

TESTING TELESCOPES

INTRODUCTION

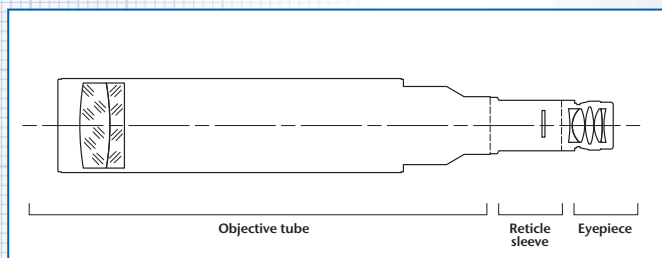
Layout and principle of operation

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

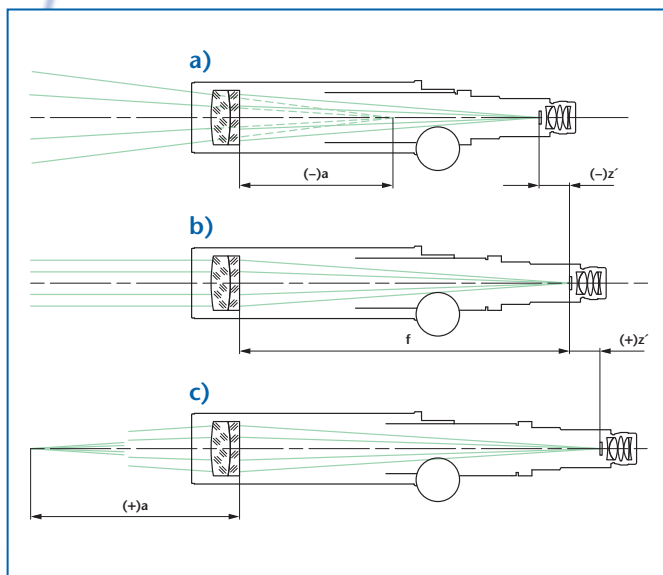
Besides testing telescopes with fixed distance between reticle and objective telescopes with adjustable focus are available. With these telescopes the distance between reticle and objective is adjustable.

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.

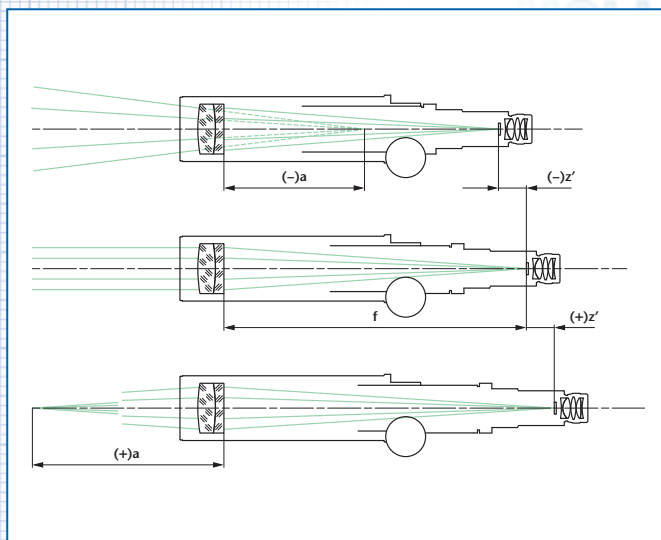
TESTING TELESCOPES

FOCUS ADJUSTABLE – WITH STRAIGHT VIEWING

Description:

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

An adjustable focus telescope allows the distance between reticle and telescope objective to be adjusted for measurements made at other than infinity. Additionally, infinity can be set for different wavelengths of light.



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.
- The nomenclature of the focus adjustable telescope with straight viewing is as follows:

Example:

F G V 90/ 40/ 14,7 ±6

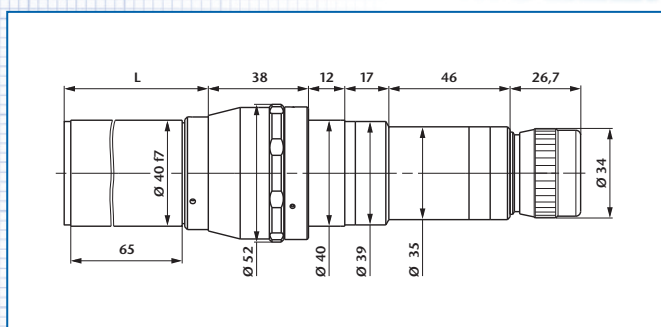
Testing telescope
Straight viewing
Variable
Focal length
Tube diameter
Eyepiece focal length
Tube extension in mm

Important:

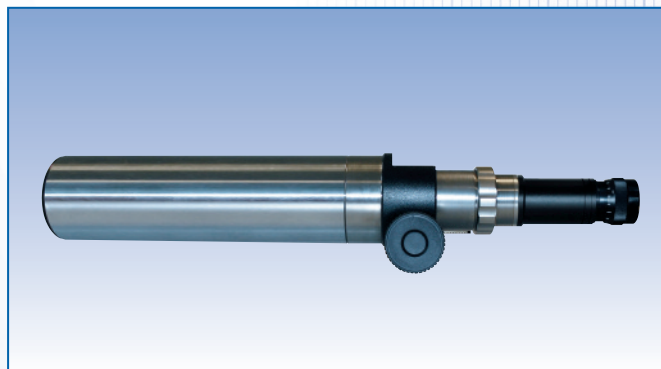
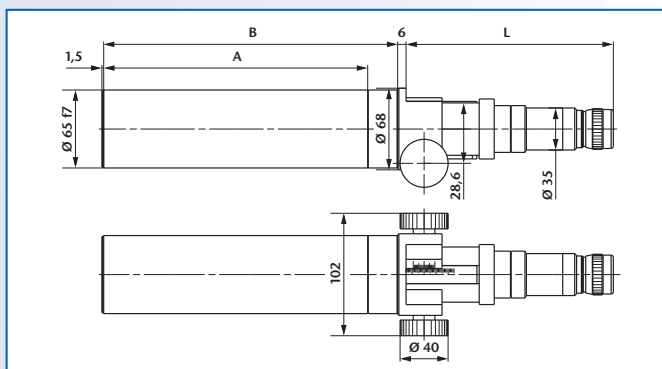
Please specify reticle (see page 82) when ordering.

Application examples:

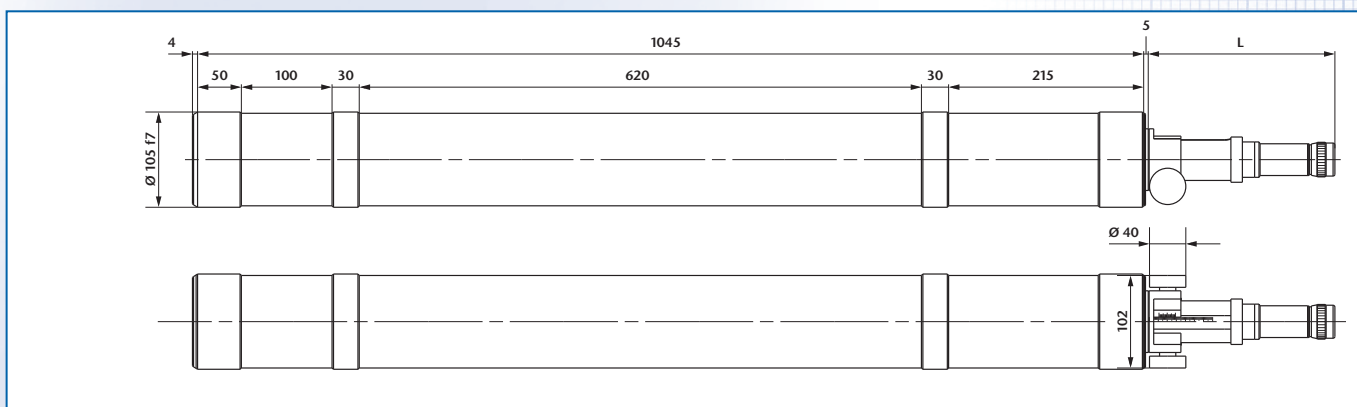
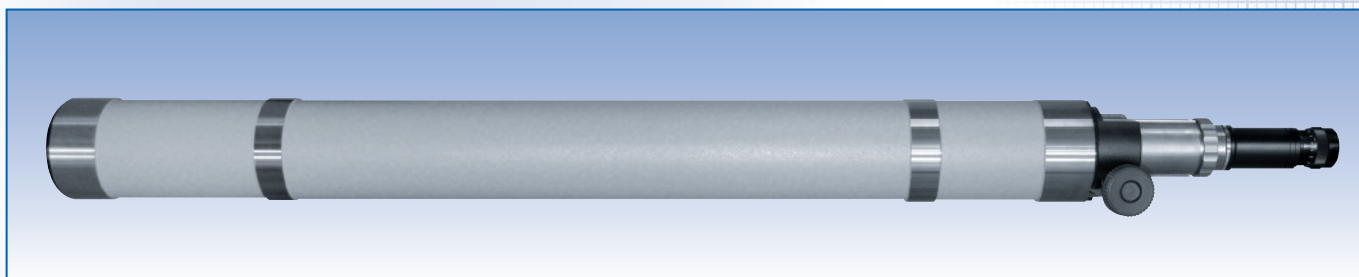
- Adjustment of optical and mechanical systems
- Qualitative testing of image quality of optical elements and systems (additional collimator required)
- Testing at different wavelengths of light



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	L
227 501	FGV 90/40/14,7/±6	90	16	±6	6,0°	-∞...-1,25 m 1,40 m...+∞	77±6
227 502	FGV 90/40/14,7/+12	90	16	+12	6,0°	0,80 m...+∞	71 ⁺¹²
227 503	FGV 90/40/14,7/-12	90	16	-12	6,0°	-∞...-0,60 m	83 ⁻¹²
227 504	FGV 140/40/14,7/±6	140	28	±6	4,0°	-∞...-3,10 m 3,30 m...+∞	77±6
227 505	FGV 140/40/14,7/+12	140	28	+12	4,0°	1,70 m...+∞	71 ⁺¹²
227 506	FGV 140/40/14,7/-12	140	28	-12	4,0°	-∞...-1,40 m	83 ⁻¹²



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	A	B	L
227 507	FGV 300/65/14,7/±25	300	50	±25	2,0°	−∞...−3,4 m 3,8 m...+∞	220	245	173±25
227 508	FGV 300/65/14,7/+50	300	50	+50	2,0°	2,1 m...+∞	220	270	148 ⁺⁵⁰
227 509	FGV 300/65/14,7/−50	300	50	−50	2,0°	−∞...−1,5 m	220	220	198 ^{−50}
227 510	FGV 500/65/14,7/±50	500	50	±50	1,0°	−∞...−4,5 m 5,4 m...+∞	310	360	198±50
227 511	FGV 500/65/14,7/+100	500	50	+100	1,0°	3,0 m...+∞	310	410	148 ⁺¹⁰⁰
227 512	FGV 500/65/14,7/−100	500	50	−100	1,0°	−∞...−1,5 m	310	310	248 ^{−100}



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	L
227 516	FGV 1100/105/14,7/±50	1100	78	±50	0,5°	−∞...−23,70 m 25,80 m...+∞	202±50
227 517	FGV 1100/105/14,7/+100	1100	78	+100	0,5°	13,20 m...+∞	202 ⁺¹⁰⁰
227 518	FGV 1100/105/14,7/−100	1100	78	−100	0,5°	−∞...−12,00 m	202 ^{−100}

TESTING TELESCOPES

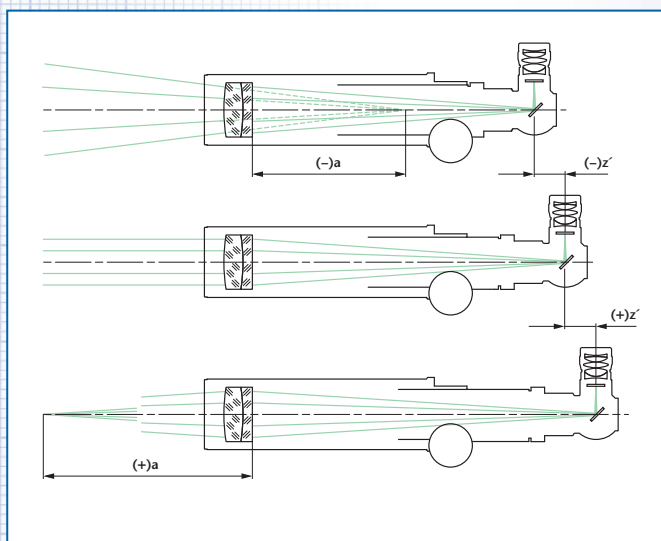
FOCUS ADJUSTABLE – WITH 90°-VIEWING

Description:

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

An adjustable focus telescope allows the distance between reticle and telescope objective to be adjusted for measurements made at other than infinity. Additionally, infinity can be set for different wavelengths of light.

The following figure shows the set-up of a focusable telescope with 90° viewing. In contrast to a telescope with straight viewing the image appears upright and laterally reversed.



Application examples:

- Adjustment of optical and mechanical systems
- Qualitative testing of image quality of optical elements and systems (additional collimator required)
- Testing at different wavelengths of light

Notes on ordering:

- 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 instrument.
- The nomenclature of the focus adjustable testing telescopes with 90°-viewing is as follows:

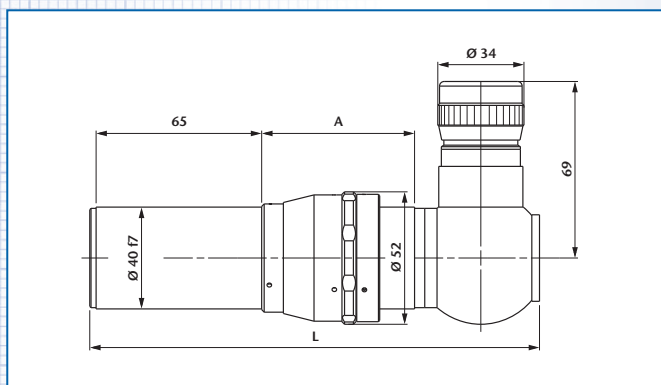
Example:

FRV 90/40/14,7 ±6

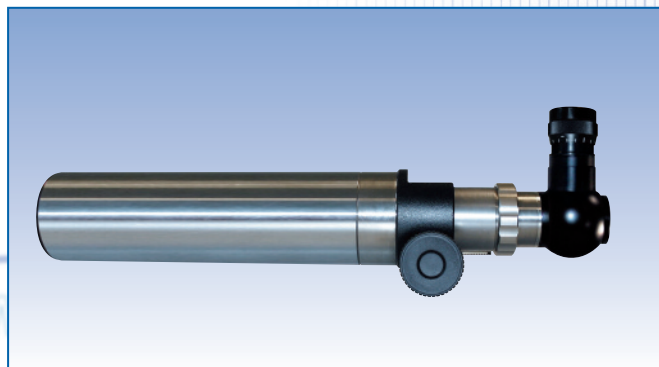
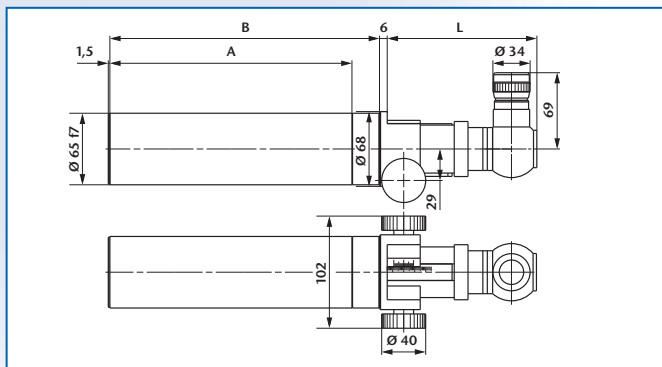
Testing telescope
90° viewing
Variable
Focal length
Tube diameter
Eyepiece focal length
Tube extension in mm

Important:

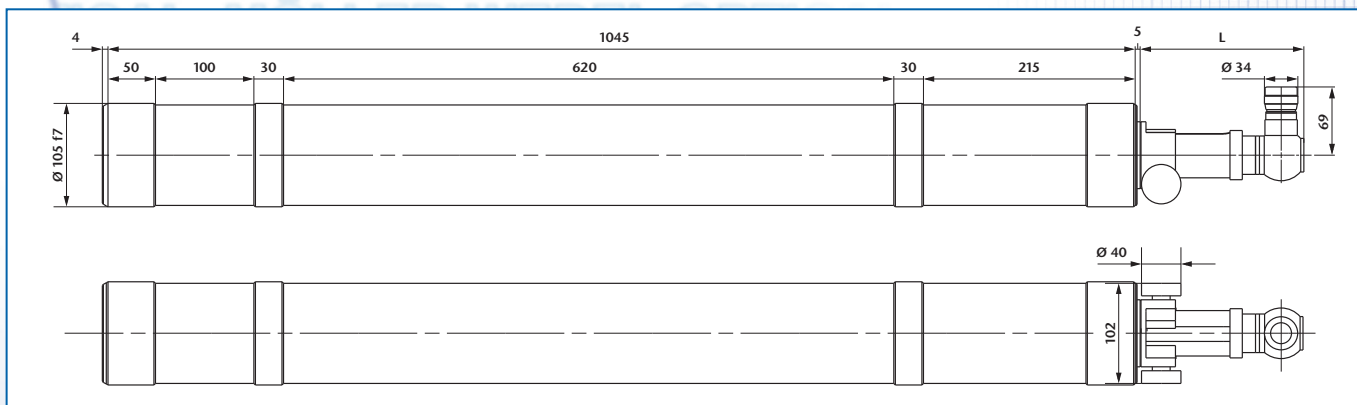
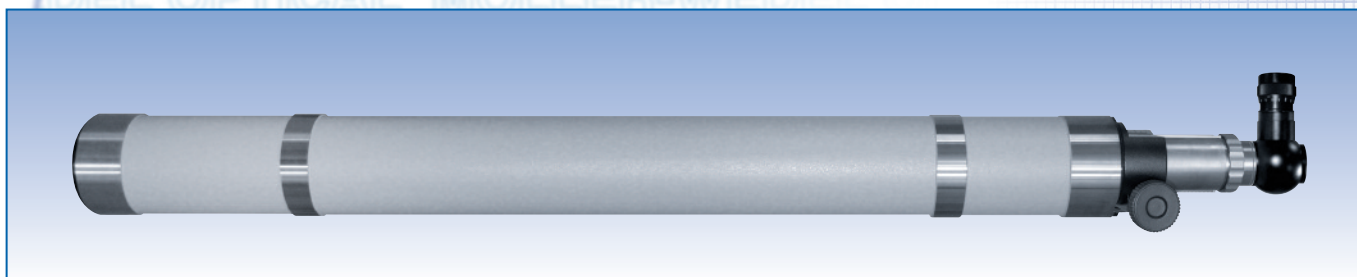
Please specify reticle (see page 82) when ordering.
Please specify direction of use if reticles with lettering are used so that the lettering will be right-side-up.



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	A	L
227 541	FRV 90/40/14,7/±6	90	16	±6	6,0°	−∞...−1,25 m 1,40 m...+∞	60±6	176,5±6
227 542	FRV 90/40/14,7/+12	90	16	+12	6,0°	0,80 m...+∞	54 ⁺¹²	170,5 ⁺¹²
227 543	FRV 90/40/14,7/−12	90	16	−12	6,0°	−∞...−0,60 m	66 ^{−12}	182,5 ^{−12}
227 544	FRV 140/40/14,7/±6	140	28	±6	4,0°	−∞...−3,10 m 3,30 m...+∞	60±6	176,5±6
227 545	FRV 140/40/14,7/+12	140	28	+12	4,0°	1,70 m...+∞	54 ⁺¹²	170,5 ⁺¹²
227 546	FRV 140/40/14,7/−12	140	28	−12	4,0°	−∞...−1,40 m	66 ^{−12}	182,5 ^{−12}



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	A	B	L
227 547	FRV 300/65/14,7/±25	300	50	±25	2,0°	−∞...−3,4 m 3,8 m...+∞	220	245	140±25
227 548	FRV 300/65/14,7/+50	300	50	+50	2,0°	2,1 m...+∞	220	270	115 ⁺⁵⁰
227 549	FRV 300/65/14,7/−50	300	50	−50	2,0°	−∞...−1,5 m	220	220	165 _{−50}
227 550	FRV 500/65/14,7/±50	500	50	±50	1,0°	−∞...−4,5 m 5,4 m...+∞	310	360	165±50
227 551	FRV 500/65/14,7/+100	500	50	+100	1,0°	3,0 m...+∞	310	410	115 ⁺¹⁰⁰
227 552	FRV 500/65/14,7/−100	500	50	−100	1,0°	−∞...−1,5 m	310	310	215 _{−100}



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Field of view	Distance range	L
227 556	FRV 1100/105/14,7/±50	1100	78	±50	0,5°	−∞...−23,70m 25,80 m...+∞	161±50
227 557	FRV 1100/105/14,7/+100	1100	78	+100	0,5°	13,20 m...+∞	161 ⁺¹⁰⁰
227 558	FRV 1100/105/14,7/−100	1100	78	−100	0,5°	−∞...−12,00 m	161 _{−100}

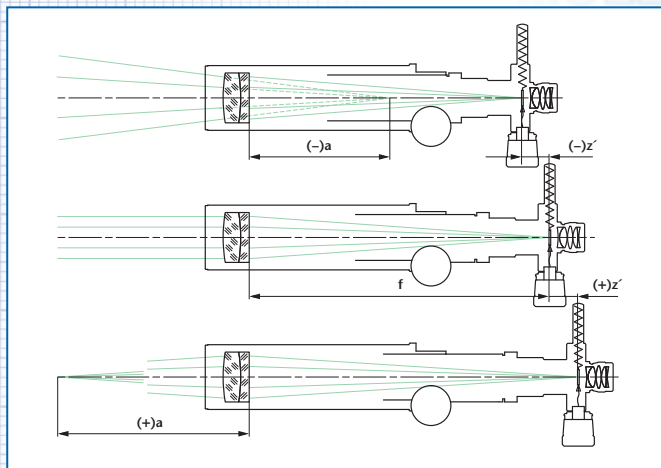
TESTING TELESCOPES

FOCUS ADJUSTABLE – STRAIGHT VIEWING WITH DOUBLE

Description:

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

An adjustable focus telescope with mechanical double micrometer allows the distance between reticle and telescope objective to be adjusted for measurements made at other than infinity. Additionally, infinity can be set for different wavelengths of light. The scale division (SD) of the micrometer drums is 5 μm .



Notes on ordering:

- 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 instrument.
- The nomenclature of the focus adjustable testing telescopes with straight viewing and mechanical double micrometer is as follows:

Example:

F G V 90/ 40/ 14,7 ± 6 MD

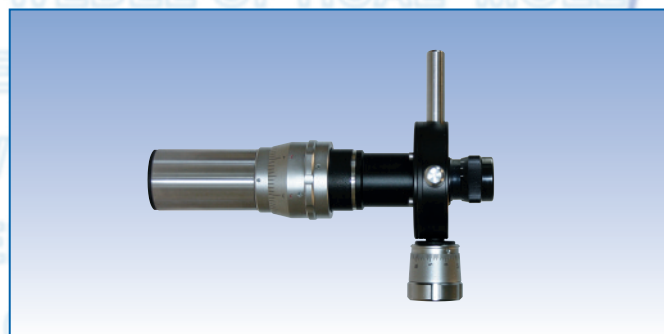
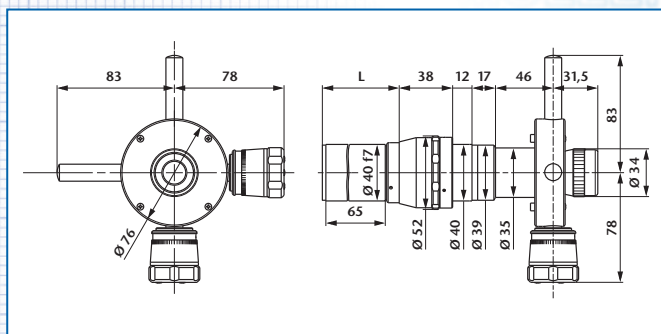
Testing telescope
Straight viewing
Variable
Focal length
Tube diameter
Eyepiece focal length
Tube extension in mm
Double micrometer

Important:

Please specify reticle (see page 82) when ordering.

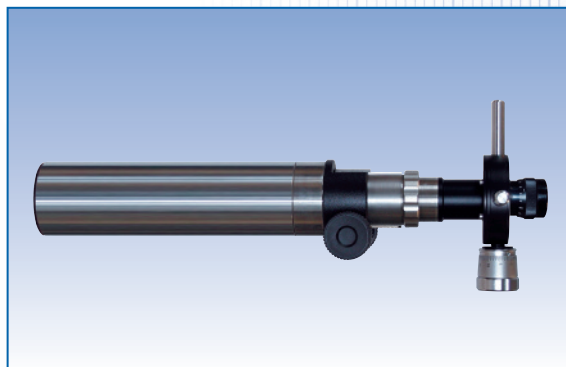
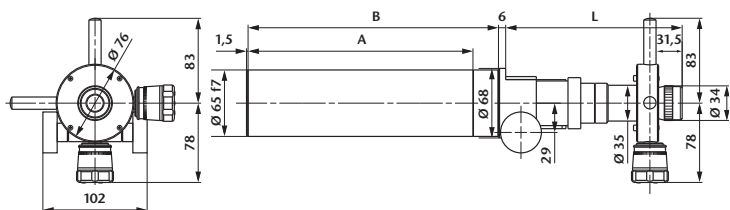
Application examples:

- Adjustment of optical and mechanical systems
- Qualitative testing of image quality of optical elements and systems (additional collimator required)
- Testing at different wavelengths of light
- Measurement of deflection angles (add. collimator required)

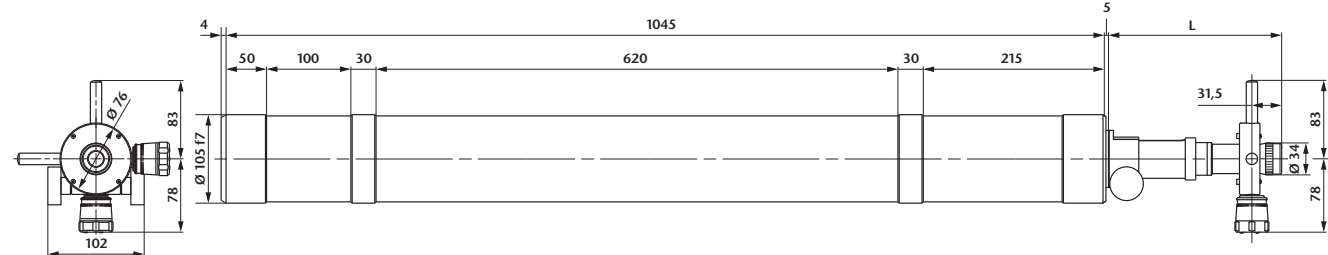
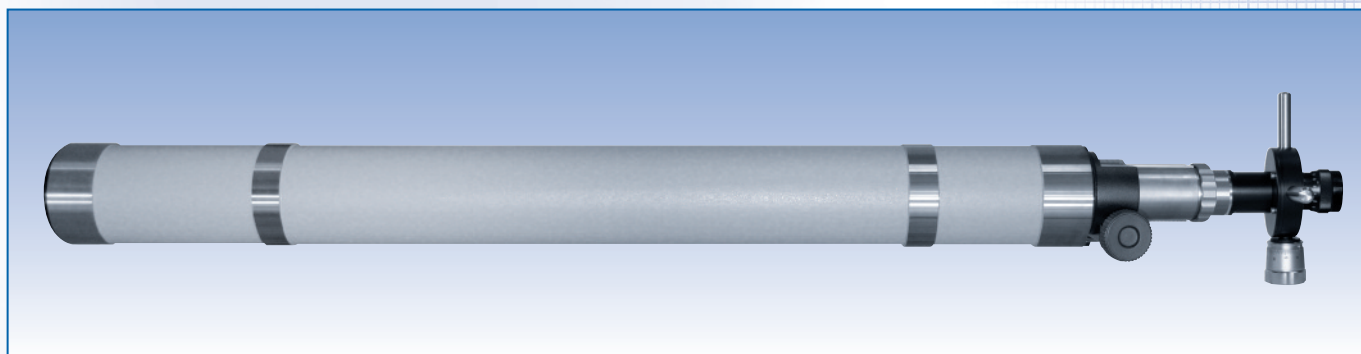
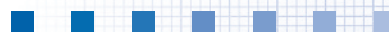


Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	SD	Distance range	L
227 661	FGV 90/40/14,7/ ± 6 MD	90	16	± 6	2,0°	11,5"	$-\infty \dots -1,25$ m 1,40 m... $+\infty$	77 ± 6
227 662	FGV 90/40/14,7/+12 MD	90	16	+12	2,0°	11,5"	0,80 m... $+\infty$	71 $^{+12}$
227 663	FGV 90/40/14,7/-12 MD	90	16	-12	2,0°	11,5"	$-\infty \dots -0,60$ m	83 $_{-12}$
227 664	FGV 140/40/14,7/ ± 6 MD	140	28	± 6	1,2°	7,5"	$-\infty \dots -3,10$ m 3,30 m... $+\infty$	77 ± 6
227 665	FGV 140/40/14,7/+12 MD	140	28	+12	1,2°	7,5"	1,70 m... $+\infty$	71 $^{+12}$
227 666	FGV 140/40/14,7/-12 MD	140	28	-12	1,2°	7,5"	$-\infty \dots -1,40$ m	83 $_{-12}$

MICROMETER



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	SD	Distance range	A	B	L
227 667	FGV 300/65/14,7/±25 MD	300	50	±25	0,6°	3,5"	−∞...−3,4 m 3,8 m...+∞	220	245	173±25
227 668	FGV 300/65/14,7/+50 MD	300	50	+50	0,6°	3,5"	2,1 m...+∞	220	270	148 ⁺⁵⁰
227 669	FGV 300/65/14,7/−50 MD	300	50	−50	0,6°	3,5"	−∞...−1,5 m	220	220	198 _{−50}
227 670	FGV 500/65/14,7/±50 MD	500	50	±50	0,4°	2,0"	−∞...−4,5 m 5,4 m...+∞	310	360	198±50
227 671	FGV 500/65/14,7/+100 MD	500	50	+100	0,4°	2,0"	3,0 m...+∞	310	410	148 ⁺¹⁰⁰
227 672	FGV 500/65/14,7/−100 MD	500	50	−100	0,4°	2,0"	−∞...−1,5 m	310	310	248 _{−100}

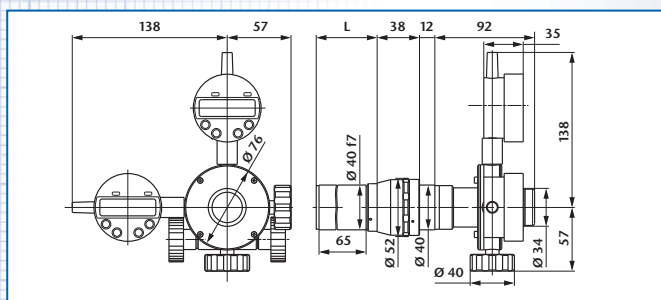
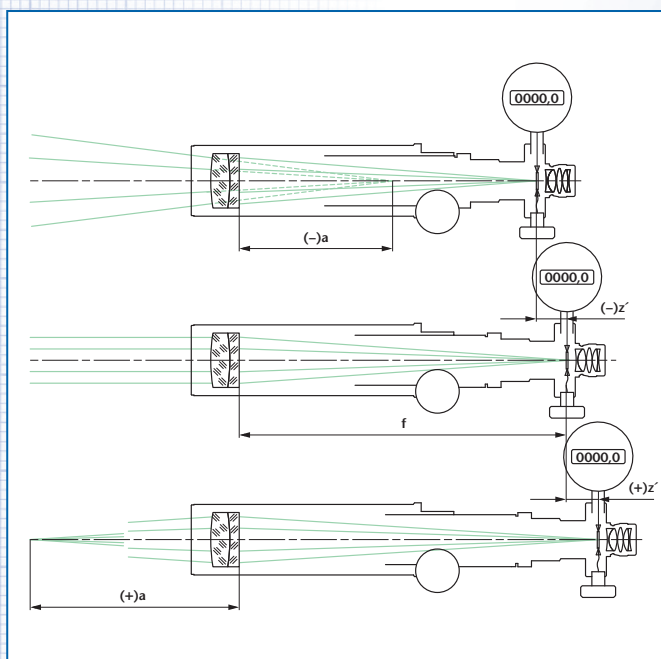


Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	SD	Distance range	L
227 676	FGV 1100/105/±50 MD	1100	80	±50	0,16°	1,0"	−∞...−23,70 m 25,80 m...+∞	202±50
227 677	FGV 1100/105/+100 MD	1100	80	+100	0,16°	1,0"	13,20 m...+∞	202 ⁺¹⁰⁰
227 678	FGV 1100/105/−100 MD	1100	80	−100	0,16°	1,0"	−∞...−12,00 m	202 _{−100}

Description:

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

An adjustable focus telescope with digital double micrometer allows the distance between reticle and telescope objective to be adjusted for measurements made at other than infinity. Additionally, infinity can be set for different wavelengths of light. The programmable digital gauges of the telescope allow the operator to read directly angular displacement in arcsec or mrad.



Application examples:

- Adjustment of optical and mechanical systems
- Measurement of big radii of curvature (additional collimator required)
- Adjustment for different wavelengths of light
- Measurement of deflection angles (additional collimator required)

Notes on ordering:

- Testing telescopes can be equipped with eyepieces $f=25$ mm or $f=10$ mm on request.
- One reticle and eyepiece are included in the instrument.
- Please specify the unit of reading (mm or arcsec or mrad) when ordering.
- The nomenclature of the adjustable testing telescopes with straight viewing and digital double micrometer is as follows:

Example: F G V 90/ 40/ 14,7 ±6 MDD

Testing telescope

Straight viewing

Variable -

Focal length

Tube diameter

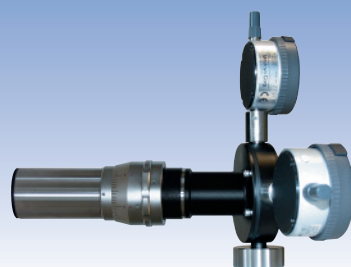
Eyepiece focal length

Tube extension in mm

Digital double micrometer

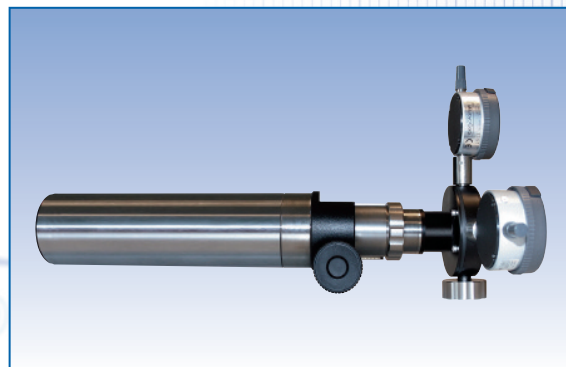
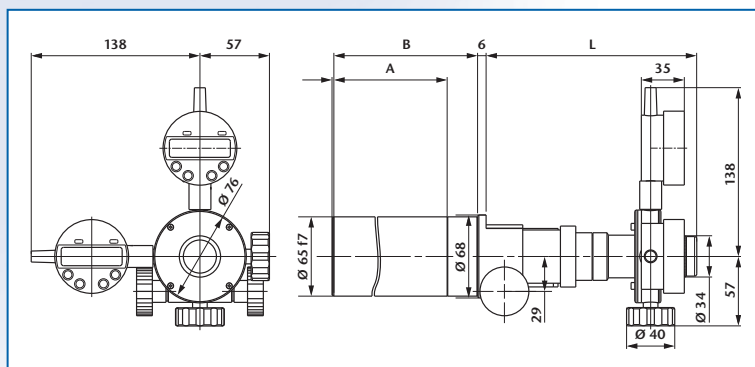
Important:

Please specify reticle (see page 82) when ordering.

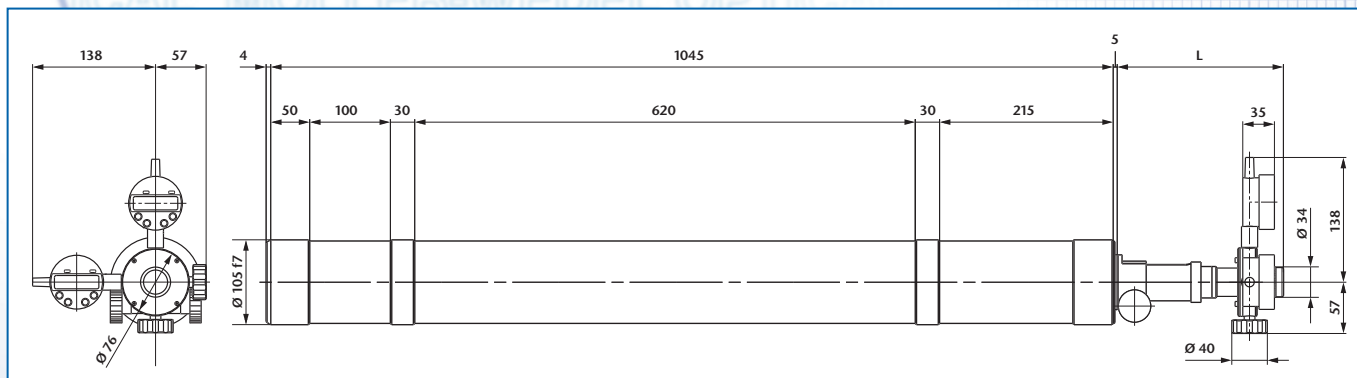
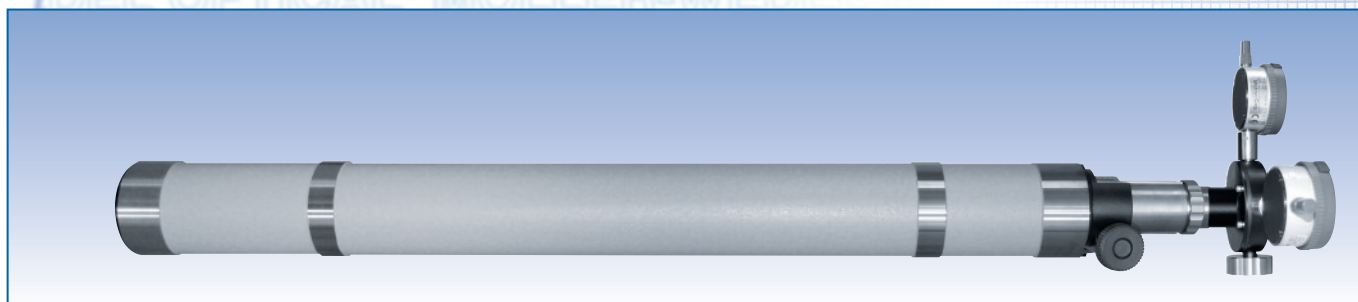


Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	Resolution	Distance range	L
227 681	FGV 90/40/14,7/±6 MDD	90	16	±6	6,0°	5,0"	−∞...−1,25 m 1,40 m...+∞	77±6
227 682	FGV 90/40/14,7/+12 MDD	90	16	+12	6,0°	5,0"	0,80 m...+∞	71 ⁺¹²
227 683	FGV 90/40/14,7/−12 MDD	90	16	−12	6,0°	5,0"	−∞...−0,60 m	83 ^{−12}
227 684	FGV 140/40/14,7/±6 MDD	140	28	±6	4,0°	2,0"	−∞...−3,10 m 3,30 m...+∞	77±6
227 685	FGV 140/40/14,7/+12 MDD	140	28	−12	4,0°	2,0"	1,70 m...+∞	71 ^{−12}
227 686	FGV 140/40/14,7/−12 MDD	140	28	−12	4,0°	2,0"	−∞...−1,40 m	83 ^{−12}

MICROMETER



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	Resolution	Distance range	A	B	L
227 687	FGV 300/65/14,7/±25 MDD	300	50	±25	1,0°	0,5"	-∞...-3,4 m 3,8 m...+∞	220	245	140±25
227 688	FGV 300/65/14,7/+50 MDD	300	50	+50	1,0°	0,5"	2,1 m...+∞	220	270	115 ⁺⁵⁰
227 689	FGV 300/65/14,7/-50 MDD	300	50	-50	1,0°	0,5"	-∞...-1,5 m	220	220	165 ₋₅₀
227 690	FGV 500/65/14,7/±50 MDD	500	50	±50	0,5°	0,2"	-∞...-4,5 m 5,4 m...+∞	310	360	165±50
227 691	FGV 500/65/14,7/+100 MDD	500	50	+100	0,5°	0,2"	3,0 m...+∞	310	410	115 ⁺¹⁰⁰
227 692	FGV 500/65/14,7/-100 MDD	500	50	-100	0,5°	0,2"	-∞...-1,5 m	310	310	215 ₋₁₀₀



Ord.-No.	Description	Focal length	Free aperture	Tube extension	Meas. range	Resolution	Distance range	L
227 696	FGV 1100/105/14,7/±50 MDD	1100	78	±50	0,5°	0,1"	-∞...-23,7 m 25,8 m...+∞	161±50
227 697	FGV 1100/105/14,7/+100 MDD	1100	78	+100	0,5°	0,1"	13,2 m...+∞	161 ⁺¹⁰⁰
227 698	FGV 1100/105/14,7/-100 MDD	1100	78	-100	0,5°	0,5"	-∞...-12,0 m	161 ₋₁₀₀