CHAPTER 5

5.0 DETECTION TECHNIQUES

5.1 Introduction

In the following experiments two different techniques to produce phase modulation and demodulation are used. Both use either Mach Zehnder or Michelson interferometers. Here both techniques are discussed in detail.

5.2 Mach Zehnder Technique

In this technique a beam splitter has been use to carry out amplitude division into two halves and then it is recombined. This is shown in Fig. 5.1. Light emitted by the laser diode, which has an elliptically spatial distribution and is focused by the plano-convex lens. A plane polarizer ensure a simple plane of polarization. This plane-polarized light is split into two with a non-polarizing beam splitter cube (NPBS-1). This splitter does not change the plane of polarization. Then the mirror-1 and mirror-2 reflect these two light waves toward another non-polarizing beam splitter cube (NPBS-2) where lightwave are combined.

Assuming that all components are ideal, and the splitting ratio is 50:50, the path length for the lightwave reflected by the mirror-1 and that reflected by mirror-2 are exactly same. It is also assumed that all components (two splitters and two mirrors) are in the same plane, and both mirrors are exactly parallel to each other and are 45^0 to the direction of the light waves. When these light waves reach the second non-polarizing beam splitter cube (NPBS-2), they are again split into two equal parts. On emerging, both light waves have two components of light, one reflected from mirror-1 and the other after reflected from mirror-2. The output can be observed on both sides of NPBS-2. In this ideal condition no fringes will be observed. There with be only one spot on each side of the beam splitter NPBS-2. The intensity of this spot will change if the path length is changed. If any of the angles is changed then interference pattern is obtained. This pattern is due to the path difference. This pattern can also be obtained when all four components are not in the same plane. The thickness of the fringes depend on three main factors.

i) Path difference between the two lights waves.

ii) Coherence length of the light source.

iii) Overall geometry of the system.

Coherence length is due to the source coherence time. It is the average time during which the light wave maintains its phase. This depends on the structure and type of the light source. The laser diodes, which are used in the experiments, have an average coherence length of 25-cm. Path difference and geometry of the interferometer can be manipulated to get the required type of fringes. This is shown in Fig.5 2. Where a slight angle change in turn changes the path length of one of the light wave and on the output side of NPBS-2 where two light waves interact the characteristics light and dark pattern of interferometer is seen.

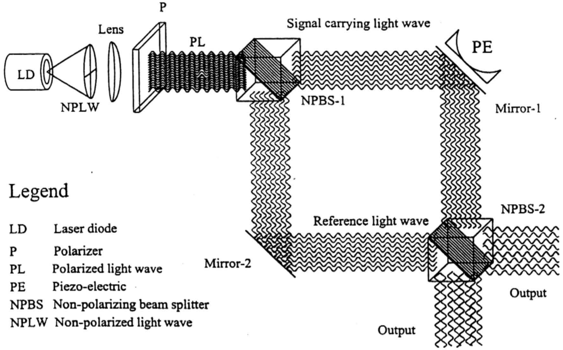


Fig. 5.1 Signal encoder, using Mach Zehnder technique

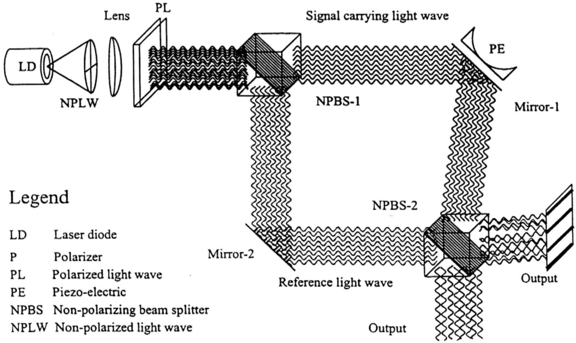


Fig. 5.2. Singal encoder when all angles are not 90 degree.

5.3 Michelson Technique

In the Michelson technique a light wave is split into two and then recombined by the same beam splitter as shown in Fig. 5.3.

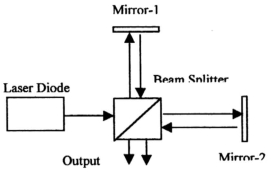


Fig. 5.3 Michelson Interferometer Technique

In this case the spacing between a bright fringe and dark line depends on the path difference, coherence length, and the geometry of the system. Detectors are used to decode signal by detecting the bright and dark fringes.

The detector is very small as compared to the width of the dark and bright lines. Position of the detector between the fringes is very important. This is because concise interpretation of the detector output is essential for accurate interpretation of the signals. In the Fig. 5.4a and Fig. 5.4b The Michelson and Mach Zehnder techniques are shown where in both cases light wave is split into two light waves A and B. These lightwaves travel two different directions and then are combined back at the surface of the detector after being reflected by the mirror-A and mirror-B. The detector output current depends on the intensity of the light hence placement of detector with respect to light or dark fringes is extremely important. If two light waves completely cancel each other then the detector output shows zero current and detector output shows a maximum current if two light wave completely coincide with each other as shown in the Fig 5.4. In both Fig. 5.4a and 5.4b, mirror-A is attached to piezo-electric modulator and mirror-B is stationary. When a signal is applied to the piezoelectric modulator, mirror-A vibrates in turn creating a varying path length. Light reflected of mirror-A becomes signal carrying light wave while light reflected of the mirror-B, which is fixed, is called the reference light wave.

The detector is positioned on the dark fringe when no signal is applied to the piezoelectric modulator, when a voltage is applied, the mirror-A moves forward. The detector detects the presence of a bright fringe and when mirror-A moves to its original position detector detects a dark fringe and so output signal is exact replica of the input signal. A typical output signal is shown in Fig. 5.4c while the input signal is shown in Fig. 5.4d. As long as the amplitude with which mirror-A vibrates does not create a path difference of more than $\lambda/2$ (λ is the wavelength of light wave used) since exceeding this path difference the output will not be an exact replica of input signal. The output signal amplitude is proportional to the difference in path length of two lightwaves as long as it is equal or less than $\lambda/2$.

If detector is placed on bright fringe then upon applying the signal to the piezoelectric modulator mirror-A will move forward and a bright line will change to a dark line. In this case the output signal will be a mirror image of the input signal which is shown in Fig. 5.4e and Fig. 5.4f.

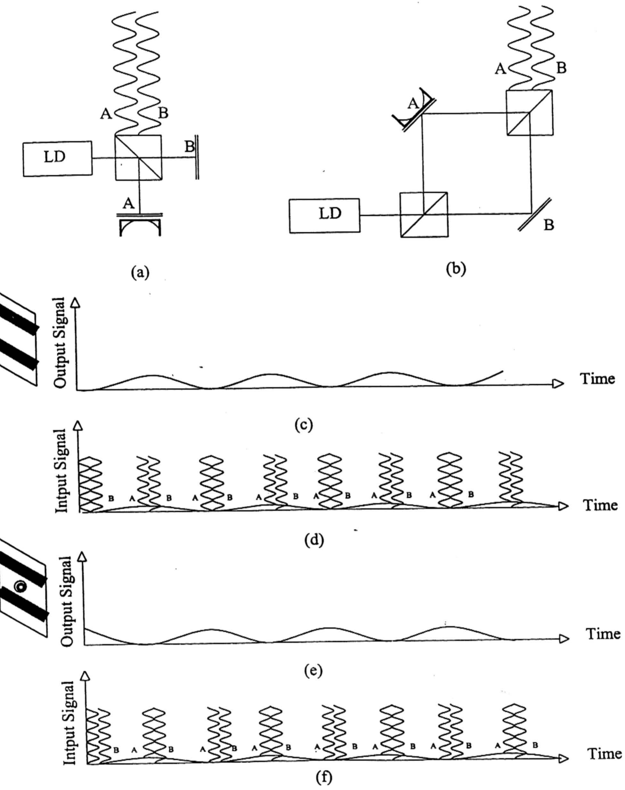


Fig. 5.4 (a) Michelson technique. (b) Mach Zehnder technique
(c) Output signal when detector is on the dark line (d) Input signal
(e) Output signal when detector is on the bright line (f) Input signal

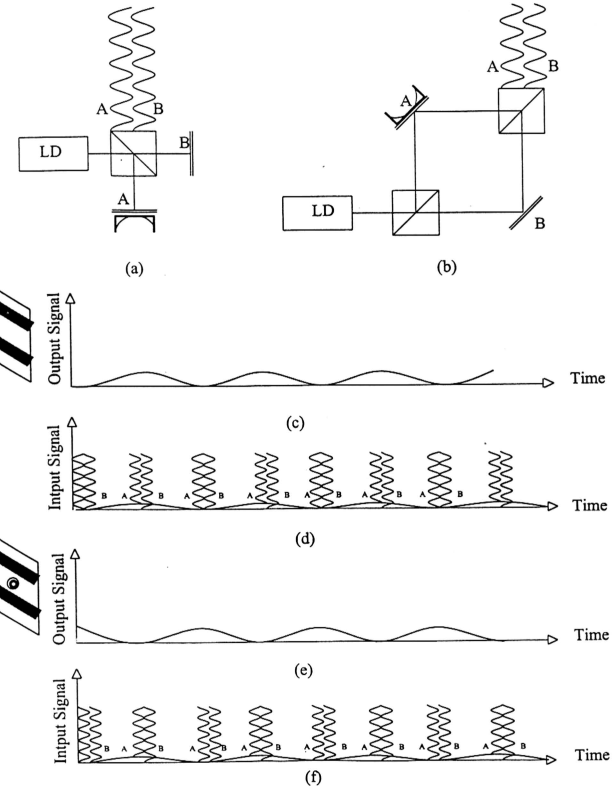
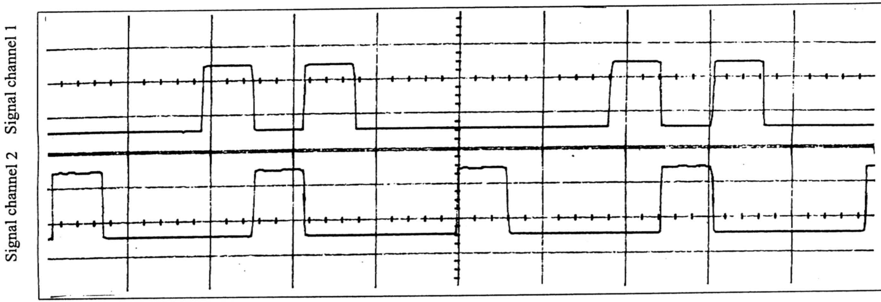


Fig. 5.4 (a) Michelson technique. (b) Mach Zehnder technique
(c) Output signal when detector is on the dark line (d) Input signal
(e) Output signal when detector is on the bright line (f) Input signal

-10.0000nm Main: 2.00 ms/div CENTER 0.00000 s REPETITIVE 10-0000 ms
-10.0000nm 2.00 ms/div 0.00000 s AVERAGE = 2 10.0000 ms

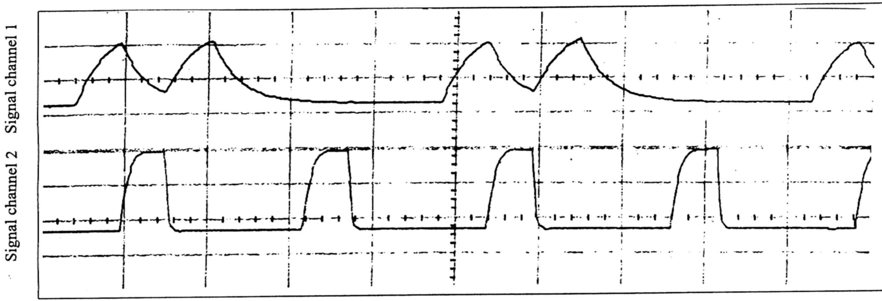


	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	2.00 V/div	3.00000 V	1:1	dc	1M ohm
Channel 2	2.00 V/div	1.00000 mV	1:1	dc	1M ohm

Trigger Mode: Edge
On the Positive Edge of Channel22
Trigger Level (s)
Channel12 = 1.50000 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.5. Two signals from the signal generator, without being connected to Piezo-electric element.

-5.00000nm Main: 1.00 ms/div CENTER 0.00000 s REPETITIVE 5.00000 ms
-5.00000nm 1.00 ms/div 0.00000 s NORMAL (minimum) 5.00000 ms

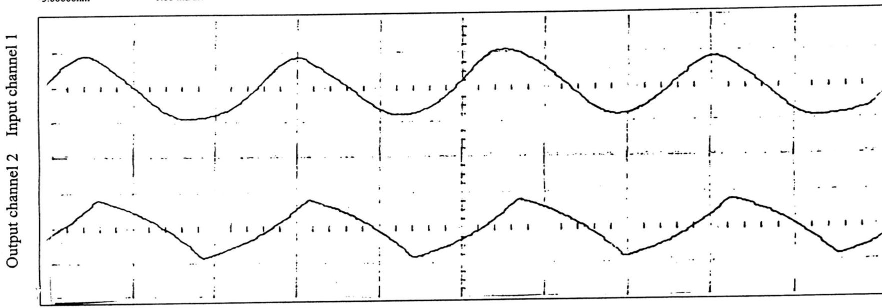


	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	2.00 V/div	3.00000 V	1: 1	dc	1M ohm
Channel 2	2.00 V/div	1.00000 mV	1: 1	dc	1M ohm

Trigger Mode: Edge
On the Positive Edge of Channel22
Trigger Level (s)
Channel12 = 1.50000 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.6 Two signals from the signal generator, after they are connected to Piezo-electric element.

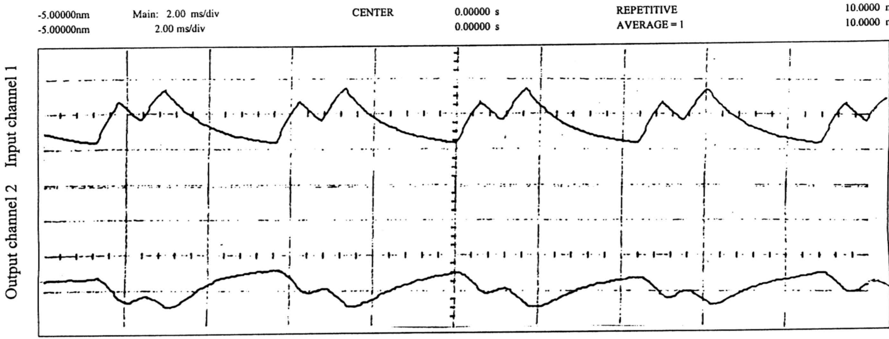
-5.00000nm	Main: 1.00 ms/div	CENTER	0.00000 s	REPETITIVE	5.00000 ms
-5.00000nm	1.00 ms/div		0.00000 s	NORMAL (minimum)	5.00000 ms



	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	2.00 V/div	5.43760 V	1:1	dc	1M ohm
Channel 2	10 mV/div	282.500 mV	1:1	dc	1M ohm

Trigger Mode: Edge
On the Positive Edge of Channel22
Trigger Level (s)
Channel12 = 5.77800 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.7 Input and Output singals when the detector is placed at the dark fringe.



	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	1.00 V/div	1.00000 V	1: 1	dc	1M ohm
Channel 2	10 mV/div	270.000 mV	1: 1	dc	1M ohm

Trigger Mode: Edge
On the Positive Edge of Channel22
Trigger Level (s)
Channel12 = 270.000 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.8 Input and Output singals when the detector is placed at the bright fringe.

A signal generator circuit designed in chapter 3, shown in Fig. 3.2. supplies the modulating signal to piezo-electric. This signal generator generates two different signals as shown in Fig. 3.3.

The actual signals taken from this generator, without connecting to a piezo-electric element , are plotted as shown in Fig. 5.5. But when these signals are connected to the Piezo-electric element the shape of the signals is changed, which is due to the large capacitance of Piezo-electric element and these graphs are shown in Fig. 5.6. These two signals are used as input signals. The output graphs, which are obtained from the experiment are shown in Fig. 5.7 and Fig. 5.8. In Fig. 5.7 the output is an exact replica of the input signal. This is the case in which the detector is placed at the dark fringe with no signal applied. If we observe closely, the output graph edges are broadened slightly and there is a time delay of less than 0.1 ms between input and output signal. This is due to the inertia of the mirror attached to the piezoelectric. In Fig. 5.8 the output signal is a mirror image of the input signal. This is because detector is placed at the bright fringe with no signal is applied. For all the other positions the graphs are shown in the Fig. 5.9 and Fig. 5.10.

In Fig. 5.9 The detector is placed half way between a bright and dark fringe. When a voltage is applied to the piezoelectric element the fringes move upward and a dark fringe goes over the detector, followed by a bright fringe and the output and input signals are shown in Fig. 5.9a and Fig. 5.9b respectively. Similarly when the detector is placed between bright and dark fringe as shown in Fig. 5.10. When the signal is applied to the to the piezoelectric element, fringes move upward and the detector experiences a bright fringe before dark fringe and its input and output signals are shown in Fig. 5.10a and Fig. 5.10b respectively.

When the mirror, which is attached to the piezoelectric element, vibrates with an amplitude larger than $\lambda/2$ (half-wavelength of lightwave used) then the output signal frequency will be a multiple of the input signal frequency. This is shown in the Fig. 5.11. If the variation in path difference is exactly one wavelength then the output signal frequency is double the input signal frequency, a graph of which is shown in Fig. 5.12. Similarly if the variation in path difference is $3\lambda/2$ then the output signal frequency will be three times of the input signal frequency. If on the other hand the amplitude variation of the mirror which is attached to the piezoelectric element creates more then $\lambda/2$ but less than λ path difference the output will look like that as shown in Fig. 5.13. Again, here the detector is placed in the center of dark fringe. If the detector is placed in the center of bright fringe then the output signal will be a mirror image of the input signal, which is as discussed before.

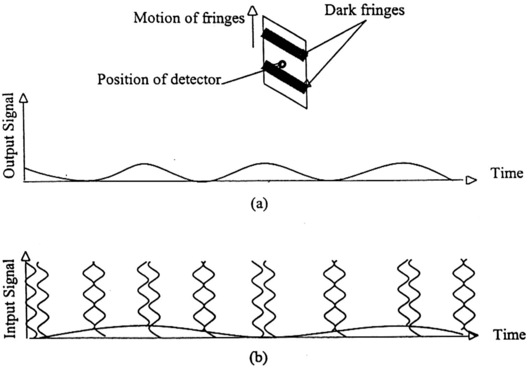


Fig. 5.9. Input output signal when detector is placed between dark and bright line, with detector closer to dark fringe.

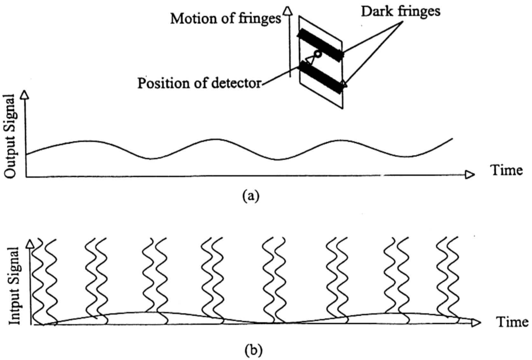
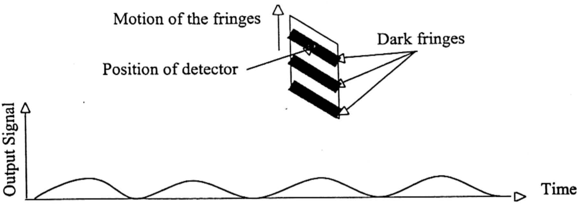
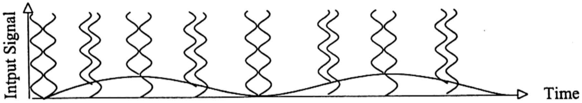


Fig. 5.10. Input output signal when detector is placed in between bright and dark with detector closer to bright fringe.



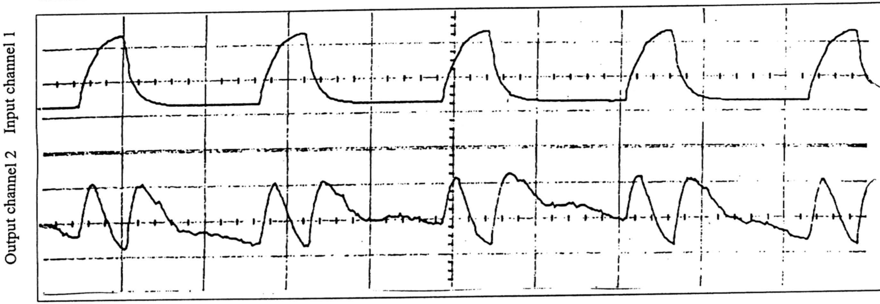
(a)



(b)

Fig. 5.11 Input and output signal when detector is placed on the dark line
(a) Output signal (b) Input signal

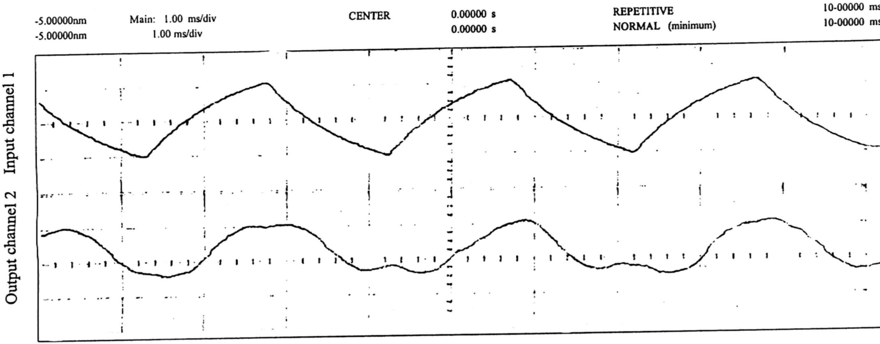
-5.00000nm	Main: 1.00 ms/div	CENTER	0.00000 s	REPETITIVE	5-00000 ms
-5.00000nm	1.00 ms/div		0.00000 s	NORMAL (minimum)	5-00000 ms



	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	2.00 V/div	1.43750 V	1: 1	dc	1M ohm
Channel 2	4.00 mV/div	298.000 mV	1: 1	dc	1M ohm

Trigger Mode: Edge
On the pPositive Edge of Channel2
Trigger Level (s)
Channel1 = 1.93750 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.12 Input and output signal when variation in the path difference is one wavelength.



	Sensitivity	Offset	Probe	Coupling	Impedance
Channel 1	2.00 mV/div	8.06250 V	1: 1	dc	1M ohm
Channel 2	10.0 mV/div	282.500 mV	1: 1	dc	1M ohm

Trigger Mode: Delay <Qualify on Edge>
On the Positive Edge of Channel l2
Trigger Level (s)
Channel1 = 8.60250 V (noise reject OFF)
Holdoff = 40.000 ns

Fig. 5.13 Input and output signal when detector is placed on the bright fringe and path difference is more than half a wavelength but less than one wavelength.