WEL04 HOLOGRAPHY & MICHELSON'S INTERFEROMETER

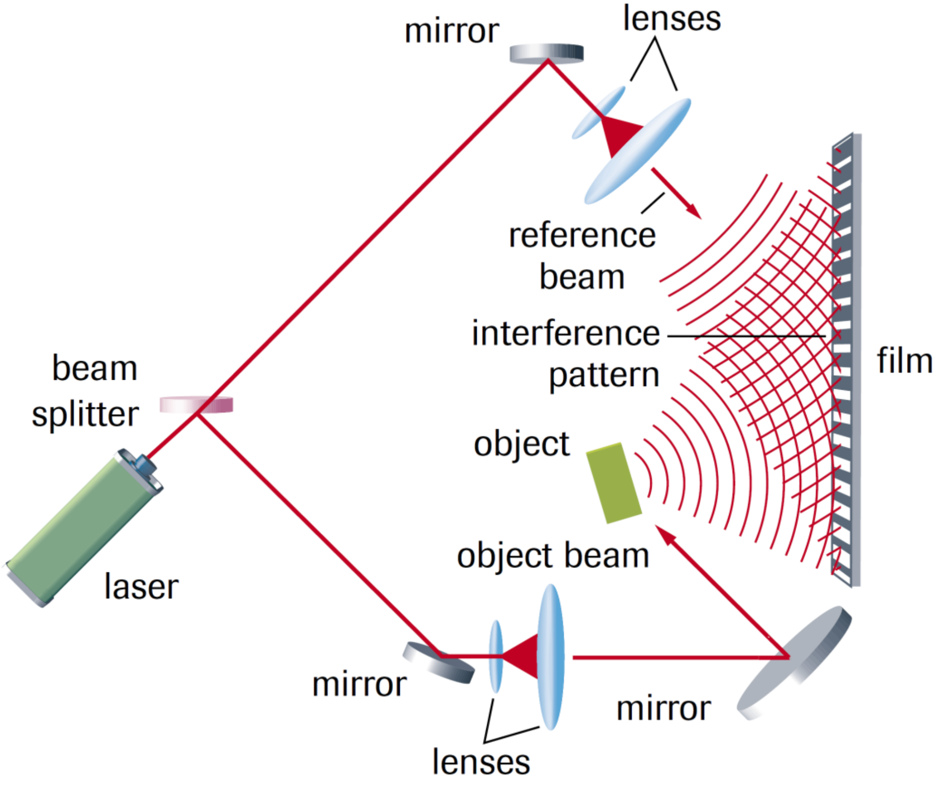
SPH4U

CH 10 (KEY IDEAS)

- describe polarized light in terms of its properties and behaviour and how it is applied in everyday applications
- explain single-slit diffraction and diffraction grating interference patterns, both qualitatively and quantitatively
- explain the operation of the spectroscope and the interferometer in terms of the wave properties of light
- describe how the wave properties of light are important in resolution of optical instruments and how these properties are applied in various applications of thin-film interference, for example: Newton’s rings, colours in thin films, coated surfaces, CDs, and DVDs
- explain the basic concepts holography
- describe electromagnetic waves in terms of their properties and where they belong in the electromagnetic spectrum

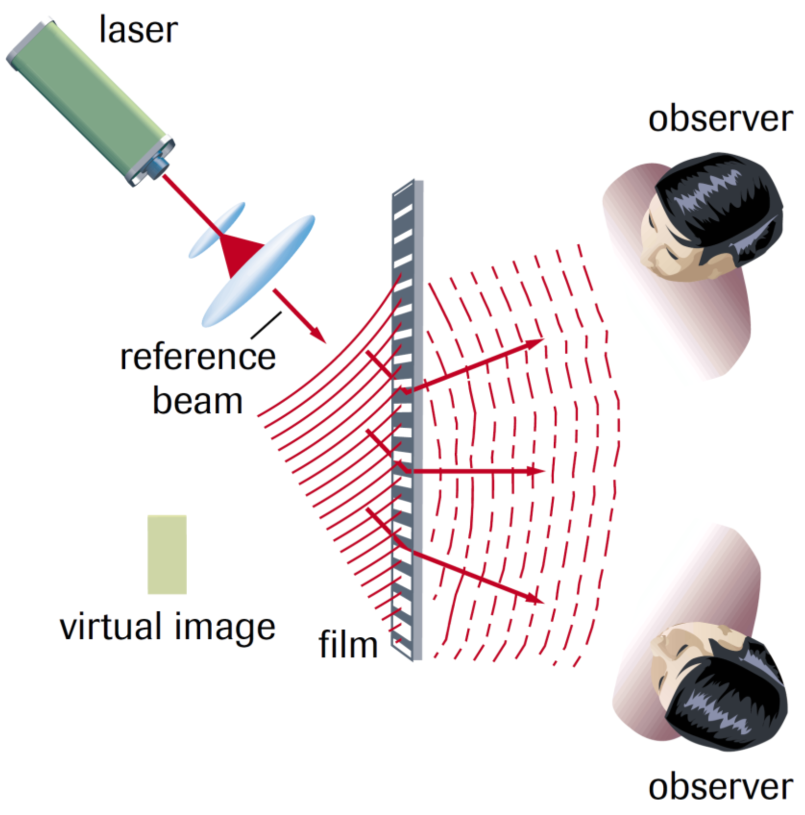
HOLOGRAPHY

- **Hologram:** the three-dimensional image formed as a result of interference of (transmitted or reflected) coherent light
- Monochromatic light from a laser is used to create interference patterns in a film
  - One beam is reflected off the object and onto the film
  - The other beam is shone directly onto the film, causing interference patterns with the reflect beam



HOLOGRAPHY – CONT.

- These patterns act as gratings, partially reflecting and partially transmitting the light
- This causes a single light source to be split, allowing observers to see multiple light rays and a 3D virtual image
- Holography video: https://youtu.be/yVzk7bbQOA8?t=245
  - Watch from 4:05 to 9:40

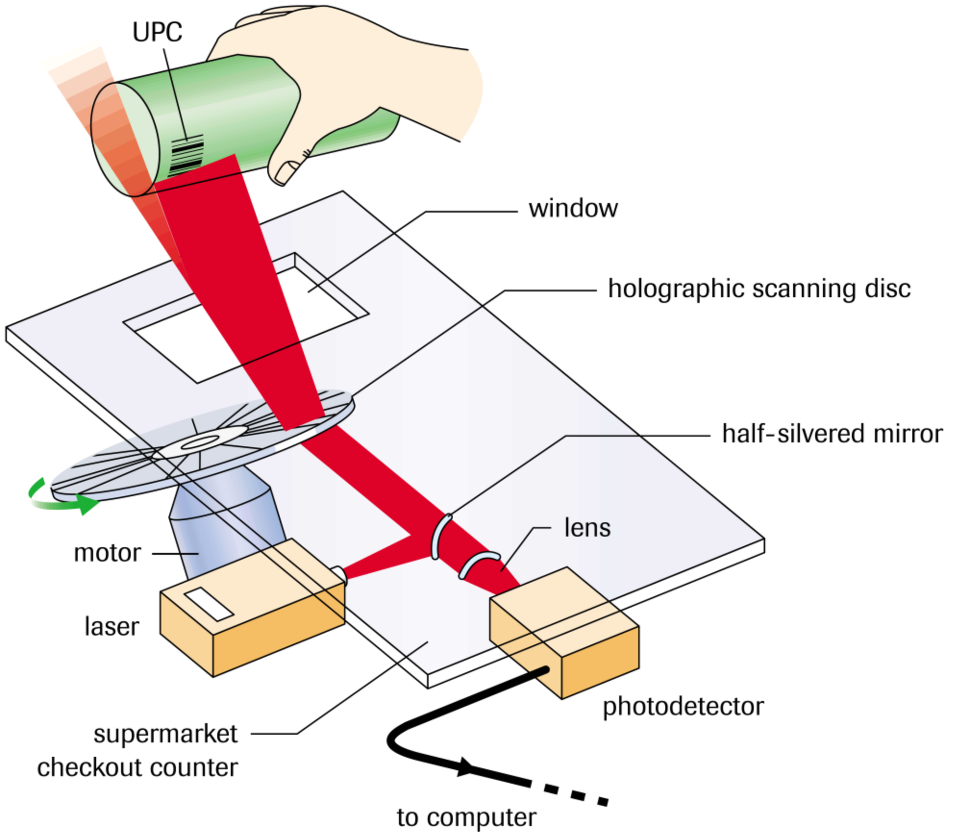


HOLOGRAPHY APPLICATIONS

- Holograms (the interference patterns of reflecting light) have many uses in everyday life
- 3D ultrasound images of organs and internal structures can be seen on a monitor
- Holographic images on credit cards and printed money are added as a security measure to discourage counterfeiting
- UPC, or barcode, scanners also use this technique

HOLOGRAPHY APPLICATIONS: THE BARCODE SCANNER

- Low-powered laser light is directed through a spinning set of holograms
- Each pie-shaped hologram send the light in a different direction
- This causes the light to sweep in multiple directions
- Once a beam sweeps the UPC, the light is reflected back to the photodetector
  - Light signals are converted into computer electrical signals, and are read by the software to identify the product
- Note: there is always light reflected back, but most patterns will not register with the software and will be ignored

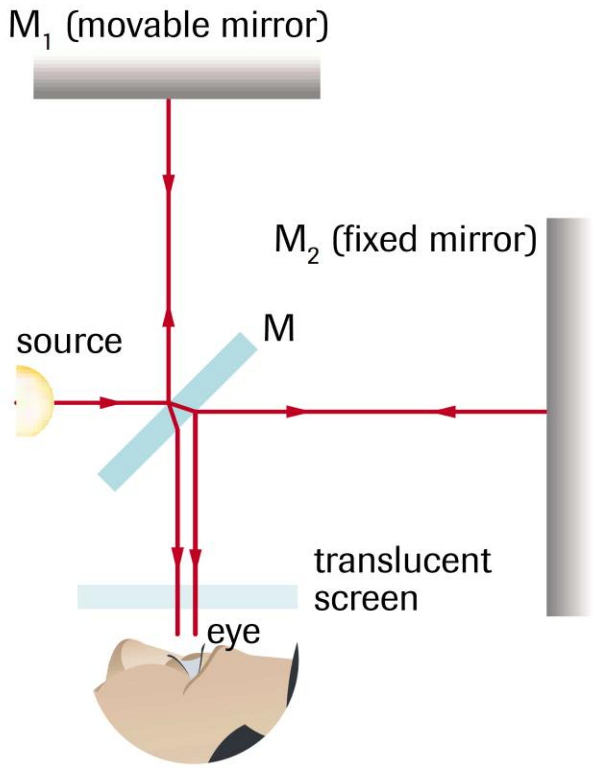


WHAT ABOUT HOLOGRAPHIC PEOPLE?

- How do we see 3D holograms on a stage or in a performance?
- These are not really holograms! They are cleverly placed projections that are reflected off a screen to appear to be on stage
- Here is a quick video demonstrating this phenomenon: https://youtu.be/pSICZ_7hpho
  - You only need to watch the first half to get the idea

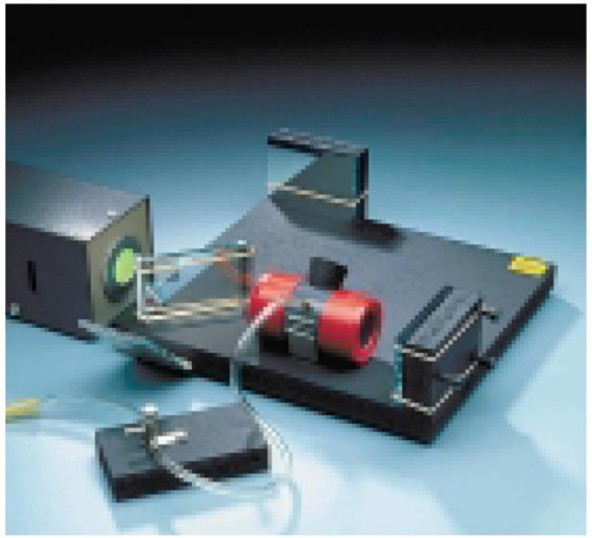
MICHAELSON'S INTERFEROMETER

- **Interferometer:** a device used to measure small distances
- A single beam of monochromatic light is sent through a half-silvered mirror
  - This partially reflects the light, with the transmitted light being split in two directions
- The reflected light is sent to a movable mirror (M_1)
- One beam of split light is sent to a fixed mirror (M_2), with the other going directly to the observer



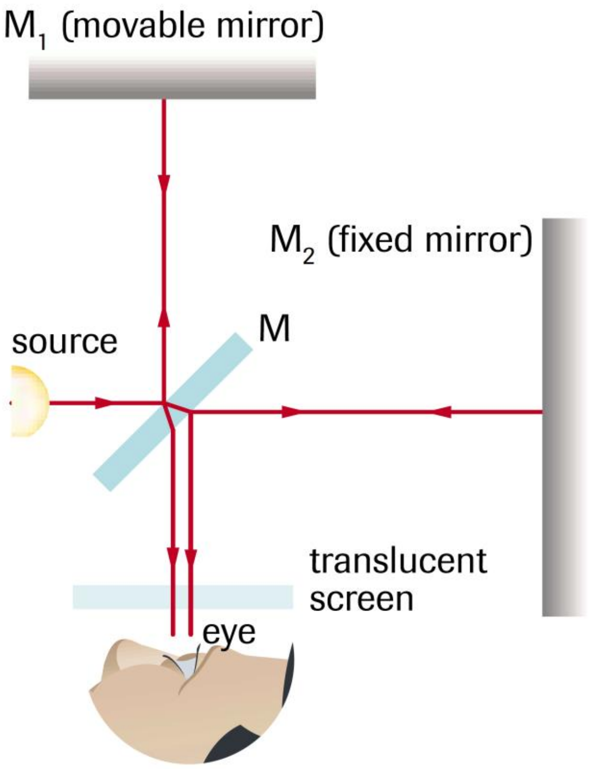
MICHAELSON'S INTERFEROMETER – CONT.

- If the path lengths are the same, constructive interference is seen by the observer
- Moving M_1 by $\frac{\lambda}{4}$ will cause a half wavelength path difference and result in destructive interference
- Tilting one of the mirrors will create a fringe pattern
  - the path differences will change depending on where they reflect off the mirrors



MICHAELSON'S INTERFEROMETER – CONT.

- As M_1 moves through a distance of $\frac{\lambda}{2}$, an interference fringe will change from dark to light and back to dark (or vice versa)
  - This is a shifting of a fringe by one position
- Counting the number of fringes that shift through a position will allow us to calculate how far the mirror was moved
  - Every shift indicates a displacement of $\frac{\lambda}{2}$



PROBLEM 1

You visit an optical engineering house in which an interferometer is illuminated by a monochromatic source of wavelength 6.4×10^{-7} m. You slowly and carefully move the movable mirror. You find that 100 bright fringes move past the reference point. How far did you move the mirror?

PROBLEM 1 – SOLUTIONS

$\lambda = 6.4 \times 10^{-7}$ m

100 fringes $= 50\lambda$

The path difference is 50λ, or $(50)(6.4 \times 10^{-7}\text{ m}) = 3.2 \times 10^{-5}$ m.

The mirror has moved half this distance, or 1.6×10^{-5} m.

USING THE INTERFEROMETER

- Michaelson used the interferometer for the following notable uses:
  - The standard meter was refined using the wavelength of the orange-red line spectrum of krypton-86
  - The speed of light was measured in various media, which helped define the refractive index and its relation to the speed of light
  - Helped discover that the speed of light is constant in a vacuum and independent of the motion of its observer (important in Einstein’s Theory of Special Relativity)

SUMMARY – HOLOGRAPHY

- Holography is the process of storing all of the light radiated from an object and then reproducing it.
- Holography is used for three-dimensional viewing, security, scanning, and quality control.

SUMMARY – MICHELSON'S INTERFEROMETER

- Interferometers can measure distances as small as a wavelength of light, using interference fringes.
- Interferometers have been used to define the standard metre and to measure the speed of light in various media. Interferometers were used historically to verify that the speed of light is a constant.

PRACTICE

Readings

- Section 10.6 (pg 525)
- Section 10.7 (pg 528)

Questions

- pg 527 #1-3
- pg 529 #1-5