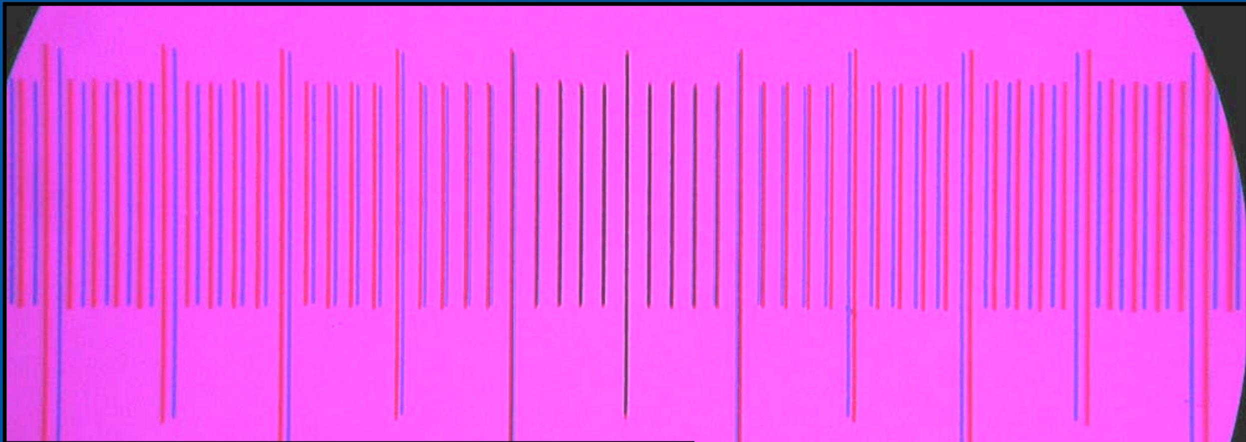
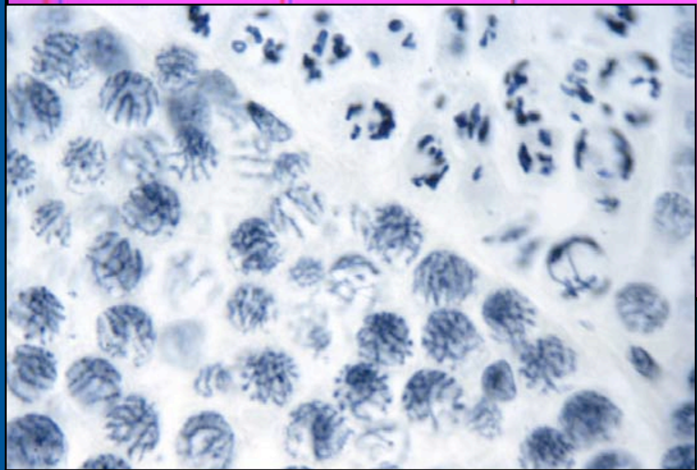
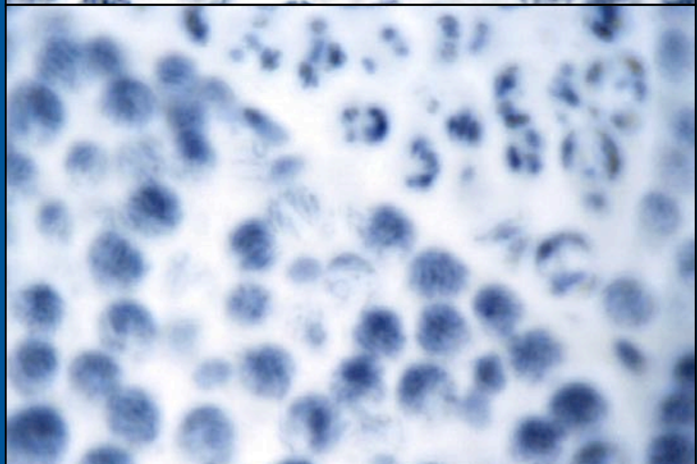
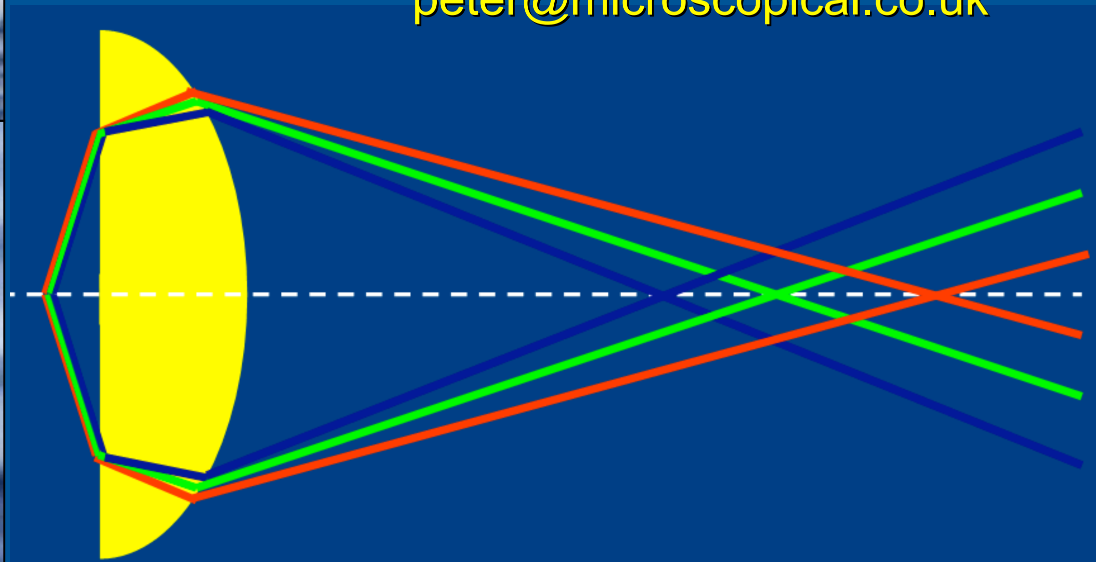


Defects of lenses

peter@microscopical.co.uk





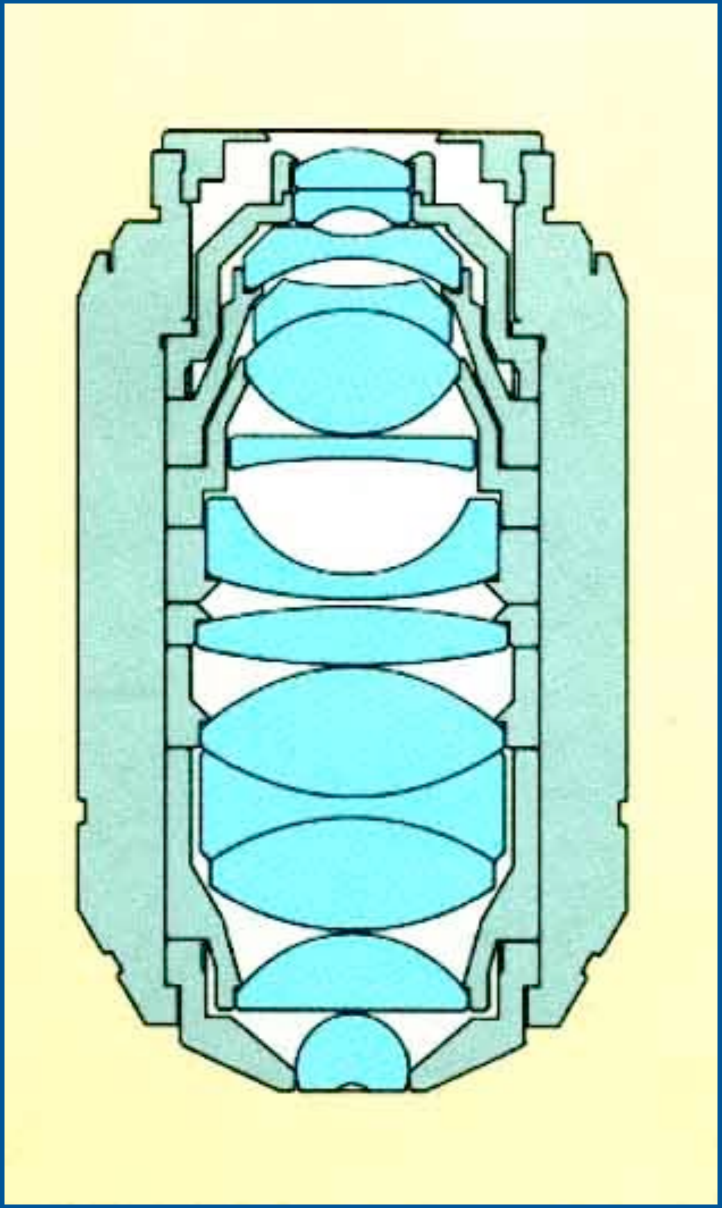


Defects of lenses

- Simple single pieces of glass do not act as perfect lenses
- They suffer from several *errors*, or

aberrations

The objective lens



The most important lens of the microscope

The principal Aberrations are:

- **Spherical aberration**

- caused because the surface of most lenses is made to be part of a sphere

- easy and cheap to make

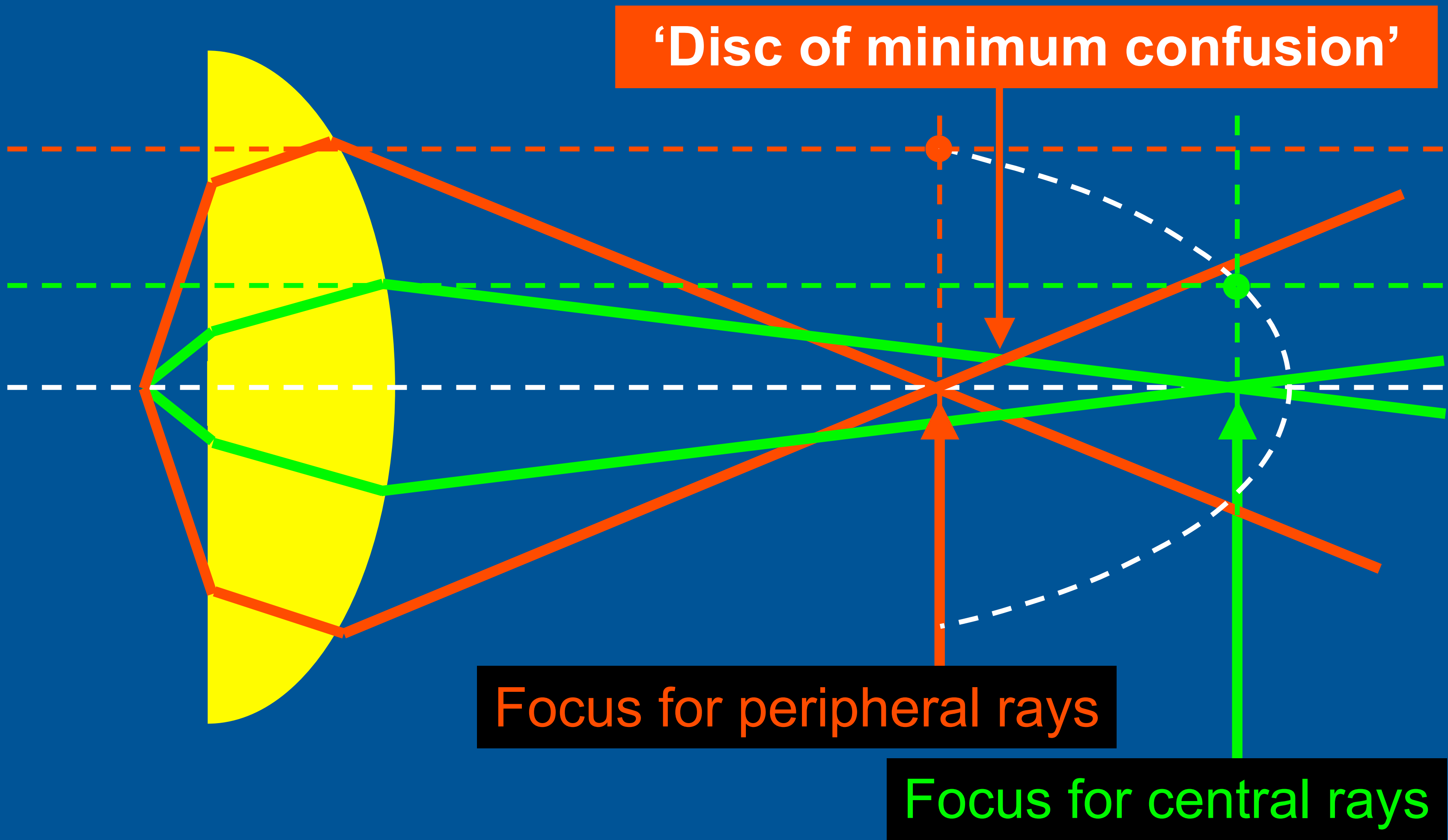
but it is *the wrong shape*

- **Chromatic aberration**

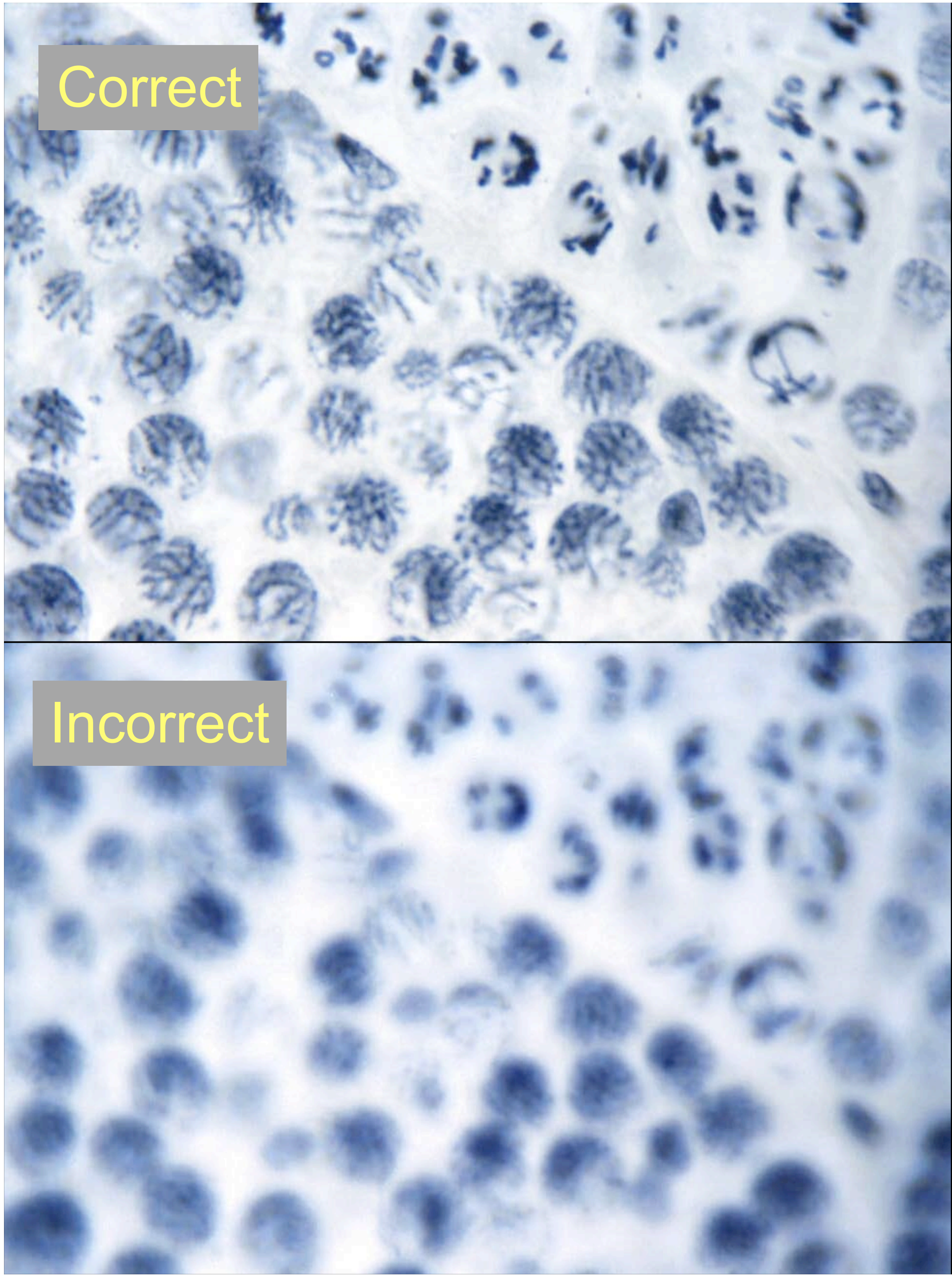
'colour' aberration

- caused because all materials from which lenses can be made have a different refractive index for each colour

Spherical aberration

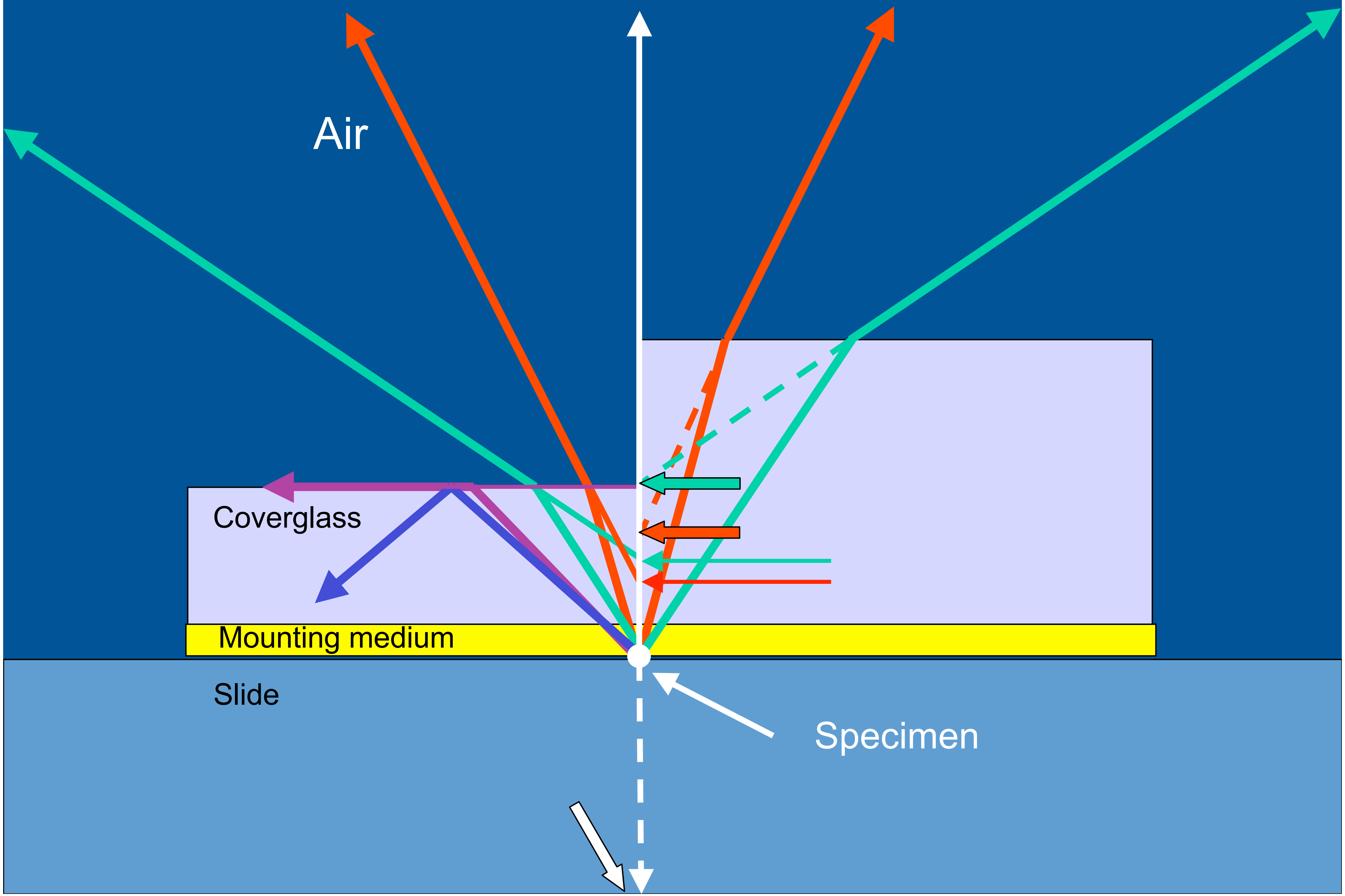


Spherical aberration



Objective with ‘correction collar’

Effect of Coverglass Thickness



160 / -

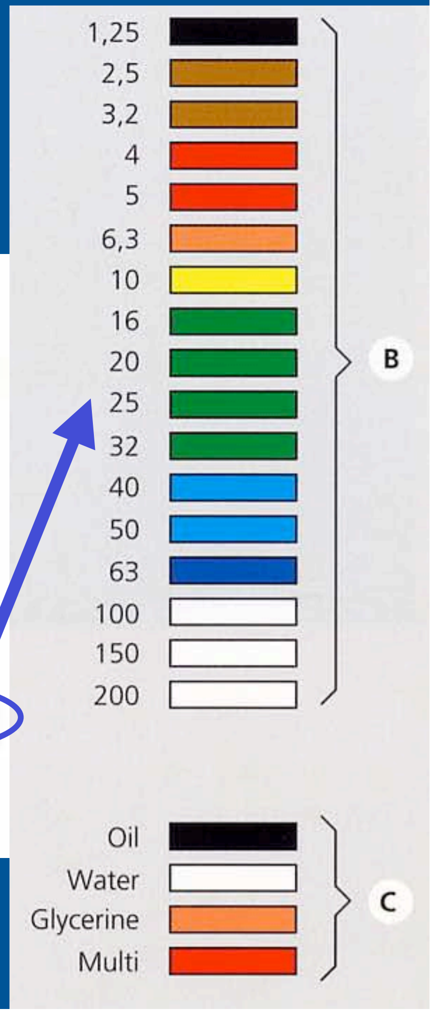
Tubelength 160mm
Coverslip thickness Unimportant

10x / 0.4

Magnification 10x
Numerical Aperture 0.4

∞ / 0.17

Tubelength Infinite
Coverslip thickness 0.17mm



Magnification	40x
Numerical Aperture	1.0

Oil immersion
Iris in back focal plane
Corrected for infinite tubelength
Corrected for 0.17mm coverglass

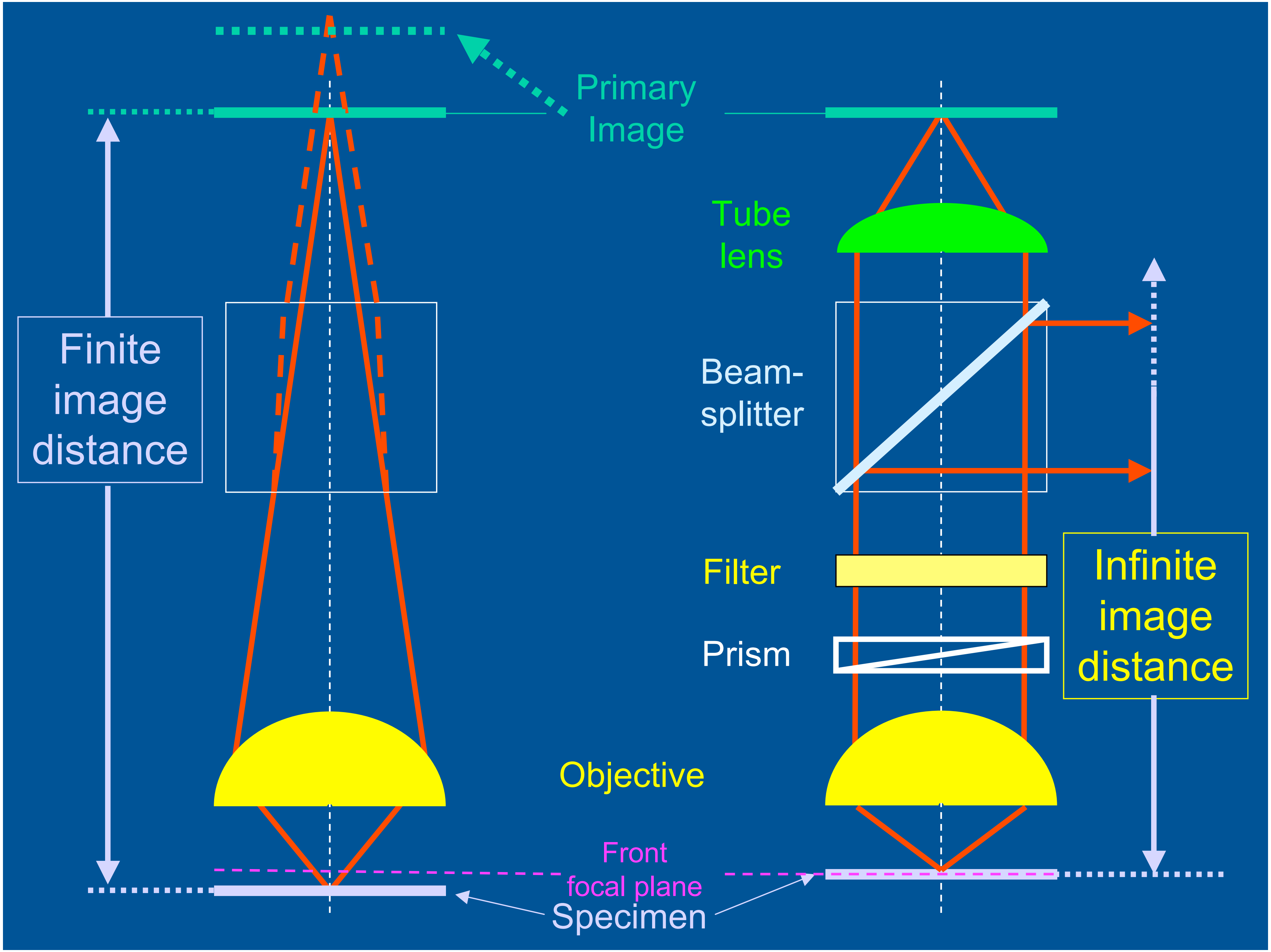
Magnification	10x
Numerical Aperture	0.30

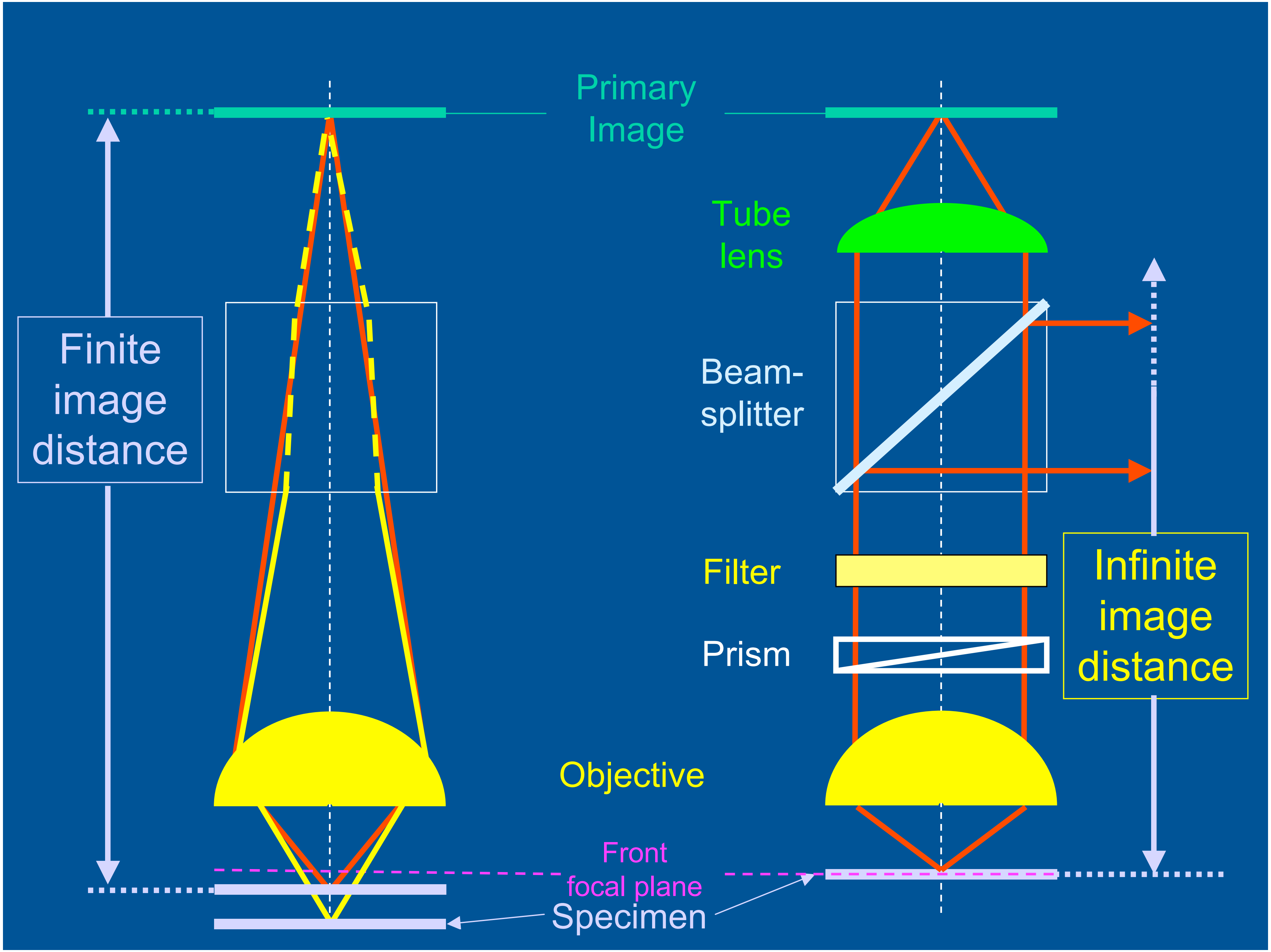
‘Hell- und Dunkelfeld’

Suitable for Differential Interference Contrast

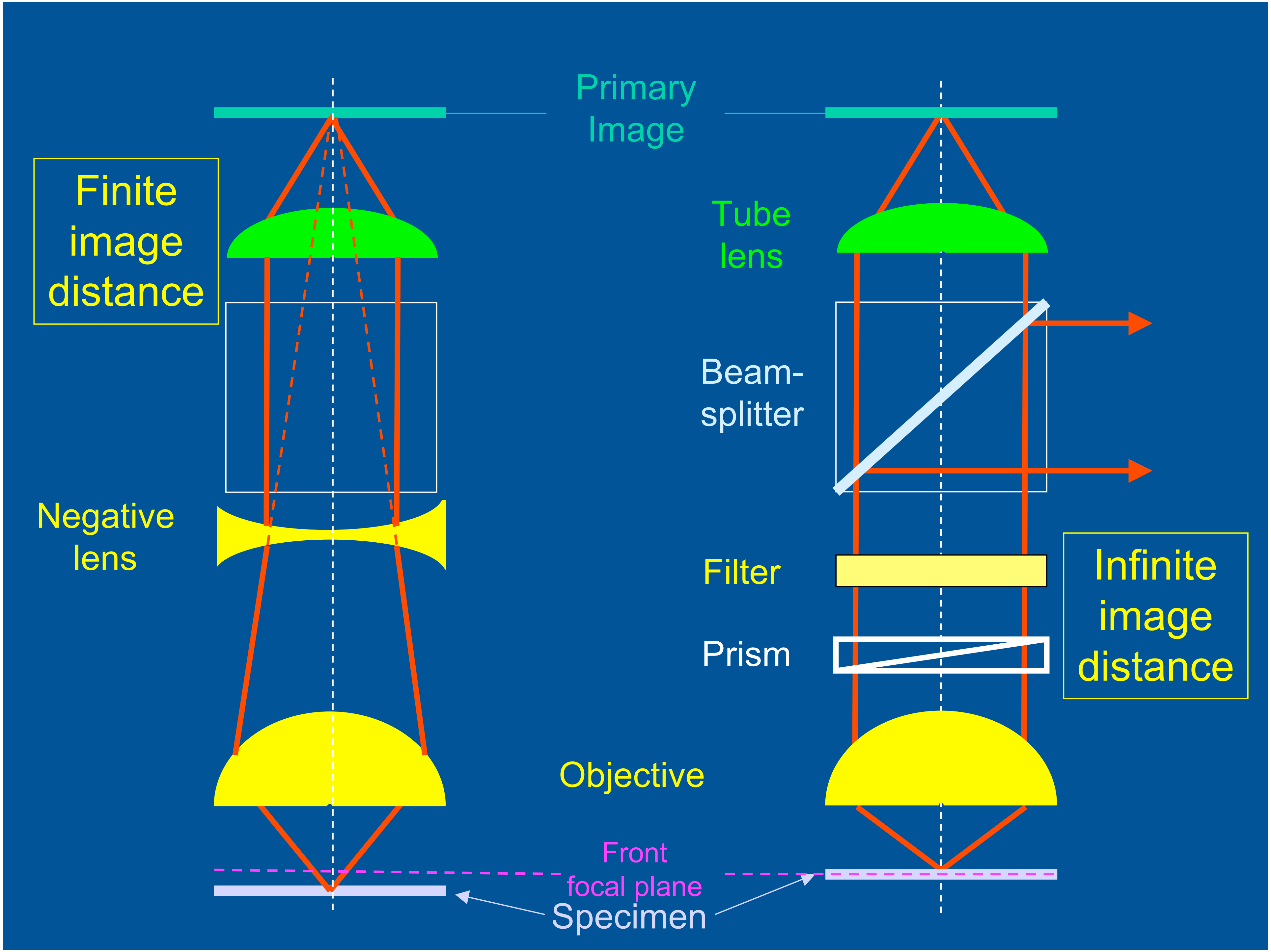
Corrected for infinite tubelength

Corrected for use without coverglass


Primary
Image
Tube
lens
Finite
image
distance
Beam-
splitter
Filter
Prism
Infinite
image
distance
Objective
Front
focal plane
Specimen



Primary Image
Tube lens
Beam-splitter
Filter
Prism
Objective
Front focal plane
Specimen
Finite image distance
Infinite image distance



Primary Image
Finite image distance
Tube lens
Beam-splitter
Negative lens
Filter
Infinite image distance
Prism
Objective
Front focal plane
Specimen

The principal Aberrations are:

- **Spherical aberration**

- caused because the surface of most lenses is made to be part of a sphere

- easy and cheap to make

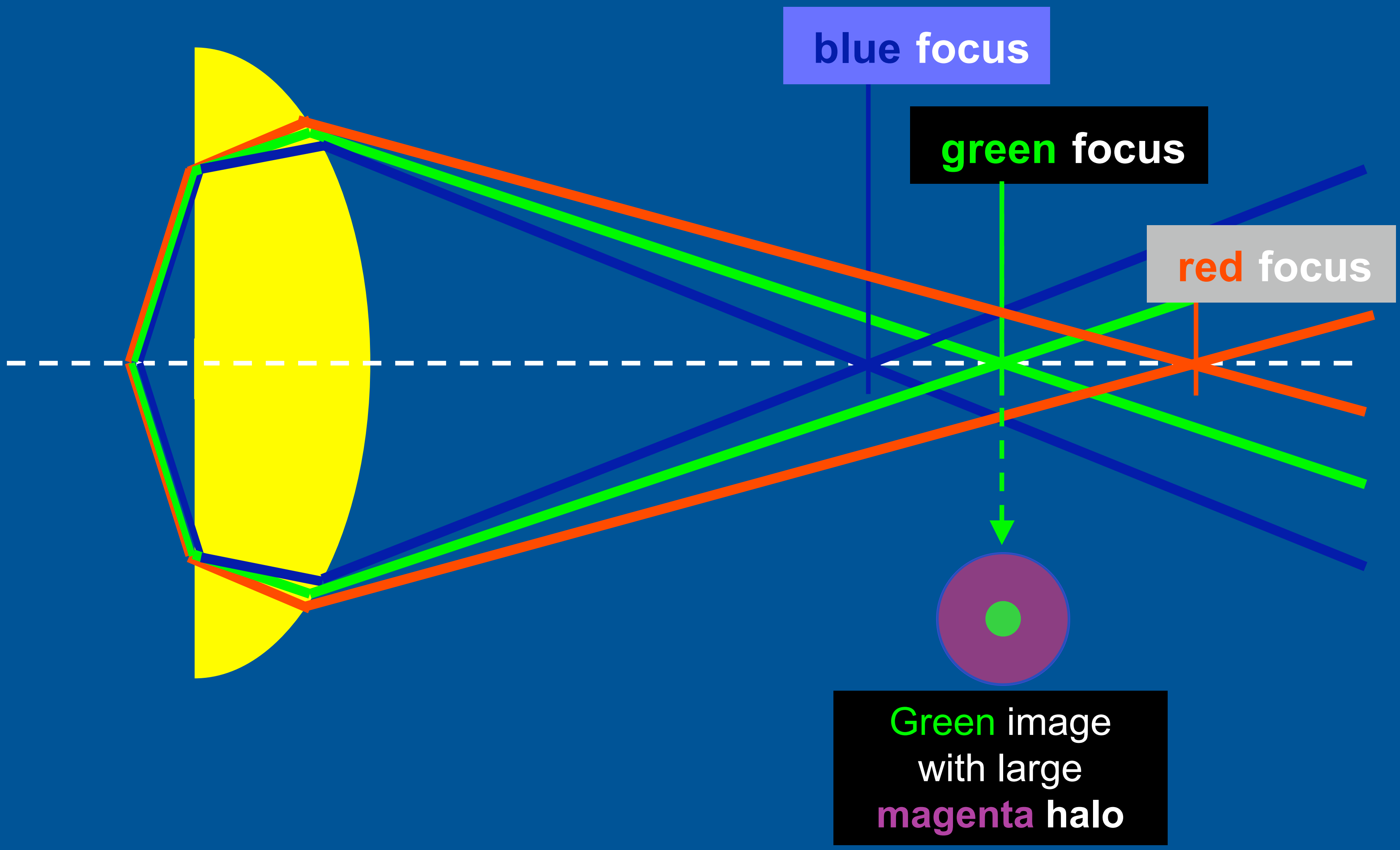
but it is *the wrong shape*

- **Chromatic aberration**

'colour' aberration

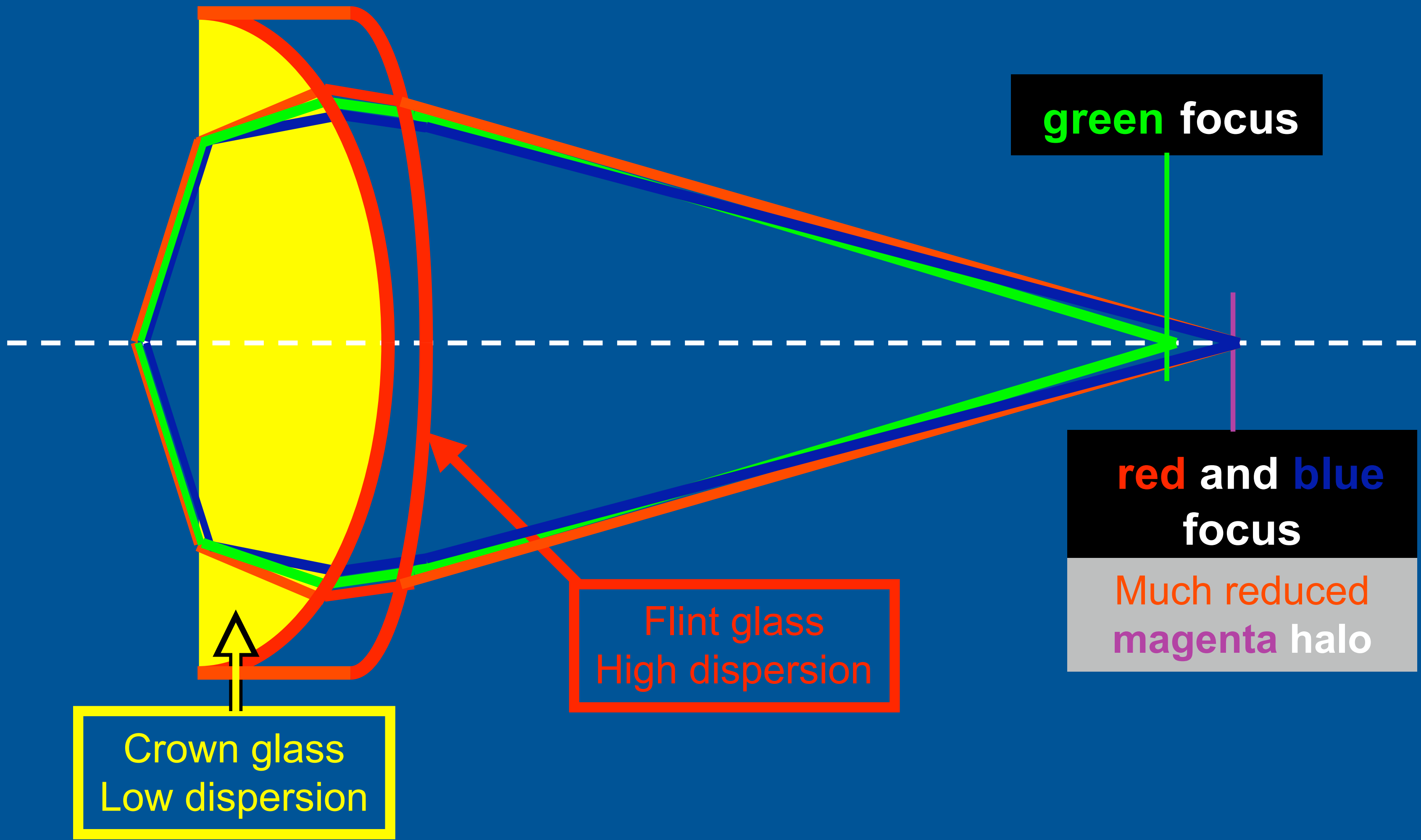
- caused because all materials from which lenses can be made have a different refractive index for each colour

Chromatic aberration



Chromatic aberration

The achromatic doublet



Types of objective lens

- Achromatic
  - Chromatic aberration minimised for ***two*** wavelengths, and spherical aberration for ***one*** (usually green).
    - Relatively inexpensive
    - Adequate for routine work
    - Can give excellent results when used with green filter
- Fluorite (‘Semi-Apochromatic’)
  - Chromatic aberration better corrected than achromats due to optical properties of fluorite (calcium fluoride) lens elements.
    - Perform well at larger apertures than achromats
    - Simpler design and therefore cheaper than apochromats
- Apochromatic
  - Chromatic aberration minimised for ***three*** wavelengths, and spherical aberration for ***two*** wavelengths.
    - Virtually perfectly corrected, even for large apertures
    - Complex design, therefore very expensive

Lens Aberrations

Aberrations are minimised by careful design

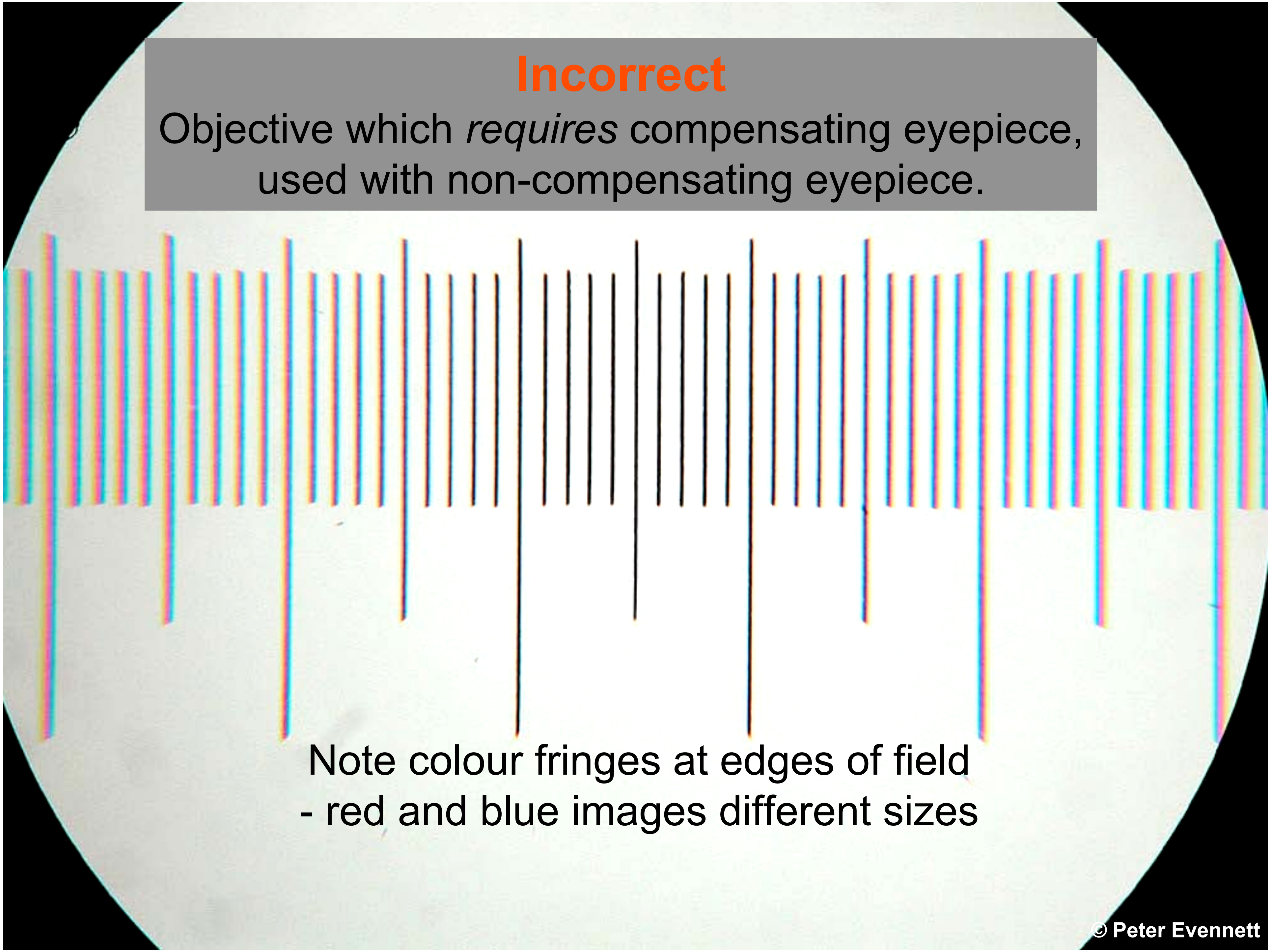
…but only for certain conditions of use:

Correct matching of

- Objective
- Microscope stand
- Eyepiece

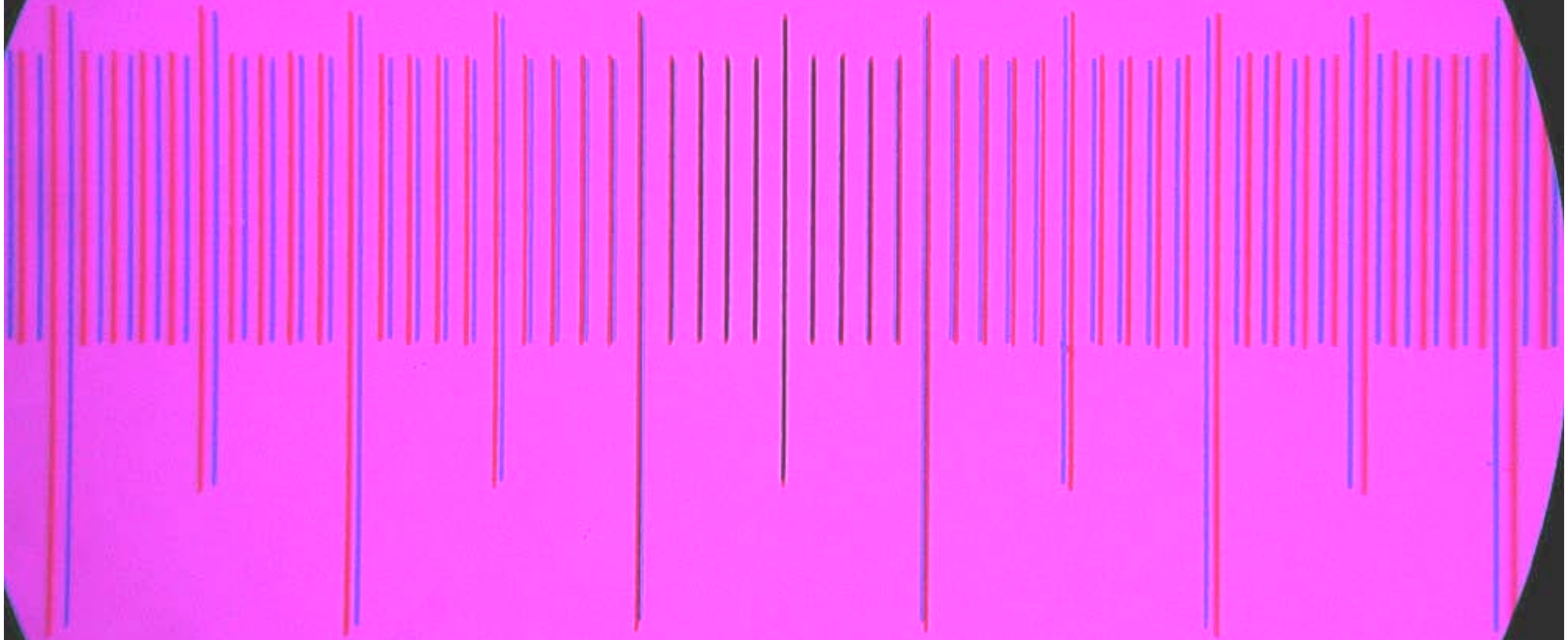
Microscope parts may seem to be ***mechanically*** interchangeable

But they are not ***optically*** interchangeable


Incorrect
Objective which requires compensating eyepiece,
used with non-compensating eyepiece.
Note colour fringes at edges of field
- red and blue images different sizes
© Peter Evennett

Incorrect

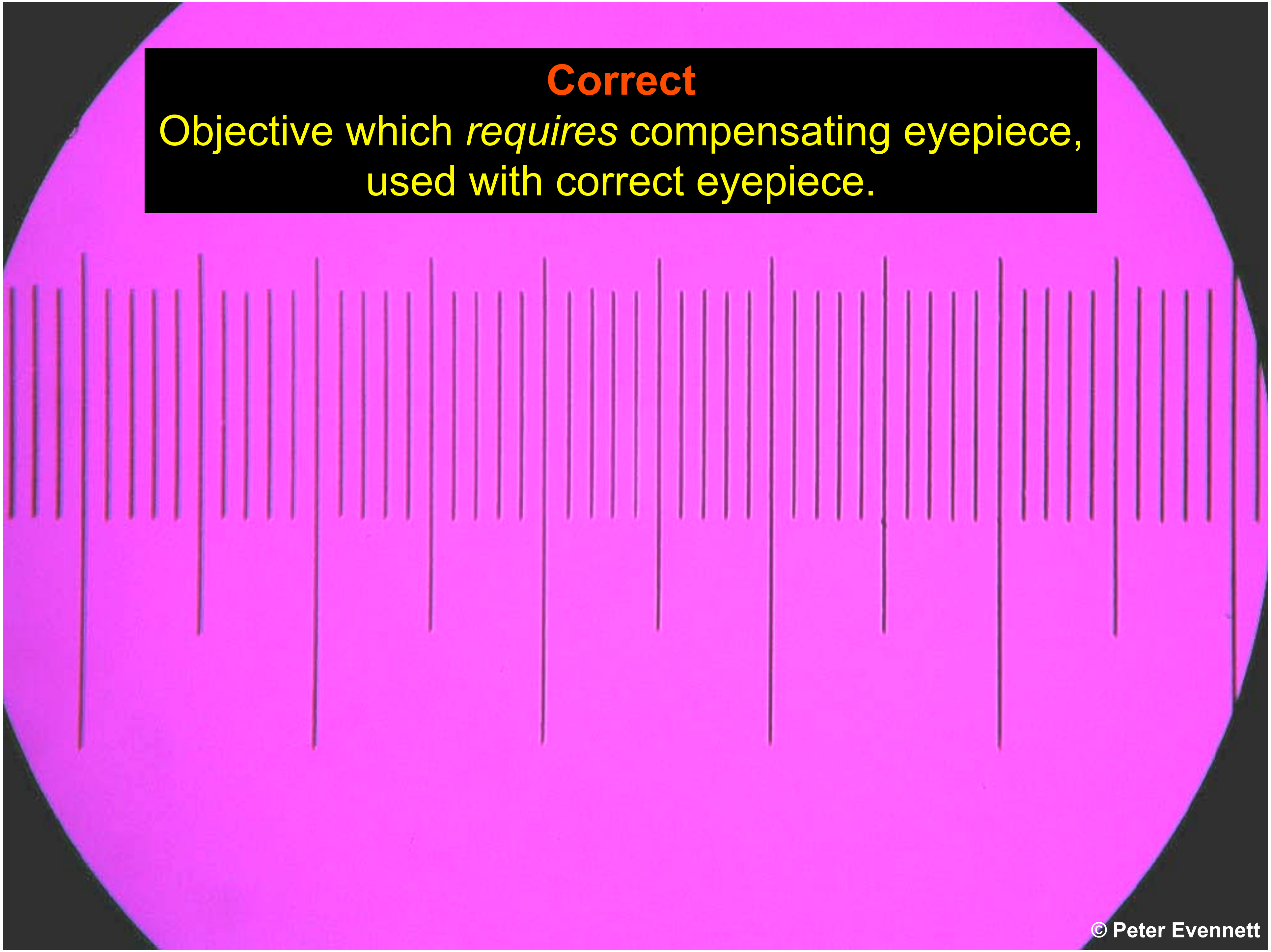
Objective which *requires* compensating eyepiece, used with non-compensating eyepiece.

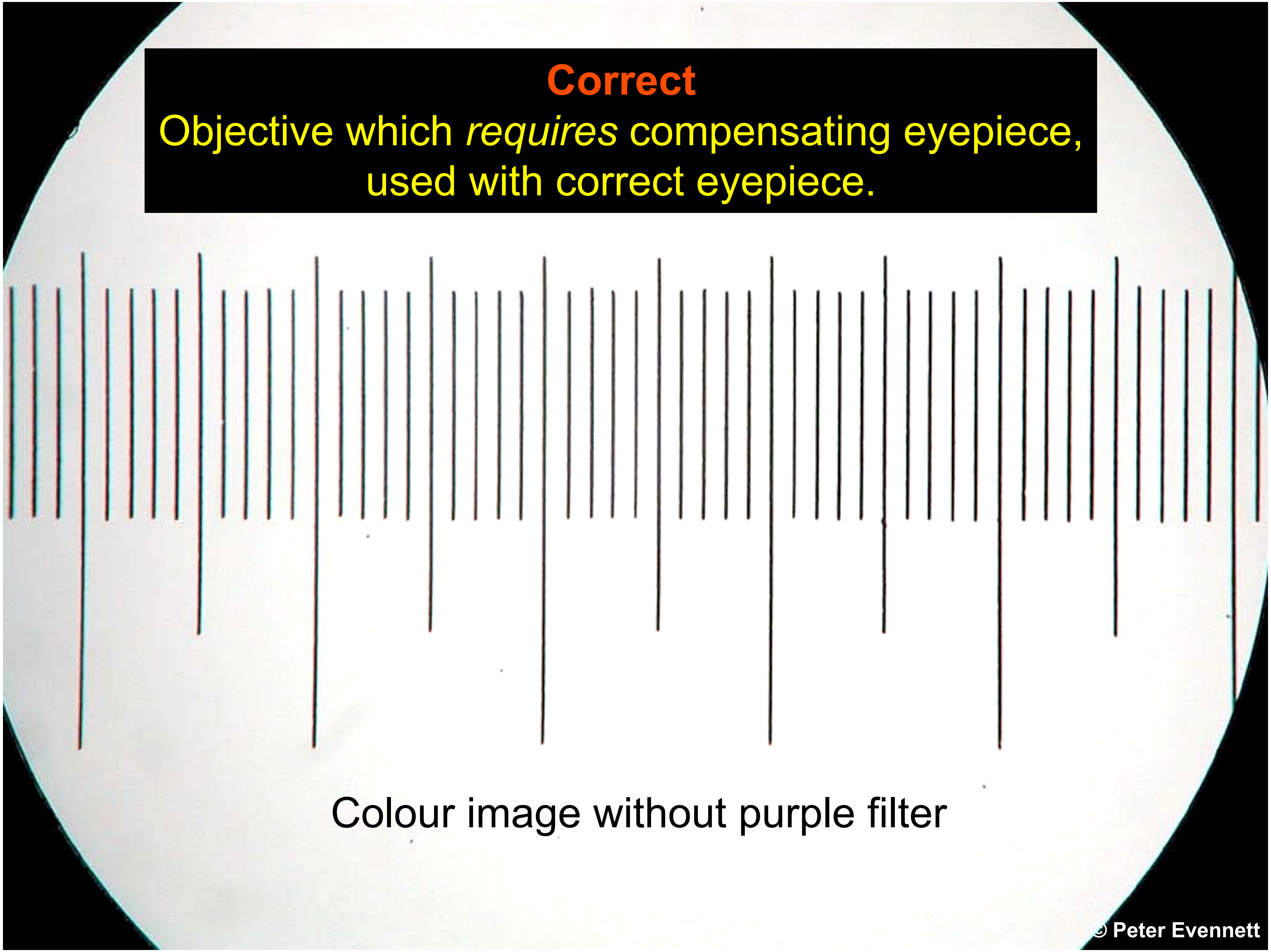


Purple filter emphasises colour fringes at edges of field - red and blue images different sizes

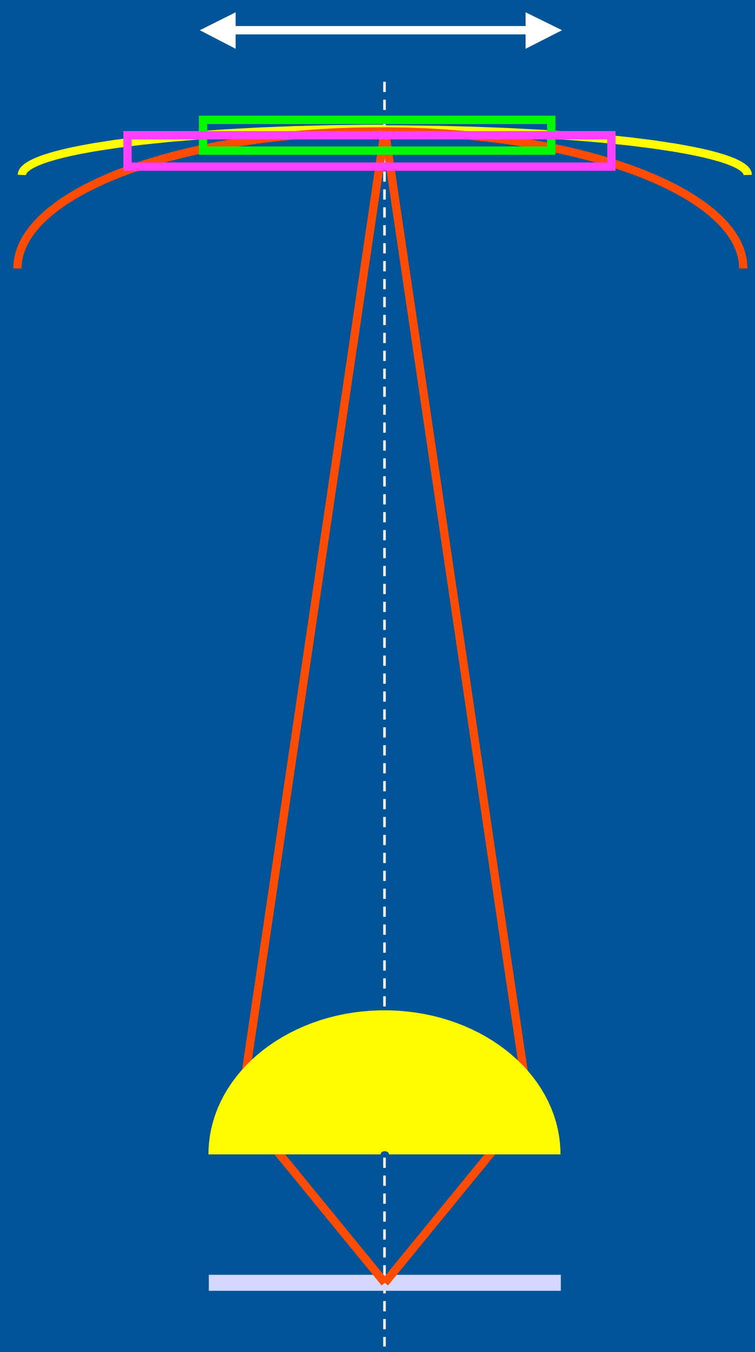
Correct

Objective which *requires* compensating eyepiece, used with correct eyepiece.



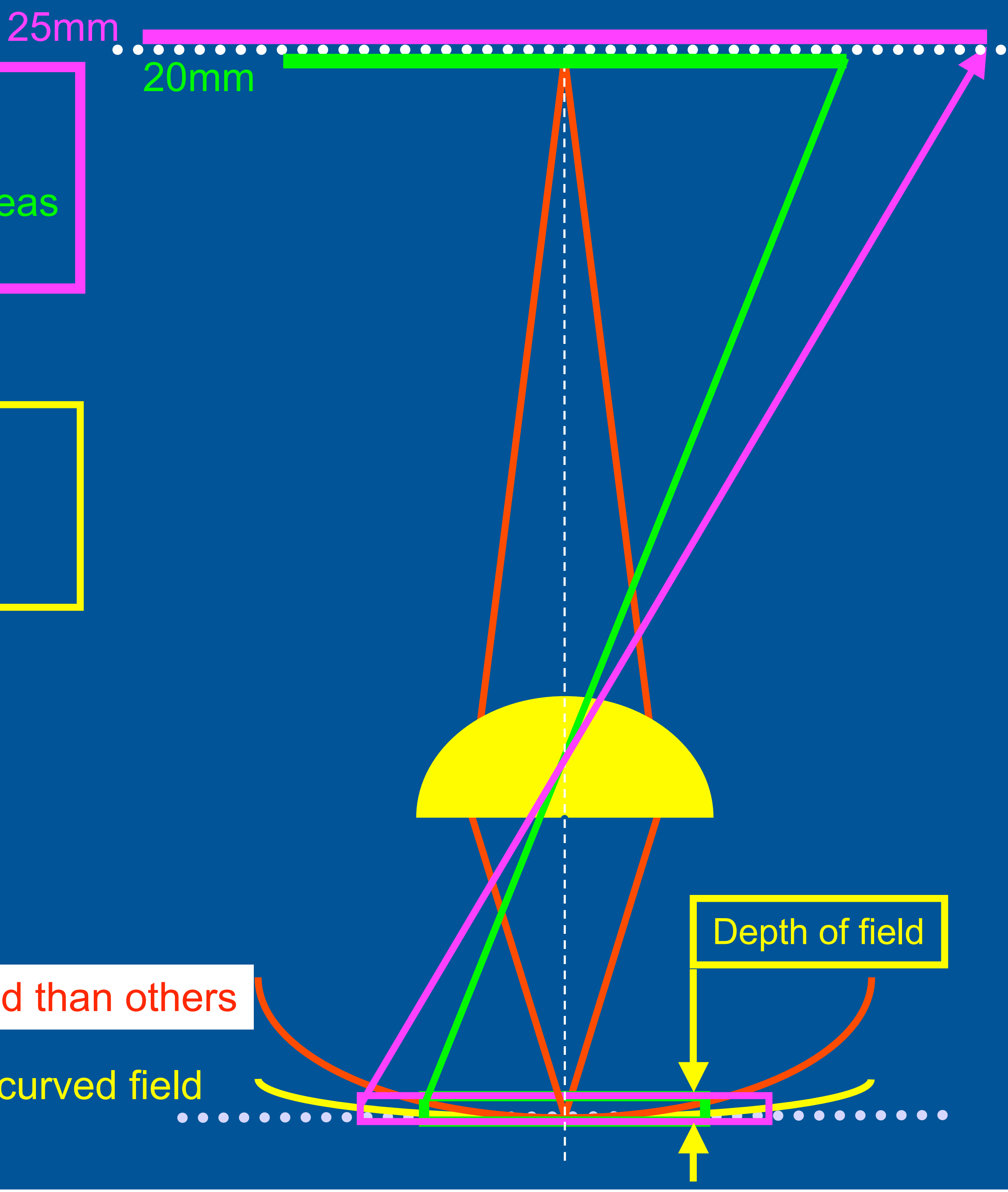

Correct
Objective which *requires* compensating eyepiece,
used with correct eyepiece.
Colour image without purple filter
© Peter Evennett

Curvature of Field



Curvature of Field

Eyepieces have
different fields of view
- they include different areas
of the primary image



And some are more curved than others

Most objectives have a curved field