

Kuyatt C E & Simpson J A. Electron monochromator design.
Rev. Sci. Instr. 38:103-11, 1967.
[National Bureau of Standards, Washington, DC]

The limiting factors of high-resolution electron monochromators are studied, incorporated into design equations for optimum monochromators, and tested on a prototype instrument. A new limiting factor, an anomalous energy spread in dense electron beams, is found to be required. [The SCI® indicates that this paper has been cited in over 205 publications since 1967.]

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"In 1960, the electron physics section at the National Bureau of Standards began a program in low-energy (0 to 500 electron volts) (eV) electron interactions with gases. To carry this out required the design and construction of apparatus to produce and transport low-energy electron beams, monochromatize these beams, and energy-analyze the scattered electrons. While the electron physics section had significant expertise with higher-energy electron beams, neither they nor anyone else had developed a comparable expertise in the low-energy regime. Hence, J.A. Simpson and I took up the task of developing this low-energy expertise.

"We first studied the problem of producing space-charge-limited beams of low-energy electrons. The key development was to prove that the popular Pierce gun was unsuitable for the low-energy region, and that formation of the electron beam at higher energies followed by deceleration was essential to produce the desired high-current

beams.¹ We were then able to design electron guns to produce any space-charge-limited beams which we needed.

"The next key development was by Simpson,² who designed a very successful electron monochromator involving a 180° spherical electrostatic deflector, deceleration of the electron beam entering the deflector, and careful collimation of the electron beam. The monochromator was mated with a similar energy analyzer to form a high-resolution electron spectrometer. This spectrometer set a resolution record of 0.005 eV, and with a working resolution of 0.03-0.05 eV was used to discover resonance effects in electron scattering from atoms and molecules and new energy levels in the rare gases.

"Despite the success of this monochromator, it was still not known what the maximum possible monochromatized electron current at a given energy spread was, nor how to produce this maximum current. We therefore made a study of all the known factors which limit the performance of electron monochromators, and incorporated them into design models of optimum monochromators. Through testing on a prototype monochromator, we found that an additional limiting factor, an anomalous energy spread in dense electron beams,³ must be included in the optimization. When this was done, we could reproduce the experimental results and show how to design optimum monochromators. Such monochromators have been widely used and have defined the state of the art for the past 15 years. For this reason, our paper is still much cited.

"Other varieties of electron monochromators have been designed and used, but none have exceeded the currents produced by our optimum monochromator. The challenge remains of how to produce substantially higher currents at a given energy spread."

1. Simpson J A & Kuyatt C E. Limitations on electron beam density of unipotential electron guns at low voltages. *J. Res. Nat. Bur. Stand.* 67C:279-81, 1963.
2. Simpson J A. High resolution, low energy electron spectrometer. *Rev. Sci. Instr.* 35:1698-704, 1964.
3. Simpson J A & Kuyatt C E. Anomalous energy spreads in electron beams. *J. Appl. Phys.* 37:3805-9, 1966.