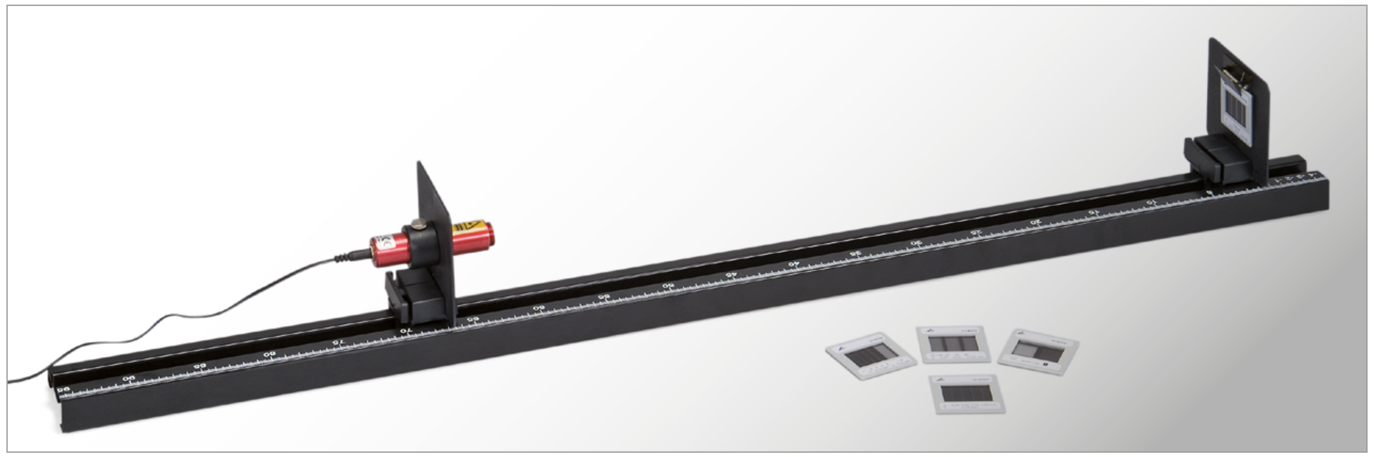
UE4030200
DIFFRACTION BY MULTIPLE SLITS AND GRATINGS



EXPERIMENT PROCEDURE

- Investigate diffraction at a pair of slits with different distances between the slits.
- Investigate diffraction at a pair of slits with different slit widths.
- Investigate diffraction by multiple slit systems with different numbers of slits.
- Investigate diffraction by a line grating and a lattice grating.

OBJECTIVE

Demonstrate the wave nature of light and determine the wavelength

SUMMARY

The diffraction of light by multiple slits or a grating can be described by considering how the individual components of the coherent wave radiation are superimposed as they emerge from the various slits, which can each be regarded as a single point of illumination so that the waves superimpose according to the Huygens principle. The interference of the individual waves explains the pattern of bright and dark bands that is observed beyond the system of slits. If the separation between the slits and the distance to the observation screen is known, the wavelength of the light can be calculated from the distance between any two bright bands.

REQUIRED APPARATUS

Quantity	Description	Item Number
1	Laser Diode, Red 230 V	1003201 or
	Laser Diode, Red 115 V	1022208
1	Optical Bench K, 1000 mm	1009696
2	Optical Rider K	1000862
1	Clamp K	1008518
1	Holder K for Diode Laser	1000868
1	Diaphragm with 3 Double Slits of Different Widths	1000596
1	Diaphragm with 4 Double Slits of Different Spacings	1000597
1	Diaphragm with 4 Multiple Slits and Gratings	1000598
1	Diaphragm with 3 Ruled Gratings	1000599
1	Diaphragm with 2 Cross Gratings	1000601

BASIC PRINCIPLES

The diffraction of light by multiple slits or a grating can be described by considering the superimposition of individual components of the coherent wave radiation, which emerge from each point of illumination formed by the multiple slits, according to the Huygens principle. The superimposition leads to constructive or destructive interference in particular directions, and this explains the pattern of bright and dark bands that is observed beyond the system of slits.

In the space beyond a pair of slits, the light intensity at a particular angle of observation α_n is greatest when, for each individual wave component coming from the first slit, there exists an exactly similar wave component from the second slit, and the two interfere constructively. This condition is fulfilled when the path difference Δs_n between two wave components emerging from the centers of the two slits is an integral multiple of the wavelength λ of the light (see Fig. 1), thus:

(1) $$\Delta s_n(\alpha_n) = n \cdot \lambda$$

$n = 0, \pm 1, \pm 2, \ldots$: is called the diffraction order.

At large distances L from the pair of slits and for small angles of observation α_n, the relationship between the path difference Δs_n and the position coordinate x_n of the nth-order intensity maximum is:

(2) $$\frac{\Delta s_n}{d} = \sin\alpha_n \approx \tan\alpha_n = \frac{x_n}{L}$$

d: Distance between the slits.

Thus the maxima are spaced at regular intervals with a separation a given by:

(3) $$a = x_{n+1} - x_n = \frac{\lambda}{d} \cdot L$$

This relationship is also valid for diffraction at a multiple slit system consisting of N equidistant slits ($N > 2$). Equation (1) states the condition for constructive interference of the wave elements from all N slits. Therefore, equations (2) and (3) can also be applied to a multiple slit system.

The mathematical derivation of the positions of the intensity minima is more difficult. Whereas in the case of a pair of slits there is an intensity minimum exactly halfway between two intensity maxima, for the multiple slits system a minimum is observed between the nth and the (n+1)th maxima when the wave components from the N slits interfere in such a way that the total intensity is zero. This occurs when the path difference between the wave components from the centers of the slits satisfies the condition:

(4) $$\Delta s = n \cdot \lambda + m \frac{\lambda}{N}$$

$$n = 0, \pm 1, \pm 2, \ldots,\; m = 1, \ldots, N-1$$

Therefore N-1 minima are visible and between them are N-2 “minor maxima” with intensities smaller than those of the principal maxima. As the number of slits N is progressively increased, the contribution of the minor maxima gradually disappears. Then the system is no longer described as a multiple slit system but as a line grating. Finally, a lattice grating can be regarded as an arrangement of two line gratings, one rotated at 90° relative to the other. The diffraction maxima now become points on a rectangular grid with a spacing interval given by Equation (3). The intensity (brightness) of the principal maxima is modulated according to the intensity distribution function for diffraction at a single slit. The greater the slit width b, the greater the concentration of intensity towards smaller values of the angle α. For an exact derivation it is necessary to sum the amplitudes of all the wave components, taking into account the path differences, to obtain the total amplitude A. At a point on the screen defined by x, the intensity is:

(5) $$I = A^2 \propto \left(\frac{\sin\left(\frac{\pi \cdot b}{\lambda} \cdot \frac{x}{L}\right)}{\frac{\pi \cdot b}{\lambda} \cdot \frac{x}{L}} \right)^2 \cdot \left(\frac{\sin\left(N \cdot \frac{\pi \cdot d}{\lambda} \cdot \frac{x}{L}\right)}{\sin\left(\frac{\pi \cdot d}{\lambda} \cdot \frac{x}{L}\right)} \right)^2$$

EVALUATION

The wavelength λ of the diffracted light can be determined from the separation a between the principal maxima, and is given by:

$$\lambda = d \cdot \frac{a}{L}$$

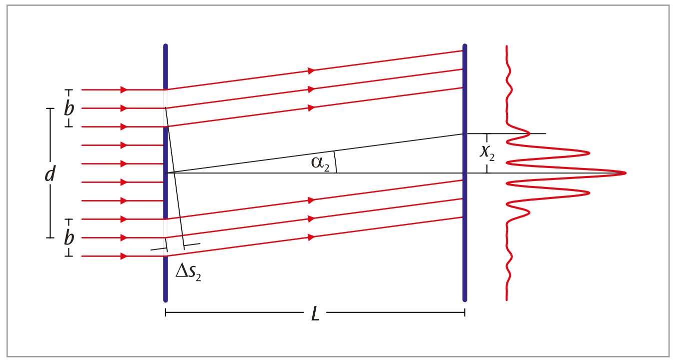


Fig. 1: Schematic diagram of the diffraction of light at a pair of slits

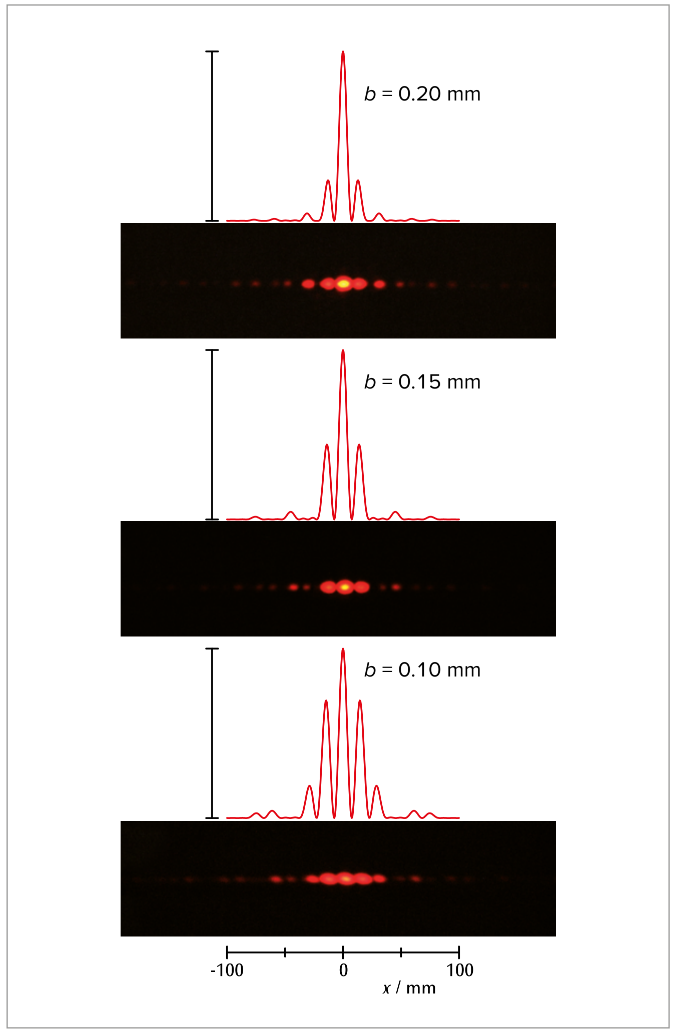


Fig. 2: Calculated and observed intensities for diffraction at a pair of slits with different distances between the slits