

TESTING TELESCOPES

INTRODUCTION

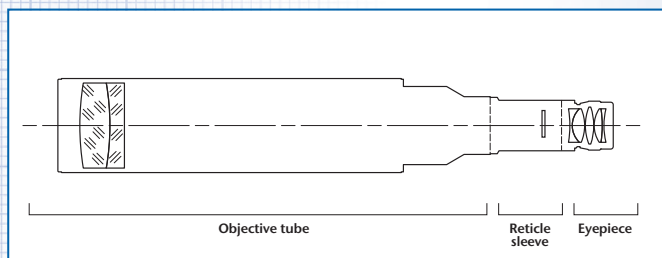
Layout and principle of operation

A testing telescope provides a magnified real image of a distant object. Usually the object is at infinity at a wavelength of 546 nm. The main components of a testing telescope are:

- objective tube with objective
- reticle sleeve with reticle
- eyepiece

The following figure shows the principle set-up of a testing telescope with straight viewing adjusted to infinity. The reticle is positioned at the rear focal plane of the objective. Due to this configuration all objects at infinity are imaged into the reticle plane. The reticle plane is viewed through the eyepiece. Due to this set-up the image in the eyepiece is rotated by 180°.

Mechanical and optical axes of testing telescopes with focal length $f \leq 300$ mm are adjusted with an accuracy of $\pm 30 \mu\text{m}/f$.



Testing telescopes form with collimators a measuring system for direction and angle testing of optical elements or optical systems in transmission.

Calculation of the angles

The angles (α_x and α_y) can be calculated from the distances Δx or Δy of the image of the collimator reticle to zero position of the eyepiece reticle as follows:

$$\alpha_x = \arctan\left(\frac{\Delta x}{f}\right) \approx \frac{\Delta x}{f}$$

$$\alpha_y = \arctan\left(\frac{\Delta y}{f}\right) \approx \frac{\Delta y}{f}$$

f : focal length of the telescope objective

Numerical example:

A displacement of 3 mm measured with a testing telescope with 300 mm focal length corresponds to an angle of:

$$\alpha \approx 3/300 \text{ rad} = 10 \cdot 10^{-3} \text{ rad} = 0,5730^\circ = 34'23''$$

A point at a distance of $10 \mu\text{m}$ to the centre of the eyepiece reticle corresponds to an angle of the parallel beam to the optical axis of the telescope as follows:

Focal length	Angle
50 mm	41"
90 mm	23"
140 mm	15"
200 mm	10"
300 mm	6,9"
500 mm	4,1"
600 mm	3,4"
1100 mm	1,9"



Adjustable Focus

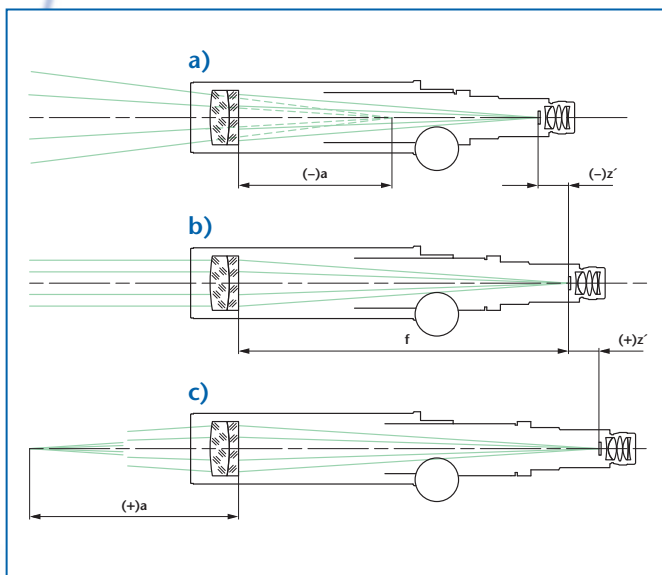
Besides testing telescopes with fixed distance between reticle and objective telescopes with adjustable focus are available. With these telescopes the distance between reticle and objective is adjustable.

If the reticle is displaced out of the focal plane by a distance z' , then the telescope is focused at a distance a according to:

$$a = \frac{f^2 + z'f}{z'}$$

$z' < 0$ corresponds to a decrease of the distance between objective and reticle. The resulting image distance is negative (virtual object position) (a).

$z' > 0$ corresponds to a real image with positive object distance (c). $z' = 0$ produces an image at infinite distance (b).



Selection criteria

Long or short focal length?

Depending on the magnification of the instrument a longer focal length leads to a greater measuring sensitivity and measurement accuracy. As the focal length increases, the measuring range (FOV) decreases proportionally. Additionally, the intensity of the light bundle received by the telescope decreases with increased focal length. A longer focal length affects the mechanical extension of the tube, as well.

Small or large objective aperture?

Light conditions are more favourable when large apertures are used, and the evaluation of the results is easier and more accurate. A long distance between test specimen and telescope demands a relatively large free aperture (or aperture ratio). For these measurements a relatively large aperture diameter should be used.

Fixed or variable distance setting?

Fixed, infinity focus testing telescopes are generally the best choice when testing systems adjusted to infinity. Fixed focus tubes set at other than infinity can be ordered.

For measurement tasks requiring an adjustable focal distance like adjustment at different wavelengths or to different distances, focusable testing telescopes with objective tube with tube extensions are used.

Eyepiece focal length?

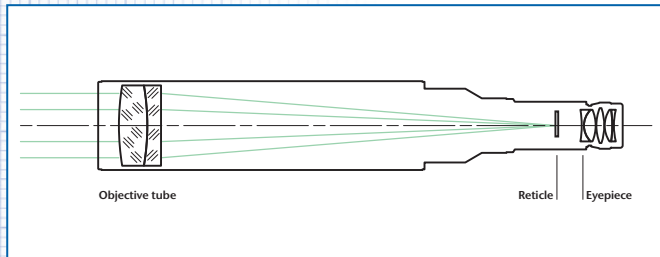
Usually eyepieces with $f=14,7$ mm are used. Eyepieces with $f=10$ mm give greater magnification but less field angle. Eyepieces with $f=25$ mm give larger field of view but less magnification. For eyepieces with $f=14,7$ mm and $f=25$ mm a C-Mount Camera adapter is available.

TESTING TELESCOPES

STRAIGHT VIEWING

Description:

For a general description of the operating principle of testing telescopes see page 20.



Application examples

(additional collimator required):

- Measurement of angular displacement
- Parallelism measurement of uncoated flats
- Testing of the imaging properties of optical elements and systems

Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- The nomenclature of the testing telescopes with straight viewing is as follows:

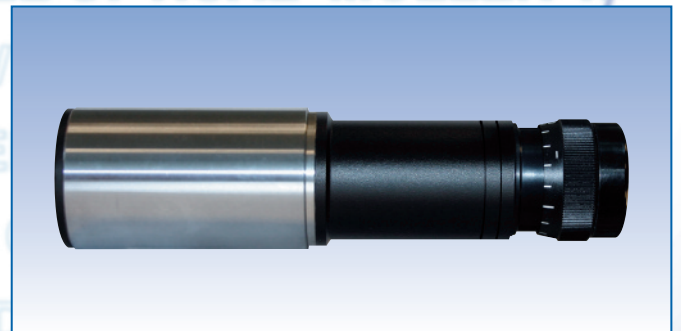
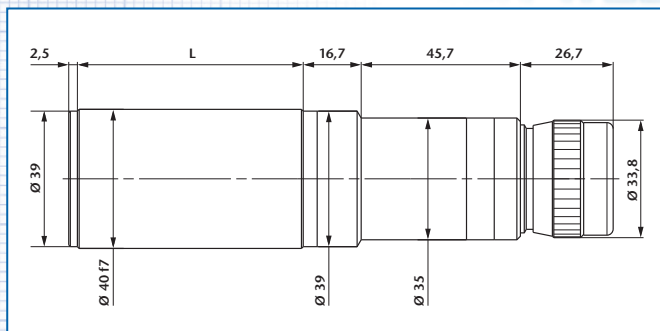
Example:

F G 50/ 40/ 14,7

Testing telescope
Straight viewing
Focal length
Tube diameter
Eyepiece focal length

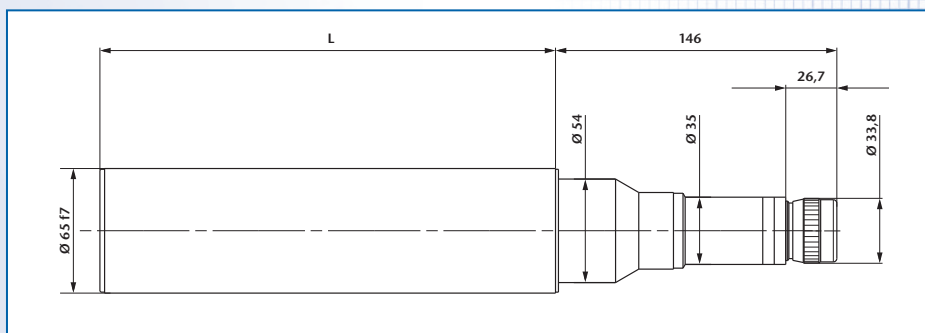
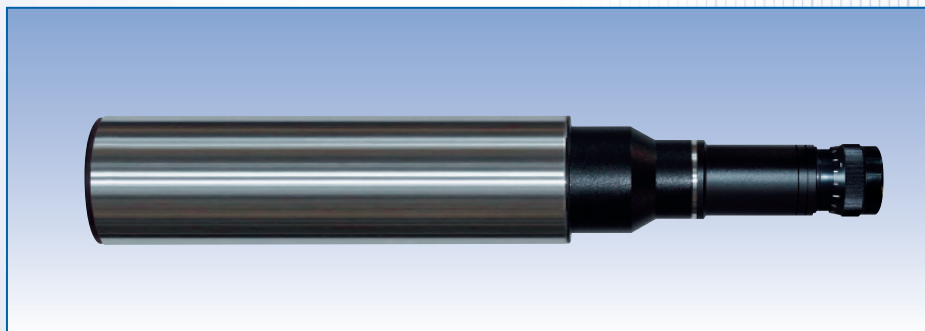
Important:

Please specify reticle (see page 82) when ordering.

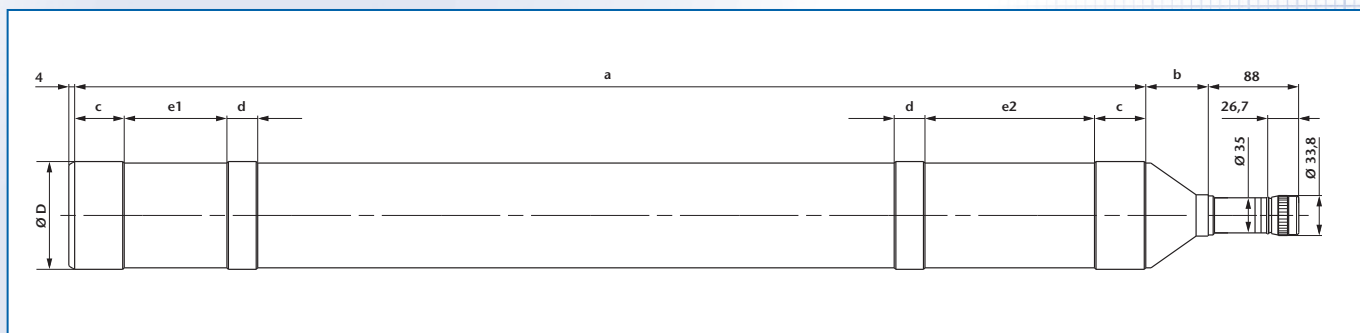
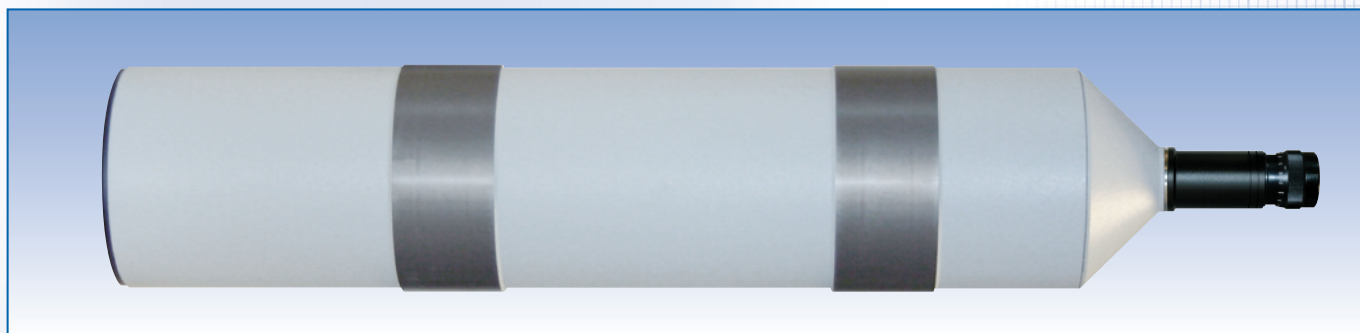


Ord.-No.	Description	Focal length	Free aperture	Field of view	L
227 004	FG 50/40/14,7	50	10	10,0°	65
227 005	FG 90/40/14,7	90	16	6,0°	65
227 006	FG 140/40/14,7	140	28	4,0°	118
227 007	FG 200/40/14,7	200	28	3,0°	173
227 008	FG 300/40/14,7	300	28	2,0°	274
227 009	FG 500/40/14,7	500	28	1,0°	474





Ord.-No.	Description	Focal length	Free aperture	Field of view	L
227 010	FG 300/65/14,7	300	50	2,0°	233
227 011	FG 500/65/14,7	500	50	1,0°	415
227 012	FG 500T/65/14,7	500	50	1,0°	233



Ord.-No.	Description	Focal length	Free aperture	Field of view	D	a	b	c	d	e1	e2
227 015	FG 600/128/14,7	600	100	0,8°	Ø 128 f7	530	46	—	58	154	78
227 016	FG 1100/105/14,7	1100	80	0,5°	Ø 105 f7	1045	66	50	30	165	100

TESTING TELESCOPES

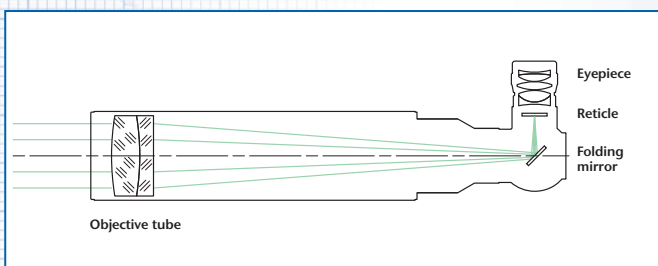
90°-VIEWING

Description:

For a general description of the operating principle of testing telescopes see page 20.

The basic function and design of testing telescopes with 90° viewing is the same as of testing telescopes with straight viewing.

The testing telescopes with 90° viewing contain an additional folding mirror. This kind of testing telescope is used for vertical set-ups or for set-ups on optical tables where straight viewing is not practical from point of view of ergonomics and space.



Application examples

(additional collimator required):

- Measurement of angular displacement
- Parallelism measurement of uncoated flats
- Testing of the imaging properties of optical elements and systems
- Measurement of the focal length of negative optical systems/elements (additional attachment achromat required)

Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- The nomenclature of the testing telescopes with 90°-viewing is as follows:

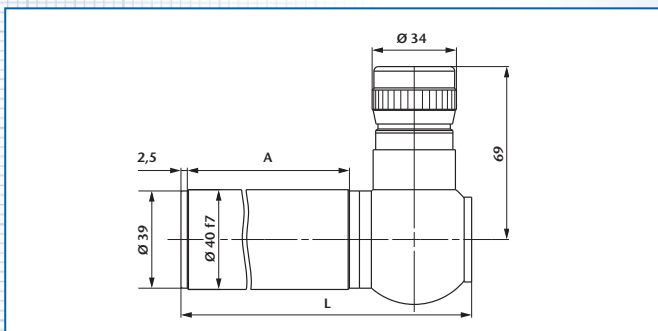
Example:

F R 50/ 40/ 14,7

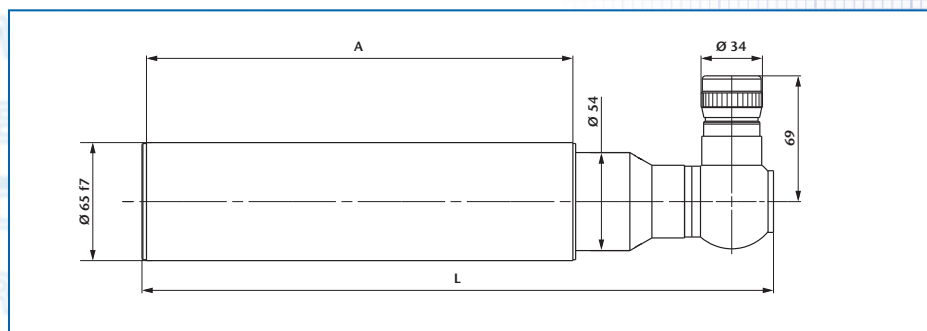
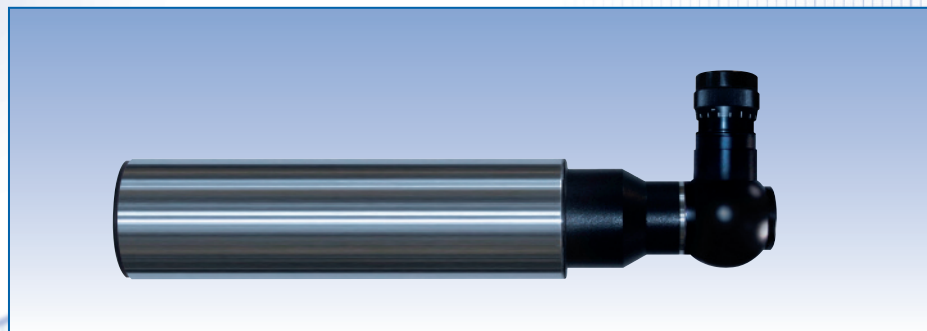
Testing telescope
90° viewing
Focal length
Tube diameter
Eyepiece focal length

Important:

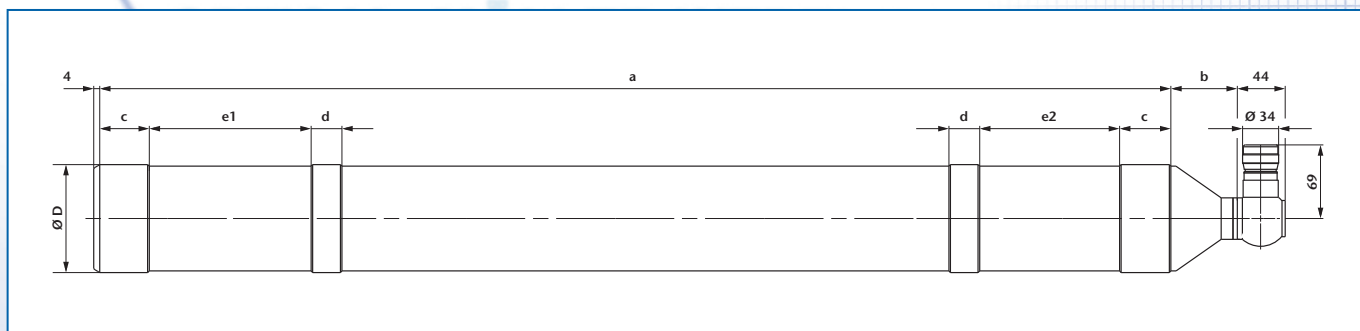
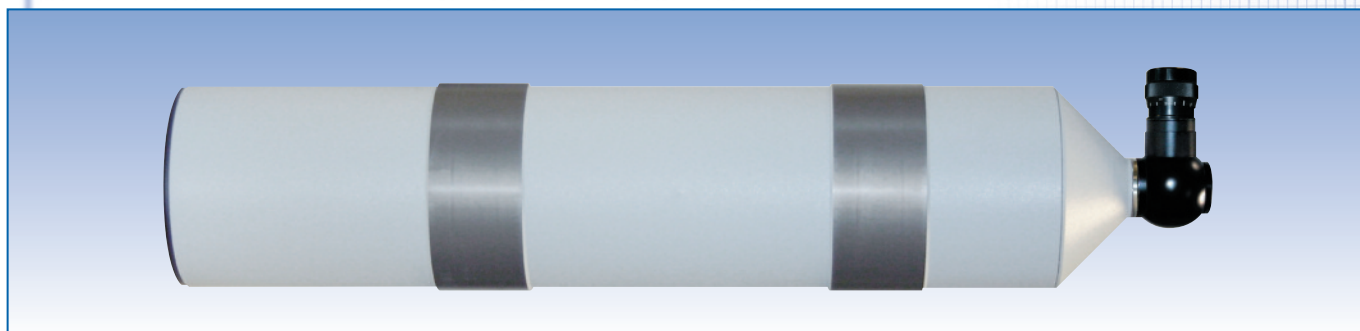
Please specify reticle (see page 82) when ordering.
Please specify direction of use if reticles with lettering (e.g. co-ordinate division etc.) are used so that the lettering will be right-side-up.



Ord.-No.	Description	Focal length	Free aperture	Field of view	A	L
227 041	FR 50/40/14,7	50	10	10,0°	65	116,5
227 042	FR 90/40/14,7	90	16	6,0°	65	116,5
227 043	FR 140/40/14,7	140	28	4,0°	118	169,5
227 044	FR 200/40/14,7	200	28	3,0°	173	224,5
227 045	FR 300/40/14,7	300	28	2,0°	274	325,5
227 046	FR 500/40/14,7	500	28	1,0°	474	525,5



Ord.-No.	Description	Focal length	Free aperture	Field of view	A	L
227 047	FR 300/65/14,7	300	50	2,0°	233	346,0
227 048	FR 500/65/14,7	500	50	1,0°	415	528,0
227 049	FR 500T/65/14,7	500	50	1,0°	233	346,0



Ord.-No.	Description	Focal length	Free aperture	Field of view	D	a	b	c	d	e1	e2
227 052	FR 600/128/14,7	600	100	0,8°	Ø 128 f7	530	46	—	58	154	78
227 053	FR 1100/105/14,7	1100	78	0,5°	Ø 105 f7	1045	66	50	30	165	100

TESTING TELESCOPES

60°-VIEWING/60°-VIEWING WITH DOUBLE MICROMETER

Description:

For a general description of the operating principle of testing telescopes see page 20.

The basic function and design of testing telescopes with 60°-viewing is the same as of testing telescopes with 90°-viewing. The testing telescopes with 60° viewing contain a folding mirror (see following figure). The image appears upright but laterally reversed. This kind of testing telescopes is used for horizontally set-ups because the 60°-viewing is more ergonomic.

The testing telescopes with 60° viewing (figure A) are available also with mechanical micrometer (figure B) and digital double micrometers (figure C).

The scale division (SD) of the mechanical micrometer drum is 5 µm. For a general description of the operating principle of testing telescopes with double micrometers see page 28 and 30 respectively.

Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- When ordering a telescope with digital double micrometer please specify the unit of display of the digital gauges (mm, arcsec, milliradians).
- The nomenclature of the testing telescopes with 60°-viewing and 60° viewing with double micrometer respectively is as follows:

Example:

F	W	300/	65/	14,7	MD
					MDD

Testing telescope
60° viewing
Focal length
Tube diameter
Eyepiece focal length
Double micrometer
Digital double micrometer

Important:

Please specify reticle (see page 82) when ordering.

Fig. A

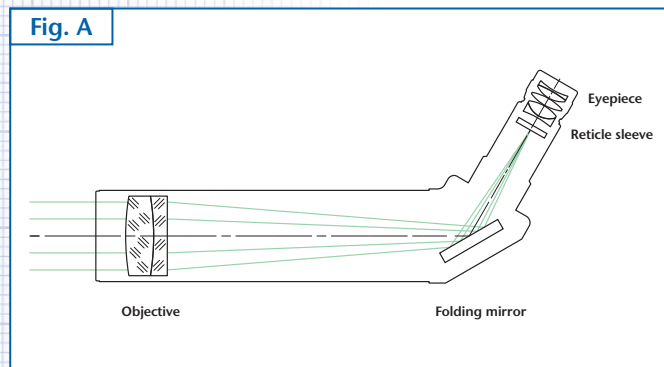


Fig. B

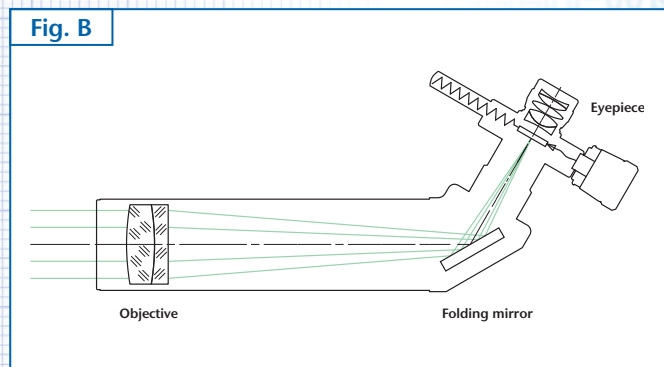
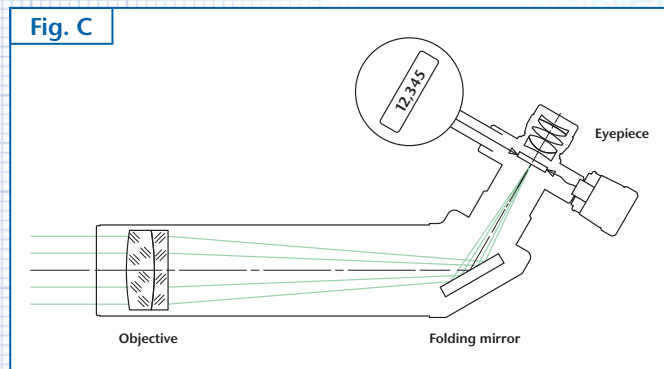
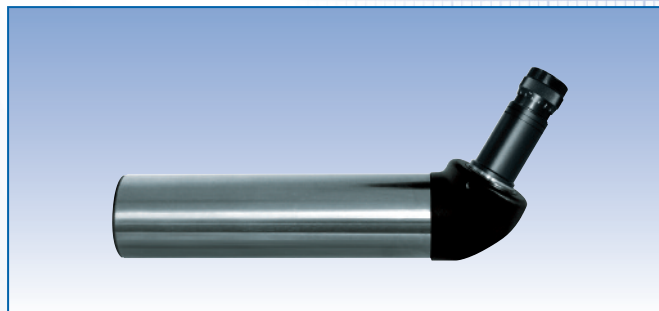
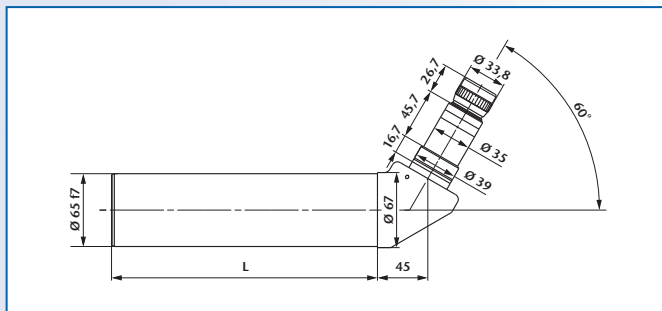


Fig. C



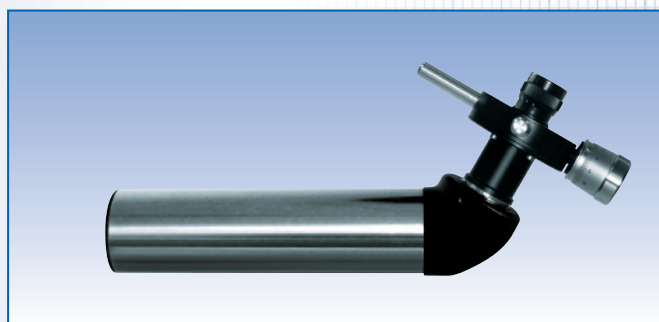
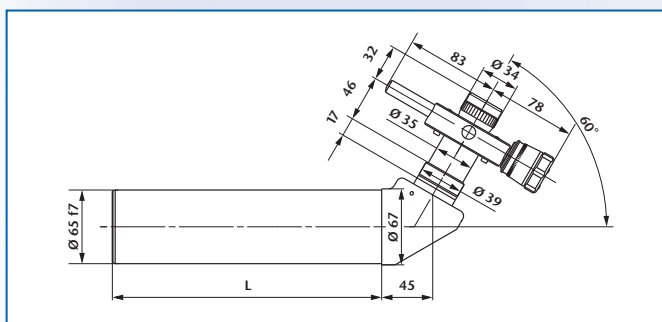
60°-VIEWING



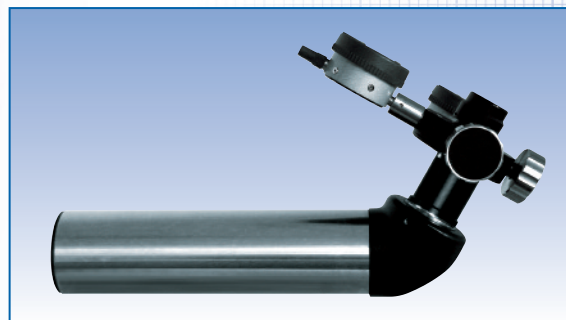
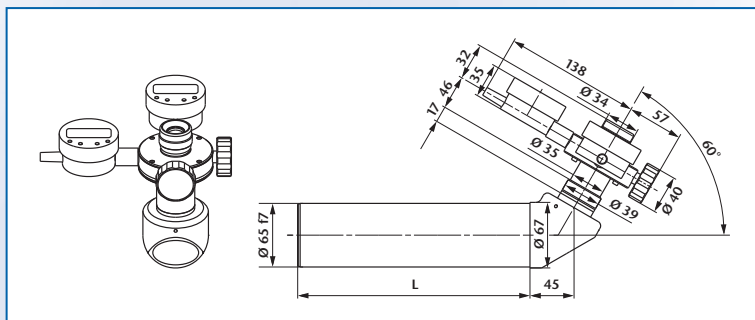
Ord.-No.	Description	Focal length	Free aperture	Field of view	L
227 067	FW 300/65/14,7	300	50	2,0°	233
227 068	FW 500/65/14,7	500	50	1,0°	415
227 069	FW 500T/65/14,7	500	50	1,0°	233



60°-VIEWING WITH DOUBLE MICROMETER



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	L
227 177	FW 300/65/14,7 MD	300	50	0,6°	3,5"	233
227 178	FW 500/65/14,7 MD	500	50	0,4°	2,0"	415
227 179	FW 500T/65/14,7 MD	500	50	0,4°	2,0"	233



Ord.-No.	Description	Focal length	Free aperture	Meas. range	Resolution	L
227 217	FW 300/65/14,7 MDD	300	50	0,6°	1,0"	233
227 218	FW 500/65/14,7 MDD	500	50	0,4°	0,5"	415
227 219	FW 500T/65/14,7 MDD	500	50	0,4°	0,5"	233



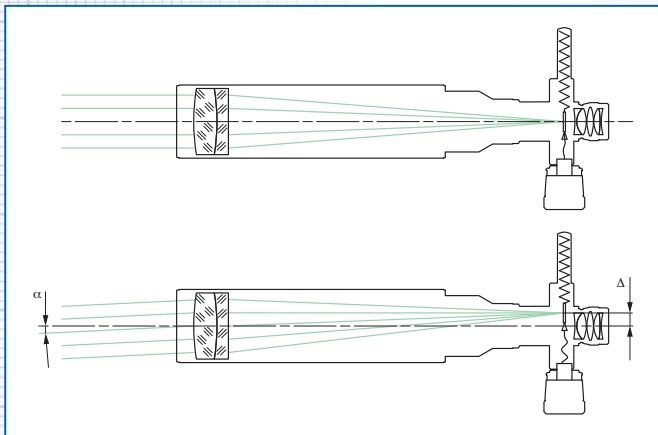
TESTING TELESCOPES

STRAIGHT VIEWING – WITH DOUBLE MICROMETER

Description:

For a general description of the operating principle of testing telescopes see page 20.

Testing telescopes with mechanical double micrometer allow the measurement of deflection angles in two directions. The movement of the eyepiece reticle in x- and y-direction in the image plane can be read from the scale of the micrometer drums. The scale division (SD) is 5 μm .



Application examples

(additional collimator required):

- Measurement of deflection angles
- Parallelism measurement of uncoated flats

Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- The nomenclature of the testing telescopes with straight viewing and mechanical double micrometer is as follows:

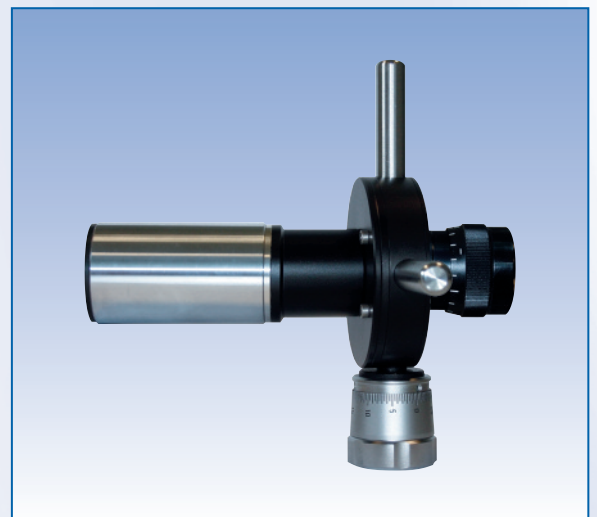
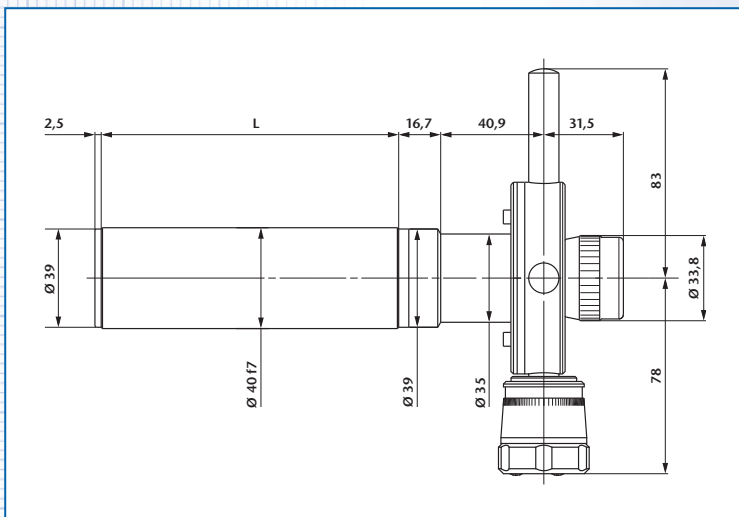
Example:

F G 50/ 40/ 14,7 MD

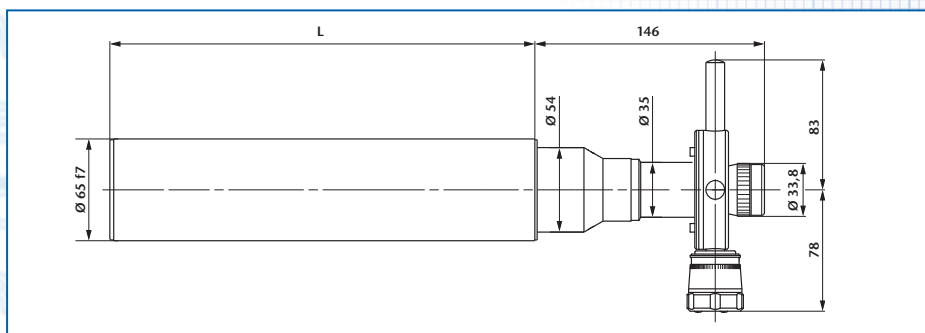
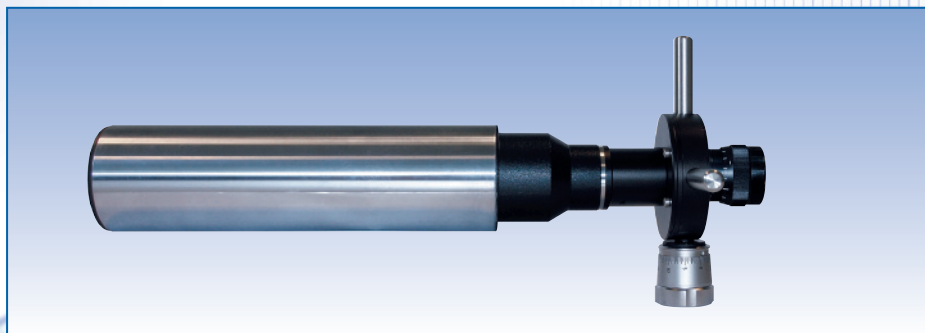
Testing telescope
Straight viewing
Focal length
Tube diameter
Eyepiece focal length
Double micrometer

Important:

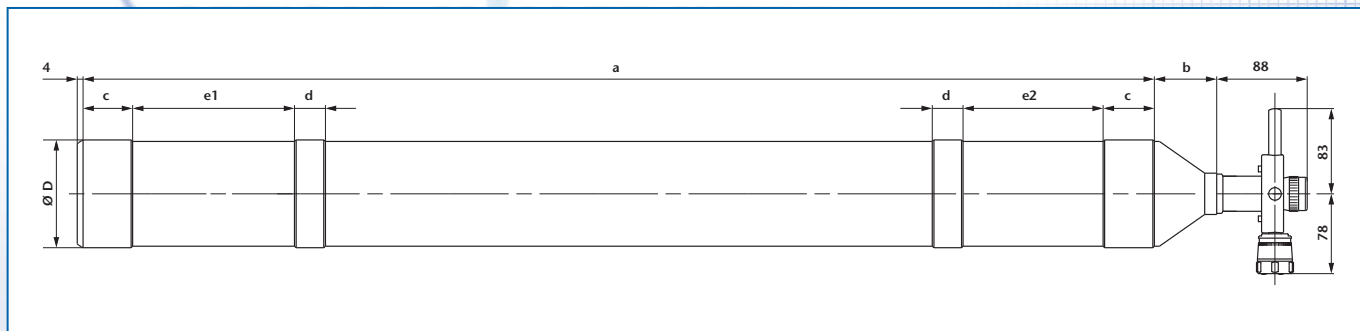
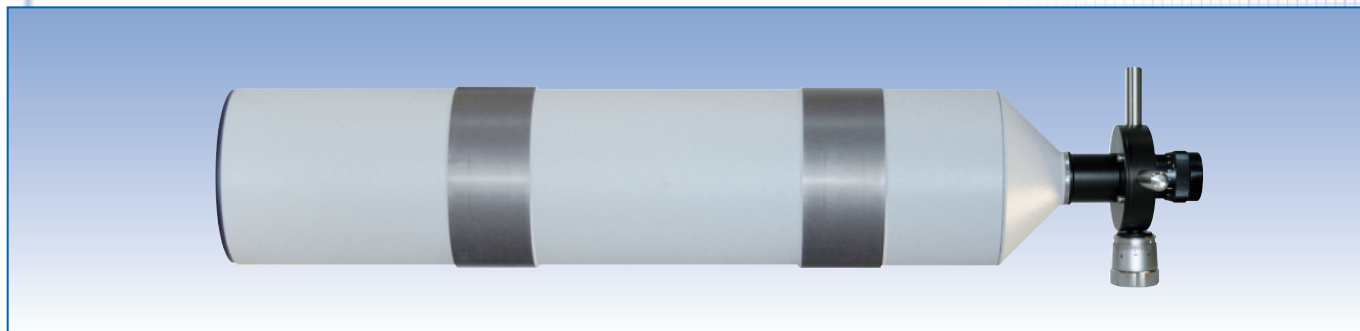
Please specify reticle (see page 82) when ordering.



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	L
227 161	FG 50/40/14,7 MD	50	10	3,2°	20,0"	65
227 162	FG 90/40/14,7 MD	90	16	2,0°	11,5"	65
227 163	FG 140/40/14,7 MD	140	28	1,2°	7,5"	118
227 164	FG 200/40/14,7 MD	200	28	0,8°	5,0"	173
227 165	FG 300/40/14,7 MD	300	28	0,6°	3,5"	274
227 166	FG 500/40/14,7 MD	500	28	0,4°	2,0"	474



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	L
227 167	FG 300/65/14,7 MD	300	50	0,6°	3,5"	233
227 168	FG 500/65/14,7 MD	500	50	0,4°	2,0"	415
227 169	FG 500T/65/14,7 MD	500	50	0,4°	2,0"	233



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	D	a	b	c	d	e1	e2
227 172	FG 600/128/14,7 MD	600	100	0,30°	1,7"	Ø 128 f7	530	46	—	58	154	78
227 173	FG 1100/105/14,7 MD	1100	78	0,16°	1,0"	Ø 105 f7	1045	66	50	30	165	100

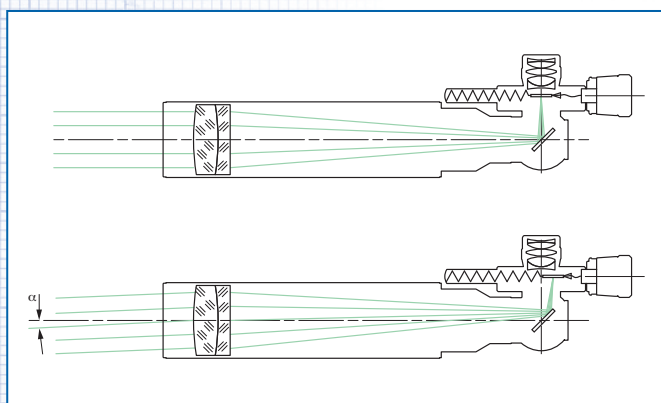
TESTING TELESCOPES

90°-VIEWING – WITH DOUBLE MICROMETER

Description:

For a general description of the operating principle of testing telescopes see page 20.

Testing telescopes with mechanical double micrometer allow the measurement of deflection angles in two directions. The movement of the eyepiece reticle in x- and y-direction in the image plane can be read from the scale of the micrometer drums. The scale division (SD) is 5 μm . The following figure shows the set-up of a testing telescope with 90° viewing. In contrast to a testing telescope with straight viewing the image appears upright and laterally reversed.



Application examples

(additional collimator required):

- Measurement of deflection angles
- Parallelism measurement of uncoated flats

Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- The nomenclature of the testing telescopes with 90°-viewing and mechanical double micrometer is as follows:

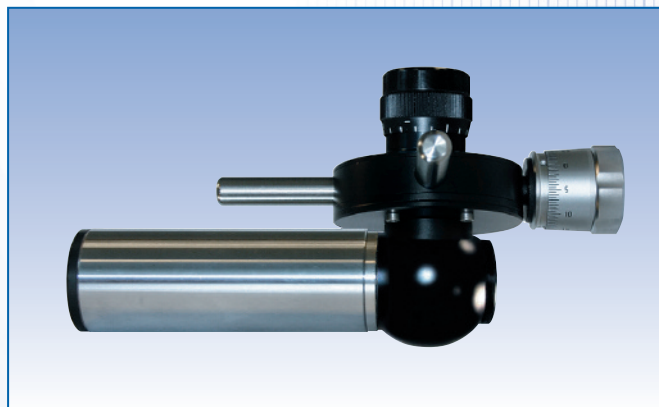
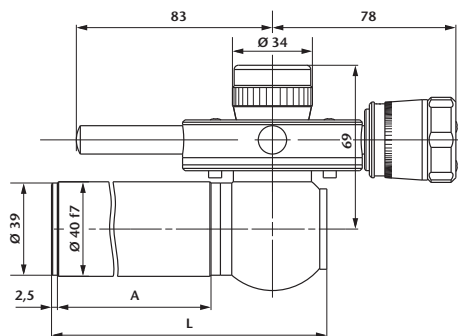
Example:

F R 50/ 40/ 14,7 MD

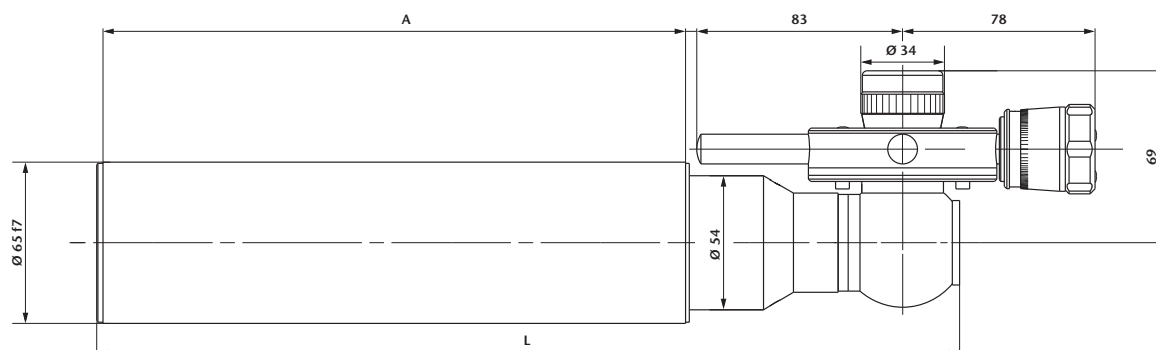
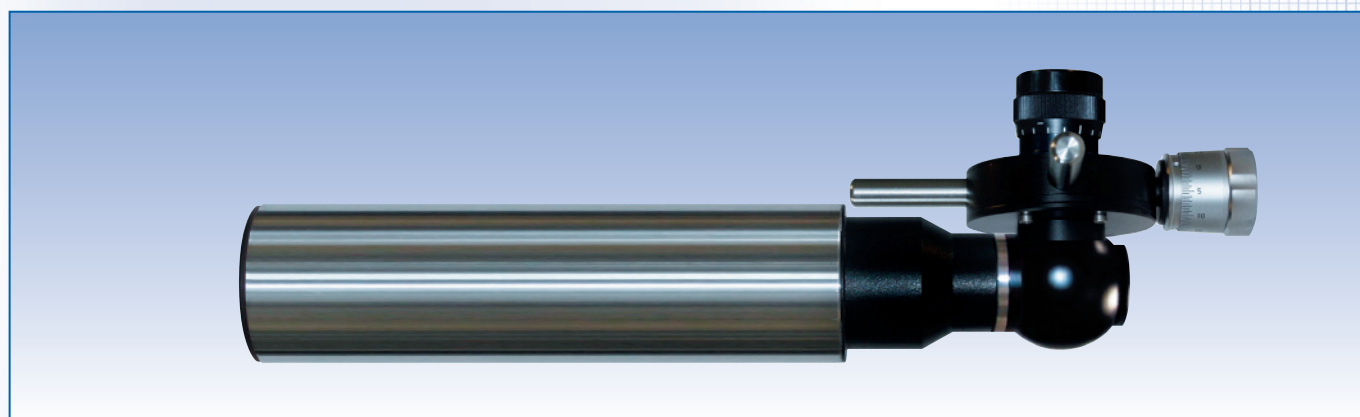
Testing telescope
90° viewing
Focal length
Tube diameter
Eyepiece focal length
Double micrometer

Important:

Please specify reticle (see page 82) when ordering.
Please specify direction of use if reticles with lettering (e.g. co-ordinate division etc.) are used so that the lettering will be right-side-up.



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	A	L
227 181	FR 50/40/14,7 MD	50	10	3,2°	20,0"	65	116,5
227 182	FR 90/40/14,7 MD	90	18	2,0°	11,5"	65	116,5
227 183	FR 140/40/14,7 MD	140	28	1,2°	7,5"	118	169,5
227 184	FR 200/40/14,7 MD	200	28	0,8°	5,0"	173	224,5
227 185	FR 300/40/14,7 MD	300	28	0,6°	3,5"	274	325,5
227 186	FR 500/40/14,7 MD	500	28	0,4°	2,0"	474	525,5



Ord.-No.	Description	Focal length	Free aperture	Meas. range	SD	A	L
227 187	FR 300/65/14,7 MD	300	50	0,6°	3,5"	233	346,0
227 188	FR 500/65/14,7 MD	500	50	0,4°	2,0"	415	528,0
227 189	FR 500T/65/14,7 MD	500	50	0,4°	2,0"	233	346,0



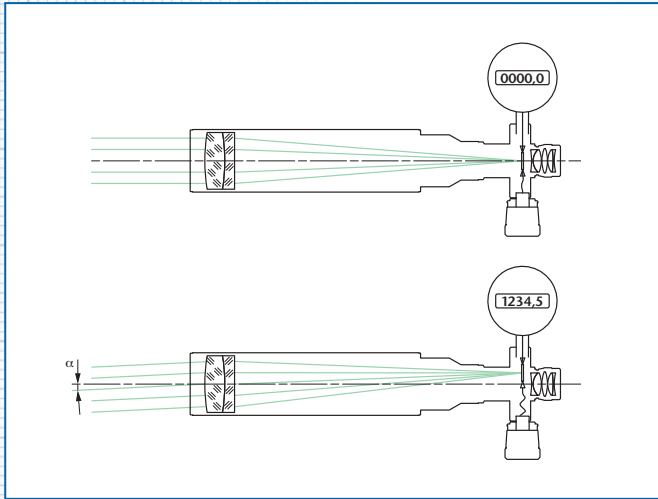
TESTING TELESCOPES

STRAIGHT VIEWING – WITH DIGITAL DOUBLE MICROMETER

Description:

For a general description of the operating principle of testing telescopes see page 20.

Testing telescopes with digital double micrometer allow the measurement of deflection angles in two directions. The programmable measuring gauges allow the operator to read the angular displacement in arcsec or mrad.



Notes on ordering:

- Testing telescope eyepiece is commonly $f=14,7$ mm but can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and one eyepiece are included in the standard instrument.
- If not specified otherwise, the testing telescope is adjusted to infinity at 546 nm wavelength. Adjustment to other distances or wavelengths is also possible on demand.
- Please specify the unit of reading (mm or arcsec or mrad) when ordering.
- The nomenclature of the testing telescopes with straight-viewing and digital double micrometer is as follows:

Example:

F G 50/ 40/ 14,7 MDD

Testing telescope
Straight viewing
Focal length
Tube diameter
Eyepiece focal length
Digital double micrometer

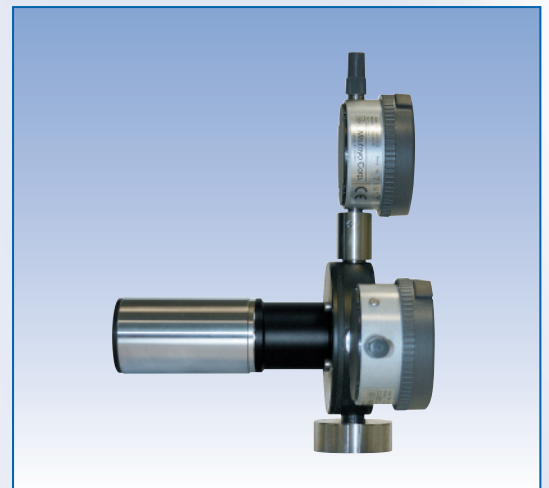
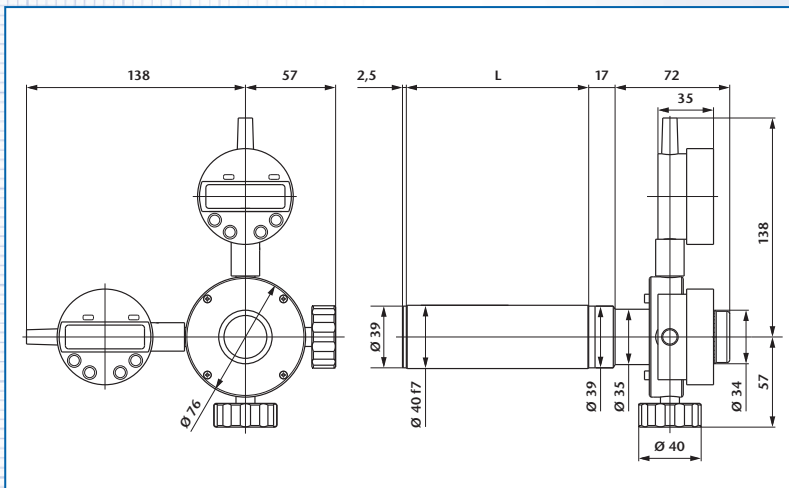
Application examples

(additional collimator required):

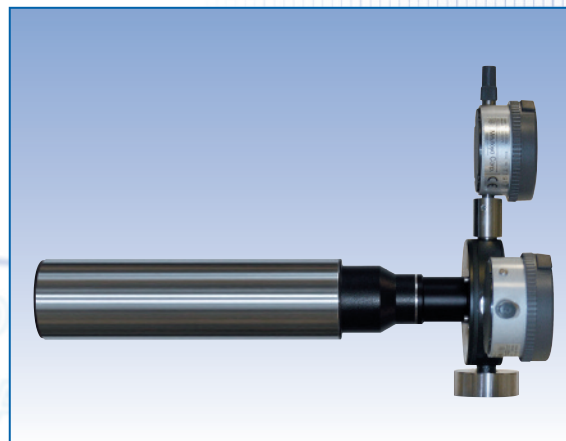
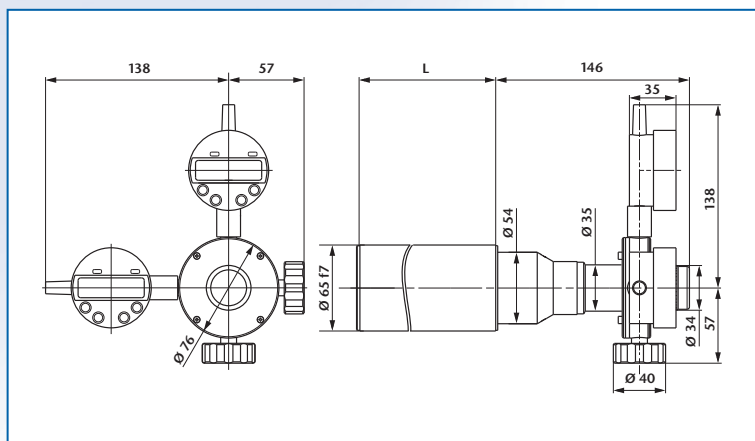
- Measurement of deflection angles
- Parallelism measurement of uncoated flats

Important:

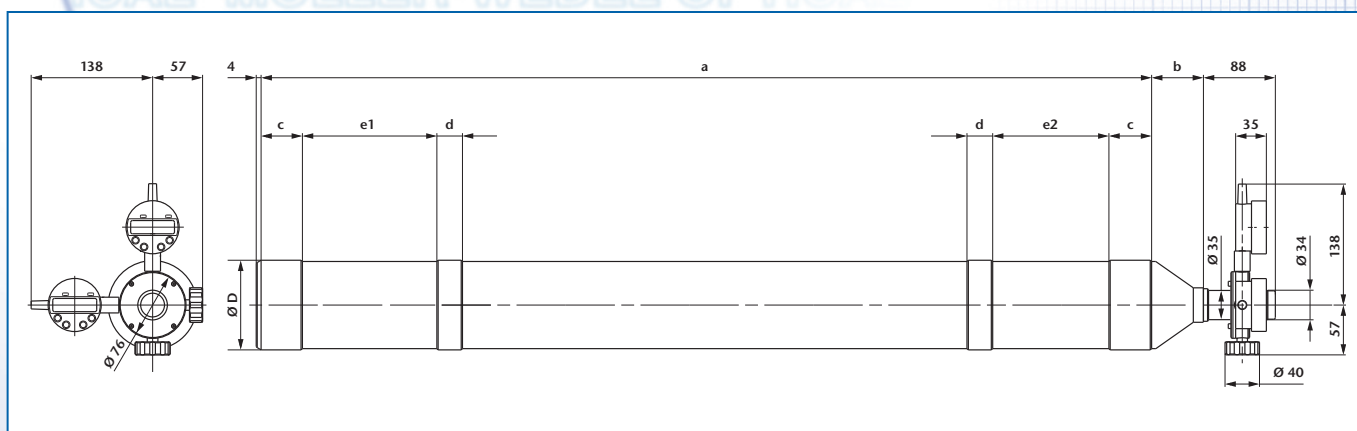
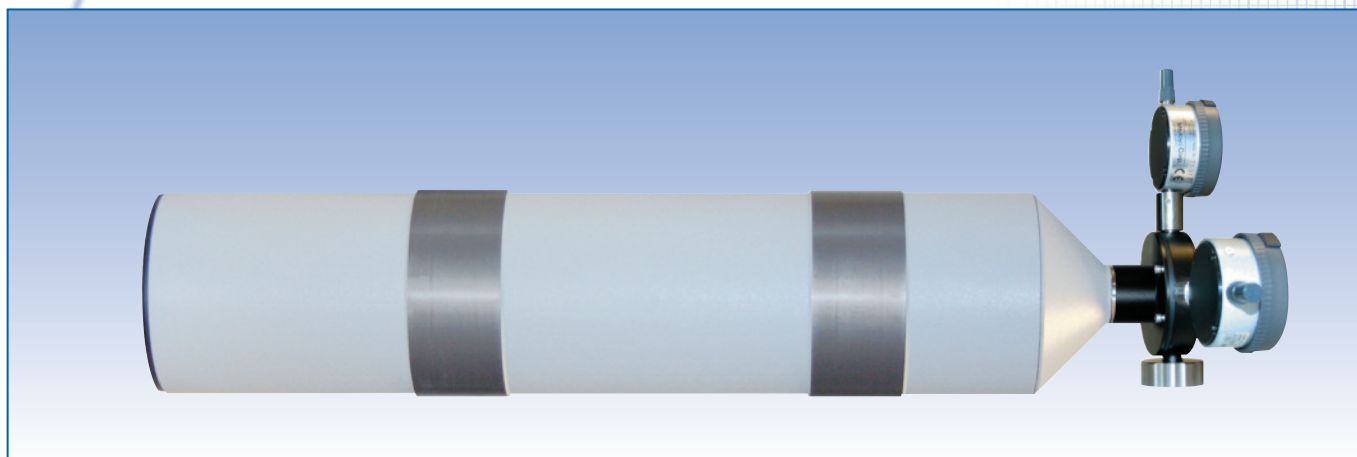
Please specify reticle (see page 82) when ordering.



Ord.-No.	Description	Focal length	Free aperture	Meas. range	Resolution	L
227 201	FG 50/40/14,7 MDD	50	10	5,6°	5,0"	65
227 202	FG 90/40/14,7 MDD	90	16	3,0°	5,0"	65
227 203	FG 140/40/14,7 MDD	140	28	2,0°	2,0"	118
227 204	FG 200/40/14,7 MDD	200	28	1,4°	2,0"	173
227 205	FG 300/40/14,7 MDD	300	28	1,0°	1,0"	274
227 206	FG 500/40/14,7 MDD	500	28	0,5°	0,5"	474



Ord.-No.	Description	Focal length	Free aperture	Meas. range	Resolution	L
227 207	FG 300/65/14,7 MDD	300	50	1,0°	1,0"	233
227 208	FG 500/65/14,7 MDD	500	50	0,5°	0,5"	415
227 209	FG 500T/65/14,7 MDD	500	50	0,5°	0,5"	233



Ord.-No.	Description	Focal length	Free aperture	Meas. range	Resolution	D	a	b	c	d	e1	e2
227 212	FG 600/128/14,7 MDD	600	100	0,40°	0,5"	Ø 128 f7	530	46	—	58	154	78
227 213	FG 1100/105/14,7 MDD	1100	78	0,24°	0,2"	Ø 105 f7	1045	66	50	30	165	100