LBT AGW

Technical Note

PRELIMINARY OPTICAL DESIGN FOR THE ON-AXIS TTS AND WFS

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1 Introduction

The on-axis sub-system of the AGW shall incoporate a tip-tilt sensor (TTS) and a WFS for correction of the high order aberrations due to the atmosphere. The WFS shall be used with a NGS as well as with the LGS. The feeding of the WFS could be done via a micro-lens array (WFS I) or a pyramid sensor (WFS II) requiring different pupil sizes. The principal specifications for the units are:

TTS	CCD 512 x 512 pixel, 15 μm pixelsize, 7.7 x 7.7 mm
	Direct Imaging with pre-optics, scale 0.15 arcsec/pixel
	FOV 77 x 77 arcsec
	Wavelength range 500–1000 nm
	Image quality (rms polychromatic) better than 0.15 arcsec
	Access to a field of up to 2 arcmin radius (via steering mirror)
WFS I	CCD 256 x 256 pixel, 24 μm pixelsize, 6.1 x 6.1 mm
	FOV 1 x 1 arcsec
	20 x 20 element micro-lens array, each covering 6 x 6 pixels
	Pupil diameter 2.9 mm (20 x 6 x 0.024)
	Wavelength range 500–1000 nm
	Access to a field of up to 30 arcsec radius (via steering mirror)
WFS II	Four quadrant CCD or four photodiodes
	FOV 1 x 1 arcsec
	Pyramid Sensor
	Pupil diameter 10.0 mm (preliminary, to be confirmed)
	Wavelength range 500–1000 nm
	Access to a field of up to 30 arcsec radius (via steering mirror)

The tilted instrument entrance window (dichroic) and the numerous folding mirrors, needed to fit the mechanical design to the available space and to keep the unit compact, as well as the filter required to separate the LGS light, were not included in the optical design as these are passive elements. They will have to be included at a later stage.

2 General Layout

The telescope exit pupil is reimaged (d = 29 mm) by a relay triplet lens C1 (420 mm distance to telescope focus) at a location 438 mm behind triplet. At this position, a steering mirror for field

scanning can be placed.

The beam will be separated in front of the pupil by a filter or mirror to account for the various modes with NGS/LGS. This means that two pupil positions are available where independent steering pupil mirrors PM for the TTS and the WFS can be put in. The tilt sensitivity of those mirrors is about 142, i.e. by a mirror tilt of 142 arcsec the position on sky is changed by 1 arcsec. The factor is calculated from f(tel)/f(RT1)/2.

The TTS camera C4 has a focal length of 72.5 mm and follows the pupil image at 72.5 mm distance. The steering mirror PM2 should allow for field chopping of up to ±2 arcmin.

In the optical path for the WFSs, a second relay triplet lens C2 follows the pupil to give a 1:1 relayed focus. Here a field stop for the WFS can be put in. A doublet lens C3 forms a pupil of the appropriate size. This doublet has to be refocus by about 170 mm for a LGS at 90 km height.

3 Relay Optics

The optical layout of C1 is shown in Fig. 1. The distance from focus to first lens is 420 mm, the lens thickness is 36 mm and the distance from the last surface to the pupil is 438 mm. The focal length is 435 mm.

The diameter of C1 is chosen to provide the nominal field for the TTS without vignetting. With this size, a maximum field of up to 1.3 arcmin radius (50% vignetting) could be covered via a PM2. To provide a 2 arcmin field, the size of C1 would have to be increased to 150 mm diameter.

The steering mirror PM1 for the WFS path will cover not more than the nominal TTS field and is therefore completely free of vignetting. The proposed scanning range is ±30 arcsec.

The triplet C2 used to refocus in the WFS path is optically an exact copy of C1. Only the diameter can be reduced to 45 mm because of the smaller field of view.

4 TTS

The TTS camera C4 has a focal length of 72.5 mm (focal ratio 2.5) to give the required image scale. A design is shown in Fig. 2 and in Fig. 3 (including C1 and PM2). The last plane parallel element is the entrance window of the dewar. The resulting polychromatic image quality in the center, at the edge and in the corner of the detector is shown in Fig 4. The circle shown corresponds to the Airy disk at 550 nm. The distortion over the field is less than 0.5%.

The light from the LGS will produce a defocussed image on the TTS CCD if not blocked. The spot diameter will be about 2 mm.

5 WFS I

To produce a pupil of 2.9 mm diameter matched to a micro-lens array, a lens doublet C3 of 43.5 mm focal length is necessary. The layout is shown in Fig. 5. The complete layout from telescope focus to WFS pupil is shown in Fig. 6. The image quality on-axis and at a field angle of 30 arcsec is shown in Figs. 7 and 8. The circle shown corresponds to the Airy disk at 550 nm.

The change of the optical path due to refocussing of C3 for a LGS is shown in Fig. 9.

6 WFS II

To produce a pupil of 10.0 mm diameter matched for a pyramid sensor, a lens doublet C3 of 150 mm focal length is necessary. In Fig. 10, the layout is shown. For the image quality see

Figs. 7 and 8.

7 Open Points

The dichroic filter to reflect the light coming from the LGS to the WFS arm must be replaced by a mirror if a NGS is used (what about chopping?). Specifications for the dichroic to be defined. The alignment of field stop for WFS with the TTS center of field

The field accessible for chopping is ± 1.3 arcmin. This corresponds to a four times larger total field as covered directly by the detector. A further increase to ± 2 arcmin would imply to increase the size of C1 to 150 mm. This will have some drawbacks, as FK51 is expensive and difficult to polish because of its high CTE. Moreover it is cemented to K7 glass with half the FK51 CTE. Therefore a small size preferred!
The chopping would require also to move PM1 synchronously to PM2 if working with a NGS. Then also C2 would have to be increased dramatically (as C1).

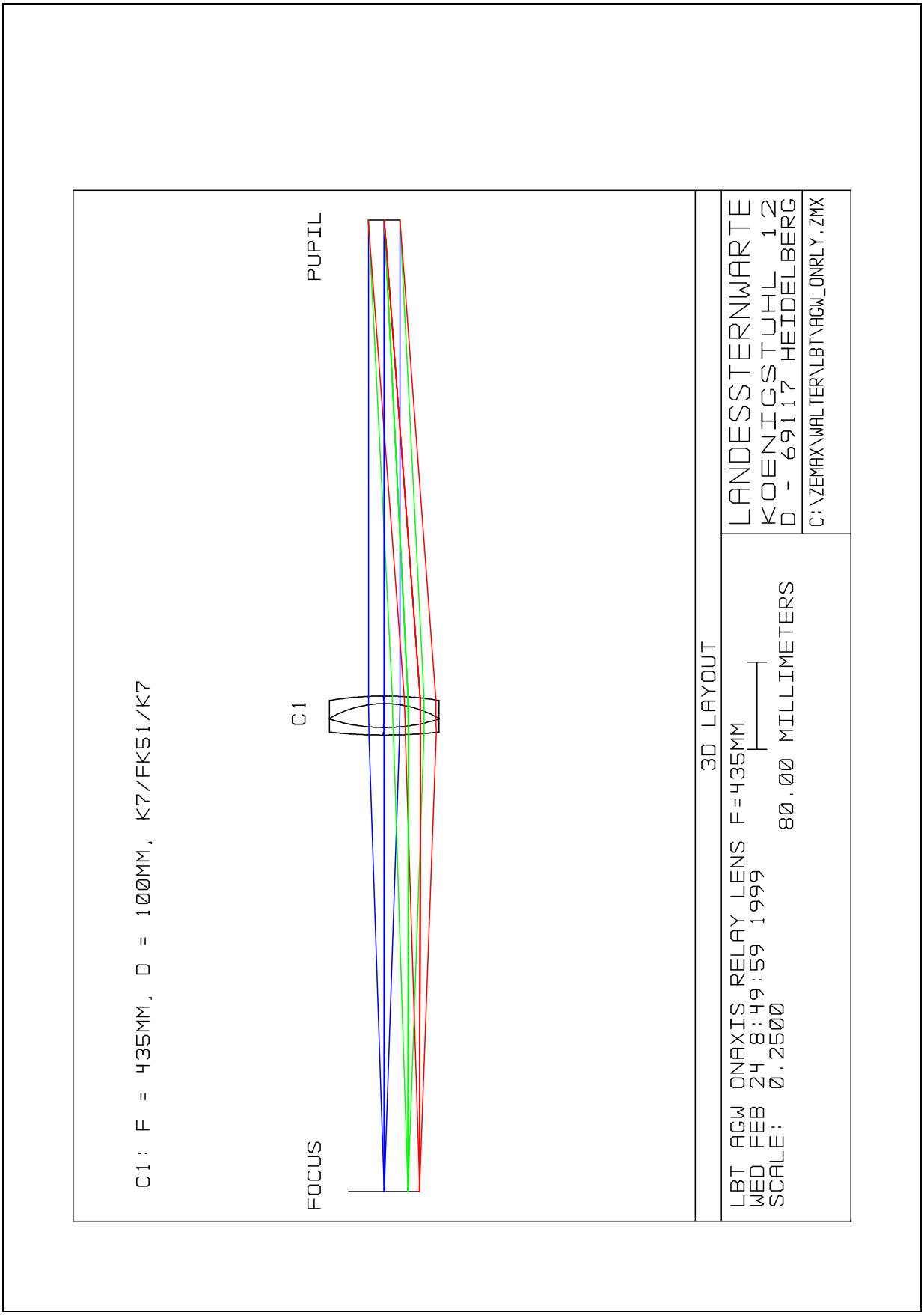

Figure 1: Layout of the relay triplet lens C1.

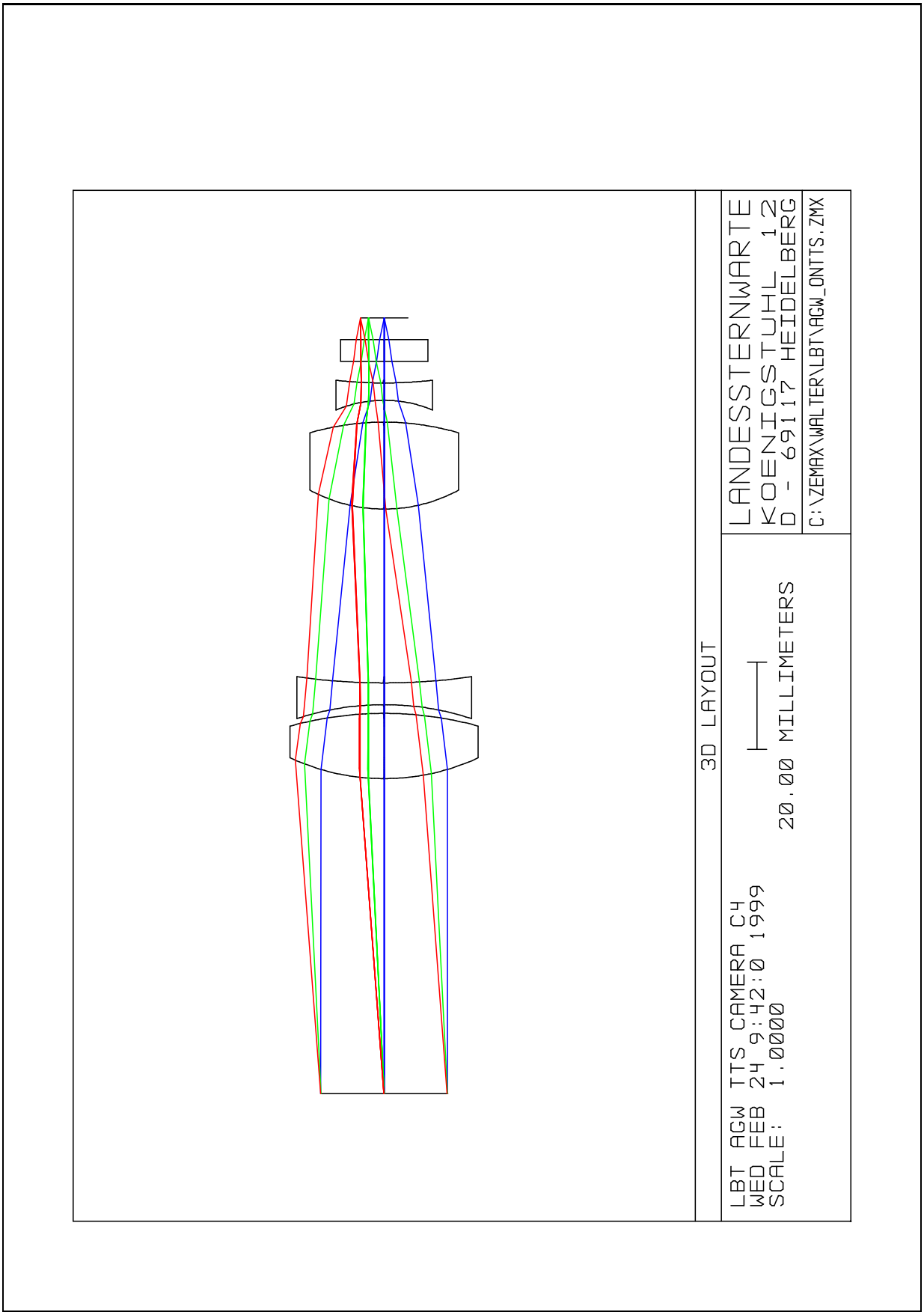

Figure 2: Layout of the TTS camera C4.

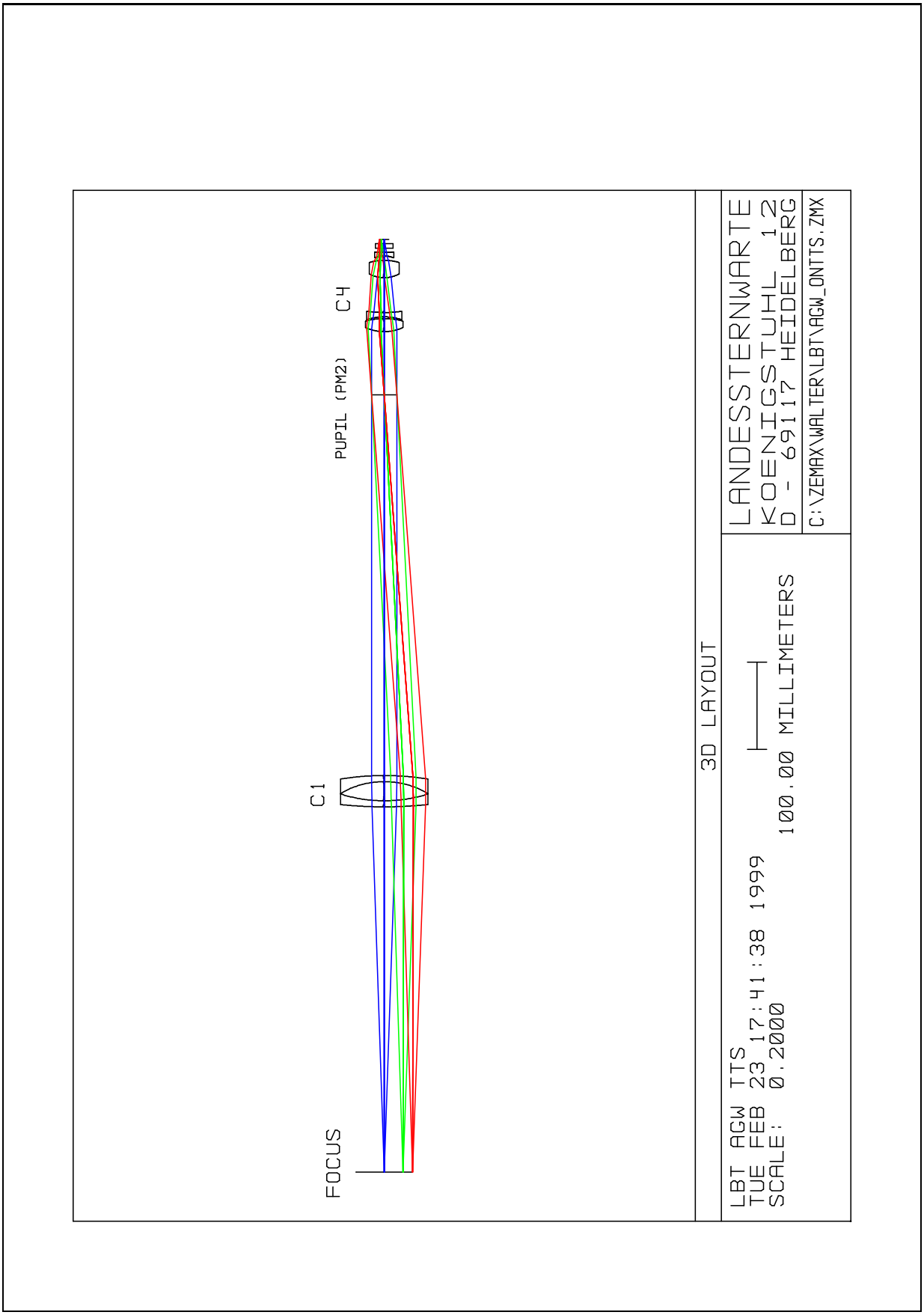

Figure 3: Layout of the TTS arm.

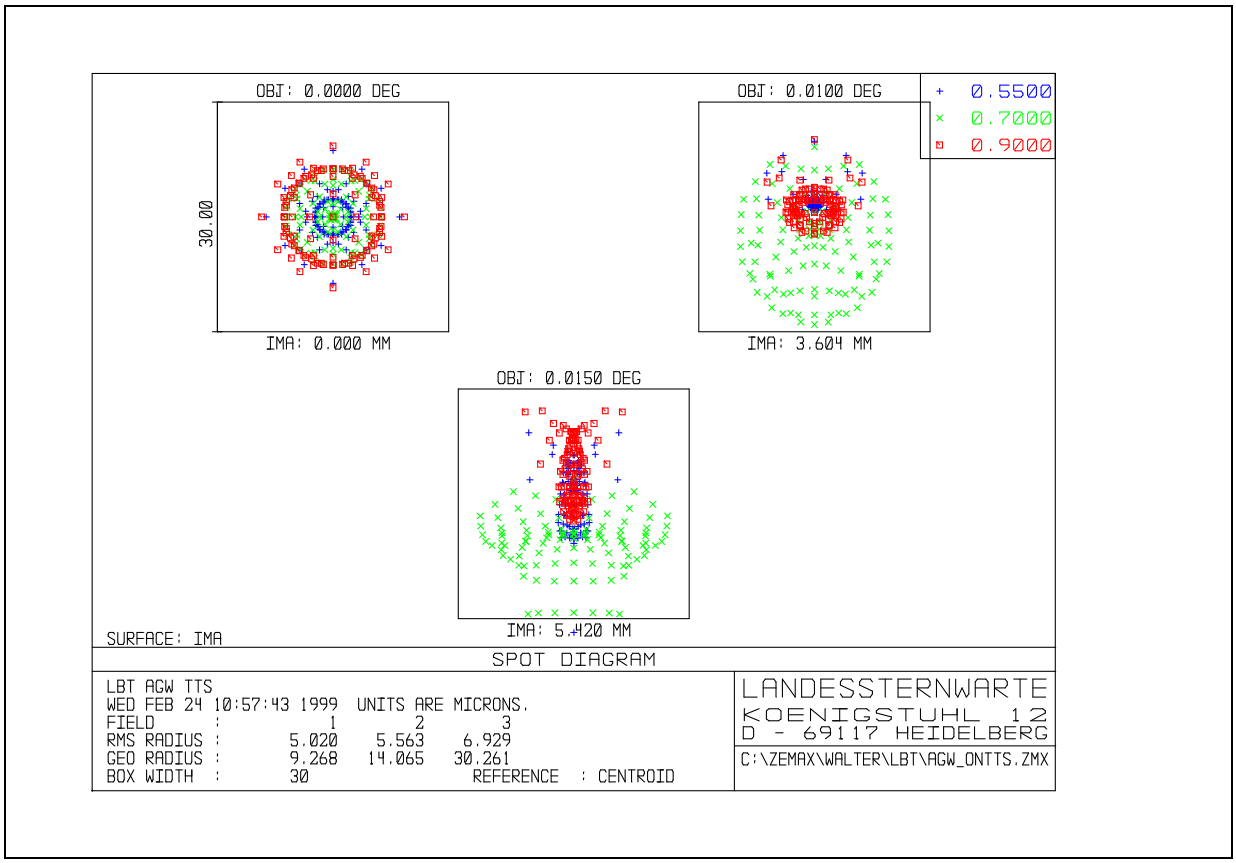

Figure 4: Polychromatic spot diagrams for the TTS system.

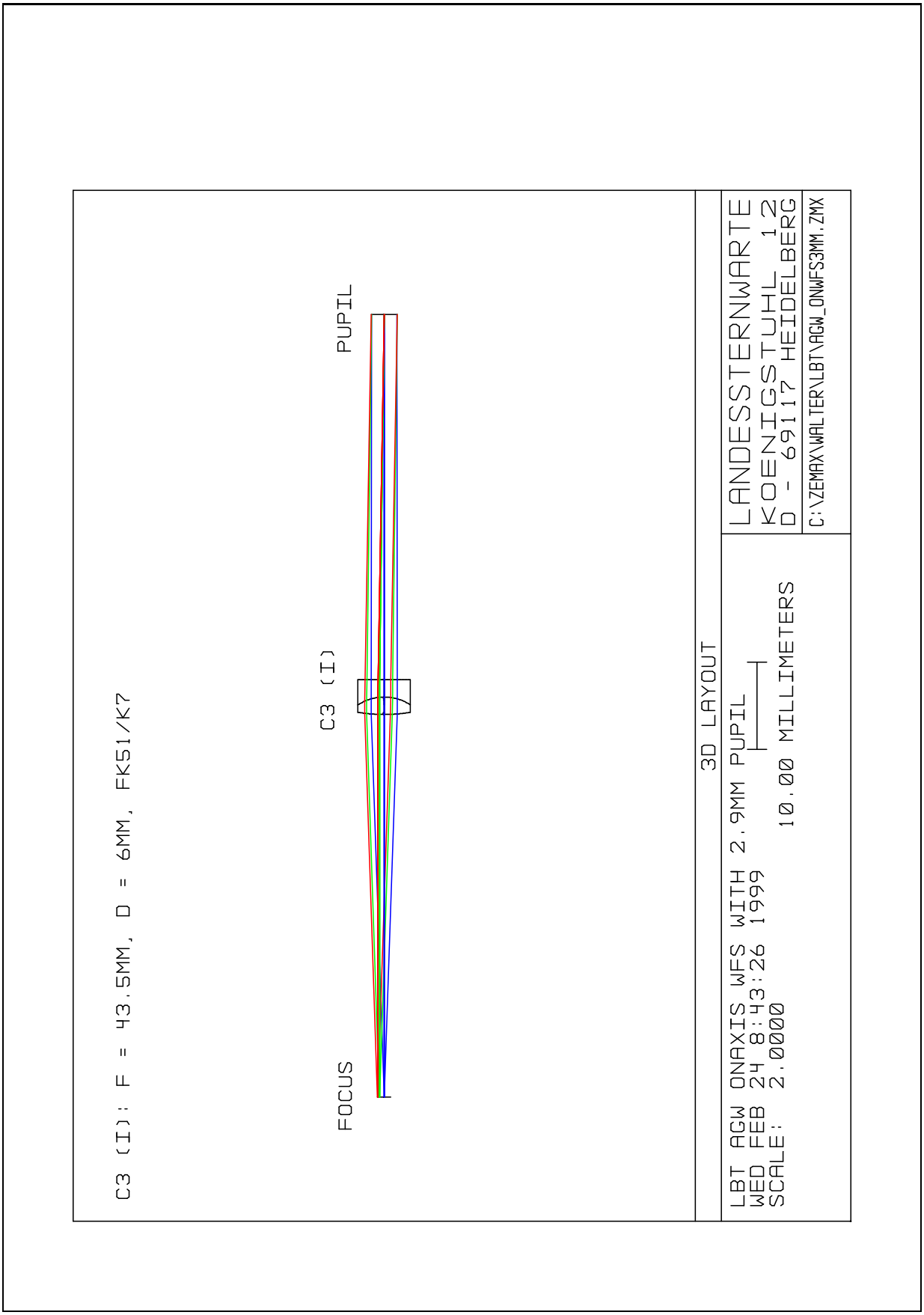

Figure 5: Layout of the WFS I with 2.9 mm pupil size, lens C3.

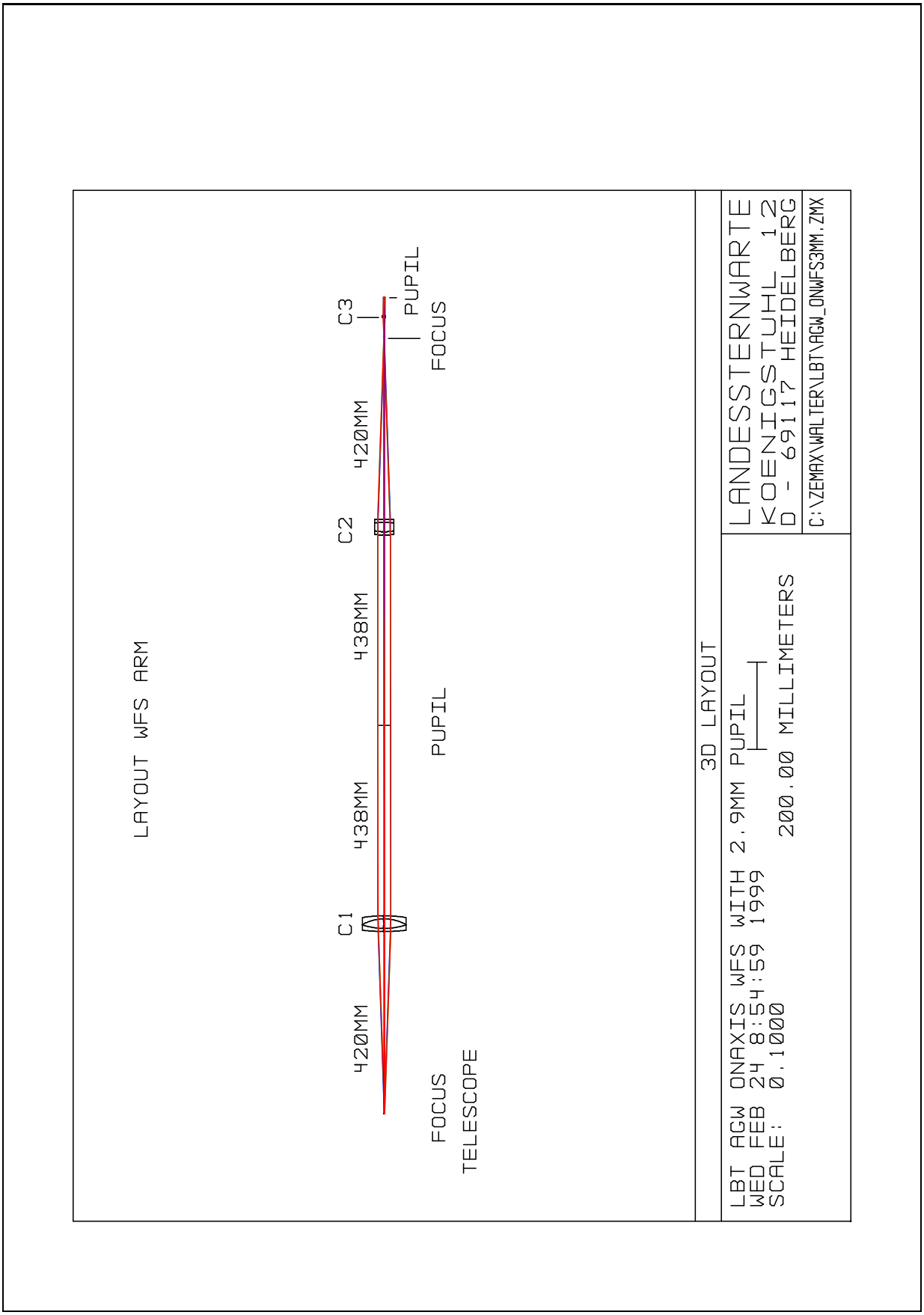

Figure 6: Layout of the complete WFS arm.

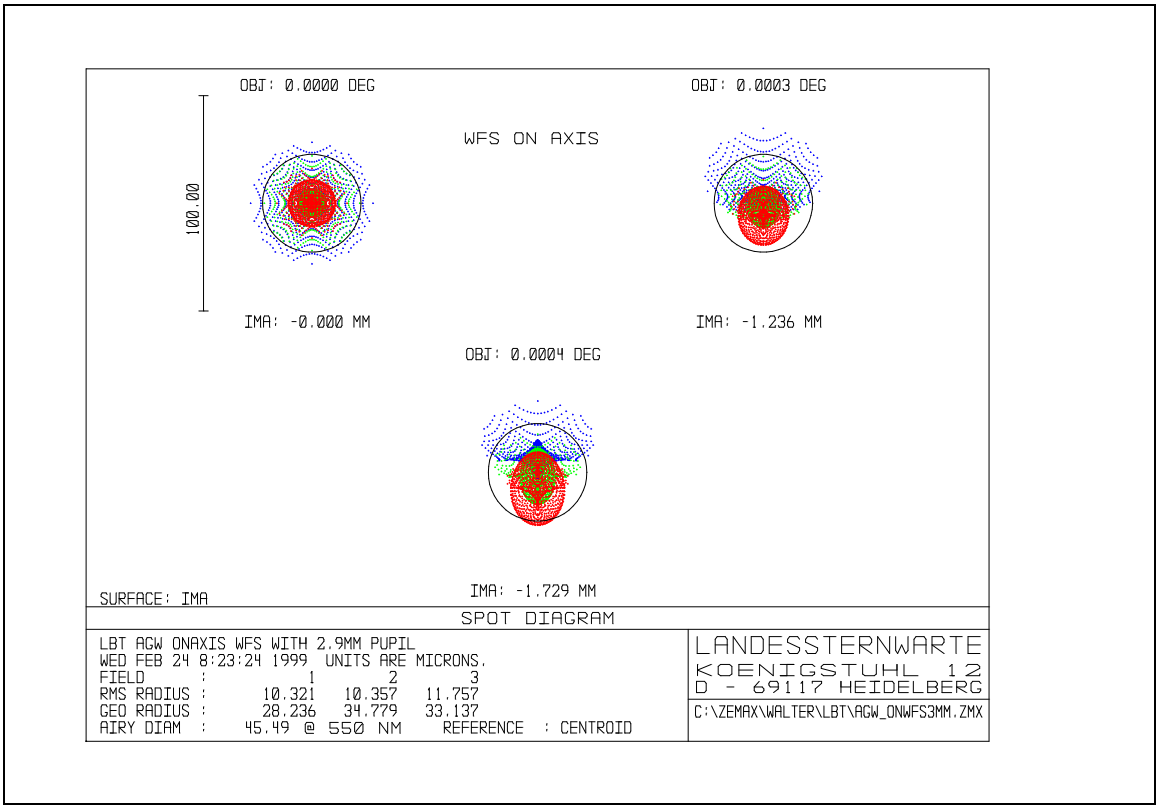

Figure 7: Polychromatic spot diagram for WFS I, on-axis.

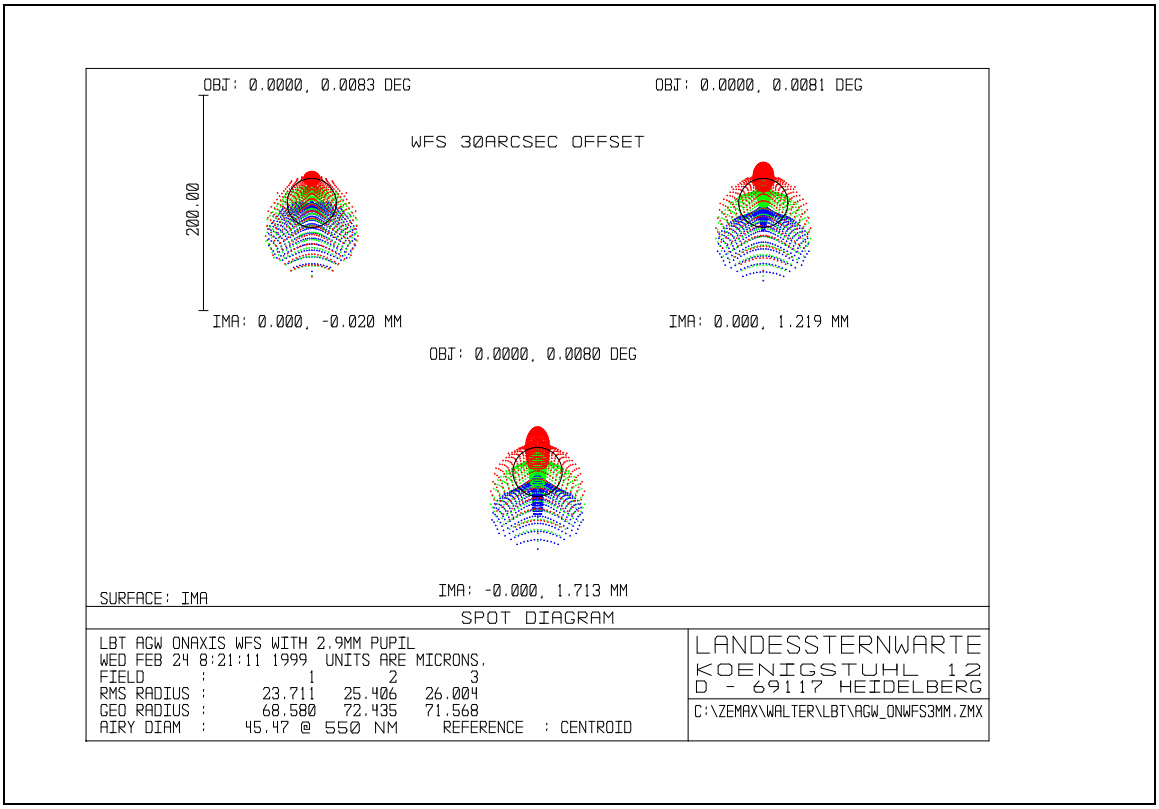

Figure 8: Polychromatic spot diagram for WFS I, 30 arcsec off-axis.

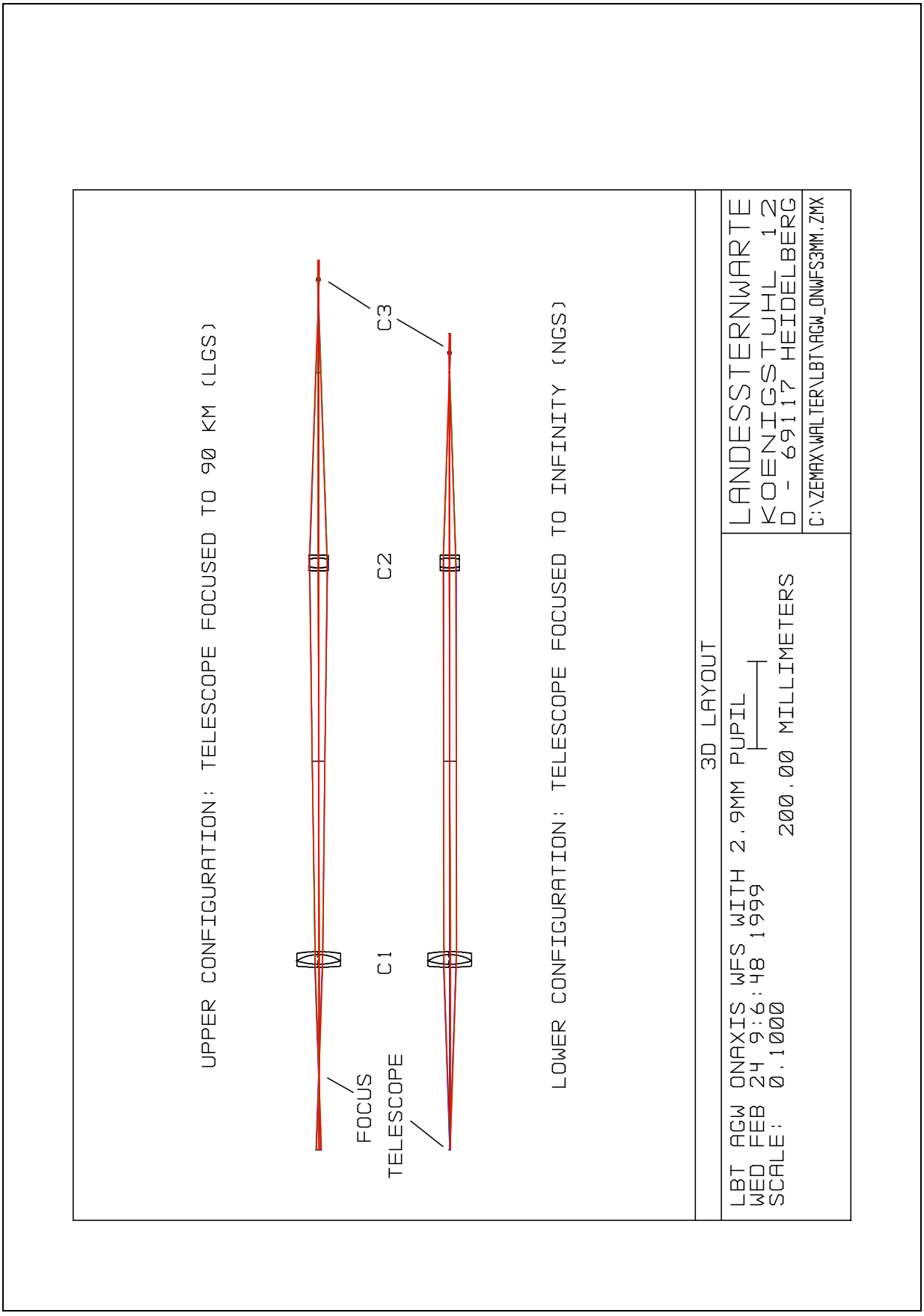

Figure 9: The change of the optical path due to refocussing of C3 for a NGS (lower) and a LGS (upper).

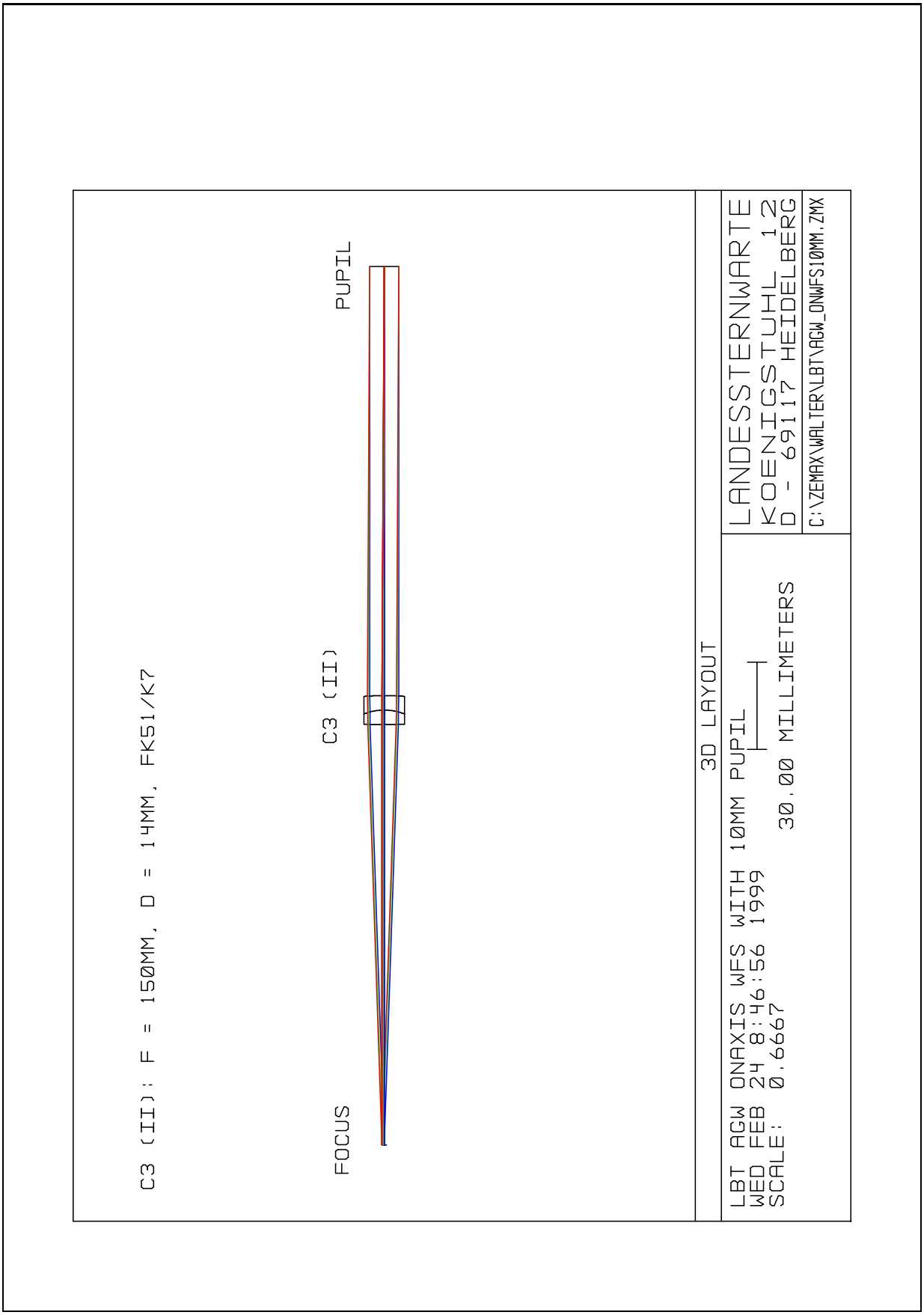

Figure 10: Layout of the WFS II with 10 mm pupil size, lens C3.