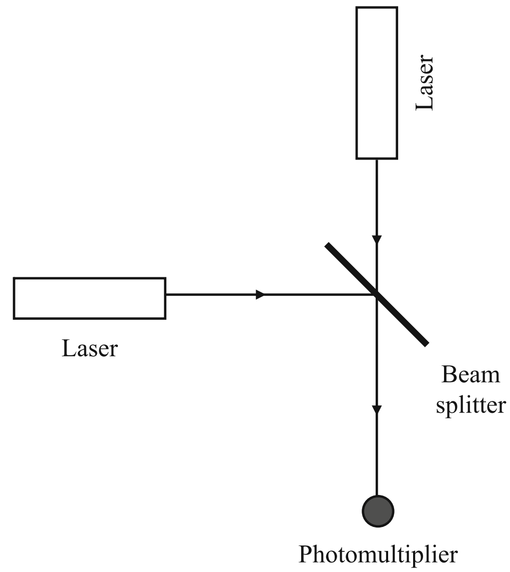

Fig. 18.15 An experimental setup for detecting the presence of ether drift

18.7 Lasers and Gravitational Waves

Einstein's general theory of relativity predicted the existence of gravitational waves which are ripples in the fabric of space–time. These waves are very weak (even for events such as supernova explosions) and supposed to be produced when massive objects accelerate through space. Scientists have been working on using the principles of interferometry to detect the existence of these waves. Gravitational waves

Fig. 18.16 The LIGO interferometer being built to detect gravitational waves. Squeezed light is expected to be used in the interferometer for increasing the sensitivity of the sensor. (Source: Ref. http://physicsworld.com/cws/article/news/33755)

passing through a Michelson interferometer (with arm lengths of a few kilometers) are supposed to stretch one arm and compress the other leading to a change of phase of the interference pattern. However the change of length is extremely tiny, about 10^{-18} m. Thus the expected fringe shift is extremely small and the interferometer to detect such effects needs to have very large arm lengths. Figure 18.16 shows a photograph of The LIGO (Laser Interferometer Gravitational Observatory) being built to detect gravitational waves. Current detectors are not sensitive enough to measure such small changes. The ultimate sensitivity is determined by quantum noise in the detector. We had discussed in Chapter 9 about squeezed states which exhibit noise level below that of vacuum state in one quadrature. Such squeezed states are expected to enable detection of gravitational waves. Such squeezed light is proposed to be produced using non-linear effects in crystals and experiments on squeezed light have demonstrated noise levels below the vacuum state.

18.8 Rotation of the Earth

Lasers have been used to detect the absolute rotation of the Earth. If light is made to rotate in both clockwise and anti-clockwise directions around a square with the help of mirrors as shown in Fig. 18.17, then if the square is at rest, the time taken for light to travel around the square in both the clockwise and the anti-clockwise directions would be the same. But if the square is rotated about an axis which is normal to the plane of the square, then the time taken for light to travel along one direction will be different from that taken along the other direction. Thus if one could measure this difference, one could obtain information about the rotation of the square.[8]

An experiment to detect the rotation of the Earth by using such a method with ordinary light sources was performed by Sagnac in 1914 and then by Michelson and Gale in 1925. With the use of lasers, one can do similar experiments with much more precision and sensitivity. The sides of the square are gas discharge tubes containing helium and neon. The corners of the square are occupied by mirrors (see Fig. 18.17). Light beams traveling along either direction would undergo amplification. Thus one would have two beams, one propagating in the clockwise direction and the other in the anti-clockwise direction. The frequency of oscillation of the laser would depend on the path length along the square. Since the path lengths along the two directions are different when the system is rotating in the plane, two different frequencies are obtained. By mixing the light beams of the two frequencies, one can detect the beat frequency of the beams and hence the rate of rotation of the square. For example, at New York (which is at a latitude of $40°40'$N) the effective speed of rotation is about one-sixth of a degree per minute; this would correspond to a beat frequency of 40 Hz.

[8] The difference in path length between the two paths is extremely small; thus only a shift of a hundred-thousandth of a wavelength would be produced when the square is of side 3 m and is kept at a latitude of 40° on the surface of the earth.