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to the readers
of the Jena Review
our best wishes
for peace,
happiness and personal
well-being in 1970.
The Staff of
the JENA Optical Works

1970

Telescopes from the Optical Museum of the C... Z.... Foundation JENA

Manfred Steinbach

The Optical Museum of the C...-Z....-Stiftung in Jena is assumed to be the most extensive one in the world with regard to the number of its collections. More than 12000 historical items are on exhibit; they are continuously supplemented by accessions and donations from all countries.

About 4000 spectacles from the 14th century up to the present days indicate the development of this most important aid to vision, supposed to be the first optical instrument of history. Some 150 reading magnifiers and loupes complement this collection. 800 microscopes, made by the most prominent European and American workshops, demonstrate the history of this scientific instrument which, only by the achievements of C... Z.... and Ernst Abbe, has attained the high standard for research, tuition and control, by which it is generally appreciated today in scientific and engineering circles. 850 telescopes (astronomical telescopes, hand telescopes, field glasses etc.) clearly show men's endeavours to penetrate the narrowness of the Earth's surroundings and to advance into the vastness of the universe. Terrestrial and celestial globes, compasses, sun dials, surveying instruments from the very beginning up to our days complete the collection of this part of the museum. Optical systems and their application in medical research, diagnosis and therapy are displayed in well over 350 instruments, 200 of which are ophthalmological instruments for use in ophthalmologists' practices and in eye hospitals. 125 historical opto-physical measuring instruments give a good insight into the development and use of opto-physical measuring and analysis methods in inorganic and organic chemistry, in foodstuff and table luxuries research and control, in medicine, metallography, mineralogy etc. It goes without saying that the history of photolenses and cameras is presented from the very beginning, for it was in Jena, where the first scientically computed and designed photolenses were made. From here they started their uninterrupted triumphal advance round the world. The collection of the Optical Museum of the C...-Z....-Stiftung in Jena is completed by additional instrument groups and single instruments, including valuable lamps, paintings, graphic arts hostorical documents, pictures, photographs and more than 900 books on the subject of optics and natural sciences. Same as in the supplement to volume 6/1968 of this journal, we also publish in the supplement to volume 6/1969 a number of reports on instrument groups and individual instruments. We hope that also these reports will meet with the same approval and interest on the part of our readers as in the previous year.

The Editor

The collection of the Optical Museum in JENA contains a number of valuable and interesting historical telescopes with apertures up to approximately 80 mm diameter. We are mentioning a reflecting tescope of the GREGORY design made by JAMES SHORT (Figure 1), and two achromatic telescopes by FRAUNHOFER (Figure 3, p. 5, and Figure 4, p. 6).

We have selected for discussion another **reflecting telescope** which has the inscription "NAIRNE & BLUNT · LONDON" and was probably manufactured around 1780 (see also Table 1, pp. 8 and 9).

It is a reflecting telescope of the GREGORY type with a primary mirror with a hole in the centre and a small concave secondary mirror completed by an eyepiece of the HUYGENS type. The optical data are: Primary mirror f = 225 mm and 64 mm∅ (59 mm clear), secondary mirror f = 38.5 mm and 16 mm∅ (14.1 mm clear), eyepiece f = 41 mm, field lens f = 72 mm and 21.3 mm∅, eyelens f = 35 mm and 12.4 mm clear ∅, total focal length of the telescope = 1640 mm, overall magnification 40×.

The first inspection resulted in a surprisingly good condition of the optical surfaces. Especially the primary mirror showed no defects with the exception of a very sligth grey coating and some brownish stains and numerous small pits (see also Figures 6 and 7, p. 9), contrary to the telescope made by SHORT (Figure 1), the mirror of which has such a thick brown coating that optical tests cause difficulties.

The surface mirrors at that time were always massive metal mirrors as a method for "applying" reflecting coatings – for instance on glass bases – was not yet known and almost exclusively bronze containing a high tin content was used. La LANDE [3] gives the following formulae:

2 parts copper, 1 part brass, 1 part tin (after HADLEY, approximately 1720)

20 parts copper, 9 parts tin, 8 parts arsenic (after PASSEMENT, 1738)

32 parts copper, 15 parts tin, 1 part brass, 1 part silver, 1 part arsenic (after EDWARDS, 1787).

Furthermore, ISAAC NEWTON had published as long ago as 1671 an alloy consisting of 6 parts copper, 2 parts tin and 1 part arsenic [1].

The NAIRNE mirror was at first subjected to a Vickers hardness test and the surprisingly high value of H_V = 420 kg/mm² was ascertained. This gave rise to doubt, whether the mirror consists actually of the usual tin bronze as, for instance, for modern spring bronze as well as for soft tin bell bronze H_V values around 200 kg/mm² are typical. The spectrochemical analysis provided then the result that copper and tin are the main constituents and a few per cent of zinc added, furthermore, approximately 1% of lead. The other elements found in addition may be impurities: Fe, Mn, Si, Al, Ag, Ca, Bi, As, Ti (in the sequence of the quantitative proportion). The conclusion may be drawn that NAIRNE has based his mirror casting approximately on the formula suggested by HADLEY.

After the visual observation with the entire telescope had confirmed the good optical quality of the system, the primary mirror was still subjected to a separate optical test by observing an artificial star usinga FOUCAULT knife-edge (Figures 6 and 7, p. 9). In Fig. 6, the mirror is tested in the same way as a spherical reflector viz.: from the centre of curvature. A slight cambering towards the marginal zone is clearly recognizable. Fig. 7 shows that parallel light is incident on the mirror. With the exception of very small local brightenings, which originate from surface deficiencies, no zonal aberrations can be detected. The measurements confirm the excellent optical quality of the optical surface: the mirror is free from zones and represents an almost perfect paraboloid.

This result is all the more surprising, as with metal mirrors the danger of subsequent slight deformation exists and as, furthermore, at that time no reliable testing methods for the shape of the mirror existed, except the direct stellar observation. One can only admire nowadays the knowledge and the experience of the opticians of that time, who were able to draw only from the observed stellar images the correct conclusions for the further polishing process.

Mechanical design of the telescope is illustrated in Figure 5 (p. 9). The tube is a hard-soldered brass tube, which at least on the outside has to be very cleanly finished. RIEKHER [1] writes about the manufacture of such brass tubes, that "brass sheet was bent to form a suitable cylinder and was soldered with hard solder. Then the tube was drawn over a polished steel mandrel to give it exact shape and to strengthen it. For this purpose usually a vertically designed drawing bench was used, consisting of a very stable wooden stand. The mandrel with the brass tube slipped on and fixed by bending the end over the top, was drawn upwards with a long chain through gauging rings of hardened steel. After each drawing process, a ring smaller by a few tenths of a millimetre was used. The working process was repeated three to six times. Thus the surface of the tubes became work-hardened. They adapted themselves accurately to the mandrel and also became longer by several per cent. The soldering seam of such drawn tubes is no longer discernable, so that one could believe them to be seamless. In order to get the tube off the mandrel again, this has to be very slightly conical. The mandrel was then pulled in the reverse direction through a fixed ring of bell metal, which had to be so narrow that the tube did not pass through as well. Therefore, the tubes are outside accurately cylindrical and only inside slightly conical . . ."

Also NAIRNE must have used this or a similar method: whilst the hardness of the flat turned parts of his instrument ranges around H_V = 60···65 kg/mm², the tubes are reinforced by cold forming to H_V = 125···130 kg/mm² and the tube is conical by approximately 1.5 mm. It is obvious from the design that NAIRNE has kept strictly to the shapes used already in the thirties of the 18th century, for instance by SHORT (Figure 8). The mirror is pressed by a three-piece

Figure 1:
A reflecting telescope from the workshop
of JAMES SHORT (Edinburgh, subsequently London) made in 1735.
Optically this is a GREGORY
system with concave secondary mirror.
The secondary mirror as well as the primary mirror
with center hole consist of massive speculum metal.
The tube is made of cardboard
and mounted in brass end rings.
The heavy base ensures a stable position
of the instrument



Figure 2:
Photograph of
the telescope
by NAIRNE & BLUNT
described in detail
in the text.
It is the work
from the climax
of English
precision
mechanics



Figure 3:
An achromatic
lens telescope
on a small
azimuthal mounting
manufactured in Benediktbeuren
by UTZSCHNEIDER
and FRAUNHOFER.
The equipment may
have been manufactured
around 1815



Figure 4:
FRAUNHOFER achromatic telescope on equatorial mounting with graduated circles and clamps.
The tube is made of wood.
Year of manufacture, approximately 1820

Figure 5:
Sectional drawing of the NAIRNE & BLUNT telescope



spring (4 in Figure 5, p. 7, T in Figure 8, p. 9) to the edge of its mounting, but does not lie there in a definite manner on three points but makes contact over the entire circumference. The mounting of the secondary mirror is connected via a single arm (6 in Figure 5, Q in Figure 8) with a dovetail piece (5 in Figure 5, RS in Figure 8), and this dovetail is moved by a threaded spindle (8 in Figure 5) and a travelling nut (7 in Figure 5, E in Figure 8). This nut is pushed through a hole of the dovetail and held by a fork-shaped leaf spring (9 in Figure 5, 10 in Figure 8). The focusing can now be effected by a knurled knob close to the end of the eyepiece (10 in Figure 5, P in Figure 8). The method of the multiple seating of the spindle as well as the badly defined contact of the dovetail on the inside wall of the tube may be regarded as a shortcoming, as it is the cause for stiff and irregular movement of the spindle.

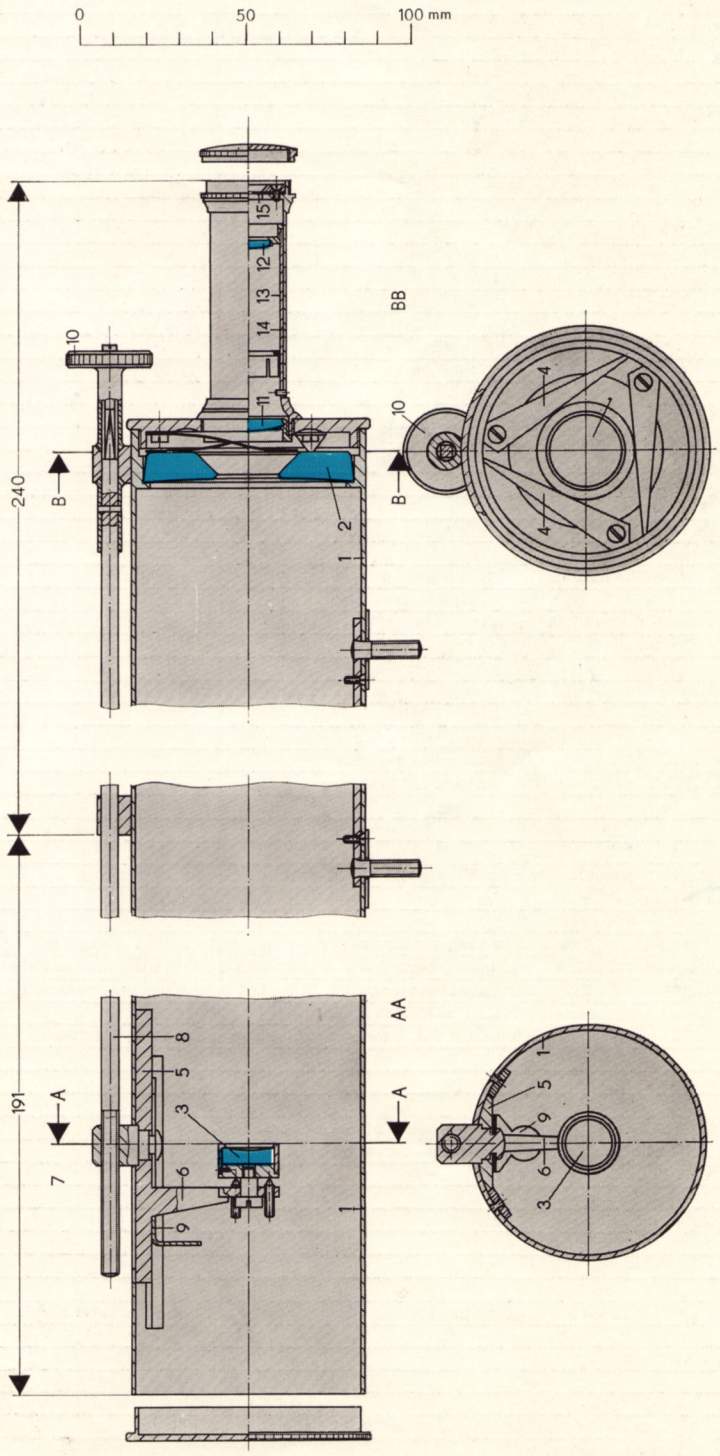
In the eyepiece, field lens (11 Figure 5) and eye lens (**12** Figure 5) are mounted in a rabbet and these mountings are screwed into the inside eyepiece tube (13 Figure 5). An outer shiftable eyepiece tube (14 Figure 5) carries a diaphragm which is adjustable at right angles to the optical axis (15 Figure 5), which should correspond to the exit pupil and which is intended to withhold disturbing extraneous light.

The adjusting devices are, as can be recognised, somewhat impracticable and effect the odd eyepiece design, but fulfilling after all adequately their purpose.

An overall evaluation is bound to describe the NAIRNE equipment as a masterpiece of English precision mechanics of the 18th century, which especially in its optical quality is hardly surpassed by modern equipment of corresponding size.

(I express my thanks for their assistance in this study to my colleagues GRIMM, PFAFF and Dr. SONNEFELD.)

Literature: [1] RIEKHER, R.: Telescopes and their masters. Berlin: Verlag Technik (1967). [2] SONNEFELD, A.: The concave mirror. Berlin: Verlag Technik and Stuttgart: Berliner Union (1957). [3] La LANDE: Astronomy. Part 2. Paris: Didot (1792). [4] REPSOLD, J. A.: On the history of the astronomical measuring tools. Vol. 1. Leipzig: WILH. ENGELMANN (1908).



1680	Time table – The asterisks in front of the date of the year denotes the year, in which the telescopes, shown in Figs. 1 to 4, are produced.
1	
2	
3	
4	
85	
6	OTTO v. GUERICKE †
7	JOHANN HEVEL †
8	
9	
1690	
1	
2	
3	JAMES BRADLEY *
4	
95	CHRISTIAN HUYGENS †
6	
7	
8	
9	
1700	
1	
2	
3	ROBERT HOOKE †
4	CHESTER MOOR HALL *. In London NEWTON's "Optics" are published
05	
6	JOHN DOLLOND *
7	LEONHARD EULER *
8	
9	
1710	JAMES SHORT *. OLAF RÖMER †
1	
2	G. D. CASSINI †
3	
4	
15	
6	
7	
8	G. D. FAHRENHEIT invents the mercury thermometer
9	JOHN HADLEY commences the building of telescopes
1720	
1	
2	
3	JOHN HADLEY submits to the Royal Society a 15 cm reflecting telescope for testing
4	IMMANUEL KANT *
25	
6	GRAHAM introduces temperature compensation in pedulum clocks by means of mercury
7	ISAAC NEWTON †. Discovery of the light sensitivity of silver salts by J. H. SCHULZE in Halle
8	SAMUEL MOLYNEUX (Manufacturer of telescopes) †. BRADLEY determines the speed of light from the aberration of the stellar light
9	Experiments on achromasy by CHESTER MOOR HALL
1730	PETER DOLLOND *. CHESTER MOOR HALL designs in London the first achromatic telescope without, however, publishing his invention
1	
2	
3	
4	JAMES SHORT manufactures telescope mirrors in larger numbers
35	JESSE RAMSDEN*. HARRISON builds the first portable chronometer
6	J. L. LAGRANGE *. JAMES WATT *
7	
8	F. W. HERSCHEL *
9	
1740	
1	
2	JAMES SHORT builds a telescope with 550 mm mirror diameter and 3650 mm focal length
3	
4	JOHN HADLEY †
45	
6	
7	L. EULER points out to the possibility of achromatic telescopes
8	P. L. GUINAND (Glass melter) *
9	P. S. LAPLACE *. J. W. GOETHE *
1750	Telescope of Count LÖSER in Germany with maximum 230 mm mirror diameter. P. DOLLOND founds in London an opticomechanical workshop.
1	Beginning of the "encyclopaedia" (DIDEROT)
2	
3	EDWARD TROUGHTON *
4	
55	DOLLOND's Heliometer completed

1755	
6	
7	
8	JOHN DOLLOND is granted a patent for achromatic telescopes
9	
1760	KLINGENSTIERNA's work on aperture errors are published. Foundation of the BREITHAUPT workshop in Kassel, the first important German company in this field
1	JOHN DOLLOND †. J. UTZSCHNEIDER *. EDWARD NAIRNE *
2	JAMES BRADLEY †
3	
4	
65	SAMUEL KLINGENSTIERNA †
6	W. H. WOLLASTON *
7	
8	JAMES SHORT † in London. WILLIAM NICOL *. First experiments of GUINAND with glass melts
9	JAMES WATT is granted a patent on his steam engine
1770	
1	CHESTER MOOR HALL †. J. G. REPSOLD *
2	GEORG REICHENBACH *. F. W. HERSCHEL commences his activities in astronomy
3	RAMSDEN's circular dividing machine
4	HERSCHEL manufactures the first reflecting telescope
75	
6	
7	K.-F. GAUSS *
8	
9	One of the first position micrometers by NAIRNE built for HERSCHEL
1780	RAMSDEN's altazimuths and theodolites
1	F. W. HERSCHEL discovers the planet Uranus
2	EDWARD NAIRNE publishes an article on compasses
3	LEONHARD EULER †. Ballooning by J. M. and J. E. MONTGOLFIER as well as A. C. CHARLES
4	F. W. BESSEL *
85	
6	GALVANIS "Frog leg experiment"
7	JOSEPH FRAUNHOFER *. S. D. POISSON *. HERSCHEL's 122 cm reflecting telescope completed. BLAIR's experiments on materials with a course of colour diffraction corresponding to each other
8	A. J. FRESNEL *
9	Great French Revolution
1790	
1	MICHAEL FARADAY *. Publication by ROBERT BLAIR on liquid lenses with reduced chromatic aberrations
2	CARY's transit circle for F. WOLLASTON
3	GEORG MERZ *. F. G. W. STRUVE *
4	
95	
6	REICHENBACH commences with the building of astronomical or nautical instruments, respectively
7	
8	LUIGI GALVANI †
9	
1800	JESSE RAMSDEN †. Discovery of infra-red radiation by F. W. HERSCHEL and W. H. WOLLASTON. Publication of the "VOLTA Column"
1	PIAZZI discovers the first planetoid Ceres. Commencement of co-operation between RECHENBACH–LIEBHERR. "VOLTA contact series" published
2	Foundation of the REICHENBACH and LIEBHERR workshop in Munich. W. H. WOLLASTON discovers absorption lines in the solar spectrum. Th. YOUNG's interference experiments
3	CHRISTIAN DOPPLER *
4	Foundation of the mechanico-optical institute by UTZSCHNEIDER, REICHENBACH and LIEBHERR
05	GUINAND joins the above-mentioned institute
6	EDWARD NAIRNE † in London
7	FRAUNHOFER joins the mechanico-optical institute
8	F. G. W. STRUVE commences his studies in Dorpat
9	GAUSS's 'Theoria motus corporum coelestium". Foundation of the company of UTZSCHNEIDER, REICHENBACH and FRAUNHOFER in Benediktbeuren mechanical workshop remains in Munich
1810	
1	
2	
3	J. L. LAGRANGE †. F. G. W. STRUVE becomes observator in Dorpat
4	Completion of a heliometer for GAUSS by FRAUNHOFER. FRAUNHOFER's list of absorption lines in the solar spectrum.
15	
6	Foundation of a further mechanical institute in Munich by UTZSCHNEIDER, LIEBHERR and WERNER. 11. 9. 1816 C . . . Z . . . . in Weimar *
7	
8	
9	JAMES WATT †. L. FOUCAULT *. A. H. FIZEAU *. UTZSCHNEIDER and FRAUNHOFER move to Munich. Only glass melting remains in Benediktbeuren
1820	PETER DOLLOND †
1	LIEBIG's article on fulminating silver. By occupying himself further with this subject LIEBIG was able to publish in 1856 a method for the silver coating of mirrors
2	Supply of the REICHENBACH meridian circle to Dorpat
3	FRAUNHOFER iss appointed professor of physics in Munich
4	P. L. GUINAND †. Supply of the large FRAUNHOFER refractor to Dorpat. (Tartu)
25	
6	JOSEFH v. FRAUNHOFER †. GEORG v. REICHENBACH †. NICÉPHORE NIÉPCE produces photographic exposures of physical objects
7	A. J. FRESNEL †. P. S. LAPLACE †. G. S. OHM publishes the law subsequently known by his name in the work "Die galvanische Kette, mathematisch bearbeitet" ("The galvanic chain, regarded from a mathematical point of view")
8	W. H. WOLLASTON †
9	Completion of thee Heliometer in Benediktbeuren intended for BESSEL. With this instrument BESSEL determined in 1838 the parallax of the double star 61 Cygni
1830	

Figure 6:
Test photograph of the primary mirror of NAIRNE & BLUNT telescope, using the FOUCAULT knife-edge method

Figure 7:
Test photograph same as Fig. 6, but with parallel light

Figure 8:
Illustration of the design of a reflecting telescope from the 18th century [3]

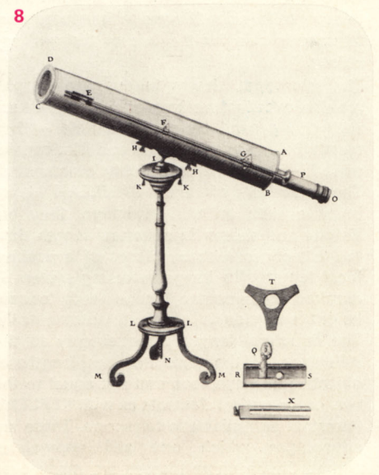
6



7



8



Small Monocular Hand Telescopes from the Optical Museum of the C... Z.... Foundation in Jena

Helmut Wolf

In the initial period after the invention of the telescope in 1609, opticians especially endeavoured to produce telescopes with a high magnification. The optical performance of the telescope was to be increased to the limit of what was possible. Only gradually was the idea accepted that small and handy telescopes with a low magnification, but a larger field of vision could also have their useful application, for instance, for huntsmen. It was also noted that, under certain circumstances, defective vision could be corrected with small hand telescopes. Thus it is said that in 1631 King GUSTAV ADOLF of Sweden used a small tescope, which he could easily hide in his hand, to compensate his shortsightedness.

Of the small hand tescopes of the 17th century up to the middle of the 18th century, only a few have survived because – like their larger brothers – the telescopes for use in astronomy were mostly made of cardboard (Fig. 3 on the right) and did not outlast their time. The single-lens objectives, which were used before the introduction of the achromat by JOHN DOLLOND in 1758, provide a chromatically satisfactory correction only when making the telescope very long with the same objective diameter and the same magnification – longer than the small hand telescopes discussed here – or if the magnification remained below three times. The latter can easily be seen from the enclosed table (p. 16).

Around 1780, telescope tubes were also made of brass and later of wood – first in England. They thus became more lasting and they are still today in collections and museums. With the improvement in the art of glass smelting at the beginning of the 19th century in England, France and especially in Germany by FRAUNHOFER, more useful optical glass was now available. In various places efficient workshops developed, which were in a position to produce, in addition to telescopes for scientific and military purposes, telescopes also for the use of the ordinary citizen.

The telescopes shown in our photographs are all of excellent workmanship in accordance with the general taste of the time – they mostly belong to the Empire and Biedermeier period – are sometimes richly ornamented. They are all of the GALILEAN type, because with an upright image, they are simpler and shorter in structural length than the telescopes with eyepieces of a positive focal length. No image-reversing system is required because an image with correct height and side is obtained automatically. The structural length is equal only to the difference of the absolute focal lengths of objective and eyepiece and not equal to the sum of the optical elements as with KEPLER's terrestrial and prismatic telescope. These are advantages which one still appreciates today. Cheap opera glasses are made even today in accordance with the GALILEAN type, dispensing with a large field of vision. Even today, the image correction of this historical small telescope for the centre of the field of vision can still be described as good. In some instances, naturally time has worn down the lenses and the telescope tubes. The formation of fungus, bubbles in the cement, decomposition of glass surfaces due to atmospheric influences, small chips on the lenses and mechanical damage on the telescope tubes occur here and there. The lenses are usually thinner than our present-day standards would permit. This indicates clearly, how economical the opticians had to be with the material, due to the chronic lack of good optical glass. Individual lenses are rather green, when looking straight on to them, another one is even bluish-green tinted, without the images becoming colour-tinged in view of the small thickness of the lenses. Bubbles and schlieren occur, but do not influence the imaging quality to any extent. Image errors in the axis, due to insufficient finish (surface fit, centering and adjusting) occur also only occasionally and to a small extent.

As all the illustrated small tescopes have only single lenses as eyepieces, the chromatic difference in magnification soon becomes noticeable outside the centre of the field of vision, especially at higher magnifications. At these telescopes, with a higher magnification, we are disturbed today by the excessively small field of vision (keyhole observation); at the small tescopes with larger fields of vision, however, the magnification is not powerful enough for present-day telescope users. We are, however, full of admiration for the meticulous craftsmanship, for the effort and untiring care taken by the opticians of that period to design a beautiful exterior for these small and convenient visual aids. The telescope tube was frequently made of rare materials, such as ivory, horn, mother-of-pearl or mahogany wood, richly ornamented and frequently extant brass parts were silver- or gold-plated when the lens mounting was not made entirely of silver. The small telescope should not only be useful but also have a very attractive appearance and attract the well-to-do client.

The small telescope of cardboard in Fig. 3 on the right is the oldest telescope discussed in this article. It still has one special feature. Although it was, no doubt, made soon after the introduction of the achromatic lens system, the objective has already three lenses. The reflections show that a collective lens is bracketed by two meniscus-shaped dispersion lenses. The objective is thus chromatically overcorrected by 1 mm, a considerable improvement compared with the single crown-glass lens as objective which, with the existing focal length of 3 mm, would entail an undercorrection.

To demonstrate the difference between our historical small telescopes and a modern type we show in Fig. 4 the monocular "Turmon" telescope. It is the smallest telescope of the current production of the JENA Works and represents in its optical design a KEPLER telescope with prism reversal set for image erection (prismatic telescope). Compared to the GALILEAN telescopes, it has an 8× magnification and a field of vision of 6.3° with a good image correction up to the edge of the image field. Due to its small size and its light weight, Turmon is very popular with students, mountaineers, skiers and other sportsmen. When applying attachment lenses, it can also be used as telescope magnifier. Although not gold-plated and not studded with semi-precious stones, it still attracts modern people by its simple appropriate design. In principle it can be stated that our present telescopes are not primarily intended as ornaments but as articles of use. Their price is kept within such limits that anyone interested in them is able to purchase them, as distinct from former centuries, when only the well-to-do could afford them.

(In conclusion I should like to express my thanks to the OPTICAL MUSEUM for the assistance given in the preparation of this article, and also Ing. SCHAU of the Telescope Laboratory of the JENA Optical Works for his advice and co-operation in determining the system constants).

Remarks to Table 1 on p. 16: In the telescopes No. 7 and 11, two eyepiece lenses, in No. 5. three eyepiece lenses can be alternately brought into the optical path for magnification changes. Unfortunately, the central eyepiece lens is missing on the last-mentioned telescope. No. 7 and 11, both from London, very closely resemble each other in their optical and mechanical design. EL = single lens, verk = cemented, diameter in brackets = stopped down diameter.

Figure 1: Left: Small telescope, goldplated with six extensions of IHOS RUBERGALL, London. Brass tube with two narrow goldplated rings, covered in the centre with ivory on which there are gold stars and gold figures. Eyepieces and objective in goldplated brass mountings. The eyepiece mounting carries the engraved name of the manufacturers. Time: end of the 17th century.

Centre: Small hand telescope with one extension, manufacturer unknown, probably Viennese, around 1825. Telescope tube of ivory with inlaid gold ornamentation

Right: Small hand telescope of brass studded with semi-precious stones and mother-of-pearl, manufacturer unknown. Time: end of the 18th century. This telescope was worn as a pendant and has the shape of a small barrel. The suspension eyelet is in the centre of the telescope. The brass body is encrusted in the centre with mother-of pearl and on top and bottom with one row of ruby-red semi-precious stones each. Two brass extensions are provided. Objective and eyepiece are mounted in brass.

Figure 2: Left: Small hand telescope by WATKINS & HILL, Charing Cross, London, with one extension. Time: 1750 bis 1780. The cylinder-shaped telescope body is made of black-dyed horn. On the silver-plated copper extension is engraved the name of the manufacturers.

Centre: Extension telescope made of brass by PLÖSSL, Vienna, dating back to the first half of the 19th century. The telescope tube and the three extensions, which may be pushed into one another, are made of brass. The smallest extension cylinder carries the name of the manufacturers. Three eyepiece lenses can be alternately brought into the path of rays by turning a knurled ring for changing the magnification. Between the thickest and the central extension there is a brass handle with a wood screw. Originally it was provided with a black wooden handle. Perhaps this screw was used also for attaching the telescope to a tree. A brass cover protects the objective.

Right: Empire period small hand telescope by RAMSDEN, London. Time: 1800–1810. The tube is made of horn and ornamented with small medallions. The extension and the lens mountings are made of silver-plated brass. On the extension is the name of the manufacturers.

Figure 3: Left: Small hand telescope of brass made by DOLLOND, London. Time: around 1800. Two magnifications can be set on the eyepiece mounting. The objective is protected by a screw-on brass cover.

Centre: Small hand telescope made of brass. Manufacturer unknown. Time: first half of the 19th century. The telescope tube is covered with reddish-brown mahogany wood.

Right: Extension telescope made of cardboard by I. MANN, London. Time after 1758. The cardboard body is covered with a green polished fish skin and carries protective silver rings on both ends. The cardboard extension is light green and provided with gold – debossed decoration and the name of the manufacturers. Objective and eyepiece are mounted in silver. The extension is protected at the eyepiece end with horn. Protective covers for objective and eyepiece are made of silver and can be opened and closed by means of a slide. The eyepiece slide has the name BANKS, London.

Figure 4: Monocular manual telescope "Turmon" made by the JENA Optical Works. Telescope tube and mountings are made of black-enamelled light metal. It is a KEPLER telescope with a collective eyepiece and prism reversal set for image erection.

1



2



3



4

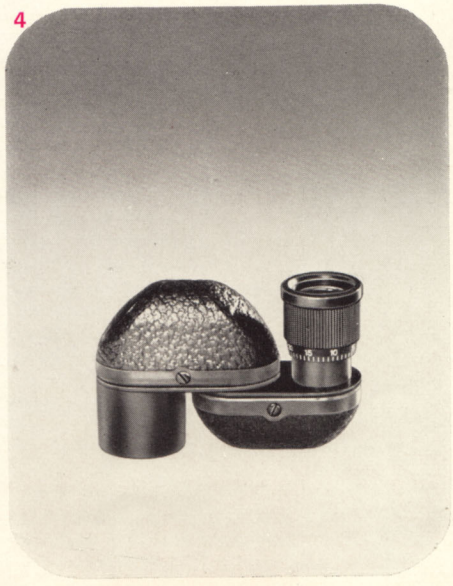


Figure 5:
Colour photograph of some of the small telescopes
already shown in the following sequence:
from left to right: cardboard telescope by I. MANN, London; ivory telescope from Vienna;
small pendant telescope with veneered mahogany, gold-plated telescope
by RUBERGALL, London and silver-plated hand telescope by RAMSDEN.
The latter has not been shown in Figs. 1 to 3.
It resembles in its design the telescope by DOLLOND in Fig. 3 on the left.
Time: end of the 18th century.
Telescope tube and extension and the lens mountings are made of silver-plated brass.
Two eyepieces can be set as required.



Opera glasses from the Optical Museum in JENA

Helmut Wolf

When JOHANN LIPPERHEY of Middelburg applied for a patent for his telescope in The Hague in 1608, he was advised to build an instrument for binocular use also, as at this time his telescope was regarded entirely as a visual aid of the spectacle type. The double telescope submitted during the same year was regarded as satisfactory. The patent was not, however, granted to LIPPERHEY as, a few days after him, J. ADRIAASZON, known as METIUS from Alkmar, applied at the same place for the same patent and, furthermore, the spectacle maker, ZACHARIAS JANNSEN from Middelburg put himself forward at the same time as the inventor.

It will probably forever remain unclarified, which of these three men can be credited with the invention. Perhaps it was none of them, for there are many reasons to assume that the telescopic effect of two afocally combined lenses had already been known hitherto; but the experimenting spactacle makers and opticians had not recognized the great importance of their discovery. It is possible that in superstitious timidity, they had withdrawn from the enlarged object brought close, as if from some devilish phenomenon.

It remains a fact that LIPPERHEY had already, a few weeks subsequently to the telescope becoming known, put together a double instrument. This was a telescope with negative eyepiece lenses (Dutch or GALILEAN telescope). SCHYRL de RHEITA (1597 bis 1660) later also manufactured KEPLER telescopes and terrestrial telescopes (these are telescopes with an eyepiece with positive refraction and a lens reversal system) as double instruments. In the SCHYRL instruments, the interpupillary distance was adjustable and for close objects, the tubes could even be set convergent. The priest CHERUBIN d'ORLEANS produced double telescopes of very suitable and different designs, – whilst the Italian D. SELVA in 1758 built for the first time double telescopes with a hinged bridge, in order to be able to adjust the interpupillary distance, similarly as in our modern fieldglasses. At that time, also reflecting telescopes of the GREGORY type were made as double instruments. With the onset of the 19th century, double telescopes became ever more frequent. This is the period, where a changeover was made from individual manual production to a modest series production. From 1807 onwards, for instance, the French optician J. G. A. CHEVALLIER produced binocular telescopes of the GALIEAN design, which were intended primarily as a visual aid for short-sighted people. The telescopic spectacles were very light, provided with temples and certainly had only a very limited magnification.

The Viennese company F. VOIGTLÄNDER, which later became so renowned for their photographic optical system, had a patent granted in 1823 for a double telescope with simple or achromatic lenses. This was intended mainly for theatregoers and, in its basic design, is still produced today. It is not, however, this company but French opticians, who a short time later were the leaders of the European market and produced beautiful opera glasses in large numbers. Whereas in Germany the gifted FRAUENHOFER had refused to deal in more detail with hand telescopes and opera glasses, as optical systems of second class, as he called them, and refrained from enlarging the glass works in Benediktbeuern for the large requirements of opticians for suitable optical glass, the French optical industry enjoyed a quite unexpected boom. To the German opticians with their modest means nothing was left but to emulate the French example, which frequently showed in French company names, such as for instance, WALDSTEIN "et" Sohn, Munich.

The first manufacturers of double telescopes will not have been quite certain about the difficulties naturally occurring in the construction of these instruments. If the observer is to succeed in bringing both telescope images to coincidence, the following conditions must be met: objectives and eyepieces must be centred, the magnification of both telescopes must be the same, eyepiece and interpupillary distance have to coincide and the axes of both telescopes must be parallel. A particularly distorting effect of the last-mentioned conditions is an altitude error or divergent position of both tubes.

The advantages of a binocular instrument are known to any telescope user: Binocular observation comes closest to natural seeing with the naked eye. It is especially the stereoscopic impression which causes the telescope user time and again to turn to the binocular type. In addition, the following physiological effects arise: The image appears brighter than with monocular viewing; fine detail is more readily discerned and magnification appears to be considerably increased. Furthermore, observers do not tire so quickly, as in the case of prolonged observation with one eye. These are considerable advantages which account for the fact that, in the design of modern optical equipment, double eyepieces are nowadays used ever more frequently.

The illustrations in this article mostly show opera glasses of the style of the Empire and Biedermeier period. Same as in the case of the historical instruments, introduced in the article on monocular small hand telescopes, the tube and lens mountings are also usually richly ornated and frequently gold-plated. It is remarkable that only opera glasses with tubes and mountings of metal have lasted through the years. One scarcely any longer finds such a binocular glass made of wood, horn or ivory.

The condition of the optical parts of these opera glasses corresponds to the condition of the lenses of the small monocular hand telescopes in the above-mentioned article. There are occasionally small bubbles and schlieren, and some lens surfaces are not perfectly polished. With this existing low magnification these shortcomings, however, hardly impair the useful value of the telescopes and the image quality is in any case good.

In the field of hand telescopes for use in nature by huntsmen, hikers, ornithologists and seamen, the prismatic lens (field-glasses) became increasingly popular towards the end of the last century, even practically entirely replacing the long-viewing and extension telescopes. ERNST ABBE, the co-founder of the Optical Works in JENA, has carried out great pioneering work in this respect. This development towards prism binoculars did not stop even at the opera glasses of higher optical performance. Around 1910 opera glasses with a prism reversal set, after PORRO, were produced for the first time in JENA. Their main features, as compared to the traditional GALILEAN system, are the essentially larger field of vision, the considerably smaller and, therefore, lighter-weight objectives, the sharp outline of the field of vision by a real diaphragm in the eyepiece image plane, and the smaller volume. As an example of this is shown in Figure 5 the "Teleperl" opera glass by the JENA Optical Works dating back to 1922. This is a very massive and heavy but efficient binocular glass.

The historical GALILEAN glasses and the TELEPERL are compared with the modern "Theatis" opera glasses of the current production of the JENA Optical Works (Figure 4). Of all the telescopes shown, it is the smallest with regard to volume and of very light weight, since case and mountings are made of light metal. Teleperl has the highest magnification and largest field of vision, as can be seen from the attached table and technical data of the opera glasses illustrated. This shows the superiority of the prismatic glass over the GALILEAN glass which, however, for less exacting demands still have, even today, a perfect right of existence.

A special prism after LEMAN permits the Theatis to be made extremely flat so that it can really be described as a pocket telescope. This small double telescope may be a lifelong, faithful and indispensable companion for its owner in the theatre, at the opera and also during hiking, nature observation and on the sportsfield.

In conclusion I should like to express my sincere thanks to Mr. Jähnert of the telescope laboratory for his suggestions and for reading this manuscript.

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Figure 1: Double telescope made of brass. Manufacturer unknown. The telescope body is covered with mother-of-pearl. The handle and the focusing screw are also of mother-of-pearl. Objective and eyepiece mountings are gold-plated. The eyepiece mounting is provided with an inscription reading: "Par brevet de Perfectionnement." In the background: The JENA "Teleperl."

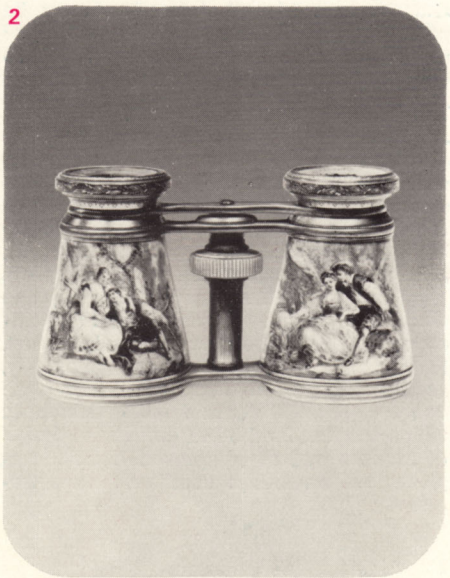
Figure 2: Double telescope made of brass. French manufacture. The body is covered with enamel and beautifully painted with landscapes and two loving couples (shepherd scenes). The eyepiece mountings are decorated with gold-plated engravings and display the following company name: "Petitpierre, Opticien de S(on) M(ajesté) le Roi, Berlin."

Figure 3: Left: Double telescope made of brass, gold-plated. The body is provided with decorated brass rings and with beautiful enamel work (bird on branch). The handle is made of horn. In the eyepiece mounting is engraved: "Par brevet d'invention et de perfectionnement".

Right: Opera glasses with ivory incrustations (leaf pattern) and gold ornaments. On the eyepiece mountings, same as on the telescope of Figure 2, the company name of Petitpierre Berlin is engraved.

Bottom: Collapsible double telescope of brass, gold-plated. The attachments of the telescope body are painted black. The material for the bellows is missing. The handle is made of mother-of-pearl. A patent for a telescope with fabric bellows was granted to the optician THIRION in Paris in 1837. This telescope has, therefore, probably been produced subsequently to this period. The name of the manufacturer is found on the eyepiece mounting: WALDSTEIN et Sohn, Munich.

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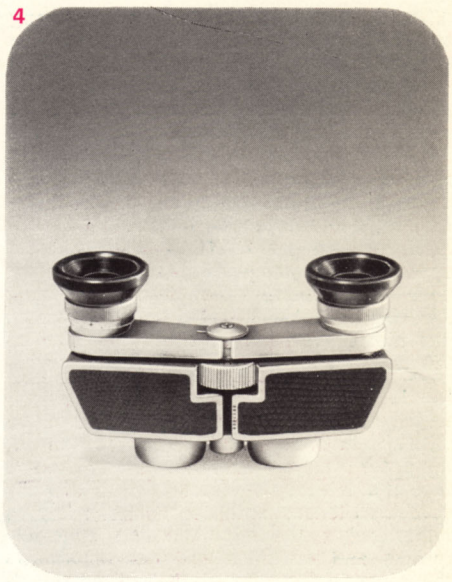


Figure 4: "Theatis" prism binocular of the current production of the JENA Optical Works. The telescope body and lens mounting are of light metal. The telescope is small, light, attractive and has excellent optical properties. One eyepiece can be focused separately and independent of the central focusing device in order to be able to focus each eyepiece optimally in the case of visual defects of the observer. In addition to the "gold" design illustrated in the photograph, which is preferred by the ladies, there also exists a simple "black" design.

Literature:

[1] RIEKHER, R.: Fernrohre und ihre Meister, (Telescopes and their Masters). Verlag Technik Berlin 1957.

[2] ROHR, M. v.: Die binokularen Instrumente, (The Binocular Instruments). Verlag Springer, Berlin 1920.

Figure 5:

Top: "Teleperl" opera glass from the JENA Optical Works. Year of manufacture: approximately 1922. The telescope body, objective and eyepiece mountings are made of gold-plated brass. The bodies are covered with mother-of-pearl. It is a prism binocular with a reversal set after PORRO. The objectives are focused together by means of a centre screw. One eyepiece can be focused separately.

Centre: The same opera glass as shown in Figure 3 on the left.

Below: Double telescope of brass, gold-plated. Both bodies are made of silver-plated brass with beautiful coloured enamel paintings and inlaid white pearls. Inbetween there are gold-plated brass rings. The objectives are in gold-plated brass, the eyepieces in mother-of-pearl mountings. The handle has also beautiful coloured enamel paintings (flower pattern). The centre rod is gold-plated, the focusing screw is covered with mother-of-pearl. The name of the manufacturer is on the eyepiece mounting: "M. Cristiani, Frankfurt a/M".

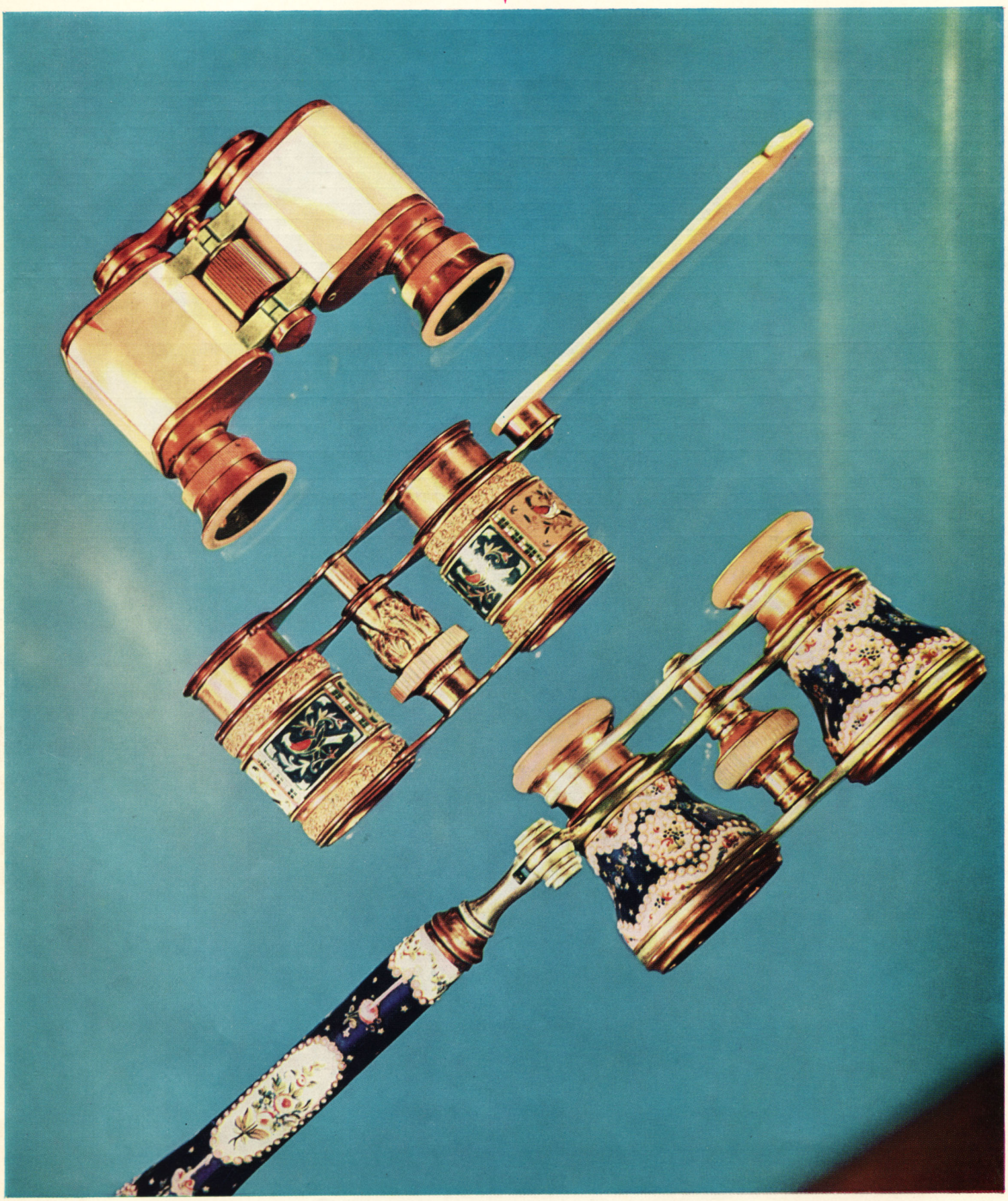


Table 1: Technical details of the telescope in the illustrations

Consecutive No.	Illustrations		Length of telescope closed mm	extended mm	Objective Type	∅ mm	f' mm	Type	Eyepiece ∅ mm	f' mm	Field of vision in degrees	in metres at 100 m distance	Telescope magnification
1		left	40	100	Achromat, 2 lenses, cemented	36	120	EL planoconcave	12 (8)	–40	5	8.7	3×
2	Fig. 1.	centre	70	100	EL planoconvex	33	130	EL biconcave	8	–54	6.5	11.3	2.4×
3		right	20	40	EL planoconvex	8	80	EL biconcave	4	–53	12	20.9	1.5×
4		left	85	120	EL biconvex	41	155	EL planoconcave	–17 (14)	–78	9	15.7	2×
5	Fig. 2.	centre	67	143	Achromat I cemented element 1 EL	25	135	a) EL, b) –, c) EL	2, –, 2	–21, –, –9	1.5, –, 0.6	2.6, –, 1.0	6.5×, –, 15×
6		right	70	105	EL planoconvex	42	125	EL biconcave	15, (8)	–45	7	12.2	2.8×
7		left	95	130	Achromat, 3 lenses, 2 lenses, cemented	2 33	130	a) EL, b) EL	4, 4,	–30, –15	2.5, 1.1	4.5, 1.9	4.3×, 8.5×
8	Fig. 3.	centre	125	180	Achromat, 2 lenses, cemented	35	180	EL biconcave	17, (12)	–33	2	3.5	5.5×
9		right	125	195	Achromat, 3 lenses, not cemented	15 (8)	190	EL plano concave	10	–42	1.5	2.6	4.5×
10	Fig. 4.	"Turmon"	45	–	Achromat, 2 lenses, cemented	21	89	4 lenses	12	+11	6.3	11.0	8×
11	Fig. 5.	back cover right	9	145	Achromat, 3 lenses, 2 lenses cemented	32	140	a) EL, b) EL	3, 3	–31, –16	2.8, 1.25	5.0, 2.2	4.5×, 9×

Table 2: Technical Data of the Opera Glasses in the Illustrations

No.	Illustrations	Objective Type	∅ in mm	f' in mm	Eyepiece Type	∅ mm	f' in mm	Field of vision in degrees	In metres at 100 m	Magnification	Interpupillary distance	Parallelism of the telescope	Height of the opera glass
1.	Fig. 1	Achromat	22	90	Biconcave single lens	15	–43	7.2	12.6	2.1×	66	large altitude error, no fusion	53
2.	Fig. 2	Achromat with 1 plane surface	33	100	Biconcave single lens	13	–36	7	12.3	2.7×	2.7×	one eyepiece missing	69
3	Fig. 3 left Fig. 5 centre	Planoconvex lens	22	108	Biconcave single lens	15	–54	9	15.8	2.0×	66	OK	52
4.	Fig. 3 right	Planoconvex lens	24	80	Biconcave single lens	16	–36	7	12.3	2.2×	67	small altitude error, fusion possible	54
5.	Fig. 3 bottom	Achromat	26	80	Biconcave single lens	21	–40	9	15.8	2.0×	66	OK	45
6.	Fig. 4	Achromat	15	42	Kellner eyepiece	9	+12	11	19.7	3.5×	Adjustable	OK	60
7.	Fig 5. top	Achromat	32	86	Biconcave single lens	15	–35	6.5	11.4	2.5×	64	bad, no fusion	56
8.	Fig. 5 bottom	Achromat	13.5	57	multielement positive eyepiece	9	+19	13.7	24.0	3.0x	Adjustable	OK	62