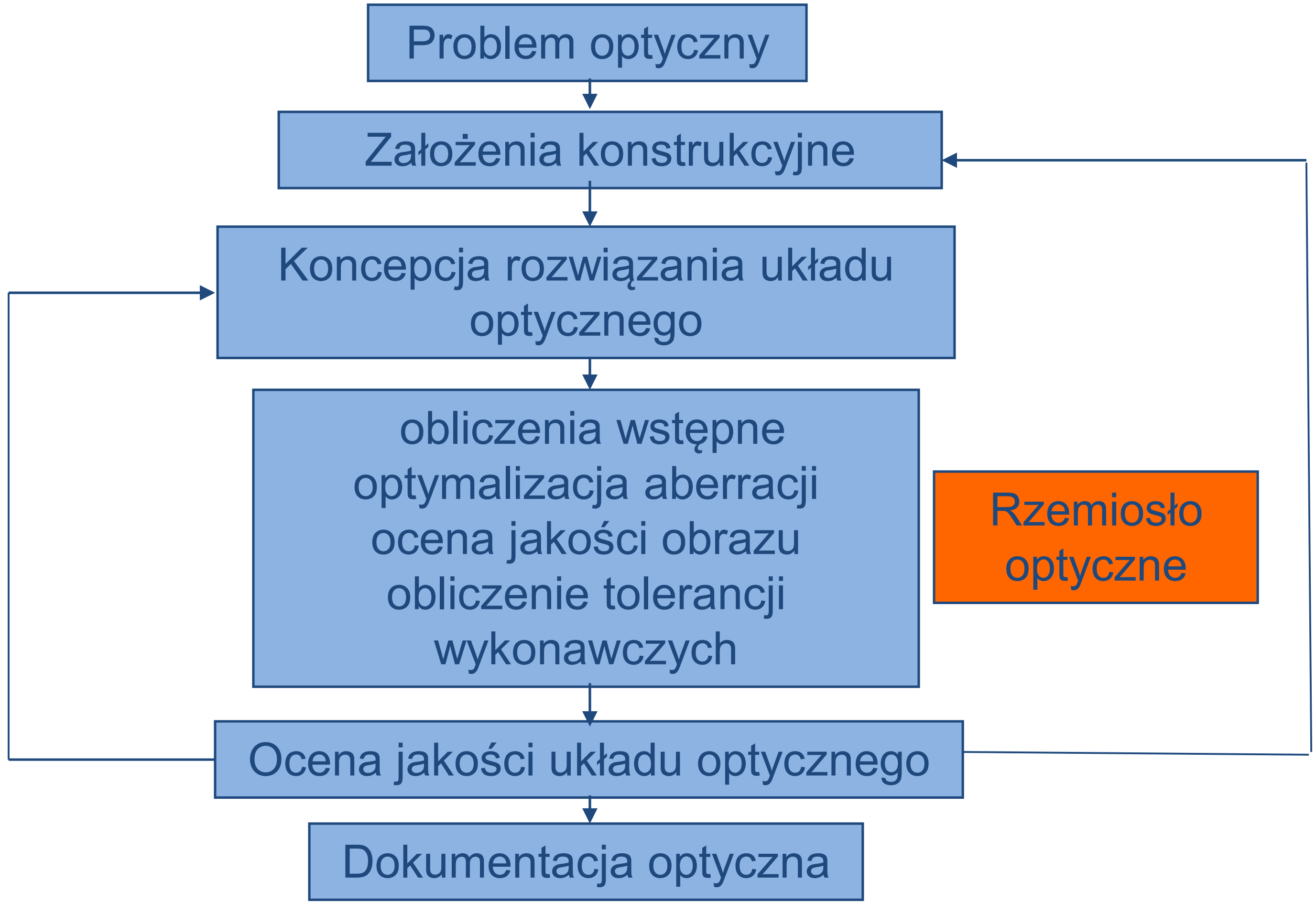
Konstrukcja Układów Optycznych

Projekt Rzutnika Multimedialnego

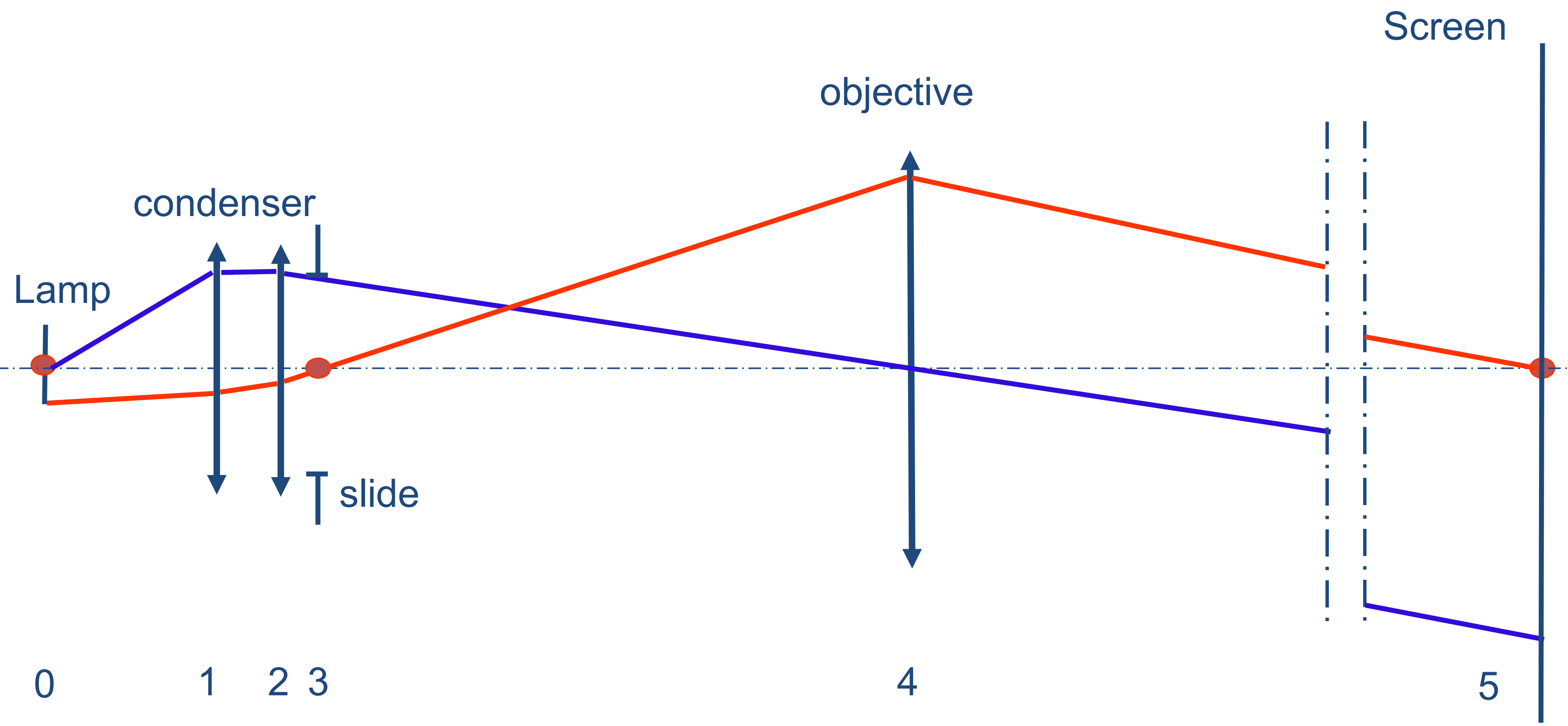


Schemat blokowy procesu projektowania układów optycznych

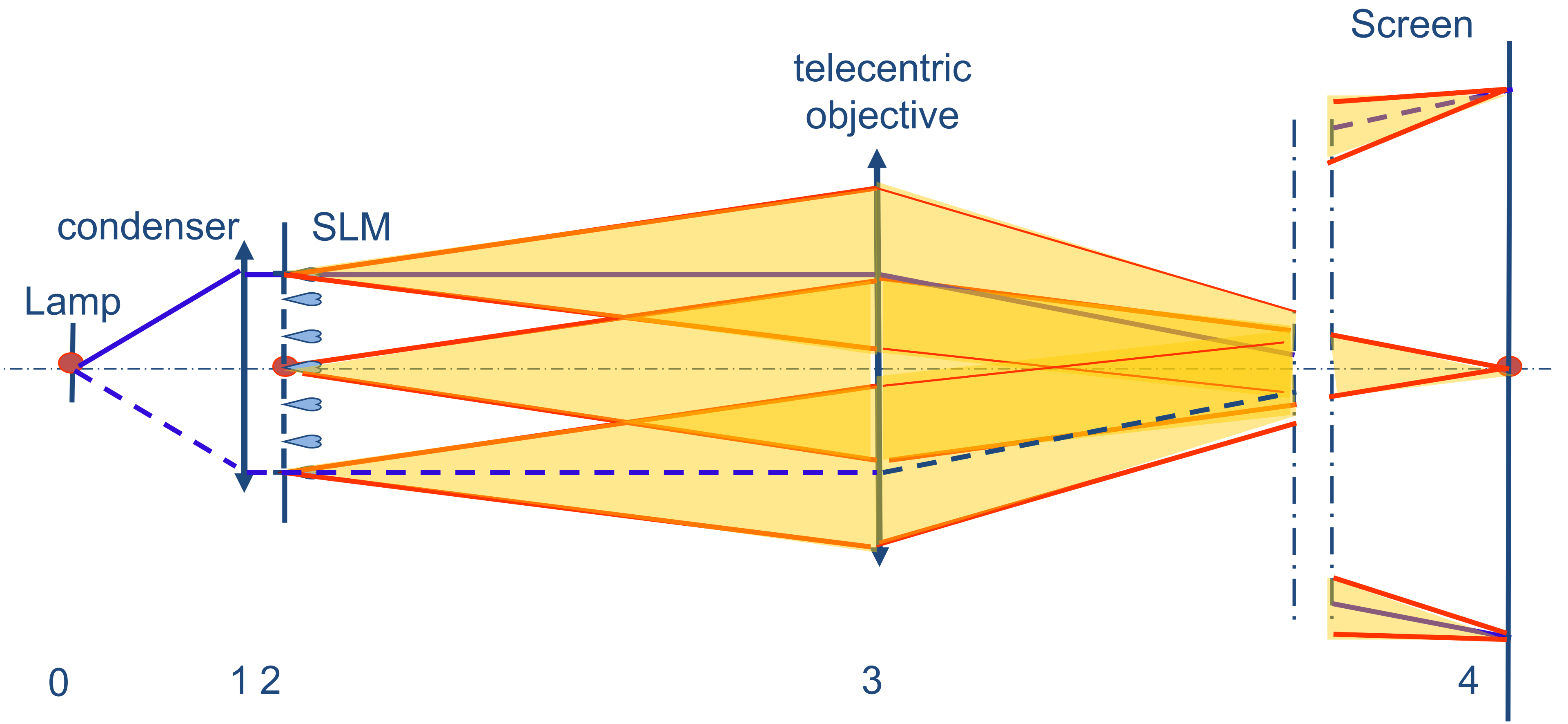
❑ Specyfikacja Optyczna

- Wybór modelu startowego projektu
- Ustawienie optycznych parametrów:
  - wymiar slajdu 24x36 mm,
  - baza ekranu 1500 mm,
  - odległość do ekranu,
  - natężenie oświetlenia 1000 lx,
  - współczynnik transmisji układu optycznego 0.7,
  - lampa halogenowa 150 W.

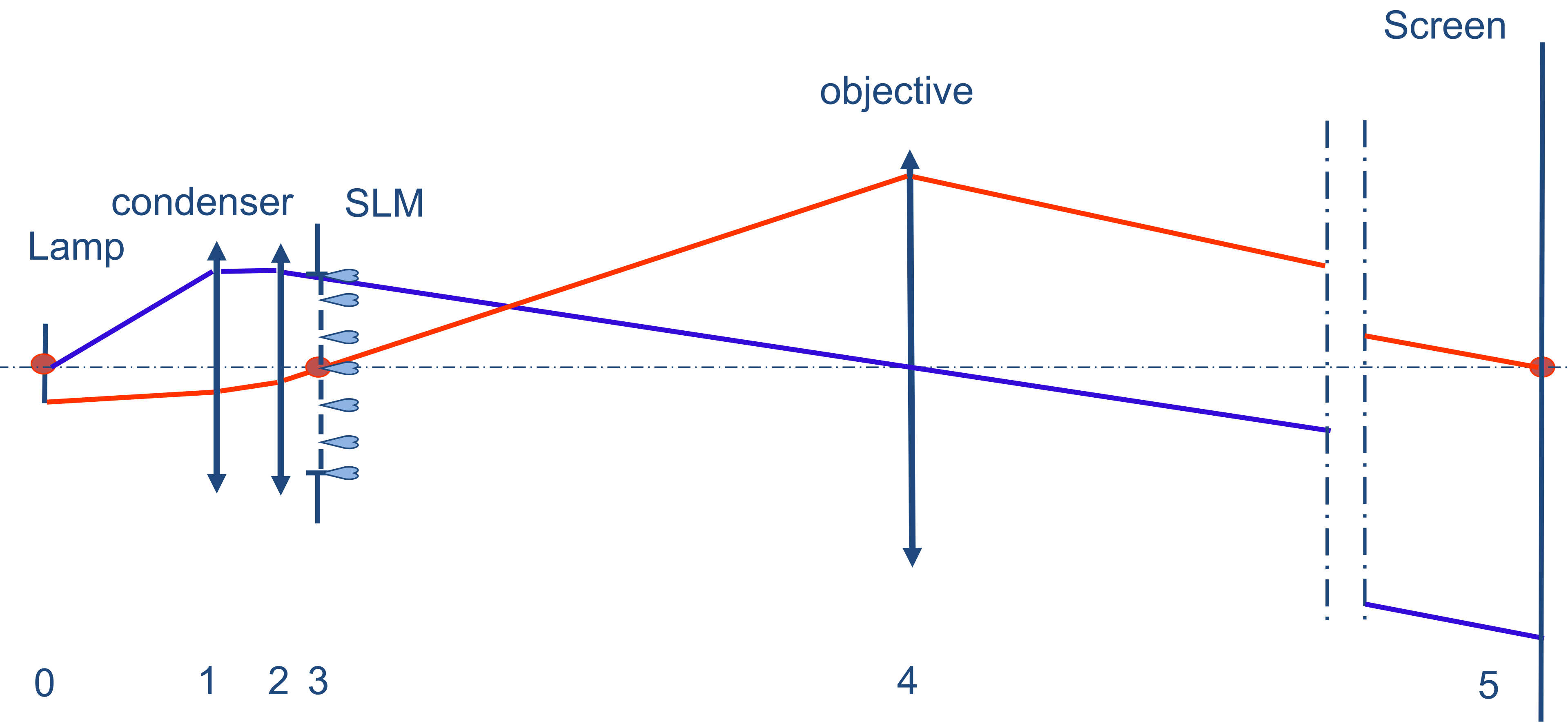
Wybór rozwiązania



Wariant #1: Klasyczny układ projektora analogowego

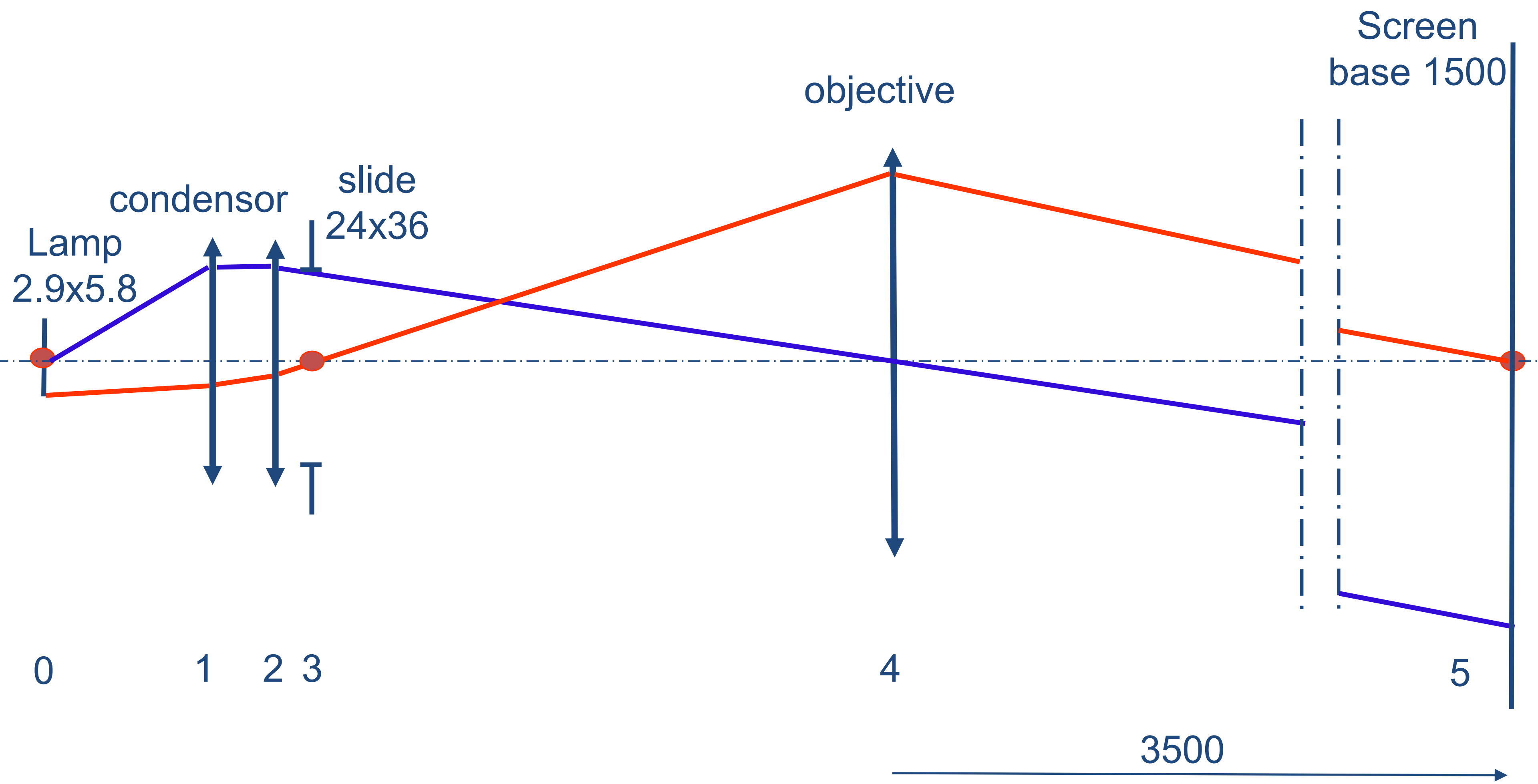


Wariant #2: Model projektora cyfrowego



Variant #3: Model projektora cyfrowego wg schematu klasycznego (problem z kontrastem)

Obliczenia wstępne



Model cienko elementowy wybranego rozwiązania

2.9x5.8

(5.8x1.4)/2=4.1

$$\frac{\sqrt{24^2+36^2}}{2}=21{,}6$$

$$E' = \pi \left(\frac{n'}{n}\right)^2 \tau \, L \sin^2 u'$$

E’ = 1000 lx

liczba elem.	5

Nr. pow	0	1	2	3	4	5
f				1,00E+20		
d			10			
H	0			21,6		
Alfa		0				
V						
L						
Y	-4,12			0		0
Beta					0,004	
Q						
T						

Niezmiennik L-H	

Program GABAR

1500/36=41,7

liczba elem.	5

Nr. pow	0	1	2	3	[illegible]	5
f				1,00E+20		
d			10			
H	0			21,6		-900,72
Alfa	-0,874485	0				
V						
L						
Y	-4,12		-1,668	0		0
Beta			-0,1668	-0,1668	0,004	
Q				1	-41,7	
T				0		

Niezmiennik L-H	3,60288

Program GABAR

Screen distance

liczba elem.	5

Nr. pow	0	1	2	3	4	5
f		27,6431	93,93285372	1,00E+20	81,96721	
d	27,6431		10	83,93285372	3500	
H	0	24,17349	24,17348571	21,6	0	-900,72
Alfa	-0,874485	0	0,257348571	0,257348571	0,257349	
V			0	1	1	
L				0	0	
Y	-4,12		-1,668	0	14	0
Beta		-0,149043	-0,1668	-0,1668	0,004	
Q			0,893540975	1	-41,7	
T			-1,191428571	0	3583,933	

Niezmiennik L-H	3,60288

Program GABAR

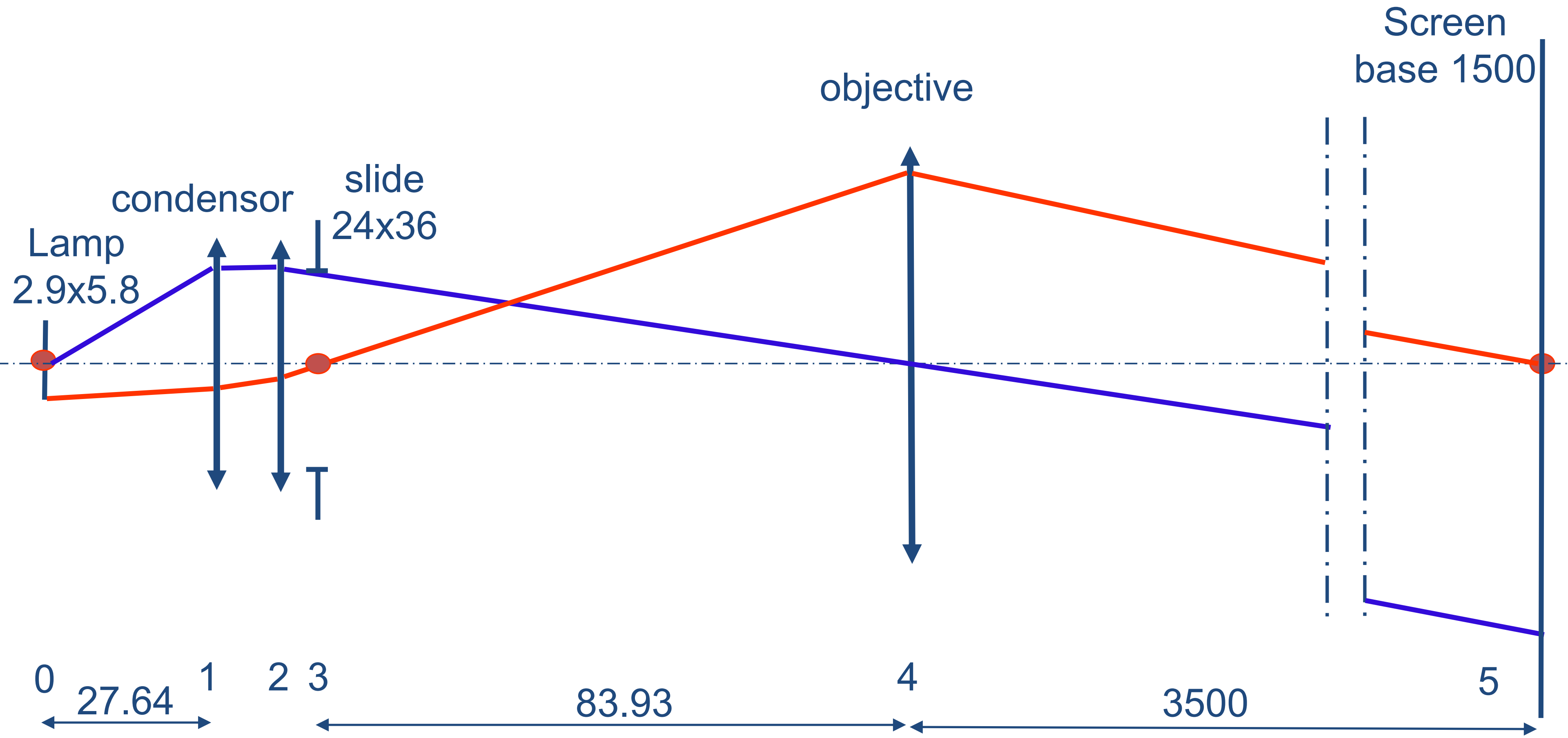
inter lens distance

liczba elem.	5

Nr. pow	0	1	2	3	4	5
f		27,6431	93,93285372	1,00E+20	81,96721	
d	27,6431	15	10	83,93285372	3500	
H	0	24,17349	24,17348571	21,6	0	-900,72
Alfa	-0,874485	0	0,257348571	0,257348571	0,257349	
V			0	1	1	
L				0	0	
Y	-4,12	-3,90364	-1,668	0	14	0
Beta	-0,007827	-0,149043	-0,1668	-0,1668	0,004	
Q		0,052515	0,893540975	1	-41,7	
T		-472,5535	-1,191428571	0	3583,933	

Niezmiennik L-H	3,60288

Program GABAR



f ’= 27.64
A = 0.87
y = 4.12

f ’= 93.93
A = 0.26
y = 14

f ’= 81.97
A = 0.17
y = 21.63
m = -41.7

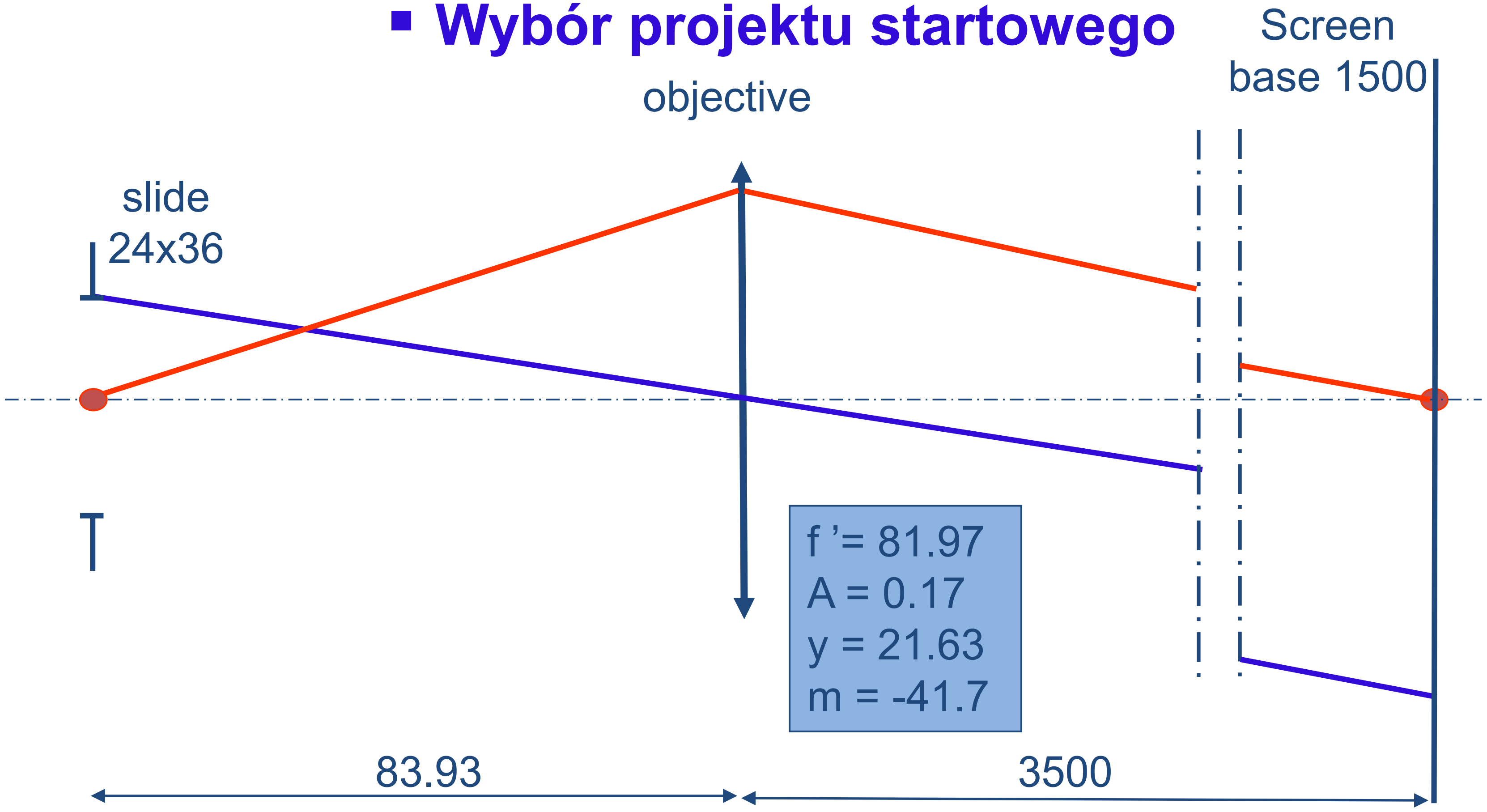
Model cienko elementowy

Projektowanie obiektywu

❑ Projektowanie obiektywu

- **Wybór startowego projektu**
- **Ustawienie warunków pracy dla projektu startowego**
- **Vinietowanie**
- **Dyskusja aberacyjna**
- **Optymalny defocusing**
- **Kryteria do oceny jakości układu optycznego**
- **Spot Diagram**
- **MTF**

▪ Wybór projektu startowego



Numerical Aperture = 0.17

$$\text{Field Angle} = Tan^{-1}\frac{\sqrt{12^2+18^2}}{83.93} = 14.45°$$

Definicja systemu (working condition):

EFL = 81.97

m = - 41.7X

Numerical Aperture = 0.17

Field Angle = 14.45 deg

It implies:

F# = 2.94 such a large aperture must be specially considered (spherical and coma aberrations must be corrected)

Field Angle = 14.45 deg, such an angle requires correction of field curvature aberrations (design type: anasitigmat must be used)

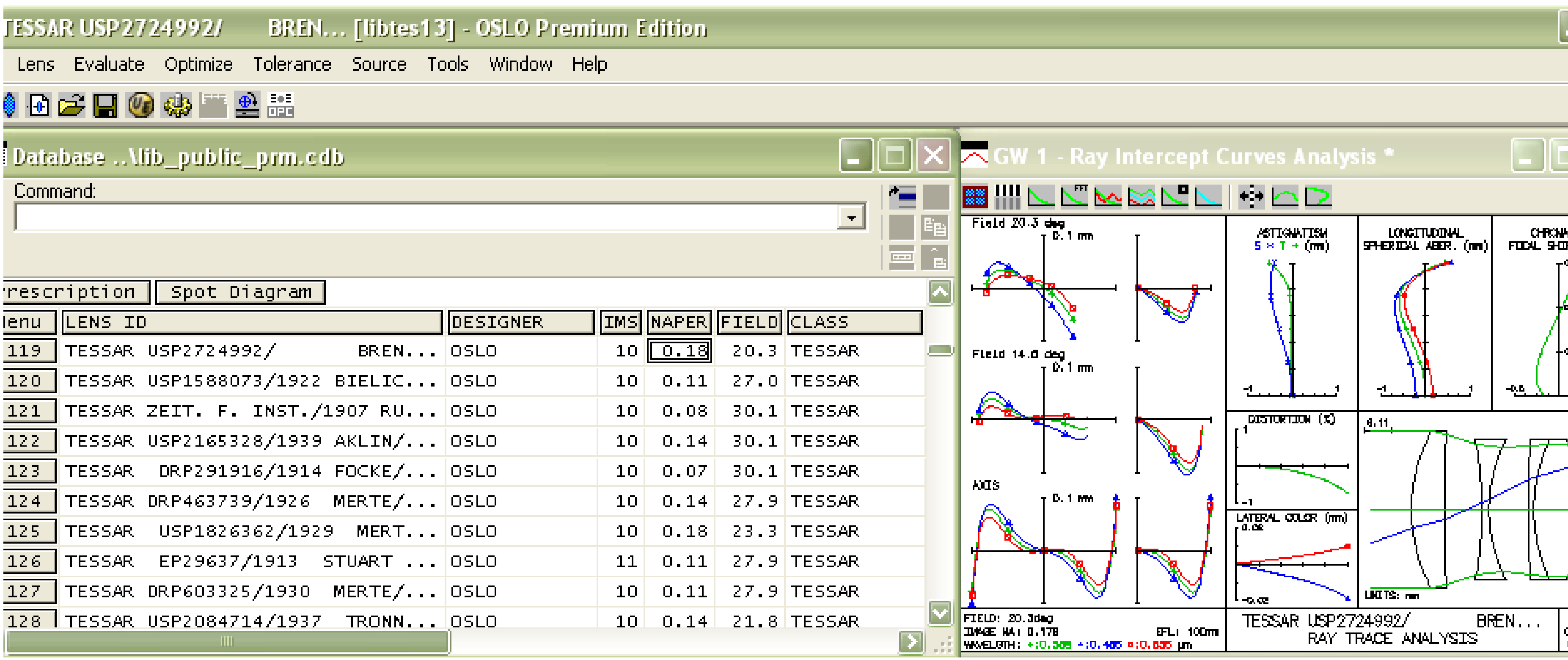
Wybieramy obiektyw typu Tessar

Parametry systemu:

Numerical Aperture = 0.17

Field Angle = 14.45 deg

‘OSLO → Lens → Lens Database’



lenu	LENS ID	DESIGNER	IMS	NAPER	FIELD	CLASS
119	TESSAR USP2724992/ BREN...	OSLO	10	0.18	20.3	TESSAR
120	TESSAR USP1588073/1922 BIELIC...	OSLO	10	0.11	27.0	TESSAR
121	TESSAR ZEIT. F. INST./1907 RU...	OSLO	10	0.08	30.1	TESSAR
122	TESSAR USP2165328/1939 AKLIN/...	OSLO	10	0.14	30.1	TESSAR
123	TESSAR DRP291916/1914 FOCKE/...	OSLO	10	0.07	30.1	TESSAR
124	TESSAR DRP463739/1926 MERTE/...	OSLO	10	0.14	27.9	TESSAR
125	TESSAR USP1826362/1929 MERT...	OSLO	10	0.18	23.3	TESSAR
126	TESSAR EP29637/1913 STUART ...	OSLO	11	0.11	27.9	TESSAR
127	TESSAR DRP603325/1930 MERTE/...	OSLO	10	0.11	27.9	TESSAR
128	TESSAR USP2084714/1937 TRONN...	OSLO	10	0.14	21.8	TESSAR

DESIGN INPUT: TESSAR USP2724992/ BREN...

Surface Data

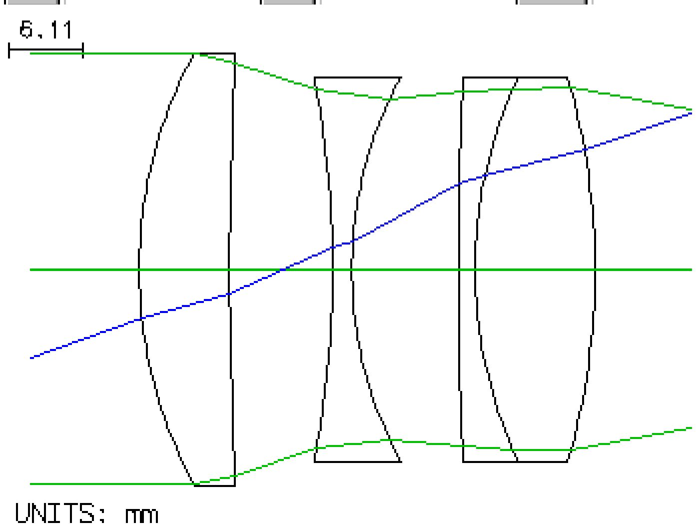
17.9

Gen | Setup | Wavelength | Field Points | Variables | Draw Off | Group | Notes

Lens:TESSAR USP2724992/ BREN... | Zoom 1 of 1 | Efl 99.973638

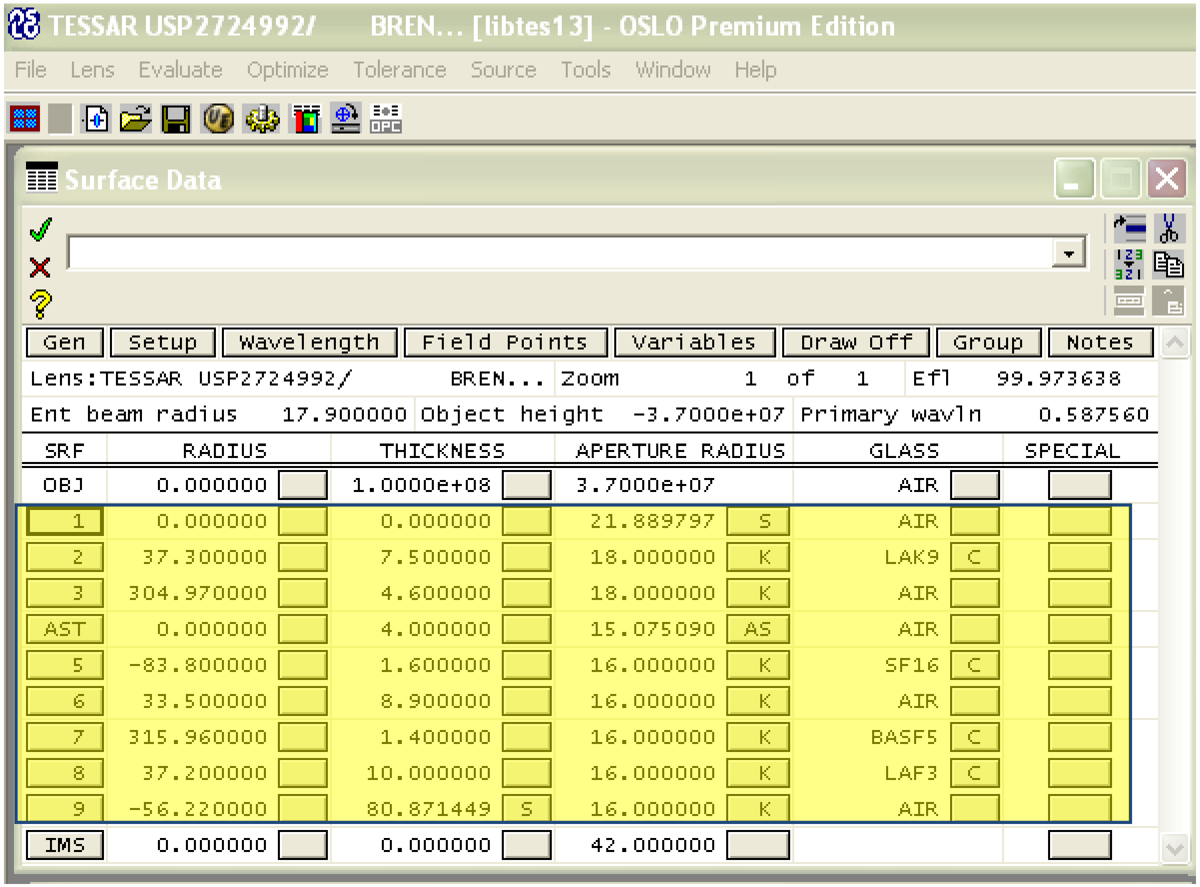
Ent beam radius 17.900000 | object height -3.7000e+07 | Primary wavln 0.587560

SRF	RADIUS	THICKNESS	APERTURE RADIUS	GLASS	SPECIAL
OBJ	0.000000	1.0000e+08	3.7000e+07	AIR	
1	0.000000	0.000000	21.889797 S	AIR	
2	37.300000	7.500000	18.000000 K	LAK9 C	
3	304.970000	4.600000	18.000000 K	AIR	
AST	0.000000	4.000000	15.075090 AS	AIR	
5	-83.800000	1.600000	16.000000 K	SF16 C	
6	33.500000	8.900000	16.000000 K	AIR	
7	315.960000	1.400000	16.000000 K	BASF5 C	
8	37.200000	10.000000	16.000000 K	LAF3 C	
9	-56.220000	80.871449 S	16.000000 K	AIR	
IMS	0.000000	0.000000	42.000000		

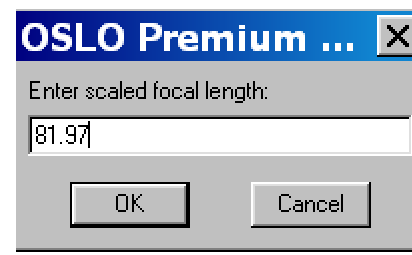


▪ Ustawienie warunków pracy układu

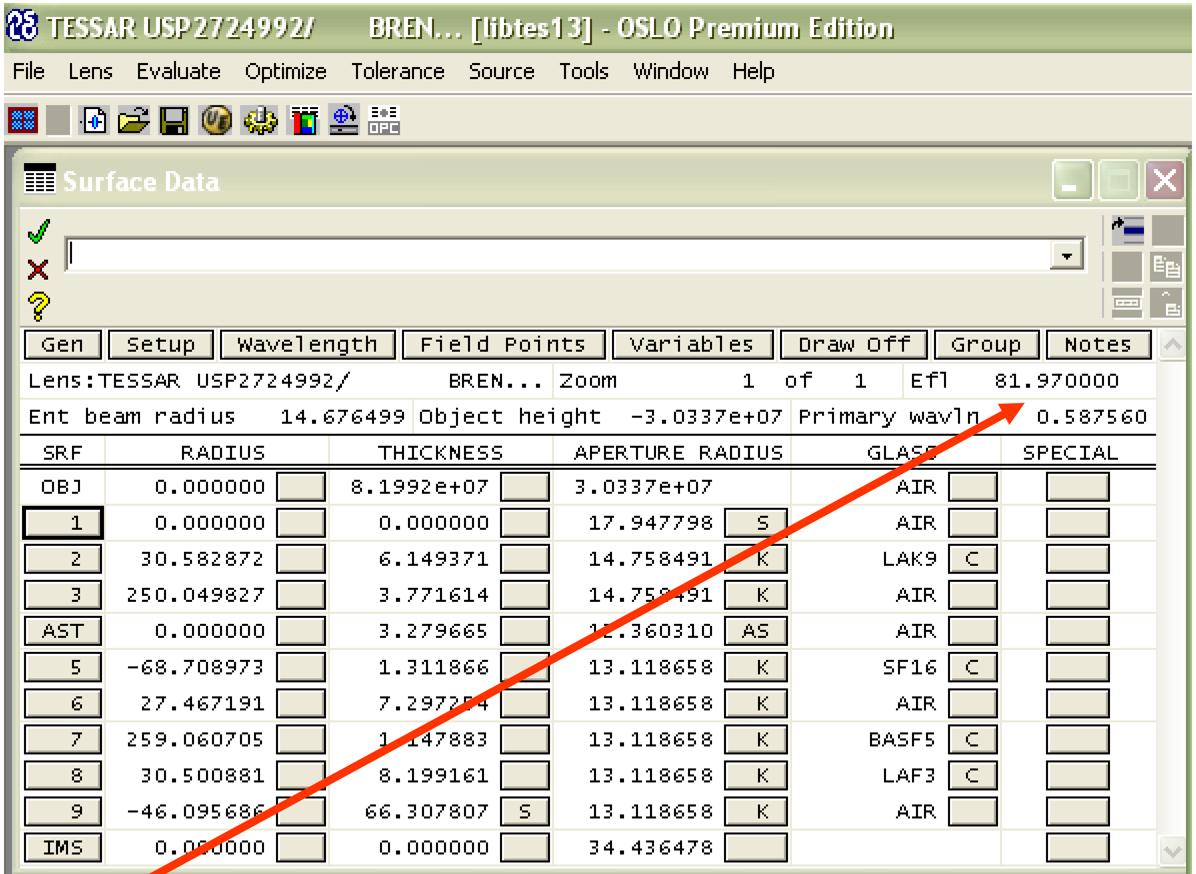
Rescale lens ‘<u>Scale Lens -> Scale to new focal length</u>’



f ’= 81.97
A = 0.17
y = 21.63



Po przeskalowaniu sprawdź EFL



SRF	RADIUS		THICKNESS		APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000		8.1992e+07		3.0337e+07		AIR		
1	0.000000		0.000000		17.947798	S	AIR		
2	30.582872		6.149371		14.758491	K	LAK9	C	
3	250.049827		3.771614		14.758491	K	AIR		
AST	0.000000		3.279665		12.360310	AS	AIR		
5	-68.708973		1.311866		13.118658	K	SF16	C	
6	27.467191		7.297254		13.118658	K	AIR		
7	259.060705		1.147883		13.118658	K	BASF5	C	
8	30.500881		8.199161		13.118658	K	LAF3	C	
9	-46.095686		66.307807	S	13.118658	K	AIR		
IMS	0.000000		0.000000		34.436478				

EFL = 81.97
m = - 41.7X
Numerical Aperture = 0.17
Field Angle = 14.45 deg

Specify working condition ‘Surface Data -> Paraxial Setup Editor’

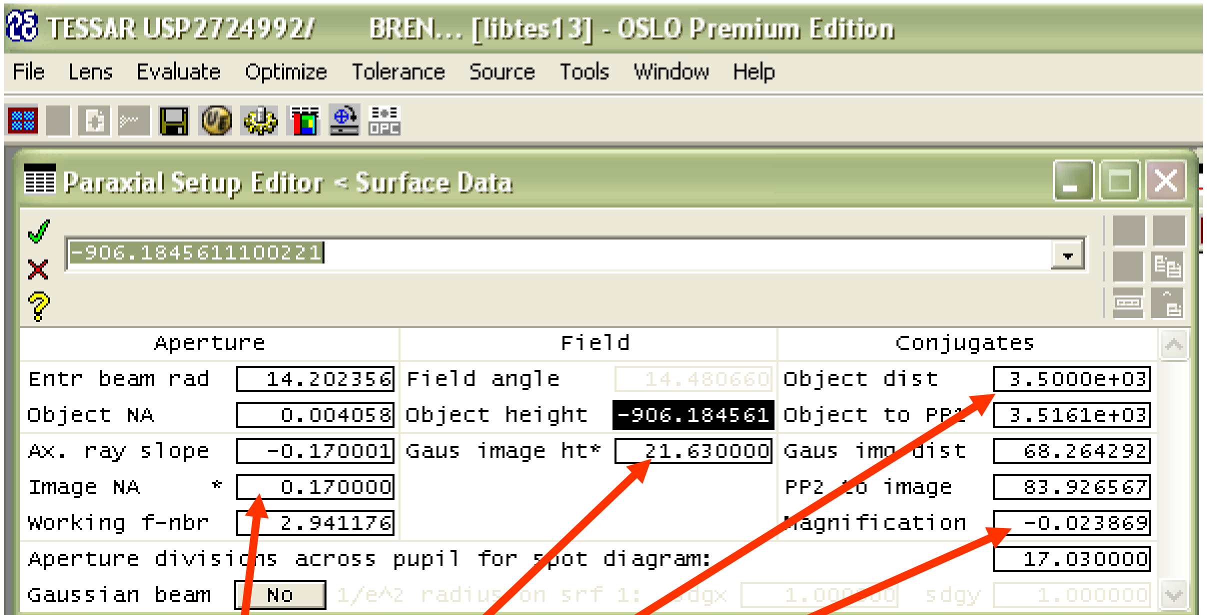
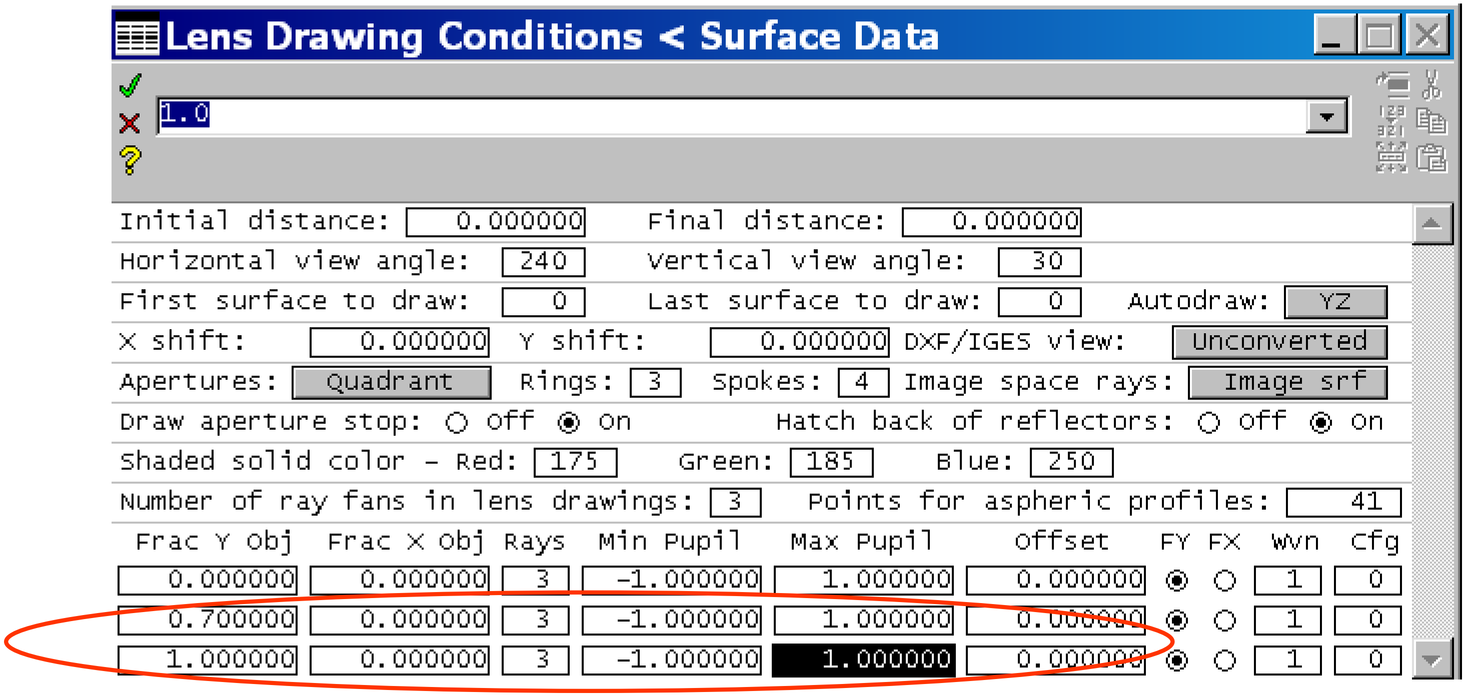


Image height = 21.63
m = - 41.7X
NA = 0.17
object. dist =3500 mm

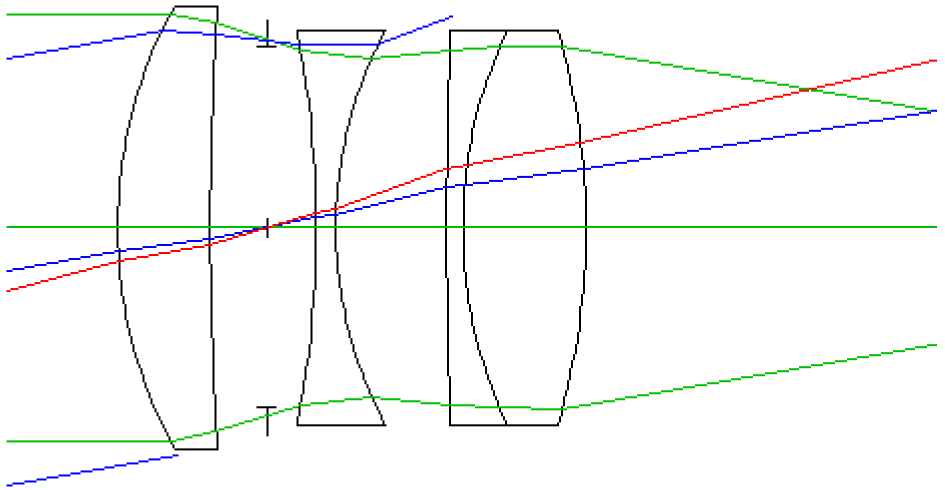
Aberracje są wyznaczane w kierunku mniejszego powiększenia!

▪ Winietowanie

Set Lens Drawing Conditions to see if for all of field angles all of the rays are transferred.

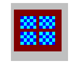


Set rows 2 and 3 to observe vignetting

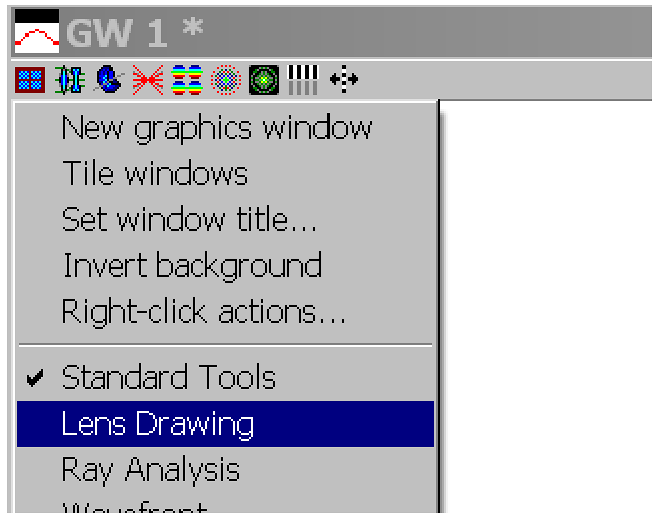


Winietowanie musi być skorygowane dla obu kątów pola

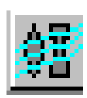
Ustawienie winietowania

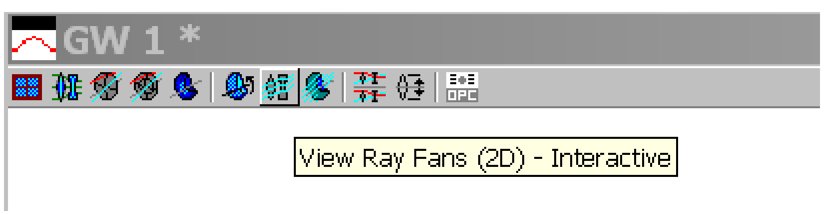


W oknie GW 1 naciśnij przycisk i wybierz opcję meni ‘<u>Lens Drawing</u>’

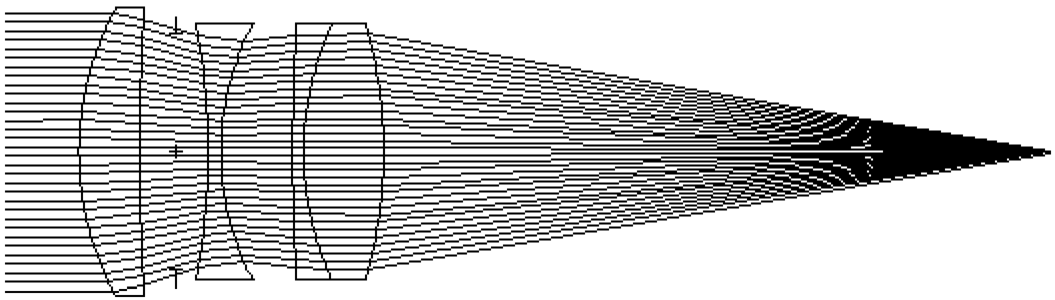


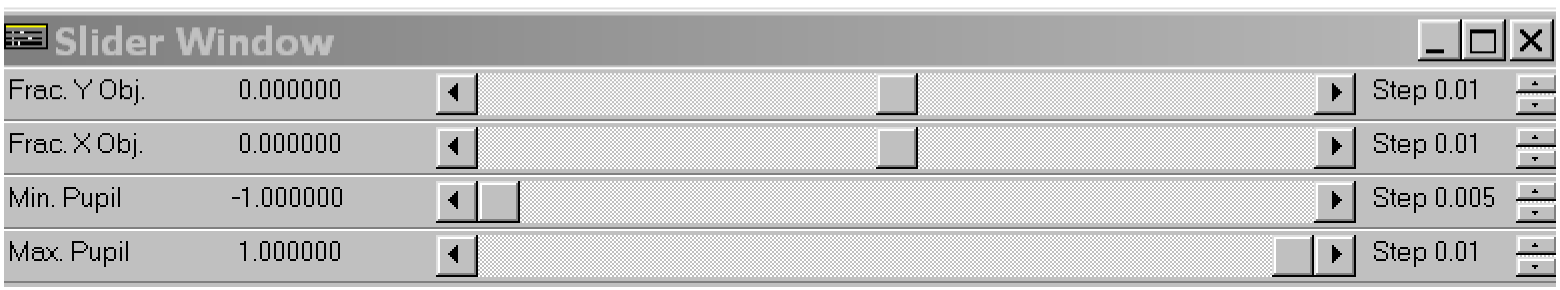
Naciśnij przycisk





Okno do graficznej analizy vinietowania



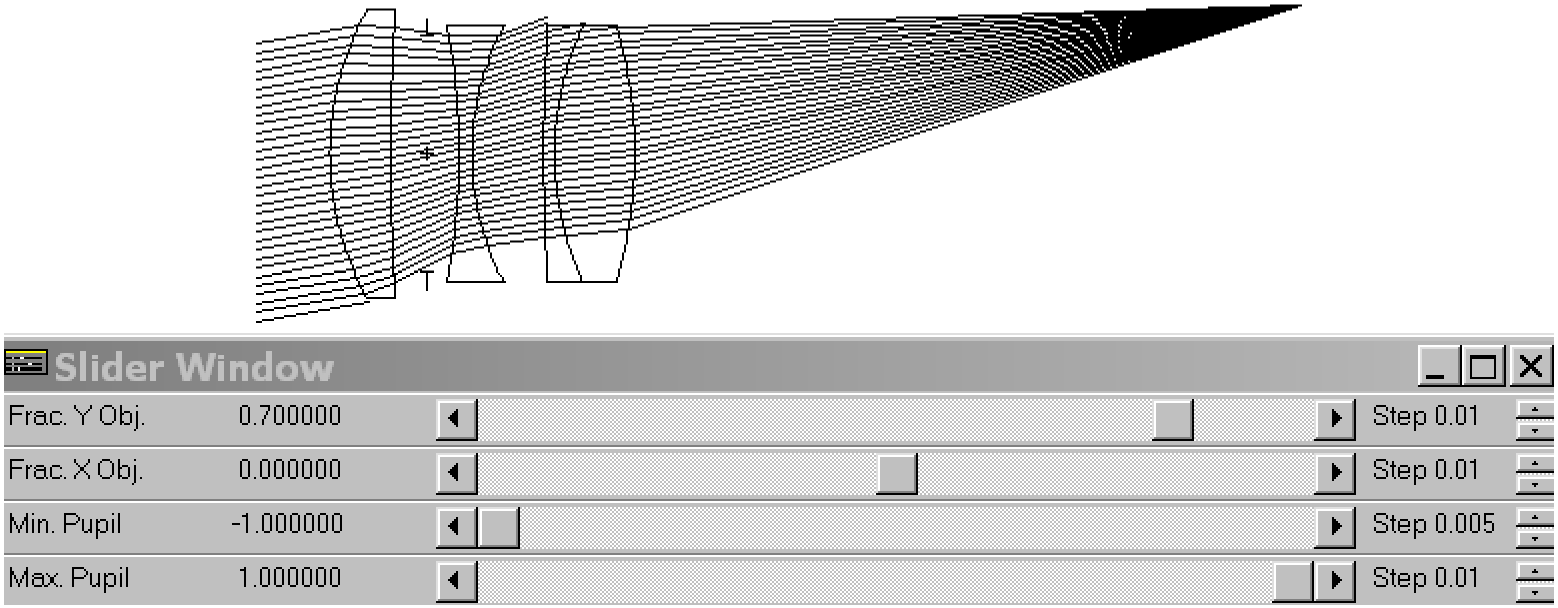


Frac Y (X) Obj. – actual tangential (sagital) field of view (normalized to max angle),
Min (Max) – actual down (upper) effective aperture diameter (normalized to max aperture)

Frac Y obj	Frac X obj	Rays	Min Pupil	Max Pupil	Offset	FY	FX	Wvn	Cfg
0.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
0.700000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
1.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0

Actual field of view

Analiza winietowania dla 0.7 pola widzenia

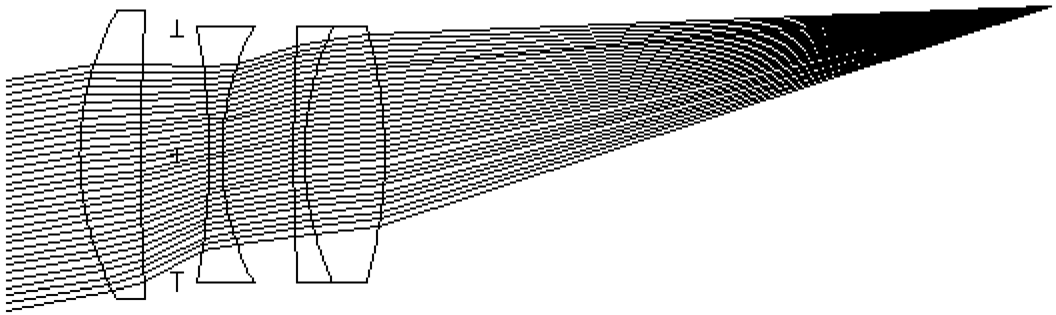


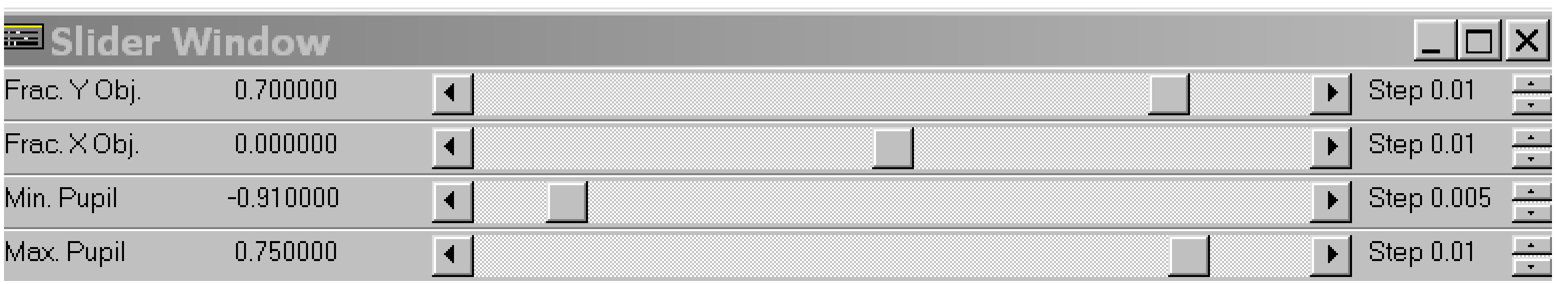
Wiązka promieni nie jest w pełni przetransmitowana przez układ – konieczna analiza winietowania

Frac Y obj	Frac X obj	Rays	Min Pupil	Max Pupil	offset	FY	FX	wvn	cfg
0.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
0.700000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
1.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0

Actual field of view

Analiza winietowania dla 0.7 pola widzenia



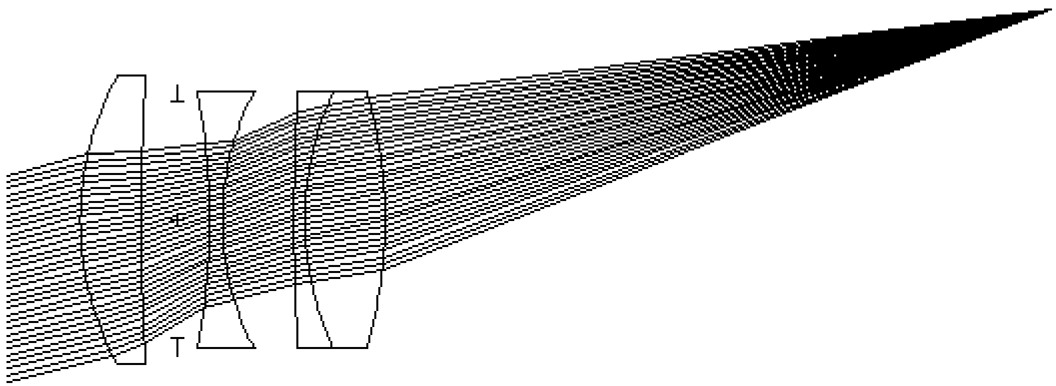


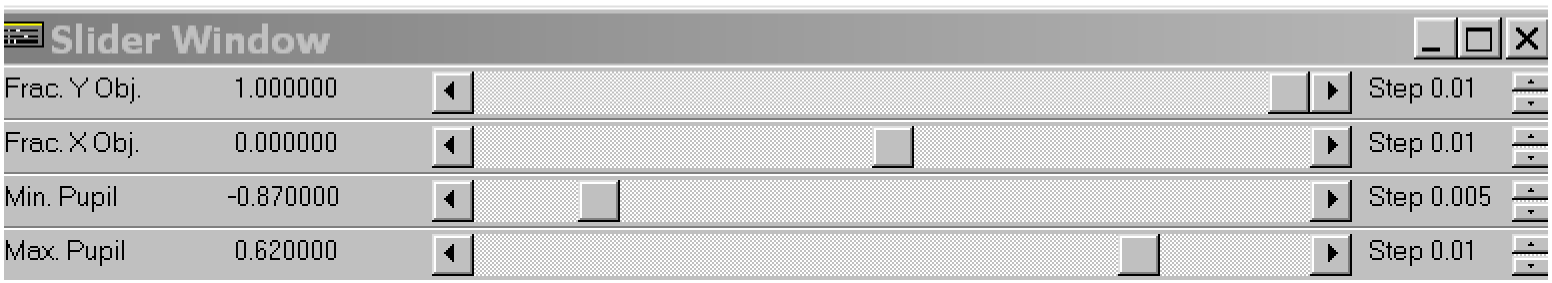
Przy użyciu slajderów pełna wiązka promieni jest transmitowana przez układ, weźmy również pod uwagę średnice montażowe
Możemy teraz ustawić parametry winietowania
Mamy do czynienia z winietowaniem nie symetrycznym

Frac Y Obj	Frac X Obj	Rays	Min Pupil	Max Pupil	Offset	FY	FX	Wvn	Cfg
0.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
0.700000	0.000000	3	-0.910000	0.750000	0.000000	◉	○	1	0
1.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0

Actual field of view

Analiza winietowania dla 1.0 pola widzenia





Mamy do czynienia z winietowaniem niesymetrycznym

Frac Y Obj	Frac X Obj	Rays	Min Pupil	Max Pupil	Offset	FY	FX	Wvn	Cfg
0.000000	0.000000	3	-1.000000	1.000000	0.000000	◉	○	1	0
0.700000	0.000000	3	-0.910000	0.750000	0.000000	◉	○	1	0
1.000000	0.000000	3	-0.870000	0.620000	0.000000	◉	○	1	0

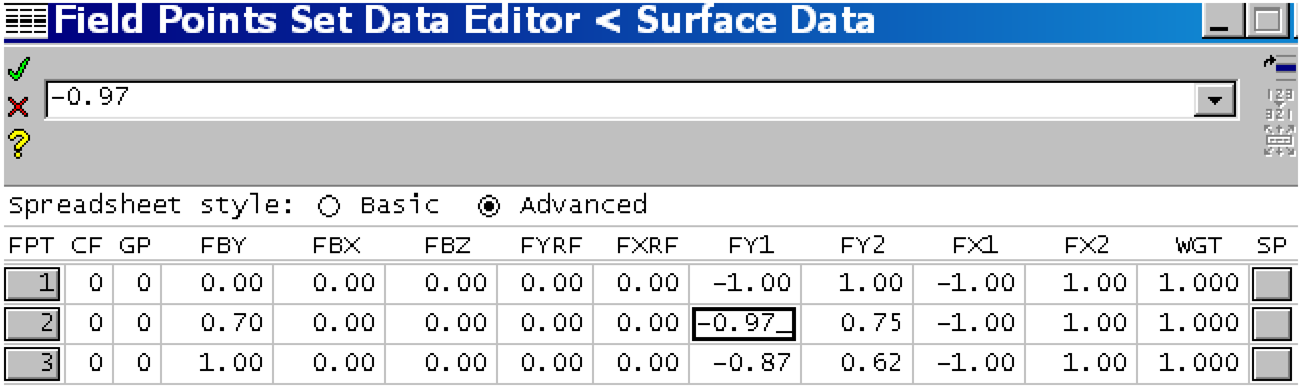
Actual field of view

Total vignitting coefficients for fields:

0.7 – 0.83

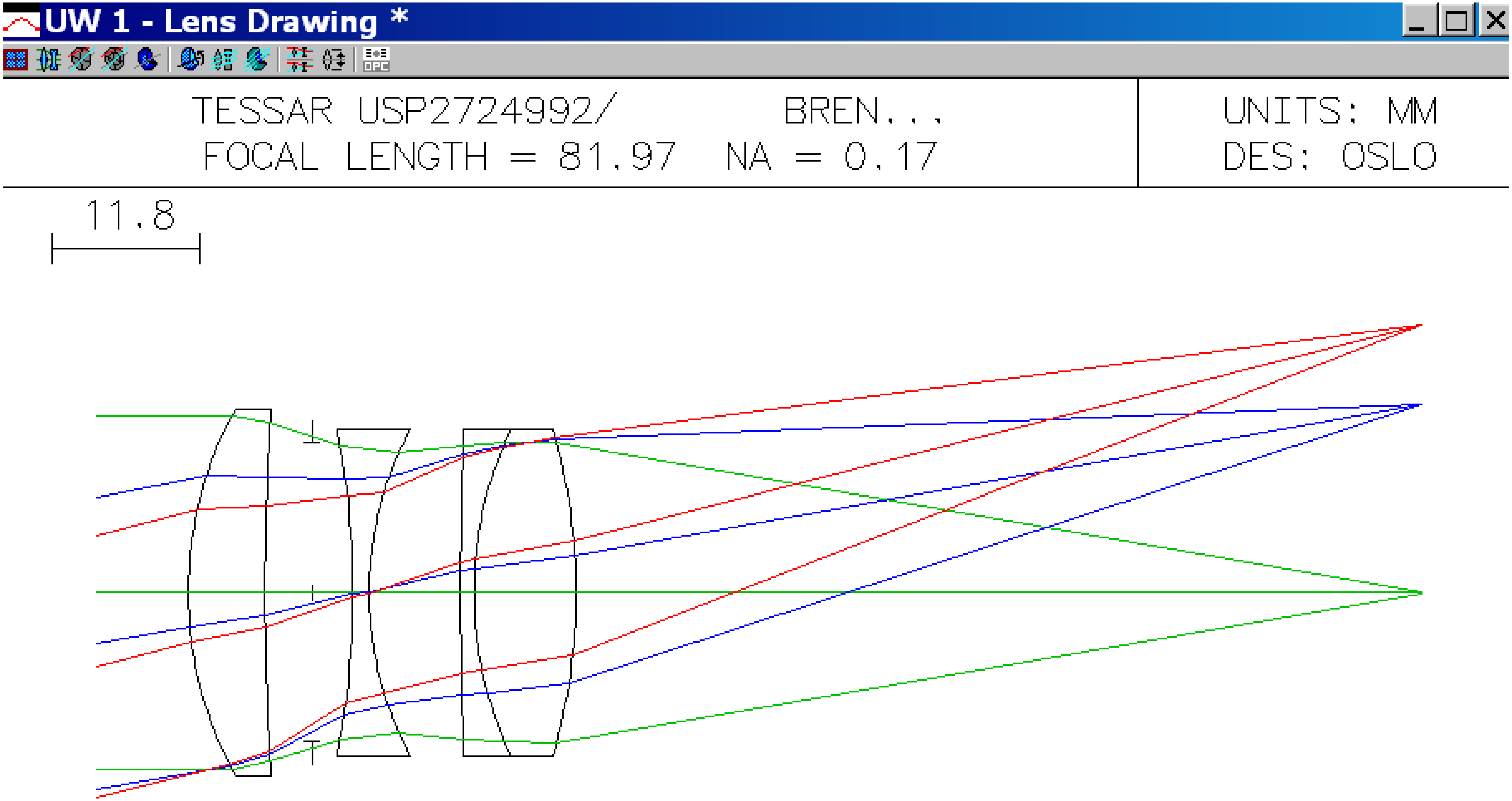
1.0 – 0.745

W celu użycia wyznaczonych współczynników przy analizie aberracyjnej musimy ustawić je w oknie ‘Surface Data - > Field Points Set Data Editor’



FPT	CF	GP	FBY	FBX	FBZ	FYRF	FXRF	FY1	FY2	FX1	FX2	WGT	SP
1	0	0	0.00	0.00	0.00	0.00	0.00	-1.00	1.00	-1.00	1.00	1.000	
2	0	0	0.70	0.00	0.00	0.00	0.00	-0.97_	0.75	-1.00	1.00	1.000	
3	0	0	1.00	0.00	0.00	0.00	0.00	-0.87	0.62	-1.00	1.00	1.000	

Efekt ustawienia winietowania



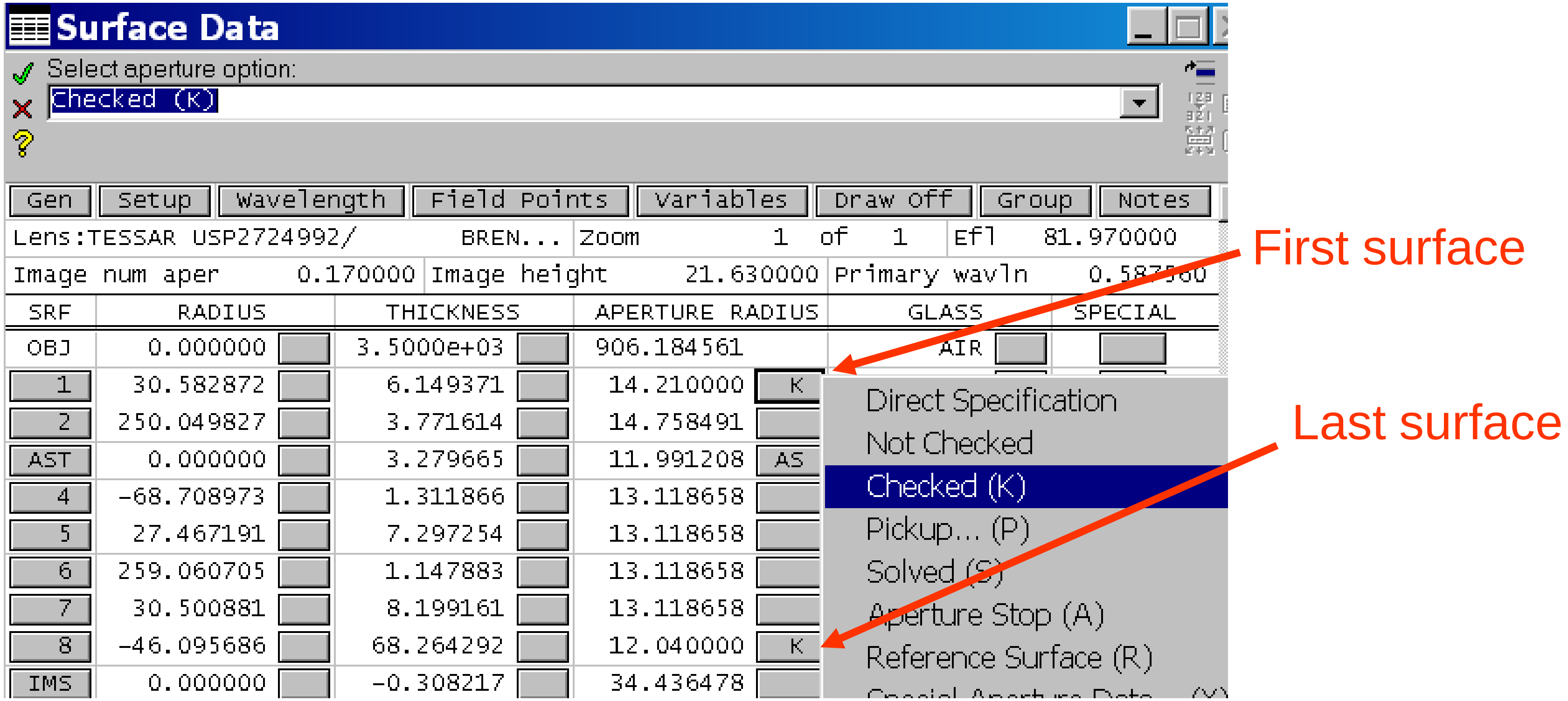
Automatyczne ustawienie winietowania

Funkcja ‘Vig’

Funkcja wyznacza współczynniki vinietowania i wyświetla wyniki. Domyślnie, wyiniki są przekopiowane do field points set i do Lens Drawing Conditions.

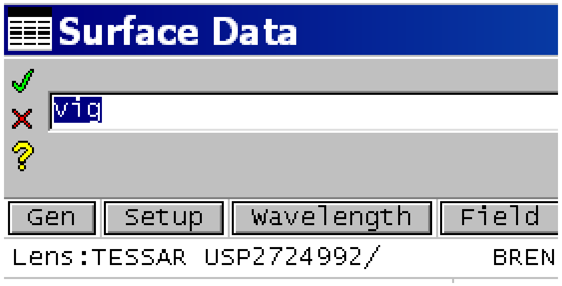
Uwaga: Checked apertures are taken into account

We will set ‘Checked’ setting to aperture radiuses: first and the last one

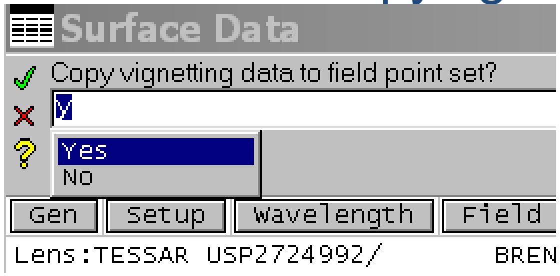


Runing ‘vig’ command

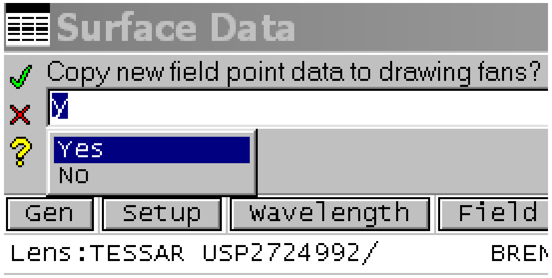
Step 1: write ‘vig’ and press



Step 2: press ‘Yes’ for copying results to ‘Field Points’ set and press



Step 3 : press ‘Yes’ for copying results to ‘Lens Drawing Conditions’ set and press



Step 4: Accept default value 5.0 for ‘ Enter maximum pupil position to test’

RUN COMMAND ‘vig’:

```
>> vig
<< Copy vignetting data to field point set?
>> y
<< Copy new field point data to drawing fans?
>> y
<< Enter maximium pupil postion to test?
>> 5.0
```

SETS PARAMETARS:

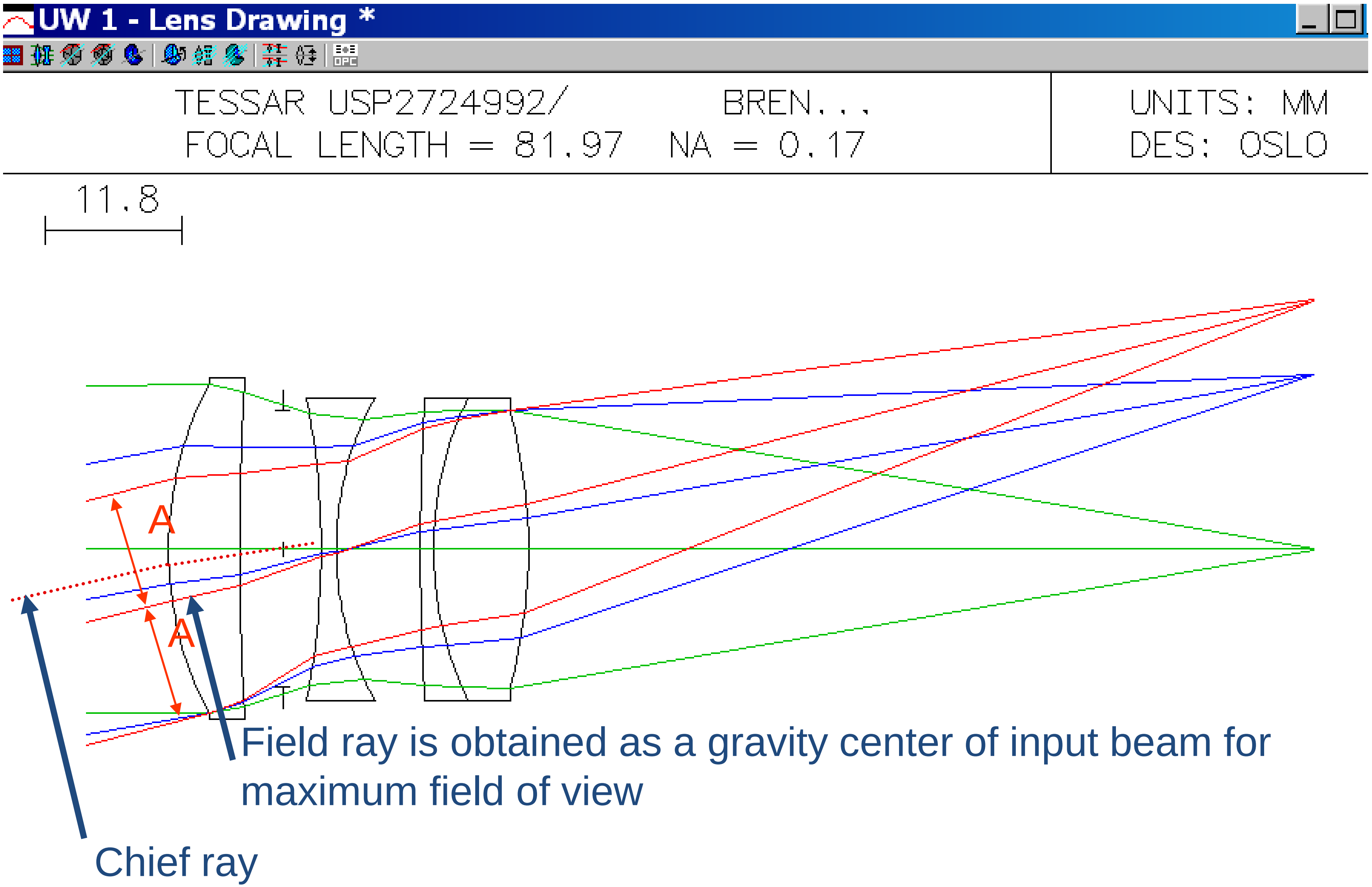
*VIGNETTING FACTORS

FPT	CFG	FBY	FBX	FY1	FY2	FXMAX
1	0	--	--	-0.999539	0.999539	0.999539
2	0	0.700000	--	-0.931181	0.724541	0.980700
3	0	1.000000	--	-0.901139	0.585673	0.961303

Results copied to 'Field Point Set'

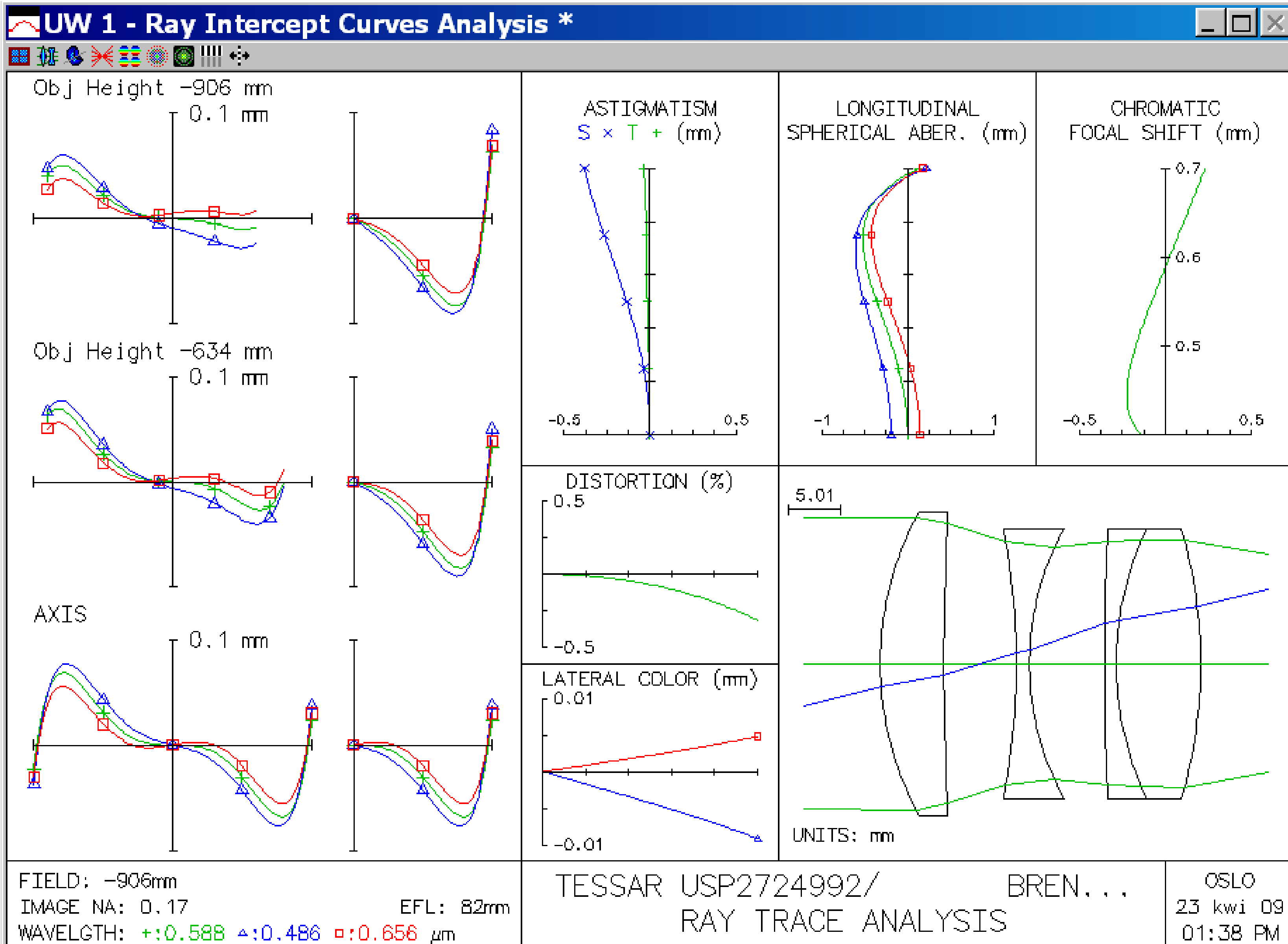
'Field Point Set' copied to 'Drawing Operating Conditions

Otrzymany układ

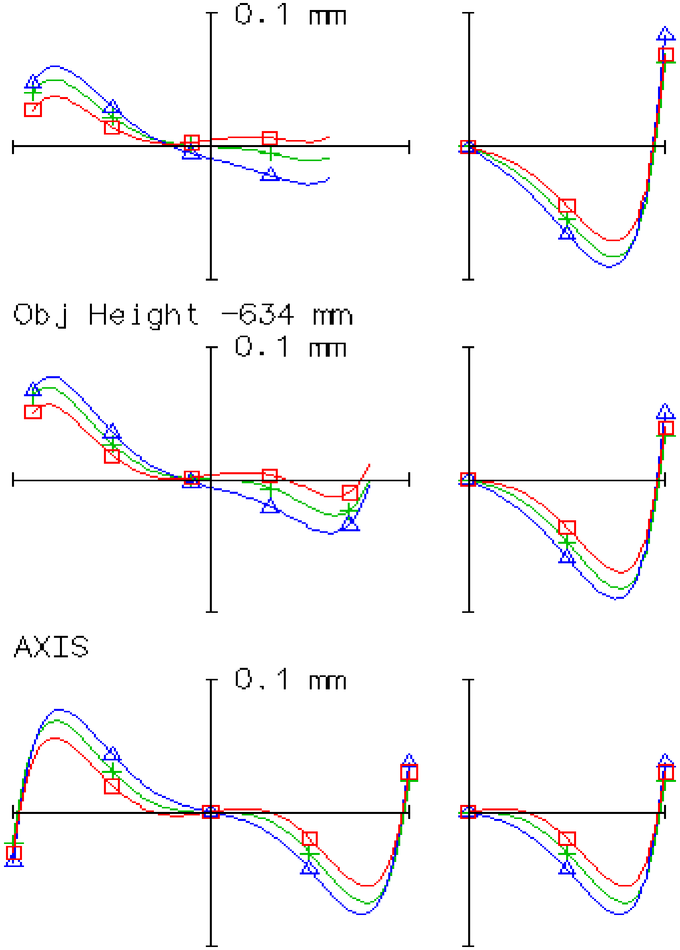


▪ Dyskusja aberracji

‘Standard Tools -> Ray Intercept curve Analysis’



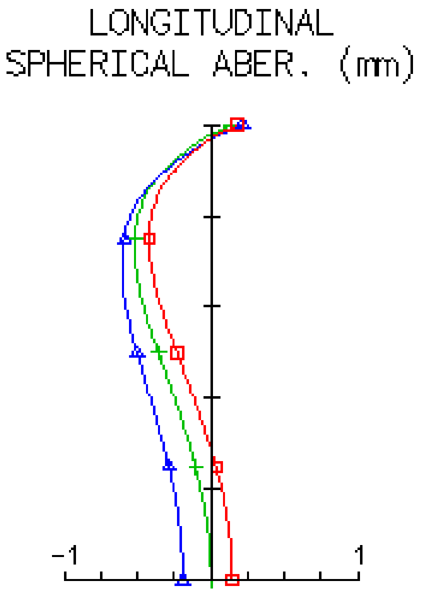
Poprzeczne (Lateral) aberracje



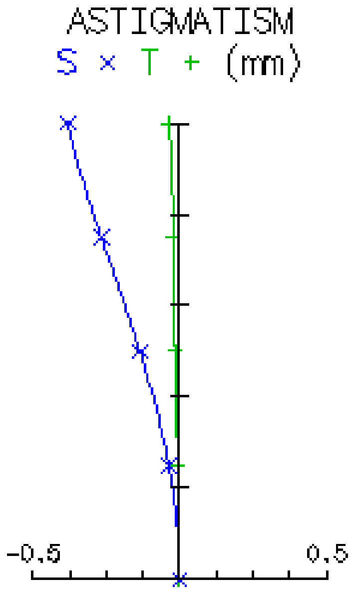
1 field : appears field curvature aberration (transverse aberration plot tilt), asymmetrical geometrical vignetting enlarges

0.7 field : appears field curvature aberration (transverse aberration plot tilt), asymmetrical geometrical vignetting

On axis: spherical aberrations
5-th order type
Lateral color (chromatic aberrations) present

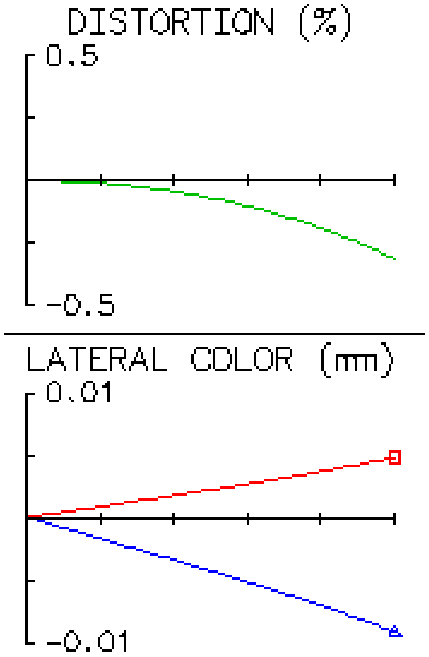


Longitudinal spherical aberrations (5-th order type)
Longitudinal color (defined for blue - F and red - C wavelengths)



Field aberrations:
Astigmatism and field curvature present and must be corrected, considerable Sagittal Field curvature

Field aberrations



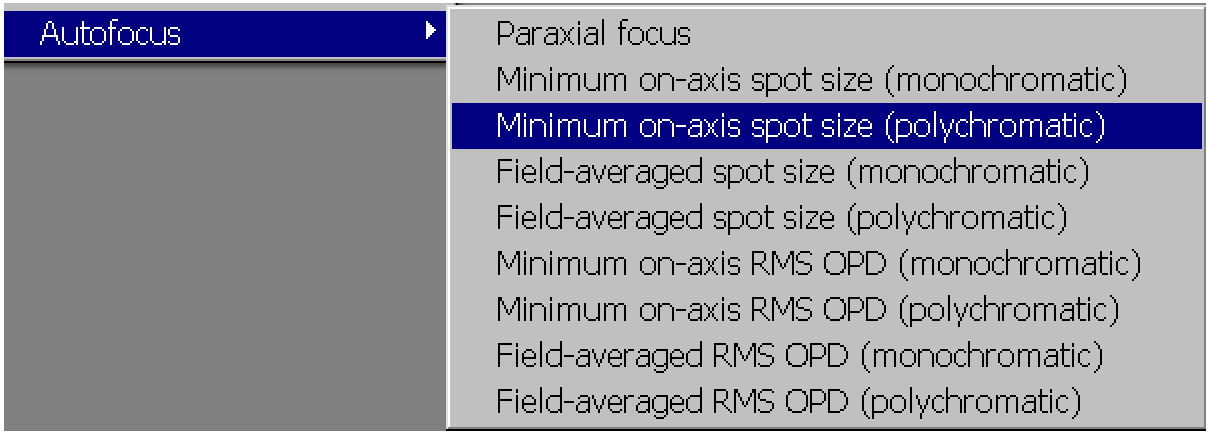
Distortion expressed in % from image size
~0.25 % for full field of view

Lateral color aberration ~ 0.015 mm for full field of view

➢Optymalne przeogniskowanie

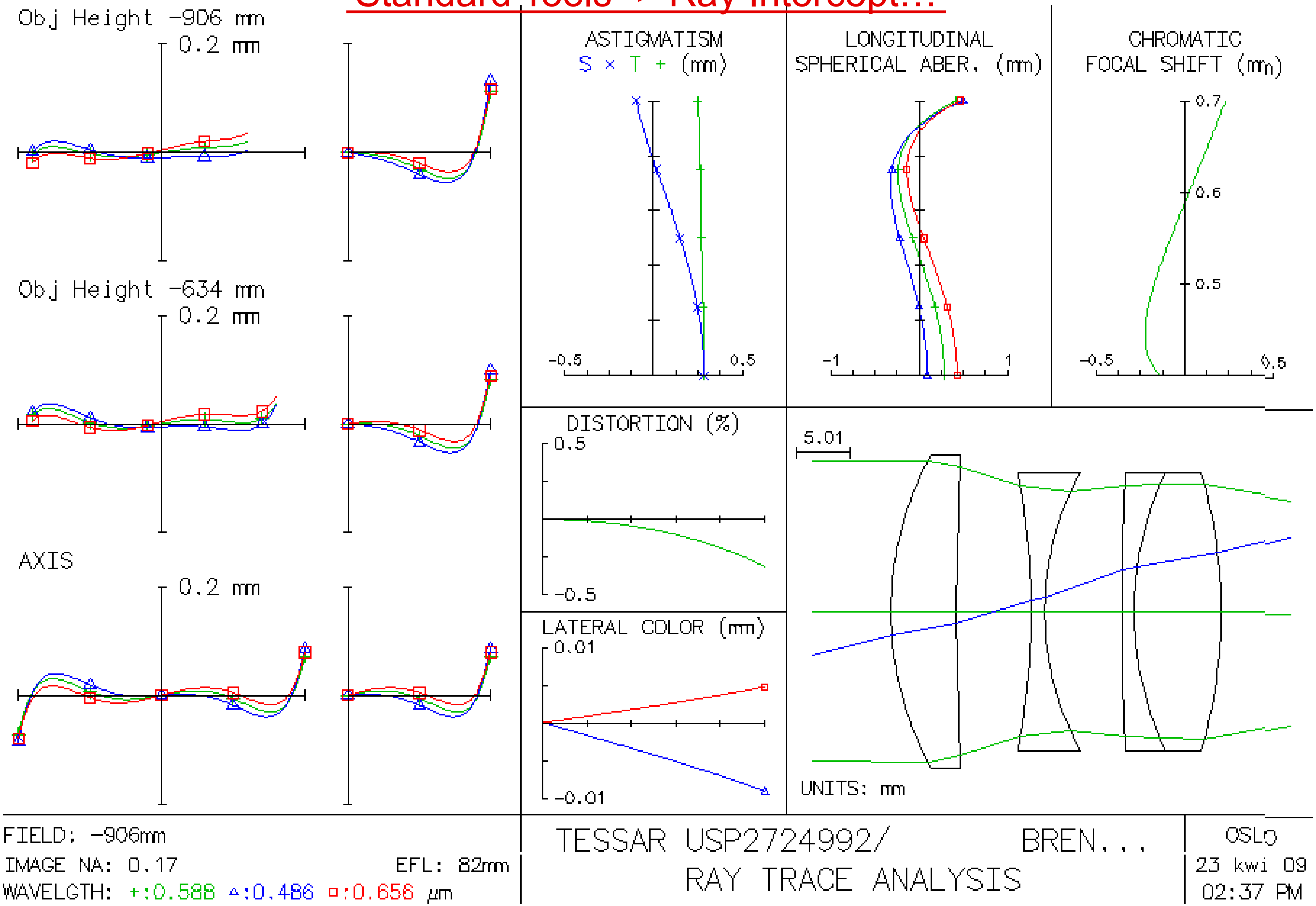
Ocena jakości powinna zostać wykonana dla płaszczyzny przeogniskowania

Użyj funkcję OSLO: <u>‘Evaluate -> Autofocus -> Minimum on-axis spot size (polychromatic) ‘</u>



Optymalne przeogniskowanie: -0.2844 mm

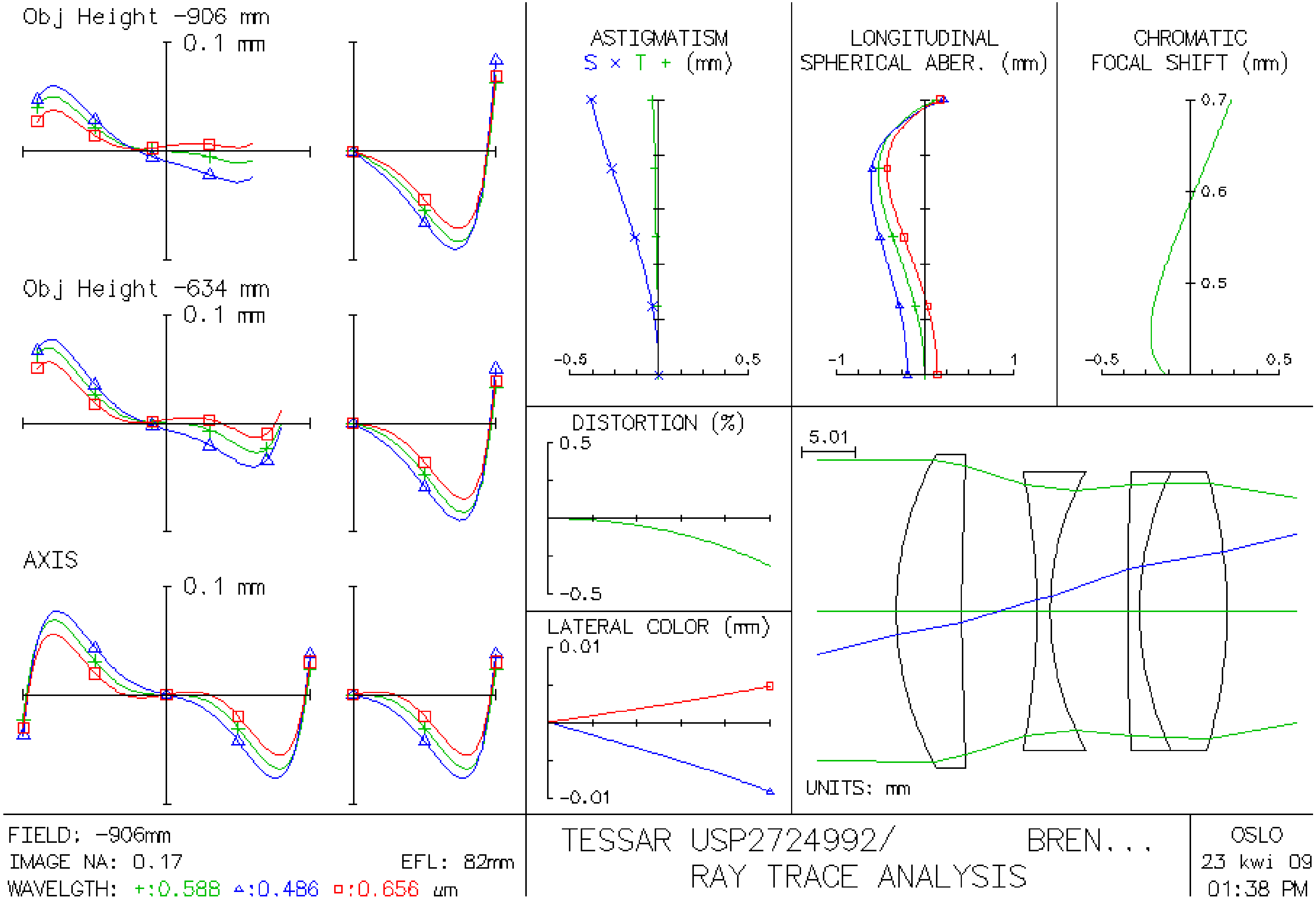
‘Standard Tools -> Ray Intercept…’



Aberrations at optimal defocusing plane

Compare aberrations with paraxial focus

‘Standard Tools -> Ray Intercept…’



Aberration at paraxial focus

▪Kryteria oceny jakości

Expected resolution:

Aberrational spot size (screen)
For visual observation from 3.5 m and human eye angular resolution 1’ of arc (0.0003 rad) aberrated spot can not exceed

$$3500 \cdot 0.0003 = 1.05 \text{ mm}$$

At image plane (film slide plane) aberration spot can not exceed

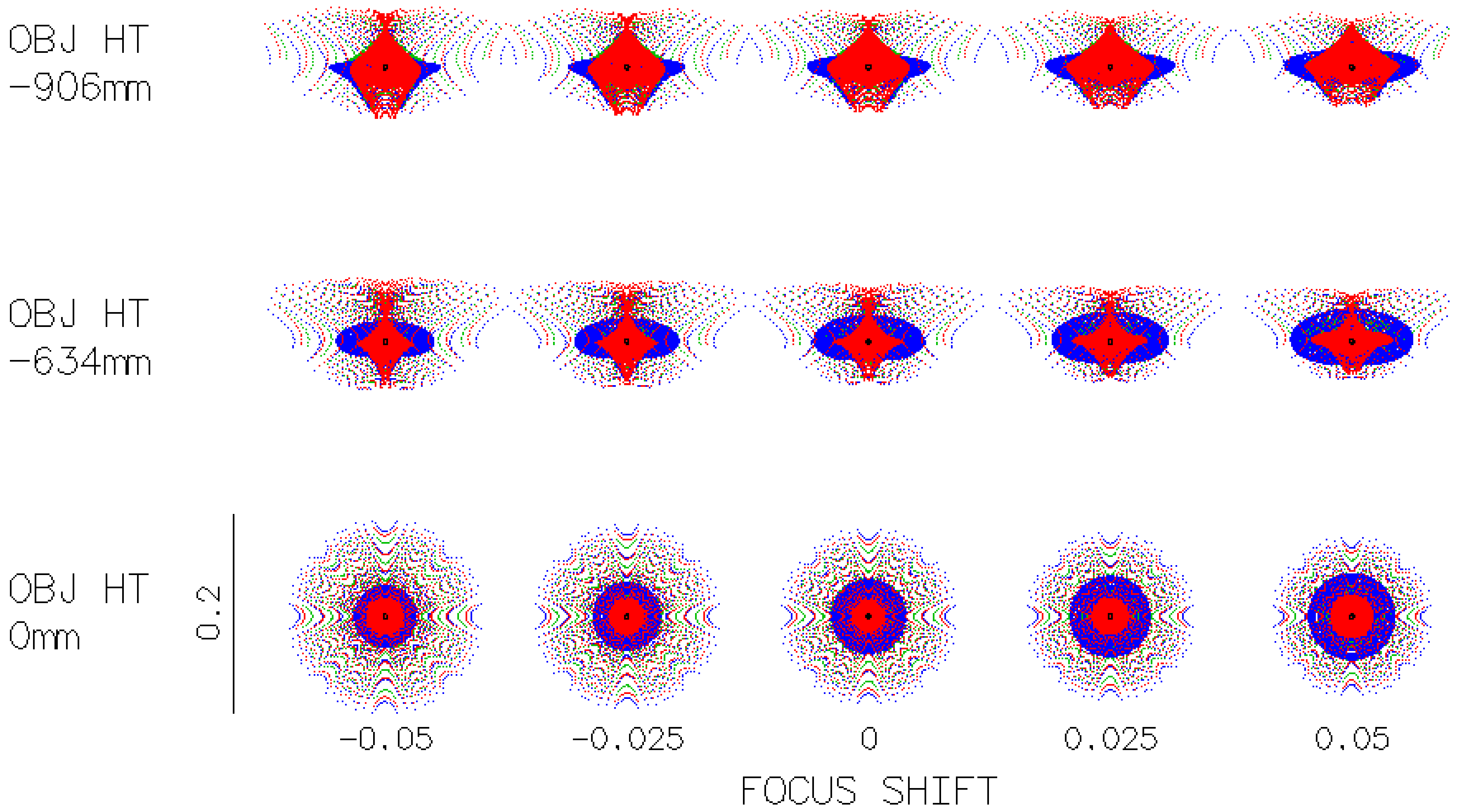
$$1.05 \cdot 0.02387 = \mathbf{0.024\ mm}$$

where 0.02387 is a transverse magnification

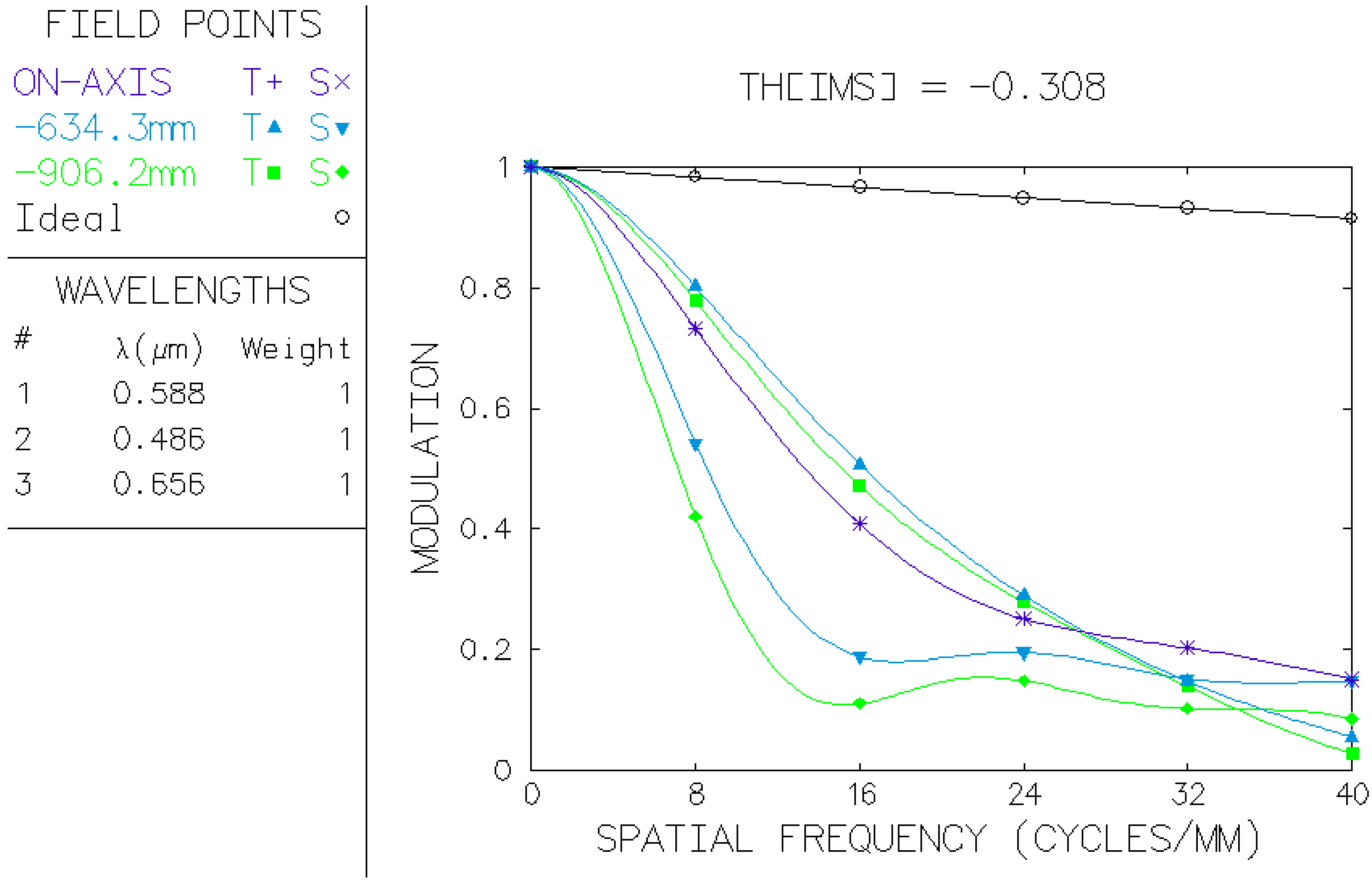
The spot size corresponds to (40 l/mm)

40 l/mm will be used as a criteria for design evaluation

▪ Spot Diagram and MTF evaluation



We get spot of effective size around 0.05 mm, it is to high and should be corrected. Spot size on screen is 2 mm what corresponds to angle aberration 2‘ of arc and can be acceptable especially that is fulfill in whole field of view.



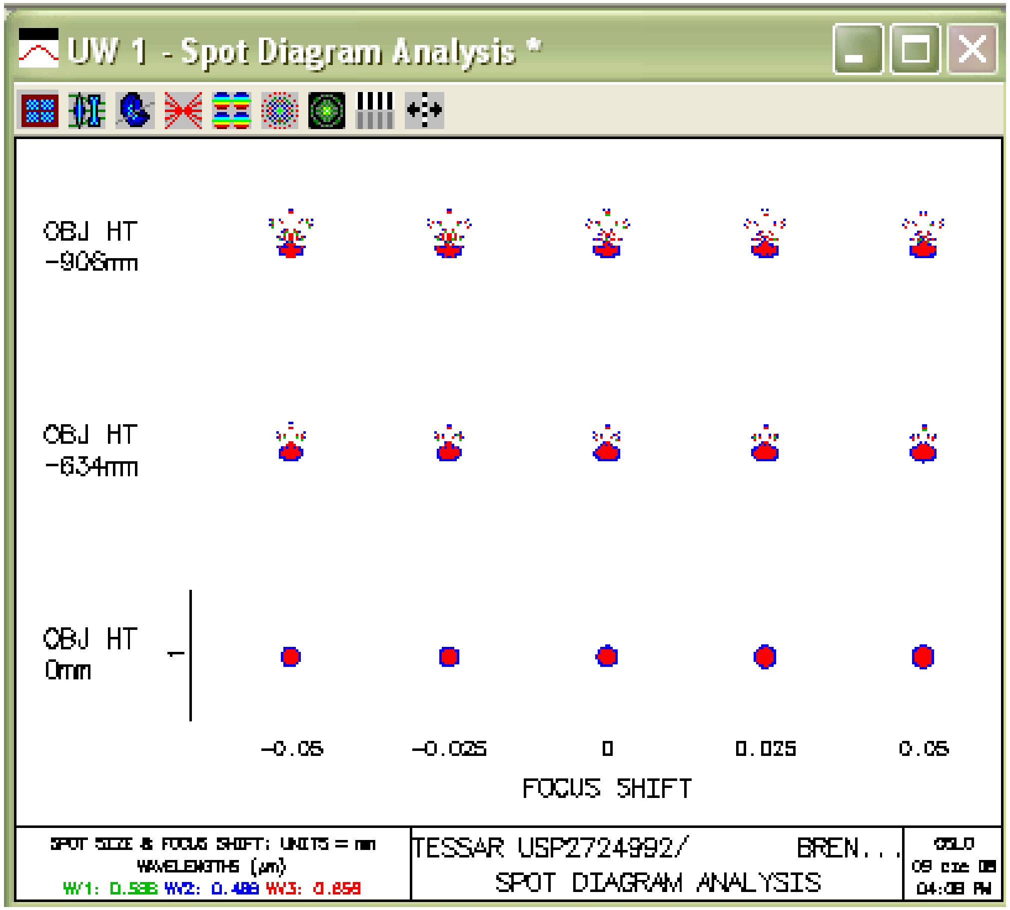
The MTF plot shows that the lens do not transmit the frequencies above 20 l/mm with acceptable contrast (must be corrected)

‘Standard Tools -> Spot Diagram Analysis’

Expected resolution:

Aberrational spot size (screen)
3500·0.0003=1.05 mm

Aberrational spot size (slide)
1.05·0.02387=0.024 (40 l/mm)



Expected resolution:

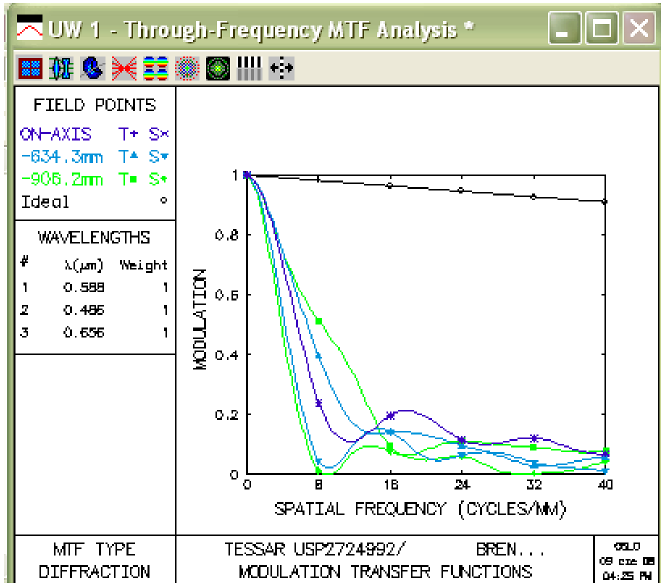
Aberrational spot size (screen)

3500·0.0003=1.05 mm

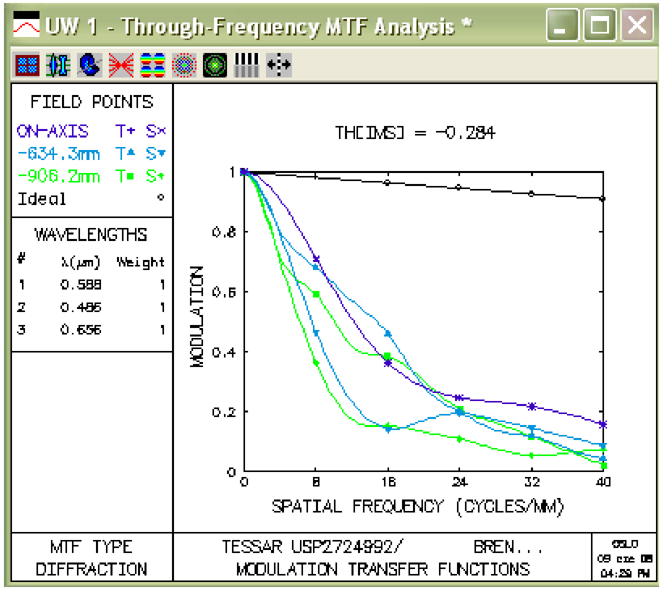
Aberrational spot size (slide)

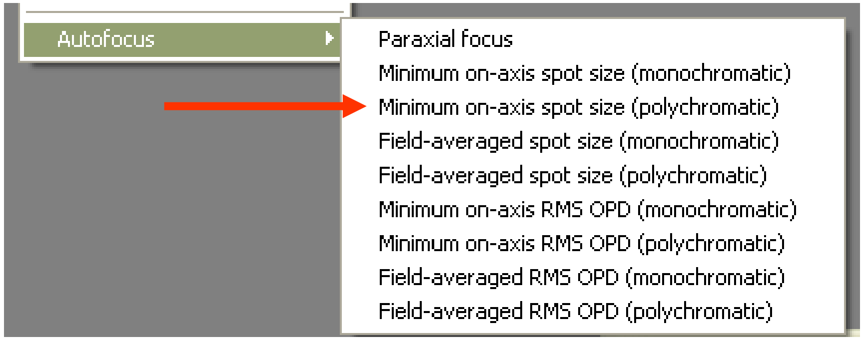
1.05·0.02387=0.024 (40 l/mm)

MTF before defocusing

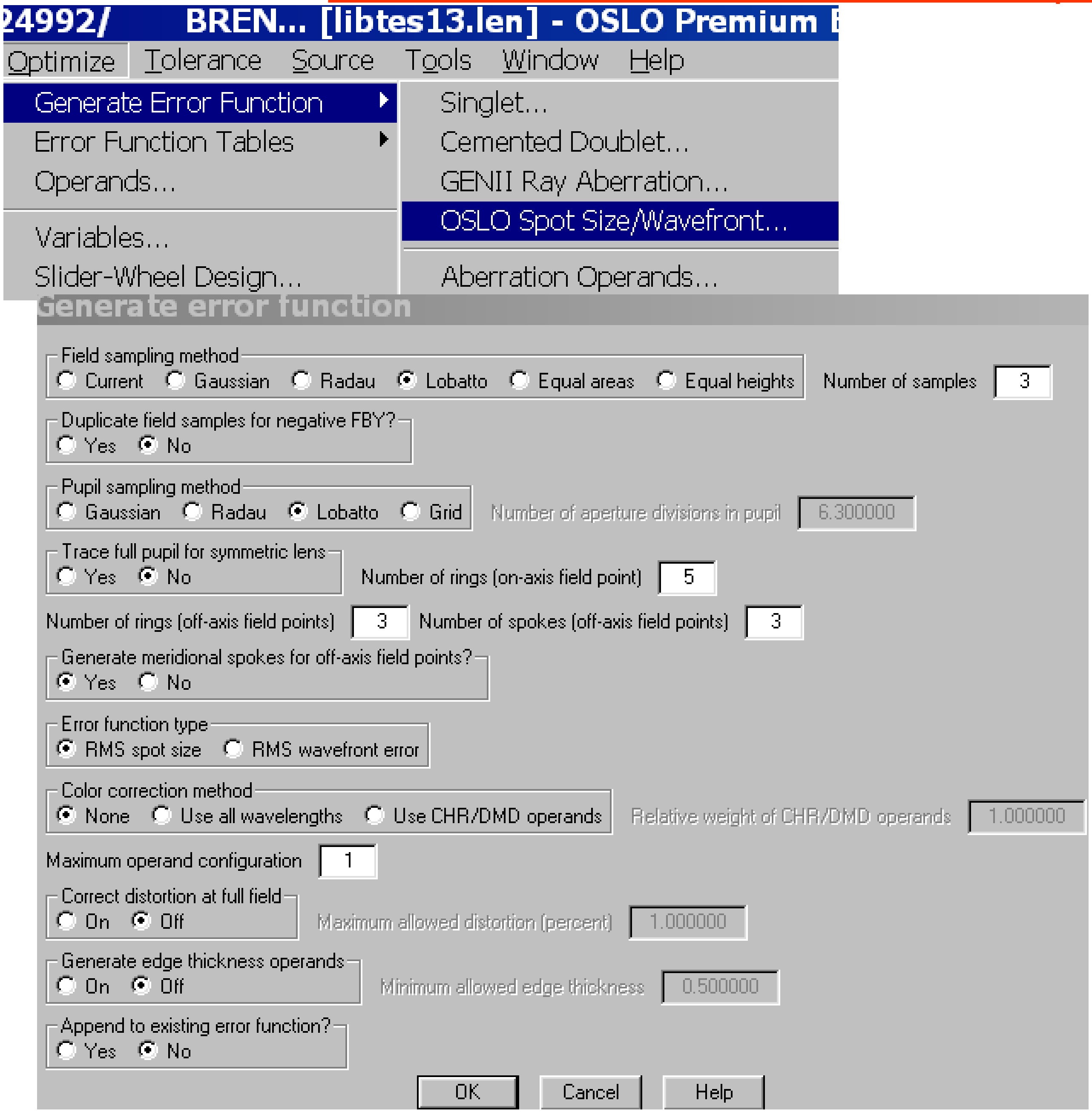


MTF after defocusing





Optimization using ‘Generate Error Function -> OSLO Spot Size/Wavefront’



Optimization using

Surface Data

Gen | Setup | Wavelength | Field Points | Variables | Draw Off | Group | Notes

Lens:TESSAR USP2724992/ BREN... Zoom 1 of 1 Efl 81.970000

Image num aper 0.170000 Image height 21.630000 Primary wavln 0.587560

SRF	RADIUS		THICKNESS		APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000		3.5000e+03		906.184561		AIR		
1	0.000000	V	0.000000		16.600000		AIR		
2	30.582872	V	6.149371		15.500000	K	LAK9	C	
3	250.049827	V	3.771614		14.600000		AIR		
AST	0.000000		3.279665		12.600000	AK	AIR		
5	-68.708973	V	1.311866		12.300000		SF16	C	
6	27.467191	V	7.297254		12.500000	K	AIR		
7	259.060705	V	1.147883		16.600000		BASF5	C	
8	30.500881	V	8.199161		16.600000		LAF3	C	
9	-46.095686	V	68.264292		16.600000		AIR		
IMS	0.000000		-0.284499	V	21.611386	S			

We add

EFL requirement

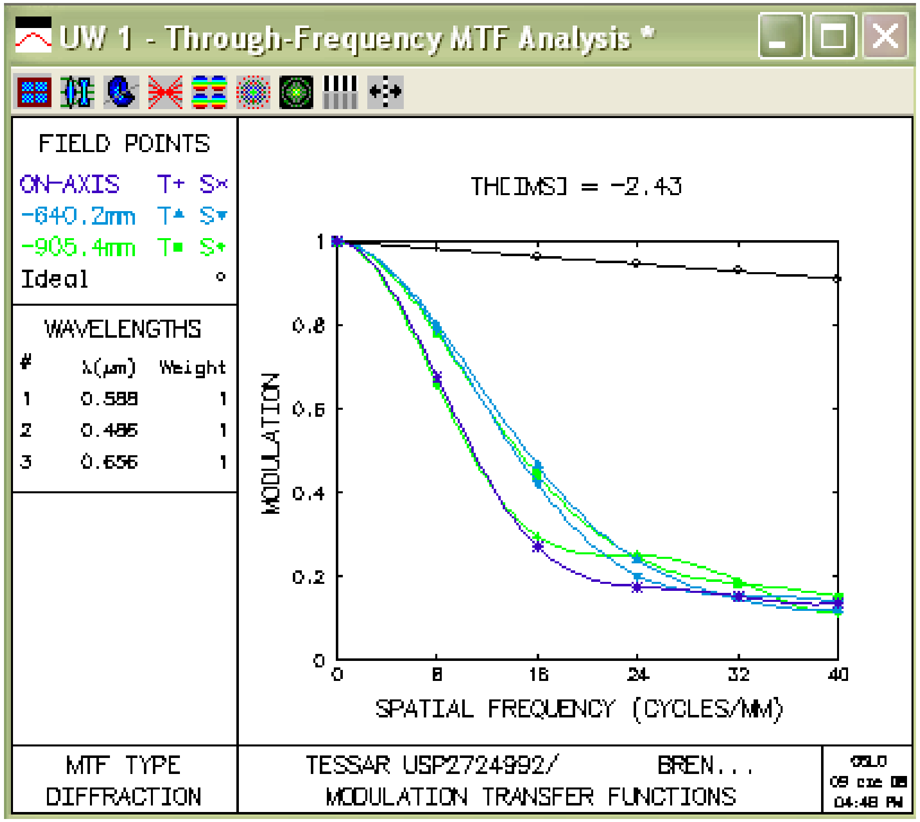
64	Min	0.001736	_DY64	Y(3,16)-054
65	Min	0.003472	_DY65	Y(3,17)-054
66	Min	0.003472	_DY66	Y(3,18)-054
67	Min	0.001736	_DY67	Y(3,19)-054
68	Min	0.000000	Yrms3	RMS
69	Min	1.000000	efl	EFL-82.0

Obtained MTF

Expected resolution:

Aberrational spot size (screen)
3500·0.0003=1.05 mm

Aberrational spot size (slide)
1.05·0.02387=0.024 (40 l/mm)

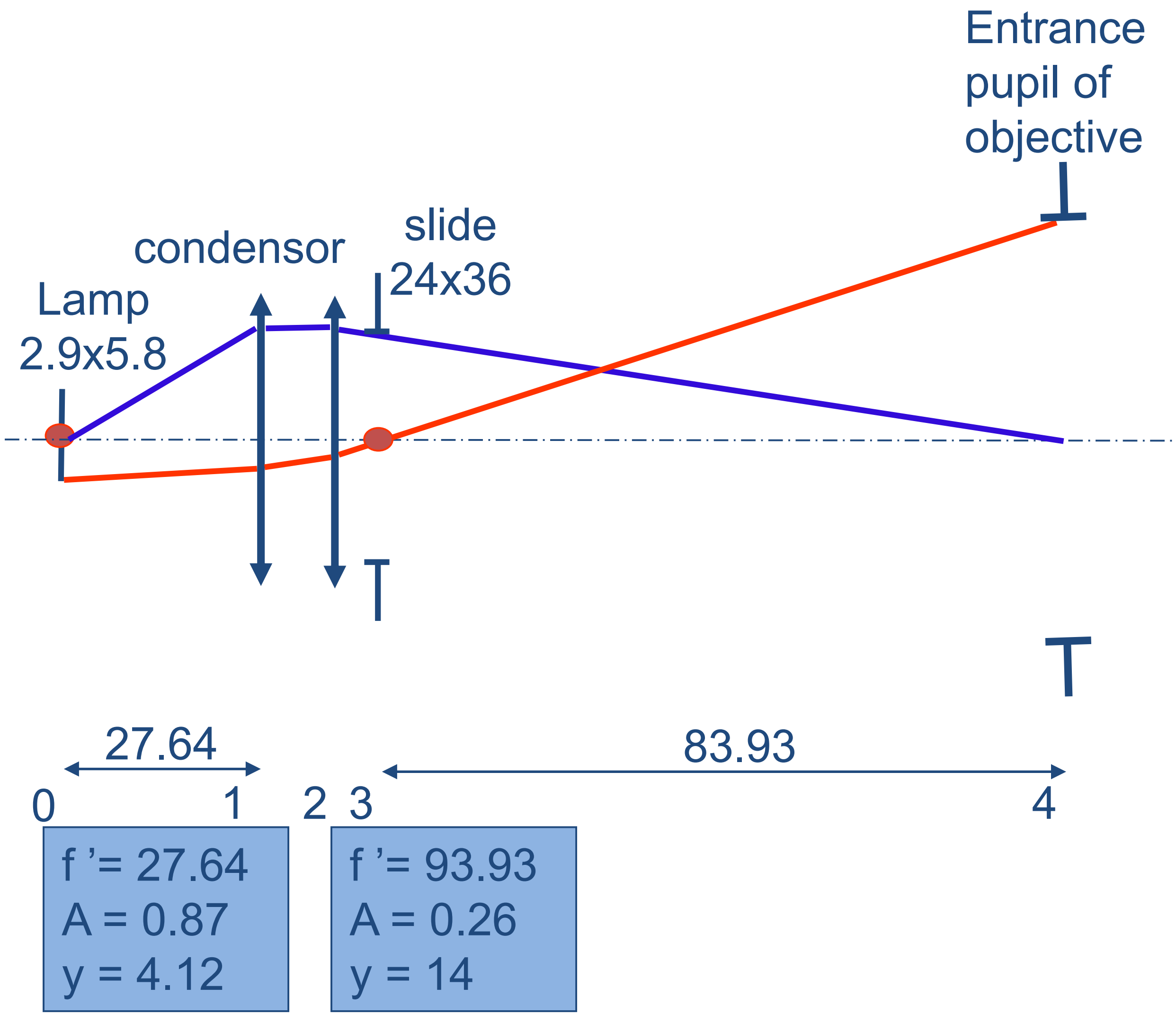


Projekt kondensora

❑ Design of a condensor lens

- Choosing thin element starting design
- Inserting and specifying Aspheric lens in OSLO
- Evaluation of chosen Aspheric lens
- Adding 2-nd lens to the condenser design
- Setting of working conditions of a starting design
- Vignieting analysis
- Evaluation of the condenser design

➢ Choosing starting design



First element requires at least 3 spherical lenses or one aspheric one (due to the working conditions, especially high numerical aperture)

▪ Inserting and specifying Aspheric lens in OSLO

From ThorLabs catalog we find aspheric lans No. AL 4532 f=32, NA = 0.612

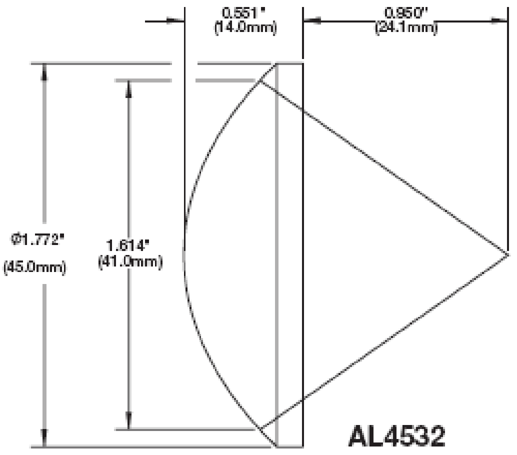
Large-Diameter Aspheric Lenses – Page 4 of 5

AL4532 f = 32.0mm and 0.612 NA

Specifications

- **Effective Focal Length:** 32.0mm
- **Numerical Aperture:** 0.612
- **Diameter:** 45.0mm
- **Scratch-Dig:** 60-40
- **Design Wavelength:** 780nm
- **Clear Aperture (Collimation):** 41.00mm
- **Clear Aperture (Focusing):** 37.30mm
- **Aspheric Lens Material:** S-LAH64
- **Refractive Index (@ Design λ):** 1.788
- **Abbe #:** V_d=47.3

NEW



Edge Thickness: 3.12mm
Working Distance: 24.12mm

Aspheric Coefficients

	R	k	A_2	A_4	A_6	A_8	A_{10}
AL4532	23.88	-1.678413	-8.294534E-4	9.229323E-06	-3.656184E-09	1.102823E-12	-6.146323E-16

The closest matching lens from catalog

Aspheric Lens Equation

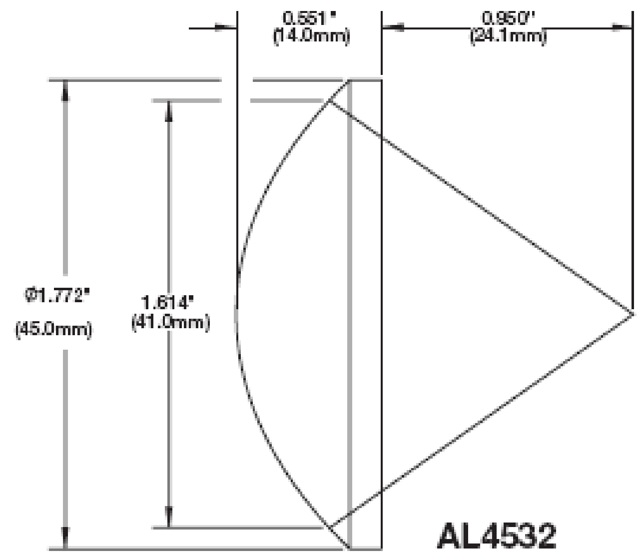
Lens Design Formula

- Positive radius indicates the center of curvature is to the right
- Negative radius indicates the center of curvature is to the left

$$z = \frac{Y^2}{R\left(1 + \sqrt{1 - (1+k)\,Y^2 / R^2}\right)} + A_2 Y^2 + A_4 Y^4 + A_6 Y^6 + A_8 Y^8 + A_{10} Y^{10} + A_{12} Y^{12}$$

Variable Definitions

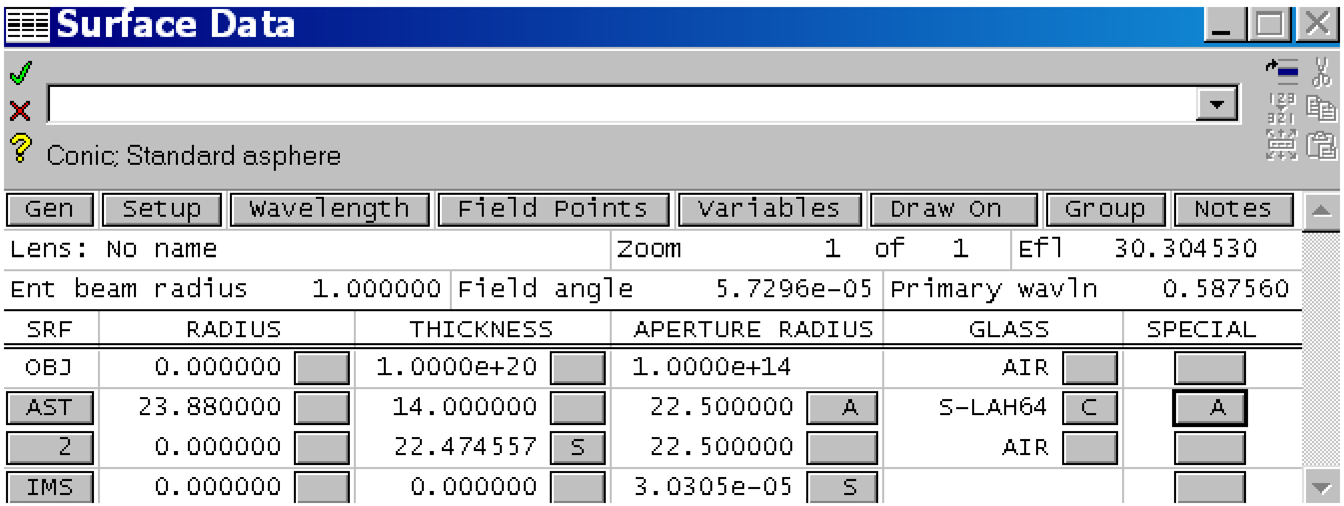
z	SAG as a function of Y
R	Radius of curvature
k	Conic constant
A_2	2^{nd} order aspheric coefficient
A_4	4^{th} order aspheric coefficient
A_6	6^{th} order aspheric coefficient
A_8	8^{th} order aspheric coefficient
A_{10}	10^{th} order aspheric coefficient
A_{12}	12^{th} order aspheric coefficient



AL4532

Open New Lens with 2 surfaces

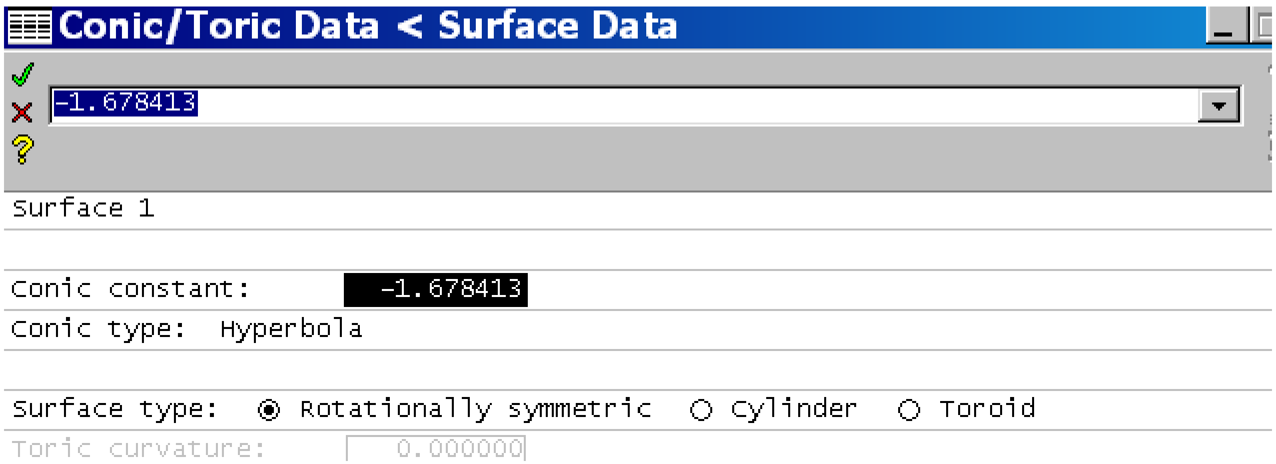
Insert lens parameters: surface radius, thickness, clear radius and glass type (from OHARA catalog S-LAH64)



Difference between catalog and obtained EFL is due to use different wavelengths, we use 0.587 um instead 0.78 um

Specify conic constant

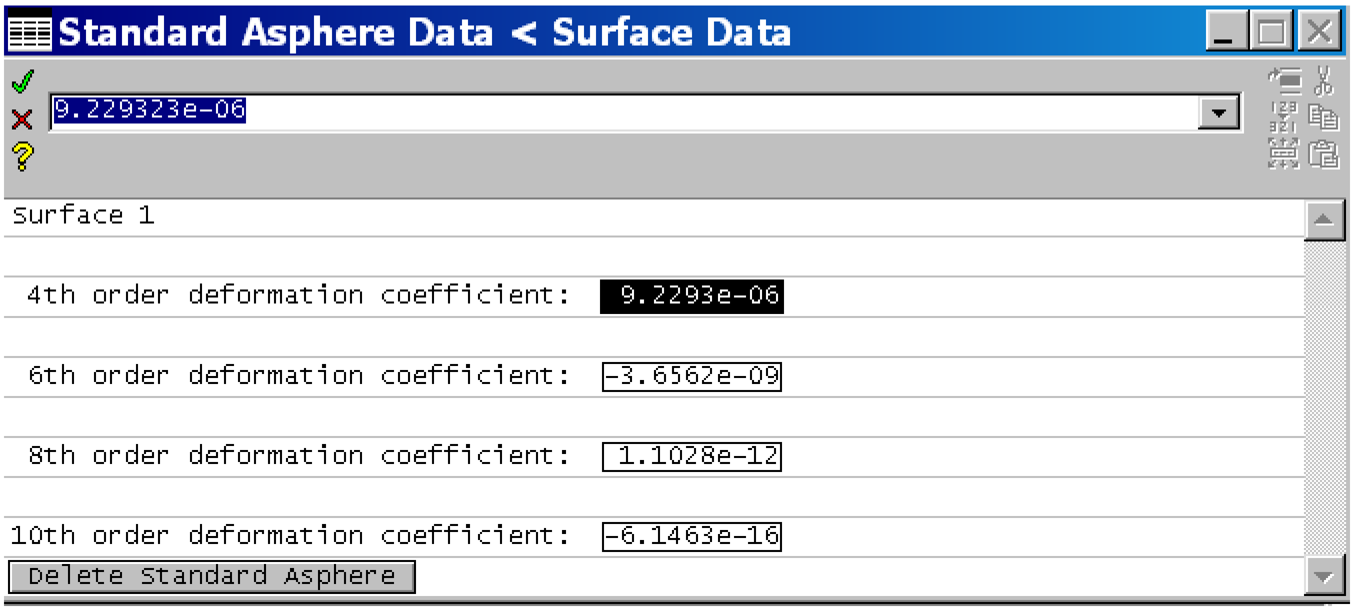
At surface of radius 23.88 and column ‘SPECIAL’ press right button, chose ‘Polynomial Asphere (A) -> Conic / Toric ‘



Aspheric Coefficients

	R	k	A_2	A_4	A_6	A_8	A_{10}
AL4532	23.88	-1.678413	-8.294534E-4	9.229323E-06	-3.656184E-09	1.102823E-12	-6.146323E-16

Specify Aspheric coefficients
At surface of radius 23.88 and column ‘SPECIAL’ press right button, chose ‘Polynomial Asphere (A) -> Standard Asphere‘



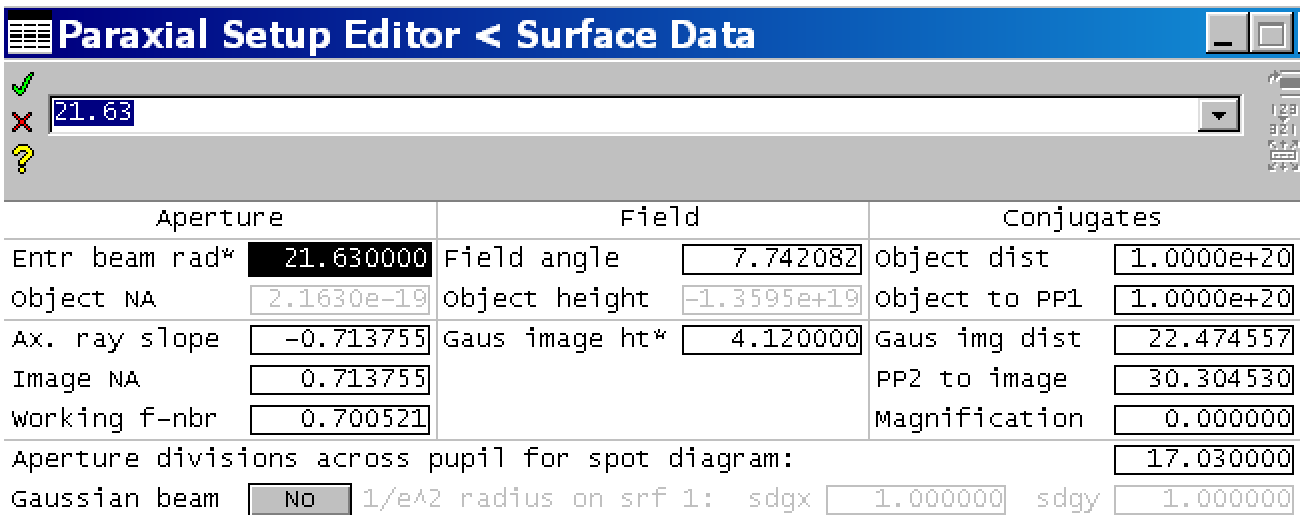
Aspheric Coefficients

	R	k	A_2	A_4	A_6	A_8	A_{10}
AL4532	23.88	-1.678413	-8.294534E-4	9.229323E-06	-3.656184E-09	1.102823E-12	-6.146323E-16

➢ Evaluation of chosen Aspheric lens

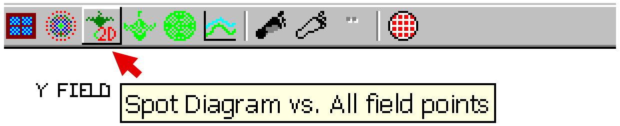
Setting lens working conditions for infinite conjugation

In window ‘Surface Data->Paraxial Setup Editor’ we set entrance beam radius 21.63, gauss image height 4.12 and magnification 0 (object at infinity)

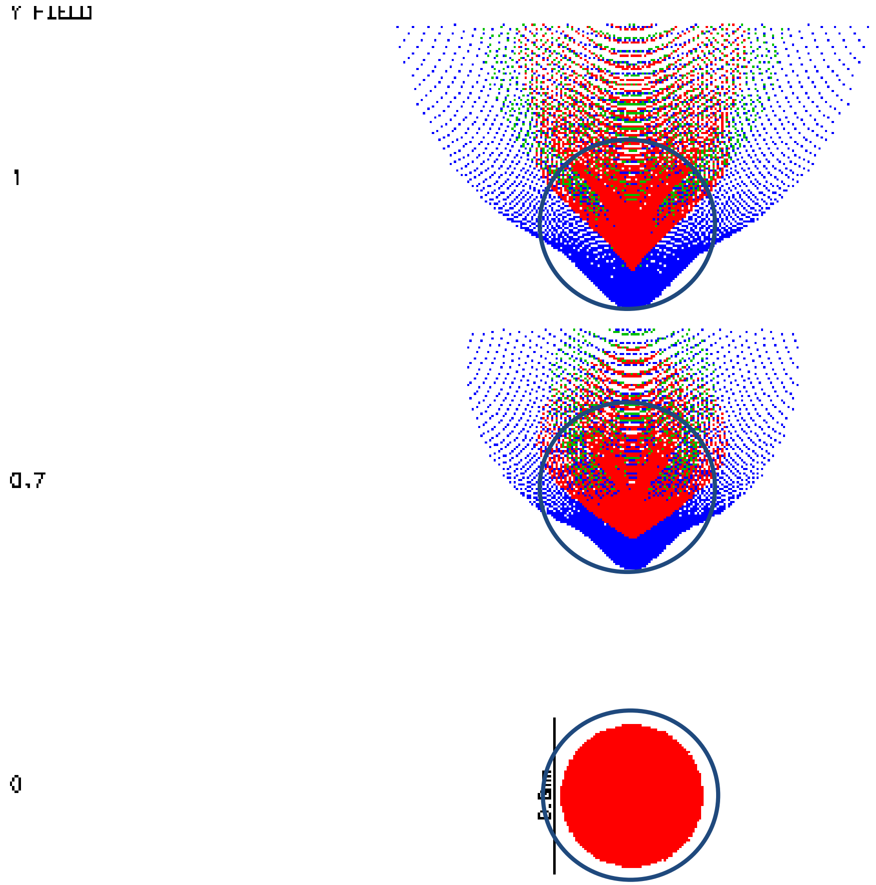


For condenser lens usually we apply criterion :
spot diagram size can not exceed 3 to 10 % of image size, for our case an image (lamp diagonal) is 8,24 mm, the spot size is to be smaller then 0.8 mm

Open ‘Spot Diagram’ Window toolbar, and run ‘Spot Diagram vs. All field points’



Recalculate window to ‘scale’ 0.8

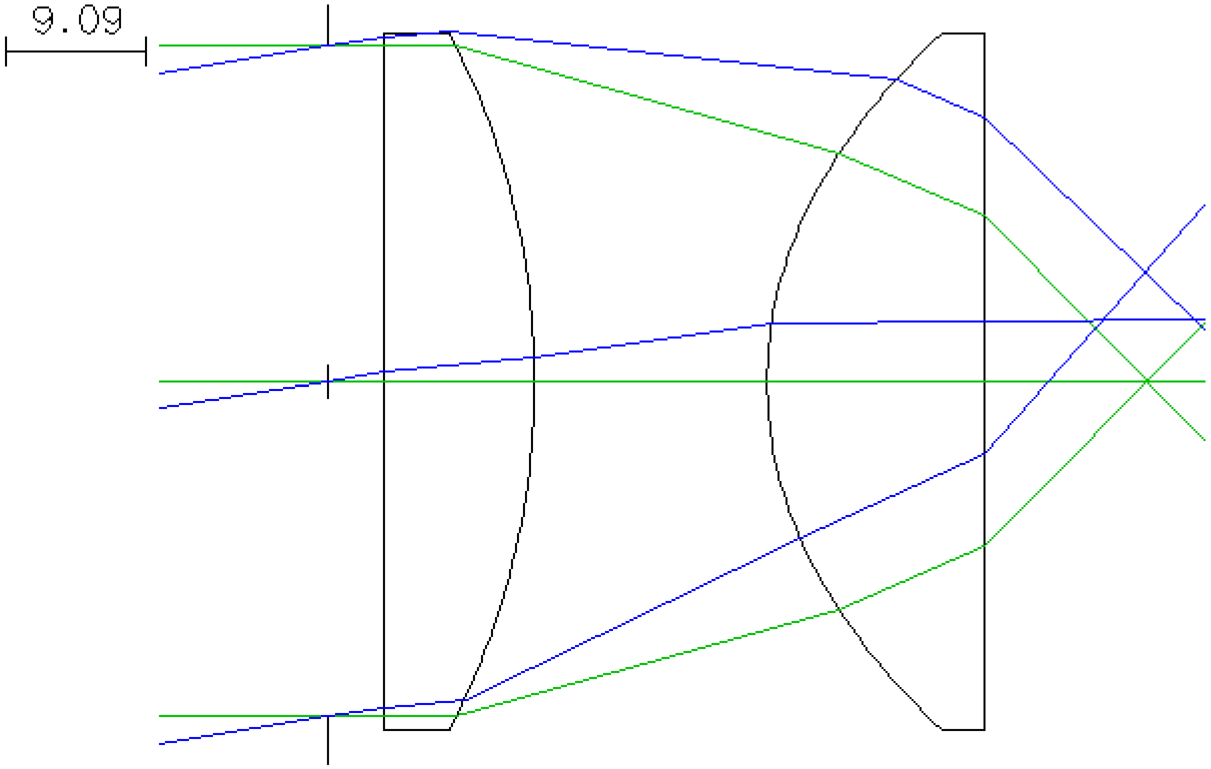


Conclusion:

Obtained spot diagram size on-axis satisfy our criterion, off-axis most of the energy is contained within required circle

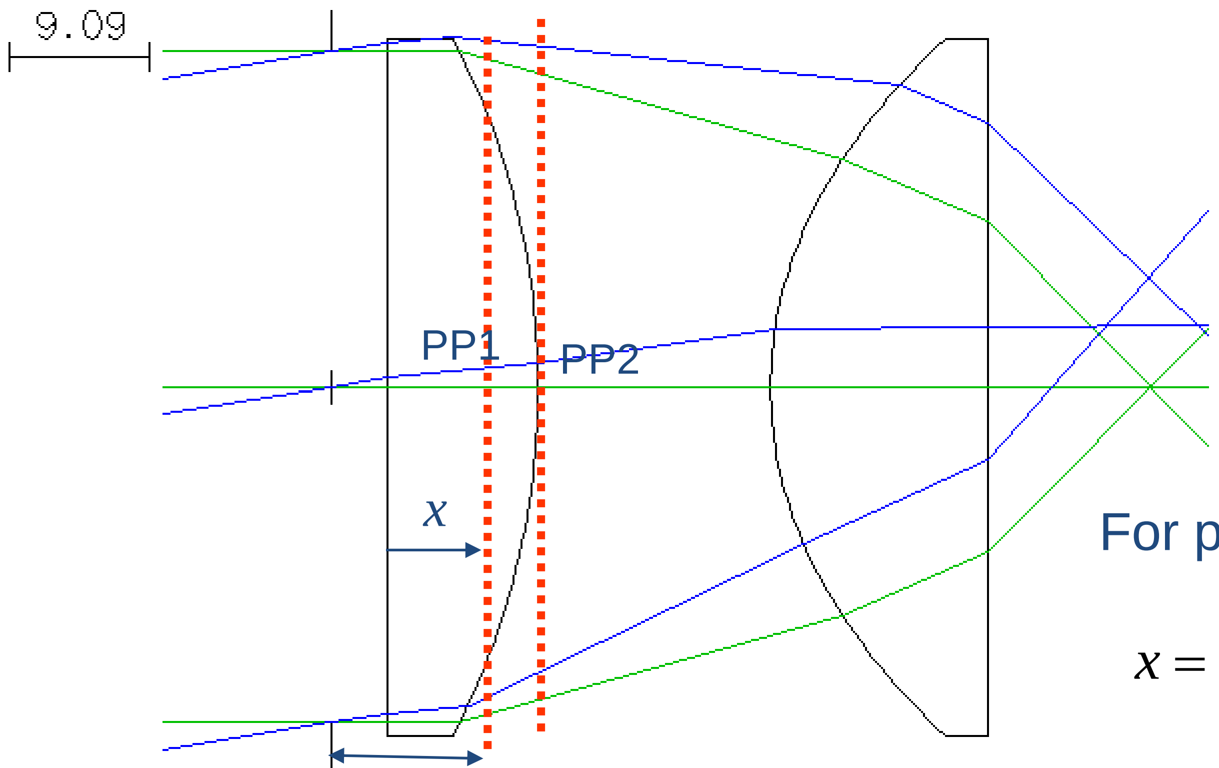
▪ Adding 2-nd lens to the condenser design

Insert catalog lens from Melles-Griot OSLO catalog, part number MG01LPX167 (EFL 95.3), then using right bottom menu command '<u>Reverse</u>' obtain following



The lenses must be directed with convexities (typical condenser setup for small magnification) according to aberration correction

Add new surface specifying position of aperture stop (slide position)



10 mm to first PP1 of the lens 1

For plane convex lens

$$x = \frac{\text{lens thickness}}{\text{refractive index}}$$

Obtained data

Surface Data

15.0

Gen | Setup | Wavelength | Field Points | Variables | Draw On | Group | Notes

Lens: No name	Zoom 1 of 1	Efl	26.113292
Ent beam radius 21.630000	Image height 4.120000	Primary wavln	0.587560

SRF	RADIUS		THICKNESS		APERTURE RADIUS		GLASS		SPECIAL
OBJ	0.000000		1.0000e+20		1.5777e+19		AIR		
AST	0.000000		3.600000		21.630000	AS	AIR		
2	0.000000		9.700000		20.179357		BK7	C	
3	-49.279000		0.000000		22.500000		AIR		
4	0.000000		15.000000		22.500000		AIR		
5	23.880000		14.000000		22.500000		S-LAH64	C	A
6	0.000000		14.175478	S	22.500000		AIR		
IMS	0.000000		0.000000		4.120000	S			

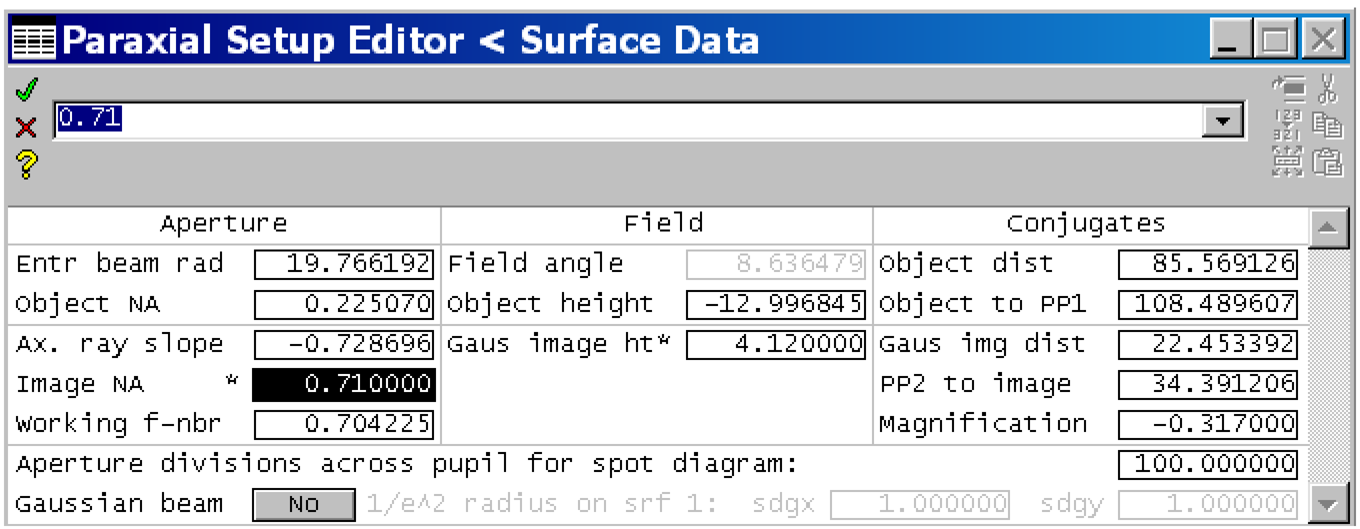
▪ Setting of working conditions of a starting design

We set: numerical aperture and magnification
- numerical aperture is obtained from specification of aspheric lens:

NA = 0.71

- magnification is a ratio of condenser afocal system

$$\text{Magnification} = \frac{f_1}{f_2} = \frac{30.3}{95.3} = -0.318$$



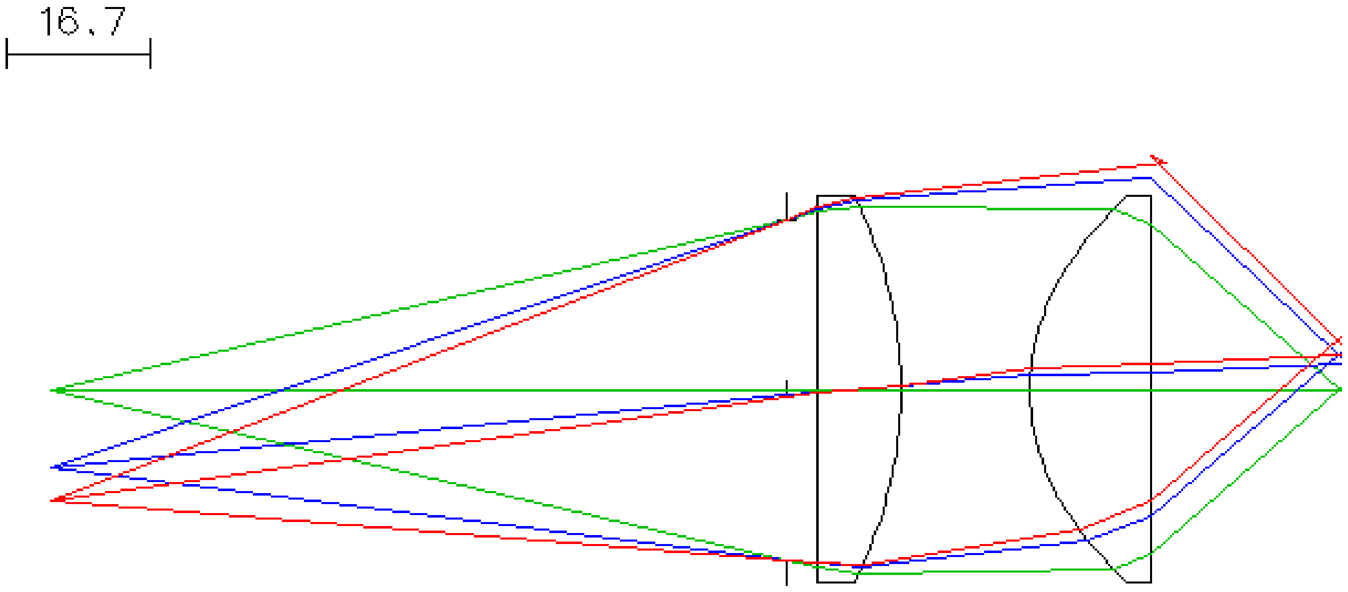
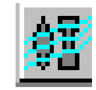


Fig. Obtained condenser lens design

Conclusion: Severe vignieting, necessary correction

▪ Vignieting analysis

From window ‘Lens Drawing’ toolbar choose 

Complete vignieting analysis for both 0.7 and 1 field angle

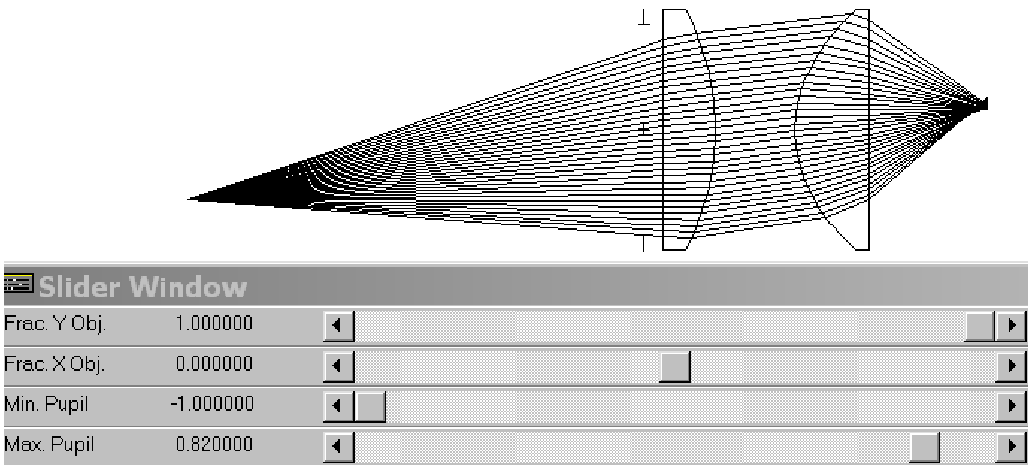


Fig. Vignieting Setting for field angle 1

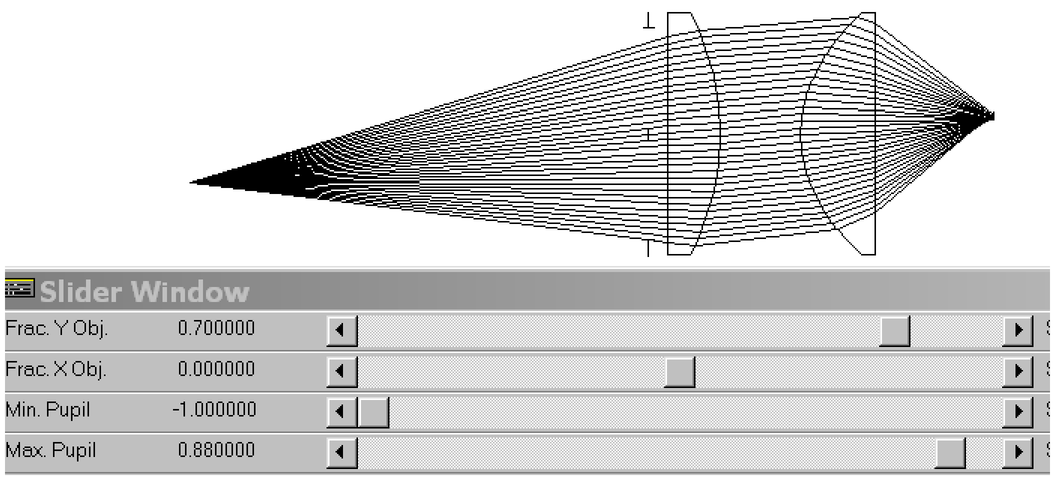


Fig. Vignieting Setting for field angle 0.7

Obtained values are introduced into the field points set (Advanced) and to the Lens Drawing Conditions.

Frac Y Obj	Frac X Obj	Rays	Min Pupil	Max Pupil	Offset
0.000000	0.000000	3	-1.000000	1.000000	0.000000
0.700000	0.000000	3	-1.000000	0.880000	0.000000
1.000000	0.000000	3	-1.000000	0.820000	0.000000

Fig. Setting 'Lens Drawing Conditions'

Field Points Set Data Editor < Surface Data

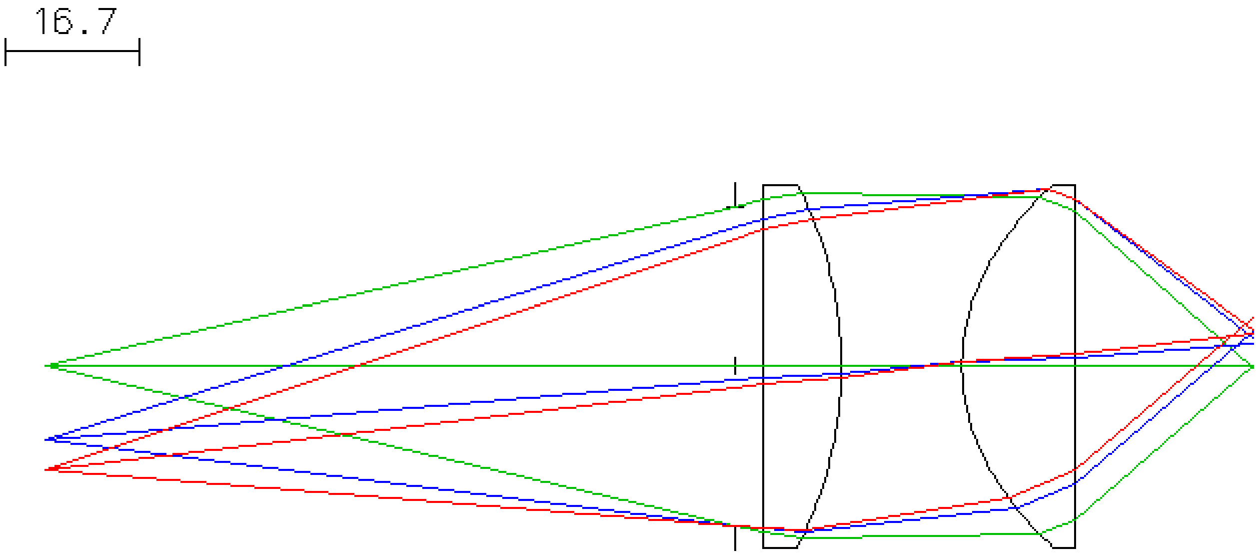
0.0

Spreadsheet style: ○ Basic ◉ Advanced

FPT	CF	GP	FBY	FBX	FBZ	FYRF	FXRF	FY1	FY2	FX1	FX2	WGT	SP
1	0	0	0.00	0.00	0.00	0.00	0.00	-1.00	1.00	-1.00	1.00	1.000	
2	0	0	0.70	0.00	0.00	0.00	0.00	-1.00	0.88	-1.00	1.00	1.000	
3	0	0	1.00	0.00	0.00	0.00	0.00	-1.00	0.82	-1.00	1.00	1.000	

Fig. Setting 'Field Point Set'

Effect of vignietting correction on ray transfer for considered 3 angles of field of view



▪ Evaluation of the condenser design

Run spot diagram analysis and recalculate for ‘Scale’ 0.8

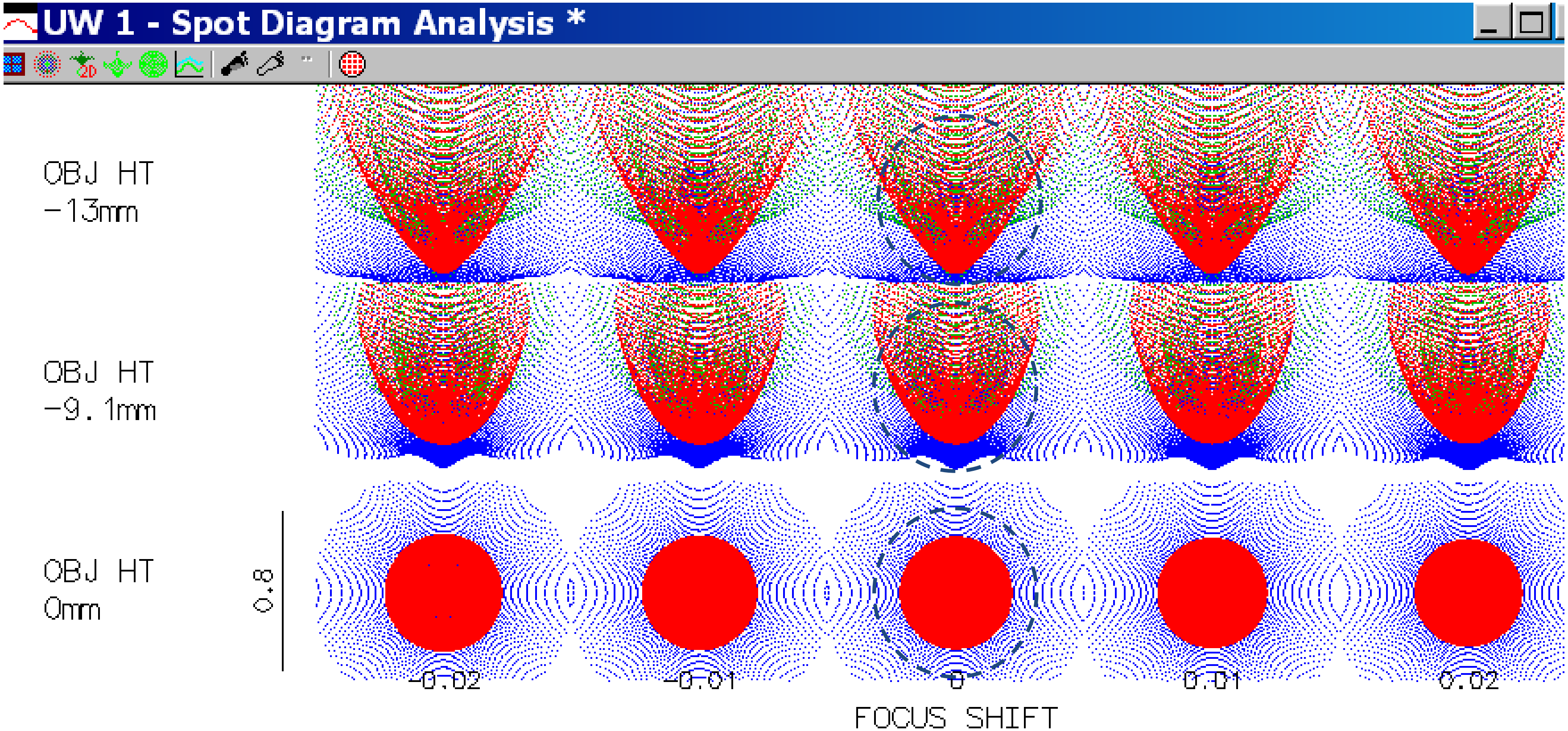


Fig. Spot diagram condenser analysis

Our design meets our demands

Individual projects

Projectors:

Project 1: slide projector
Distance to the screen – 5 m
Slide size – 40 x 40mm
Screen base: 2 m

Project 2: movie projector
Cine film – 16 mm
Distance to the screen – 15 m
Screen base: 4 m

Project 3: movie projector
Cine film – 35 mm
Distance to the screen – 15 m
Screen base: 6 m

Project 4: back projection projector
Distance to the screen – 1 m
Slide size – 24 x 36 mm
Screen base (monitor size 25 inch)

Project 5: micro film projector
Cine film – 16 mm
Distance to the screen – 1,5 m
Screen base (format A3)

Project 6: overhead projector
Distance to the screen – 5 m
Slide size – 24x36
Screen base: 4 m

Project 7: Multimedia projector
Distance to screen: 4m
Slide size – 8,64x15,36
Screen base: 1,5m