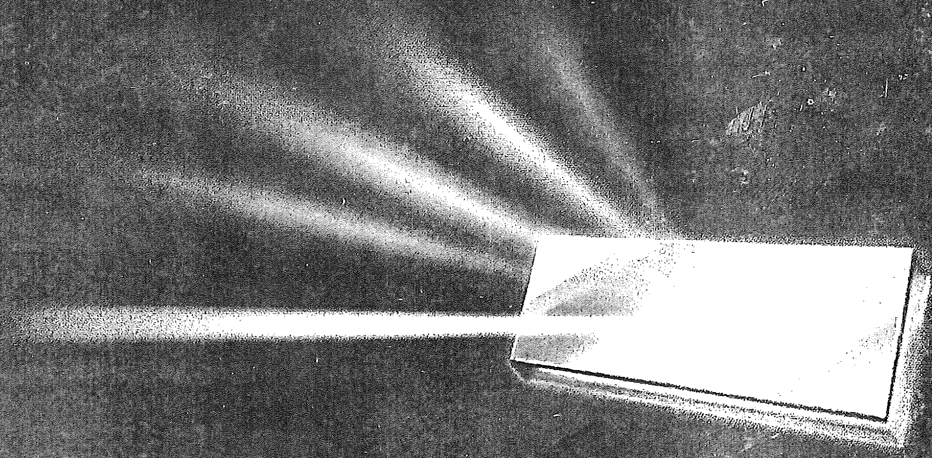
Diffraction Grating Handbook

fourth edition



RICHARDSON
GRATING LABORATORY

DIFFRACTION GRATING HANDBOOK

fourth edition

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The *Diffraction Grating Handbook* is supplemented by the Richardson Grating Laboratory's *Grating Catalog*, which lists the standard plane and concave gratings available. If the *Catalog* does not offer a diffraction grating that meets your requirements, please contact us for a listing of new gratings or a quotation for a custom-designed and -fabricated grating.

The Richardson Grating Laboratory remains committed to maintaining its proud traditions – using the most advanced technology available to produce high-quality precision diffraction gratings, and providing competent technical assistance in the choice and use of these gratings.

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that, for any grating instrument configuration, the light of wavelength λ diffracted in the m = 1 order will coincide with the light of wavelength $\lambda/2$ diffracted in the m = 2 order, *etc.*, for all m satisfying inequality (2-7). In this example, the red light (600 nm) in the first spectral order will overlap the ultraviolet light (300 nm) in the second order. A detector sensitive at both wavelengths would see both simultaneously. This superposition of wavelengths, which would lead to ambiguous spectroscopic data, is inherent in the grating equation itself and must be prevented by suitable filtering (called *order sorting*), since the detector cannot generally distinguish between light of different wavelengths incident on it (within its range of sensitivity). [See also Section 2.7. below.]

2.3. DISPERSION

The primary purpose of a diffraction grating is to disperse light spatially by wavelength. A beam of white light incident on a grating will be separated into its component colors upon diffraction from the grating, with each color diffracted along a different direction. *Dispersion* is a measure of the separation (either angular or spatial) between diffracted light of different wavelengths. Angular dispersion expresses the spectral range per unit angle, and linear resolution expresses the spectral range per unit length.

2.3.1. Angular dispersion.

The angular spread $d\beta$ of a spectrum of order m between the wavelength λ and $\lambda + d\lambda$ can be obtained by differentiating the grating equation, assuming the incidence angle α to be constant. The change D in diffraction angle per unit wavelength is therefore

$$D = \frac{\partial\beta}{\partial\lambda} = \frac{m}{d\cos\beta} = \frac{m}{d}\sec\beta = Gm\sec\beta, \qquad (2\text{-}9)$$

where β is given by Eq. (2-2). The ratio $D = d\beta/d\lambda$ is called the *angular dispersion*. As the groove frequency $G = 1/d$ increases, the angular dispersion increases (meaning that the angular separation between wavelengths increases for a given order m).

In Eq. (2-9), it is important to realize that the quantity m/d is not a ratio which may be chosen independently of other parameters; substitution of the grating equation into Eq. (2-9) yields the following general equation for the angular dispersion:

4. HOLOGRAPHIC GRATINGS

4.0. INTRODUCTION

Since the late 1960s, a method distinct from mechanical ruling has also been used to manufacture diffraction gratings. This method involves the photographic recording of a stationary interference fringe field. Such *interference gratings*, more commonly (though inaccurately) known as *holographic gratings*, have several characteristics that distinguish them from ruled gratings.

In 1901 Aimé Cotton produced experimental interference gratings, fifty years before the concepts of holography were developed by Gabor. A few decades later, Michelson considered the interferometric generation of diffraction gratings obvious, but recognized that an intense monochromatic light source and a photosensitive material of sufficiently fine granularity did not then exist. In the mid 1960s, ion lasers and photoresists (grainless photosensitive materials) became available; the former provided a strong monochromatic line, and the latter was photoactive at the molecular level, rather than at the crystalline level (unlike, for example, photographic film). In 1967 D. Rudolph and G. Schmahl at the University of Göttingen and A. Labeyrie and J. Flamand in France independently produced the first holographic diffraction gratings of spectroscopic quality.

4.1. PRINCIPLE OF MANUFACTURE

4.1.1. Formation of an interference pattern

When two sets of coherent equally polarized monochromatic optical plane waves of equal intensity intersect each other, a standing wave pattern will be formed in the region of intersection if both sets of waves are of the same wavelength λ (see Figure 4-1). The combined intensity distribution forms a set of straight equally-spaced fringes (bright and dark lines). Thus a photographic plate would record a fringe pattern, since the regions of zero field intensity would leave the film unexposed while the regions of maximum intensity would leave the film maximally exposed. Regions between these extremes, for which the combined intensity is neither maximal nor zero, would leave the film partially exposed. The combined intensity varies sinusoidally with position as the interference pattern is scanned along a line. If the beams are not of equal