

Microscopes

■ Numerical Aperture (NA)

The NA figure is important because it indicates the resolving power of an objective lens. The larger the NA value the finer the detail that can be seen. A lens with a larger NA also collects more light and will normally provide a brighter image with a narrower depth of focus than one with a smaller NA value.

$$NA = n \cdot \sin\theta$$

The formula above shows that NA depends on n, the refractive index of the medium that exists between the front of an objective and the specimen (for air, n=1.0), and angle θ , which is the half-angle of the maximum cone of light that can enter the lens.

■ Resolving Power (R)

The minimum detectable distance between two image points, representing the limit of resolution. Resolving power (R) is determined by numerical aperture (NA) and wavelength (λ) of the illumination.

$$R = \lambda / 2 \cdot NA \text{ (}\mu\text{m)}$$

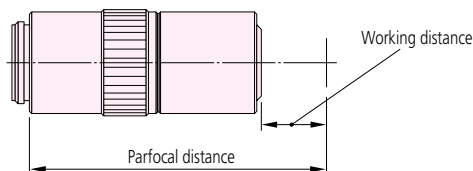
$\lambda = 0.55\mu\text{m}$ is often used as the reference wavelength

■ Working Distance (W.D.)

The distance between the front end of a microscope objective and the surface of the workpiece at which the sharpest focusing is obtained.

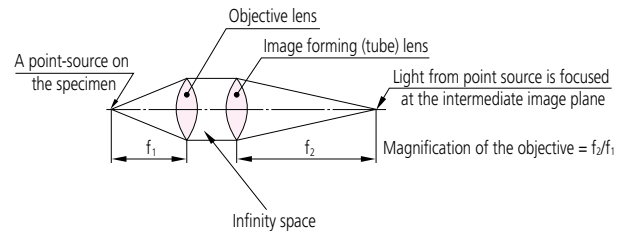
■ Parfocal Distance

The distance between the mounting position of a microscope objective and the surface of the workpiece at which the sharpest focusing is obtained. Objective lenses mounted together in the same turret should have the same parfocal distance so that when another objective is brought into use the amount of refocussing needed is minimal.



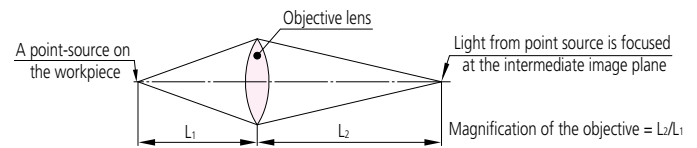
■ Infinity Optical System

An optical system where the objective forms its image at infinity and a tube lens is placed within the body tube between the objective and the eyepiece to produce the intermediate image. After passing through the objective the light effectively travels parallel to the optical axis to the tube lens through what is termed the 'infinity space' within which auxiliary components can be placed, such as differential interference contrast (DIC) prisms, polarizers, etc., with minimal effect on focus and aberration corrections.



■ Finite Optical System

An optical system that uses an objective to form the intermediate image at a finite position. Light from the workpiece passing through the objective is directed toward the intermediate image plane (located at the front focal plane of the eyepiece) and converges in that plane.



■ Focal Length (f)

unit: mm

The distance from the principal point to the focal point of a lens: if f_1 represents the focal length of an objective and f_2 represents the focal length of an image forming (tube) lens then magnification is determined by the ratio between the two. (In the case of the infinity-correction optical system.)

$$\text{Objective magnification} = \text{Focal length of the image-forming (tube) lens} / \text{Focal length of the objective}$$

Examples: $1X = 200/200$
 $10X = 200/20$

■ Real Field of View

unit: mm

- (1) Diameter of surface observed through eyepiece
 Real field of view = Eyepiece field number / Objective magnification
 Example: Real field of view of 10X lens ($\phi 2.4$ eyepiece) = $2.4/10 = 0.24$
- (2) Diameter of surface observed on video monitor
 Real field of view = Size (length x width) of CCD camera pickup device / Objective magnification
 *Size (length x width) of 1/2-inch CCD camera pickup device = 4.8×6.4
 Example: Real field of view of 1X lens (length x width) = 4.8×6.4
 Real field of view of 10X lens (length x width) = 0.48×0.64

■ Focal Point

Light rays from an object traveling parallel to the optical axis of a converging lens system and passing through that system will converge (or focus) to a point on the axis known as the rear focal point, or image focal point.

■ Depth of Focus (DOF)

unit: μm

Also known as 'depth of field', this is the distance (measured in the direction of the optical axis) between the two planes which define the limits of acceptable image sharpness when the microscope is focused on an object. As the numerical aperture (NA) increases, the depth of focus becomes shallower, as shown by the expression below:

$$\text{DOF} = \frac{\lambda}{2 \cdot (\text{NA})^2} \quad \lambda = 0.55\mu\text{m} \text{ is often used as the reference wavelength}$$

Example: For an M Plan Apo 100X lens (NA = 0.7), and light wavelength of $0.55\mu\text{m}$, the depth of focus of this objective is $0.55 / (2 \times 0.7^2) = 0.6\mu\text{m}$.

■ Bright-field Illumination and Dark-field Illumination

In brightfield illumination a full cone of light is focused by the objective on the specimen surface. This is the normal mode of viewing with an optical microscope. With darkfield illumination, the inner area of the light cone is blocked so that the surface is only illuminated by light from an oblique angle. Darkfield illumination is good for detecting surface scratches and contamination.

■ Apochromat Objective and Achromat Objective

An apochromat objective is a lens corrected for chromatic aberration (color blur) in three colors (red, blue, yellow).

An achromat objective is a lens corrected for chromatic aberration in two colors (red, blue).

■ Magnification

The ratio of the size of a magnified object image created by an optical system to that of the object. Magnification commonly refers to lateral magnification although it can mean lateral, vertical, or angular magnification.

■ Principal Ray

A ray considered to be emitted from an object point off the optical axis and passing through the center of an aperture diaphragm in a lens system.

■ Aperture Diaphragm

An adjustable circular aperture which controls the amount of light passing through a lens system. It is also referred to as an aperture stop and its size affects image brightness and depth of focus.

■ Field Stop

A stop which controls the field of view in an optical instrument.

■ Telecentric System

An optical system where the light rays are parallel to the optical axis in object and/or image space. This means that magnification is nearly constant over a range of working distances, therefore almost eliminating perspective error.

■ Erect Image

An image in which the orientations of left, right, top, bottom and moving directions are the same as those of a workpiece on the workstage.

■ Field Number

The field of view size (diameter) of an eyepiece, expressed in millimeters.

■ Precautions in Using a Microscope for YAG Laser Machining

Laser machining with a microscope is used on thin films such as semiconductors and liquid crystals, but high-power laser radiation cannot be transmitted through a normal objective lens. Therefore, if using a YAG laser, limit the laser power output as follows:

YAG laser wavelength	Irradiation energy density (output)	Pulse width	Applicable objective
1064nm	0.2J/cm ²	10ns	M Plan NIR
532nm	0.1J/cm ²	10ns	M Plan NUV
355nm	0.05J/cm ²	10ns	
266nm	0.04J/cm ²	10ns	M Plan UV

* If the pulse width of a laser becomes shorter, the irradiation energy density is reduced by the root of the ratio of the pulse widths.

Example: If the pulse width decreases to 1/4, the energy density is reduced to approximately 1/2.

Note: When intending to use a laser with a microscope, contact the nearest Mitutoyo Sales Center beforehand to prevent unexpected damage to equipment and materials.