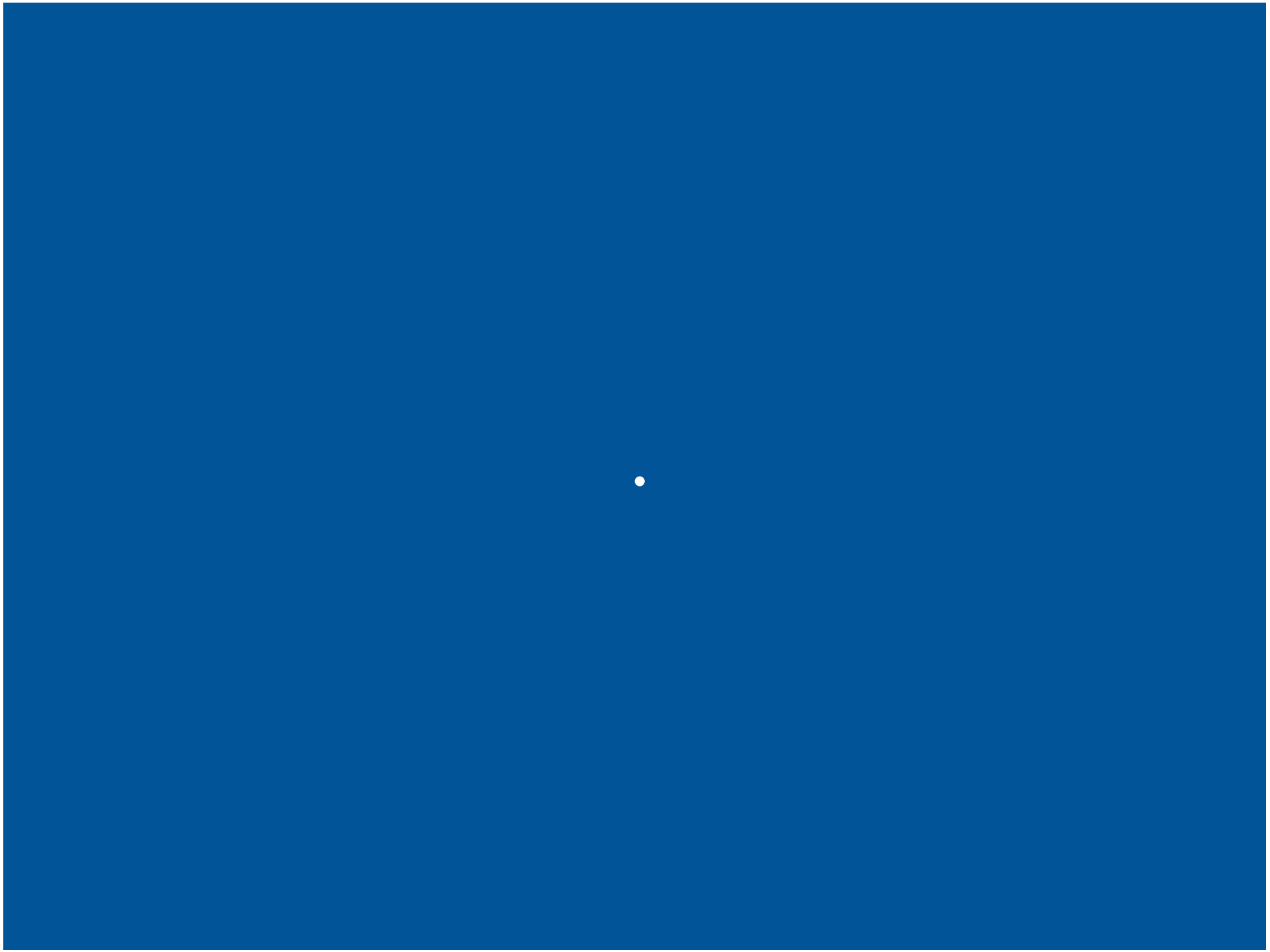
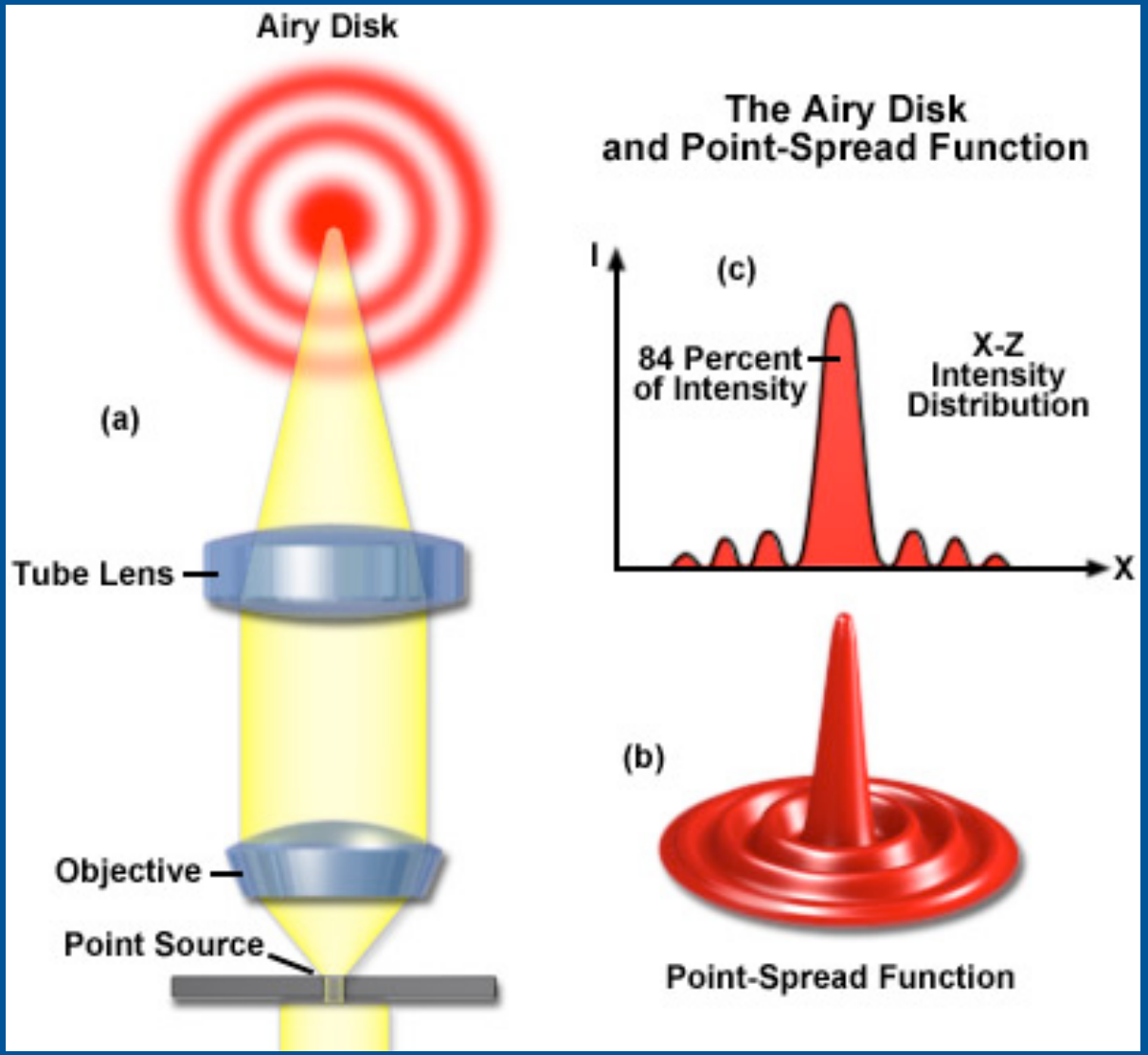
Resolution

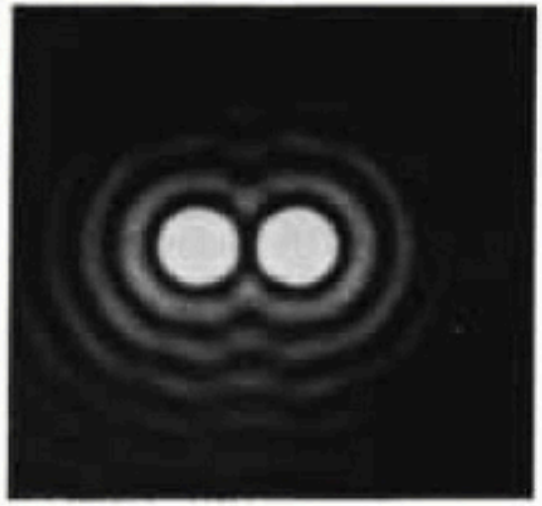
The primary purpose of a microscope is not to magnify, but to RESOLVE.

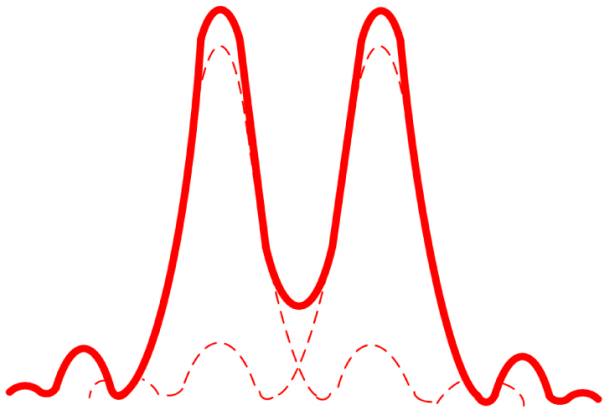


The image of a point is not a point



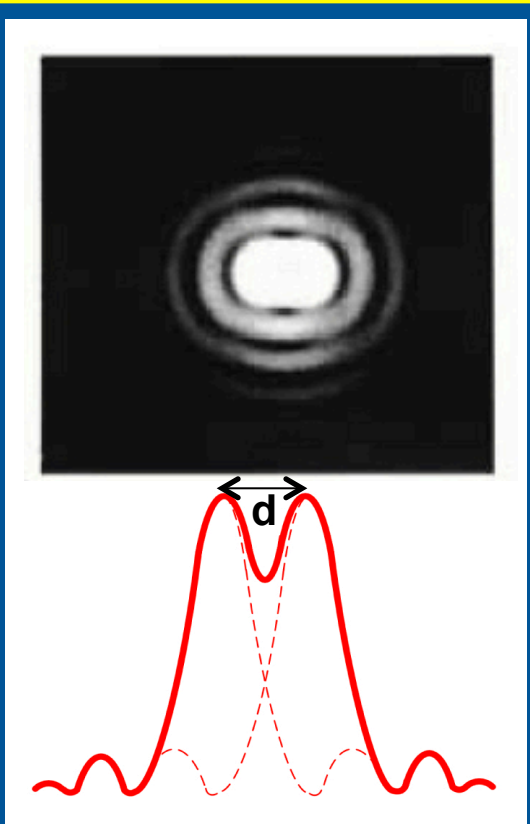
Resolution is limited because the image of a point is an Airy disk





Minimum resolved distance was derived by Ernst Abbe

$$d = \lambda / 2 \times NA$$

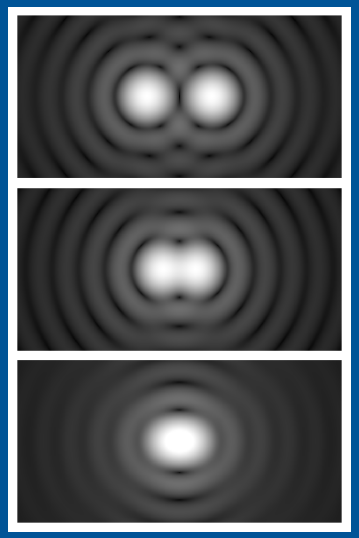


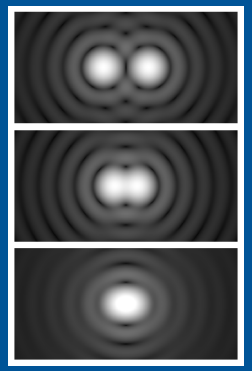
d	Minimum resolved distance
λ	Wavelength of imaging radiation
NA	Numerical Aperture

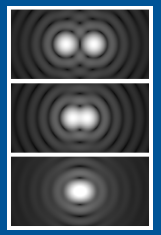
Numerical Aperture (NA) determines Airy disk size

NA increasing

Numerical Aperture (NA) determines Airy disk size and resolution

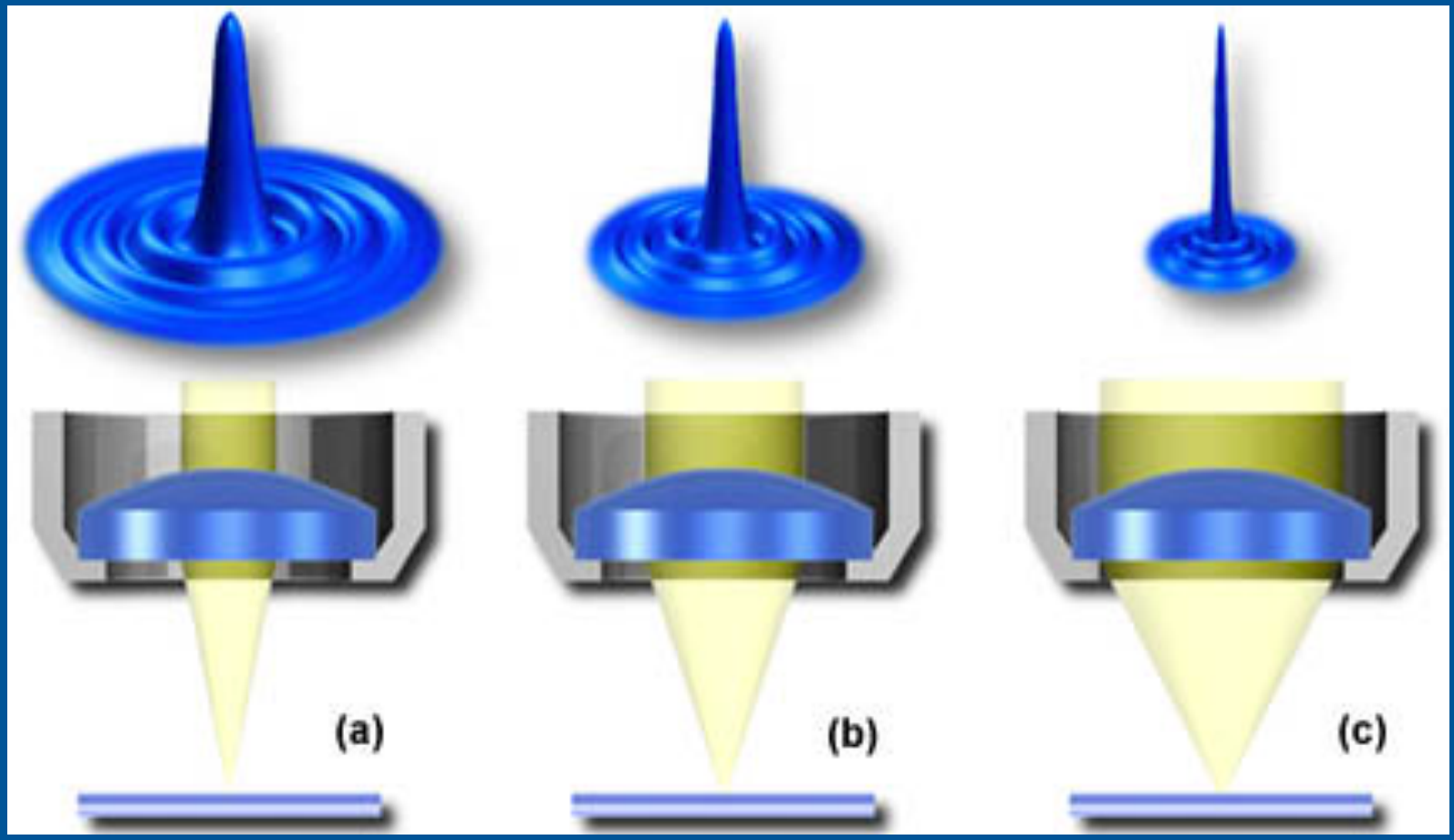






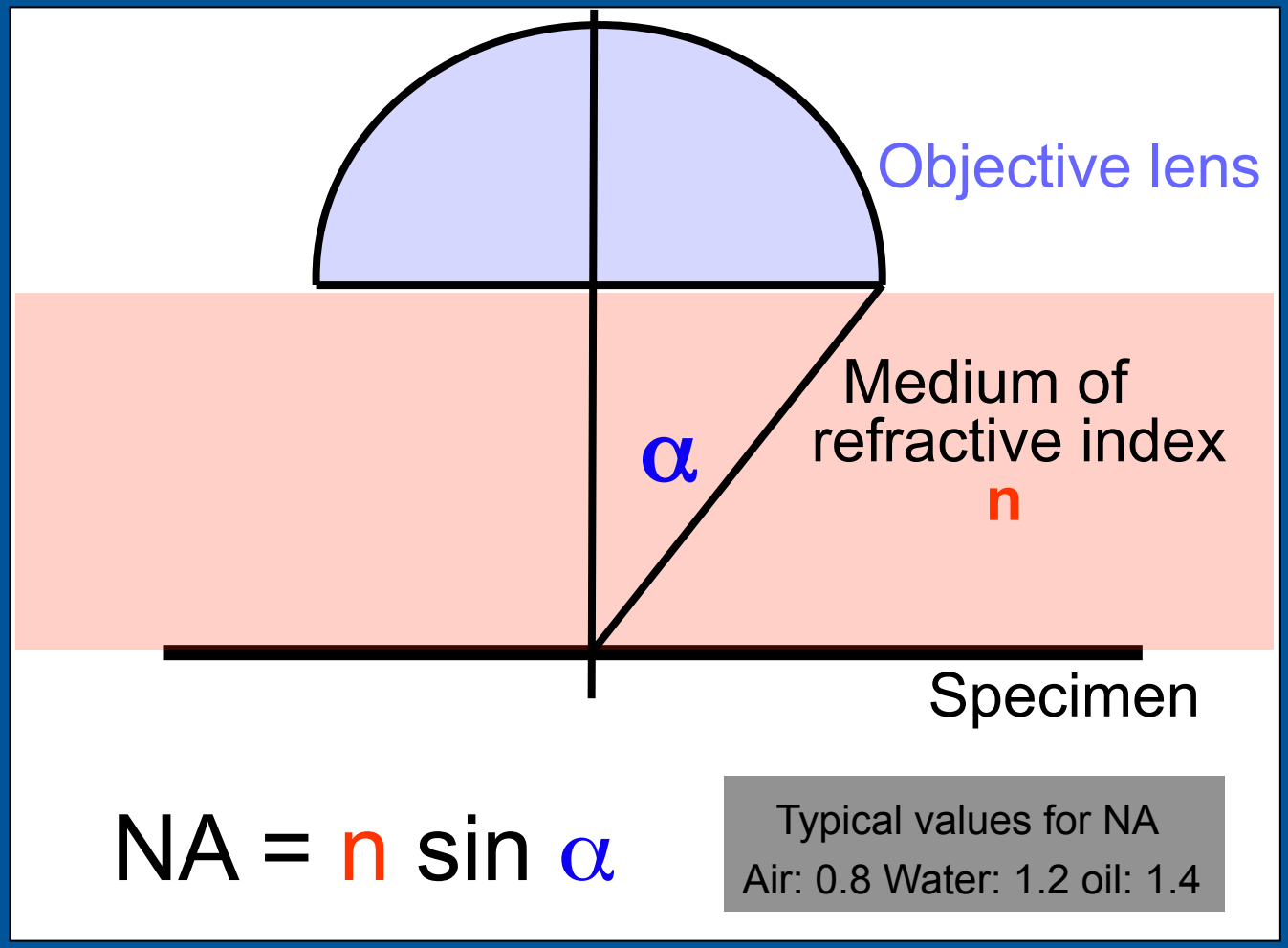
NA increasing

Numerical Aperture (NA) determines Airy disk size and light acceptance cone



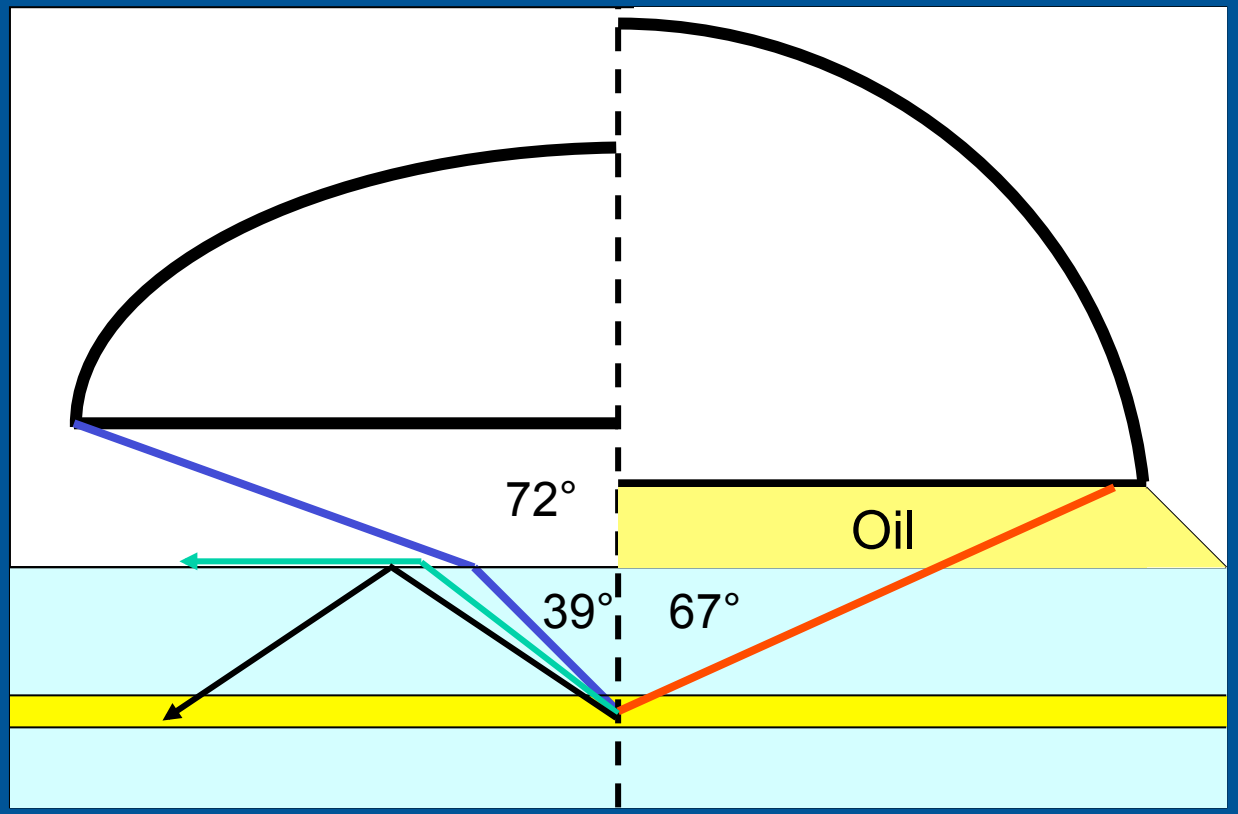
NA increasing

Numerical Aperture is a key parameter of an objective lens



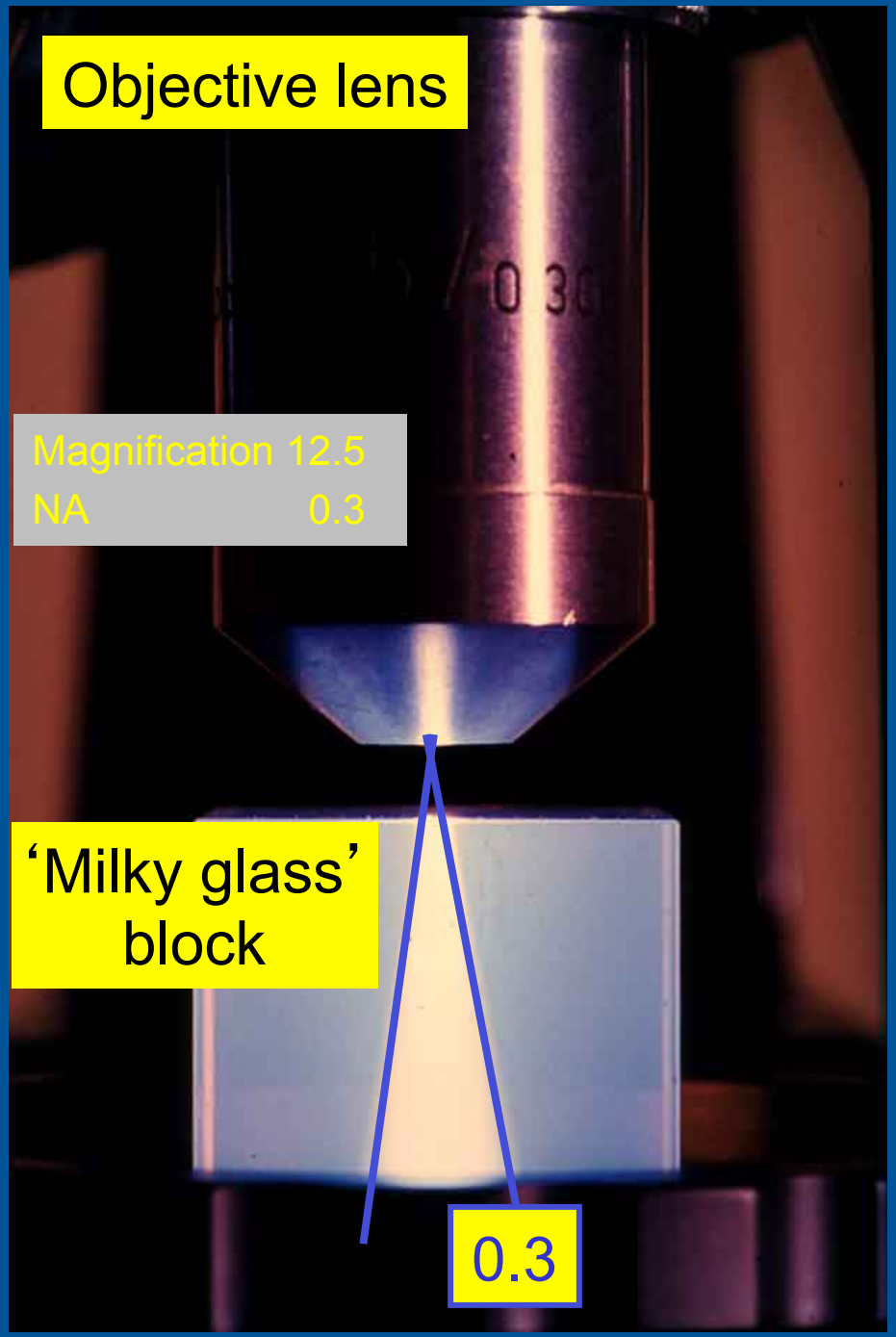
Dry Objective

Immersion Objective



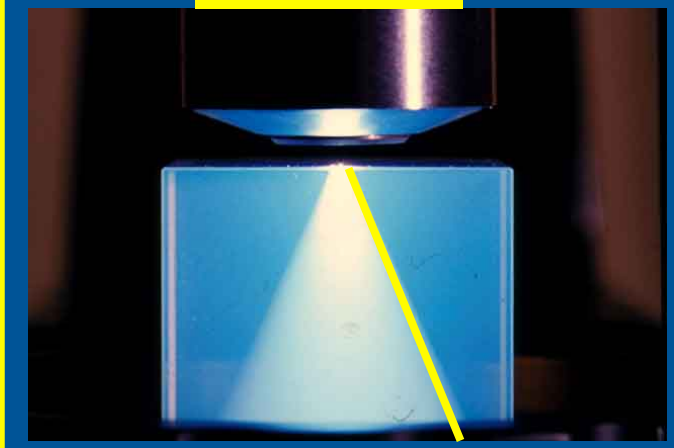
NA = 1 x sin 72°
= 1 x 0.95
= 0.95

NA = 1.515 x sin 67°
= 1.515 x 0.92
= 1.4

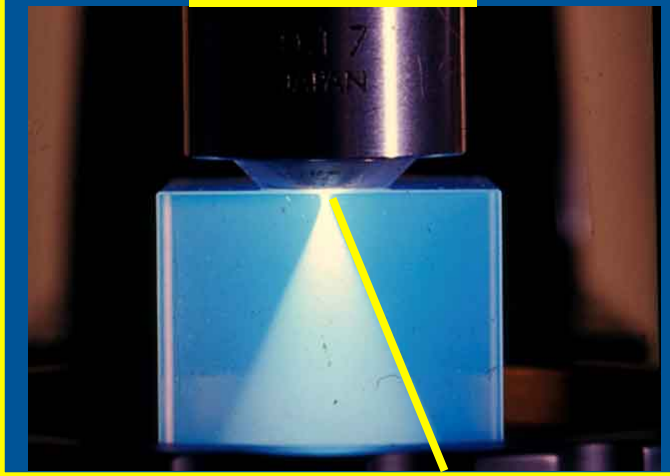

Objective lens
Magnification 12.5
NA 0.3
‘Milky glass’ block
0.3

Same aperture
different magnifications

25 / 0.65



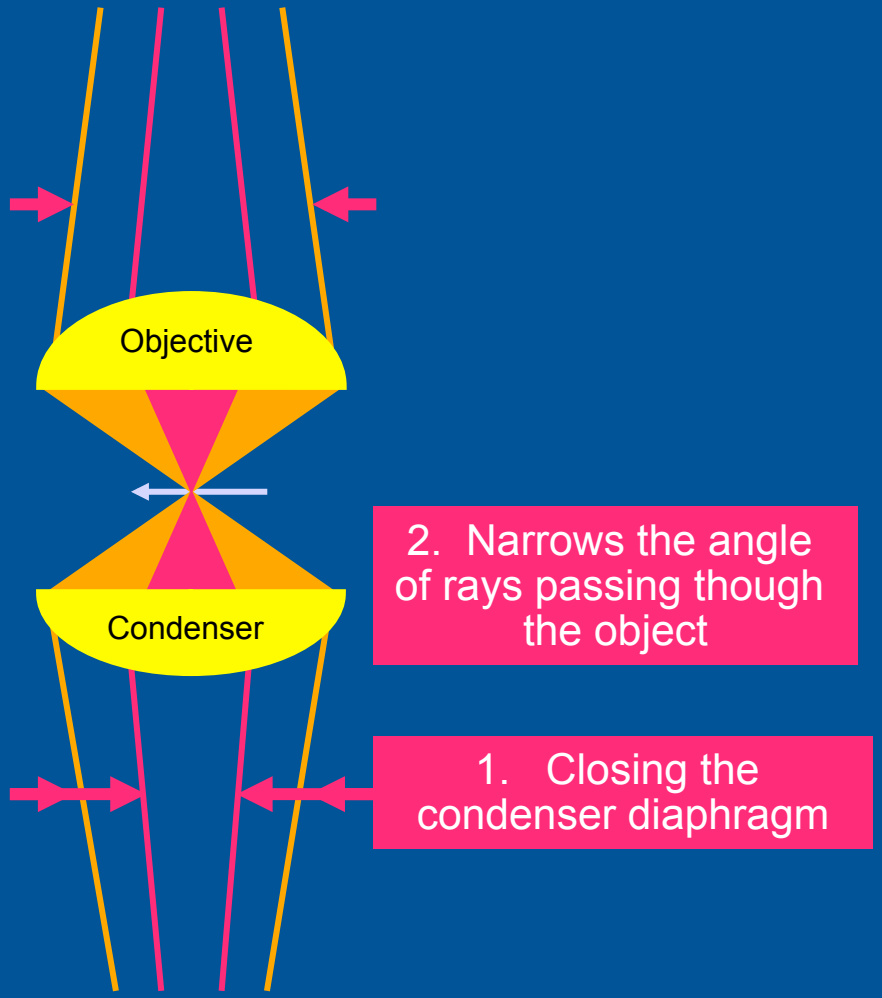
40 / 0.65



40 / 0.95

Same magnification
different apertures

NA of objective lens and condenser determine the NA of the complete system



Numerical Aperture is important in various ways

- Resolution depends on NA
  ($d = \lambda / 2 \times NA$, e.g. 200nm = 560nm / 2 x 1.4)
- Light transmission of objective depends on NA^2
- Depth of field of objective is (approximately) inversely proportional to NA^2

Minimum resolved distance was derived by Ernst Abbe

$$d = \lambda / 2 \times NA$$

Backup

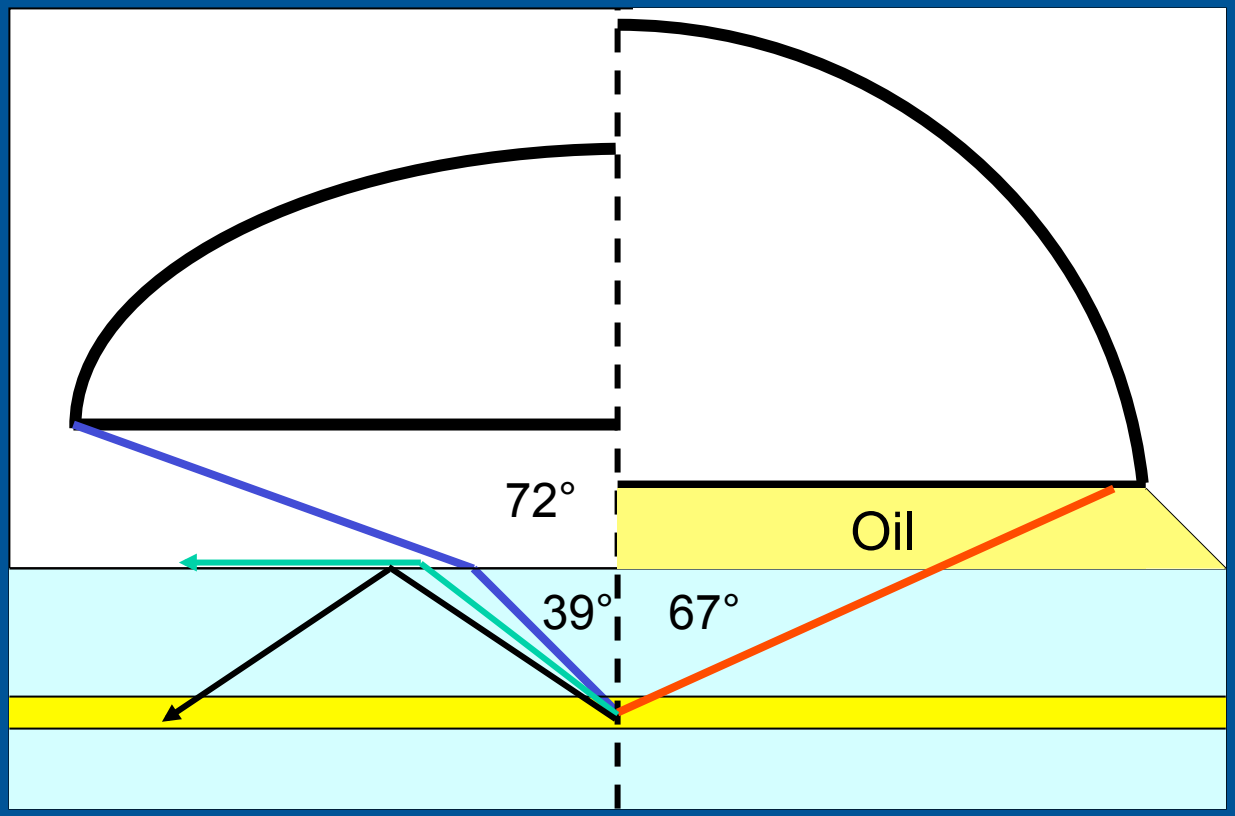
Numerical Aperture

Dry Objective

NA = 1 x sin 72°
= 1 x 0.95
= 0.95

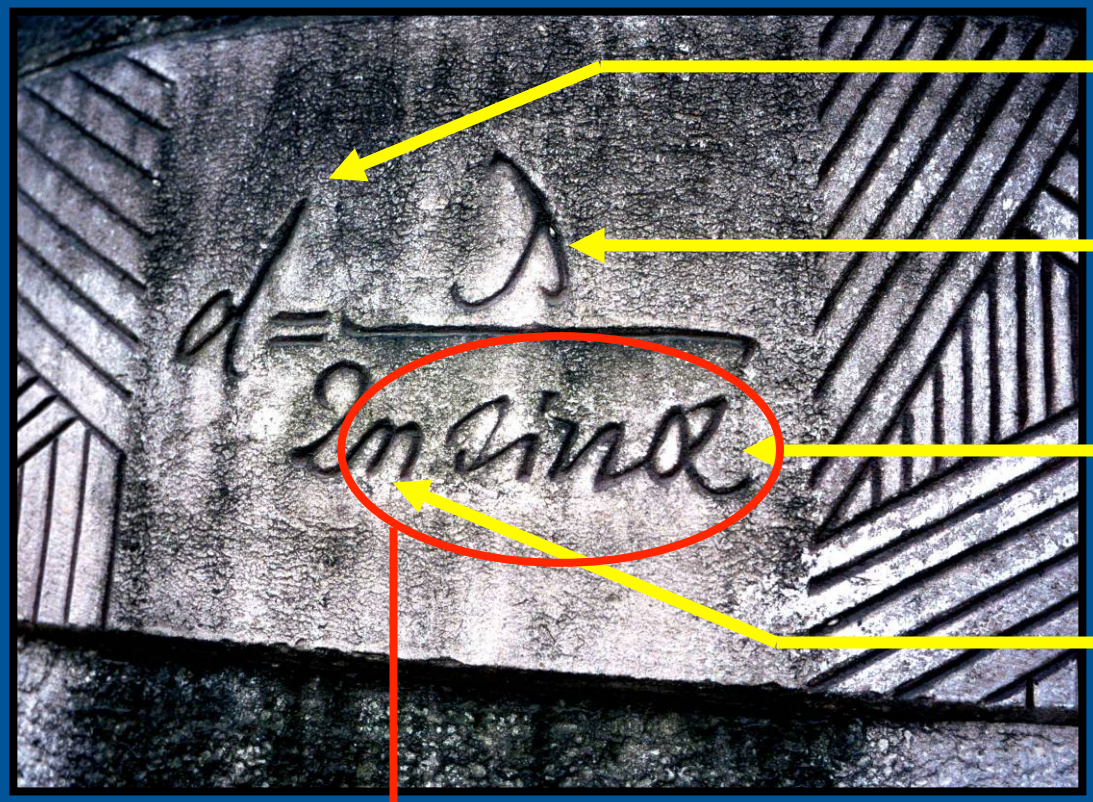
Immersion Objective

NA = 1.515 x sin 67°
= 1.515 x 0.92
= 1.4



Why is Numerical Aperture Important?

Inscription on Ernst Abbe's memorial



d — Minimum resolved distance

λ — Wavelength of imaging radiation

α — Half-aperture angle

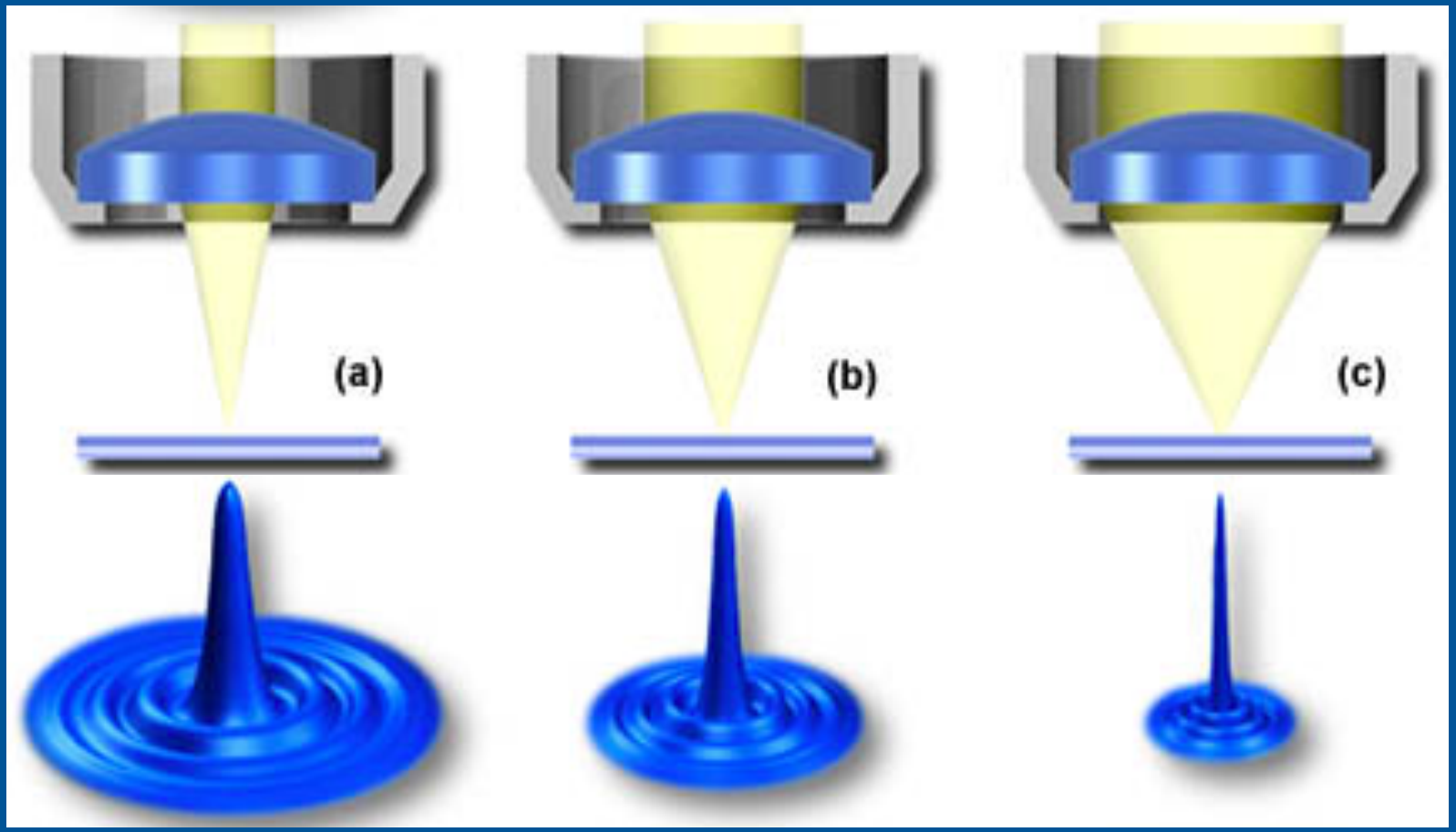
n — Refractive index of medium

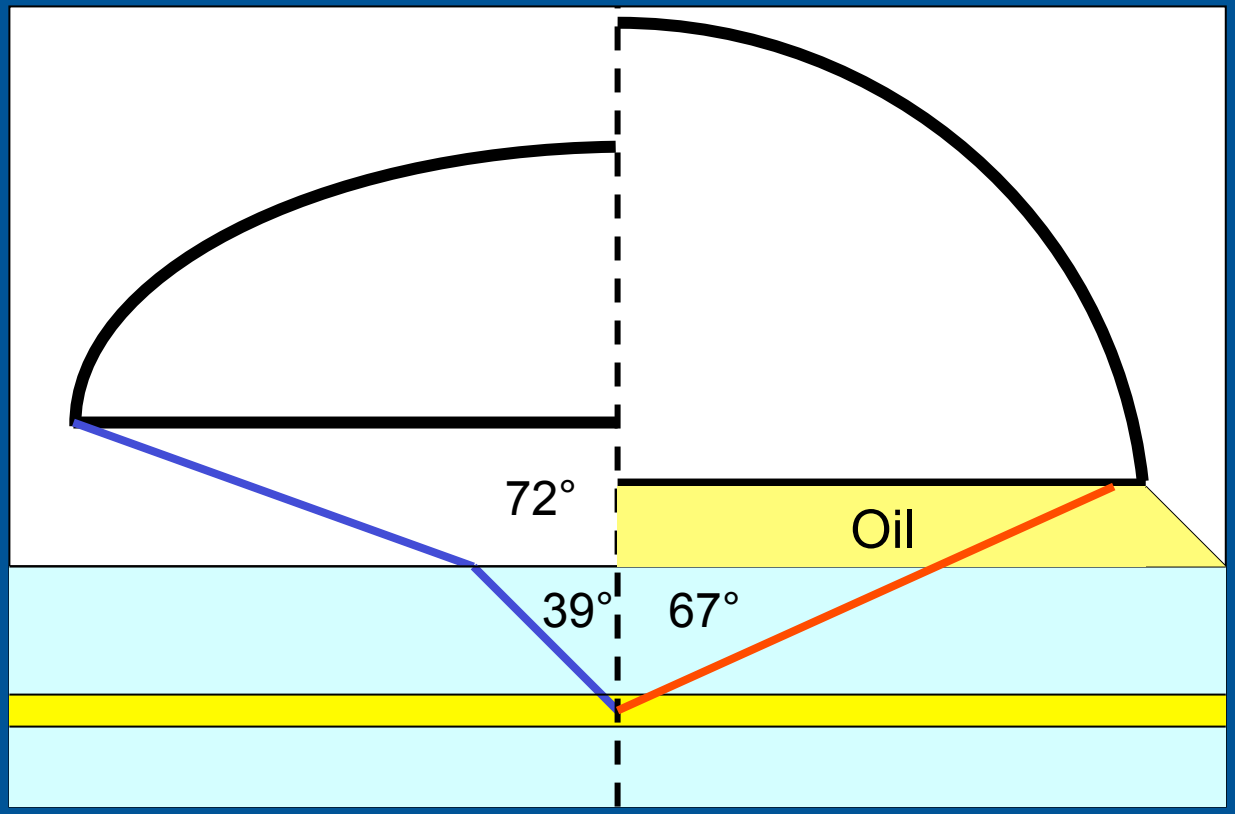
Numerical Aperture

Minimum resolved distance is now commonly expressed as

$d = \lambda / 2 \times NA$

Numerical Aperture determines Airy disk size



Numerical Aperture

Dry Objective	Immersion Objective
NA = 1 x sin 72°	NA = 1.515 x sin 67°
= 1 x 0.95	= 1.515 x 0.92
= 0.95	= 1.4