

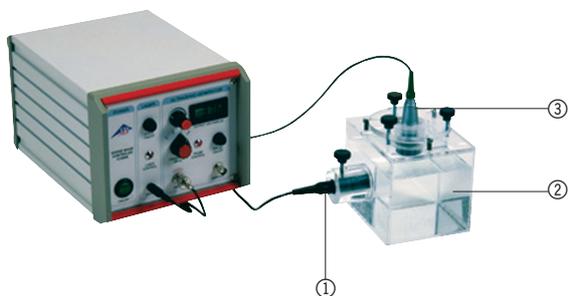
Ultrasonic CW generator U10006

Laser diode for Debye-Sears effect U10007

Test vessel U10008

Instruction sheet

8/03 ALF



- ① Laser diode
- ② Test vessel
- ③ Ultrasonic transducer

Ultrasound generator with accessories for the Debye-Sears experiment and for demonstrating standing ultrasonic waves.

Safety instructions

Before switching on the ultrasound generator and accessories, carefully read the following instructions for the sake of your safety and for the safety of the equipment.

- The slits in the device are for ventilation and must be kept clear to avoid overheating the equipment. It is recommended that the device be placed on its own stand (also included).
- Before switching on the device make sure that it is adjusted to the mains voltage you intend to use. Make sure that you keep within the operating specifications.
- Never try to push objects through the slits in the device since this could cause short circuits or electric shocks.
- Only use 3B's own ultrasound transducer with the "PROBE" connection. Be careful, voltages may be as high as 70 V.
- Do not use the ultrasound transducer for a lengthy period without contact to fluids. Otherwise the transducer may overheat and be destroyed.
- Do not turn on the U10007 laser diode if there are

people standing in the beam. This is a class II laser with power < 1 mW. Do not look into the beam or aim it at other people or animals.

- Beware: high-powered ultrasound! Do not use the probe on people or animals.

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1. Introduction

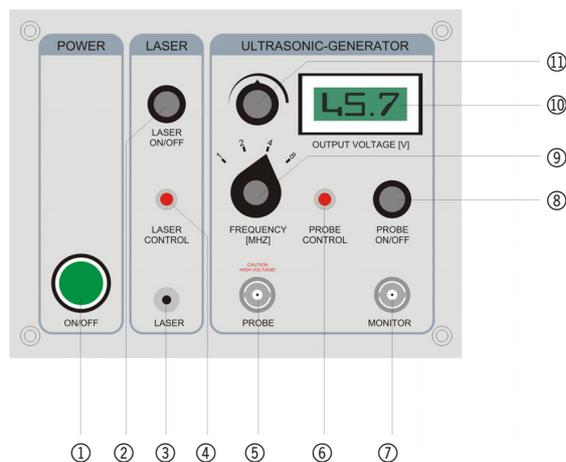
In 1932 Debye and Sears demonstrated for the first time how light is refracted when passing through a fluid excited to high-frequency oscillation. The maxima and minima in density act here like the grid elements of an optical diffraction grating. The grating constant corresponds to the ultrasonic wavelength and is thus dependent on the frequency of the ultrasound and the speed of sound in the medium through which the sound is travelling.

The CW (continuous wave) generator with its accompanying broad-band ultrasound transducer, along with an adjustable test vessel and its integrated laser holder, mean that it is possible for the first time to demonstrate this phenomenon to schoolchildren and college students alike using simple and compact equipment. The equipment can demonstrate both frequency dependence (with four different frequencies) and the ultrasonic wavelength in various fluids, allowing the speed of sound in the medium to be calculated.

It is also possible to project standing ultrasonic waves by inserting an optical lens between the laser source and the ultrasonic waves. The waves are then projected by the diverging laser beam.

2. Components

2.1 Ultrasound generator - operating elements



- ① Mains switch
- ② On/off switch for laser
- ③ Connector socket for laser
- ④ Control light for laser
- ⑤ Connector socket for ultrasonic transducer
- ⑥ Control light for ultrasonic transducer
- ⑦ Monitor output
- ⑧ On/off switch for ultrasound
- ⑨ Frequency selection switch
- ⑩ Voltage display
- ⑪ Voltage setting

The ultrasound generator generates continuous high-power ultrasonic waves (CW = continuous wave). The voltage ⑪ can be adjusted between 5 and 65 V. There is an LCD display for the voltage output ⑩. The transmitted voltage can be switched off separately ⑧. The frequency can be set to one of four frequencies (1, 2, 4 or 8 MHz) ⑨. An additional monitor output ⑦ allows the output frequency to be determined precisely with the aid of an oscilloscope or a frequency counter. A suitable output ③ is provided to supply power to a laser diode. This can also be switched off separately ②.

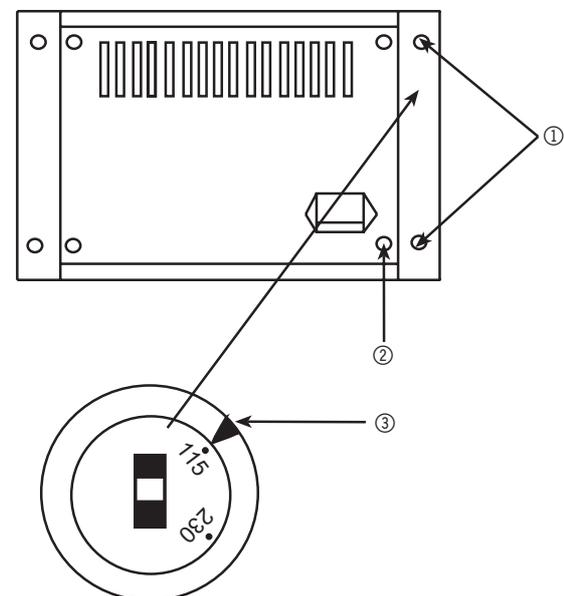
Adjustment of mains voltage

The ultrasound generator can operate with 230 V or 115 V mains voltage. A voltage selector switch is situated on the rear of the casing and is hidden beneath the covering to the right of the rear panel. A screwdriver is used to alter the switch setting (see illustration). If the mains voltage is altered, the fuse needs to be changed to suit the mains voltage. A T630 mA fuse should be used with 115 V mains voltage and a T315 mA fuse for 230 V mains.

Warning:

Unplug from the mains before altering the mains setting.

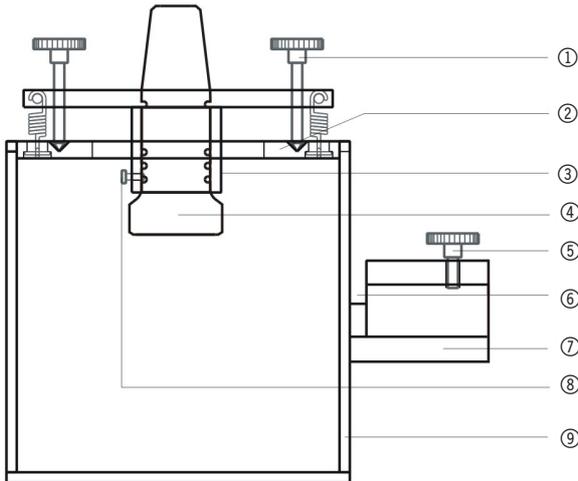
No voltage may be applied to the device while making the adjustment,



- ① Remove the two screws from the rear panelling and take off the panel. The voltage selector switch is revealed.
- ② Fuse

115 V	630 mA
230 V	315 mA
- ③ An arrow indicates the voltage that is currently set. Adjust using a screwdriver inserted into the slit.

2.2 Set-up for U10008 test container



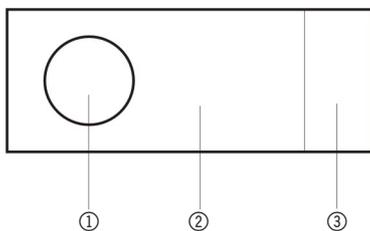
- ① Adjustment screw for changing the angle of the transducer
- ② Lid
- ③ Transducer holder
- ④ Ultrasonic transducer (supplied with U10006)
- ⑤ Securing screw for laser diode
- ⑥ Slot for lens holder
- ⑦ Laser holder
- ⑧ Securing screw for ultrasonic transducer
- ⑨ Glass vessel

Standing ultrasonic waves are generated in a special container. It allows the angle of incidence of the waves to be set precisely to the perpendicular by means of a special holder for the ultrasound transducer.

The test vessel consists of a glass vessel with a lid and a holder for the transducer, three adjustment screws to set the alignment for the standing wave and a laser holder perpendicular to the axis of the waves which also has a holder for a lens so that the ultrasonic waves and the Debye-Sears effect can be projected.

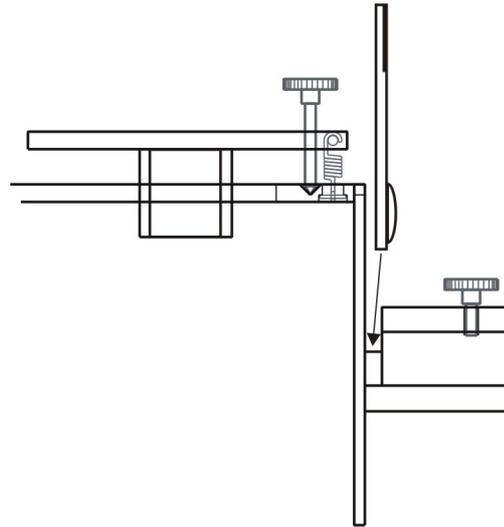
2.3 Lens on a glass slide

A plane-convex lens is attached to a rectangular slide. This is inserted into the slot in the laser holder of the test container for experiments involving projection.

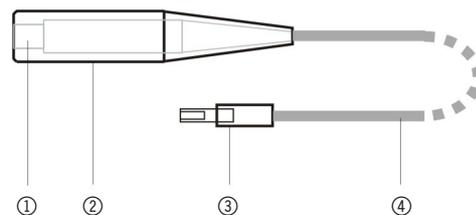


- ① Plano-convex lens ($f=100\text{ cm}$)
- ② Glass slide
- ③ Grip

The following illustration shows how the lens should be properly placed in the test container.



2.4 Laser diode (U10007)



- ① Laser beam window
- ② Laser module jacket
- ③ Plug for connecting to ultrasound generator
- ④ Connecting lead

Class II laser diode for demonstrating the Debye-Sears effect and projecting ultrasonic waves for use with the ultrasound generator and test container.

3. Experiment procedure

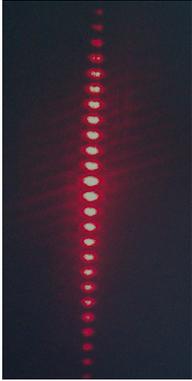
3.1 General instructions for experiments

Pay attention to the following instructions if the experiment is to work:

- Use water that contains as little air as possible since air bubbles disturb both the ultrasound field and the refraction of the laser beam.
- Any air bubbles around the probe should be removed.
- Allow for the maximum distance between the test container and the projection screen.
- When no measurements are being made, the ultrasound should be switched off so that the test fluid does not heat up.

- For precise measurements, also measure the temperature and include this in the comparison.
- When using high voltage at any frequency and when the transducer is properly aligned, at least 3 orders of diffraction should be visible.
- The projection experiment is much more sensitive to the angle of the transducer than the refraction experiment. Thus for this experiment the conditions for generating standing waves need to be adhered to more precisely.

3.2 Debye-Sears effect

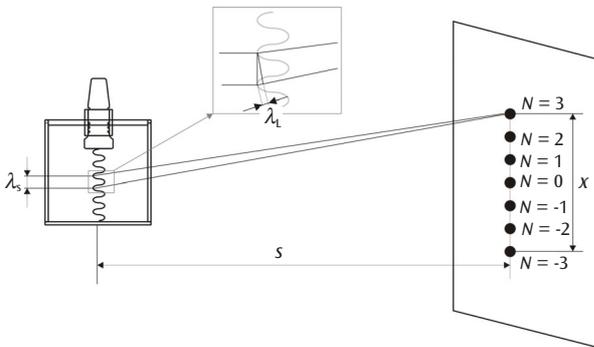


The wavelength of the ultrasonic waves in the Debye-Sears experiment (photo left, 4 MHz in water) can be determined for various different test fluids (water, glycerine, cooking oil). This means measuring the distance s between the ultrasound transducer and the refracted image. Then the number of orders of refraction N and distance between the $-n$ th and $+n$ th bands x can be determined. Since the wavelength of the laser light λ_L is known then:

Since the wavelength of the laser light λ_L is known then:

$$(1) \quad \lambda_s = \frac{2N\lambda_L s}{x}$$

gives the ultrasonic wavelength λ_s . The individual variables can be calculated as in the following diagram.



The ultrasonic frequency n is measured at the monitor socket. Then the speed of sound c in the fluid is given by:

$$(2) \quad c = \lambda_s \nu$$

Example results:

1. Water

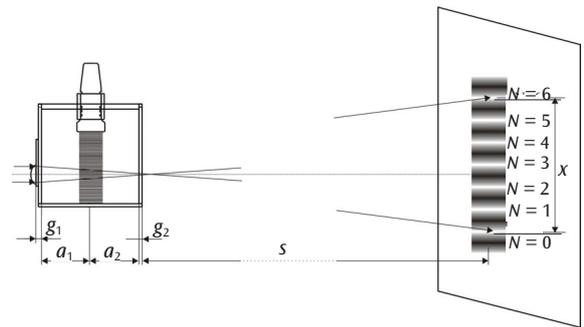
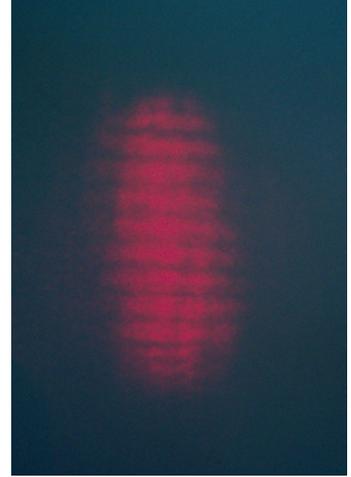
$\nu = 4$ MHz, $s = 2.90$ m, $N = 4$, $x = 4.1$ cm, $\lambda_L = 650$ nm therefore: $\lambda_s = 367.8$ μ m, $c = 1471$ m/s (Table: 1480 m/s at 20°C)

2. Glycerine

$\nu = 4$ MHz, $s = 2.90$ m, $N = 2$, $x = 1.6$ cm, $\lambda_L = 650$ nm therefore: $\lambda = 471.2$ μ m, $c = 1885$ m/s (Table: 1900 m/s at 25°C)

3.3 Projection of standing ultrasonic waves

Direct projection of ultrasonic waves can be an interesting extension to the experiment. The sound wave is projected by inserting a convex lens into the laser beam so that the beam is diverged. The density variations in the standing wave then appear as light and dark regions on the projection screen (see photograph right). To determine the wavelength from the diffraction image and the geometry involved, as well as the focal length f of the lens in air (100 mm in this case), corrections due to the glass walls of the vessel and the test fluid also need to be considered.



The light refraction method as described in 3.2 is thus better suited for calculating the wavelength precisely. The precise equation for λ_s in the projection experiment is:

$$(3) \quad \lambda_s = \frac{2x}{N} = \frac{f - \frac{g_1}{n_g} - \frac{a_1}{n_{FL}}}{s - \left(f - \frac{g_1 + g_2}{n_g} - \frac{a_1 + a_2}{n_{FL}} \right)}$$

The distance a_1 between the glass wall towards the lens and the distance a_2 can be approximated as half the internal width of 9.6 cm. The thickness of the glass g_1 and g_2 is about 4 or 5 mm. The refractive indices n_{FL} for the test fluid and n_g for the glass may be measured or taken from tables.

N is the number of bright maxima and x the separation between them.
The speed of sound in the medium can now be calculated once again from the measured frequency n using equation (2).

Note:

With the U10008 test vessel it is only possible to set up a good projection of the standing ultrasonic wave at a frequency of 4 MHz. At 2 MHz and especially at 1 MHz ultrasonic waves reflected from the bottom of the container are superimposed destructively on the impinging ultrasonic beam. Only for 4 MHz waves is the difference in the path length of the order of several wavelengths. At 8 MHz the amplitude of the emitted wave is too small and also the absorption is much greater (the absorption coefficient is proportional to the square of the frequency). This means that no clear standing waves are produced.

Example results:

Water:

$a_1 = a_2 = 4.8 \text{ cm}$, $f = 10 \text{ cm}$, $n_{\text{FL}} = 1.33$, $n_{\text{g}} = 1.45$,
 $s = 3.03 \text{ m}$, $n = 4 \text{ MHz}$, $x = 8.9 \text{ cm}$, $g_1 = 5 \text{ mm}$, $g_2 = 4 \text{ mm}$
therefore: $\lambda = 397 \text{ }\mu\text{m}$, $c = 1590 \text{ m/s}$
(Table: 1480 m/s at 20°C)

4. Technical details

4.1 Ultrasound generator (U10006)

Frequency: 1, 2, 4, 8 MHz adjustable
Output signal: Sine wave, continuously adjustable between 5 V_{pp} to approximately 65 V_{pp}. Can be switched off.
Red control light
Display: 3-digit LCD, one decimal place, height of digits 10 mm
Monitor signal: TTL, Frequency signal

Laser output: 3 V DC, max. 300 mW at socket
5.5 mm outer Ø, 2.5 mm inner Ø,
Can be switched off.
Red control light
Dimensions: 256 x 86 x 156 mm
Mains voltage: 115/230 V, 50/60 Hz
Power consumption: max. 60 VA; 5 VA minimum power (laser and ultrasound switched off)
Fuse: T 315 mA (230 V) / T 630 mA (115 V)

Ultrasonic transducer

Probe diameter: 27 mm
Active surface area: 2 cm²
Cable length: 1 m with BNC socket

4.2 Test vessel (U10008)

Test vessel: 100 x 100 x 120 mm
Volume: 900 ml approx.
Laser holder: 17 mm internal diameter
Transducer holder: adjustable, designed for the supplied transducer

Lens on glass slide

Lens slide: 76 mm x 26 mm Glass slide with roughened gripping surface
Lens: Plano-convex, $f = 100 \text{ mm}$ (in air), 16 mm Ø

4.3 Laser diode (U10007)

Beam spot: < 6 mm at 3 m
Wavelength: 650 nm
Power: < 1 mW, laser safety class II
Supply voltage: 3 V DC
Current consumption: max. 35 mA
Connecting plug: 1 m cable with plug of 5.5 mm outer Ø, 2.5 mm inner Ø
Dimensions: 80 mm x 17 mm Ø