UNIVERSITY OF WATERLOO

Physics 360/371 – Experiment 6

ULTRASONIC DIFFRACTION OF LIGHT

References: Fundamentals of Ultrasonics, J. Blitz; Ultrasonics, B. Carlin

This experiment serves as an introduction to ultrasonic waves. Ultrasonic waves are longitudinal waves with frequencies extending from beyond the audio range up to a practical limit of ~ 10^9 Hz.

Ultrasonic waves have many applications, from burglar detection to medical therapy, but we shall use the waves in this experiment to measure the speed of sound and the bulk modulii of a few liquids. If such waves are generated in a liquid, then the index of refraction varies periodically throughout the liquid as a result of changes in density resulting from the passage of the wave. Therefore, the liquid will act as a phase diffraction grating when a beam of light is passed through it, and from the resulting diffraction pattern the wavelength of the ultrasonic waves can be determined. In this experiment standing waves may be set up between a quartz transducer and a parallel surface. The spacing between the transducer and plate is adjusted using a micrometer. Note that standing waves are not necessary but some improvement in the diffraction pattern may result when standing waves are set up.

The crystal has a fundamental resonance near 5 MHz and so a frequency of approximately this value should be used in the initial set up. The driving frequency is derived from an oscillator and fed to the crystal via a power amplifier. Measurements may also be carried out in the region of the third and fifth harmonics of the crystal near 15 and 25 MHz.

Note that it is necessary to carefully adjust the incoming light beam to be as nearly as possible parallel to the piezoelectric crystal – as the "grating" extends over a relatively large distance in the direction of the light.

EXPERIMENT

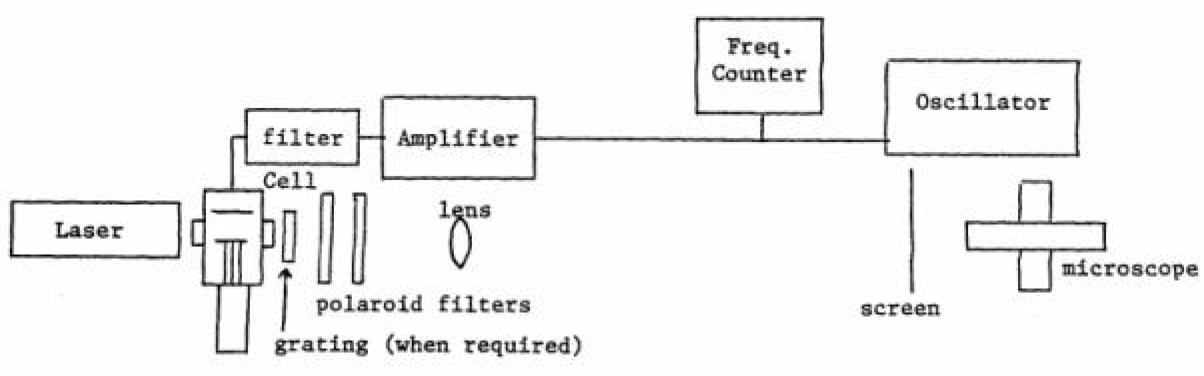
Determine the wavelength of the light from the source provided (a laser). A diffraction grating (ronchi ruling) is provided for this purpose, along with a traveling microscope which can be used to measure the spacing of the lines on the grating as well as the spacing of the points in the diffraction pattern.

Two polaroid filters are provided to vary the beam intensity as required. For direct viewing of the beam, the filters should be oriented approximately 90° to each other to minimize the brilliance. The liquid cell and the grating are placed nearest the laser. The polaroid filters are placed next in the beam. The lens (focal length given) is placed next. A ground glass screen is placed in the focal plane of the lens with the ground side toward the lens. The traveling microscope is focused on the ground side of the screen.

If the grating is moved along the optical axis or across the beam (within reason), is the diffraction pattern altered? Explain using a ray diagram.

Note that the index of refraction of the liquid will have two effects (a) the wavelength of light will be different in the liquid and (b) the light will be refracted at the cell windows. Explain why this refraction has no net consequence.

A block diagram of the set-up is shown below.



Make sure you rinse the cell out with the liquid to be used as a guarantee that the previous liquid is completely removed. Do not leave any water in the cell! Use methanol (highly flammable) last. Dump used liquids in the container provided.

(1) Using the travelling microscope determine the grating space of the diffraction grating (ronchi ruling).

(2) Place the grating and lens perpendicular to the laser beam as shown in diagram. This can be achieved by noting when the spacing between the diffraction spots is minimized. Explain.

(3) Determine the wavelength of the laser source from the diffraction pattern in the focal plane of the lens.

(4) With the liquid cell in place as the phase diffraction grating determine the wavelength of sound in two liquids from the observed diffraction patterns at the three frequencies 5, 15, and 25 MHz.

(5) Determine the speed of sound in each liquid from your data.

(6) Calculate the bulk moduli for the liquids and compare with the accepted values.

(7) Keep track of errors and assign uncertainties to your final results.

<u>APPARATUS LIST</u>

Optical bench
Laser, mounted
2 polaroid filters, mounted
Transmission diffraction grating, mounted
Thin bi-convex lens (focal length given), mounted
Traveling microscope, mounted
Radio frequency oscillator
Frequency counter
Radio frequency amplifier
Radio frequency filter
Diffusing screen, mounted
Ultrasonic cell with two quartz transducers, mounted
Waster liquid container

Liquids: Methanol, distilled water