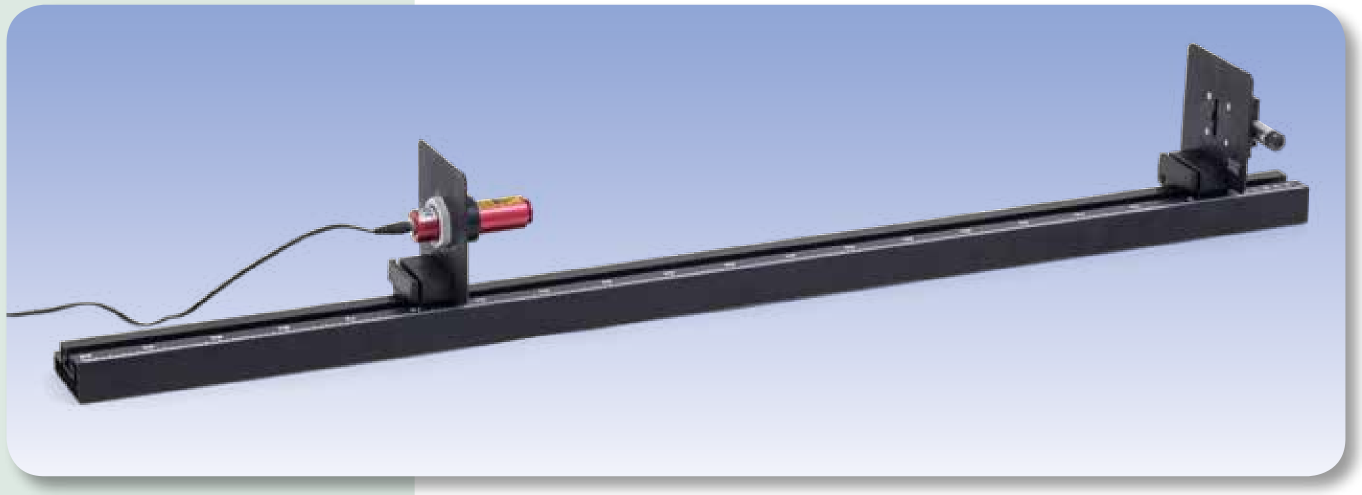
DIFFRACTION BY A SINGLE SLIT



EXPERIMENT PROCEDURE

- **Investigate diffraction by single slits of various different widths.**
- **Investigate diffraction by a single slit for light of differing wavelengths.**
- **Investigate diffraction by a single slit and by an opaque object of the same size (Babinet's principle).**

OBJECTIVE

Demonstrate the wave nature of light and determine the wavelength

SUMMARY

Diffraction of light by a single slit can be described as the superposition of coherent wavelets which, according to Huygens' principle, spread out from the illuminated slit in all directions. Depending on the angle along which they propagate, the wavelets cause either constructive or destructive interference. If the width of the slit and the distance to the screen are known, then the wavelength can be calculated based on the distance between adjacent dark bands of the interference pattern.

REQUIRED APPARATUS

Quantity	Description	Number
1	Laser Diode, Red	1003201
1	Laser Module, Green	1003202
1	Optical Bench K, 1000 mm	1009696
2	Optical Rider K	1000862
1	Adjustable Slit K	1008519
1	Holder K for Diode Laser	1000868
Additionally required		
	Wire	

BASIC PRINCIPLES

Diffraction of light by a single slit can be described as the superposition of coherent wavelets which, according to Huygens' principle, spread out from the illuminated slit in all directions. This superposition leads to either constructive or destructive interference depending on the angle. Beyond the slit a system of light and dark bands can be observed on a screen.

Where the wavelets cancel – i.e. where the bands are darkest – it can be seen that for every wavelet from one half of the slit there is another wavelet from the second half which interacts with it in such a way that the combined amplitude is reduced to a minimum. This happens when the path difference Δs_n between the beam through the middle of the slit and a ray from the edge is precisely an integer multiple n of half the wavelength λ:

(1) $$\Delta s_n = n\cdot\frac{\lambda}{2} = \frac{b}{2}\cdot\sin\alpha_n$$

$n = 0, \pm1, \pm2, \ldots$: Order of diffraction
b: Width of slit,
α_n: Angle of propagation

The regions of maximum darkness are symmetrical about the primary ray (see Fig. 1). Their distance from the primary ray, as measured in the plane of observation is as follows:

(2) $$x_n = L\cdot\tan\alpha_n$$

L: Distance between slit and plane of observation

For a small angle, the following is therefore true:

(3) $$\alpha_n = x_n = \frac{\lambda\cdot L}{b}\cdot n = \Delta\cdot n \quad\text{where}\quad \Delta = \frac{\lambda\cdot L}{b}.$$

Δ: Relative distance between minima

A slit and an opaque obstruction of the same size and shape are considered complementary diffraction objects. According to Babinet's principle, the diffraction patterns of both objects, outside of the "unaffected" beam, are identical. The diffraction minima in both patterns are therefore in the same place.

In this experiment diffraction by single slits of various widths is investigated, along with diffraction of different wavelengths of light. Moreover, it will be shown that diffraction by a single slit and by an opaque object of the same width results in complementary diffraction patterns.

EVALUATION

The brightness is greatest in the direction of the primary ray. The value Δ can be determined as the gradient of the straight line graph when the distances x_n are plotted against n. Since Δ is obviously inversely proportional to the width of the slit b, the quotients Δ/L can be plotted in a graph against $1/b$ and the wavelength λ is then determined as the gradient of the graph of these measurements.

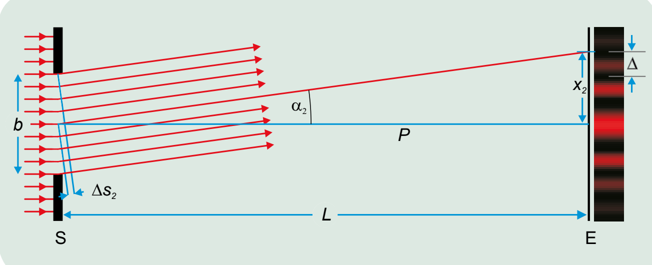


Fig. 1: Schematic diagram of diffraction of light by a single slit (S: Slit, b: Width of slit, E: Plane of observation, P: Primary beam, L: Distance of observation screen from slit, x_2: Distance of second minimum from centre, α_2: Direction of observation for second minimum, Δs_2: Path difference between ray through centre and ray from edge).

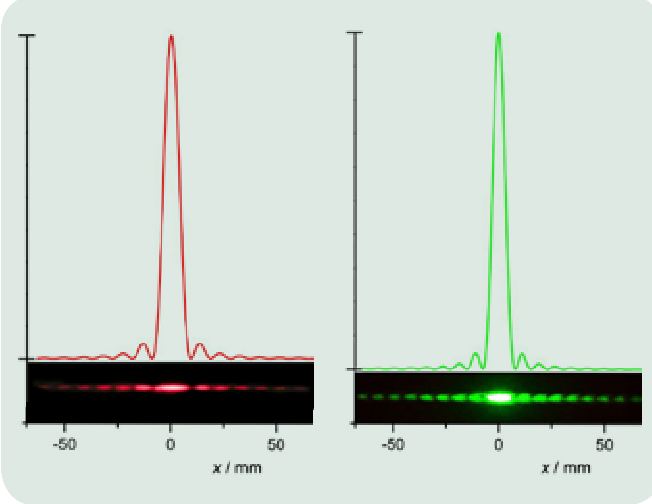


Fig. 2 Calculated and measured intensities for diffraction from a slit of width 0.3 mm with light of wavelength λ = 650 nm and λ = 532 nm.

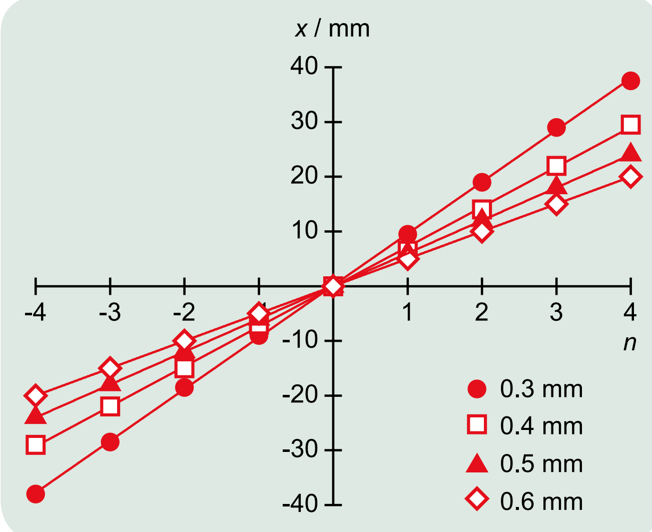


Fig. 3: Separations x_n as a function of diffraction order n for various widths of slit b where λ = 650 nm.

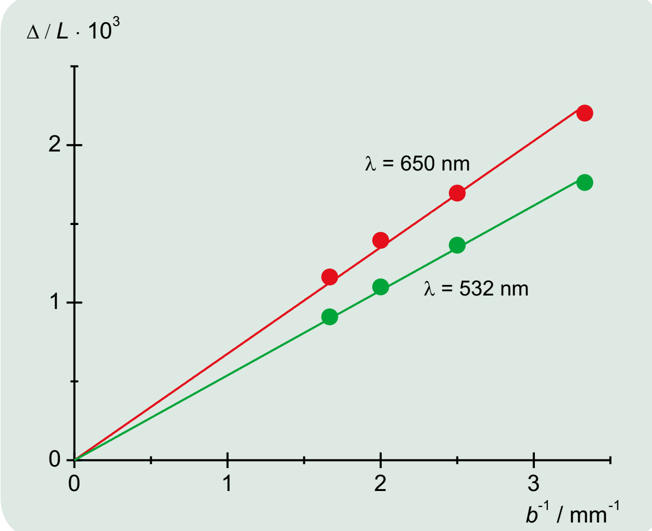


Fig. 4: Quotient of relative separation of minima Δ and distance L as a function of width of slit $1/b$.