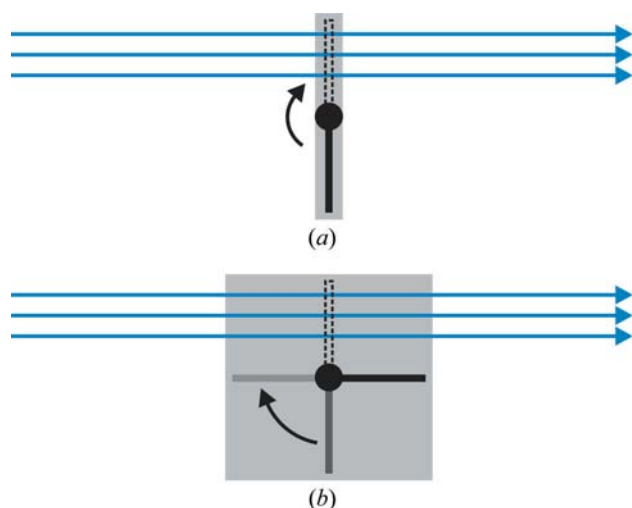


## 2.1. LABORATORY X-RAY SCATTERING



**Figure 2.1.15**  
Motorized switchable (a) and rotating (b) absorbers.

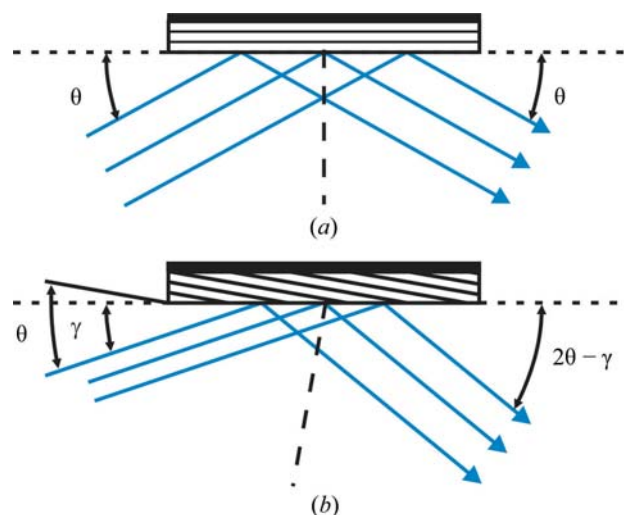
Mo or Ag, this rule can be extended to two atomic numbers. A list of metal filters suitable for the most commonly used target materials is given in Table 2.1.3.

A major disadvantage of metal filters is that they cannot completely eliminate  $K\beta$  radiation at bearable intensity losses. In addition, they introduce absorption edges at the high-energy (low-angle) side of diffraction peaks, the magnitudes of these being dependent on the wavelength as well as on the filter material and its thickness. While for point detectors absorption edges are usually obscured by counting statistics, they are much more readily visible to position-sensitive detectors owing to the high number of counts that are typically collected.

Positioning of the metal filter does not make a difference in terms of filtering of  $K\beta$  or white radiation, but can in the case of specimen fluorescence. Placing the metal filter in the diffracted beam can filter some fluorescence radiation, unless the specimen contains the same element as the metal filter. Taking Cu radiation as an example, most fluorescence radiation excited by Ni in the specimen will pass through a diffracted-beam Ni filter. In this instance, the  $K\beta$  filter should be mounted in the incident beam to suppress Cu  $K\beta$  radiation, which is very efficient at exciting Ni fluorescence. Balanced-filter techniques, employing two (or more) filters that have absorption edges just above and below  $K\alpha$ , are no longer in use as the resulting bandpass is still much wider than that of crystal monochromators at even higher intensity losses.

Metal filters are generally supplemented by some energy discrimination by the detector to remove the high-energy white radiation from the X-ray source. The effectiveness of this white-radiation removal depends upon the energy resolution of the detector, and is discussed in Section 2.1.7 for the different detector technologies currently in use. Recent improvements in the energy-discrimination capabilities for silicon strip detectors now even allow filtering of  $K\beta$  radiation, completely eliminating the need for metal filters (see Section 2.1.7.2.3.2). As a consequence, the use of metal filters is likely to decline.

Another type of metal filter is represented by absorbers, e.g. Cu foils, which are used at high intensities to avoid detector saturation or even damage. Absorbers can be motorized and switched in and out automatically depending on the actual count rates that are detected (Fig. 2.1.15a). Several absorbers with different thickness may be combined in the form of motorized rotating absorbers (Fig. 2.1.15b).



**Figure 2.1.16**  
Illustration of flat single-reflection monochromators. (a) Symmetrically cut crystal, (b) asymmetrically cut crystal with an angle  $\gamma$  between the reflecting lattice planes and the crystal surface.

## 2.1.6.3.2. Diffractive X-ray optics

Single crystals or highly textured polycrystals (mosaic crystals) represent effective beam conditioners by allowing the spectral bandwidth as well as the X-ray beam divergence to be modified. When they are placed at a specific angle with respect to the incident and diffracted beams, according to Bragg's law, only a small spectral bandwidth will be transmitted depending on the divergence of the incident beam and the rocking angle (mosaic spread) of the crystal. Higher harmonics ( $\lambda/2$ ,  $\lambda/3$ , ...) are diffracted as well, but can be successfully suppressed by using materials with small higher-order structure factors and *via* energy discrimination by the detector. Depending on the application, a crystal monochromator can be either used as a spectral filter ('monochromator'), typically used in the incident beam, or as an angular filter ('analyser'), typically used in the diffracted beam to restrict the angular acceptance of the detector.

It is likely that all monochromators currently employed in laboratory X-ray diffractometers are of the reflective type ('Bragg geometry'). Transmission-type monochromators ('Laue geometry') play no role in laboratory powder diffraction. Two designs are in common use and are described below: (a) single-reflection monochromators and (b) multiple-reflection monochromators.

## 2.1.6.3.2.1. Single-reflection monochromators

The most common types of single-reflection monochromators are illustrated in Figs. 2.1.16 and 2.1.17. Flat crystals (Fig. 2.1.16) are used in parallel-beam geometry and curved crystals in focusing geometries (Fig. 2.1.17). A beam reflected from a flat crystal with the reflecting lattice planes parallel to its surface (symmetric cut) is nearly parallel (Fig. 2.1.16a). If the crystal is cut at an angle to the reflecting lattice planes (asymmetric cut), then the beam will be expanded (Fig. 2.1.16b), or compressed if reversed (Fankuchen, 1937). Monochromators can be curved (Johann, 1931) or curved and ground (Johannsson, 1933), and may be cut symmetrically (Fig. 2.1.17a) or asymmetrically (Fig. 2.1.17b). The latter has the particular advantage of providing different focal lengths for the incident and diffracted beam. A shortened incident beam allows the monochromator to be mounted closer to the X-ray source to capture a larger solid angle of the emitted beam. If the diffracted-beam focusing length is