in which $(x - \bar{x}) = d$.

$$s = \left(\frac{\Sigma d^2}{n-1}\right)^{\frac{1}{2}} = 26 \times 10^{-2} \text{ where } n = 16 .$$

The standard deviation of the mean (Equation 1.3) is

$$s_m = \frac{s}{\sqrt{n}} = \frac{26 \times 10^{-2}}{\sqrt{16}} = 6{\cdot}50 \times 10^{-2} .$$

The fractional error $= \dfrac{s_m}{\text{mean value}} = \dfrac{6{\cdot}50 \times 10^{-2}}{3{\cdot}37} = \dfrac{2}{100} = 2\%$. 2% of the nominal value 1015 = 20

Hence the resolving power calculated from $pN = 990 \pm 20$, which is in good agreement with $\lambda/d\lambda = 985$.

Other doublets may be used in checking the resolving powers of spectrometers:

Element	Wavelengths constituting the doublet (Å)	Separation (Å)
Ti	5036·4 5035·9	0·5
Fe	6137·6 6136·6	1·0
Ti	5038·4 5036·4	2·0
Fe	5269·5 5266·5	3·0
Ti	5020·0 5016·1	3·9
Fe	5434·5 5429·6	4·9
Fe	4619·2 4611·2	8·0
Mg	5183·6 5172·6	11·0
Fe	5191·4 5175·5	19·9

2.4 The determination of the speed of ultrasound in a liquid by a diffraction method

A specially constructed rectangular trough, preferably made of metal, is required which has two plane glass windows, one in each long side (Fig. 2.5). This is filled with the liquid (carbon tetrachloride CCl_4 or paraffin is suitable) and an ultrasonic generator is mounted within the trough at one end.

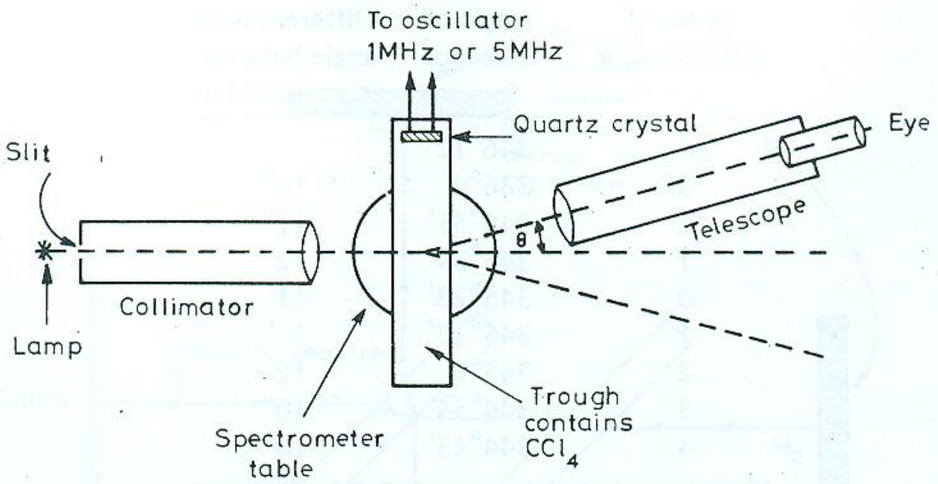

Fig. 2.5 The determination of the speed of ultrasound in carbon tetrachloride.

The ultrasonic generator is a quartz crystal which is set oscillating by connecting it to a crystal-controlled oscillator with an output at a frequency conveniently of either 1 MHz or 5 MHz. Longitudinal standing waves of ultrasonic frequency are thereby set up in the liquid because the far flat end of the trough acts as a reflector. In these standing waves a rarefaction diminishes and a compression increases the refractive index of the carbon tetrachloride. If, therefore, this trough is firmly fixed (plasticene may be used to make a temporary seal) on a spectrometer table (of which the slit is illuminated by light from a sodium discharge lamp) light rays undergo various phase retardations in traversing the liquid. As the wavelength of the 1 MHz (or 5 MHz) ultrasonic waves is very short, the liquid hence behaves as a diffraction grating provided that the tank is wide enough to support plane waves.

Equation (2.9) applies :

$$e \sin \theta = p\lambda$$

where λ is the known wavelength of the sodium light (5893 Å), θ is recorded for given orders p and e is calculated.

As there is only one point of maximum compression in each wavelength of the ultrasound, the separation e is the wavelength λ of the ultrasonic vibrations. The frequency f of the crystal controlled oscillator is known, so that speed v of the ultrasound in the carbon tetrachloride is given by

$$v = f\lambda'.$$

In an experiment an oscillator of frequency 5 MHz was used. With the collimator set normally to the plane parallel entrance and exit glass windows in the long sides of the rectangular tank, the angle of setting of the telescope was recorded at various orders of diffraction, p. Values obtained are tabulated.

Order of diffraction, p	Angle of telescope	Differences in angle between adjacent orders
4	346°12′	
3	346°2′	10′
2	345°51′	11′
1	345°39′	12′
0	345°28′	11′
1	345°17′	11′
2	345°5′	12′
3	344°55′	10′
4	344°45′	10′

The mean difference in angle for one order $= 10{\cdot}88'$, which is θ for $p = 1$.

$$e \sin \theta = \lambda$$

so that

$$e \sin 10{\cdot}88' = 5{\cdot}893 \times 10^{-4}\,\text{mm}$$

$$\sin 10{\cdot}88' = 3{\cdot}2 \times 10^{-3}\,.$$

Therefore

$$e = \frac{5{\cdot}893 \times 10^{-4}}{3{\cdot}2 \times 10^{-3}} = 1{\cdot}8416 \times 10^{-1}\,\text{mm}$$

As e is the wavelength λ' of the ultrasound in the carbon tetrachloride, it follows that the speed v of this sound is

$$v = 5 \times 10^{6} \times 1{\cdot}8416 \times 10^{-1}\,\text{mm}\,\text{s}^{-1}$$
$$= 92{\cdot}88\,\text{m}\,\text{s}^{-1}$$

2.5 The Michelson interferometer

In order to use a Michelson interferometer successfully, it must be set up initially in accordance with a satisfactory procedure.

The Michelson interferometer is illuminated with light from an extended source (e.g. a ground glass screen illuminated by light from a discharge lamp). Initially the distance M_1E is made approximately equal to distance M_2E (Fig. 2.6).

An interference pattern will not normally be seen unless mirrors M_1 and M_2 are in planes at 90° to one another. To adjust them to be so, a large pin on a stand is set up vertically between the extended source and E. Multiple images will be seen of this pin by the observer. The screws in the supports behind the mirrors M_1 and M_2 are carefully adjusted until the images of the pin coincide, only two images being finally visible. This coincidence occurs when the mirrors M_1 and M_2 are in planes at 90° to one another. As the pin images are made to coincide, interference fringes become