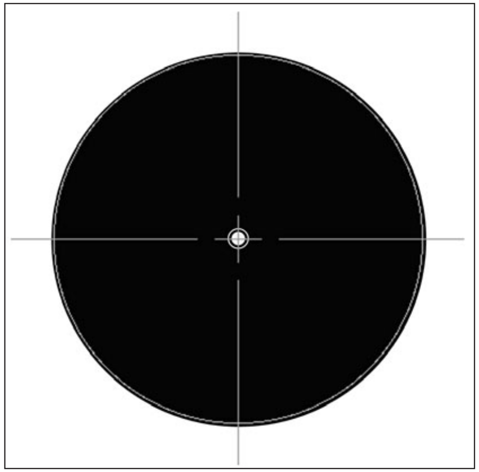
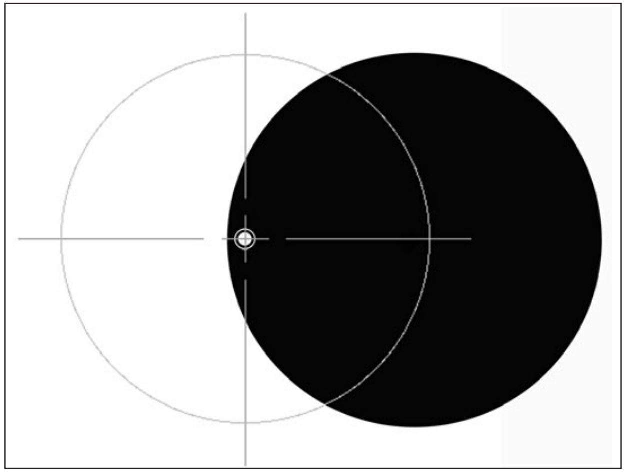
EDGE PERFORMANCE OF HIGH POWER EYEPIECES BY TESTING THE AIRY DISC IN 15 EYEPIECES

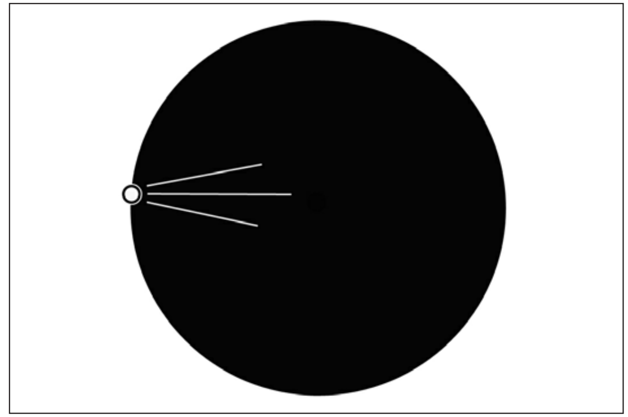
Equipment: autocollimation setup of two objectives: 200mm f/8 and 140mm f/7; artificial star Ø7.0µk; light source - lamp 2÷5V; Mitutoyo digital micrometer with measurement error ±10µk. Min number of measurements for each eyepiece position - 5.

										Edge aberrations				Reflections[1]
#	Eyepiece FL (mm)	Brand	Design/scheme	FOV	Eyerelief	N [2]	Hight mm	Weight (g)	Price	Astigmatism	Defocus [3] µk	Def. µk/deg.	ROC[4](mm)	Lens / Interionr
1	Hi-Ortho 2.8	Takahashi	Ortho + Barlow	40°	4.0	6	45	36	$140	vsa	none	-	∞	Yes / No
2	3.6	Celestron	Plossl	40°	3.0	4	30	55	$45	none	40	2.0	21	Y / N
3	A 4.0	Zeiss	Abbe-Ortho	45°	2.0	4	33	58	$600	vsa	30	1.3	46	N / N
4	SPL 5.0	Astro-Physics	3 elem./2 group	42°	6.3	4	36	73	$245	vsa	70	3.3	26	Y / N
5	Ortho 5.0	Baader Planet.	Abbe-Ortho	40°	(?)	4	38	68	$119	sa	30	1.5	55	Y / Y
6	XO 5.0	Pentax	5 elem./3 group	44°	3.6	6	45	90	$339	none	60	2.7	35	N / N
7	XW 5.0	Pentax	8 elem./5 group	70°	20	10	127	408	$339	none	none	-	∞	N / N
8	LE 5.0	Takahashi	Ortho + Barlow	52°	10	6	66	133	$179	none	none	-	∞	N / N
9	Supermono 5.0	TMB	Steinheil triplet	30°	4.2	2	36	52	$225	none	90	6.0	10	Y / Y
10	SPL 6.0	Astro-Physics	3 elem./2 group	42°	7.5	4	37	75	$245	vsa	80	3.8	33	Y / N
11	Ortho 6.0	Baader Planet.	Abbe-Ortho	40°	(?)	4	39	73	$119	sa	30	1.5	80	Y / N
12	Supermono 6.0	TMB	Steinheil triplet	30°	5	2	38	54	$225	none	110	7.3	12	N / N
13	7.0	Nikon	Kerber	70°	20	8	83	170	$300	none	none	-	∞	N / N
14	LE 7.5	Takahashi	Ortho + Barlow	52°	10	6	56	118	$179	sa	30	1.2	220	N / N
15	XP 8.5	Pentax	(?)	60°	20	8	80	149	$159	none	30	0.5	400	N / N

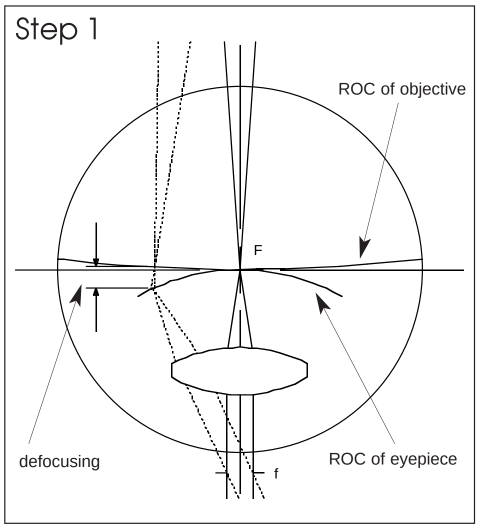
[1]Reflections - may appear in FOV on lens or on interior surface when Airy disk goes behind edge. [2]N - number of glass-to-air surfaces. [3]Defocus - measured difference between focal position in center and on the edge of FOV.
[4]ROC - calculated radius of curvature of eyepiece. SA - small astigmatism on the edge; VSA - very small astigmatism on the edge. Test performed by Y.Petrunin with help of A.Rychenko and E.Trygubov. TEC 11/29/04.



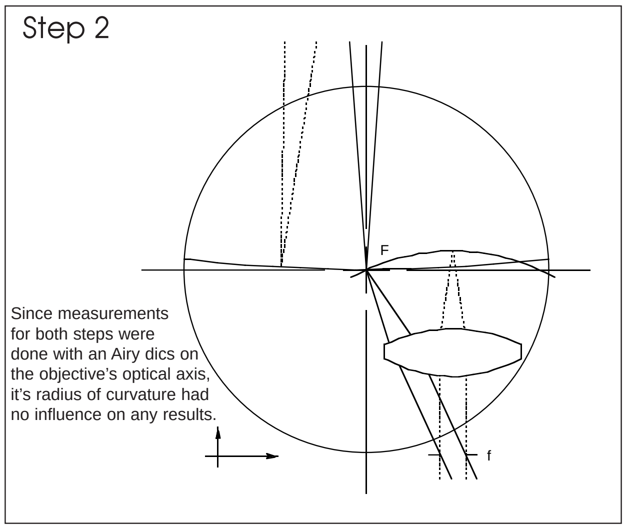




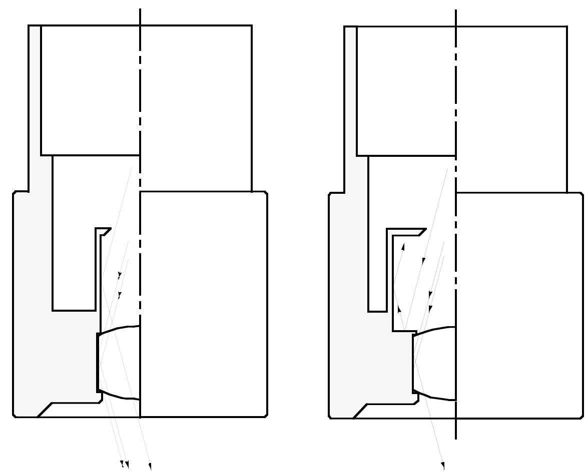
To check internal reflections, scatter, ghosting, etc. the light source was setup for higher brightnes. Most unnecessary reflections appears in the FOV at the moment as a splash of light or ghost when the Airy disc is going behind the edge of FOV.
Un-needed reflection could be caused by: unpainted lens edges; reflectivity of cylindrical parts at the low angles; specular reflections from rough lens bevels, etc.



The first measurement was done with an eyepice position on the axis - Airy dics at the center of FOV.



For the second measurement the eyepiece was shifted to the position when the Airy disc was near the edge of FOV and focused on the Airy disc image (if required).



Changing geometry of internal parts and blackening lens edges may dramatically reduce unneeded reflections.

C O M M E N T S

The first question that may arise: Why to check edge performace of the eyepices most of which are called “planetary”? - The answer is simple and comes from our ordinary reality - people just trying to use them on other objects such as the Moon and deep sky, at least at the time when planets behind the horizont.

The eyepices in table are organized in alphabetic order with focal length increasing from top to bottom.

1. TAK Hi-Ortho 2.8 - highest power eyepiece tested, no defocusing on the edge, but very small astigmatism.
2. Celestron Plossl 3.6 - cheapest on the list, has simple MgF2 coating and not perfect polished lenses, but as a design, Plossl has it’s potential, if made properly and with better polishing and coating.
3. Zeiss Abbe A-4 - most expensive on the list. No longer in production. Has good balance between astigmatism and curvature of field. It is Zeiss after all.
4. AP SPL-5.0 has slightly lesser astigmatism on the edge compared to Zeiss, but stronger field curvature.
5. Baader Planetarium Genuine-Ortho 5.0 - has flatter field compared to (3) and (4), but for the price of a bit stronger astigmatism on the edge. Best value among hi-end planetary eyepieces (in USA available from Alpine Astronomical).
6. Pentax XW-5.0 - biggest and heaviest eyepiece on the list. Has 10 air-to-glass surfaces, but as an exchange - the widest FOV and no aberrations on the edge - the Airy disk does not change its shape to the very edge of FOV.
7. TAK LE-5 - has widest field among Orthos, thanks to added Barlow element, images on the edge same good as in (6).
8. TMB Supermono 5.0 - being simple cemented triplet* has min air-to glass surfaces - 2 and possibly shortest light pass in the glass, from other side - strongest field curvature with edge image defocused, but no astigmatism at all.
9. AP SPL-6.0 - same comments as for 5mm eyepiece (4).
10. Baader Planetarium Genuine-Ortho 6.0 - same comments as for 5mm eyepiece (5)
11. TMB Supermono 6.0 - same comments as for 5mm eyepiece (8).
12. Nikon 7.0 - this eyepiece made for Nikon’s line of Field scopes, using for astronomy will require 1.25” adapter (available from APM - Markus Ludes) - has same wide FOV as Pentax and same perfect performance on the edge, but is relatively smaller - shorter and much lighter.
13. TAK LE-7 - same design as LE-5 (7), but not as good in performace, has small astigmatism at the edge of FOV.
14. TEC 7.5 - was designed as a combination with Mac-Cassegrain telescopes line, made only as a prototype, edge performance similar to Orthos.
15. Pentax SP 8.5 - best value for wide field eyepieces, edge performance is csimilar to (6).

Above is an “eyepiece carusel” that shows the tops of all tested eyepices. Note that TAK, TMB and Baader eyepieces have dimmer surfaces with no outer surface reflections.

**not a monocentric by principle. The monocentric design has a common center for all surfaces and infinite number of optical axis, being this way is not sensitive to decentrations , but has much longer light pass in the glass.*

IN CONCLUSION:

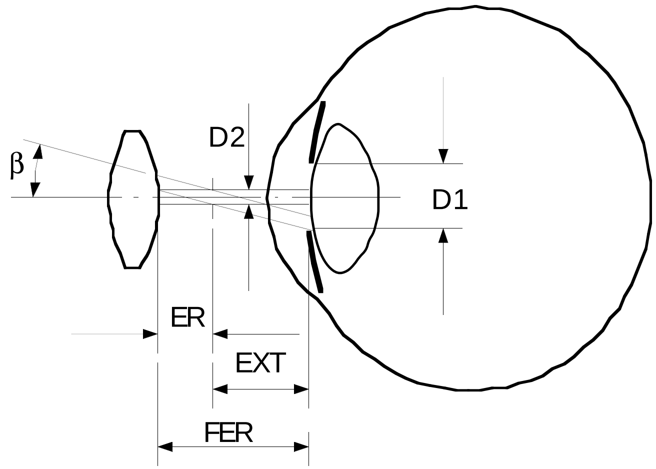
The 5 best “planetary” eyepieces / center performance: Zeiss A-4, Baader Ortho 5.0, AP SPL5.0, TMB Supermono 5.0, TAK LE-5.

Most of them have short eye relief, but do not forget about added value for eye relief when observing planets at high power (scope exit pupil is smaller than the eye pupil).

Best “Lunar” eyepieces / center and edge performance - TAK LE-5, Pentax XW 5.0, Nikon 7.0. All of these eyepieces have no unneeded reflections, wide FOV with no aberrations from center to the edge, long eye relief, that is required for bright lunar surface observations (scope exit pupil is similar in size to the eye pupil).

Please note: tests were performed in a lab environment, measurements could be repeated, some subjective issues may occur. Comments and corrections are welcome. YP12/5/2004

THE EYE RELIEF EXTENSION FOR HIGH POWER EYEPIECES



$$FER = ER + EXT = ER + \frac{D1 - D2}{2\ tg\ \beta}$$

ER - eye relief based on specifications
EXT - extension to the given eye relief
FER - full eye relief for given object
D1 - eye pupil diameter for given object
D2 - exit pupil
β - 1/2 of FOV

Sample 1
telescope 140mm dia., F=1000mm
eyepice 5mm, 30° FOV, 4mm eye relief
observing planet at high power 200X
D2 exit pupil = 140/200 = 0.7mm
D1 eye pupil opening ~5mm

$$FER = 4 + \frac{5 - 0.5}{2\ tg\ 15°} = 4 + 8.4 = 12.4mm$$

Sample 2
telescope 140mm dia., F=1000mm
eyepice 5mm, 30° FOV, 4mm eye relief
observing the Moon at power 200X
D2 exit pupil = 140/200 = 0.7mm
D1 eye pupil opening ~ 2mm

$$FER = 4 + \frac{2 - 0.5}{2\ tg\ 15°} = 4 + 2.8 = 6.8mm$$

More readings :

D.D. Maksutov, Astronomical Optics, Moscow, 1946. Chapter 25 - Oculars. Language - Russian.