LU5: LAB 1-5B2: Interference & Diffraction: Pinhole

REFERENCES:

- *Fundamentals of Light & Lasers* (OPTEC), 2nd edition
- Mod 5, Laboratory 1-5B.2, pages 50-51.
- http://optecvideo.opteccrm.org, Video 18: Read these instructions and watch the videos before doing the lab.
  - Course 1: Fundamentals of Light and Lasers
  - Lab Activity Video
  - Choose Video #

THEORY:

Light transmitted through pinhole will produce a diffraction pattern with a bright center disc (Airy disc) with circular rings around the central disc. The Airy disc radius and the size of the pinhole are mathematically related.

OBJECTIVE:

Use a pinhole to produce a diffraction pattern.
Determine the diameter of the pinhole from the diffraction pattern.
To do a comprehensive and precise Lab Write-up.
Take appropriate pictures (5 or more) to show/prove lab work.

EQUATIONS:

$d = (1.22\lambda D)/R$

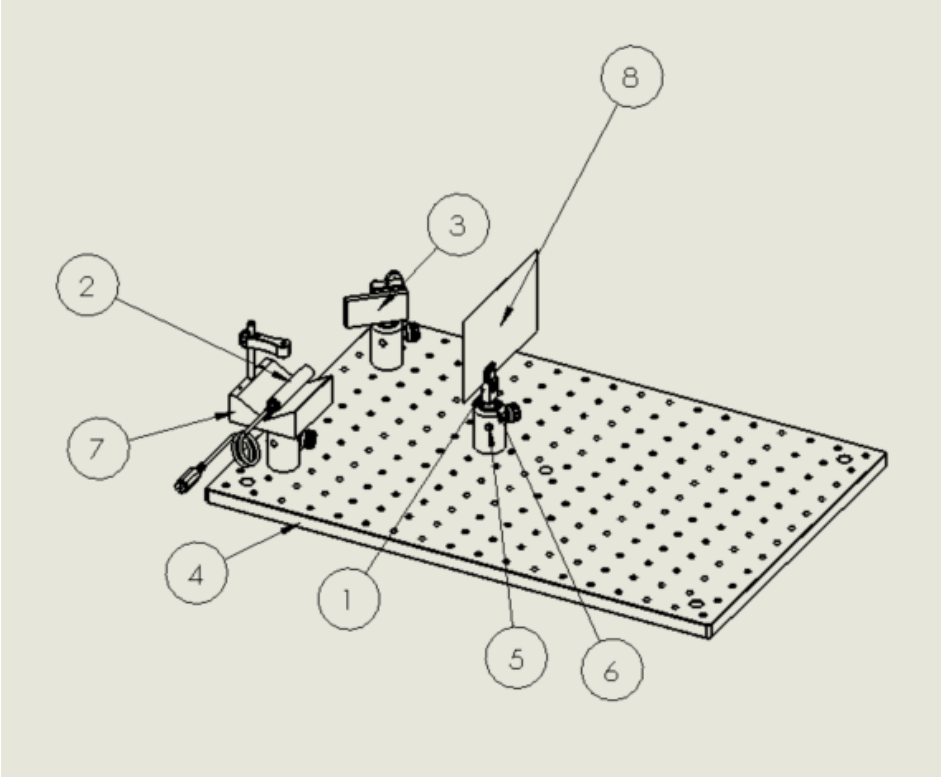
d = diameter of the pinhole
D = distance from pinhole to screen
R = radius of Airy Disc
λ = wavelength of incident light

$Z' > 100$ (area of aperture opening/λ) or $(\pi d^2/4) / \lambda$

Z' = minimum screen distance for **Fraunhofer diffraction**
area of aperture opening = $\pi d^2/4$
(d = diameter of the pinhole)
λ = wavelength of incident light

EQUIPMENT:

List and diagram may be *different*
Fixed Lens Mount (key 1)
Pinhole, Mounted 50 µm (key 8)
No index card
Laser Diode Module (key 2)
Laser Diode Power Supply
Mirror (key 3)
Optical Breadboard (key 4)
(3) Post Holder (key 5)
(3) Post (key 6)
V-Clamp (key 7)
Misc. Hardware

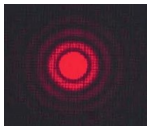


SET-UP: Read the entire SET-UP and PROCEDURE before starting the lab.

1. Mount post holders near each corner of one end of the breadboard.
2. Mount a post in the center hole on the bottom of the V-camp and insert the assembly in one of the post holders.
3. Mount a post on the long edge of a mirror assembly. Insert the assembly in the other post holder.
4. Mount the pinhole into the fixed lens mount. Secure to a post and insert into a post holder.
    a. Do not mount the post holder.
5. Place a screen assembly opposite the mirror along the length of the board.
6. Mount the laser diode so that the beam will be projected along the width of the board to the mirror.

PROCEDURE: Read this complete procedure before following it.

1. The mirror will be used to adjust the laser beam so that it is centered on the 50µm mounted pinhole.
2. A diffraction pattern on the screen will be used to calculate the diameter of the pinhole.
3. Turn on the laser and adjust the mirror so that the beam is retroreflected back to the laser output aperture.
4. Rotate the mirror/post assembly so that the beam is reflected at 90° down the length of the board toward the screen and tighten the thumb screw on the post holder.
    a. Must maintain vertical height throughout beam path.
5. Position the pinhole into the center of the reflected laser beam as close to the mirror as possible.
6. Position the screen to be able to see the Airy Disk pattern. This may be at the end of the optical plate.



7. **Take a picture of final lab set-up and include in Lab Write-Up**.
8. **Measure (3 times) and record** the metric distance (D) from the pinhole to the screen.
9. Use the mirror adjustments to obtain the brightest diffraction pattern on the screen.
    a. Optical alignment is very important when doing this.
    b. The environment may need to be dark to very dark.

NOTE: If you are unable to see the Airy disk, set up the short focal length convex lens between the mirror and pinhole. Focus the now much higher irradiance laser beam into the center of the pinhole. This may take several attempts. Position an index card as close and behind the pinhole so that you may see the beam coming through. You should then see the Airy disk and be able to complete the lab.

10. The Airy Disc is the central bright spot of the diffraction pattern. Place marks on the screen at the midpoint of the dark band just outside the Airy disc. **Take a picture of Airy Disc pattern and include in Lab Write-Up.**
11. Remove the paper with the marks, **measure and record** the diameter of the Airy disc, 2R.

2R = _____mm = _____m R = _____mm = _____m

CALCULATIONS:

1. Use **$d = (1.22\lambda D)/R$** to **calculate & record** the diameter of the pinhole. Use the wavelength of the laser for λ. Use D from Procedure Step 8 and R from Procedure Step 11.
    a. d = _____m = _____µm
2. **Calculate and record**: Use **$Z' > 100(\text{area of aperture opening}/\lambda)$** to determine if the screen is an adequate distance from the pinhole (or at least close) for Fraunhofer diffraction. Use d from the step above to calculate the area **($\text{area} = \pi(d^2/4)$)** and the wavelength of the laser for λ. The screen distance, D, was measured in Procedure Step 8.
    a. D = _____m Z' = _____m
3. **Analyze, compare and explain** the differences between D and Z' in the Lab Write-Up.

DISCUSSION:

- The Airy disc is name after British astronomer and mathematician, Sir George Airy.
- The resolution of optics is limited by the diffraction seen in the Airy disc. The resolution of a microscope can be optimized by using a shorter wavelength (ultraviolet) to view the object. An electron microscope uses a beam of electrons which behave like waves. The effective wavelength is around 4×10^{-3}nm. The short effective wavelength allows very small objects to be observed.