TRANSMISSION GRATINGS

Transmission gratings have specialized uses in spectrometry. Any optical imaging system, such as a camera or telescope, can be converted into a spectrograph by placing a transmission grating in the system, typically in front of the objective lens. Transmission gratings also serve as convenient beamsplitters for monochromatic light sources such as lasers.

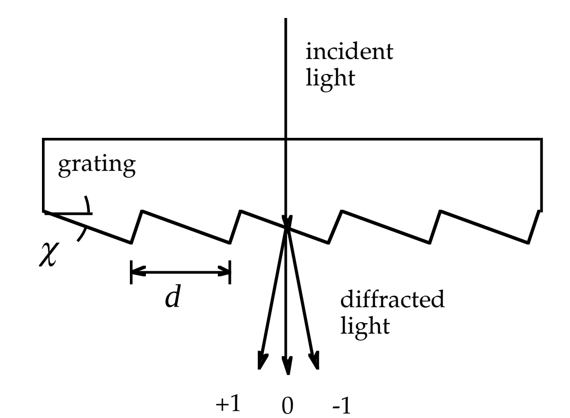
TRANSMISSION GRATING PHYSICS

Light incident on a transmission grating is often normal to the back surface of the grating ($\alpha = 0$; see Fig. 1), in which case the familiar grating equation reduces to

$$m\lambda = d \sin\beta. \qquad (1)$$

Here m is the (integral) diffraction order (usually $|m| \leq 2$), λ is the wavelength, d the groove spacing and β the angle of diffraction (measured from the normal).

Figure 1 – Transmission grating in use. The incident light is usually normal to the grating surface and strikes the back of the grating. Only three spectral orders are shown.

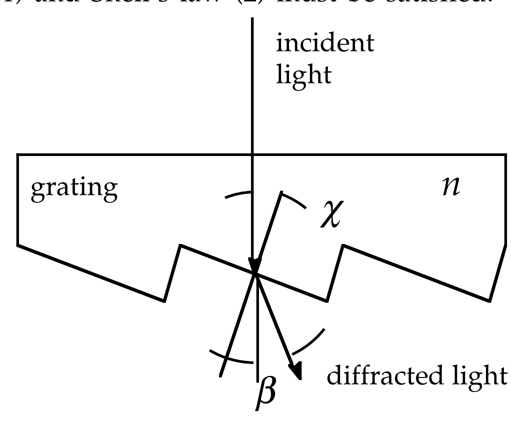


The efficiency behavior of transmission gratings is simpler than that for reflection gratings, since no metals are present to introduce complicated electromagnetic effects and since the angles of diffraction are usually small. Thus, polarization effects are virtually absent.

BLAZED TRANSMISSION GRATINGS

The peak efficiency of a blazed (triangular-groove) transmission grating occurs when the refraction of the incident beam though the mini-prism that constitutes a groove lies in the same direction as the diffraction given by the grating equation (see Fig. 2). Unlike reflection gratings, the groove angle is much larger than the blaze angle for a transmission grating, since the phase retardation doubles upon reflection but is multiplied by n-1 for a transmission grating, where n is the refractive index of the grating medium.

Figure 2 – A blazed transmission grating. For the wavelength λ to be blazed in the direction shown, both the grating equation (1) and Snell's law (2) must be satisfied.



Applying Snell's law to the interface between the groove facet and air,

$$n \sin\chi = \sin(\chi+\beta). \qquad (2)$$

Combining this relation with the grating equation, yields the relationship between the blaze angle β_B and the groove angle χ:

$$\tan\chi = \frac{\sin\beta_B}{n - \cos\beta_B}. \qquad (3)$$

For small groove angles and for $\lambda << d$, a useful approximation to Eq. (3) relates the blaze wavelength of a reflection grating to that of the corresponding transmission grating. For transmission gratings used in air or vacuum, the ratio of its blaze wavelength (for normal incidence) to that of the equivalent reflection grating (used in Littrow) is

$$\frac{\lambda_B^{trans}}{\lambda_B^{refl}} \approx \frac{n-1}{2}, \qquad (4)$$

where λ_B^{refl} is the blaze wavelength of the corresponding reflection grating. This approximate formula, rarely in error by more than ten percent, simplifies conversion of information in the Milton Roy *Grating Catalog* from reflection gratings to transmission gratings. Taking $n \approx 1.6$, which is true for most transmission gratings, yields

$$\frac{\lambda_B^{trans}}{\lambda_B^{refl}} \approx 0.3. \qquad (5)$$

A corollary to this approximation is that, for $n \approx 1.6$, the grooves of a transmission grating are about 10/3 times as deep as those of the corresponding reflection grating. For small diffraction angles (*i.e.*, diffraction near the normal), this ratio holds for the angle χ as well.

The choice of groove angle for transmission gratings is limited by total internal reflection effects:

$$\chi \le \arcsin\left(\frac{1}{n}\right). \qquad (6)$$

For $n \approx 1.6$, this yields about 40° as the upper limit on χ, though in many cases the effective limit is somewhat lower. This means that transmission gratings cannot be used for high-dispersion applications.

TRANSMISSION GRATING EFFICIENCY

The shape of an ideal efficiency curve for a blazed transmission grating is the same as for a reflection grating in the scalar region (χ < 8°). Peak efficiency occurs at

$$\lambda_B = (n-1) d \sin\chi. \qquad (7)$$

It can be shown that most of the incident light will be diffracted into either the zero order or positive first order if

$$\frac{\lambda}{n-1} d \sin\chi > 0.85; \qquad (8)$$

very little light will go into the negative first order or higher orders.

TRANSMISSION GRATINGS AS BEAM DIVIDERS

When the angle between two divided beams is small, transmission gratings serve as ideal beamsplitting elements. Most of the transmitted light will be in the zero and first diffracted order when the grating is used off-blaze, and the ratio of the zero order efficiency to the first order efficiency can be varied over a wide range. [For three beams, a symmetrical groove profile is required.]

FOR FURTHER INFORMATION

For technical information, E-mail us at
gratings@spectronic.com