Optics

Wave Optics
Diffraction & Interference

Ripple Tank

Diffraction is a characteristic of wave dynamics
Diffraction

“Airy Disk” Diffraction Pattern

Interference

“George Biddell Airy” Airy Disk
Constructive interference

Destructive interference

Thomas Young (1773 - 1829)
Pattern produced from a single slit.

Pattern produced from a double slit.

Interference

Single Photon Sources

1 2

Images of interference patterns.
The lens is a light gathering instrument that collects a cone of light emanating from the object.
Basic optics: simple thin lens

\[ \frac{1}{O} + \frac{1}{I} = \frac{1}{f} \]

Image Formation

Image Magnification

\[ \text{mag} = -\frac{I}{O} \]
Spherical Aberration

non-paraxial rays do not meet at the paraxial focus

Spherical Aberration can be reduced by introducing additional carefully designed lenses into the optical path.

Each lens element scatters light and costs photons -- resulting in loss of image contrast.

Spherical Aberration of a Point Source

"Negative"  "Zero"  "Positive"

Chromatic Aberrations is due to wavelength dependence of refractive index of transparent media

Can be reduced by coating lens elements to selectively correct refraction of various wavelengths
lenses corrected for achromatic aberration

uncorrected  achromatic  semi-apochromatic  apochromatic

Objective lenses

Single Lens Imaging System
Anatomy of a Compound Microscope

- base
- lamp housing
- stage
- condenser
- turret
- objective
- eye piece
- trinocular tube
- stand

Nomenclature

- Robert Hooke (1635 - 1703)
  - Built one of the first useful compound microscopes
  - Observed structure of cork
  - Coined the term “Cell”.
  - Published Micrographia (1665)
1665  Hooke publishes Micrographia
1678  van Leeuwenhoek observes protozoa ("little animals")
1838-9  Schleiden & Schwann proposed "Cell Theory"
1860  Pasteur confirms Cell Theory
1871-9  Schleiden & Schwann proposed "Cell Theory"
1860  Pasteur confirms Cell Theory
1931  Ruska invents electron microscope
1932  Zerniki develops phase contrast microscopy
1955  Minsky invents the laser scanning microscope (LSM)
1989  Webb, Denk & Strickler invent multiphoton LSM
**Objective Lens**

- Optical Correction
- Magnification
- Objective Working Parameters
- Coverslip Thickness Gauge

![Figure 1](Image)

**Upright Microscope**

- Specimen
  - Must be "transparent" to visible light
  - Usually either single cells, or ...
  - A thin section of tissue
  - Usually "stained" to reveal structures of interest

- Figure

![Unright Microscope](Image)
Image is NOT Everything

The image is the product of the interaction of incident light with the object.

Light must INTERACT with the object.

Light interacts with objects through wave-like and particle-like properties.

Magnification vs Resolution

- Low Mag
- More Mag
- High Mag
- Whoa Baby!

Diffraction pattern of a saw blade
Diffraction through a grating

Effect of Oil
Wavelength dependence

Airy Disk Patterns

Light Microscopy

Fig. 9A

Fig. 17

Fig. 19
Limit of resolution (D)

\[ D = \frac{(0.61) \lambda}{n \sin (\alpha)} \]

\( \lambda \) = wavelength of light  
\( n \) = refractive index  
\( \alpha \) = angular aperture

Numerical Aperture = N.A.

N.A. \( \sim \) 0.3 - 1.65

\( (0.61) \) \( (450 \text{ nm}) \)
\( (1.5) \sin (70^\circ) \)

\( \geq 200 \text{ nm} \)
\( \leq 0.2 \mu\text{m} \)