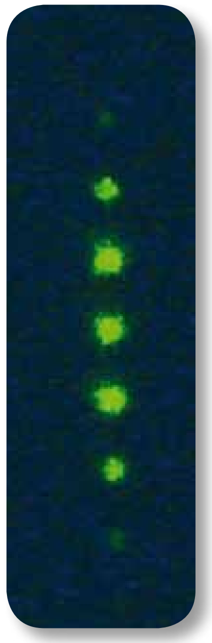
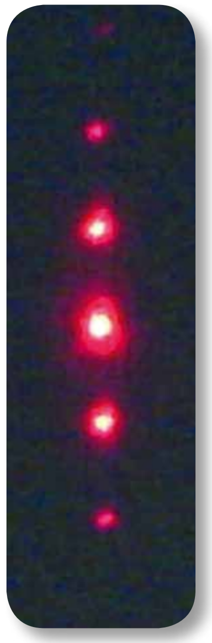
DEBYE-SEARS EFFECT





EXPERIMENT PROCEDURE:

- **Observing the diffraction pattern at a fixed ultrasound frequency for two different light wavelengths.**
- **Observing the diffraction pattern for different ultrasound frequencies between 1 MHz and 12 MHz.**
- **Determining the corresponding sound wavelengths and the velocity of sound.**

OBJECTIVE

Determine the velocity of ultrasonic waves in liquids.

SUMMARY

The periodic variations of density caused by an ultrasonic standing wave pattern in a liquid act as an optical grating for the diffraction of a monochromatic parallel light beam that is transmitted in the direction perpendicular to the direction of the ultrasonic wave. From the diffraction pattern and the known wavelength of the light, it is possible to determine the sound wavelength and use that to calculate the velocity of sound in the liquid.

REQUIRED APPARATUS

Quantity	Description	Number
1	Ultrasonic cw Generator	1002576
1	Test Vessel	1002578
1	Laser Diode for Debye-Sears Effect, Red	1002577
1	Laser Diode for Debye-Sears Effect, Green	1002579
1	Pocket Measuring Tape, 2 m	1002603
1	Ultrasonic Coupling Gel	1008575

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BASIC PRINCIPLES

The diffraction of light by ultrasonic waves in liquids was predicted by Brillouin in 1922, and the effect was confirmed experimentally in 1932 by Debye and Sears and also by Lucas and Biquard. It is caused by the periodic variations in the refractive index of the liquid that are produced by ultrasonic waves. If a light beam is passed through the liquid perpendicular to the ultrasound direction, the arrangement acts as a phase grating, which moves depending on the velocity of sound. Its grating constant corresponds to the wavelength of the ultrasound, and thus depends on its frequency and the velocity of sound in the medium. The movement of the phase grating can be neglected if the effect is observed on a screen at a large distance.

In the experiment, a vertically orientated generator couples ultrasonic waves at frequencies between 1 MHz and 12 MHz into the test liquid. A monochromatic parallel light beam passes through the liquid in the horizontal direction and is diffracted by the phase grating. The diffraction pattern contains several diffraction maxima spaced at regular distances.

The k-th-order maximum of the diffraction pattern is found at the diffraction angle α_k, defined by

(1) $$\tan \alpha_k = k \cdot \frac{\lambda_L}{\lambda_S}$$

λ_L: light wavelength, λ_S: ultrasound wavelength.

Thus, the ultrasound wavelength λ_S can be determined from the separation between the diffraction maxima. Furthermore, according to the relationship

(2) $$c = f \cdot \lambda_S$$

it is possible to calculate the velocity of sound c in the liquid, since the frequency f of the ultrasonic waves is also known.

EVALUATION

It is necessary to measure the distance s between the ultrasound generator and the screen used to observe the diffraction pattern, and the distance x_{2k} between the -kth and the +kth diffraction maxima. From these two distances, it is possible to calculate the diffraction angle α_k for the kth-order maximum, given by:

$$\tan \alpha_k = \frac{x_{2k}}{2 \cdot s}$$

This leads to the following equation for determining the ultrasound wavelength λ_S:

$$\lambda_S = \frac{2 \cdot k \cdot s}{x_{2k}} \cdot \lambda_L$$

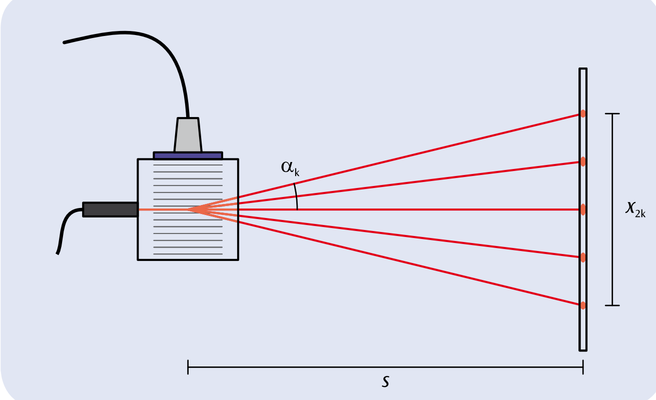

Fig. 1: Diagram showing the diffraction of light by a phase grating that is produced in a liquid by ultrasonic waves (Debye-Sears effect).

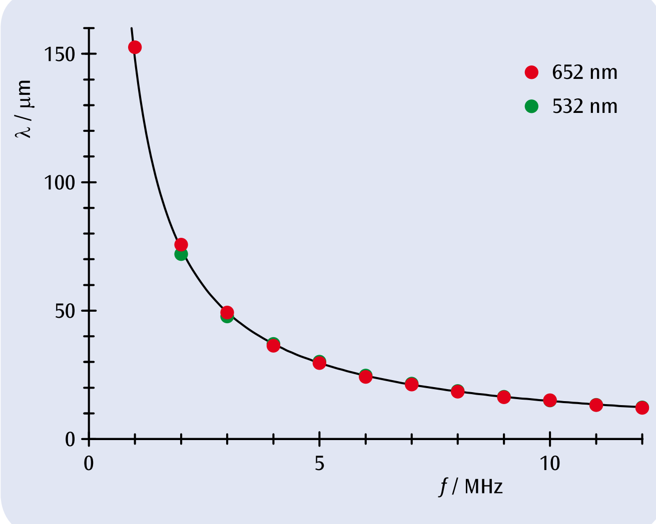

Fig. 2: Sound wavelength λ_S in water as a function of the frequency f.