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CS23B1014
Batch 1

Optics Assignment

1. Michelson Interferometer

The Michelson interferometer is an optical instrument used to measure small displacements, wavelength differences, or changes in refractive index by employing interference patterns generated by the splitting and recombining of light waves.

Key components of a Michelson interferometer include:

1. Beam splitter.
2. Mirrors
3. Path length adjustors.

The basic principle behind the Michelson interferometer is the phenomenon of "Interference of light waves". When two coherent light waves overlap, they produce an interference pattern. This pattern results from the constructive and destructive interference of the waves, which occurs when the waves are in phase and out of phase respectively.

Working Principle

The working principle of the Michelson interferometer relies on the interference of light waves to produce an interference pattern. It works as follows:

Beam splitting: The Michelson interferometer begins with a beam splitter - a partially silvered mirror - that divides a coherent light beam into two seperate paths. One path is transmitted through the beam splitter, while the other is reflected.

2. Path difference: The two beams travel along different optical paths and are reflected by mirrors placed at the ends of these paths. As a result, the two beams accumulate a path difference, which is the disparity (or) difference in the distance travelled by each beam. This path difference can be precisely controlled by adjusting the positions of the mirrors.

3. Recombination: After reflecting off the mirrors, the two beams are recombined at the beam splitter. Here, they overlap and interfere with each other.

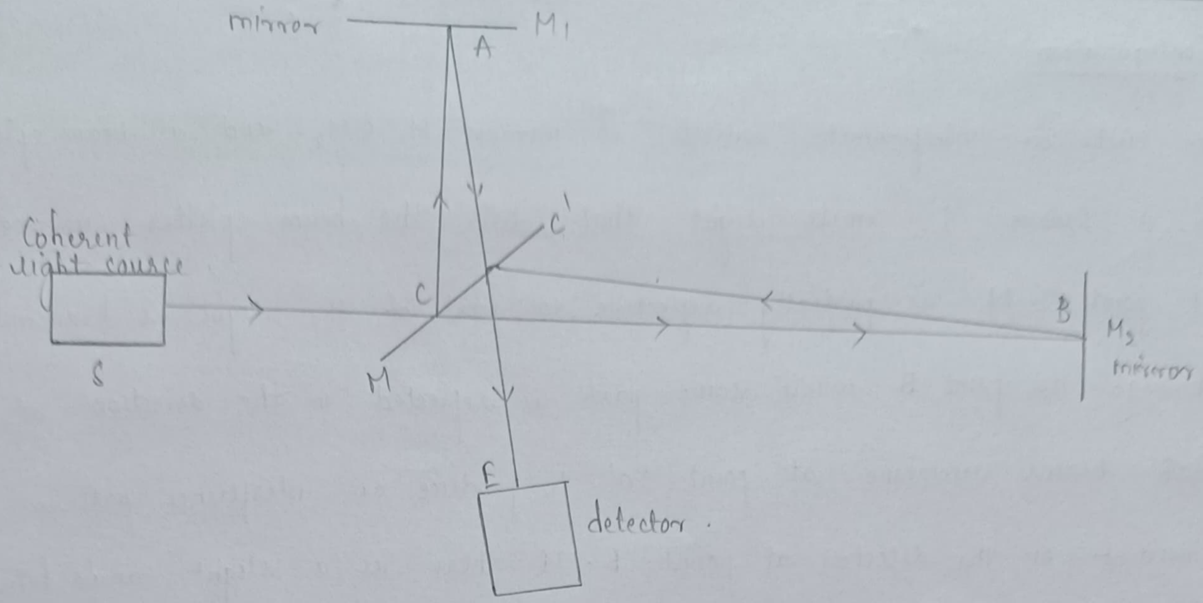
4. Interference: Depending on the path difference between the two beams, they may interfere constructively (peaks aligning with peaks and troughs aligning with troughs) or destructively (peaks aligning with troughs), leading to the formation of an interference pattern.

5. Observation: The interference pattern can be observed by directing the combined beams onto a screen or detector. This pattern consists of alternating bright and dark fringes known as interference fringes or fringes of equal inclination.

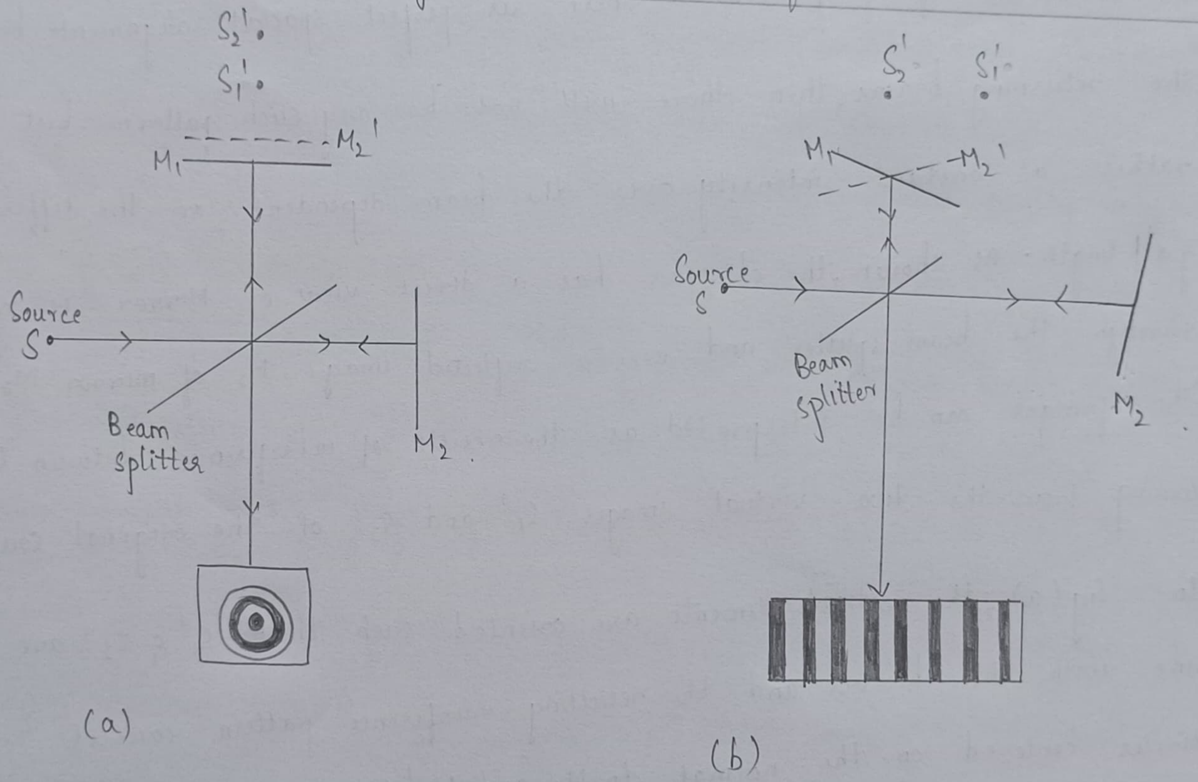
Analysis: The interference pattern provides valuable information about the relative phase difference between the two beams, which in turn relates to factors such as the path length differences, wavelength of light and refractive index of the medium. By analysing the interference pattern, one can make precise measurements of various physical quantities, such as small displacements, changes in refractive index or wavelength differences.

Configuration

A Michelson interferometer consists of mirrors M_1 & M_2 and a beam splitter M. A source 'S' emits light that hits the beam splitter surface M at point C. M is partially reflective, so part of the light is transmitted through to point B while some part is reflected in the direction of A. Both beams recombine at point 'C' to produce an interference pattern incident on the detector at point E. If there is a slight angle between the two returning beams, for instance, then an imaging detector will record a sinusoidal fringe pattern. If there is perfect spacial alignment between the returning beams, then there will not be any such pattern but rather a constant intensity over the beam dependent on the differential path length. As shown, the observer has a direct view of Mirror M_1 seen through the beam splitter and sees a reflected image M_2' of mirror M_2. The fringes can be interpreted as the result of interference between light coming from the two virtual images S_1' and S_2' of the original source S. In fig (a), the optical elements are oriented such that S_1' & S_2' are in line with the observer and the resulting interference pattern consists of circles centered on the normal to M_1 and M_2' (fringes of equal inclination). In fig (b) as M_1 and M_2' are tilted with respect to each other, the interference fringes will generally take the shape of conicsections but if M_1 and M_2' overlap, the fringes near the axis will be straight, parallel and equally spaced.



Path of light in Michelson interferometer



Formation of fringes in a Michelson interferometer

Applications of Michelson interferometer

Michelson interferometer configuration is used in a number of applications.

* Fourier transform spectrometer
* Twyman - Green interferometer
* Laser unequal path interferometer.
* Stellar measurements
* Gravitational wave detection

2. Fabry - Perot Interferometer

The fabry-perot interferometer is an optical device used to enhance and analyze the interference of light waves. In optics, a fabry-perot interferometer (or) etalon is an optical cavity made from two parallel reflecting surfaces (thin mirrors). Optical waves can pass through the optical cavity only when they are in resonance with it.

The basic principle behind the fabry-perot interferometer is the multiple-beam interference of light waves within an optical cavity formed by two parallel and highly reflective surfaces. It works as follows:

1. Optical cavity: The fabry-perot interferometer consists of two parallel and highly reflective mirrors seperated by a precise distance. This arrangement creates an optical cavity, where light can undergo multiple reflections between the mirrors.

2. Incident light: A coherent light source, such as a laser or a monochromatic light beam is directed towards the fabry-perot interferometer.

3. Multiple reflections: The incident light enters the interferometer and undergoes

reflections between the two mirrors. Each time the light reflects off a mirror, it travels back and forth between the mirrors, creating a multitude of light paths within the cavity.

4. Interference: As the light waves reflect between the mirrors, they interfere with each other. This interference results in constructive and destructive interference depending on the relative phases of the waves. Constructive interference occurs when waves are in phase and adds up to increase the intensity of light, while destructive interference occurs when the waves are out of phase and cancel each other out, leading to reduced intensity.

5. Transmitted Light: Some of the light is transmitted through one of the mirrors. The intensity of the transmitted light depends on the interference pattern created within the cavity. Constructive interference enhances certain wavelengths of light, resulting in transmission peaks, while destructive interference suppresses others, leading to transmission dips.

6. Interference pattern: The transmitted light forms an interference pattern, with peaks and troughs.

7. Spectral Analysis: By ~~changing~~ scanning the wavelength of the incident light or changing the separation between the mirrors, the fabry-perot interferometer can be used to analyze the spectral properties of the incident light. The interference pattern provides information about the wavelengths present in the light and their intensities, enabling high-resolution spectral analysis.

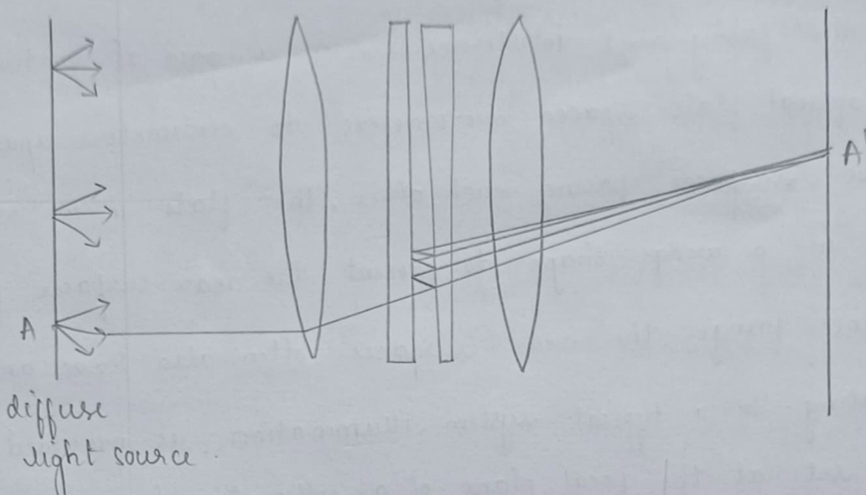
→ The fabry-perot interferometer exploits the interference of multiple light waves within an optical cavity to analyse the spectral properties of light sources and measure narrow line widths with high resolution.

Configuration and fringe pattern

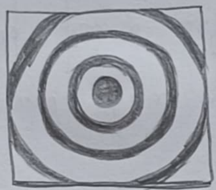
The heart of the fabry-perot interferometer is a pair of partially reflective glass optical flats spaced micrometers to centimeters apart, with the reflective surfaces facing each other. The flats in an interferometer are often made in a wedge shape to prevent the rear surface from producing interference fringes; the rear surfaces often also have an anti-reflective coating. In a typical system, illumination is provided by a diffuse source set at the focal plane of a collimating lens. A focusing lens after the pair of flats would produce an inverted image of the source if the flats were not present; all light emitted from a point on the source is focused to a single point in the systems image plane. In the figure, only one ray emitted from point A on the source is traced. As the ray passes through the paired flats, it is reflected repeatedly to produce multiple transmitted rays which are collected by the focusing lens and brought to point A' on the screen. The complete interference pattern takes the appearance of a set of concentric rings. The sharpness of the rings depends on the reflectivity of flats

Applications

They are widely used in telecommunications, lasers and spectroscopy to control and measure the wavelengths of light. It is also used in astronomy, optical instruments.



Fabry-perot interferometer



Fringepattern

3. Mach-Zehnder Interferometer

The mach-zehnder interferometer is an important optical device used in interferometry, a technique for making precise measurements by observing interference patterns. The Mach-Zehnder interferometer operates on the principle of splitting a beam of light into two paths, recombining them and observing interference patterns that result from their interaction. The interference patterns provide valuable information about the properties of light and the environment it has passed through.

Mach-Zehnder interferometer works as follows:

1. Beam splitting: the incoming light beam is split into two seperate

beams by a beam splitter. This splitter is usually a partially reflective surface or a polarizing beam splitter. One beam continues straight through (called the reference beam), while the other is deflected at an angle (called the sample beam).

2. Seperate paths: The two beams follow seperate paths, often guided by mirrors or optical fibres. The sample beam might pass through a sample or undergo some other manipulation that changes its properties.

3. Phase shift (optional): One of the paths may contain an element, such as a phase shifter, that introduces a phase difference between the two beams. This phase shift can be used to control the interference pattern.

4. Recombination: After travelling their respective paths, the two beams are recombined using another beam splitter. This second beam splitter typically recombines the beams so that they overlap spatially.

5. Interference: When the two beams overlap, they interfere with each other. If the beams have traveled different distances (or) have a relative phase difference due to the sample, they will be out of phase when they recombine, leading to interference. This interference can be ~~(contructi)~~ constructive or destructive depending on the path length and phase relationship of the beams.

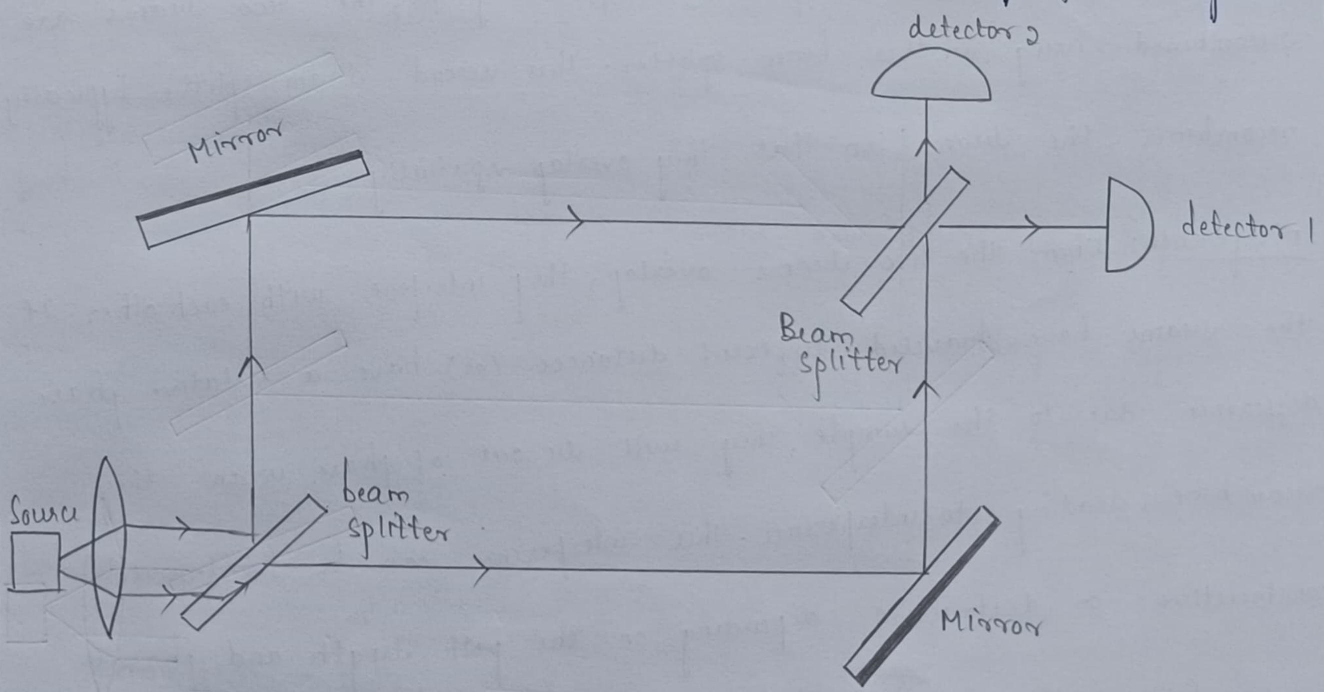
Detection: The interference pattern can be observed using a detector, such as a photodiode or a camera. The detector measures variations in light intensity caused by constructive and destructive interference. By analysing this pattern, information about the phase difference between the two beams, or about changes induced in one of the beams can be obtained.

Applications

1. Interferometry: Mach-Zehnder interferometers are widely used for making precise measurements, such as length measurements, displacement measurements and refractive index measurements.

2. Quantum optics: In quantum optics, Mach-Zehnder interferometers are used to study the behaviour of photons and to perform quantum information processing tasks.

3. Telecommunications: Mach-Zehnder interferometers are used in optical communication systems for tasks such as modulating and demodulating optical signals.



4. Sagnac Interferometer

The sagnac interferometer is a type of interferometer used to measure rotation or angular velocity. It's based on the sagnac effect, which describes the phase shift that occurs between two beams of light travelling in opposite directions around a closed loop.

Sagnac Interferometer works as follows:

1. **Beam splitting**: A coherent light source, such as a laser, emits light that is directed towards a beam splitter. The beam splitter divides the light into two seperate beams, typically with equal intensity.

2. **Loop configuration**: The two beams travel along seperate paths around a closed loop. This loop can be constructed using mirrors arranged in a ring configuration or through optical fibers forming a coil. Importantly, the light beams travel in opposite directions around the loop.

3. **Sagnac effect**: As the two beams travel around the loop in opposite directions, they experience different travel times due to the rotation of the loop. This difference in travel time results in a phase shift between the two beams. According to the sagnac effect, the phase shift is proportional to the angular velocity (or) rotation rate of the loop.

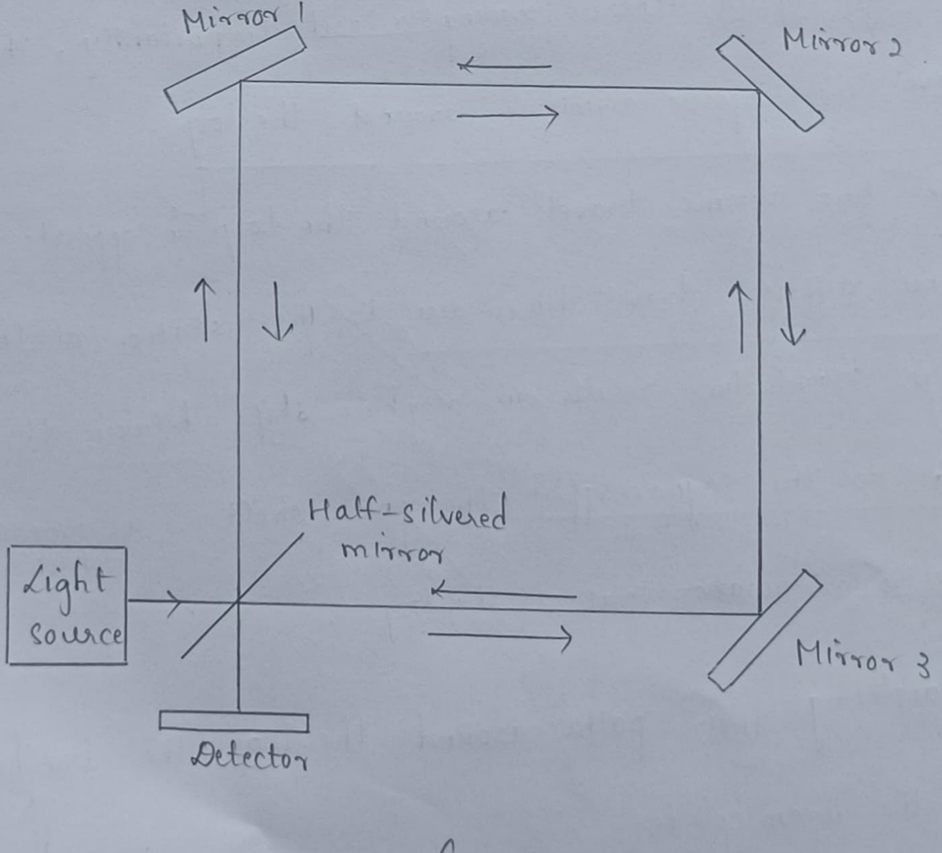
4. **Recombination**: After completing their paths around the loop, the two beams are recombined at the beam splitter.

5. Interference: when the two beams are recombined, they interfere with each other. The interference pattern is affected by the phase difference between the beams, which in turn is influenced by the rotation rate or angular velocity of the loop.

6. Detection: Detectors measure the interference pattern produced by the recombined beams. Changes in the interference pattern can be analyzed to determine rotation rate of the loop.

Applications

The sagnac interferometer finds its applications in various fields. It is used mainly in gyroscopes, Geodesy and Geophysics. It is also used in Inertial Navigation Systems (INS), rotation sensors, optical fibre communications, Interferometric measurements etc.



Sagnac effect.