

## Simple nonpolarising high-frequency modulator for interferometry

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**Abstract** A modulator based on standing density waves in water for a parallel-ray interferometer is described. The local changes in the refractive index of the water lead to optical path modulation at a typical frequency of 100 kHz. This modulator is easy to construct, has a high optical efficiency and low power consumption.

During our work with a stellar shearing interferometer, (Ribak and Lipson 1981), we encountered the need for a convenient modulator. The interferometer has two parallel light beams, and the modulator must introduce an alternating path difference of a quarter-wavelength between them. Because of atmospheric fluctuations, it is necessary to work at frequencies above about 50 kHz, which is too high for mechanical systems. Most other modulators were also ruled out since they involve polarisers and therefore waste at least half of the light, which is very precious in astronomical observations.

Thus the idea arose of using density waves in water. Density waves cause a change in the refractive index, which modulates the optical path. Water is known (Hartfield and Thompson 1978) to be very efficient for this purpose and is easily available.

The geometrical layout is shown in figure 1. A standing acoustic wave is excited across a water cell, and the two light beams intersect it transversely at two antinodes of the wave. At a peak of the acoustic wave, one beam experiences a maximum of refractive index and the other a minimum; thus the optical path difference is achieved. The amplitude of the acoustic wave is chosen so that the path difference is a quarter-wavelength. Half a cycle later, the path difference is reversed. At the output of the interferometer there is a constructive interference in one exit and destructive at the complementary one. After half a cycle the roles are reversed, since the phase difference has changed by  $\pi$ . It should be noted that *all* the light that enters the interferometer reaches one exit or the other, and can therefore be used. This is the advantage of this type of modulator over other types.

The cell was machined from an aluminium block of dimensions  $40 \times 40 \times 35$  mm<sup>3</sup>. Two horizontal holes were drilled through it at right angles, one for the light beams and one for the acoustic wave. The former had a diameter of 25 mm and was closed by two parallel optical windows. The latter, of 30 mm diameter, was closed by two thin (0.3 mm) stainless steel plates. On one of them was glued a home-made piezoelectric stack driver; the other acted as a plane reflector. Finally two small holes (1 mm) were drilled in the top to allow the cell to be filled without leaving air-bubbles. The light beams have a path length of 35 mm, of which approximately 10 mm (dependent on frequency) is within the modulated region. The acoustic path is 40 mm long. It is possible

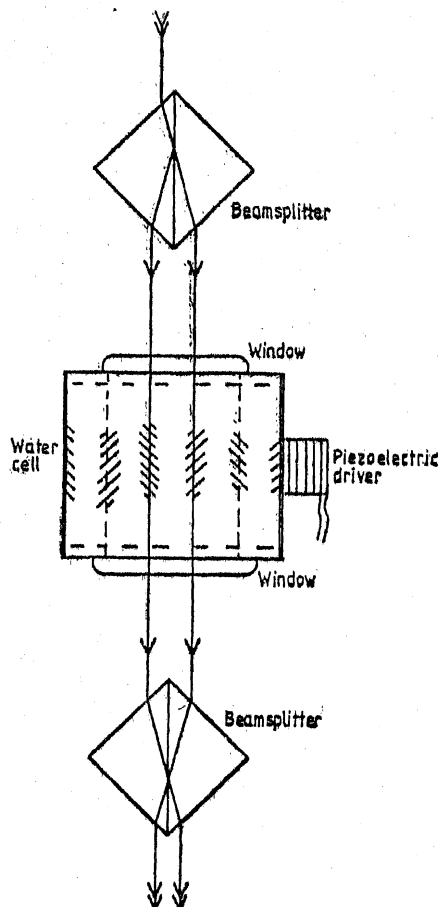


Figure 1 Top view of the interferometer and the modulator. Diagonal hatched lines represent maxima and minima in water.

that a spectroscopic cell (cuvette) could be adapted for this purpose.

When a frequency scan was applied to the driver, it was found that low modes were difficult to excite, because of beam divergence. At higher frequencies, such as 124 kHz, a satisfactory resonance was found with acoustic wavelength of 12 mm. Thus light beams up to about 3 mm diameter could be modulated if separated by 6 or 18 mm. The cell has worked satisfactorily up to 2 MHz, but the beam diameter must then be very small. The necessary driver voltage was found to be 7.5 V RMS and the power consumption was less than 0.25 W. It is an advantage that the resonance is not very sharp ( $q \sim 10$ ) because then the driver frequency does not need accurate stabilisation.

To summarise, a simple, highly efficient modulator has been described, which does not involve polarised light and can be used at high frequencies.

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### References

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