Historically, many types of spectrometer have been used since the first suggestion by Wien (1897) that an energy analyser could be designed by employing crossed electric and magnetic fields. Reviews have been published by Klemperer (1965), Metherell (1971), Pearce-Percy (1978), and Egerton (1986). Nowadays, two configurations are mostly used and have become commercially available on modern electron microscopes: these are spectrometers on TEM/STEM instruments and filters on CTEM ones. In the first case, *homogeneous magnetic sectors* are the simplest and most widely used devices. Recent instrumental developments by Shuman (1980), Krivanek & Swann (1981), and Scheinfein & Isaacson (1984) have given birth to a generation of spectrometers with the following major characteristics: double focusing, correction for second-order aberrations, dispersion plane perpendicular to the trajectory. This has been made possible by a suitable choice of several parameters, such as the tilt angles and the radius of curvature for the entrance and exit faces and the correct choice of the object source position. As an example, for a 100 keV STEM equipped with a field emission gun, the coupling illustrated in Fig. 4.3.4.9 leads to an energy resolution of 0.35 eV for $\beta_0 = 7.5$ mrad on the specimen as visible on the elastic peak, and 0.6 eV for $\alpha_0 = 25$ mrad as checked on the fine structures on core losses. Krivanek, Manoubi & Colliex (1985) demonstrated a sub-eV energy resolution over the whole range of energy losses up to 1 or 2 keV.

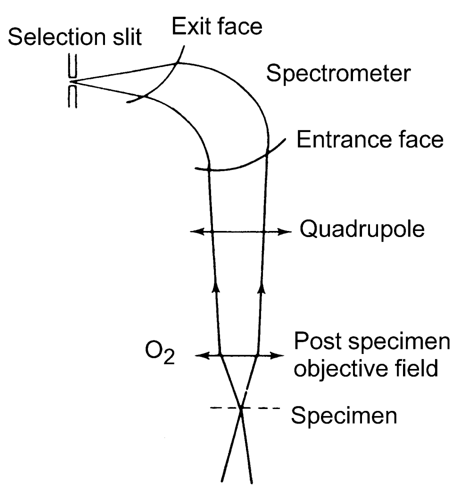

Fig. 4.3.4.9. Optical coupling of a magnetic sector spectrometer on a STEM column.

A very competitive solution is the *Wien filter*, which consists of uniform electric and magnetic fields crossed perpendicularly, see Fig. 4.3.4.10. An electron travelling along the axis with a velocity $\mathbf{v}_0$ such that $|\mathbf{v}_0| = E/B$ is not deflected, the net force on it being null. All electrons with different velocities, or at some angle with respect to the optical axis, are deflected. The dispersion of the system is greatly enhanced by decelerating the electrons to about 100 eV within the filter, in which case $D \simeq$ a few 100 µm/eV. A presently achievable energy resolution of 150 meV at a spectrometer collection half-angle of 12.5 mrad has been demonstrated by Batson (1986, 1989). It allows the study of the detailed shape of the energy distribution of the electrons emitted from a field emission source and the taking of it into account in the investigation of band-gap states in semiconductors (Batson, 1987).

Filtering devices have been designed to form an energy-filtered image or diffraction pattern in a CTEM. The first

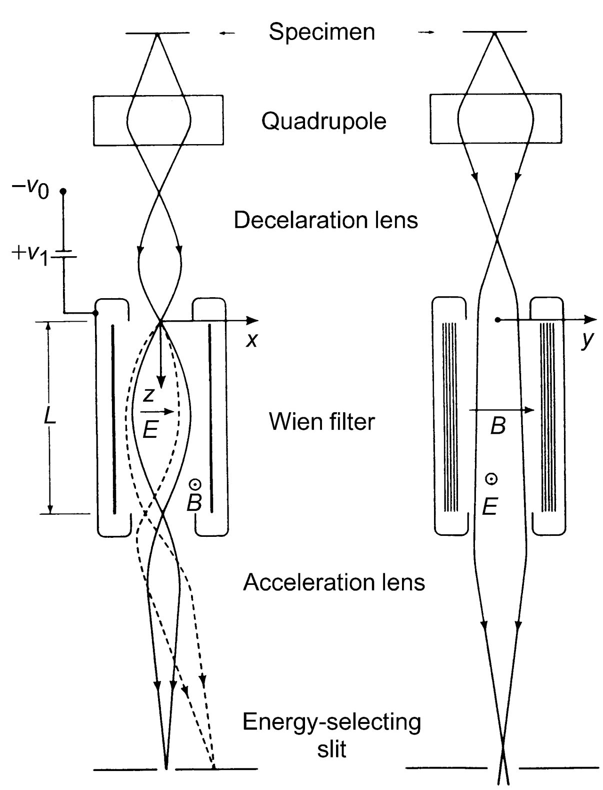

Fig. 4.3.4.10. Principle of the Wien filter used as an EELS spectrometer: the trajectories are shown in the two principal (dispersive and focusing) sections.

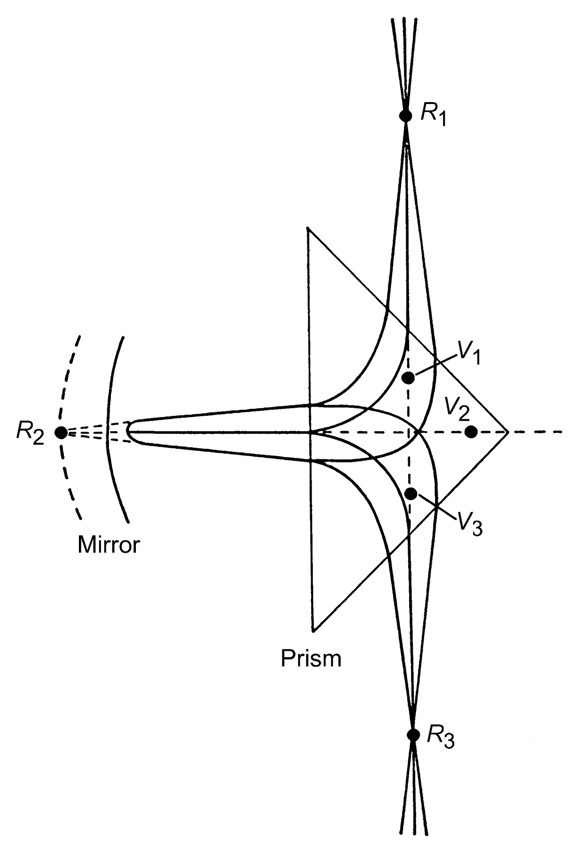

Fig. 4.3.4.11. Principle of the Castaing & Henry filter made from a magnetic prism and an electrostatic mirror. (R_1, R_2, and R_3 are the real conjugate stigmatic points, and V_1, V_2, and V_3 the virtual ones: the dispersion plane coincides with the R_3 level and achromatic one with the V_3 level.)

references