DOE/NV/25946--1585

Design, assembly, and testing of a telecentric zoom lens for the Cygnus x-ray source

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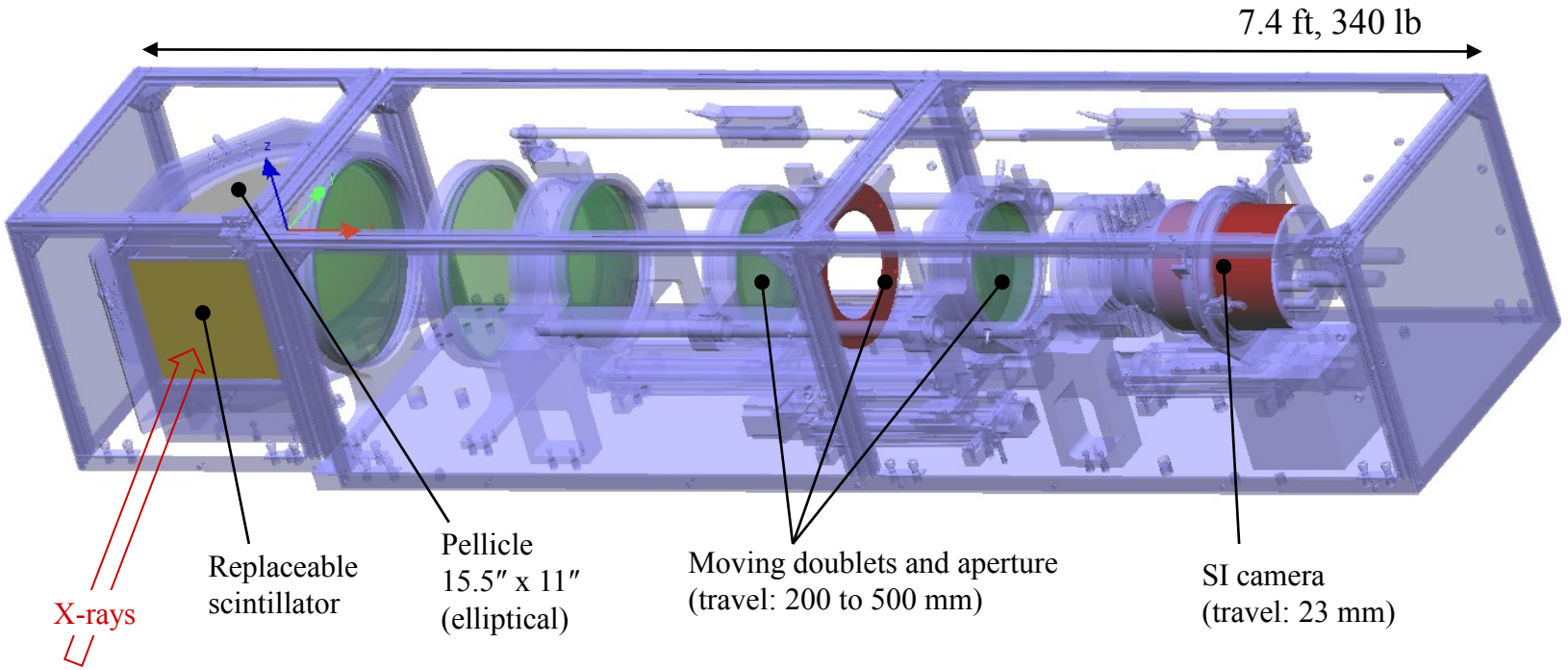
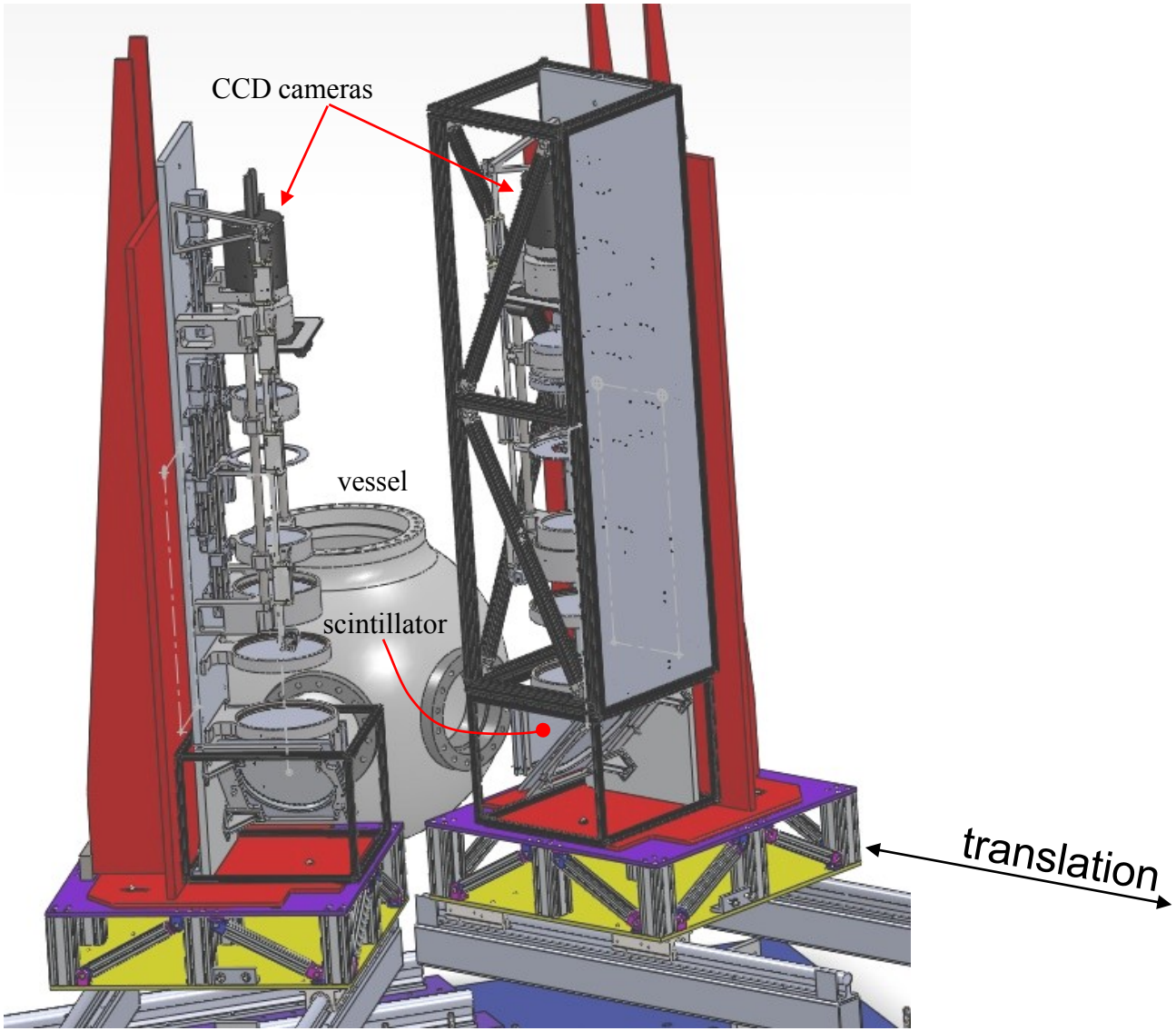
Los Alamos National Laboratory

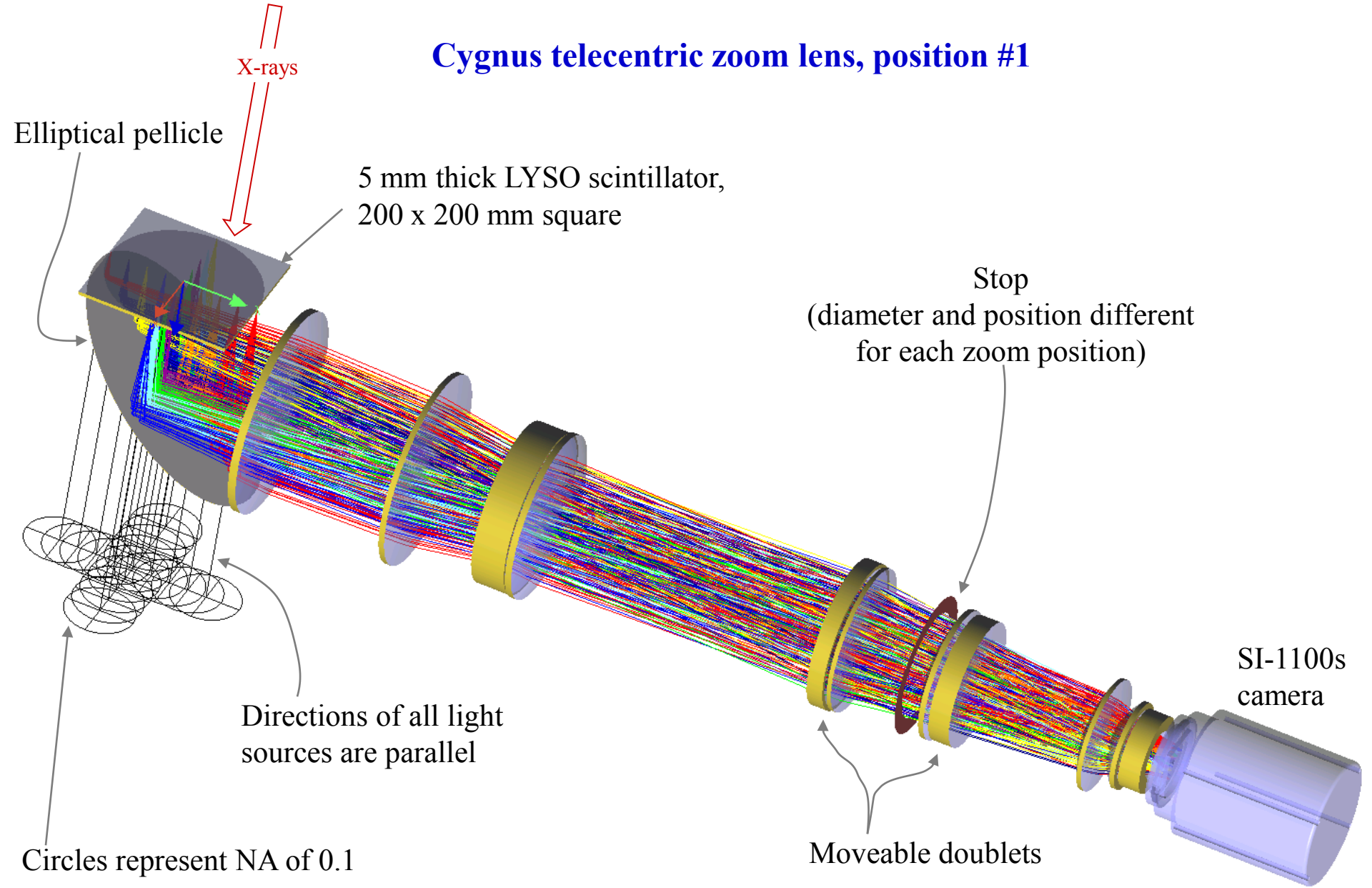


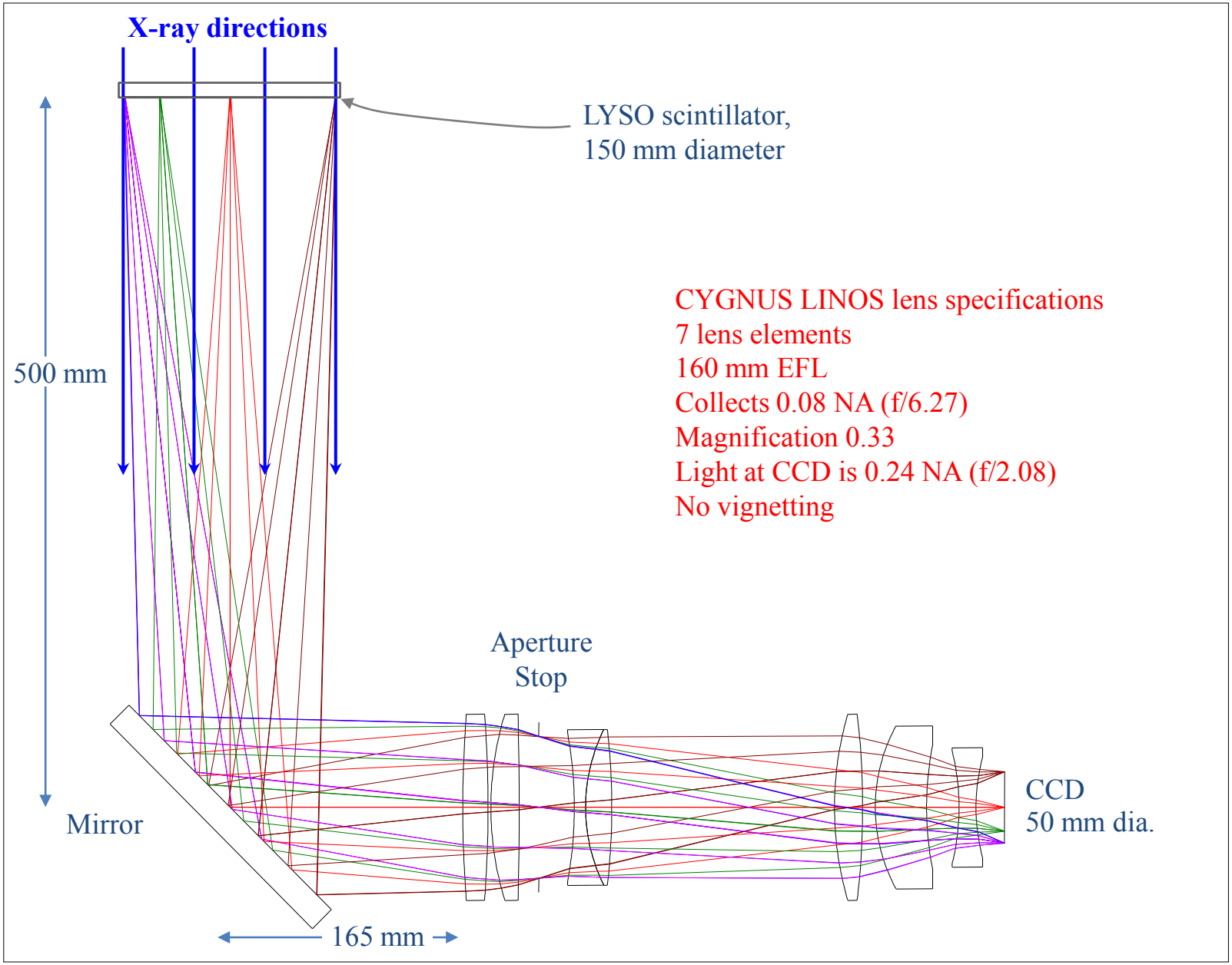
This work was done by National Security Technologies, LLC, under Contract No. DE-AC52-06NA25946 with the U.S. Department of Energy.

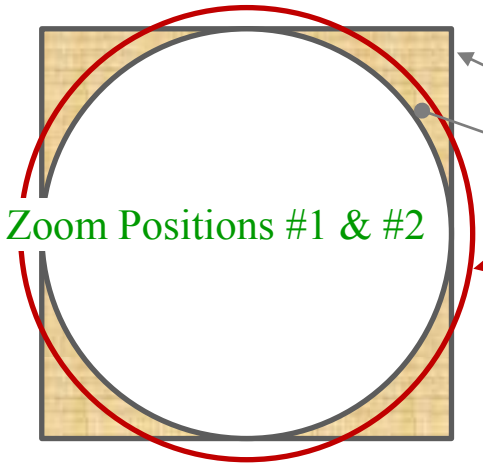
Our goal is to collect x-ray images of different sized targets, which are positioned inside a containment vessel, onto different sized CCD cameras.



Cygnus telecentric zoom lens, position #1




X-ray directions
LYSO scintillator,
150 mm diameter
500 mm
CYGNUS LINOS lens specifications
7 lens elements
160 mm EFL
Collects 0.08 NA (f/6.27)
Magnification 0.33
Light at CCD is 0.24 NA (f/2.08)
No vignetting
Aperture
Stop
Mirror
CCD
50 mm dia.
165 mm

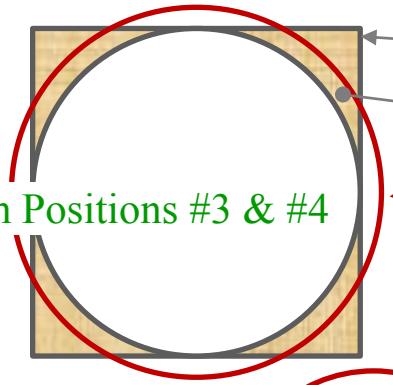


Zoom Positions #1 & #2

Square scintillator material measures 200 × 200 mm

10 mm thick zone for calibration features

220 mm diameter object field of view to be imaged

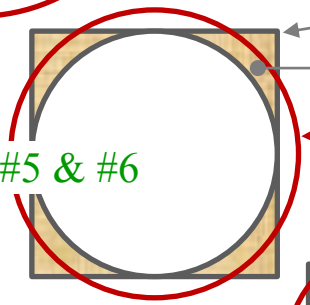


Zoom Positions #3 & #4

Square scintillator material measures 160 × 160 mm

10 mm thick zone for calibration features

180 mm diameter object field of view to be imaged

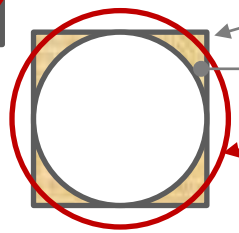


Zoom Positions #5 & #6

Square scintillator material measures 120 × 120 mm

10 mm thick zone for calibration features

140 mm diameter object field of view to be imaged

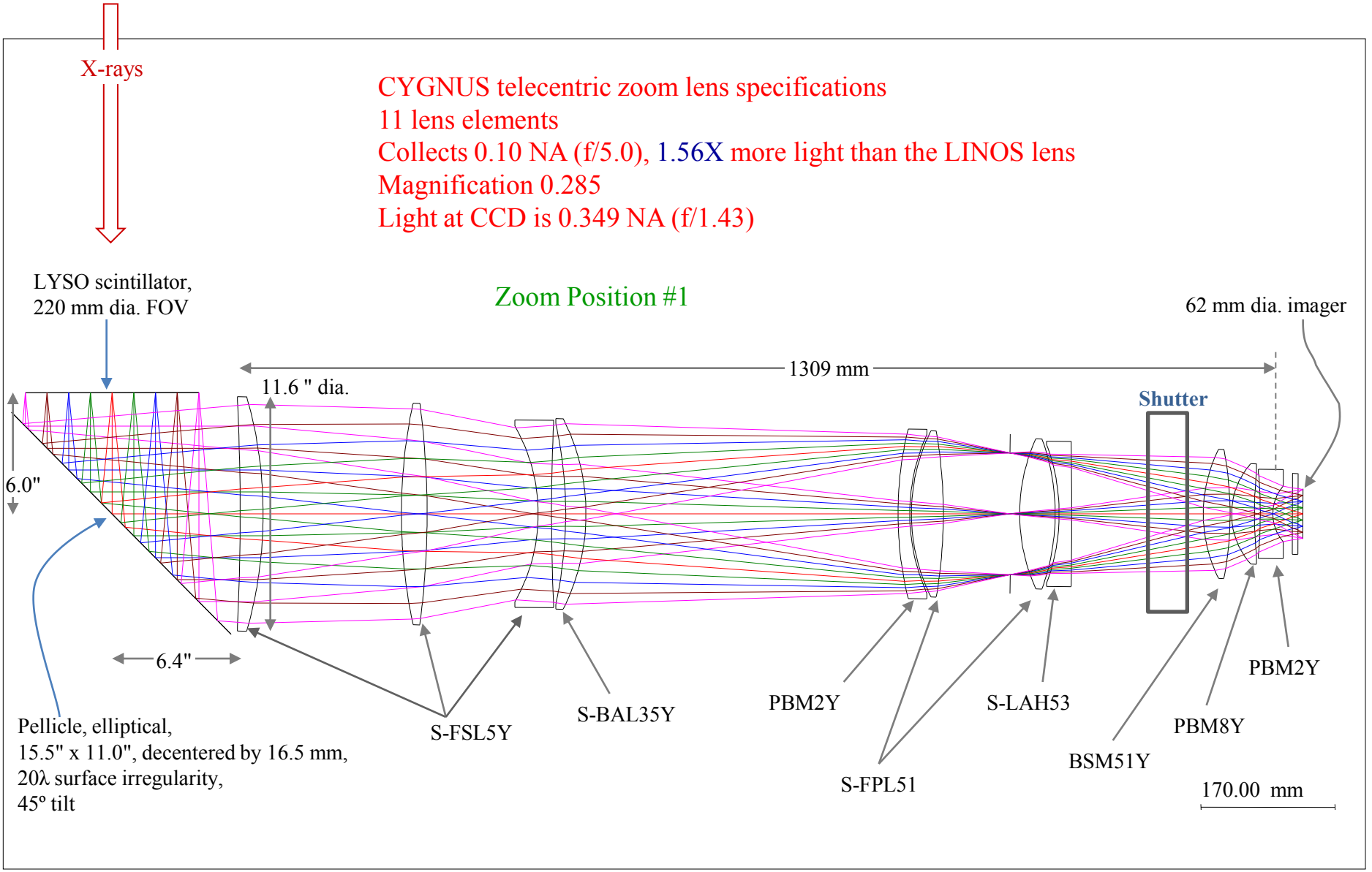


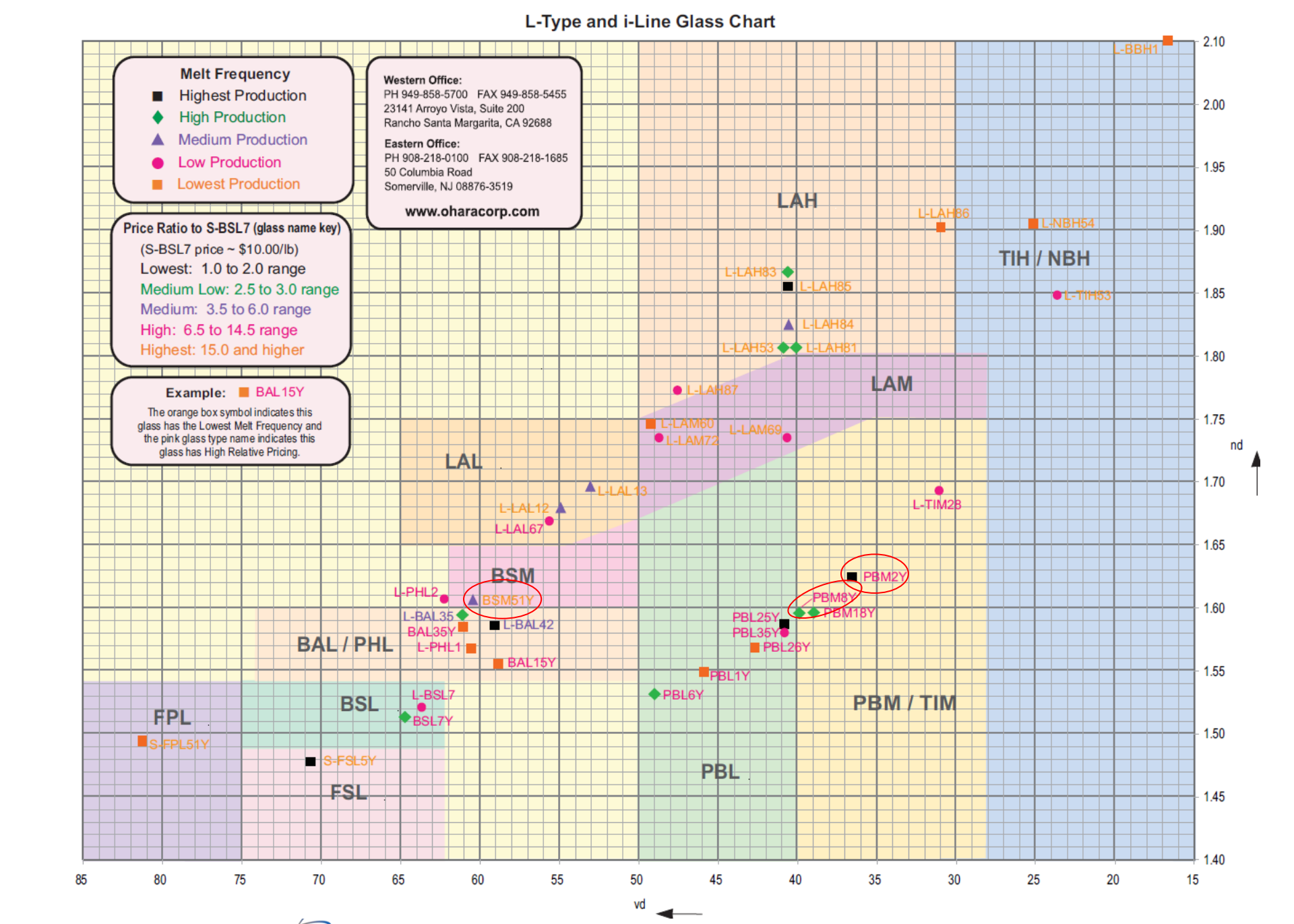
Zoom Positions #7 & #8

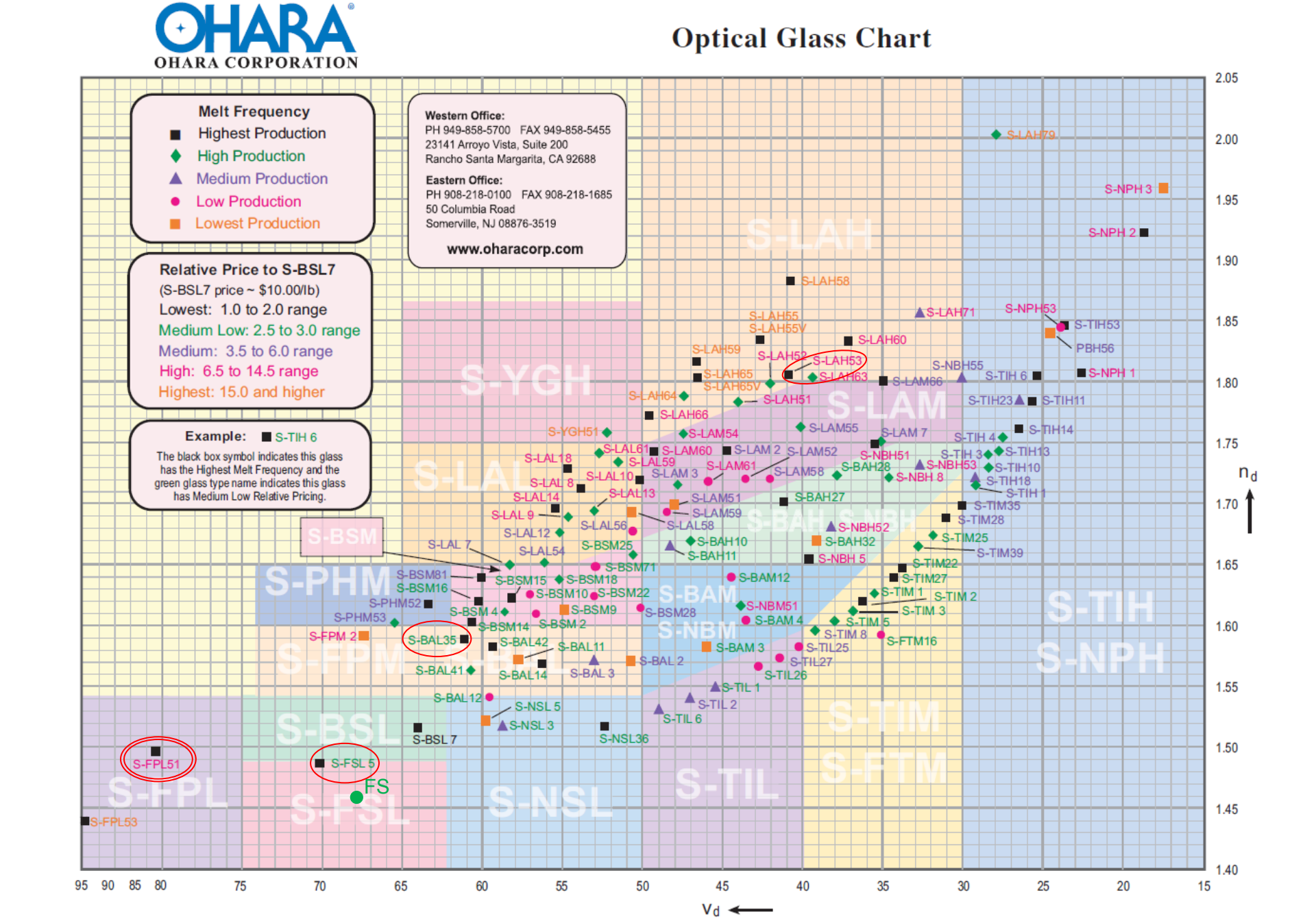
Square scintillator material measures 85 × 85 mm

10 mm thick zone for calibration features

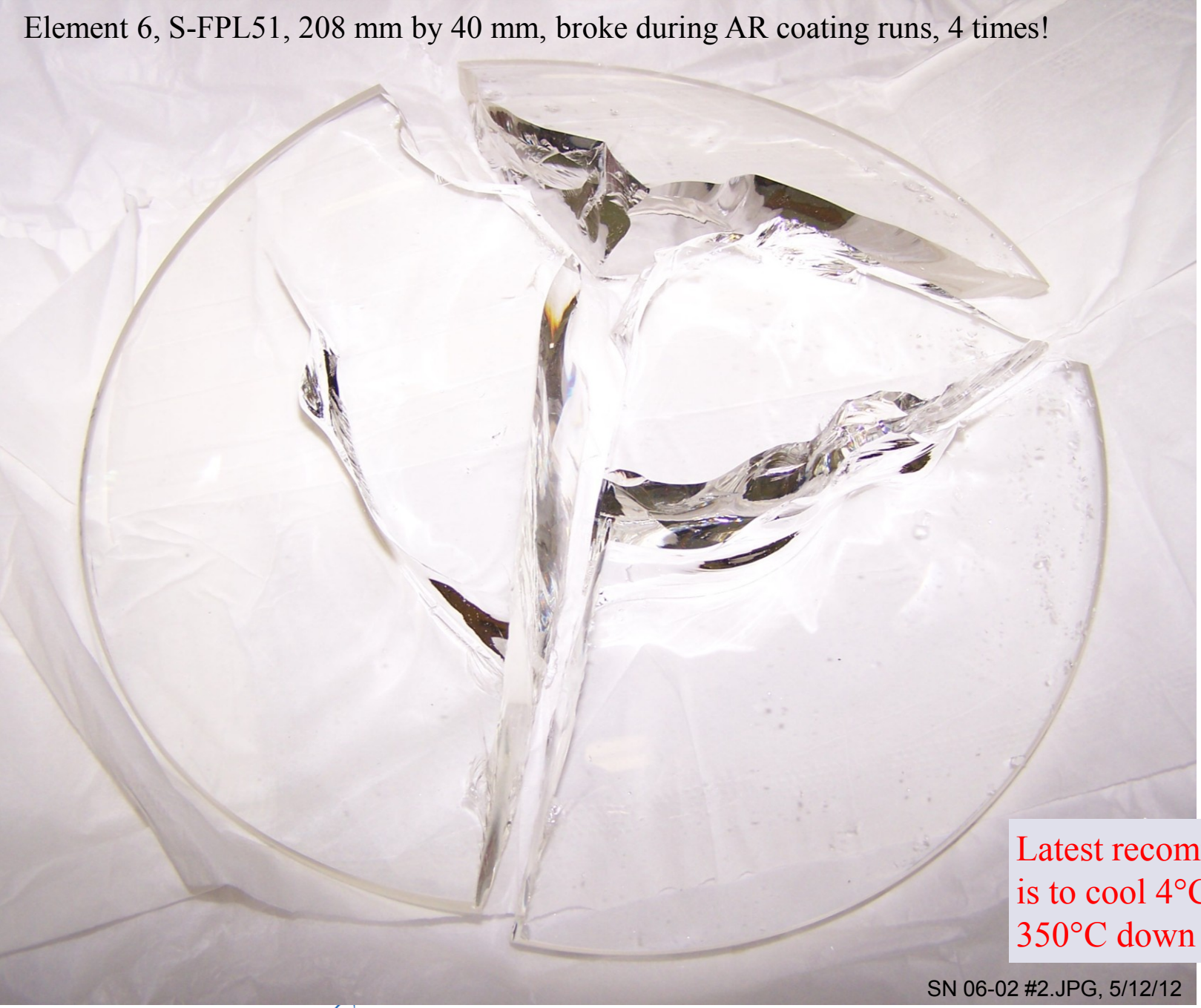
105 mm diameter object field of view to be imaged


X-rays
CYGNUS telecentric zoom lens specifications
11 lens elements
Collects 0.10 NA (f/5.0), 1.56X more light than the LINOS lens
Magnification 0.285
Light at CCD is 0.349 NA (f/1.43)
LYSO scintillator,
220 mm dia. FOV
Zoom Position #1
62 mm dia. imager
1309 mm
11.6 " dia.
Shutter
6.0"
6.4"
Pellicle, elliptical,
15.5" x 11.0", decentered by 16.5 mm,
20λ surface irregularity,
45° tilt
S-FSL5Y
S-BAL35Y
PBM2Y
S-FPL51
S-LAH53
BSM51Y
PBM8Y
PBM2Y
170.00 mm


L-Type and i-Line Glass Chart
Melt Frequency
Highest Production
High Production
Medium Production
Low Production
Lowest Production
Western Office:
PH 949-858-5700 FAX 949-858-5455
23141 Arroyo Vista, Suite 200
Rancho Santa Margarita, CA 92688
Eastern Office:
PH 908-218-0100 FAX 908-218-1685
50 Columbia Road
Somerville, NJ 08876-3519
www.oharacorp.com
Price Ratio to S-BSL7 (glass name key)
(S-BSL7 price ~ $10.00/lb)
Lowest: 1.0 to 2.0 range
Medium Low: 2.5 to 3.0 range
Medium: 3.5 to 6.0 range
High: 6.5 to 14.5 range
Highest: 15.0 and higher
Example: BAL15Y
The orange box symbol indicates this glass has the Lowest Melt Frequency and the pink glass type name indicates this glass has High Relative Pricing.
LAH
TIH / NBH
LAM
LAL
BSM
BAL / PHL
BSL
FPL
FSL
PBL
PBM / TIM
L-BBH1
L-LAH86
L-NBH54
L-LAH83
L-LAH85
L-TIH53
L-LAH84
L-LAH53
L-LAH81
L-LAH87
L-LAM60
L-LAM72
L-LAM69
L-LAL13
L-LAL12
L-LAL67
L-TIM28
PBM2Y
PBM8Y
PBM18Y
L-PHL2
BSM51Y
L-BAL35
BAL35Y
L-BAL42
L-PHL1
BAL15Y
PBL25Y
PBL35Y
PBL26Y
PBL1Y
PBL6Y
L-BSL7
BSL7Y
S-FPL51Y
S-FSL5Y
2.10
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
nd
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
vd


OHARA
OHARA CORPORATION
Optical Glass Chart
Melt Frequency
Highest Production
High Production
Medium Production
Low Production
Lowest Production
Relative Price to S-BSL7
(S-BSL7 price ~ $10.00/lb)
Lowest: 1.0 to 2.0 range
Medium Low: 2.5 to 3.0 range
Medium: 3.5 to 6.0 range
High: 6.5 to 14.5 range
Highest: 15.0 and higher
Example: S-TIH 6
The black box symbol indicates this glass has the Highest Melt Frequency and the green glass type name indicates this glass has Medium Low Relative Pricing.
Western Office:
PH 949-858-5700 FAX 949-858-5455
23141 Arroyo Vista, Suite 200
Rancho Santa Margarita, CA 92688
Eastern Office:
PH 908-218-0100 FAX 908-218-1685
50 Columbia Road
Somerville, NJ 08876-3519
www.oharacorp.com
S-LAH
S-YGH
S-LAM
S-LAL
S-BSM
S-PHM
S-BAM
S-NBM
S-TIH
S-FPM
S-NPH
S-BSL
S-TIM
S-FTM
S-FPL
S-FSL
S-NSL
S-TIL
FS
nd
Vd
2.05
2.00
1.95
1.90
1.85
1.80
1.75
1.70
1.65
1.60
1.55
1.50
1.45
1.40
95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15

Element 6, S-FPL51, 208 mm by 40 mm, broke during AR coating runs, 4 times!

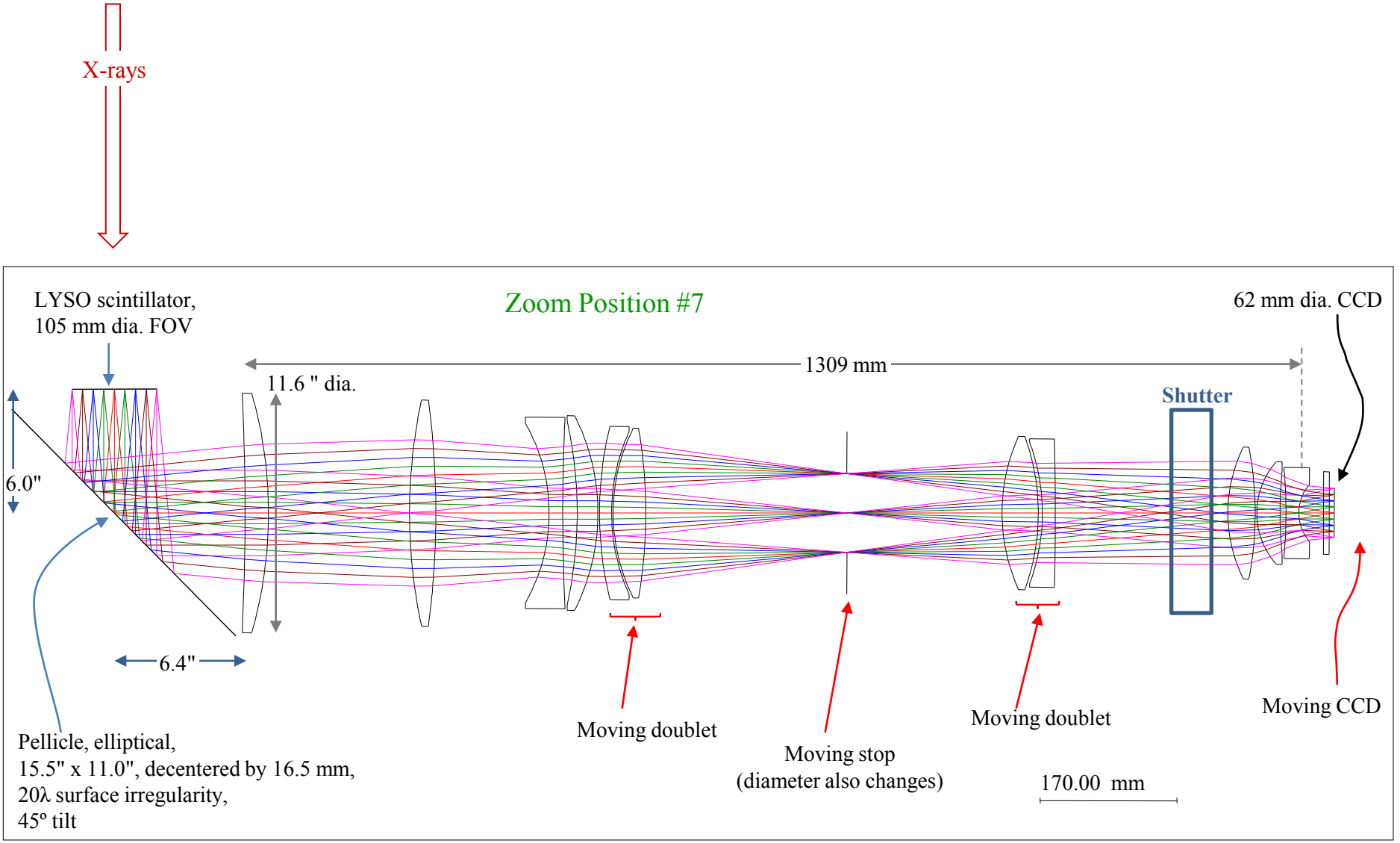


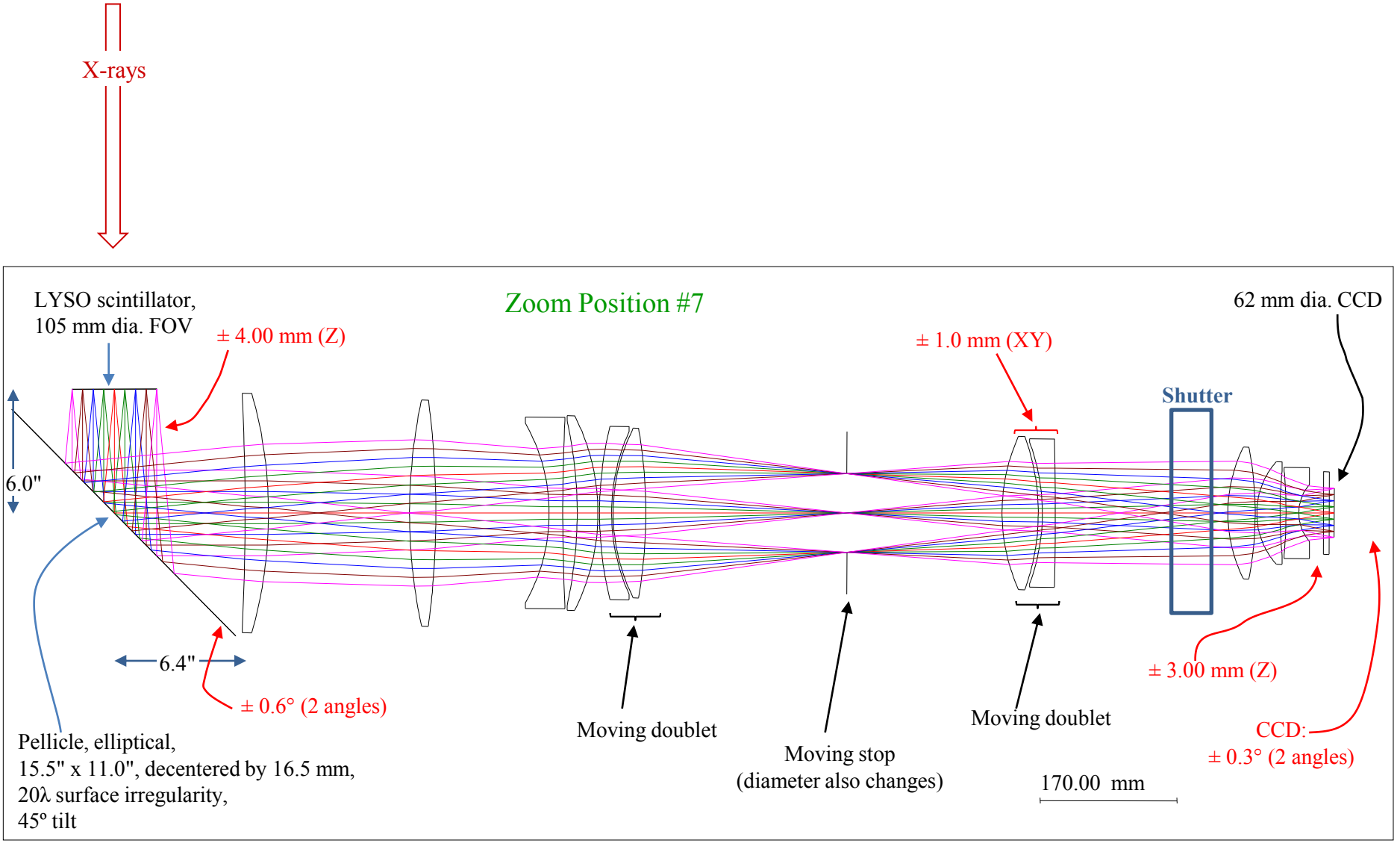
25% P_2O_5
15% AlF_3
25% SrF_2
15% BaF_2
15% CaF_2
15% SrO
BaO
Al_2O_3
MgF_2

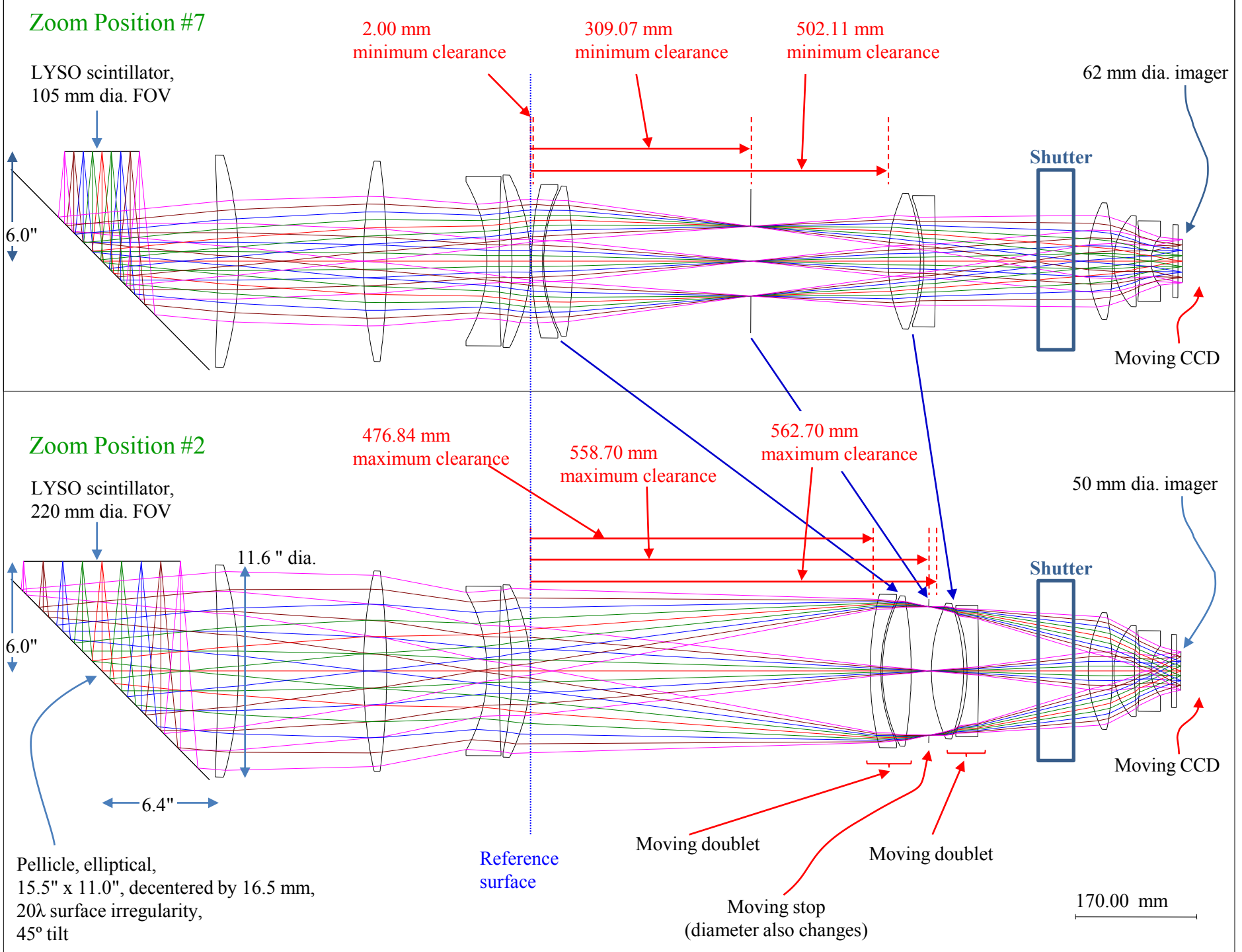
no SiO_2 !?!

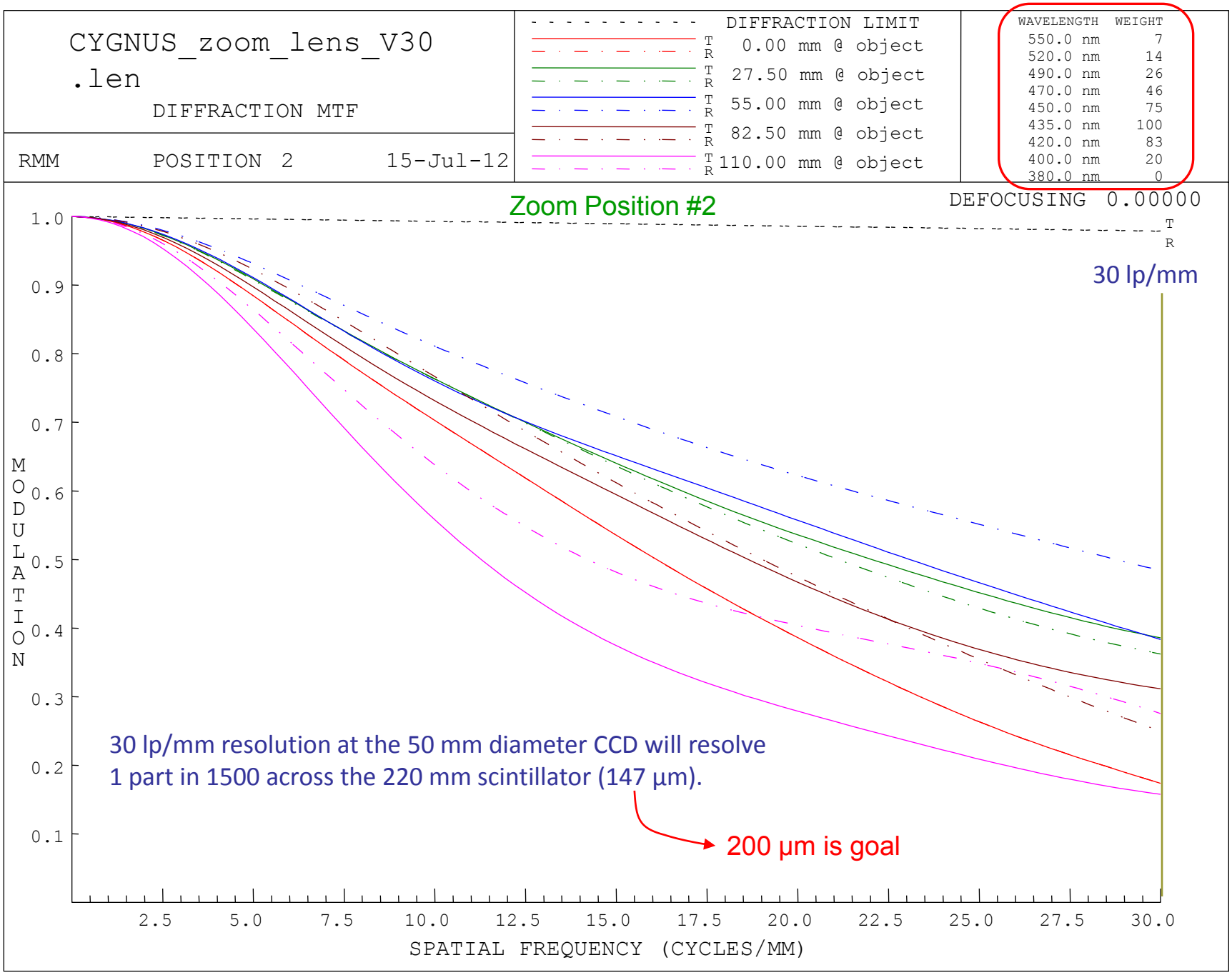
Latest recommendation is to cool 4°C / hr, from 350°C down to 80°C.

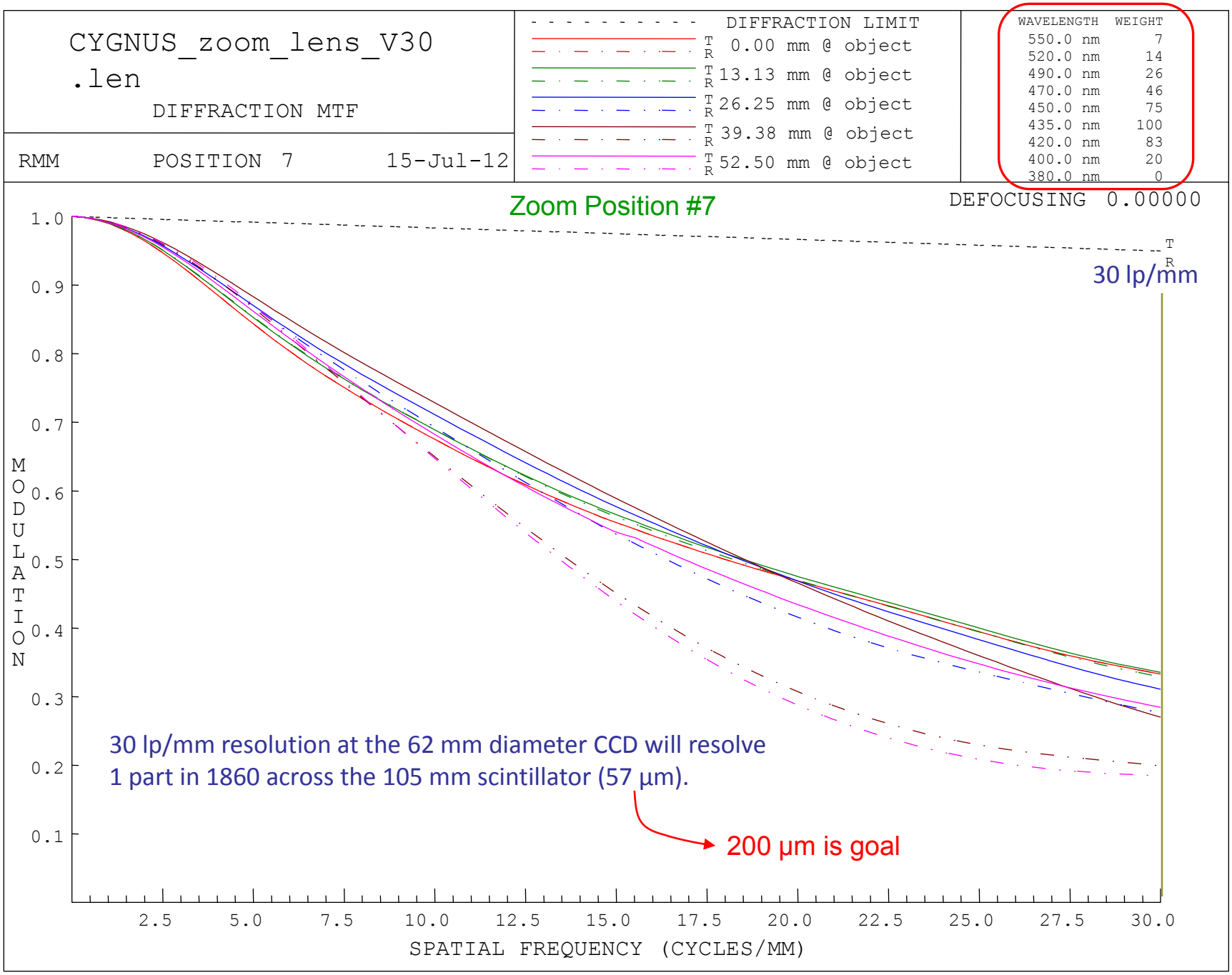
SN 06-02 #2.JPG, 5/12/12

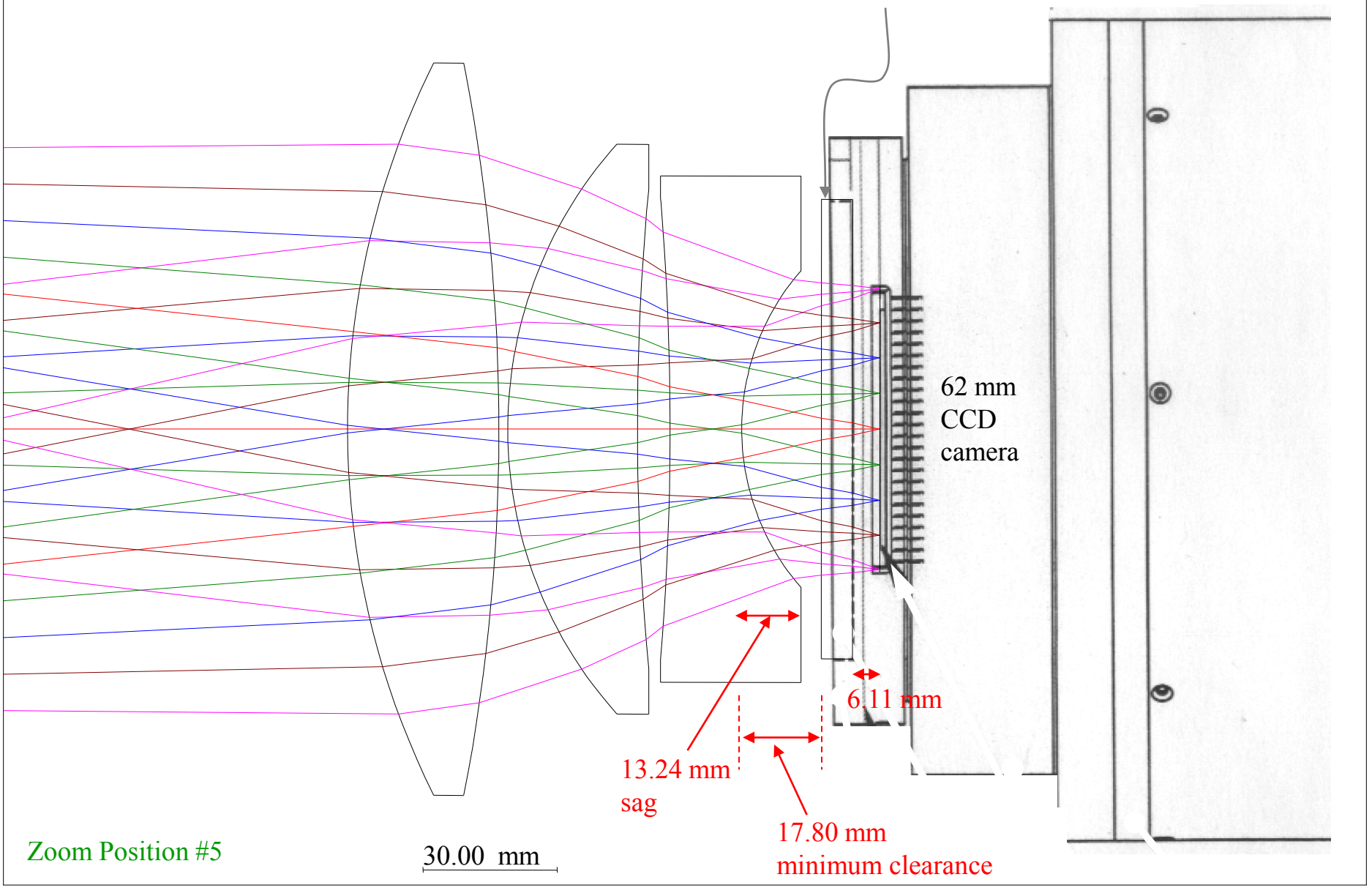

X-rays
LYSO scintillator,
105 mm dia. FOV
Zoom Position #7
62 mm dia. CCD
1309 mm
11.6 " dia.
Shutter
6.0"
6.4"
Pellicle, elliptical,
15.5" x 11.0", decentered by 16.5 mm,
20λ surface irregularity,
45° tilt
Moving doublet
Moving stop
(diameter also changes)
Moving doublet
Moving CCD
170.00 mm

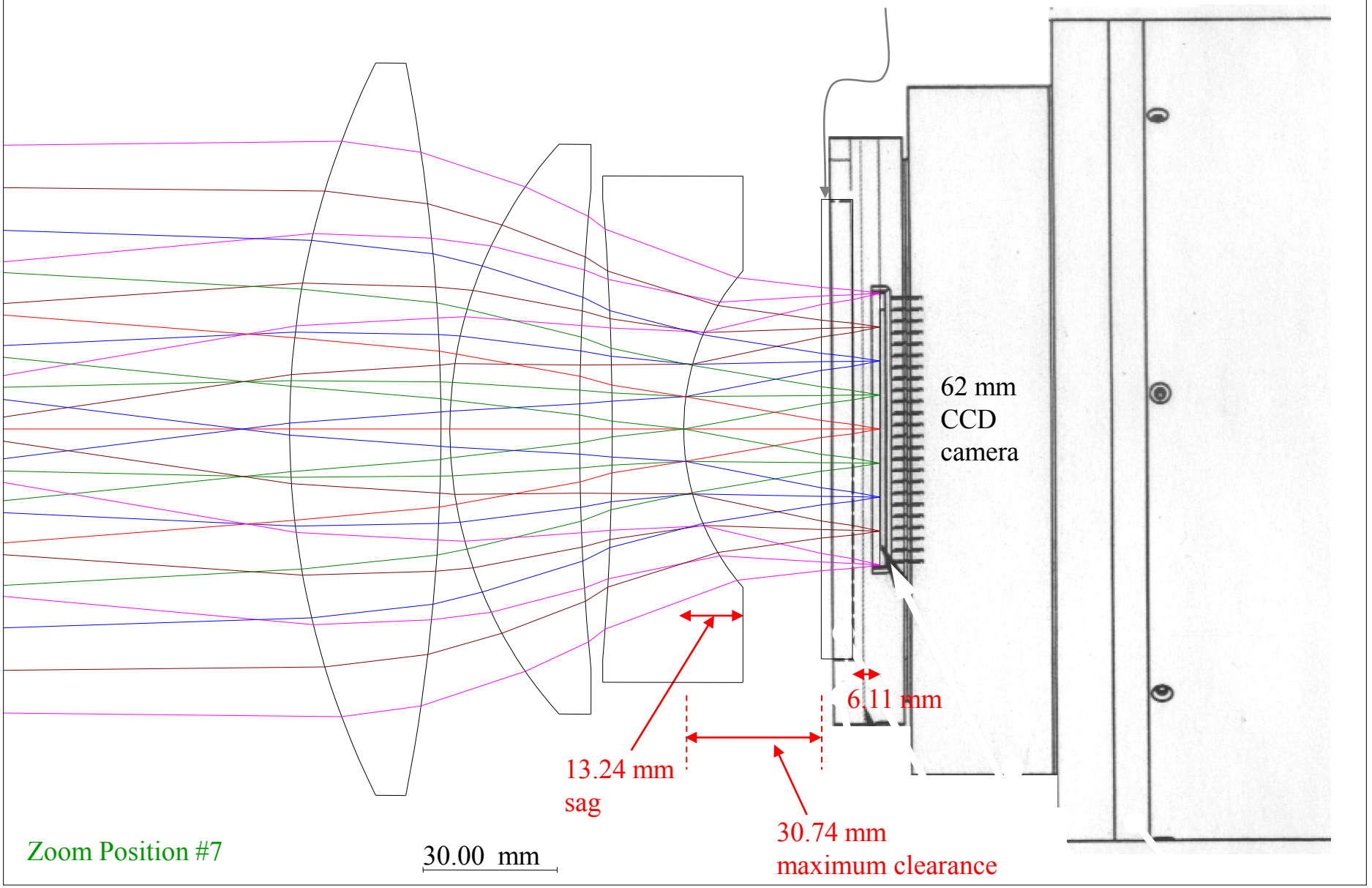

X-rays
LYSO scintillator,
105 mm dia. FOV
± 4.00 mm (Z)
Zoom Position #7
± 1.0 mm (XY)
62 mm dia. CCD
Shutter
6.0"
6.4"
± 0.6° (2 angles)
± 3.00 mm (Z)
Pellicle, elliptical,
15.5" x 11.0", decentered by 16.5 mm,
20λ surface irregularity,
45° tilt
Moving doublet
Moving stop
(diameter also changes)
Moving doublet
CCD:
± 0.3° (2 angles)
170.00 mm

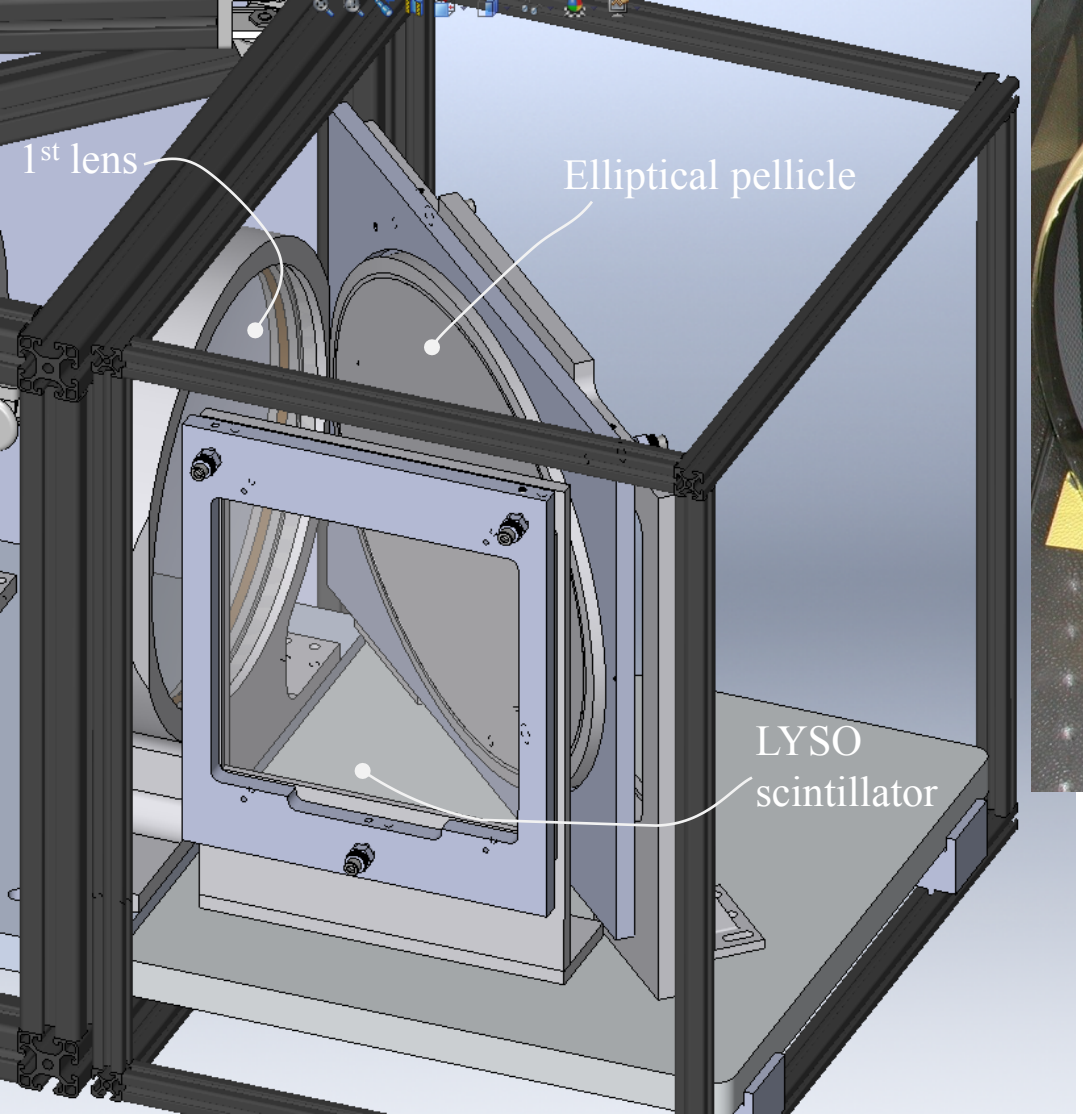

Zoom Position #7
LYSO scintillator,
105 mm dia. FOV
6.0"
2.00 mm
minimum clearance
309.07 mm
minimum clearance
502.11 mm
minimum clearance
62 mm dia. imager
Shutter
Moving CCD
Zoom Position #2
LYSO scintillator,
220 mm dia. FOV
6.0"
11.6 " dia.
6.4"
476.84 mm
maximum clearance
558.70 mm
maximum clearance
562.70 mm
maximum clearance
50 mm dia. imager
Shutter
Moving CCD
Pellicle, elliptical,
15.5" x 11.0", decentered by 16.5 mm,
20λ surface irregularity,
45º tilt
Reference
surface
Moving doublet
Moving doublet
Moving stop
(diameter also changes)
170.00 mm

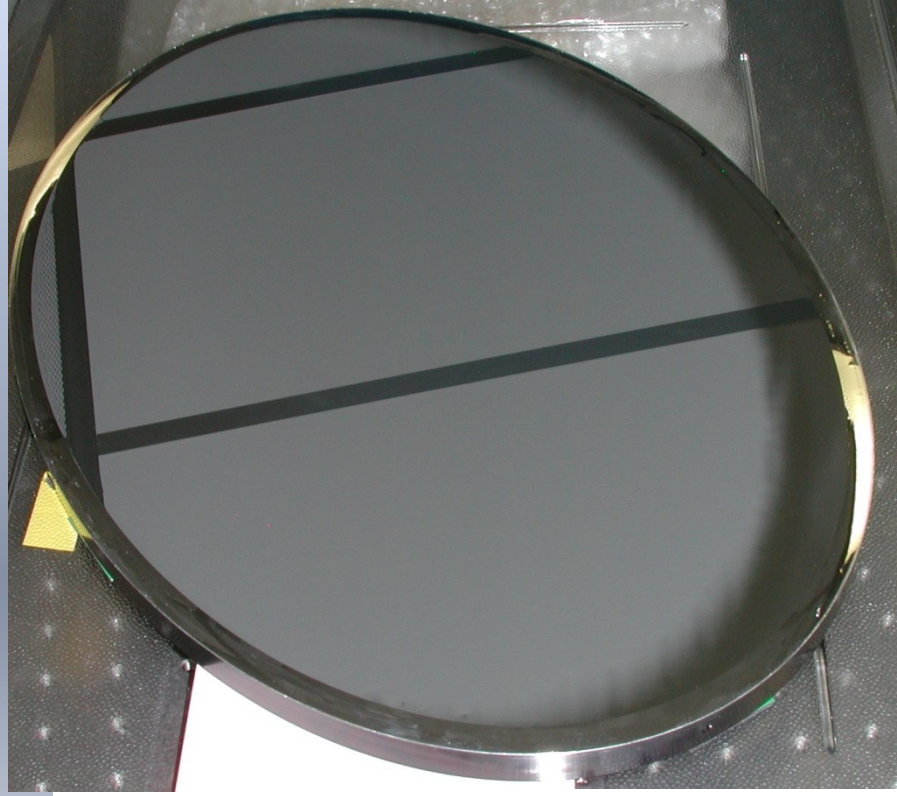

CYGNUS_zoom_lens_V30
.len
DIFFRACTION MTF
RMM POSITION 2 15-Jul-12
DIFFRACTION LIMIT
T R 0.00 mm @ object
T R 27.50 mm @ object
T R 55.00 mm @ object
T R 82.50 mm @ object
T R 110.00 mm @ object
WAVELENGTH WEIGHT
550.0 nm 7
520.0 nm 14
490.0 nm 26
470.0 nm 46
450.0 nm 75
435.0 nm 100
420.0 nm 83
400.0 nm 20
380.0 nm 0
Zoom Position #2
DEFOCUSING 0.00000
T R
30 lp/mm
MODULATION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
30 lp/mm resolution at the 50 mm diameter CCD will resolve
1 part in 1500 across the 220 mm scintillator (147 µm).
200 µm is goal
2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0
SPATIAL FREQUENCY (CYCLES/MM)


CYGNUS_zoom_lens_V30
.len
DIFFRACTION MTF
RMM POSITION 7 15-Jul-12
DIFFRACTION LIMIT
T 0.00 mm @ object
R
T 13.13 mm @ object
R
T 26.25 mm @ object
R
T 39.38 mm @ object
R
T 52.50 mm @ object
R
WAVELENGTH WEIGHT
550.0 nm 7
520.0 nm 14
490.0 nm 26
470.0 nm 46
450.0 nm 75
435.0 nm 100
420.0 nm 83
400.0 nm 20
380.0 nm 0
Zoom Position #7
DEFOCUSING 0.00000
30 lp/mm
30 lp/mm resolution at the 62 mm diameter CCD will resolve
1 part in 1860 across the 105 mm scintillator (57 µm).
200 µm is goal
MODULATION
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
2.5 5.0 7.5 10.0 12.5 15.0 17.5 20.0 22.5 25.0 27.5 30.0
SPATIAL FREQUENCY (CYCLES/MM)

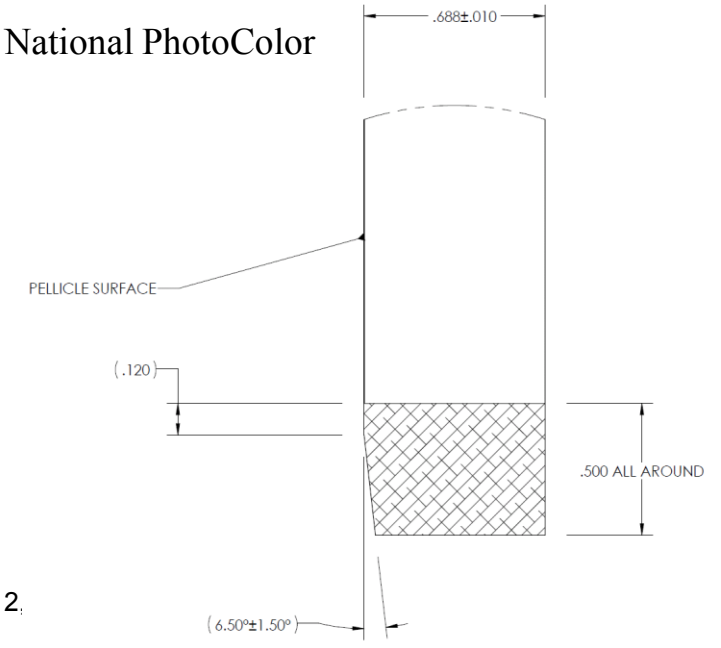

7 mm thick window protrudes 2.25 mm past metal housing
62 mm
CCD
camera
6.11 mm
13.24 mm
sag
17.80 mm
minimum clearance
Zoom Position #5
30.00 mm


7 mm thick window protrudes 2.25 mm past metal housing
62 mm
CCD
camera
6.11 mm
13.24 mm
sag
30.74 mm
maximum clearance
Zoom Position #7
30.00 mm





National PhotoColor



Pellicle, elliptical,
15.5" x 11.0", decentered by 16.5 mm,
20λ surface irregularity,
45° tilt

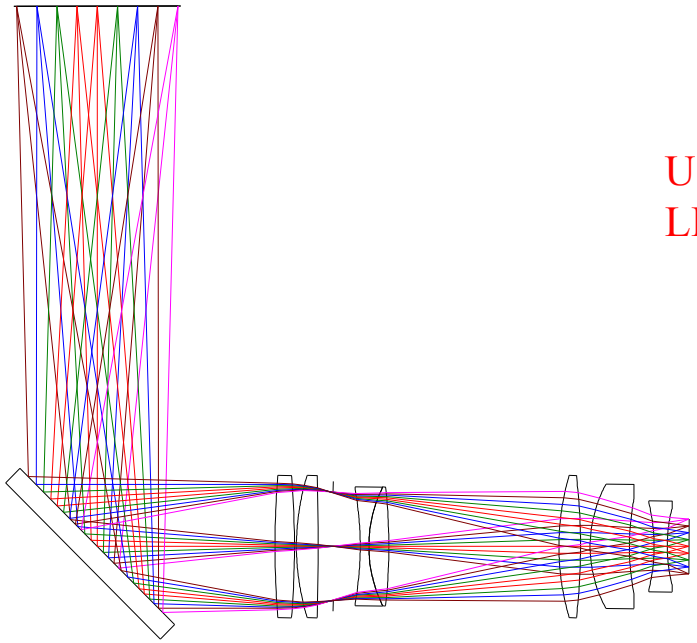
CYGNUS_zoom_lens_V30.len **2/22/12** **Centered Tolerances**

SUR	RADIUS	RADIUS TOL	FRINGES POW/IRR	THICKNESS	THICKNESS TOL	GLASS	INDEX TOL	V-NO (%)	
0				0.00000					
1				0.00000					
2	INF	0.1000	20.0/ 5.00	0.00000	0.10000	SILICA	0.00500	0.80	**Scintillator**
3	INF	0.1000	20.0/ 5.00	152.40000	0.10000				
4	INF		**30.0/15.00**	0.00000	0.10000	REFL			**Pellicle**
5				-152.40000					
6				-10.00000					
7	2887.70000	0.1000	20.0/ 5.00	-29.00000	2.00000	SFSL5Y	0.00500	0.80	**Lens 1**
8	530.00000	0.1000	20.0/ 5.00	-175.33484	2.00000				
9	-658.16000	0.1000	20.0/ 5.00	-32.53600	2.00000	SFSL5Y	0.00300	0.80	**Lens 2**
10	1060.10000	0.1000	20.0/ 5.00	-140.82159	2.00000				
11	220.51000	0.1000	20.0/ 5.00	-17.00000	2.00000	SFSL5Y	0.00100	0.50	**Lens 3**
12	-2442.20000	0.1000	20.0/ 5.00	-17.82853	2.00000				
13	522.15000	0.1000	20.0/ 5.00	-25.84599	2.00000	BAL35Y	0.00350	0.50	**Lens 4**
14	261.31000	0.1000	20.0/ 5.00	-395.57153	2.00000				
15	-443.60000	0.1000	14.0/ 3.50	-15.00000	2.00000	PBM2Y	0.00300	0.50	**Lens 5**
16	-240.69000	0.1000	14.0/ 3.50	-2.00000	0.20000				
17	-230.60000	0.1000	18.0/ 4.50	-40.40030	2.00000	SFPL51	0.00100	0.50	**Lens 6**
18	613.33000	0.1000	18.0/ 4.50	-84.74121	2.00000				
19				-12.15292	2.00000				**Stop**
20	-227.39000	0.1000	18.0/ 4.50	-45.00000	1.70000	SFPL51	0.00100	0.50	**Lens 7**
21	272.09000	0.1000	16.0/ 4.00	-5.02312	1.70000				
22	248.10000	0.1000	10.0/ 2.50	-16.00000	2.00000	SLAH53	0.00200	0.50	**Lens 8**
23	5342.00000	0.1000	12.0/ 3.00	-166.83169	2.00000				
24	-179.83000	0.1000	20.0/ 5.00	-33.85089	2.00000	BSM51Y	0.00100	0.80	**Lens 9**
25	421.85000	0.1000	20.0/ 5.00	-2.00000	0.20000				
26	-93.58000	0.0500	20.0/ 5.00	-28.97314	0.30000	PBM8Y	0.00050	0.80	**Lens 10**
27	-558.02000	0.1000	20.0/ 5.00	-7.30526	0.30000				
28	613.33000	0.1000	20.0/ 5.00	-16.00000	0.30000	PBM2Y	0.00050	0.80	**Lens 11**
29	-52.88000	0.0300	20.0/ 5.00	-24.79190	2.00000				
30	INF		5.0/ 1.00	-7.00000	0.20000	SILICA	0.00500	0.80	**window**
31	INF		5.0/ 1.00	-6.11000					
32	**Image**			0.00000					

To minimize cost of large optics, their thickness tolerance is ± 2.0 mm

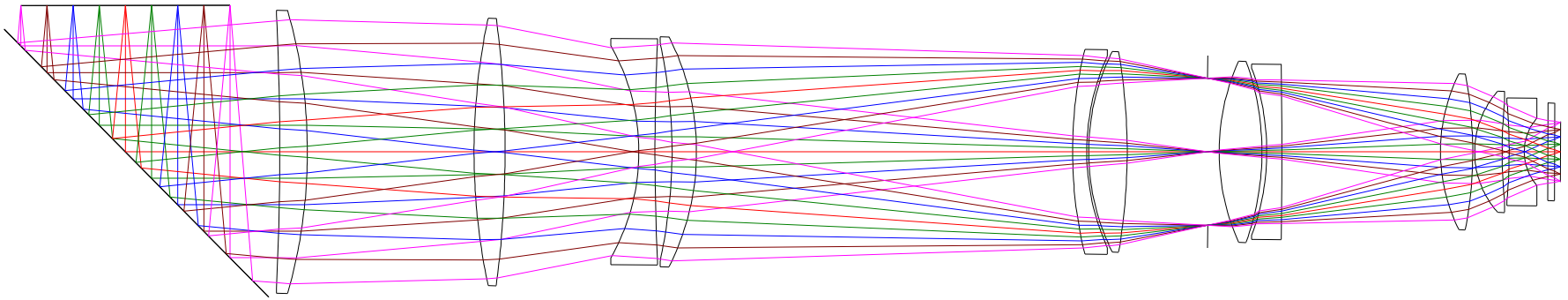
Radius, radius tolerance, thickness and thickness tolerance are given in mm.
Fringes of power and irregularity are at 546.1 nm over the clear aperture.
Irregularity is defined as fringes of cylinder power in test plate fit.

150 mm sq.



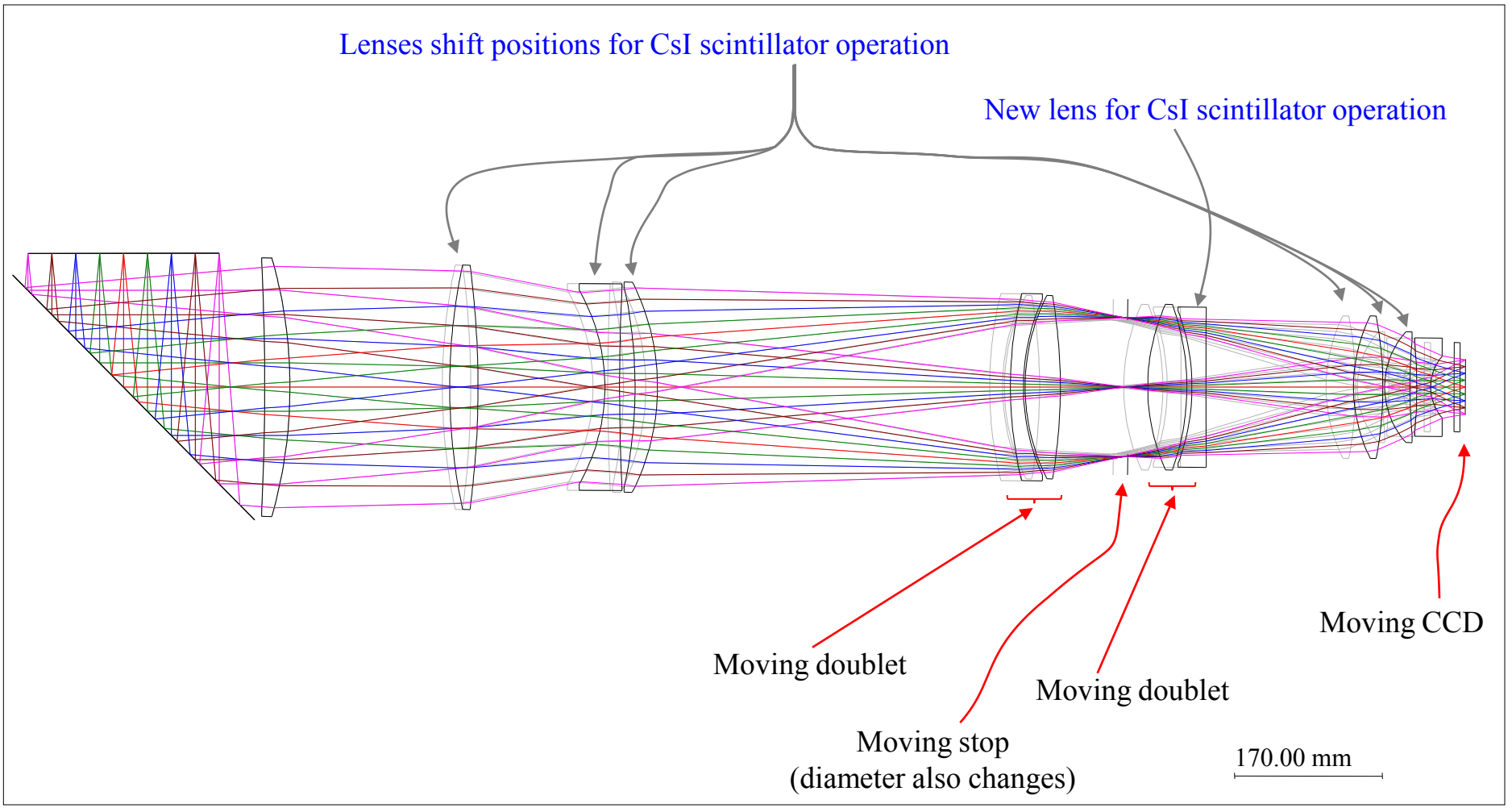
Using the same scaling for the current LINOS lens and for the new zoom lens

200 mm sq.



Zoom Position #1

170.00 mm


Lenses shift positions for CsI scintillator operation
New lens for CsI scintillator operation
Moving CCD
Moving doublet
Moving doublet
Moving stop
(diameter also changes)
170.00 mm

Summary

We have enough optical elements to finish the first system. (We are building 3 systems.)

- This is a telecentric zoom lens.
- Each optical element or lens group protected inside a lens cell.
- We are using counter propagating laser beams to align each optical element and verify tracking.
- First system to be tested at Sandia on the RITS x-ray machine in the horizontal position.
- Then, testing in the vertical position.
- Order the replacement lens for green scintillator operation on the 3rd system.