EXPERIMENT 6: DEBYE-SEARS EFFECT

THEORY

In 1932 Debye and Sears showed that light undergoes diffraction when passing through a liquid being excited into high- frequency vibrations. By means of this effect, ultrasound can be made more or less visible. When this effect is used, the density maxima and minima produced in the liquid by a standing or travelling ultrasonic wave act like an optical diffraction grating. The grating constant of a such a grating produced by an ultrasonic wave corresponds to the wavelength of this ultrasonic waves (Fig. 1). It can be determined by means of the diffraction patterns of the light of a laser beam of known wavelength (Fig. 2). Because the wavelength is defined by frequency and sound velocity, the Debye-Sears effect can be used in this experiment set-up to determine – with a high degree of precision- the sound velocity in the liquid through which the sound is passing. If the distance s between ultrasonic wave and diffraction pattern, the number N of diffraction maxima, the distance x between the –Nth and +Nth diffraction order, the sound frequency f and the wavelength λ_l of the laser light are known, the wavelength of the sound λ_s and the sound velocity c in the liquid can be calculated according to the following formula:

$$\lambda_s = 2N\lambda_L \frac{s}{x} \tag{1}$$

$$c = \lambda_s f \tag{2}$$

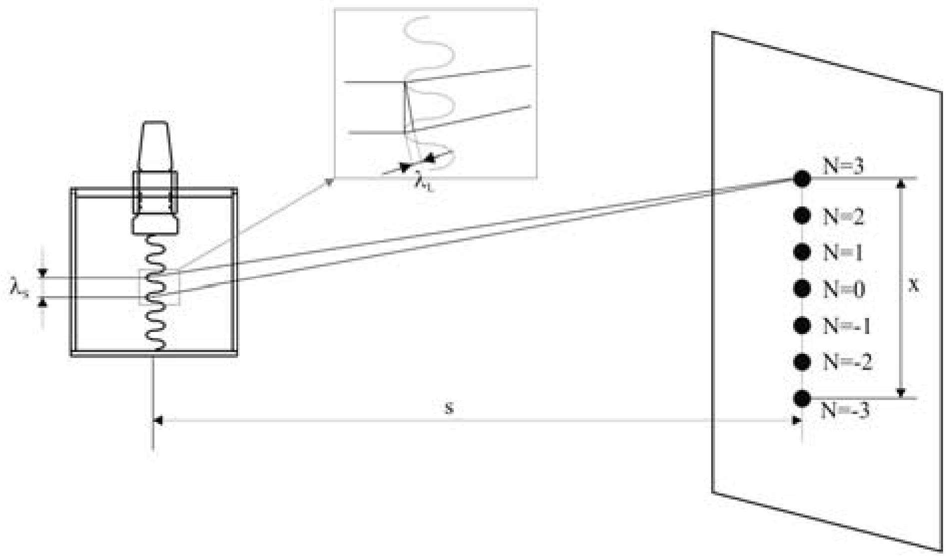


Fig.1 Diagram of the geometric conditions for the Debye-Sears test.

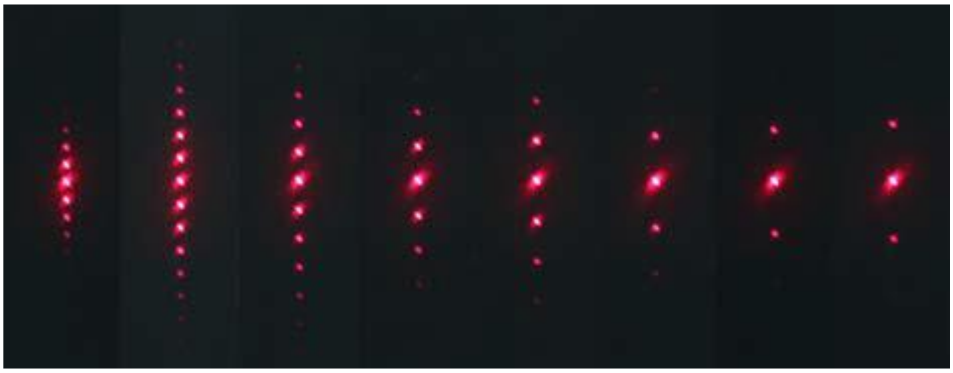
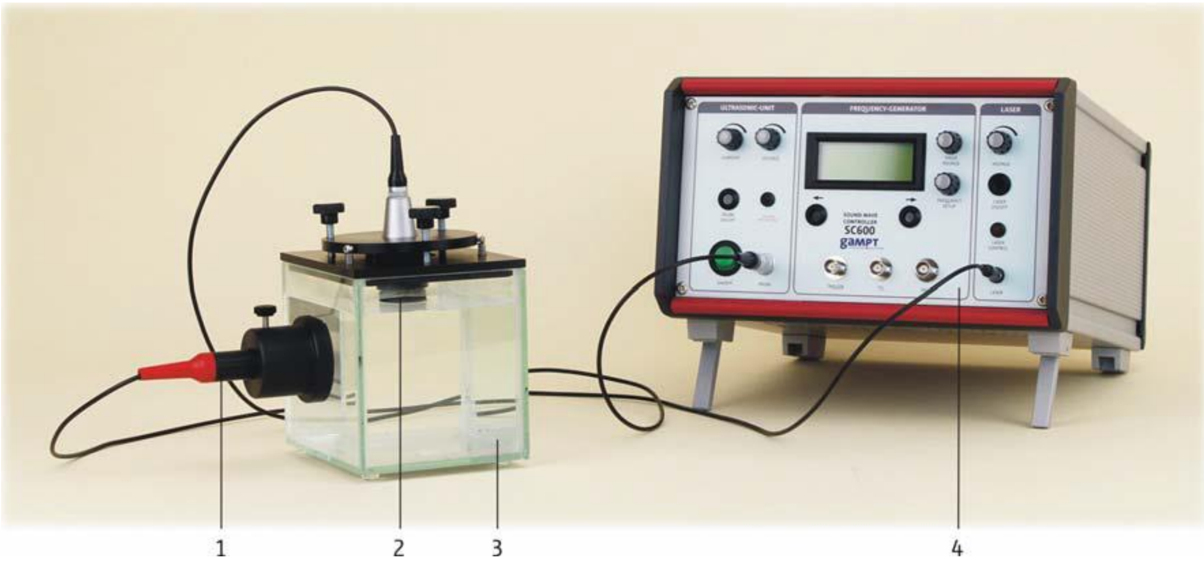
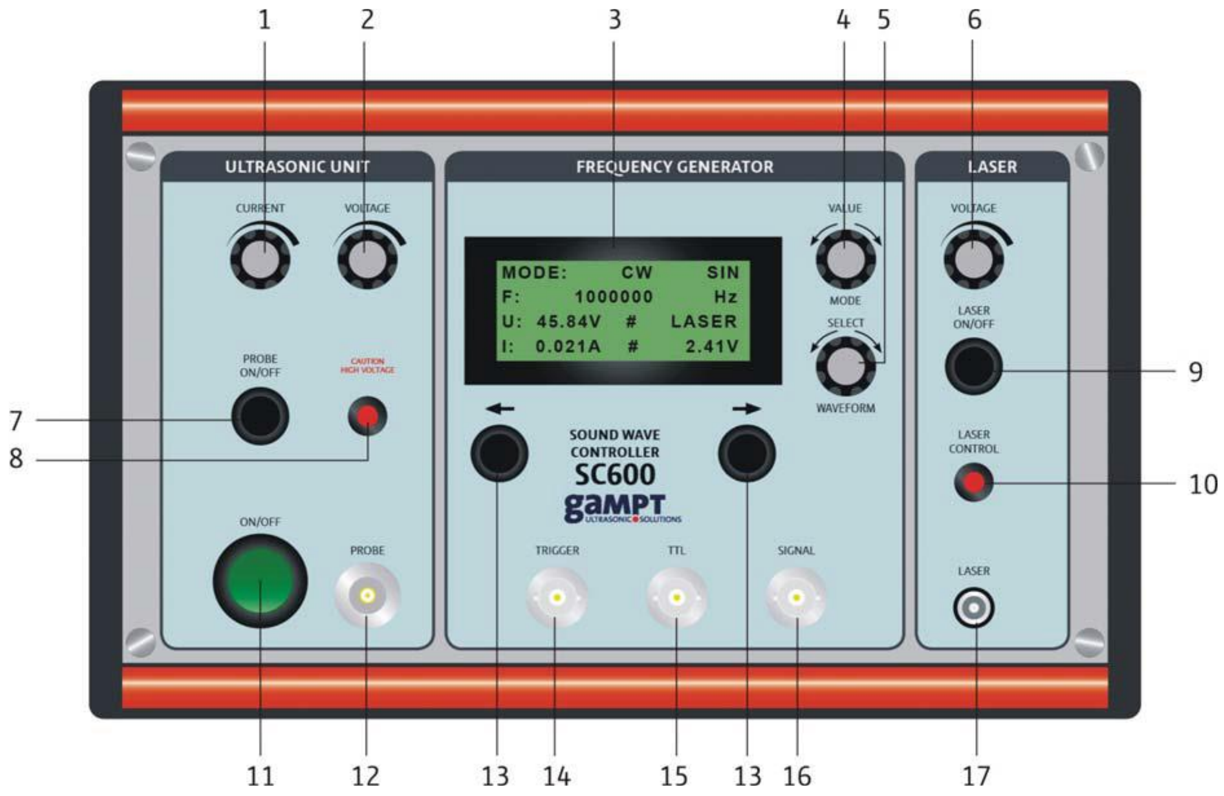


Fig 2. Diffraction patterns for red laser light at sound frequencies of 3-10 MHz in steps of 1 MHz.



(1) laser module
(2) ultrasonic probe
(3) sample reservoir with probe adjustment and laser support
(4) Sound Wave Controller SC600

Fig 3. Experimental set-up for the Debye-Sears test.



(1) current regulator output PROBE
(2) voltage regulator output PROBE
(3) LCD display
(4) setting value/mode
(5) setting selection/signal shape
(6) voltage regulator output LASER
(7) on/off button output PROBE
(8) status LED output PROBE
(9) on/off button output LASER
(10) status LED output LASER
(11) on/off switch device
(12) output ultrasound generator
(13) button decimal place selection
(14) trigger output
(15) TTL output
(16) signal output signal generator
(17) output laser voltage

Fig 4. Front view of the screen.

PROCEDURE AND CALCULATIONS

1. Fill the box in water.
2. Adjust the frequency value at 3MHz and observe the diffraction gratings.
3. Using eq.1 and eq.2 calculate wavelength and speed of sound.
4. Change the frequaecy value until 10Mhz in steps of 1MHz.
5. Record all datas and results in table 1.
6. If the speed of sound is 1.480 m/s in the water, find the percentage error value.

N	**λ_L (nm)**	**f (MHz)**	**x (cm)**	**s (m)**	**c (m/s)**	**λ_s (µm)**
4	532	5	3.5	3.25		
3		6	3.4			
2		7	3.7			
2		8	3.8			
2		9	4.2			
1		10	2.5			
1		11	2.7			
1		12	3.0			