Preliminary design of an ADC prism proposed for the 60” Tillinghast reflector and TRES spectrograph

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This document very briefly describes the problem of using the TRES spectrograph on the 60” Tillinghast reflector, due to atmospheric refraction, and a possible solution in form of an ADC prism. The purpose is to serve as a feasibility study for a possible research equipment proposal.

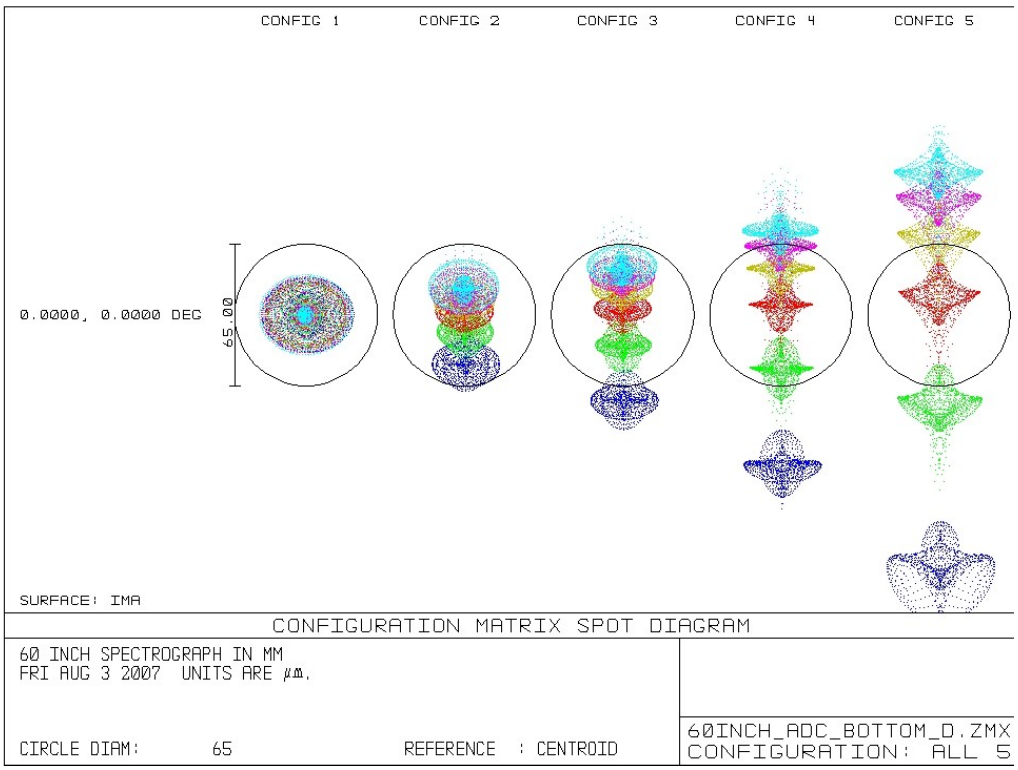

Fig. 1.

On-axis spot diagram of TRES for 0, 30, 45, 60 and 75 degree zenith distances, for the 3700-9000 A wavelength range. The circle represents the highest resolution fiber of TRES (62.5 micron = 1.4 arcsec sky coverage)

Figure 1. shows the image quality of the telescope plus TRES F/6 focal reducer, at 0^o (config 1), 30^o (config 2), 45^o (config 3), 60^o (config 4) and 75^o (config 5) degrees zenith distances, on axis (0’ field of view). The circle represents 65 micron in diameter, which is the size of the smallest

TRES fiber (covering 1.4 arcsecond, providing the highest R=60.000 resolution). Colors are representing different wavelengths between 3800 and 9100 Angstroms, the TRES wavelength coverage

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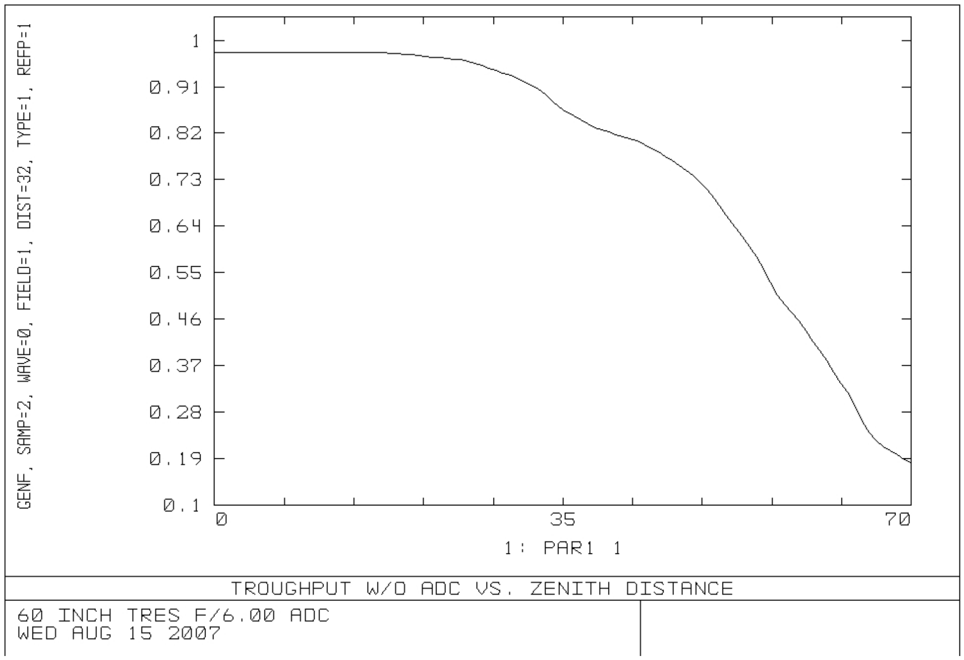

Fig. 2.

Effective throughput of the TRES fiber feed (integrated over the 3800-9100 Angstrom wavelength range) as a function of zenith distance (0 to 70 degrees). The light loss due to atmospheric dispersion is significant (>20%) even at 45 degree zenith distance.

It is clear from Fig. 1 and 2. that wihtout an ADC even at 45 degrees zenit distance TRES would loose ~20% of wavelength coverage, and at 60 degrees nearly 60% of the light is lost. As the effect is significant in the 1.5-2 airmass range, this is seriously degrading the performance of TRES.

A solution would be an ADC prism. To keep the size of the prisms minimal we considered placing it just above the instrument mounting surface (rotator plate), inside the cylinder going through the hole in the primary mirror. As Fig. 3 indicates this is a ~7 inch diamater cylinder, and to avoid vignetting we only need 3 inches clear aperture at the rotator plate.

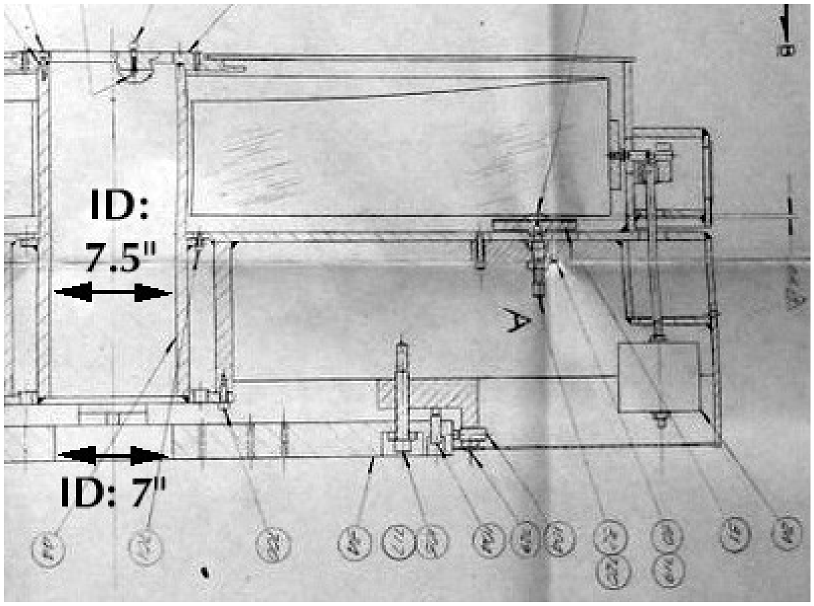

Fig. 3.

Part of the 60 inch mirror cell asembly cross-section drawing, showing the approximate clearence available mounting the ADC prism (just above the lower 'ID: 7" ' sign)

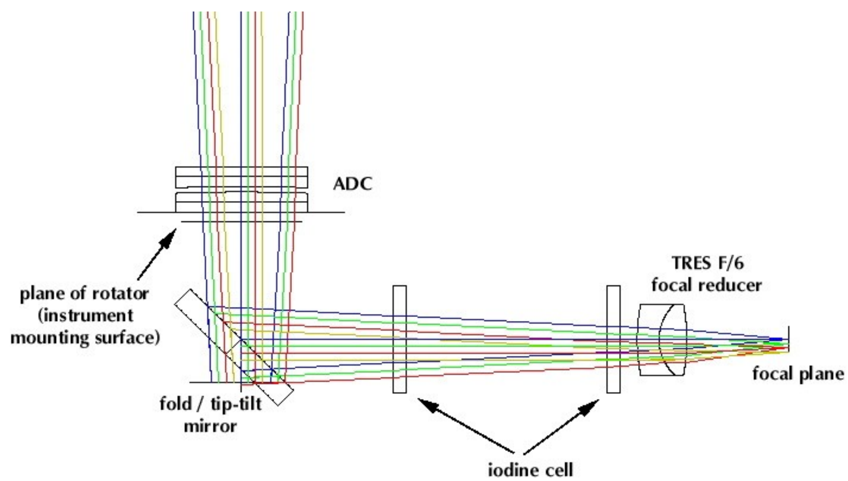

Fig. 4.

Layout of the TRES front-end optical train showing the tip-tilt mirror, iodine cell and focal reducer – with the proposed ADC in front. The prisms are 3 inches in diameter and each of the fours glasses have a central thickness of 6 mm.

Figure 4. shows an optical layout of the ADC prism and TRES. During the optimization we found that putting curvatures on the two inner surfaces of the prisms the image quality can be very good for all zenith angles and field locations. Although this reduces the effective focal length of the telescope, and thereofre we have to slightly modify the original F/6 focal reducer to keep the effective focal ratio at F/6 with the ADC.

The prescription of the prisms and re-designed corrector is summarized below (with the radii test-plate fitted to Coastal Optics plates):

Name	Thicknes s [mm]	Curvatur e [mm]	Material	Tangent of angle
From Epps corrector to 1st prism	508.80	-.	Air	0
1st prism front	6.00	Inf.	FSL5Y	0
Glass 1/2 interface	-	Flat, tilted	Glued	0.0500
Second prism	6.00	Inf.	PBL6Y	0
Back of 2nd prism	-	819.500	-	0
Separation	3.00	-	Air	0
3rd prism front	6.00	439.270	FSL5Y	0
Glass 3/4 interface	-	Flat, tilted	Glued	0.0514
Back 4th prism	6.00	Inf.	PBL6Y	0
To rotator plane	5.43	-	air	0
To tip-tilt mirror	69.85	-	Air	0
Tip-tilt mirror	-	Flat	-	1
To focal reducer	229.40	-	Air	0
Lens A – 1st surface	12.7	100.670	BSM51Y	0
Lens A 2nd = Lens B 1st surface	16.11	28.510	FPL51Y	0
Lens B 2nd surface	-	-290.320	-	0
To focal plane	59.25	-	Air	0

The performance of the ADC, for on-axis imaging, is shown in Fig. 5. Compare it to Figure 1.

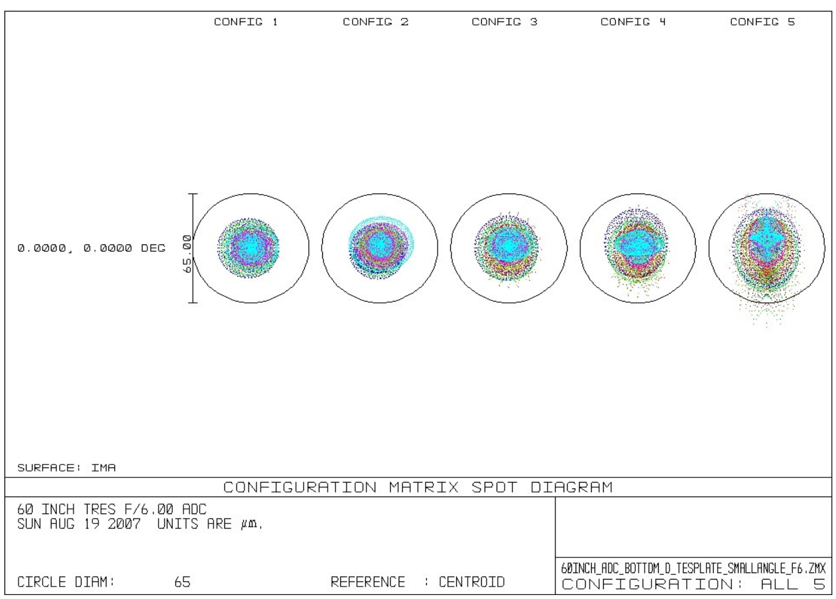

Fig. 5.
Same as Fig 1., but with ADC

Fig. 6 and 7 compares the 0 degree zenit angle image quality at 0, 1, 2 and 3 arcminutes field of view, without (Fig. 6.) and with ADC (Fig. 7.). It is obvious that the ADC does not degrade but even a bit improves the image quality, thanks to correction introduced by the the two spherical surfaces of the prisms.

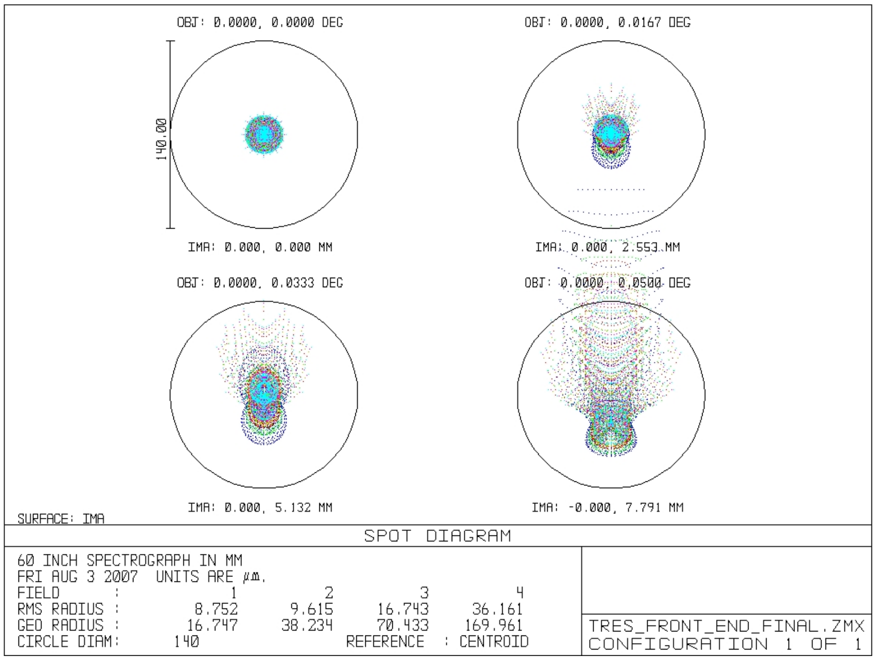

Fig. 6.

Image quality over the field of view, at 0 deg zenith distance - without ADC. The circle corresponds to the largest TRES fiber.

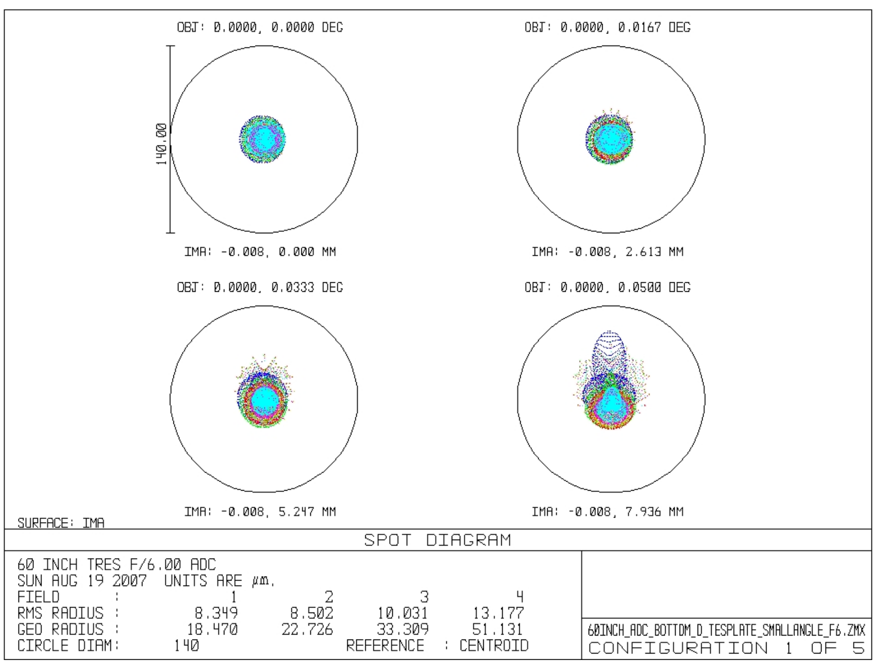

Fig. 7

Same as Fig. 6 but with ADC.

Spots for all field angles and all zenith angles, with and without the ADC, are shown on Fig. 8 and 9. Since without ADC at large zenith angles the spots are dispersed, we used a 300 micron scale for this full-matrix spot comparison.

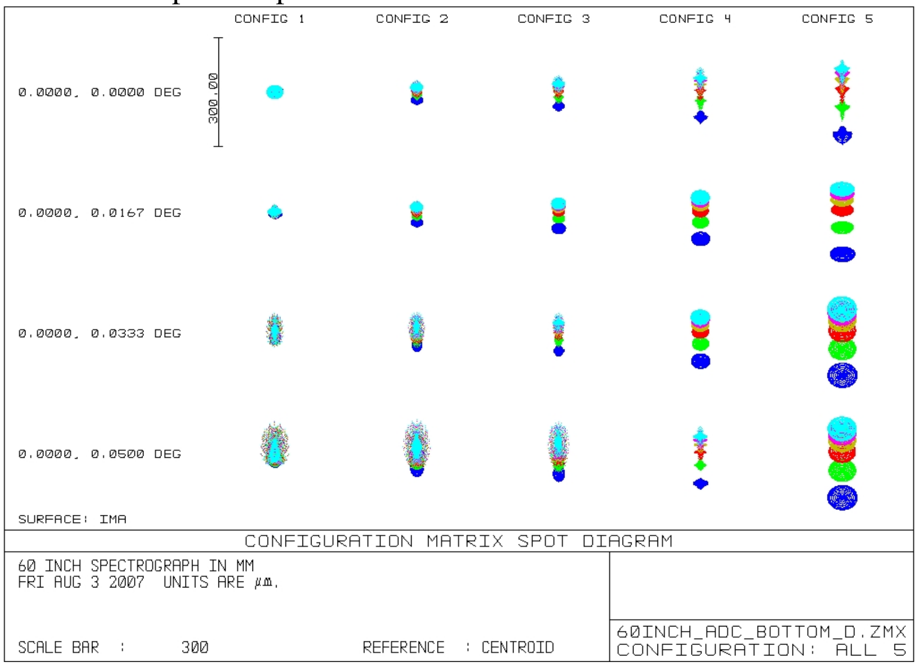

Fig. 8.

Full configuration matrix spot diagram. Columns: 0, 30, 45, 60 and 75 degree zenith distance (left to right); rows: on axis, 1, 2 and 3 arcmin FOV (top to bottom) – no ADC.

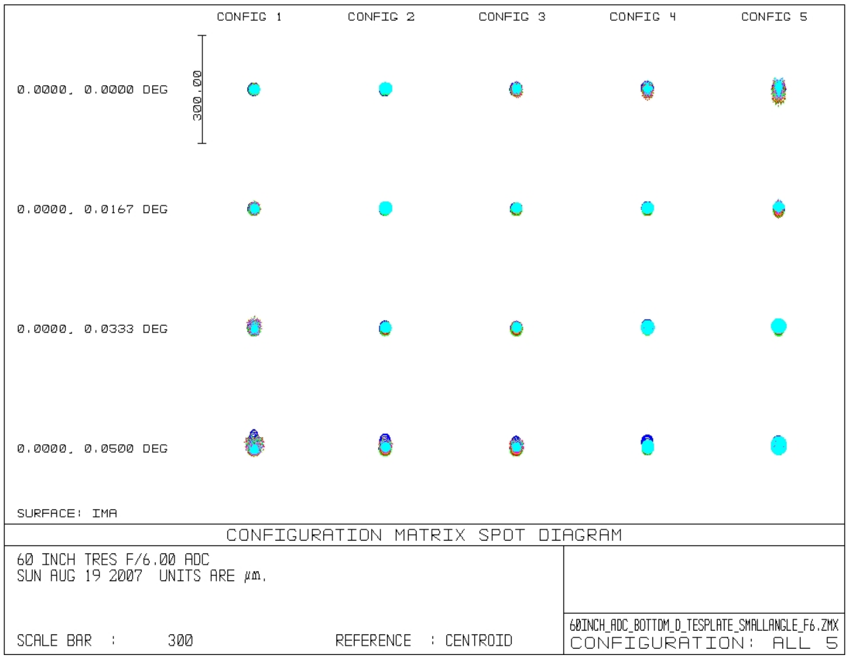

Fig. 9.

Same as Fig. 8. but with ADC.

Finally, a full configuration matrix with ADC is presented, same as Fig. 9., but instead of 300 micron scale (which was set to make a 1:1 comparison with Fig. 8.) here we display the 65 micron circle, representing the smallest TRES fiber.

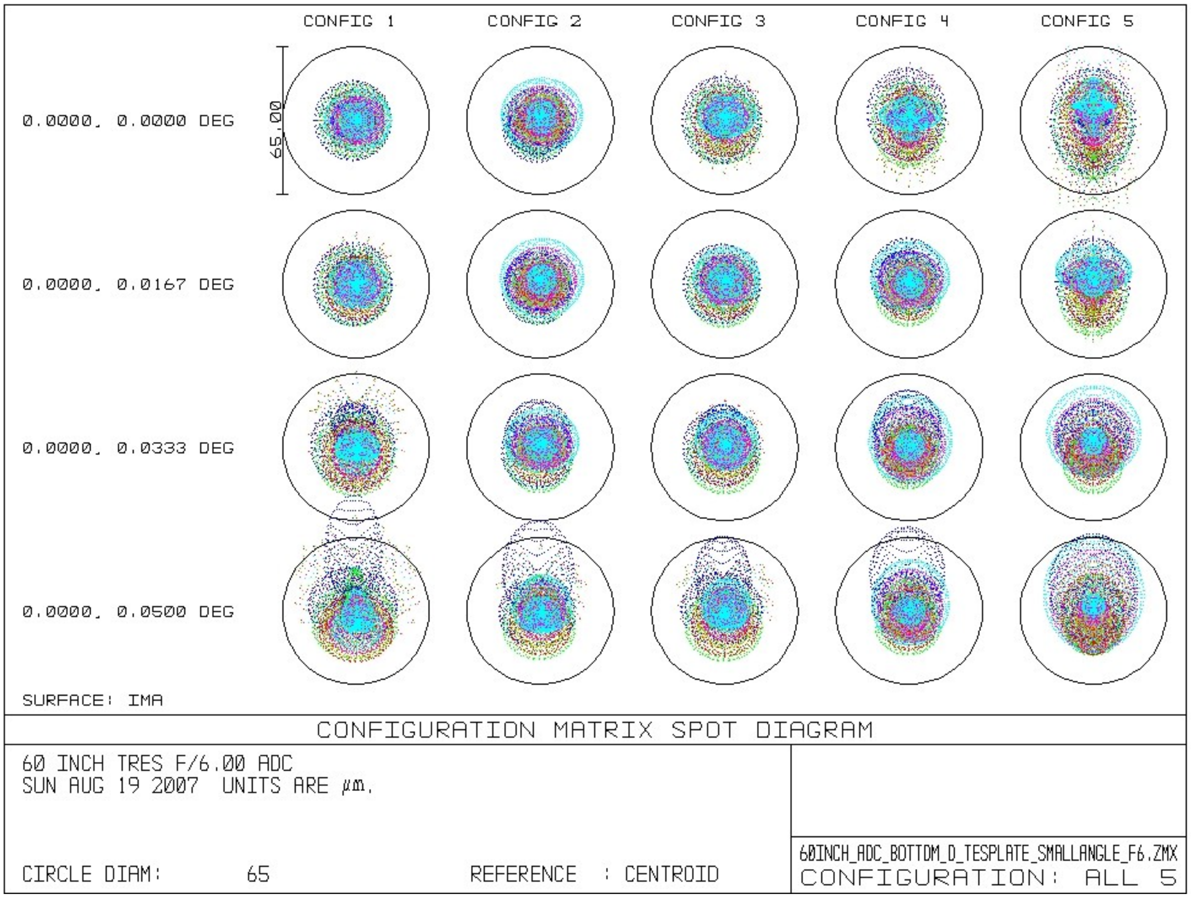

Fig. 9.

Same as Fig. 8 but for with a scale of 65 micron.

As the field of view is 4.5 by 4.5 arcmin for the TRES guider, the 3' field position represents the very corner of the guider image. Also, the 75 degree zenith distance is a very extreme case for observations. So basically the configurations represented in the last row and rightmost column of above spot matrix is very unlikely to be a real situation, but even though those are still providing very good image quality.

Therefore we can say that with this preliminary ADC design for all zenith distances and field angles we can maintain a geometricalspot diameter smaller than the smallest TRES fiber (with 1.4 arcsec angular coverage).