1/3 \text{ or } 1/2,$$
$$m = -1/6,\ -1/3 \text{ or } -3/2.$$

However, the origin of the anomalous spread was not discovered[2].

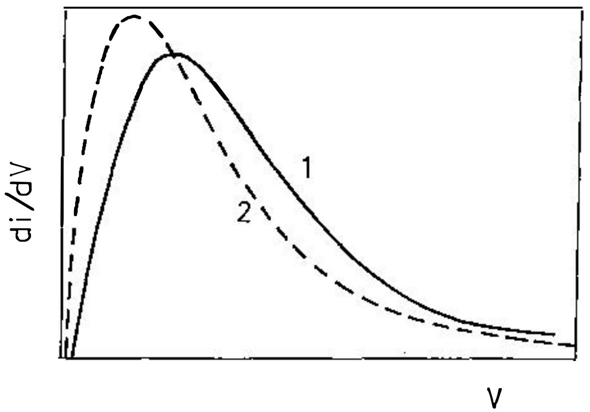

Fig. 1 Electron beam energy spread: 1- experimental result, 2- Maxwellian distribution.

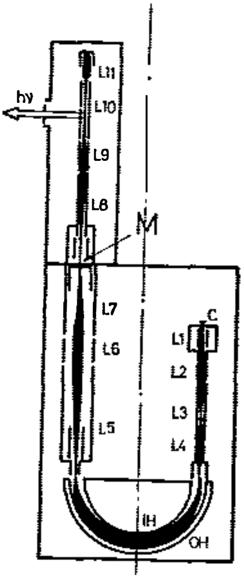

Fig. 2 Schematical diagram of the 180° electrostatic energy analyser and electron lenses used in the experiment.

Loeffler[3] developed a theory of the anomalous energy spread in cross-over regions in electron beams in terms of the Coulomb interaction between a test electron and other beam electrons. His assumptions were: constant current density at a cross-over, infinite beam length and constant electron-electron separation. The form of the anomalous energy spread for a single cross-over point is

$$\Delta E = \frac{0.132}{\alpha \cdot r_0^{1/2}} \cdot \frac{I^{1/2}}{V^{1/4}} \left[3.69 + 2 \ln\left(0.81 \cdot 10^{12} \frac{I}{V^{1/2}} \cdot r_0\right) + \frac{1}{4} \ln^2 \left(0.84 \cdot 10^{12} \frac{I}{V^{1/2}} r_0\right)\right]^{1/2},$$

where α is the beam semi-angle, r_0 the cross-over radius, I is the current in amps and V the electron energy in volts.

We have analysed the electron optics of our 180° electrostatic analyser shown in Fig. 2. The electron source is a Mullard dispenser cathode operated under space charge limited conditions and the whole monochromator was housed in a beakable stainless steel vessel at a pressure of 5×10^{-10} torr. It can be seen from Fig. 2. that we have two cross-over regions in injection and also a region of high current density at the cathode aperture.

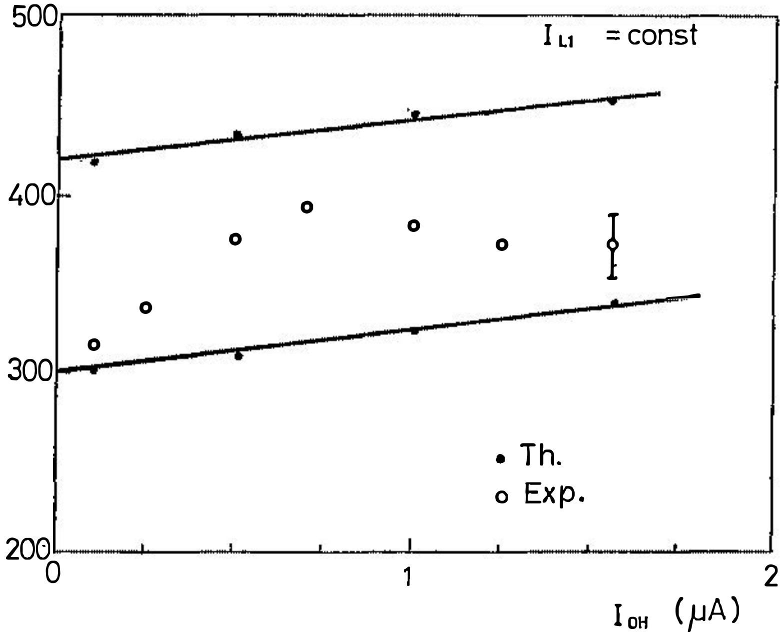

Fig. 3 Comparison of theoreticaly predicted energy spread using Loeffler's equation (upper curve, by assuming that I_{OH} is only the current which enters the spherical analyser, lower curve assuming that I_{OH} is the total current in the injection optics) with experimental results.

The monochromator is normally set up to pass electrons from the maximum of the energy distribution through aperture M (Fig. 2). The E. W. H. M. is given by $V/150$, where V is the electron energy in the hemispheres. The energy distribution of the electrons is measured at M by sweeping the cathode voltage and monitoring the current through M.

Fig. 3 shows one of our results compared with Loeffler's theoretical predictions. From such measurements we have been able to analyse the contribution to the anomalous energy spread at both the injection and pre-injection foci and also to estimate the effect due to the cathode region. Extrapolating our experimental data to zero current we have been able to obtain the energy spread due to the cathode temperature alone.

References

1) H. Boersch, Z. Phys. 139 (1954) 115;
2) J. A. Simpson and C. E. Kuyatt, J. App. Phys. 37 (1966) 3805;
3) K. H. Loeffler, Z. f. Angewandte Phys. 27 (1969) 145.

1.15 Field lens application in electron-atom collision experiments

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1.16 The effective geometrical factor $(Ld\Omega)_{eff}$ in differential cross section measurements

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1. Angular scattering of electrons

An electron-atom collision with the angular analysis of scattered electron including the most important experimental parameters, such as the electron beam divergence angle $2\,\alpha$, the analyser view angle $2\,\beta$, gun (r) and detector (R) distances from the scattering center, in the horizonatal plane, is shown schematicaly in Fig. 1.

In the formula for differential cross section calculation from experimentally measured data

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}E\,\mathrm{d}\Omega}=\frac{I_s}{I_0}\cdot\frac{1}{n\cdot L\cdot \mathrm{d}\Omega\cdot \mathrm{d}E} \tag{1}$$

a geometrical factor ($L\mathrm{d}\Omega$) appeares which takes into account the different scattering geometry at various scattering angles θ. It is necessary either to normalize all measurements to the same scattering geometry, or to determine exactly the