Large format lenses from Carl Zeiss Oberkochen 1950-1972

Carl Zeiss Jena and Carl Zeiss Oberkochen

Before and during WWII, the Carl Zeiss company in Jena was one of the largest optics manufacturers in Germany. They produced a variety of lenses suitable for large format (LF) photography, including the well-known Tessars and Protars in several series, but also process lenses and aerial lenses. The Zeiss-Ikon sister company in Dresden manufactured a range of large format cameras, such as the Zeiss "Ideal", "Maximar", Tropen-Adoro", and "Juwel" (Jewel); the latter camera, in the 3¼" x 4¼" size, was used by Ansel Adams for some time.

At the end of World War II, the German state of Thuringia, where Jena is located, was under the control of British and American troops. However, the Yalta Conference agreement placed it under Soviet control shortly thereafter. Just before the US command handed the administration of Thuringia over to the Soviet Army, American troops moved a considerable part of the leading management and research staff of Carl Zeiss Jena and the sister company Schott glass to Heidenheim near Stuttgart, 126 people in all [1]. They immediately started to look for a suitable place for a new factory and found it in the small town of Oberkochen, just 20km from Heidenheim. This led to the foundation of the company "Opton Optische Werke" in Oberkochen, West Germany, on Oct. 30, 1946, initially as a full subsidiary of the original factory in Jena. The new company was headed by the 45 year old Heinz Küppenbender[1], the inventor of the Contax camera in the 1930's. The company name was then changed to "Zeiss Opton" on March 3, 1947.

In addition to the relocation of personnel after the war, in June 1945 some tools and machines had been moved from the Zeiss subsidiary "OAS" in Saalfeld near Jena. They ended up not in Oberkochen, but at the Kollmorgen Company [2] in Coburg in West Germany; Kollmorgen had ties to Zeiss from before the war. Since there were initially no production facilities available in Oberkochen, lens manufacturing started in Coburg, in November 1945, and continued until June 1951 when the production in Coburg was closed down and moved to Oberkochen. Those Coburg-made Opton lenses produced from 1945-1951 were mostly lenses for 35mm or medium format cameras, such as the Contax and Rolleiflex. The few LF lenses Zeiss sold in those years were still produced by Zeiss Jena, such as the 135mm and 150mm Tessars for Linhof shown in fig. 2.

In 1948, the communist rulers of the GDR nationalized Carl Zeiss Jena as well as its legal owner, the Zeiss foundation in Jena. The nationalization and the Cold War subsequently led to the complete separation of Zeiss into two independent companies, the original one in Jena under communist rule described in ref. [3], and the new West-German plant in Oberkochen, which changed its name back to "Carl Zeiss" in 1953. The Zeiss foundation as the sole owner of Carl Zeiss, Zeiss-Ikon, and the Schott glass works, was also relaunched in West-Germany, with its new seat in Heidenheim.

After the reunification of Germany in October 1990, Carl Zeiss in Oberkochen and Carl Zeiss Jena became one company again in 1991. However, since Carl Zeiss Jena had more than four times as many employees in the GDR than Carl Zeiss in Oberkochen had worldwide, only the core parts of the Jena

[1] Küppenbender stayed on as CEO for 26 years, until 1972.

company could be taken back, including microscope and planetarium manufacturing, but not photographic lenses. The plant in Saalfeld that had made the Zeiss Jena LF lenses became part of Docter Optic shortly thereafter, as described in another article [4]. The development of photographic lenses stayed in Oberkochen, but the production of large format lenses, which had been stopped in 1972, was not resumed even after the reunification. Large format photography was and is a rather small market and at the time of the reunification had four established players, i.e. Rodenstock, Schneider-Kreuznach, Nikon, and Fuji. One can probably assume that the prospect of trying to reestablish a presence in that market, even with the Zeiss name behind it, was not considered a profitable venture.

Carl Zeiss Oberkochen large format lenses

The postwar separation of Zeiss led to two distinctively different large format lens lines. Carl Zeiss Jena initially continued some of the pre-war lens lines for large format (f/3.5, f/4.5 and f/6.3 Tessars) and process cameras (Apo-Tessar), and later phased in replacements and new developments of their process lens lines (Apo-Germinar, Apo-Germinar W), as described in an article on Carl Zeiss Jena [3]. Zeiss Oberkochen did not continue any of the prewar lenses, but developed a completely new line of Biogon, Planar, Sonnar, and Tessar large format lenses for the 6.5x9cm and 9x12cm/4x5" formats, respectively[2]. Apart from prototypes, no commercial LF lenses were ever produced for 13x18cm/5x7", 18x24cm/8x10", or larger formats. Carl Zeiss Oberkochen also never entered the market for standard process lenses. However, lenses for photomacrography, aerial photography, photogrammetry, and some specialized reproduction and enlarging lenses were made for 6.5x9cm, 9x12cm/4x5", and larger LF film sizes such as 23x23cm.

"Carl Zeiss" is the name engraved on most lenses from Oberkochen, although some late ones show only a "Zeiss" designation. If the country of manufacturing is stated, it says either "Germany" or "West Germany", with no clear relation to the production time. Some variation is probably due to labeling requirements for different export countries: Over the years, a long and convoluted legal struggle on the use of the Zeiss name ensued between Zeiss in Oberkochen and Zeiss Jena, which was finally resolved in 1971 with the "London agreement" between the two Zeiss companies [1]. As a result, Carl Zeiss Jena (CZJ) could not use the Carl Zeiss name in most Western countries (with some exceptions, e.g. the British Commonwealth), but had to use the name "Jenoptik" instead. Conversely, Carl Zeiss Oberkochen (CZO) had to continue to use the name "Opton" or "Oberkochen Opton" for exports to the Eastern Bloc countries; an example can be seen in fig. 6. Similar rules governed the use of the established prewar lens names such as Biogon, Planar, Sonnar, Tessar, etc. Carl Zeiss in Oberkochen used the first two letters of the lens name for the versions exported to the Eastern bloc, e.g. "Bi" for the Biogon or "So" for the Sonnar, whereas Carl Zeiss Jena used just the first letter for export to the West, e.g. "T" for Tessar.

The serial numbers for the Oberkochen production, including the lenses made at the Kollmorgen plant in Coburg, essentially started over at 1001 [2], whereas CZJ continued their numbers at around 3,000,000 from the end of WWII. The basic procedure in Oberkochen seemed to have been the same as for Carl Zeiss Jena, i.e. once an internal order for a batch of lenses was issued, a continuous block of numbers was assigned to this order, even though the production might have taken considerable time, some-

[2] Although 6x9cm/2¼ x 3¼" is, strictly speaking, medium format and not large format, I included these lenses, as well as lenses for 6x7cm/2¼ x2¾", in this article since they were either made for view cameras such as Linhof's "Baby Technika", or could be used with them.

times years. Production lists from Oberkochen are well known after 1964, i.e. from serial no. 4,000,000 on, but are quite incomplete before that [2]. Therefore exact production numbers and serial number ranges can only be given for the last 8 years of LF lens production and can be found in [2]; an approximate list based on [2, 5] is given in table 1, but deviations of several years are certainly possible.

Carl Zeiss in Oberkochen did not produce any large format cameras after WWII through its Zeiss-Ikon camera factory in Stuttgart. Instead, they closely cooperated with Linhof in Munich. Many of their LF lenses were exclusively made for Linhof, although some were occasionally sold for other LF cameras, such as the sets for the Graflex XL press cameras. They commanded a premium price compared to the offerings from the competition, e.g. Schneider-Kreuznach.

Design dates of the new Zeiss lenses for view cameras start with a 105mm f/3.5 Tessar for 6.5x9cm in 1950, but the main series were designed a few years later, in 1954 for the medium format view camera lenses, and in 1956 for the 9x12cm/4x5" format lenses, with a few additions and redesigns introduced in later years. Production started shortly after the design dates given above: the 6.5x9cm lenses were available in 1954 [6], the 9x12cm/4x5" lenses in 1958 [7, 8]. Zeiss Oberkochen stopped production of their LF lenses in 1972, although the existing stock was sold for a few more years – Zeiss advertised their LF lenses at least until spring of 1974 [9] and Linhof camera advertisements showed the Zeiss LF lenses even longer. The last Zeiss lens listed in the Linhof catalog was a 80mm Planar in 1979 [57]. The regular production times were therefore just 18 years and 14 years for the 6.5x9cm and 9x12cm/4x5" lenses, respectively, with one exception: Zeiss Oberkochen did a few special order runs of the 135mm f/3.5 Planar in the 1980's and 1990's, the rare T* version of this lens.

Table 1: Approximate serial no. ranges for lenses from Carl Zeiss Oberkochen. After [2, 5].

10,000-500,000	1947-1950
500,000-1,000,000	1950-1954
1,000,000-2,000,000	1953-1958
2,000,000-3,000,000	1958-1960
3,000,000-4,000,000	1960-1964
4,000,000-5,000,000	1964-1970
5,000,000-6,000,000	1970-1977
6,000,000-7,000,000	1977-1986
7,000,000-8,000,000	1986-1996

Most of Carl Zeiss Oberkochen's new LF lenses exhibited very different design goals compared to their pre-war predecessors. Zeiss' main LF lines before WWII had been the convertible Protar VII series and the wide angle Protar V series for studio photography, architectural photography, still life, and landscapes. These were lenses of moderate aperture - f/6.8 to f/7.7 for the convertible Protar VII and f/18 for the Protar V wide angle - but large image circles to allow ample movements. They were complemented by the f/2.7, f/3.5, f/4.5, and f/6.3 Tessar series with less coverage, but wider apertures for portraits and other areas of photography requiring shorter exposure times. There were also a few uncommon lenses for LF like the Biotessar, Tele-Tessar, Orthometar, Hypergon, and the Zeiss-made version of the Dagor. After the war, neither Carl Zeiss Jena nor Carl Zeiss Oberkochen continued any of the Protar series or developed replacements with similar design goals, such as the now ubiquitous Plasmat-type lenses. Zeiss Oberkochen apparently ceded that market segment to Schneider-Kreuznach and their postwar Symmar line and later also to Rodenstock with their Sironar line, despite the fact that they already had developed a Plasmat-type lens with the pre-war Orthometar mapping lens.

The newly developed Carl Zeiss lenses were optimized to be used at wider apertures - actually they were claimed to be "fully corrected at full aperture" according to the book "Linhof Practice" [53]. This feature came at the expense of larger image circles and therefore allowed only limited camera movements. This change in philosophy was probably due to

a) the increasing prevalence of and competition by medium format cameras like the Rollei and Hasselblad and even 35mm cameras in professional photography: the best-known Linhof cameras, the Technika and its derivatives such as the Technika Press, were advertised by Linhof as being able to be used handheld [6, 7], e.g. in press, sports, and fashion photography, and
b) the concomitant change in aesthetics, where full sharpness from the foreground to infinity was not always required and was replaced by the interplay between sharply focused parts of the image and out of focus areas, but still with the superior tonality of large format, plus
c) the increasing use of electronic flash especially for lighting larger areas such as an industrial setting with moving machinery that necessitated wide angle lenses with a larger useable maximum aperture compared to, say, the old Protar V f/18.

Before the war, the Tessar and the related Biotessar were the only Zeiss LF lenses in that category. The fastest prewar designs – the Tessar f/3.5 in several focal lengths, the Tessar 165mm f/2.7, and the Biotessar 165mm f/2.8 – were, however, somewhat strained when used wide open and showed residual spherical aberration and other problems. The coverage was also quite restricted. They were fine for portraits, news photography, and similar applications, but not good enough for an aesthetic requiring a succinctly defined focus juxtaposed to the out of focus areas.

Oberkochen's lineup after the war apparently wanted to offer these new characteristics for their whole line of lenses, including their wide angles and long-focus lenses. The Zeiss invention of lens coating shortly before WWII (initially marked by a red "T" on the mount of Jena-made lenses, standing for transparency), helped with the introduction of new lens types to fulfill these design goals. It allowed more air-glass surfaces than their predecessors, e.g. in the new Biogon line, and the resurrection of lens types that had been sidelined before due to flare problems, such as the Planar series. All Zeiss Oberkochen LF lenses made until 1972 were coated, but only single coated, since the introduction of multicoating at Zeiss Oberkochen in 1972 coincided with the stop of the regular LF lens production. Only the special order batches of the 135mm f/3.5 Planar from the 1980's and 1990's received Zeiss' T* multicoating.

The Zeiss LF lenses usually came in Synchro-Compur or new style Compur shutters; Zeiss held majorities of both the Deckel company that made the original Synchro-Compur shutters, and of the Alfred Gauthier company that made Prontor shutters and later also the Compur shutters. A few late lenses used the short-lived Compur electronic. Only shutter sizes 0 and 1 were used for the regular LF lenses. The majority of Compurs sold through Linhof had a different outside design compared to the standard version until the mid to late 1960's; the earlier Synchro-Compurs came with a conical face plate, as shown in figs. 2-4, and later Compurs with a cylindrical body and a design using chrome-plated little squares on the shutter speed ring (figs. 9-12). The Linhof logo is usually engraved on the outside, normally in red. The conical face plate shutters came in two versions, initially they were all chrome plated, and a later version was black (fig. 4). The lenses for Graflex often had the Graflex name engraved on the shutter, but otherwise their Synchro-Compurs were standard models with a flat faceplate. The last type of Compur shutters with a torsion-type mainspring [10] also came unmodified in addition to the "chrome squares" design version. The newer versions can be distinguished by the blocky serration of the shutter speed ring (fig. 4 upper right) instead of the fine serration of the previous model and by the plastic-tipped levers – early new versions have a chrome ring and white lever tips, the last versions have black rings and black lever tips. In addition, the older Synchro-Compurs have nearly round apertures with ten blades, with the classic nonlinear spacing of apertures, and the newer Compurs have only 5 aperture blades and linear spacing. The newer version of the size 1 also had a slightly higher top speed, 1/500s instead of 1/400s.

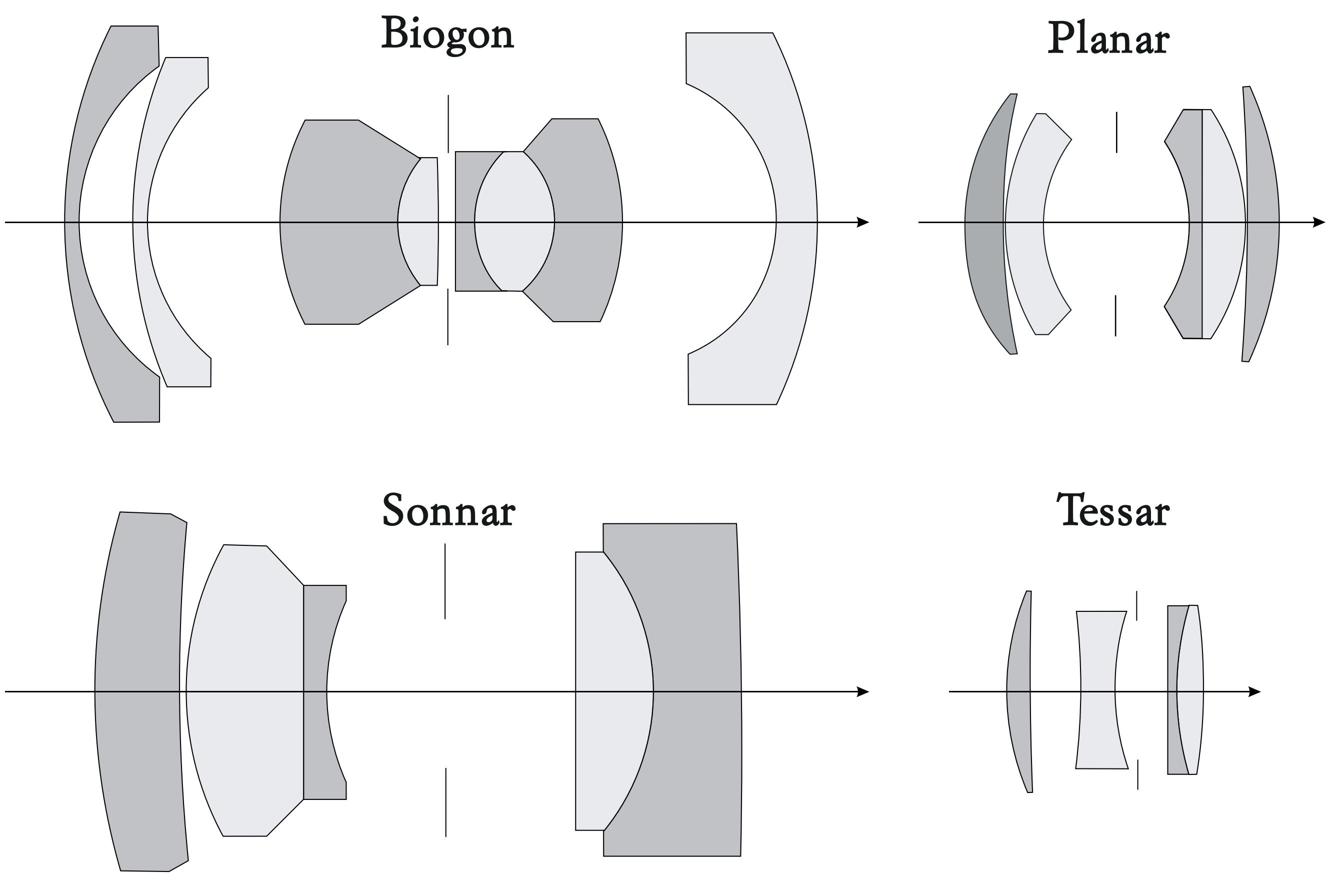

Fig. 1: Schematic lens diagrams of the post-WWII lenses for 9x12cm/4x5" from Carl Zeiss Oberkochen. Clockwise from upper left: Biogon 75mm f/4.5, Planar 135mm f/3.5, Tessar 150mm f/4.5, Sonnar 250mm f/5.6. The smaller versions for 6.5x9cm have similar layouts.

Note that, except for the Tessars, all of the special Linhof shutter versions were attached to the lens board by 4 screws from the back side, not by the standard retaining ring of the shutter, as seen in fig. 13. In addition, some of the lens cells were not screwed into the shutter threads but used additional threads on the mounting flange (fig. 13). This can be a complication when switching lens boards or shutters. Additional mount versions, e.g. focus mounts, were made for the Linhof Press cameras and for the aerial cameras like the Linhof Aero Technika.

Over the years, Zeiss made a variety of prototype LF lenses that occasionally find their way to the used market; some (but not all!) of them can be detected by "V" in the serial number, standing for "Versuch" in German, meaning a "trial" or "experimental" lens. I have included some of those lenses in the tables for comparison. They also produced a variety of special purpose lenses, e.g. for photogrammetry and aerial photography that might be useful for LF. Some of those lenses are listed in the last section of this article.

Tessar large format lenses from Oberkochen

The Tessar was originally invented by Paul Rudolph for Carl Zeiss Jena, patented in 1902. It was licensed by Zeiss to several other companies in the early 1900’s and also widely copied later. It consists of 4 lens elements in 3 groups as shown in fig. 1 lower right, with two single lenses in front of the aperture and a cemented doublet in the back. The four lens elements are also reflected in the name, “tessares” means four in classic Greek. Although Paul Rudolph arrived at the design coming from his previous Unar and Protar, it can be regarded as a variant of the classic triplet design with the last biconvex lens being replaced by a cemented doublet. All of the focusing power is concentrated in that doublet; the front cell has actually negative power and is only there for correcting the aberrations of the back cell. The Tessar design has been used widely for all formats including large format. Apart from Zeiss, Tessar type LF lenses were made by Kodak (some of the Ektars), Ilex (Acutar), Schneider-Kreuznach (Xenar), Rodenstock (Ysarex), Nikon (Nikkor-M), and Fuji (Fujinon L). The last Tessar types made for LF were the Nikkor-M’s from Nikon; their production stopped when Nikon left the LF lens market around 2005/06.

The first postwar Tessars for LF, made in the late 1940’s, still came from Jena (fig. 2, top row). In 1950 Zeiss Opton took up the production of large format Tessars. At that time the basic design was 48 years old and had seen several redesigns and refinements, in 1907 by Wandersleb, and in the 1920’s and 1930’s by Merté. The arrival of new glass types after the war, such as lanthanum glass, allowed further improvements of the design.

Table 2: Large format Tessars from Carl Zeiss Oberkochen.

<table>
<tr><th>Focal Length [mm]</th><th>Max. / Min. Aperture</th><th>Angle of Coverage [°]</th><th>Image Circle [mm]</th><th>Mount/ Shutter</th><th>Filter Size</th><th>Weight [g/oz.]</th><th>Remarks</th></tr>
<tr><td>100</td><td>3.5/22</td><td>57</td><td>120</td><td rowspan="2">Synchro-Compur 0</td><td rowspan="2">M40.5x0.5</td><td></td><td>1964 design, for 6.5x9cm</td></tr>
<tr><td>105</td><td>3.5/22</td><td>57</td><td>120</td><td></td><td>1950 design, for 6.5x9cm</td></tr>
<tr><td>150</td><td>4.5/32</td><td>57</td><td>165</td><td rowspan="2">Synchro-Compur 1</td><td>M49x0.75</td><td>289/ 10.2</td><td>1956 design, for 9x12cm/4x5”</td></tr>
<tr><td>150</td><td>3.5/22</td><td>?</td><td>?</td><td>?</td><td>?</td><td>Prototype, 1954</td></tr>
</table>

The first Tessar produced by Zeiss Opton for 6.5x9cm view cameras was the 105mm f/3.5, a 1950 redesign of the prewar version with the same specifications. It was the same lens that was fitted in much larger numbers to the postwar 6x9cm Ikonta and Super-Ikonta folders from Zeiss-Ikon (only 1,000-2,000 lenses out of ca. 40,000 lenses were marked “Linhof” in the production books). The 105mm lens was later replaced with a newer version, a 100mm f/3.5 designed in 1964. For the 9x12cm/ 4x5” format, Zeiss Oberkochen introduced the new 150mm f/4.5 version in 1958, with a design date of 1956 (fig. 2).

Fig. 2: Tessars for the post-war Linhof Technika from Carl Zeiss Jena and Carl Zeiss Oberkochen. Top left: "13.5cm"=135mm f/4.5 Tessar, one of the last lenses produced by Carl Zeiss Jena in 1950 for Linhof (the design was from 1948, CZJ redesigned the 135mmf/4.5 again in 1957). Top right: "15cm"=150mm f/4.5 Tessar from Carl Zeiss Jena for Linhof produced in 1949 (design from 1911). Front: the new 150mm f/4.5 Tessar from Carl Zeiss Oberkochen, produced around 1958 (design from 1956) for Linhof. Scale is in cm.

The Tessars were intended to be the economical alternative to the more expensive Planars with similar focal lengths. In 1958, Linhof sold the 105 and 150mm Tessars in Germany for DM 211 and DM 420, respectively, whereas the 100mm and 135mm Planars cost DM 528 and DM 597 [12]. Even then, the Zeiss Tessars were more expensive than the more versatile, but slower f/5.6 Schneider Symmar, or the Voigtländer f/4.5 Apo-Lanthar. The 105mm Symmar and Apo-Lanthar were DM 203 and DM 204, respectively, and the 150mm versions were DM 314 (Symmar) and DM 318 (Apo-Lanthar) [12]. For comparison, the average gross income in Germany in 1958 was DM 5330 per year [13]; a 9x12cm/4x5" Super-Technika IV cost DM 1485, and a 6.5x9cm Super Technika DM 1180 [12]. Nowadays, the Tessars are "sleeper" lenses, since the Planars, as well as the Biogon and Sonnar lenses for the Linhof, were more in the spotlight. In addition, on the used market the 105 and 150mm Apo-Lanthars now command much higher prices than their Tessar counterparts. Most of the 150mm Tessar lenses were produced in one single batch of 1000 units around 1958, only a few were made later. Those Tessars were sold off into the 1970's [2]. Therefore the serial nos. of nearly all 150mm Tessars are in one range, starting with no. 2,283,747 (the remaining batch is in the 2,6xx,xxx range). There were approximately 13 batches for the 105/100mm Tessars [2]. More than 2000 105mm lenses and 6000 lenses of the 100mm version were made according to the production lists [2].

Zeiss also developed prototypes of other Tessars, including a 150mm f/3.5 version (fig. 3), but it did not make it into production. Such prototypes occasionally show up on the used market.

Fig. 3: Tessar 150mm f/3.5 prototype in Compur 1. Image courtesy of Westlicht Photographica Auction [11].

Planar large format lenses from Oberkochen

The Planar was also invented by Paul Rudolph, actually six years before the Tessar, in 1896 [14]; it is a variant of the "double Gauss" lens type. The standard double Gauss lens, 4 elements in 4 groups, consists of a positive and a negative meniscus lens on each side of the aperture. LF examples include the Hugo Meyer Aristostigmat or the Kodak WF Ektar lenses. Rudolph improved them by thickening the inner negative menisci considerably and splitting them into cemented doublets. The two glasses of the doublet had about the same index of refraction, but different dispersion; by adjusting the curvature of the interface between the two elements, Rudolph could change the chromatic aberration correction in a wide range to improve the lens correction considerably. The "Planar" name is due to the low field curvature, giving a "plane" image [14]. The original Planar was somewhat prone to flare due to the eight air-glass interfaces and for that reason this type was not very common before WWII, although some well-known lenses for cine and 35mm were produced, including the TTH Opic, the Schneider Xenon, or Zeiss' own Biotars for the Exacta. The only Planars usable for LF that Zeiss produced between WWI and WWII were the Apo-Planar process lenses [3]. The advent of coating changed that and allowed the resurrection of the Planar type – since the end of WW II it has been the main design type for high speed lenses of normal or slightly long focal lengths in many formats. In general, it allows for a high correction of aberrations at wide apertures over a moderately wide field. Compared to a standard Plasmat type lens like the Schneider Symmar, the coverage is smaller, but the correction at wide apertures is better.

Fig. 4: Bottom row: Planar 135mm f/3.5 (1956 design) in chrome barrel (left), Planar 100mm f/2.8 in chrome barrel (right). Top row: Planar 135mm f/3.5 (1956) in black barrel (left), Planar 135mm f/3.5 T (1968/69 design) from the 1980's (right). Note the recessed boards of the lenses on the left. Scale is in cm.*

Zeiss Oberkochen pursued the development of Planars for all formats in the 1950's, as shown by several patents [15-17]. The resulting new Planars for large format used a slightly simplified construction of 5 lens elements in 4 groups – one of the cemented inner menisci was replaced by a single, but strongly curved meniscus (fig. 1, upper right). This type had supposedly been developed by Zeiss Jena already during the war years [5], but not made it into production then. This 5/4 Planar was not only used for large format, but also in the 100mm f/3.5 Hasselblad Planar. Similar constructions were Schneider-Kreuznach's new Xenotar and Carl Zeiss Jena's postwar Biometar, also using 5/4 designs [18]. In the case of the Zeiss Oberkochen LF Planars, the group employing the single meniscus was in the front [17] as shown in fig. 1, whereas the Schneider and Jena equivalents had it in the back.

Carl Zeiss Oberkochen initially produced two different Planar versions for view cameras; the 100mm f/2.8 for 6.5x9cm that came out in 1954 and the 135mm f/3.5 for 9x12cm/4x5" from 1958. In 1958, the German price of the 100mm version was DM 528 and of the 135mm version DM 597 [12]. The engraving for "Opton"-labeled Planars was "Pl". An 80mm f/2.8 was added in 1963 for the 6x7cm ("ideal format") view and press cameras from Linhof [19], together with the 45mm f/4.5 Biogon wide angle for the same format.

The original 135mm version was sold in two slightly different mounts. Initially it was all chrome plated (fig. 4 lower left), but in 1961 the front parts became black – this is the most common version on the used market (fig.4 upper left). The coating color is also slightly different, the older chrome version shows a golden coating color, the newer one a mixture of gold and purple colors (it is not multicoated, though). Optically, these models are identical. Both came in a special recessed Linhof Technika board (fig. 4) that allowed a Technika camera to be closed with the lens installed.

Table 3: Large format Planars from Carl Zeiss Oberkochen. All are 5/4 constructions as shown in fig. 1, upper right. [a]includes Linhof Technika plate, [b]includes recessed Linhof Technika plate, [c]includes Linhof "Baby" Technika plate.

Focal Length [mm]	Max./Min. Aperture	Angle of Coverage [°]	Image Circle [mm]	Mount/ Shutter	Filter Size	Weight [g/oz.]	Remarks
80	2.8/22	64	100	Synchro-Compur 0	M49x0.75		For 6x7cm
100		62	120		M67x0.75	477/16.8[c]	For 6.5x9cm
135	3.5/32	64	170	Synchro-Compur 1	M58x0.75	532/18.8[b]	Both "chrome" (older) and "black" shutter versions
		67	180	Compur electronic 1 Compur 1	M67x0.75	591/20.8[a]	Single coating
							T* multicoating
150	2.8/						Several prototypes
210	5.6/			Compur 1 electronic			Prototype for 13x18cm
300	4.0/ 4.5/						Prototypes for 6x9 and 7x10cm

This first version was replaced around 1971 by a new design from 1968/69 with the same basic parameters (5 lenses in 4 groups, 135mm, f/3.5), but improved performance. The two versions can easily be distinguished by the filter size: the old version had a 58mm filter size, the new one 67mm. The new version no longer used the special recessed Technika lensboards. Fig. 6 shows Zeiss' modulation transfer function (MTF) curves for both the older version from 1954 and the younger one, the much better performance of the new version is easy to see. In addition, the image circle was 10mm larger. In my experience, the old version exhibits some focus shift [20] – the same is true for the contemporary 135mm f/3.5 Schneider

Xenotar. They actually exhibited better performance wide open than stopped down one or two stops in my tests, and only stopping down to at least f/11 improved the resolution and contrast again [20]. This can also be seen in the comparison of the MTF curves for f/3.5 and f/8 in fig. 6; it is probably residual zonal spherical aberration that leads to the lower curves at around 50mm radius at f/8. The new version was much better and did not show visible focus shift in my tests [20]. The first batches of the new version were single coated, but soon it was further improved by receiving multicoating, the famous T* coating introduced by Zeiss in 1972. Zeiss made several batches of the multicoated Planar in 1975, the 1980's, and the 1990's, 984 lenses in all [2]. The lens came in the new style Compur 1 shutter with a blocky shutter speed ring (fig. 4 upper right), initially in the chrome ring version with white lever tips (1980) and later ones in the all black version. The last batch was supposedly a special order by the Japanese Linhof importer [21]. In my experience it is one of the sharpest 4x5" lenses I have ever used [20].

As mentioned above, the Schneider-Kreuznach Xenotar was a very similar lens, it just reversed the setup with the three-element lens group in the front and the two-element one in the back. It came in three focal lengths, 105mm f/2.8, 135mm f/3.5, and 150mm f/2.8. The first two lenses were direct competitors with the Planar, at a lower price (the 105mm was DM 395 in 1958 [12], DM 133 less than the Planar equivalent); however, Zeiss never produced a Planar to compete with the fast 150mm f/2.8 Xenotar, although they made about 10 different 150mm f/2.8 Planar prototypes [22]; one is shown in fig. 5. Another Planar that unfortunately was never produced was a 210mm f/5.6 version for the 5x7"/ 13x18cm format, as described in the chapter on the 5x7" lens prototypes below (fig. 23). A few longer Planars of 300mm focal length never made it past the prototype stage, either.

Fig. 5: 150mm f/2.8 Planar prototype. Image courtesy of Westlicht Photographica Auction [23].

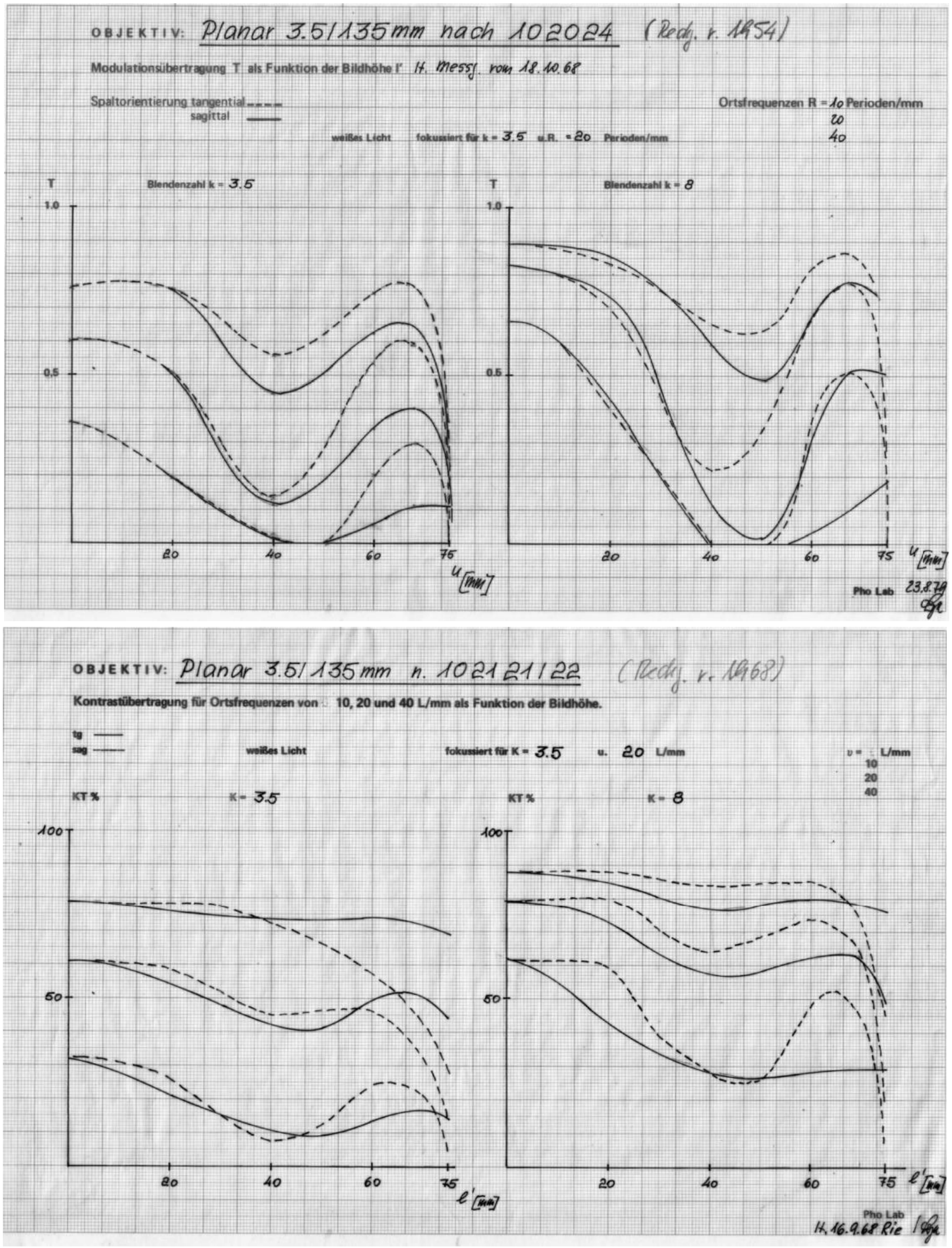

Fig. 6: Measured Zeiss MTF curves of the old 135mm Planar from 1954 (top) and the new version from 1968/69 (bottom), at f/3.5 (left) and f/8 (right) within a 150mm image circle. The solid lines are the tangential structures, the dotted lines the sagittal ones. Note that the curves are for 10, 20, and 40 lp/mm, not 5, 10, and 20lp/mm as is common for LF lenses. The lenses were focused at f/3.5 for all measurements. Graphs courtesy of Zeiss Oberkochen through Dr. H. Nasse.

Sonnar LF lenses from Oberkochen

Fig. 7: 250mm f/5.6 Sonnar (old style mount) for 4x5" (left), and 180mm f/4.8 Sonnar (old style mount) for 6.5x9cm (right). Scale is in cm.

The Sonnar is a triplet derivative developed by Ludwig Bertele in 1930 for Zeiss [24]. Bertele was originally a designer for Ernemann, where he developed the Ernostar lens, a forerunner of the Sonnar. When Zeiss took over Ernemann through the formation of Zeiss-Ikon in 1926, Bertele stayed on as lens designer and developed the Sonnar as a fast normal lens or long lens. The first Sonnars were made for 35mm film, such as the famous 50mm f/1.5 Sonnar or the 180mm f/2.8 "Olympia-Sonnar".

The "Sonnar" name was originally used by the Contessa-Nettel company for a short-lived different lens; when Contessa-Nettel became part of the Zeiss-Ikon conglomerate in 1926, Zeiss inherited the rights to the name. It is derived from the German word for sun, "Sonne". It traditionally consists of a positive single meniscus in the front, followed by a thick negative cemented group made from 2-3 lens elements, and a positive back group which can be either cemented (2-3 elements) or a single element. Sonnar lenses usually have a large aperture for the given focal length and are well corrected for being used wide open over a small to moderate angle of view. The Sonnar is *not* a telephoto design in the strict sense of the word – as a triplet variety, the first and last groups have positive power, and the center group is negative – but the back nodal point of the lens is located in a forward position, so that the flange-focal distance (FFD) is significantly shorter than the focal length. Sonnars of normal focal length cannot be used in SLR's because of the short FFD. An advantage of the Sonnar construction compared to the Planar type is that, with only six air-glass surfaces, it is not as prone to flare. This was especially important before the invention of coating.

Table 4: Large format Sonnar lenses from Carl Zeiss Oberkochen. [a] includes Linhof Technika plate [b] includes Linhof "Baby" Technika plate

Focal Length [mm]	Max./Min. Aperture	Angle of Coverage [°]	Image Circle [mm]	Mount/ Shutter	Filter Size	Weight [g/oz.]	Remarks
180	4.8/45	42	140	Synchro-Compur 1	M58x0.75	855/30.2[b]	Old style chrome mount
				Compur 0	M67x0.75	792/27.9[b]	New style "block mount"
250	5.6/45		185	Synchro-Compur 1	M77x0.75	1646/58.1[a]	Both "old" and "new" mounts exist
105	2.8						Prototypes for Linhof 6.5x9cm
150	4.0						Prototype
150	4.8						Prototype for 6x7cm
180	4.0						Prototypes for Linhof
250	4.0						
250	5.6						
300	4.0						Prototype for 8x10"

Zeiss Oberkochen produced two newly designed Sonnars for view cameras, a 180mm f/4.8 for 6.5x9cm, and a 250mm f/5.6 for 9x12cm/4x5", as shown in figs. 7-9. The German prices in 1958 were DM 670 for the 180mm, and DM 1135 for the 250mm [12]. The Opton versions are labeled "So", as shown in fig. 8. The optical design, five lens elements in three groups, is shown in fig. 1 lower left for the 250mm. Similar to other lenses designed after WWII, the new Sonnars used some of the new glass types containing lanthanum oxide and thorium oxide. Whereas lanthanum oxide is not radioactive, thorium oxide is. Both front and back cell have lens elements that apparently contain a small amount of thorium oxide, although much less than the contemporary Apo-Lanthar or Xenotar lenses from Voigtländer and Schneider-Kreuznach, respectively. Measurements of the removed back cell of a 250mm lens show about 4.0 µSv/h (micro-Sievert/hour) of □-radiation close to the inside lens element. This is about 20-30 times more than the background radiation, but only $1/7^{th}$ of the radiation coming from a 210mm Apo-Lanthar [25]. Measurements next to the outer back lens surface show smaller values, i.e. it is the inside lens that contains thorium oxide. The highest value for the front cell, again measured from the shutter side, is about 2.5.µSv/h; most likely the second lens in the front cell is the thorium-containing one, and some radiation is shielded by the third lens. Both those lenses are shown in lighter gray in fig. 1. Each lens group shows the typical yellowish discoloration due to internal radiation damage, but this is rather faint and not as pronounced as in an Apo-Lanthar. Only small amounts of radiation can be measured on the outside with the lens assembled, since most of the radiation is absorbed by the surrounding lens elements and the mount parts. The Sonnar appears to be the only Oberkochen LF lens that used thorium oxide. I have not measured the 180mm version, but it shows the slight yellowing of the glass, so it is most likely also slightly radioactive, to a lesser degree due to the smaller lenses. It is known that Voigtländer stopped using thoriated glasses in their Apo-Lanthars sometime between 1964 and 1966 [51], and Schneider-Kreuznach abandoned their use in the mid-1970's [52]. Whether Zeiss switched the glass to a nonradioactive version for the last batches of the Sonnars - made around 1969-1971 - is not known.

The 250mm Sonnar is also the only Zeiss LF lens where I have occasionally seen small areas of separation, in the front cemented group. These thin areas are only visible at the very periphery when tilting the lens and are usually not in the light path.

Fig. 8: Two versions of the 180mm f/4.8 Sonnar. On the left is the newer version with 67mm filter size and Compur 0 shutter; it is also an "Opton" version, note that the lens name is just "So". On the right is the older version with 58mm filter size and Synchro-Compur 1 shutter, with the regular "Sonnar" and "Carl Zeiss" engravings. Note the steep angle of the engraved front ring of the right lens due to the small filter size.

As one can see from the optical data in table 4, the official image circle of the 180mm lens is close to covering 4x5"; stopped down, the 180mm Sonnar actually does cover 4x5", although without movements. The 180mm Sonnar was made in two different mounts, which used two different shutter sizes. The first version, with a chrome plated front and 58mm filter size, used a Synchro-Compur 1 (fig. 7 right, fig. 8 right, fig. 9 center); the 58mm filter size was actually pushing the mechanical limits, as the front retaining ring had be rather thin and steeply angled to allow enough room for the engraving while still accommodating the maximum opening (fig. 8). The newer version, with a 67mm filter size, used a Compur 0 in a cylindrical Linhof mount (figs. 8-9). The shutter size difference might not be obvious at first glance, since that extra cylindrical housing makes the outside diameter similar to a size 1 shutter, but it can easily be seen by unscrewing the back cell. The 250mm had a similar mount redesign at some point, but it did not change the shutter size and the size and shape of the front cell; the main difference was the change of the shutter speed ring from the conical chrome plated one seen in fig. 9 center to a cylindrical one with the little chrome squares as seen for the newer 180mm in fig.9 right. Optically, there was no change between the different mount versions. Note that – similar to the Biogon lenses described below – the lens cells do not screw directly into the shutter threads. They use larger threads in additional mounting pieces attached to the lens board and shutter (compare fig. 13). It can be safely assumed that this was done to avoid undue stress on the relatively small shutter threads from the heavy and large lens cells.

Fig. 9: Left, 250mm f/5.6 Sonnar with older style chrome plated shutter speed ring; center, older version of 180mm f/4.8 Sonnar in Synchro-Compur 1 shutter with chrome-plated cone-shaped front cell and shutter speed ring; right, newer version of 180mm f/4.8 Sonnar in Compur 0 with a design of small chrome-plated squares for the cylindrical shutter speed ring. Note the nonlinear aperture scales of the two older versions vs. the linear one of the new version on right. Scale is in cm.

As mentioned above, Sonnars have a flange focal distance (FFD) that is shorter than the focal length. In the case of the 250mm Sonnar I measured approximately 183mm for the FFD, and for the

180mm Sonnar about 138mm. That places the back nodal planes inside or in the vicinity of the front lenses, which means there will be some image shift on the ground glass when using front tilt or swing.

In my experience, the Sonnar is one of the sharpest LF lenses for use at full aperture; at f/5.6, the 250mm I measured had about twice the resolution of 240-250mm Tessar, Xenar, or Heliar lenses at the same opening [12]. The downside is the significant size and weight compared to other lenses, the latter being caused by the large amount of glass used in a Sonnar (compare fig. 1).

Zeiss made some prototypes for other focal lengths, including a 300mm f/4 version for 8x10 [26], and a 150mm f/4.8 for 6x7cm [27], the latter as a companion lens to the 80mm Planar and 45mm Biogon. There were also later prototypes with the same focal length and sometimes the same aperture as the existing Sonnars, such as 250mm f/4 and f/5.6 lenses [22]. None of these ever made it into production.

Biogon large format lenses from Oberkochen

The Biogon name was first used by Carl Zeiss Jena for a 35mm wide angle lens for the pre-WWII Contax 35mm camera. That lens was also developed by Ludwig Bertele and was based on the Sonnar design, where the second group was made smaller, and the last group was enlarged considerably and split into two components [24]. The name was composed of the Greek word for angle, "γωνια (gonia)", and the prefix "bio" was indicating a dynamic, lively image [28].

The post-WWII Biogons, including all LF versions, were a totally different construction. They were again designed by Bertele, in 1952 [29]. He had moved to Switzerland after the war and became a designer for the company Wild-Heerbrugg in Switzerland, where he developed the "Aviogon" aerial wide angle lenses in the 1950's. These were based on the designs pioneered by the Russian designer Roossinov [24, 28], a near symmetric construction with large outer negative menisci. The large negative menisci increased the coverage considerably to values between 90° and 120°, and reduced the illumination falloff in the corners by tilting the entrance and exit pupils with increasing angle. Instead of the "$\cos^4$-law" for regular lenses, these lenses follow approximately a $\cos^3$-law for the falloff of the illumination. They are the forerunners of practically all modern wide-angle lenses for LF.

The original Roossinov design used menisci that were very strongly curved on both the outside and the inside, which made them difficult to produce and very expensive. Bertele reduced the need for a strong outside curvature by replacing the single meniscus with two negative menisci on each end in his Aviogon; it probably also allowed him to avoid violating the Roossinov patents.

Shortly after developing the Aviogon, he developed a series of new wide angles for Zeiss with a similar design, patented in 1955 [29]. These lenses had two large negative menisci on the front and one on the back (fig. 1 upper left), so it was a slightly simplified version of the Aviogon. Nevertheless, the large outer menisci make this type of lens one of the more expensive ones to produce. Zeiss decided to use an already established name for them, so they called these lenses Biogon, despite a totally different optical design compared to the first Biogon. Nowadays, the term "Biogon design" almost always refers to this postwar Bertele design, not the first one with that name. Since the Biogon name had already been used before the war, Biogon lenses sold under the Opton name had to be labeled „Bi", despite the fact that Carl Zeiss Jena never used the name later on; their equivalent lenses were named "Lamegon" [3, 18].

Fig. 10: Biogon 75mm f/4.5 (left) for 9x12cm/4x5" and Biogon 53mm (right) for 6.5x9cm. The 75mm is the first mount version, the 53mm one is the second version. Scale is in cm.

Bertele was able to raise the aperture for this type of lens to f/4.5 – Roossinov's "Russar" lenses typically had a maximum opening of f/6.8 or less – at the expense of coverage. Biogons typically have coverage angles of 90-95°. The large size and the curvature of the back meniscus necessitate a special mount construction to avoid damage of the lens when sitting on a surface, without introducing vignetting. This was achieved by using four small protrusions, or "ears", at 90° intervals on the back side (figs. 10-11), with their position corresponding to the edges of the film, not the corners. Carl Zeiss Jena solved a similar problem with their 90mm f/4.5 Lamegon by introducing a removable ring on the back side [18].

Fig. 11: Side view of the Biogon 75mm f/4.5 (top) for 9x12cm/4x5" and Biogon 53mm for 6.5x9cm (bottom). Scale is in cm.

Table 5: Large format Biogon lenses from Carl Zeiss Oberkochen. [a]includes Linhof "Baby" Technika plate [b]includes Linhof Technika plate

Focal Length [mm]	Max./Min. Aperture	Angle of Coverage [°]	Image Circle [mm]	Mount/ Shutter	Filter Size	Weight [g/oz.]	Remarks
45	4.5/32	95	100	Synchro-Compur 0 or Compur 0	M67x0.75		For 6x7cm
53			115			704/24.8[a]	For 6.5x9cm
75			165		M95x1.0	1482/52.3[b]	For 9x12cm/4x5"
90	2.8						Prototype for 6.5x9cm

Zeiss built the Biogon in several different focal lengths, including versions for 35mm cameras (21mm for Contax), medium format (38mm for Hasselblad SWC and more recently for Alpa), and large format. The initial two models for large format were the 53mm f/4.5 for 6.5x9cm and the 75mm f/4.5 for 9x12cm/4x5". Those two lenses, shown in figs. 10-11, were the most expensive lenses for their respective format that Linhof/Zeiss offered: The 53mm was DM 961 and the 75mm was DM 1516 in 1958 in Germany [12]. The latter cost more than the Linhof Super-Technika camera it was made for. In 1963, they added a 45mm f/4.5 model (fig. 12) for Linhof's 6x7cm view and press cameras [19]. The 45mm design was from 1961. It was introduced together with the 80mm f/2.8 Planar described above, but is a rather rare lens as only 100 units were made according to the production lists [2], with serial numbers from 4,069,635-734.

Significantly larger numbers of the 53 and 75mm versions were built, at least 3000 units of the 53mm one and 1700 units of the 75mm one [2]. Similar to the Sonnars, two mount versions existed, an earlier one with a serrated chrome-plated shutter speed ring (fig. 10 left, fig. 11 top), and the later one with the chrome square design (fig. 10 right, fig. 11 bottom). The lens board for the first version of the 75mm Biogon was recessed, allowing a front standard position on the main rail of the camera bed for the Linhof Technika, later ones also had flat lensboards. Note that – similar to the Sonnars – the lens cells of the 53mm and 75mm versions do not screw directly into the shutter threads, but screw into mounting pieces attached to the lens board and shutter, with larger threads (fig. 13). Again, it can be assumed that this was done to avoid stress on the relatively

Fig. 12: 45mm f/4.5 Biogon for the 6x7cm format. Image courtesy of Westlicht Photographica Auction.

small shutter threads from the heavy and large lens cells; as an example, deformation of the shutter threads is a known problem with the first versions of Schneider-Kreuz-nach's 90mm f/8 Super-Angulon, which initially came in a size 00 Synchro-Compur shutter. Since the cells of the Biogon are significantly heavier than Super-Angulon cells, they might have been considered too heavy even for a size 0 shutter.

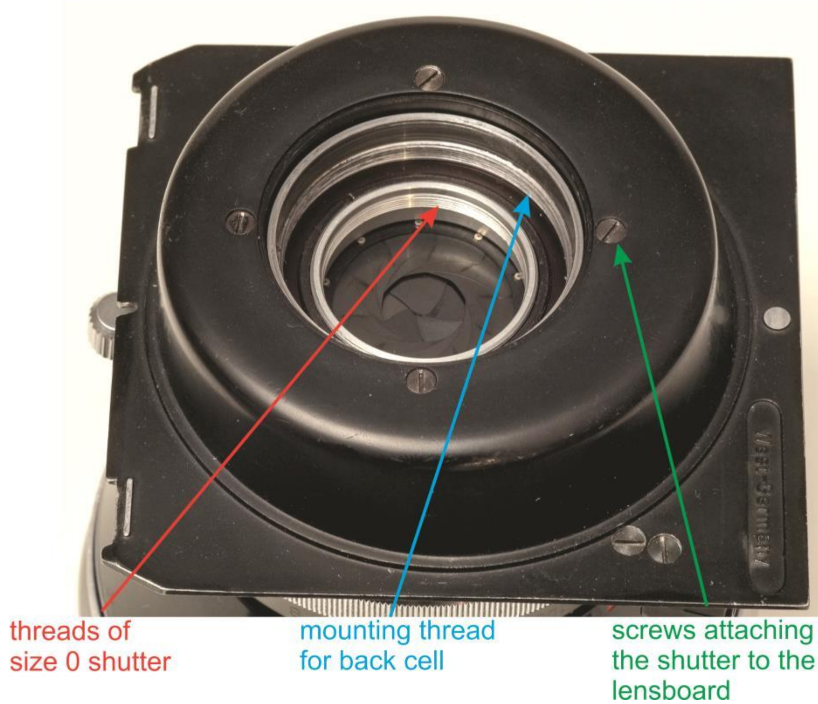

Fig. 13: Lensboard of a 75mm f/4.5 Biogon. The original shutter threads (red arrow) are not used, the back lens cell is held by a larger separate thread (blue arrow). The shutter is also not mounted with a retaining ring, but with four screws (green ar-

In addition to the civilian Linhof versions, Zeiss sold Biogons for use in aerial cameras, including 823 units of the 75mm Biogon they directly made for the Fairchild Camera and Instrument Company in the USA [2]. The design was also licensed to several other US optical companies, again for use in aerial cameras: Goerz Am. Opt. made 3" Biogons, labeled Aerogor or Biogon [30]; often another inscription is found on the mount, "Hycon", but this was actually the camera manufacturer. Pacific Optical made two different 3" f/4.5 "Paxar" lenses [31-32] derived from the Biogon; the version "1" or "A" [31] was the same as or very close to the original 75mm Biogon, the version "2" or "B" [32] had even larger outer lens elements than the original. Another company making Biogon versions was Viewlex, their 3" f/4.5 lens was called "Viewgon" [33]. Those aerial versions came without a usable shutter, but can often be adapted to a size 1 [34] or size 3 shutter. Note that they usually do not have the "ears" on the back lens cell mount, so care needs to be taken not to damage the last lens surface in use. There were also aerial versions of the medium format 38mm Biogon originally made for Hasselblad, e.g. for Vinten and AGI cameras (see table 7c), but I am not aware of any variants for the 53 or 45mm Biogons, except for Linhof's own Aero-Press cameras. A few prototypes that did not make it to market were produced and are listed in the respective production files [24], such as a 90mm f/2.8 (table 4).

As mentioned above, Zeiss emphasized the performance at large apertures for their postwar LF lenses, at the expense of a limited coverage. This is especially true for the Biogons. One has to keep in mind that Zeiss' pre-WWII wide angle lens was the Protar V with a maximum opening of f/18, and in the 1950's the only comparable lens was Schneider's Super-Angulon with a slightly larger coverage at 100°, but a maximum opening of only f/8. It took 12 years until Schneider brought out the improved f/5.6 Super-Angulons in 1966, and it was 1976, after Zeiss had left the LF market, when Rodenstock started with their f/4.5 Grandagon line. Carl Zeiss Jena had developed a set of f/4.5 lenses in 1966, but they never made it to the market as described in another article [18]. Even then, both the Grandagon and Super-Angulon were more designed towards larger coverage, with the open aperture mostly intended for focusing. Thus the

Biogon performance was outstanding in its time, as can be seen in the MTF curves of the 53mm and 75mm Biogons in figs. 14a and b. Although there is some improvement when going from f/4.5 to f/8, the difference is actually not big because of the exceptional performance already at f/4.5.

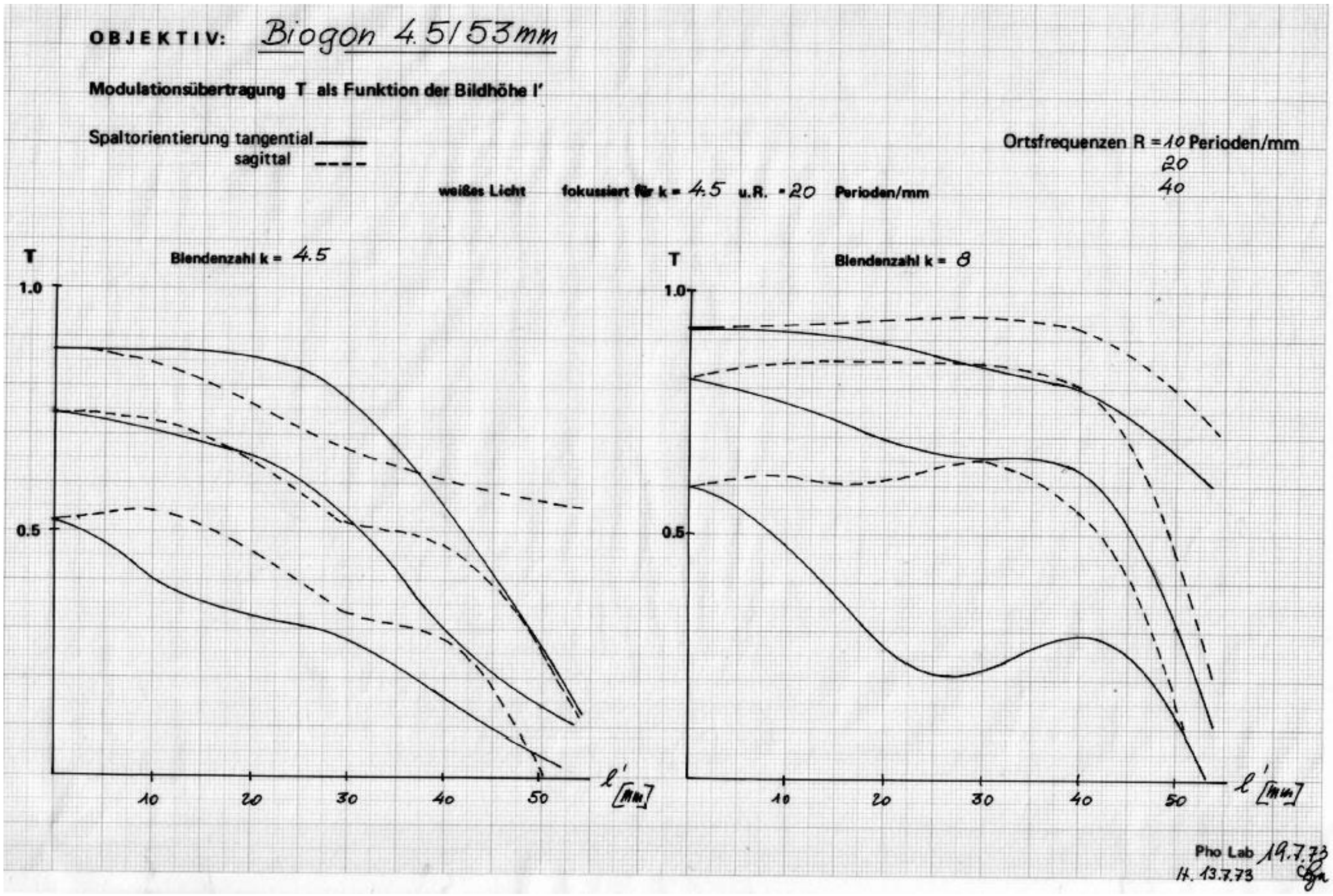

Fig. 14a: Measured Zeiss MTF curves of the 53mm Biogon at f/4.5 (left) and f/8 (right). The solid lines are the tangential structures, the dotted lines the sagittal ones. Note that the curves are for 10, 20, and 40 lp/mm, not 5, 10, and 20 as is common for LF lenses. The lens was focused at f/4.5 for both measurements. Graphs courtesy of Zeiss Oberkochen through Dr. H. Nasse.

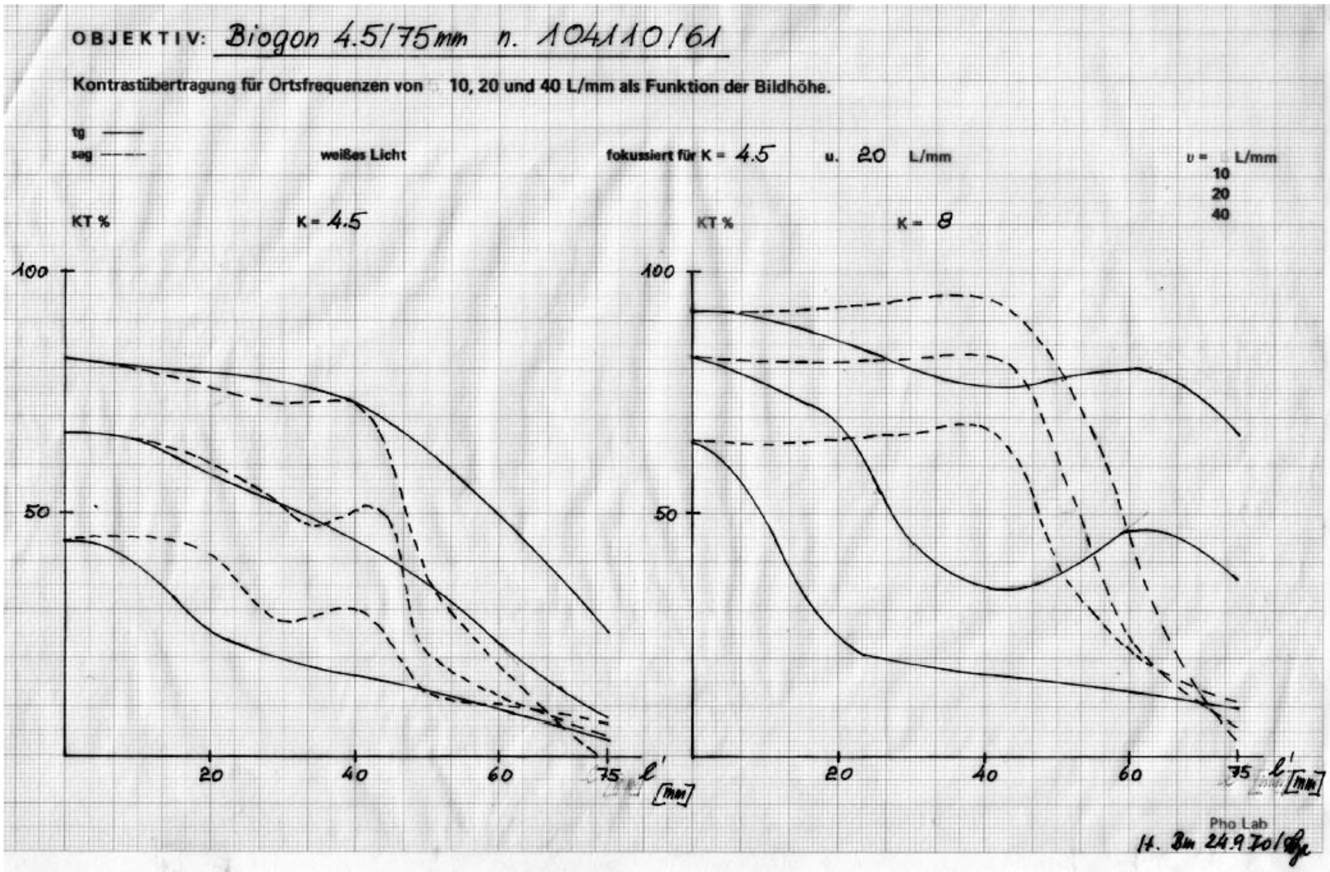

Fig. *14b: Measured Zeiss MTF curves of the 75mm Biogon at f/4.5 (left) and f/8 (right). The solid lines are the tangential structures, the dotted lines the sagittal ones. Note that the curves are for 10, 20, and 40 lp/mm, not 5, 10, and 20 as is common for LF lenses. The lens was focused at f/4.5 for both measurements. Graphs courtesy of Zeiss Oberkochen through Dr. H. Nasse.*

Luminar photomacrography lenses

Zeiss produced a range of six newly designed lenses for photomacrography after WWII, called Luminar. Available focal lengths were 16, 25, 40, 63, and 100mm, plus a rather rare "Zoom-Luminar" (tables 6-7). They were produced by the Zeiss-Winkel factory in Göttingen, Lower Saxony, which originally had been an independent company, founded in 1857 by Rudolf Winkel. The Winkel factory started out as a mechanical workshop, but added microscopes to their line in 1866. They soon became a respected microscope manufacturer in their own right. In 1911, Zeiss became the majority shareholder of Winkel, and in 1957 they were fully integrated into Zeiss as a full subsidiary of the Zeiss foundation. As a consequence, the separate Winkel brand ceased to exist at that time.

The Zeiss-Winkel factory made practically all of the West-German Zeiss microscopes and microscope objectives after WW II. Following the 1991 reunification of Zeiss Oberkochen and Zeiss Jena, the Winkel factory became part of the "Carl Zeiss Microimaging" division with production sites in both Göttingen and Jena; since 2006, when the electron microscopy division was joined with "Carl Zeiss Microimaging", their name is "Carl Zeiss Microscopy" [63].

The Luminar name originated with Winkel, as the first "Mikroluminar" lenses were built by them around 1898[3] [35], but the name was not used by Zeiss until after WW II. The Luminars are well known and highly regarded by photographers working in photomacrography, regardless of the format used. The lenses were originally designed for use with the Zeiss Ultraphot II and III research microscopes [36, 58, 61, 62][4], which featured an integrated camera for 4x5" film (there was also a 35mm setup). Except for the 100mm lenses and the Zoom Luminar, they could also be used on other microscopes.

Fig. 15: Some Zeiss Luminars and the necessary accessories for LF photomacrography. Front row from left to right: Luminar 25mm f/3.5 (old version), Luminar 63mm f/4.5 (old version), Luminar 63mm f/4.5 (new version), Linhof adapter ring from RMS thread to size 0 shutter thread, Linhof adapter ring for M35x0.75 thread to size 0 shutter thread for the newer version of the 100mm Luminar, 100mm f/6.3 Luminar (last version). Back: Linhof adapter "cone" on Technika board with Compur 0 shutter for mounting the Luminars to a Technika or similar large format camera. Scale is in cm.

The 16mm - 63mm Luminars do look like, but are not really microscope objectives: regular microscope objectives are part of a compound microscope, and the final image in a camera is formed by the combination of the objective and a second optical system, usually a photo eyepiece. The Luminars are designed to directly form the final enlarged image in one step, so if used in a microscope, it becomes what is called a "simple" microscope. For photography on a microscope, Zeiss recommended the use of the Lu-

[3] The Mikroluminars were made until about 1950, when they were replaced by the Luminars. The Winkel Mikroluminar range included 10mm f/3.8, 16mm f/3.8, 26mm f/4.5, 36mm f/4.5, 50mm f/4.5, 70mm f/4.5, and 100mm f/5.0 lenses.

[4] Zeiss made a precursor, the Ultraphot (I) microscope, before WW II; it had a different design, but similar possibilities for photomacrography with Carl Zeiss Jena Mikrotar lenses: 10mm f/1.6, 15mm f/2.3, 20mm f/3.2, 30mm f/4.5, 45mm f/4.5, 60mm f/4.5, 90mm f/6.3, 120mm f/6.3, and 165mm f/6.3 Mikrotars were available [3].

minars for magnifications of 6.8x to 50x over the use of the compound microscope setup [58]. For use on the Ultraphot II and III, the Luminars were screwed into mount adapters with an annular dovetail and then attached to the "Luminar head", a ball-shaped attachment housing an assembly of mirrors, replacing the microscope tube with the objectives and the eyepiece. It was attached to the massive microscope stand, which contained the illumination and imaging assemblies [37]. An assembly of two large movable first surface mirrors in the main housing allowed focusing and the projection onto a 4x5"/9x12cm camera. Note that the conjugate distance for regular photomicrography was usually 250mm, the distance most Luminars are optimized for, but that the light path in the Ultraphot II/III is much longer with 880-1200mm [61], leading to much higher magnifications in this setup (tables 7 and 8).

Similar to regular microscope objectives, the Luminar focal lengths are not only inscribed, but also color coded: the 16mm is brown, the 25mm orange/red, the 40mm is green, and the 63mm is blue. The older versions (see below) have the focal length inscription in the respective color, newer versions have

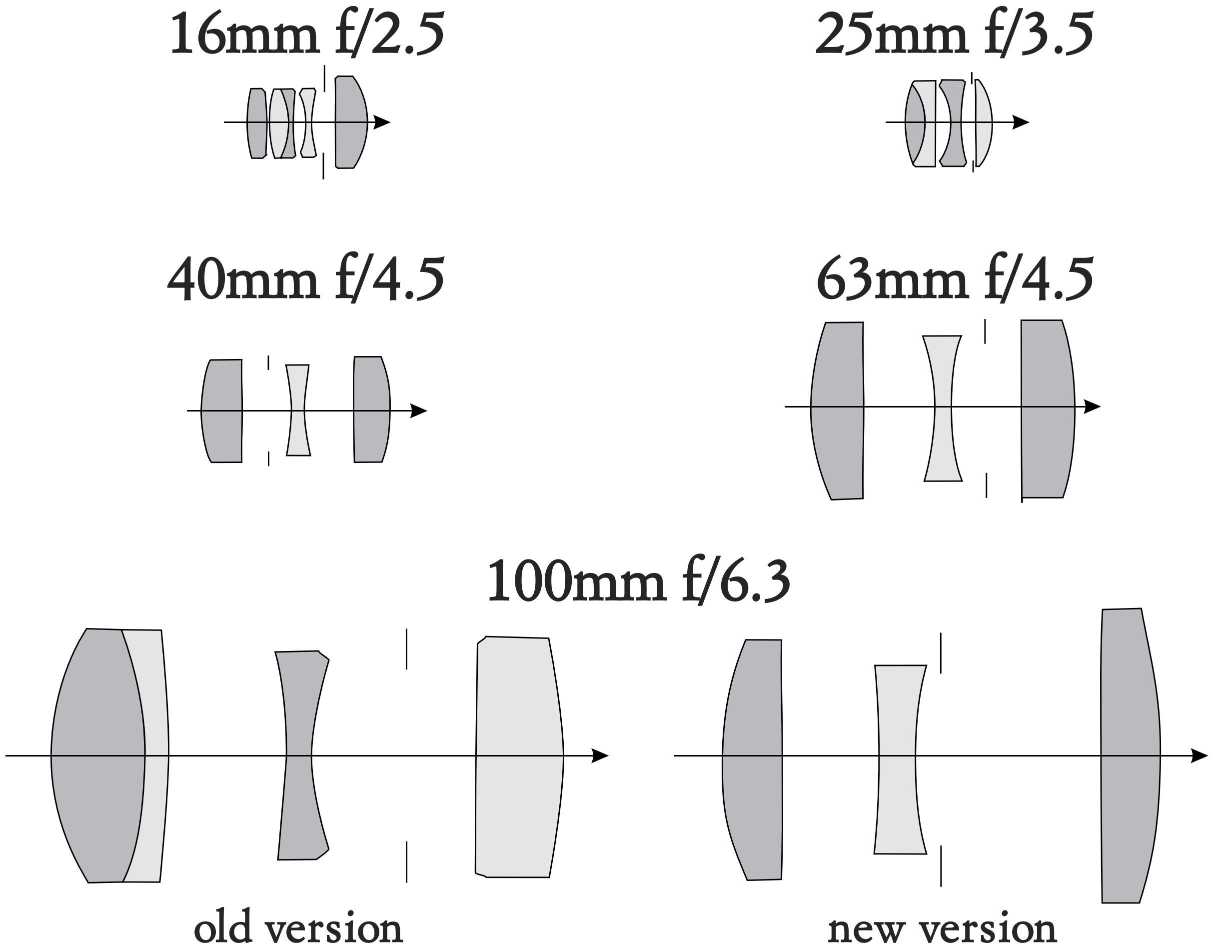

Fig. 16: Schematic lens diagrams of the Luminar lenses, after refs. [40, 56].

two colored dots on the barrel. The two versions of the 100mm f/6.3 Luminar are significantly larger than the other ones (fig. 15), there is also no specific color code for it, the lettering is white.

When Luminars are used on a microscope for transmitted light photomacrography, a special "condenser" lens should be used, positioned as close as possible to the object stage. They are different from a regular condenser lens in that they have a much longer focal lengths - 21, 36, 47, and 82mm for the 16, 25, 40, and 63mm Luminars, respectively [60]. They project the field stop of the lighting stage into the entrance pupil of the Luminar lens, whereas regular condenser lenses, with their much shorter focal lengths, project the field stop into the object plane [55]. These special condensers are just single lenses mounted at the top of a cylindrical housing that fits onto the condenser stage. For this reason they are often called "spectacle condenser lens" ("Brillenglaskondensor" in German). Zeiss produced one of these for each of the Luminars. They are color coded like the respective lenses, and carry a number: "1" is for the 16mm, "2" for the 25mm, "3" for the 40mm, "4" for the 63mm, and "5" for the 100mm Luminar. The latter could only be used on the Ultraphot II or III, not on any other microscope.

The Luminar lenses were also sold separately for use with regular cameras. Linhof offered lens boards with adapter cones for using a size 0 shutter with these lenses on their 4x5" and 6.5x9cm cameras (fig. 15). There were also adapters for medium format (Hasselblad, Rollei) and 35mm cameras (e.g. Contarex, Yashica-Contax) available. Additional adapter rings are needed for the size 0 shutter, since the 16, 25, 40, and 63mm Luminars come – true to their microscope heritage – with an RMS thread[5], and a size 0 shutter has an M29.5 x 0.5 thread. The 100mm Luminars came in 3 different threads as listed in table 6, and therefore need a different adapter. Note that for the last version of the 100mm, the back lens extends beyond the mount without the adapter, i.e. one has to be careful not to damage the exposed lens surface when unscrewing it from the adapter ring. Most or all of the 100mm Luminars also have an additional thread on the front for reversing the lens, accessible after unscrewing the knurled front ring. Since Zeiss designed the Luminars with the 9x12cm/4x5" format on the Ultraphot II/III in mind, they can all be used for LF (tables 6-7). In 1958, the German Linhof prices (in D-Mark) for the Luminars were [12]:

16mm: DM 272
25mm: DM 231
40mm: DM 204
63mm: DM 231
100mm: DM 252

For comparison, the Synchro-Compur 0 shutter needed to use the lenses directly on a large format camera was DM 61 [12]. Table 6 shows the Luminar range available. The barrels show the maximum aperture not only as the f-stop number k, but also the numerical aperture NA, standard in microscopy. NA is defined as:

$$NA = n \cdot \sin(\vartheta/2)$$

where n is the refractive index of the surrounding medium (approximately 1 for air), and ϑ is the maximum angle of the cone of light that can enter the lens. Assuming n=1 and infinity focus, NA can be calculated from k (and vice versa) by:

$$NA = 1/2k$$

[5] RMS stands for Royal Microscopical Society and refers to their standard microscope thread, defined in 1896, which is still in widespread use today. It is a Whitworth thread (55° angle) with male thread dimensions of 0.7952-0.7982" x 36tpi. Microscopists sometimes affectionately refer to it as the "Royal Screw".

*Table 6: Zeiss Luminars. The maximum aperture column shows the aperture first as the familiar f-stop number and then the numerical aperture NA. The optimum magnification refers to 250mm bellows extension – which was also the back focal distance in the regular Zeiss microscopes with photo attachment, and the usable magnification range is for 100-1000mm bellows extension. Note that the magnifications in the Ultraphot II/III microscopes were larger (compare table 7). * Zeiss data [59] – the visible entrance pupil and measured focal lengths suggests a smaller aperture for the Zoom Luminar*

Nominal (actual) focal Length [mm]	Max. Aperture	Lenses/ groups	Magni-fication range	Opti-mum magnifi-cation	Max. diameter of subject [mm] [38]	Mount	Weight [g/oz]	Remarks
16 (16.1)	2.5/0.2	5/4	10x-40x	14x	5-6	Barrel with RMS thread: 0.7982"x 36tpi		Old version
								New version
25 (26.0)	3.5/0.14	4/3	6.3x-25x	8.8x	10-12		81/2.86	Old version
								New version
40 (39.9)	4.5/0.11	3/3	4x-16x	5x	20-25			Old version
	4.0/0.13							New version
63 (63.4)	4.5/0.11		2x-10x	3x	30-40		79/2.79	Old version
							72/2.54	New version
100 (102.3)	6.3/0.08	4/3 4/3	0.8x-8x	2x	70-75	M34x0.75 M44x0.75 43.5mm annular Ultraphot dovetail	154/5.43	Old version, inverse Tessar type
		3/3				M35x0.75	148/5.22	New version, Triplet
Approx. 113-175	0.04-0.05*	6/4	2.5-3.6			43.5mm annular Ultraphot dovetail	448/15.8	Extreme retrofocus construction

The numerical aperture is also helpful in determining the "useful magnification" range in microscopy or microphotography. The "useful magnification" after Ernst Abbe is given as 500 – 1000 x NA. Lower magnifications than these values do not use the full resolving power of a lens and larger ones only produce "empty magnification" because of diffraction.

All Luminars can be stopped down; however, the (nonlinear) aperture markings are relative numbers indicating the fractions of the aperture area: 1-2-4-8-15, plus additional "30" and "60" settings for the longer focal lengths. The "1" setting is equivalent to fully open, the "2" is one stop down, the "4" is two stops down, and so on. For instance, for the 40mm f/4 Luminar, the actual nominal f-stops (at infinity) would be 4.0, 5.6, 8, 11, 22, and 32, not taking into account the magnification factor. For critical sharpness, i.e. to avoid visible diffraction, the lenses should be used wide open or with the aperture closed down only 1 stop, unless smaller stops are necessary for depth of field.

Except for the Zoom Luminar, the different focal lengths were all optimized for the same bellows extension, 250mm, and the usable magnification range on each side of that optimum (table 6) is equivalent to bellows lengths of 100-1000mm. The coverage of a given Luminar can easily be calculated from the maximum subject diameter given in table 6 and the magnification.

The Luminars were – again with the exception of the Zoom Luminar - deceptively simple constructions, using just 3, 4, or 5 lenses, as shown in fig. 16. The 40, 63, and the newer 100mm lenses were classic triplets, whereas the 25mm and the older 100mm were inverted Tessar constructions (cemented group at the front), with the aperture located in an unusual place, i.e. between the two single lenses in the back.

Fig. 17: The old and new version of the 63mm f/4.5 Luminar. Each image pair shows the old version on the left and the new version on the right. Left: In the old version the inscription is engraved and color-coded, blue for 63mm, whereas the new version used a white screen-printed inscription. Right: The logo was the traditional "Carl Zeiss" inscribed into an achromatic meniscus lens for the older version, and a new big "ZEISS" logo for the new version, flanked by two blue colored dots to indicate the focal length. Scale is in cm.

Except for the Zoom Luminar, all the lenses went through one optical redesign and several changes in the barrel mount, up to four versions are supposedly available on the used market [39]. The very first Zeiss-Winkel versions came in a chrome barrel with either "Winkel-Zeiss Göttingen" or "Zeiss-Winkel" written inside Zeiss' traditional achromatic meniscus logo, later versions were black. The first black versions still said "Zeiss-Winkel" but later the inscription was changed to the standard "Carl Zeiss" in the logo. Early versions do not carry the name Luminar on the mount. Another change of the barrel design coincides with the optical redesign. With the exception of the 100mm lens[6], the optical redesign did not change the *basic* constructions, it was just an incremental improvement, so the new 40-63mm versions were still triplets, the 25 still an inverted Tessar, etc. Fig. 17 shows the older and newer version of the 63mm side by side: the older one shows the traditional "Carl Zeiss" logo with the achromatic meniscus, the newer one uses just "ZEISS" in a blocky font. The color coding on the old version is in the engraved lettering of the lens parameters, the new one has two screen-printed colored dots. The new versions always show the name

"Luminar" on the mount. For the 40mm focal length, the redesign resulted in a slight increase of the maximum aperture, from 4.5 to 4.0; all other lenses kept their maximum opening. The production of the 100mm stopped earlier than that of the other Luminars, so there was never a version with the "ZEISS" logo, all 100mm versions have the traditional "Carl Zeiss" one. Late versions of the 100mm, which was not color coded, exhibit only 2 knurled rings on the outside instead of the 4 rings of the older versions; it is also shorter than the previous versions as shown in fig. 18. Note that the lens design of the 100mm changed from an inverted Tessar to a triplet with the newer design (fig. 16).

The earlier Luminars, both the chrome and black versions, do have serial numbers engraved. Those numbers are not part of the Zeiss numbering series given above, but are most likely a separate numbering system used by Winkel. Unfortunately, production lists for Winkel serial numbers are not known. The 16-63mm Luminars made after the redesign do not show serial numbers; the numbers printed on the mount, such as 462513-9902 for the 63mm Luminar, are part numbers, not serial numbers. This is consistent with the current practice for microscope objectives made by Zeiss or Leica, showing only part numbers [54].

Fig. 18: Back view of the two 100mm Luminar versions. Left: the last version, a triplet construction, shows only two knurled rings, and has a 35mm thread. Center: the older version, an inverted Tessar construction, has 4 knurled rings and a 34mm thread; it often comes with an adapter ring to a 44mm thread (right).

The rare Zoom Luminar (figs. 20-21) was only made to be used with the Ultraphot II/III. Zeiss' goal for the Luminar use on the Ultraphot was to allow a continuous range of magnifications from 2.5x to 70x as shown in table 7. With 880-1200mm, the Ultraphot II/III had a much longer light path than a conventional microscope with photo attachment, such as the Zeiss Universal microscope or Photomicroscope. The smallest magnification with the 100mm Luminar on the Ultraphot was therefore 6.5x (or 5.3x with an additional 0.8x reduction lens). The Zoom Luminar extended the range at the lower end with a 2.5x – 5x magnification (including the 0.8x lens). This magnification range combined with the long light path of the Ultraphot lead to a very unusual construction for a macro lens. The Zoom Luminar is an *extreme* retrofocus construction, essentially a macrophotography relative of a Distagon.

Fig. 19: The two versions of the 100mm Luminar, front view. Left: new version, right: old version

Fig. 20: The Zoom Luminar. Left: Front view, long focal length setting. Center: Front view, short focal length setting – the zoom is operated by the upper knurled ring. Right: Back view – note the much larger lens diameter compared to the front lens, and the chrome-plated annular dovetail connector for the Ultraphot II/III. See text for more details.

The front cell, consisting of three lenses in two groups (Fig. 21) with the first lens being a strong negative meniscus, has considerable negative power. The back cell, again three lenses in two groups, has strong positive power. The zoom function is achieved by moving the front cell away from the aperture and the back cell (fig. 20 center), leading to a shorter focal length and an additional reduction of the distance from the image plane to the principal plane on the image side, i.e. it is actually a varifocal lens, not a zoom lens.

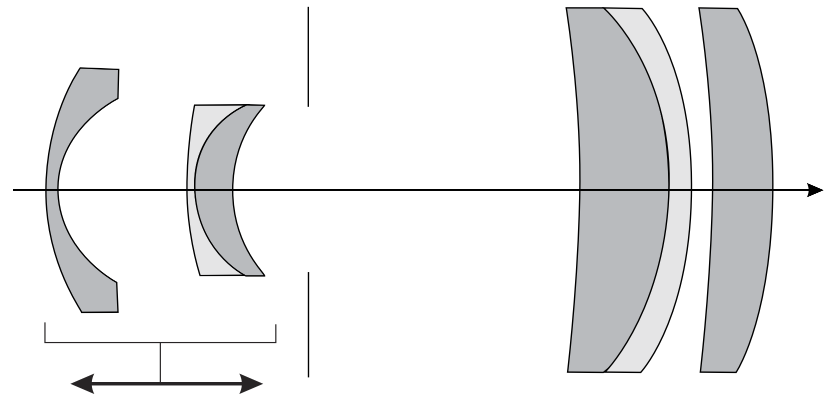

Fig. 21: Schematic lens diagram of the Zoom Luminar. This drawing is not based on the manufacturer's data or drawings as in figs. 1, 16, and 24, but on partially dismantling the lens and observing reflections in actual lens cells. Exact radii, thicknesses, and distances are not known, the sketch only indicates the basic element arrangement.

Table 7: Magnification ranges of the Luminar lenses for different microscope setups according to [59]. The Zeiss Universal microscope is a regular setup with 250mm distance between object and film, whereas the Ultraphot has an 880-1200mm long light path [61], resulting in significantly higher magnifications. The Ultraphot also had an additional 0.8x reduction lens to allow a continuous range of magnifications.

Luminar lens	Zeiss Universal microscope	Ultraphot II/III	Ultraphot with 0.8x lens
16mm	14x – 22x	50x – 70x	40x – 55x
25mm	8x – 14x	31x – 43x	25x – 34x
40mm	4x – 8x	20x – 27x	16x – 22x
63mm	2x – 4x	11.5x – 16x	9.5x – 12.5x
100mm	-	6.5x – 9.5x	5.3x – 7.5x
Zoom	-	2.5x – 3.6x	3.6x – 5x

The strong retrofocus construction is quite apparent in the measured optical data: Zeiss never published focal lengths data for the lens, but measuring the object plane – film plane distance for two different magnifications resulted in a calculated value of about 175±5 mm for the long focal length setting (fig. 20 left), and 113±5 mm for the short focal length setting (fig. 20 center)[6]. At the same time, infinity focus is achieved at about 475mm flange-focal distance (FFD) for the long focal length, and 345mm for the short focal length. These values imply that the rear principal plane is located approximately 300mm and 232mm behind the flange plane for the two extreme focal lengths, respectively. Macrophotography in the intended magnification range thus requires bellows lengths in excess of 80cm, as in the Ultraphot II/III (note that the nominal magnification range 2.5-5x engraved on the barrel is for the Ultraphot setup with the additional 0.8x lens). At infinity, the circle of illumination is about 150mm in diameter for the long focal length setting, and 88mm for the short one. At magnifications of 2x and larger it should therefore cover 4x5 without any problems. The Zoom Luminar can thus be used on a view camera with respect to coverage, but it requires some serious adaptation effort and a very long bellows.

[6] Note that these are approximate numbers from measuring the extension at infinity and at magnifications around 0.5x. The possible error for the focal length is at least ± 5mm. On the other hand, the ratio of these two focal lengths is close to the ratio of the magnifications given by Zeiss (3.6x/2.5x).

Another characteristic of retrofocus lenses is a pupillary magnification[7] >1. In the case of the Zoom Luminar it is around 3x, slightly below 3 for the 175mm setting and a bit above 3 for the 113mm setting. It is already evident in the much larger diameter of the back group vs. the front group (figs. 20-21). This strong pupillary magnification is usually encountered in super wide angle or fisheye lenses. In macrophotography lenses it is extremely uncommon, as is a retrofocus construction, but has the added benefit of increasing the effective aperture in the macro range significantly.

Zeiss also produced a range of "Epi-Luminars", in 20, 25, and 40mm focal lengths for reflected light microphotography on the Ultraphot [59]. Except for the 20mm, their optical data are similar to the regular Luminars (compare tables 6 and 8), but they were made for use with a specialized reflected light attachment, do not have adjustable apertures and are thus not as useful for photomicrography applications. They also have a different thread, M40x0.75 [62]. M40x0.75 is also the front thread of a size 1 shutter, but unfortunately a good part of the lens barrel is located behind the thread, i.e. it will collide with the shutter blades if screwed in directly. The magnifications achievable with the Epi-Luminars on the Ultraphot are listed in table 8. The Epi-Luminars could also be used on Zeiss' Universal microscope, but with smaller magnifications.

Table 8: Epi-Luminars and their magnification ranges, after ref. [59]

Nominal (actual) focal length [mm]	Maximum Aperture	Magnification range Ultraphot II/III	Magnification range Ultraphot II/III with 0.8x lens
20 (18.7)	2.8/0.18	44.5x – 61x	35x – 49x
25 (25.0)	3.5/0.14	33x – 46x	27x – 36x
40 (40.0)	4.5/0.11	22x – 29x	17x – 23x

Zeiss stopped producing Luminars sometime in the late 1970's to early 1980's. The main reason was probably the development of low magnification microscope objectives with a flat field, which allowed photomacrography with a compound microscope at similar magnifications as the Luminars, without having to change the microscope setup. However, it is occasionally conjectured that the real reason was that a special glass needed for some of the lenses was no longer available. Additional information on the Luminars and their history can be found in [39-41, 56, 58-59].

The prototype series for 13x18cm/5x7" from 1966

At the 1966 Photokina trade fair, Carl Zeiss Oberkochen announced a set of new LF lenses for the 13x18cm/5x7" format [42], i.e. for the concurrent Linhof Super-Technika V in that size. These lenses were a 110mm f/8 Hologon with 90° coverage, a 210mm f/5.6 Planar, and a 500mm f/8 Tele-Tessar. They never made it into production, apparently due to economic reasons. The crisis of Zeiss-Ikon already loomed on the horizon, and 6 years later Zeiss Oberkochen completely stopped production of the Zeiss and Voigtländer LF lens lines.

The most interesting lens was obviously the 110mm version of the Hologon. The original Hologon lens was a 15mm f/8 lens developed by Zeiss designer Erhard Glatzel for 35mm, a rectilinear lens with 110° coverage. It was introduced in 1966, too, integrated into a Zeiss-Ikon camera housing specifically produced for the Hologon. Later it was also sold separately for the Leica M mount. It was an inverse triplet, i.e. an inner positive lens surrounded by two outer negative lenses, consisting of thick and strongly curved elements, resembling a glass ball from the outside. An adjustable aperture could not be used since it

[7] Pupillary magnification = exit pupil diameter/entrance pupil diameter

interfered with the inner lens element. A related 16mm version was introduced for the Contax G 35mm camera in 1994. The 110mm large format version announced at the 1966 Photokina as a wide angle for 13x18cm/ 5x7"was pictured in a short article in the magazine "International Photo Technik" on the 13x18cm lens line [42]. It showed a different looking lens, its appearance was much more like an over-sized Super-Angulon, with large, but comparatively flat outer lens surfaces. However, this was not the only version. A list of Zeiss' experimental lenses [24] lists two different designs, from 1964 and 1965 – they were originally named "Bilagon" in those lists. In 2010, one of these lenses appeared on the used market at an auction by Westlicht [43], and subsequently the differences between the two versions came to light [45]. Fig. 22 shows both Hologon versions; the larger one with the bulbous outer lens elements came in a Com-

Fig. 22: Two prototype versions of the 110mm f/8 Hologon for 13x18cm/5x7". Left: First Version consisting of three thick lens elements with strongly curved outer surfaces, quite similar to the 15mm Hologon for 35mm film. The aperture was fixed to f/8, the shutter aperture could not be used. Right: Second version shown at 1966 Photokina, using 5 lens elements in 4 groups; the construction is closer to a Super-Angulon, although with thicker elements, and allows the use of the shutter's aperture. Image courtesy of Westlicht Photographica Auction [43].

pound IV shutter and was actually quite close to the 15mm original Hologon in design, the smaller one is the version shown at the 1966 Photokina. It turns out that this large version in the Compound shutter was actually a "real" Hologon with 3 thick elements, 110° coverage, and a fixed aperture; the aperture of the shutter was neither used nor usable. Obviously, the use of filters was also not possible. It was sold at auction for € 28800 in May 2010 [43], which probably made it the most expensive LF lens ever sold. The other version, the one shown at Photokina, came in a Compur 0, had 5 lens elements in 4 groups and 90° coverage (i.e. 220mm image circle), just enough to cover 13x18cm/5x7". It was a more traditional wide angle similar to a Super-Angulon with large negative meniscus lenses on both sides, although with much thicker lens elements than the Super-Angulon. Despite the reduced coverage, it was a much more practical choice for regular photographic use, as the aperture was adjustable and filters could be used,

The "normal" lens for the planned 13x18cm/ 5x7" set was a 210mm Planar with a maximum opening of f/5.6 (fig. 23). The official coverage is not known, but was probably similar to the Planars for the smaller format, e.g. 62-64°, which translates to an image circle of 250-260mm. It came in a Compur 3 electronic shutter (fig.21). The prototype was also recently sold at auction, for € 18,000.00 in 2012 [44].

Not much is known about the long lens of the set, the Tele-Tessar 500mm f/8. The text in International Photo Technik 1/1967 [42] claims it used a Compur 0, but this claim is doubtful given that Tele-Tessars with the same data (500mm f/8), but only medium format coverage, already used size 1 shutters (fig. 25). It may have been mixed up with the shutter information of the f/8 110mm Hologon.

It is interesting to note that in the same year their East-German counterpart Carl Zeiss Jena showed a set of 5 new LF lenses for 9x12cm/4x5" at the industry fair in Leipzig. Those lenses never made it into production either, as described in another article [18]. Two of them also covered 13x18cm/5x7" and were actually closely related to Oberkochen's new prototypes. The 90mm f/4.5 Lamegon was also a Super-Angulon-type wide angle with unusually thick outer negative menisci (although with overall 8 lens elements instead of 5), and the 210mm f/5.4 Biometar with 5 lens elements in 4 groups was a close cousin to the 5/4 Planar as mentioned above in the section on Planars.

Fig. 23: Carl Zeiss Planar 210mm f/5.6 prototype for 13x18cm/5x7"in Compur 3 electronic shutter, shown at 1966 Photokina. Image courtesy of Westlicht Photographica Auction. [44].

Aerial, photogrammetry, copying, and other specialty lenses

In addition to the lenses made for regular LF photography, Zeiss Oberkochen made several series of specialty lenses that can be adapted to be used with view cameras, or that at least do cover the format, even though "normal" use on a regular view camera is often not practical due to their weight and size[8].

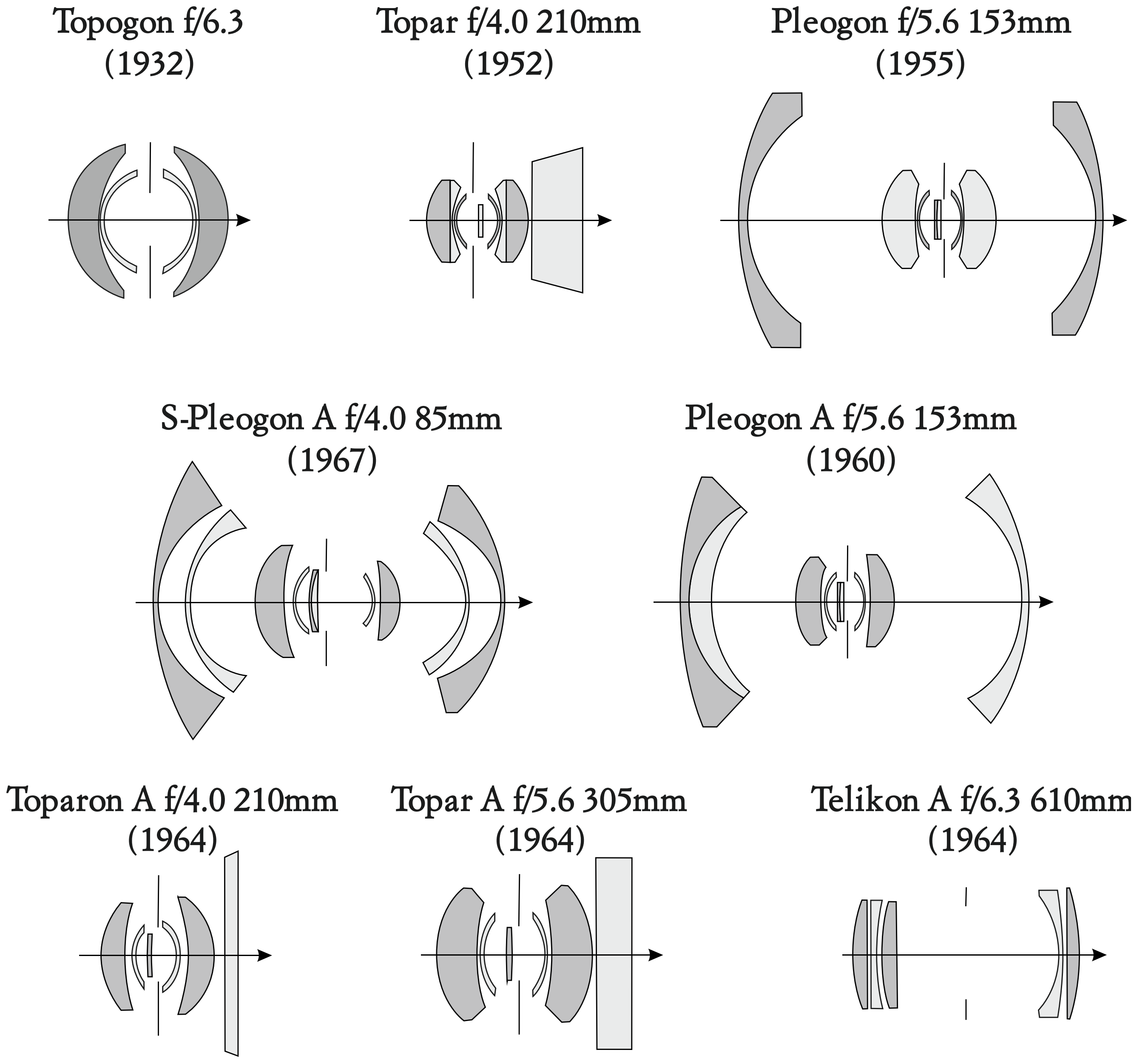

Fig. 24: Schematic lens diagrams of CZO's aerial lenses, after refs. [46, 47, 64, 65]. Compare table 9a.

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[8] As an example, the S-Pleogon A 85mm and Pleogon A 153mm lenses each weigh about 20kg without shutter, the complete RMK cameras weigh 110kg [65].

The largest set in this group are the aerial lenses. In addition to the special mount versions for the Linhof Aerotechnica and Aerotronica, as well as the Biogon clones mentioned above, Zeiss Oberkochen made a wide range of specialty lenses for aerial reconnaissance, photogrammetry, etc., for both civilian and military applications. Image sizes of the aerials cameras ranged from 40x50mm to 230x230mm, usually not on sheet film, but on 70mm, 5", 9", and 9.5" wide film rolls. Zeiss provided lenses for the cameras of other manufacturers, such as A.G.I in Britain, as well as for their own cameras made by their subsidiary Zeiss Aerotopograph in Munich.

Zeiss had made many aerial cameras and lenses before and during WWII; the best known lens was probably the Topogon designed by Robert Richter, a double Gauss lens with steeply curved menisci, such as the 100mm and 200mm f/6.3 Topogons (fig. 24, top left). Directly after the war, any commercial activities in aviation were off limits to German companies, until 1952. Zeiss (Opton) in Oberkochen made a few prototype lenses and did some R&D in those years; they resumed production of aerial cameras and lenses fully in 1952 with the RMK 21/18 camera [46]. "RMK" was Zeiss' traditional acronym for vertical aerial photography cameras and stands for "Reihenmeßkammer", meaning serial measuring camera; the postwar Zeiss Jena equivalent was named "LMK" for "Luftbildmeßkammer" (aerial image measuring camera). The two numbers following the name indicate the focal length of the lens and the film format in *cm*, i.e. the RMK 21/18 has a 210mm lens for an image size of 18x18cm. 18x18cm was the traditional size for large size aerial images in Europe, whereas the US started to use the larger 23x23cm (9x9") after WWII; for the following RMK generations, Zeiss switched to the 23x23cm size. The lens for the RMK 21/18 was a newly designed Topar 210mm f/4.0 with seven lens elements in five groups (fig. 24 top center, table 9a), the designer was again Robert Richter. The RMK 21/18 was followed in 1955 by the RMK 15/23 for 23x23cm film with the new Pleogon 153mm f/5.6 wide angle lens (fig. 24 top right), another Richter design. The inner part is a Topogon with an additional thin doublet near the center, but it is surrounded by two large negative menisci similar to the Roossinov super wide angle design [46]. The maximum opening of the Pleogon was later increased to f/4 (table 9a).

These lenses were all corrected for the visible spectrum. The increased use of infrared film led to the development of lenses that were also corrected for 800nm. This was called "A"- characteristic by Zeiss Oberkochen [46][9], and subsequently all lenses for the RMK were modified in that way, as listed in table 9a. In addition to the Pleogon, up to 1964 Zeiss also introduced a medium wide angle lens with 210mm focal length, the Toparon A, then the Topar A 305mm as "normal" lens, and the Telikon A 610mm as long lens. In 1967, they added a super wide angle lens, the S-Pleogon A 85mm with 125° coverage. The full set of "A" lenses is shown in the center and bottom row of fig. 24. Some of these lenses went through redesigns and are accordingly numbered as A1, A2, etc. An additional "R" in the name indicates a reseau plate. In 1989, the RMK cameras were modified and became the RMK TOP (TOP stands for Terminal OPerated); only two lenses remained in the lineup, the Pleogon A3 and the Topar A3 [47], due to reduced demand for the other focal lengths [46]. A few other aerial lenses from Oberkochen like the Geodar ("Geo-Dagor", originally a Goerz name) and an early Topogon 150mm have also been noted.

In addition to the aerial mapping cameras, Zeiss also made aerial reconnaissance cameras for both civilian and military use. Most of these cameras expose several images onto 240 x 240mm (9.5 x 9.5") film

[9] The equivalent designation for Carl Zeiss Jena's aerial lenses was „PI", for Pan-Infrared.

at the same time to produce horizon to horizon views, using sets of lenses. These lenses have therefore smaller coverage than the film format. Common lens arrangements were the “Trilens” one using three angled 80mm f/2 Topar lenses and the “Pentalens” one with five angled 57mm Topar f/2 lenses (table 9b). The TRb telephoto version of these cameras used only one lens, a different version of the 610/612mm Telikon, but in a rotatable mount. These Telikons are capable of covering 13x18cm/5x7” film.

Fig. 25: 500mm f/8 T Tele-Tessar, originally for the Linhof Aerotechnika, in a Compur 1 electronic shutter. This lens, with a design date of 1981 [2], is the same Tele-Tessar that was made for Hasselblad and Rollei, so it was obviously intended for 70mm film and won’t cover 4x5. Only 18 Linhof versions of the lens were supposedly made [50]. Scale is in cm.*

The 80mm Topars were also used in sets of three parallel lenses in a multispectral camera recording different parts of the spectrum in parallel on film, single images were 71x71mm. The 80mm Topar should therefore be capable of covering 6x7cm and 6.5x9cm, whereas the shorter 57mm focal length does not cover any view camera format. A related camera type is the SK 2 “strip camera” which works similar to a scanner on 5” wide film, the two lenses available were a 53mm Biogon and a specialized 105mm UV Sonnar for ultraviolet photography (table 9b). Both lenses cover 6.5x9cm. Also usable would be the Topogon 60mm and Stereotar 120mm lenses built for terrestrial photogrammetry, whereas the Topogon V 180mm enlarging lenses that were built for the large SEG-5 and -6 rectifiers as well as the lenses from the satellite tracking cameras are too big and heavy for any normal large format use.

For oblique aerial photography Zeiss offered their regular Biogon, Planar, and Sonnar LF lenses in special mounts, as mentioned above. In addition, they produced several lenses for 70mm film cameras such as the Agiflite from A.G.I. or 70mm cassettes for the Aerotechnika that were based on the 6x6cm Hasselblad and Rollei SLR lens series, listed in table 9c. Fig. 25 shows an example, a view camera version of the Hasselblad 500mm Tele-Tessar in a Compur electronic 1 that was made in small numbers for the Linhof Aerotechnika.

For unknown reasons, Zeiss Oberkochen never produced commercial process lenses such as the Apo-Tessar, leaving that market segment to Schneider, Rodenstock, and Carl Zeiss Jena. However, some lenses for photocopiers were made, e.g. the Planitar series and a 300mm S-Tessar. One should be aware that these lenses are corrected for 1:1, often come without adjustable aperture, and are quite difficult to adapt to a shutter. They also produced some high resolution lenses for reduction and enlarging on microfilm, the S-Biogon and S-Orthoplanar series. Of these, only the 105mm S-Orthoplanar covers 6x7cm and 6.5x9cm film. Reduction lenses for microchip production are another group of ultrahigh resolution lenses made by Zeiss Oberkochen, but even early examples are not that useful for LF since they cover only a small field and are large and heavy; the 195mm S-Planar covering 6x7cm weighs close to 50lbs.

Occasionally, a few oddball Zeiss Oberkochen lenses in view camera shutters show up on the used market like a 55mm Distagon version in a Prontor shutter that appeared on the German ebay in 2012 (table 9c). Often these are aftermarket conversions and one should be careful in assessing their value.

Table 9a: Carl Zeiss Oberkochen aerial mapping lenses; most data came from refs. [46, 65]..

Name (1st year of introduction)	Focal Length [mm]	Max. Aperture	Coverage	Remarks
Topar (1952)	210	4.0	18x18cm 62°	for RMK 21/18
Pleogon (1955)	153	5.6	23x23cm 93°	for RMK 15/23
S-Pleogon A (1967)	85	4.0	23x23cm 125°	for RMK A 8.5/23 lens weight approx. 20kg [65]
Pleogon A (1960) Pleogon A1 (1965) Pleogon A2 (1968)	153	5.6	23x23cm 93°	for RMK A 15/23; the version RMK AR uses an additional reseau plate lens weight approx. 20kg [65]
Pleogon (1960)	153	4.0	23x23cm 93°	155lp/mm
Pleogon A (1971) Pleogon A1 (1974) Pleogon A2 (1988) Pleogon A3 (1989)	153	4.0	23x23cm 93°	for RMK A 15/23 and RMK TOP 15 (1989)
Toparon A (1964)	210	5.6	23x23cm 75°	for RMK A 21/23
		4		
Topar A (1964) Topar A1 Topar A3 (1989)	305	5.6	23x23cm 56°	for RMK A 30/23 and RMK TOP 30 (1989)
Telikon A (1964)	610	6.3	23x23cm 30°	for RMK A 60/23
Geodar	210	15	?	Dagor type, originally a Goerz lens name
	304	22	?	
	600	?	?	
Topogon	150	15	?	Made in 1947 [48]
	153	15	?	Aerial lens

Table 9b: Carl Zeiss Oberkochen aerial reconnaissance, satellite tracking, terrestrial photogrammetry, and enlarging (for the SEG rectifier) lenses; most data came from refs. [46, 65].

Name (1st year of introduction)	Focal Length [mm]	Max. Aperture	Coverage	Remarks
Topar AS (1968)	57	2.0	50x40mm	for KRb 6/24 - KA 106A pentalens camera series and MUK 8/24 multispectral camera
	80	2.0	104mm	for KRb 8/24 – KA 107A trilens camera series, achieves 250 lp/mm within 90mm image circle [49]
Telikon A (1968)	612	4.0	115x213mm	For TRb 60/24 – KA 108A camera series
S-Topar A1 (1984)	80	2.0	50x40mm	For KS-153 modular camera system
S-Topar A2 (1984)	57	2.0	104mm	
Telikon A1 (1984)	610	4.0	115x230mm	
Biogon	53	4.5	95°	for SK 2 strip camera
UV-Sonnar	105	4.3	57°	
Astro-Topar	460	2.0	18x18cm 31°	for BMK 46/18 satellite tracking camera
	750	2.5	18x18cm 19°	for BMK 75/18 satellite tracking camera, only 2 produced
Topogon (1960)	60	11	80x100mm	For SMK 120 and SMK 40 (120cm and 40cm base length, resp.) stereometric cameras and TMK 6 terrestrial metric camera, Compur 1 shutter, fixed f/11 aperture
Stereotar (1972)	120	8		for TMK 12 terrestrial metric camera, apertures f/8-f/16
Topogon V (1952) Topogon V(2) (1972)	180	6.3		for SEG 5 (V) rectifying enlarger, for 0.5x – 6.5x enlargements. 1952 version: widest usable aperture f/12.5, 1972 version: widest usable aperture f/9
Topogon V(3) (1979)	180	5.6	8x10“	for SEG 6 rectifying enlarger, 1979, widest usable aperture f/5.6; built-in red filter, weight approx. 20lbs

Table 9c: Some Carl Zeiss Oberkochen oblique aerial photography, photocopier, and other specialty lenses

Name	Focal Length [mm]	Max. Aperture	Coverage	Remarks
Biogon	38	4.5	57x57mm	Vinten F.95 camera, and AGI/Williamson F.135 twin lens camera
Planar	3"-75mm	2.8	?	For Fairchild camera, 1970's
Planar	110	2.0	Officially 57x57mm, might cover at least 6x7cm	For A.G.I. Agiflite, same lenses or similar to Hasselblad or Rollei MF lenses, but with fixed focus at infinity.
Sonnar	150	2.8		
	250	5.6		
Tele-Tessar	350	5.6		
	500	8		T*, for Linhof Aero-Technika, 1981 design date, same as or similar to Hasselblad model, only 18 made [50]
Planitar	135	4.5	?	Photocopier lenses in barrel, 1:1 reproduction ratio; some came with and some without adjustable aperture
	150	4.5		
	180	4.5		
	210	5.6		
	230	5.6		
	290	8.2		
	300	7.0		
	360	8.0		
S-Orthoplanar	105	5.6	66x94mm	reduction/enlarging lens for microfilm, reproduction range from 6-21x, 8/6 construction
S-Planar	195	4.0	6x7cm	For microchip production, at 1:20 reduction ratio. 9 lens elements in 8 groups, weighs 49.5lbs [3]
	210	2.0	?	For Fairchild, "projection copy" [2]
S-Tessar	300	5.6	?	Photocopier lens for 1:1; barrel, no adjustable aperture, does not use lens cells: lens elements are directly mounted in the barrel
Distagon	55	4.0	57x57mm	in Prontor, acc. to serial number a WA-Rolleiflex design from 1960-1961

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