3. The apparatus and specifications

A photo of the apparatus is shown in Figure 3.

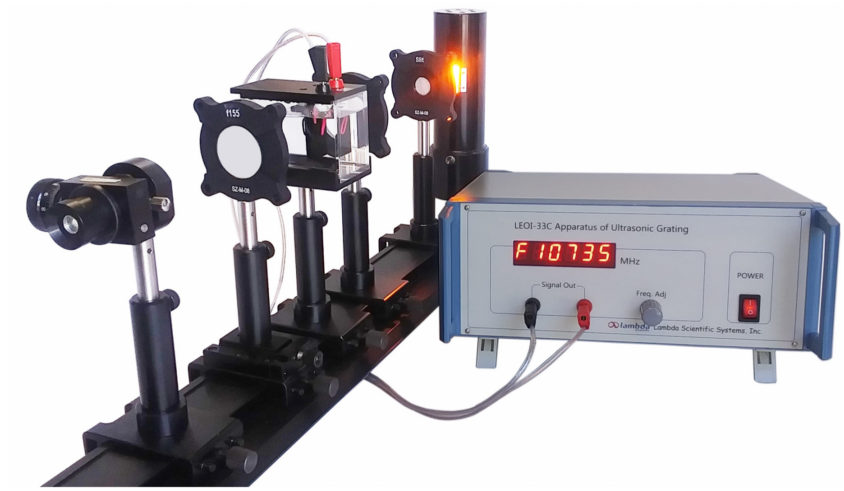

Figure 3 A photo of the setup

Specifications are given as follows:

Description	Specifications
Ultrasonic signal source	resonance frequency about 10.000 MHz, resolution 0.001 MHz
Slit	width 40 µm, length 20 mm
Lens	focal length 155 mm, effective aperture 35 mm
Ultrasonic cell	dimensions L 80 mm × W 40 mm × H 59 mm
Microscope eyepiece	measurement range 0 - 6 mm, resolution 0.01 mm
Optical rail	length 740 mm, scale 1 mm

4. Experiment contents

1) Understand the experimental principle of the acousto-optic effect.

2) Learn to measure the speed of sound in a liquid using the acousto-optic effect.

3) Learn the skills of optical path alignment.

5. Precautions

1) The liquid tank must be stable on the stage, and vibration should be avoided during the experiment, to allow the ultrasound to form a stable standing wave in the liquid tank. The change of the distributed capacitance of the wires will affect the frequency of the output signal, so the wires connecting the liquid tank and the signal source cannot be touched during experiment. Note: if the output frequency of the electronic unit deviates too far from 10 MHz, this problem can be fixed by adjusting the distance between the two connecting wires or the path of the two wires.
2) The surface of the PZT sheet and the opposite surface of the liquid tank wall must be parallel to form a good standing wave, so the upper cover of the liquid tank should be well set down during the experiment.
3) The resonance frequency of the PZT sheet is about 10 MHz. When the resonance is stable, the frequency displayed by the digital frequency meter should be stable. At most a few units change at the last one digit.
4) The experiment time should not be too long, because the speed of sound waves in the liquid is related to the temperature of the liquid. If the time is too long, the temperature may change. During the experiment, pay special attention not to keep the frequency to above 11 MHz and run for a long time to avoid overheating of the oscillation circuit.
5) When holding the liquid tank, do not touch the two light-passing surfaces to avoid contamination. If there is contamination, it can be cleaned with alcohol or wiped with lens paper.
6) During the experiment, it will generate a certain amount of heat in the liquid tank, which will cause the liquid to volatilize, and the volatilized gas will be condensed on the wall of the tank, which generally does not affect the experimental results. However, if the liquid level is too low to expose the PZT sheet, replenish the liquid to the normal liquid level.
7) After the experiment is completed, the measured liquid should be poured out. Do not immerse the PZT sheet in the liquid tank for a long time.
8) When the liquid contains impurities, it has a great influence on the measurement results. It is recommended to use purified water (commercially drinking pure water), pure

alcohol, glycerin, etc. It is not recommended for students to use toxic liquid for experiments. Teachers should pay attention to safety when they need it for teaching or scientific research.

9) When the instrument is not used for a long time, please put the microscope eyepiece in the original storage box. The liquid tank should be cleaned and allowed to dry properly.

Note

The measurement microscope consists of an objective lens and an eyepiece. The objective lens can focus an object located on the bottom plane of the tube to the reticle plate in the eyepiece with a ratio of 1:1. In this experiment, only the eyepiece is used while the objective should be removed. Refer the following picture to dismount the objective (Figure 4).

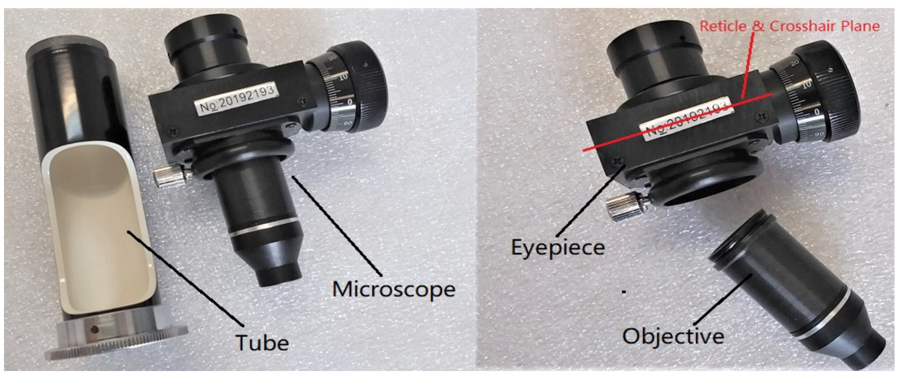

Figure 4 Configuration of reading microscope

6. Experiment procedure

1) Power on the low-pressure sodium lamp and warm up for 10 minutes. Construct experiment setup according to Figure 3. Note: use the transversally adjustable slide to hold lens L_2. This way, the central position of the group diffraction lines can be shifted left or right in the eyepiece by using this translation adjustment to bring the diffraction pattern to the middle of the viewing field if needed.

2) Adjust the height of the slit to let its center coincide with the optical axis of lens L_1 (i.e. the main optical axis). The distance between them is the focal length of lens L_1, so lens L_1 outputs a parallel light beam.

3) Adjust the height of the lens L_2 and the microscope eyepiece so that the optical axis of the two components coincides with the main optical axis. Adjust the focus of the eyepiece to see the reticle clearly.

4) Adjust the position of the sodium lamp so that the sodium lamp illuminates the slit, and it is uniform up and down, symmetrical from left to right, and the light intensity is proper.

5) Fill the liquid to be measured (such as distilled water, ethanol, or other liquids) into the liquid tank, place the liquid tank on the stage and use the lock screw to fix it. Make the front and back sides of the liquid tank substantially perpendicular to the main optical axis.

6) Place the PZT device into the tank. Connect the signal source between the electric unit and the PZT device using the pair of wires.

7) Adjust the distance between the microscope eyepiece and lens L_2, so that clear diffraction lines can be observed in the eyepiece.

8) In theory, the distance between slit and L_1 should be equal to the distance between L_2 and eyepiece reticle (which is located at the middle of the square box of the eyepiece device), and both distances are equal to lens focal length, i.e. 155 mm. To verify this point, move the liquid tank back and forth along the rail and observe from the eyepiece whether the fringe pitch changes. If changing, finely adjust the distance between the lens L_1 and the slit until the fringe pitch does not change.

9) Finely tune the “Freq. Adj.” knob to make the frequency of the signal source equal to the resonance frequency of the PZT sheet to achieve as more as possible diffraction orders. Finely and slowly rotate the liquid tank around the post (try both CW and CCW directions) to make the parallel light beam incident onto the liquid tank perpendicularly. At the same time, observe the diffraction lines through the eyepiece, the diffraction orders will increase significantly and the diffraction lines will be brighter. Observe the brightness and symmetry of the diffraction lines in the field of view. Repeat these operations until clear, symmetrical and stable diffraction fringes of 2-4 orders can be

seen in the eyepiece. Figure 5 shows an example of diffraction pattern taken from eyepiece.

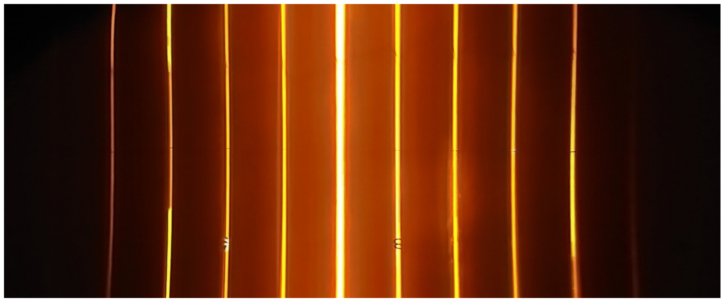

Figure 5 A diffraction pattern taken from the eyepiece

10) Use the microscope eyepiece to measure the position of each diffraction line one by one. During the measurement, rotate the microscope eyepiece drum in one direction to eliminate the backlash error.

11) Make data table, record the position reading of each diffraction order. Calculate the average spacing of diffraction lines, and calculate the speed V of sound in the liquid.

7. Examples of Data Recording and Processing

Note: Following data are for reference purpose only, not the criteria for apparatus performance:

Light source wavelength λ=（589.3 ± 0.3）nm

Lens L_2 focal length f=（155.0 ± 0.5）mm

Tested liquid pure water

Liquid temperature t= 24 ^{o}c

Theoretical sound speed $V_t = V_0 + \alpha(t - t_0)$ = 1481+2.5×(24−20) =1491 m/s

Signal frequency υ = 10.478 MHz

Table 1 diffraction order k and diffraction line position

Order k	Position L_k	$L_{\|k\|} - L_{\|k\|-1}$ (mm)	$\left(L_{\|k\|} - L_{\|k\|-2}\right)/2$ (mm)	$\left(L_{\|k\|} - L_{\|k\|-3}\right)/3$ (mm)
-3	1.080	0.630	0.636	0.640
-2	1.710	0.641	0.645	
-1	2.351	0.649		
0	3.000			
1	3.610	0.610		
2	4.260	0.640	0.630	
3	4.915	0.655	0.653	0.638

$$\Delta l_k = \frac{1}{12}\sum\left[L_{|k|} - L_{|k|-1} + \left(L_{|k|} - L_{|k|-2}\right)/2 + \left(L_{|k|} - L_{|k|-3}\right)/3\right]$$

$$= \frac{1}{12}(0.630+0.641+\ldots+0.640+0.638)$$

$$= 0.639 \text{ (mm)}$$

$V = \lambda f v/\Delta l_k = (589.3 \times 10^{-9} \times 155.0\times10^{-3}\times10.478\times10^{6}) / (0.639\times10^{-3}) = 1498$ (m/s)

Experiment errors: E = (1491 - 1498) / 1491 = 0.47%.