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(71) 가 가 1 26 2

(72) 2970 가 가
2970 가 가
2970 가 가
2970 가 가
2970 가 가

(74)
:

(54)

2 / / 1 1 , 1
/ / 2 , 3
3 3 , 1
< 2 < 3 , 1, 2 3 , 3
1 2 1 2
, 3

48

1	1	.	
2	1	= 635 nm	.
3	1	= 780 nm	NA 0.45 .
4	1	= 780 nm	NA 0.60 .
5	1	= 635 nm	.
6	1	= 780 nm	.
7	2	= 405 nm	.
8	2	= 635 nm	.
9	2	= 405 nm	.
10	2	= 635 nm	.
11	2	= 405 nm	.
12	2	= 635 nm	.
13	3	= 405 nm	.
14	3	= 635 nm	.
15	3	= 405 nm	.
16	3	= 635 nm	.
17	3	= 405 nm	.
18	3	= 635 nm	.
19	4	.	.
20	4	= 635 nm, 650 nm, 780 nm	.
21	5	.	.
22	5	= 635 nm, 650 nm, 780 nm	.

23	6	= 650 nm	.
24	6	= 780 nm (NA = 0.5)	.
25	6	= 650 ± 10 nm	0.60
26	6	= 780 ± 10 nm	0.50
27	6	= 780 nm	0.60
28	6	= 650 nm	rms
29	6	= 780 nm	rms
30	7	= 650 nm	.
31	7	= 780 nm (NA = 0.5)	.
32	7	= 650 ± 10 nm	0.60
33	7	= 780 ± 10 nm	0.50
34	7	= 780 nm	0.60
35	7	= 650 nm	rms
36	7	= 780 nm	rms
37	8	= 650 nm	.
38	8	= 780 nm (NA = 0.5)	.
39	8	= 650 ± 10 nm	0.60
40	8	= 780 ± 10 nm	0.50
41	8	= 780 nm	0.60
42	8	= 650 nm	rms
43	8	= 780 nm	rms
44	6		(annular bands)
45	7		

46	8			
47				
48	2			
49	3			
50	9	= 650 nm		
51	9	= 780 nm		
52	9	= 650 nm		
53	9	= 780 nm	NA 0.45	
54	9	= 780 nm	NA 0.60	
55	9	= 650 nm		
56	9	= 780 nm		
57	10	= 650 nm		
58	10	= 400 nm		
59	10	= 780 nm		
60	10	= 650 nm		
61	10	= 400 nm		
62	10	= 780 nm	NA 0.45	
63	10	= 780 nm	NA 0.65	
64	10	= 650 nm		
65	10	= 400 nm		
66	10	= 780 nm		
67	4			
68	11	= 650 nm		
69	11	= 400 nm		
70	11	= 780 nm		
71	11	= 650 nm		
72	11	= 400 nm		
73	11	= 780 nm	0.45	

74	11	= 780 nm	0.65	.
75	11	= 650 nm	.	.
76	11	= 400 nm	.	.
77	11	= 780 nm	.	.
78	12	= 650 nm	.	.
79	12	= 400 nm	.	.
80	12	= 780 nm	.	.
81	12	= 650 nm	.	.
82	12	= 400 nm	.	.
83	12	= 780 nm	0.45	.
84	12	= 780 nm	0.65	.
85	12	= 650 nm	.	.
86	12	= 400 nm	.	.
87	12	= 780 nm	.	.
88	13	= 650 nm	.	.
89	13	= 400 nm	.	.
90	13	= 780 nm	.	.
91	13	= 650 nm	.	.
92	13	= 400 nm	.	.
93	13	= 780 nm	0.45	.
94	13	= 780 nm	0.65	.
95	13	= 650 nm	.	.
96	13	= 400 nm	.	.
97	13	= 780 nm	.	.
98	13	= 400 nm	.	.
99	13	= 400 nm \pm 10 nm	.	.
100	13	= 650 nm \pm 10 nm	.	.
101	13	= 780 nm \pm 10 nm	.	.
102	8	1	.	.

103	8		2	.
104	8		3	.
105	8		4	.
106	8		5	.
107	8		6	.
108	8		7	.
109	Super RENS		.	.
110	8	15		m2
111	8	15	.	.
112	15	.		.
113		.		.
114	8			.
115	8		+1	.
116	8		-1	.
117	7		.	.
118	7	15	()
119	118		() = 640, 650, 660 nm	0.60
120	15		가 118	.
121	120		() = 770, 780, 790 nm	0.60
122	7	16	()
123	122		() = 640, 650, 660 nm	0.60
124	16		122	.
125	124		() = 770, 780, 790 nm	0.60
126	7	17	()
127	126		() = 640, 650, 660 nm	0.60
128	17		126	.

, DVD 가 ,

, CD 가 DVD CD-R,

8-55363, 10-92010).

785 nm가 (0) 10-283668 1 가 9-54973 (0) +1 635 nm가 -1 635 nm가 785 nm가 650 nm 가 100% , 780 nm ,

+1 -1 0 가 100%가

가 0 +1 -1 100%가

가 3.0 - 5.18 μm 가 . 가 .

/ 가 (9-286954).

light) 가 / 가 가 . (flare (light flux) (D

VD-RAM, DVD-R, DVD-RW, DVD+R) 가 CD (CD-R, CD-RW)

가 DVD CD 가 가 가 .

2 가 가 .

, CD DVD 가 가 가 .

2

2

/ 가

가

/

S

(1)

2 / 1 1 ;

1 / 2 2 ;

3 / 3 -

1 < 2 < 3 - ;

1, 2 3 가 , 3
1, 2

1 2

3

(2)

1, 2 3 , 3 가

1, 2 가 /

1 < 2 < 3

1 2

2 1

3 3

1 , 1 가, 2 2 1 2 , 1 n
, n 0 , 2 가 n .

(11-1)

가 , ,
0 , 가 , ,

(11-14)

0 가 ,

가

(11-15)

2 45 . 40
15 ,

가, , n +1 2μm -1 .

가,

(11-16)

tive effect) , , (negative effect) (posi

가

가

가, 가 , 가 가
가, 가 47(c) , 가 가

가 , , 47(d)

가 , 가 가 ,

34 p () , 134 d . 1

(11-17)

가 , , 가 ,

가, 가 , .

0% (80% , 90%) , .

(11-18)

가, 가 가 , 가
 50% , 10% 90% , 10%

(11-19)

가 , NA1>NA2 , NA2>NA1 , NA1>NAH1, NAH1 NA2, NA2 NAL1
 0 , NA1 NA2 , NA2>NAH2, NAH2 NA1, NA1 NAL2 0
 . NAH1 NAH2 1 2 1 2
 . NAL1 NAL2 1 2

(11-20)

가 가 , NA1 1
 NA1 NA1 , NA1>NA2 , NA2> NA2
 , NA2 2
 가 1 가 2 , 2 1

(11-21)

가 , n 1 n 1
 , 1 , n 1
 2 2 2
 n 0 1 2 2 1

(11-22)

가, , n 1 1
 , 1 , n 1
 가 1 2 , 0 1 2
 . n +1 , 2 -1 , n

(11-23)

$$0.4 \leq |(Ph/Pf)-2| \leq 25$$

$$0.8 \leq |(Ph/Pf)-2| \leq 6 , 1.2 \leq |(Ph/Pf)-2| \leq 2 .$$

(11-24)

Ph , , Pf , , 1/2 /
 가 가 (light flux) , , /
 가 1/2 , 1/2
 (11-25)

2 2 (no-aberratio
 n) , (flare)
 (11-26)

1 1 1 ,
 0.07 rms 1 1
 1 1 1
 0.07 rms 2 1 2
 , NA1 NA2 , NA1 NA2 0.07 rms 1
 (11-27)

2 2 2 , 2
 0.07 rms 2 2 2 , 2 0.07 rms
 1 1 2 1 2 , NA1 NA2
 , NA1 NA2 0.07 rms 2 1
 가 가
 (11-28)

1 1
 2 2 , 2
 (dichroic filter) 1
 가 ,
 (11-29)
 (under) 가 (over)
 (spherical aberration diagram)

, 가 가 . .
 (11-30)

, 1 0.07 rms 1 1 ,
 , 1 0.07 rms 1 , 1 1 1
 . 1 , NA1 NA2 0.07 rms , NA1 NA2 2 1 2 2 ,

(11-31)

2 , 2 0.07 rms 2 2 , 2 2
 , 2 0.07 rms , 2 2
 1 2 1 1 , . , NA1 NA2 1 0.07 rms
 2 , NA2 NA1

(11-32)

가 NA1 NA2 NA2 NA1 , 1
 2 1 2 1

(11-33)

, , 1 2 , . , .

(11-34)

, 가 ,
 1 2 0.07 rms
 NA1=NA2 , .

(11-35)

, 1 2 /
 . . , 가 ,
 / , ,
 , CD, CD-R, CD-RM, DVD, DVD-R

AM, LD, MD, MO

(11-36)

가 가 , 1 2
 , 가 , ,

(11-37)

100 nm 200 nm 80 nm 400 nm
 350-480 nm 760-820 nm, 630-670 nm
 4 3 4 3 4 4 3
 , 3 4 n

(11-38)

2 1 , 2 1
 - $2 / (2NA_2^2)$ Z $2 / (2NA_2^2)$

2 2 ,
 NA₂ 2 2

(11-39)

가 , t₂ > t₁ 2 > 1

$$0.2 \times 10^{-6} / < WSA3 \cdot 1 / \{ f \cdot (NA1)^4 \cdot T \} < 2.2 \times 10^{-6} /$$

NA1 : 1 1

1 : 1

f1 : 1

T :

WSA3 (1rms): 1
 3

(11-40)

1 (non-collimated) 1
 , 2 가 2

(11-41)

1 (collimated light flux) 1
 , 2 2
 , 1 1
 , 2 2

1 2 (m1) 2 (m2) 1 0-1
 /15 . , 1, 2 CD DVD 1 0-1/18 . 2> 1 t2>t1 , m1 . ,
 1 . , 1, 2 2, 1 1 2 t1, 2 t2 . ,
 , . 1 , 47a 47b 2 , 47b 47c 가

(11-42)

(divergence changing m
 eans) 1 2
 , .
 , 1 2 , 1
 2 2 , 1
 , 1< 2 t1<t2 , 1 2 2
 , 1 , 0.61<NA1<0.66 , 1
 가 1 , 1 1 1
 2 2 , t1 1 , t2 2 NA1 .
 1 , 1< 2 t1<t2 , 2 1 2
 , 1 , 1 2
 , 1 , 2 1 , 2 2
 , 1 , 1 2 2

(11-43)

2 , 2 1 2 . , 1 1 , 2

(11-44)

2 1 2 (unitize). , 1
 . , 1 2 , 2 , 1 2
 , 1 2 , NA1>NA2
 1 , NA1<NA2 2
 NA1 , 2 1
 NA2

, WD1 1 (working distance) , WD
 2가 2 , |WD1-WD2| 0.29 mm
 , 1 2
 0 , t1<t2 1< 2 WD1 WD2
 , 가 DVD 2 가 CD
 , 가 47b 47c 가 47a 47d

, NA1 NA2 , 1 2 , NA2 가 0.0
 2 2
 7 2 rms), :

0.66 2/NA2 w 1.15 2/NA2

w>0.83 2/NA1

1: 1

2: 2

NA1: 1 1

NA2: 2 2

w: 2 13.5%

(w)

0.74 2/NA2 w 0.98 2/NA2

가 , 가 ,
 가

(11-45)

* , S ,
 (overshoot) 0 20%

1 1 , 2가 2 , t1 1 t2가
 2 , NA1 1 2
 NA2가 2 2 , n

+1 , 가 ,

1< 2

t1<t2

NA1>NA2(NA1>NA2>0.5×NA1)

가 2

2 , 2 n , 가 2 112

NA2 가 . NA=0.45 , 가 , NA=0.5 , 가
 가 , 1 1
 NA1 가 n 가 0.07 rms가 1 ,
 2 2 2 가
 n 가 0.07 rms가 .
 , 가 2 , 가 2
 2 n , 27

가 , NA1 20 μm NA2 10
 μm , NA1 가 50 μm , NA2 가 2
 μm

(11-46)

2 , DVD가 1 CD가
 가 ,

0.55mm < t1 < 0.65mm

1.1mm < t2 < 1.3mm

630nm < λ < 670nm

760nm < λ < 820nm

0.55 < NA1 < 0.68

0.40 < NA2 < 0.55

가 , NA2 19 21
 , 35 33

(11-47)

가 , 1=650nm, t1=0.6mm NA1=0.6 가 ,
 가 1 1 1
 0.88 μm 0.91 μm .
 , 1=650nm, t1=0.6mm NA1=0.65 , 가 1
 1 1
 0.81 μm 0.84 μm .
 가 가 , NA=0.4 10 μm
 70 μm . 20 50 μm .
 , 가
 2 CD , NA2 0.5 , DVD
 1 , NA1 0.65 .

t1=0.6mm

$t_2=1.2\text{mm}$

$\lambda_1=650\text{nm}$

$\lambda_2=780\text{nm}$

$NA_1=0.6$

$NA_2=0.45$

(11-48)

$$\dots, n \dots -1 \dots$$

$\lambda_1 < \lambda_2$

$t_1 > t_2$

(11-49)

VD-RAM/DVD/CD-R/CD, DVD/CD, DVD/CD/CD-R, D
 DVD/CD/CD-RW, DVD/LD, CD/
 가

가
 1
 2

가
 가
 가
 가

, 1 가
 2 가

2 가
 2 가
 1 가

, 1/4, 2 가

, CD DVD

MD, LD, MO CD, DVD, DVD-ROM, DVD-RAM, DVD-R, DVD-RW CD, CD-R, CD-RW, CD DVD, DVD-ROM DVD, 가

가 DVD 2 635 nm 가 2 650 nm 가 가 CD 780 nm 가 / 3 400 nm 가 , 4 가 2 가 , 3 , 400 nm 780 nm 400 nm 650 nm

가 가 ±10 nm 가 가 가 가 가

(relief)가 가 (annular band)

0 , ±1 , ±2 , ... (+1)

100%가 가 2 가

780 nm 650 nm

()가 가 가

100%

3 2 가

3 , 2 가

4 1 . 1 +1

-1 4 , 1 , 1

5 가 가 (refraction power) 가
 . 5 ()가 가 (b)

laze) 가

5 , 가 가 ,

6

7 가 2 가

8 가 2 2

가

9 가 가

9 , 가 가

10 가 가

10 , 가 가 CD 가 DVD ,

가 , 가

가 , 가

11 가 , 가
 11
 가 가

6-242373 ,

12 0 가 2

	12	가 2	2	가	
0	13				가 2
	14				
	13				가 2
4	14		2	가	0
	15	가 1	가	0.07 rms	가
	15	가	가		0.07 rms
	16		2	(1) ±10nm	0.07 1 rms
	16	1 ±10nm		가	
가	17	가	0.07 2 rms	가 2	가 2
가	17	2 가	0.07 2 rms	가	(2 가
	18		2 가	가	가
0.10	18	2 가	0.10 2 rms	가	(2 가
가 NA2	19	가	NA1>NA2>0.5NA1	가 NA1	2 가
	20		2	가	
	20	가	2	가	2 가
	21		2	가	

22 2 2 가

23 2 가 NA 3 3
 가 - $3/(2NA^2)$ + $3/(2NA^2)$ 가

23 가

24 2 가 가

25 2 3

26 3 1, 2 3(1< 2< 3) 0.60 NA1,
 0.60 NA2, 0.40 NA3 0.50 가 NA1, NA2 NA3

27 가

28 29 가 가

30 가

31

32 (Vd)가 50

32 가 2 가 2

33 가 33 34 가 가 33

35 가 35 가

36 2 가 80 nm

37 2 가 400 nm

38 2 가 100 nm , 200 nm

39 2 가 10%

40 2 가 30%

41 2 가 50%

42 2 가
70%

43 2 가

44 2 가
가 0.07 rms

45

46 1 가 ; 2 ;
2 2 가 ; 2 ;

47 1 가 ; 2 ;
가 , 2 2

48 가 가 46 47 가

49 가 가 2 2 가

50 가 2 2 가
가 가 2

51 가 가 ,

52 가 ,

53 가 가 , 2
0.07 2 rms

54 가 가 , 2
0.07 2 rms

55 2 (wave front abberation)가 1 ± 10 nm
0.07 1 rms

56 2 2 2
가 2 0.07 2 rms

57 2 가
0.07 2 rms

2 , 58 가 NA2 , : 가 NA1 ,
 NA1 > NA2 > 0.5 x NA1

64 , 59 , 2 , 2 , 1
 , 60 , 2 , 2
 , 61 , 2 , 2
 , 62 , 2 , 2
 , 3 (axial chromatic aberration) - $\frac{2}{3} / (2NA^2)$ 가 NA + $\frac{3}{3} / (2NA^2)$ 3
 , 가 63 , 2 , 2
 , 64 , ,
 Pf 1/2 , Ph
 0.4 (Ph/Pf) - 2 25
 64 , , ,
 , 가 , 0.8 (Ph/Pf) - 2 6.0 , , 가 (Ph/Pf) - 2 2.0 ,
 , 65 , 2 , 3
 , 66 , 3 , 3 , 1 ,
 2 , 3 NA1, NA2, NA3 (1 , < 2 < 3), 3 :
 0.60 NA1, 0.60 NA2, 0.40 NA3 0.50.
 , 67 , 가 ,
 , 가 2 68 , (aperture limitation means)
 , 69 , 2 , , , , ,
 , 가 , , 가 , , ,
 , 70 , 가 1 ,

71 가 2

72

73 가 가

74 가 가 가

75 (blazed diffraction annular band) 76 가

77 가 / / / 2 2

78 / 2 / / 2

79 2 / / / 2

80 / 2 / / 2

81 2 가 가 가 가 가 2 1

1 2 1 2 , 780 nm 635 nm 2 , 1

82 가 /

	83		1	
	84		2	가
	85		2	700 nm
	86		2	600 nm
가	87	2		
	88			
	89			
	90			
er value)	91		(over value)	가 (und
0 nm	91	1.2 mm) DVD (가 650 nm	CD (가 0.6 mm) DVD 78
		, CD	가	
on)		CD	, CD	DVD (wave moti
	92		2	80 nm
	93			가
			(axial chromatic aberration)	2
Abbe	94		2	: d > 50, d 가 80 nm
	95	2	(flare)	
	96	NA1 , 2		(open aperature) NA2 :
NA1 > NA2 > 0.5 x NA1				
	97		2	가

98 / 2 98
 가
 (root mean square, rms)
 Mareshal 0.07
 가
 가
 가 /
 0.45 가 , 650 nm , CD 0.38 780 nm
 99 2
 / 가 (99) 1
 가
 100 가 3
 101 가 2
 102 가
 103
 104
 105 가 / / /
 106 (/)
 107 (/)

가 (flare)가

108

1 1 , 2 3 가 (2 1 2 , 3)

109

1 1 , 2 3 가 (2 1 2 , 3)

가

/ 109 가

2

1 2 1

2 , 3 (under) (over) 가

110

111

1

112

가

2

113

가

2

114

가

2

115

1 , 2 , 3

116

가

가

117

2 3 / 108 - 116 / / 가 1

118

119

120

121

122

123

124

125

가 NAH1 +1

가 NAL1

NAH1 < NA1, 0

≦ NAL1 ≦ NA2

126 , 122 , 1 1
 가 t1 1 , 2 (2 > 1) 2 가 t2 (t2 > t1) 2
 NA1 , NA2 (NA2 > NA1)
 , 가 +1 , 1
 가 NAH1 , 1 가 가
 +1 , 가 NAL1 ,
 NAH1 < NA2, 0 ≅ NAL1 ≅ NA1 .
 127 , 122 가 t1 1
 1 1 , / 가 t2(t2 < t1) 2 2(2 > 1)
 NA1 , NA2(NA2
 < NA1) , 1
 가 NAH1 , 1 가
 -1 , 가 NAL1 , 가
 MAH1 < NA1, 0 NAL1 NA2 .
 128 , 122 가 t1 1
 1 1 , / 가 t2(t2 < t1) 2 2(2 > 1)
 가 NA1 , 가 NA2(NA2
 < NA1) , 1
 가 NAH1 , 1 가
 -1 , 가 NAL1 , 가
 NAH1 < NA2, 0 NAL1 NA1 .
 129 가 NA1 , 125 1 ,
 .
 130 가 NA2 , 126 2 ,
 .
 131 가 NA1 , 127 1 ,
 .
 132 가 NA2 , 128 2 ,
 .
 133 가 , 2 129 2 가 NAH
 +1 +
 가 NAL2 , 가 NA1

2
 1
 1

			1	/	
, 2				가 NAH2	/
			2		/
	134		130	2	가 NAH
2	가	,	+1		+
1	, 2			가	
1		가 NAL2		가 NAH1	/
			1	가 NA2	/
, 2			2		/
	135		131	2	가 NAH
2	가	,	-1		-
1	, 2			가	
1		가 NAL2		가 NA1	/
			1	가 NAH2	/
, 2			2		/
	136		132	2	가 NAH
2	가	,	-1		-
1	, 2			가	
1		가 NAL2		가 NAH1	/
			1	가 NA2	/
, 2			2		/
	137	가 NA1	133	1	
	0.07 rms	,		1	
가 NAH2		, 2			0.07
rms		2			
	138	가 NAH1	134	1	
	0.07 rms	,		1	
가 NA2		, 2			0.07
rms		2			
	139	가 NA1	135	1	
	0.07 rms	,		1	
가 NAH2		, 2			0.07 r
ms		2			
	140	가 NAH1	136	1	
	0.07 rms	,		1	
가 NA2		, 2			0.07
rms		2			

141 , 2	122-140 (collimator)가	, 1 , 1
142 2	141	, 1
143 , 2 , 2	129, 133 137 2	, +1 2
144 , 2 2	130, 134 138 2	, +1 2
145 , 2 , 2	131, 135 139 -1 1	, 2
146 , 2 2	132, 136 140 2	, -1 2
147 , 2 , 2	129, 133 137 -1 2	, 2
148 , 2 2 -1	130, 134 138 2	, 2 2
149 , 2 , 2	131, 135 139 +1 2	, 2
150 , 2 2 +1	132, 136 140 2	, 2 2
151 1 composing means)	129, 131, 133, 135, 137, , 2	139 (light wave
(opening limiting means)		
151 1 2	129, 131, 133, 135, 137, , 1	139 ,
153 2 (annular band filter)	151	, 1

154 1	152	2
155 2	151	1
156 1	152	2
157	122-156	가 1
158 2	122-156	가 1
159	158	1 1
160 ()가	157	1 , 2 ,
161 가	158	가 , 1 1
162 가	122-161	,
163 2	1 1 , 2(1 2) 2 , 1	
0 가 $t_2(t_2 - t_1)$	가 t_1 n (, n=m)	가 m (, m 2
164 (1 2) 1 < 2 ,	163 ($t_1 - t_2$)가 $t_1 < t_2$, m n	가 1 2 +1
165 (1 2) 1 < 2 ,	163 ($t_1 - t_2$)가 $t_1 > t_2$, m n	가 1 2 -1
166 가	163, 164 165	
167 가 $2\mu\text{m}$	122-166	1
168 (2)	m (, m 0) n (, n=m)	가 , (1) 1

2 .

169 (1, 2) 1 < 2 , 1 가
 가 t1 1 (t1 t2) t1 < t2 , m n 가 t2 2
 + 1

170 (1, 2) 1 < 2 , 1 가
 가 t1 1 (t1 t2) t1 > t2 , m n 가 t2 2
 - 1

171 가 , (1)
 1 / m (, m 0 가 ,) 가 t1
 2 / n (, n=m) 가 (2)(, 2 1)
 가 t2(, t2 t1)

172 171 (1, 2)
 1 < 2 , (t1 t2)가 t1 < t2 , m n + 1 .

173 171 (1, 2) 1
 < 2 , (t1 t2)가 t1 > t2 , m n - 1 .

174 172 가 t
 1 1 가 (1) 1 / 가 (2)(2 > 1)
 2 NA1 , 가 t2(t2 > t1) 2 가 NA2(NA2 < NA
 1) / 가 + 1 , 1
 가 NAH1 , 1 가
 + 1 가 NAL1 ,

:

NAH1 < NA1
 0 NAL1 NA2

175 172 가 t
 1 1 가 (1) 1 / 가 (2)(2 > 1)
 2 NA1 , 가 t2(t2 > t1) 2 가 NA2(NA2 > NA
 1) / 가 + 1 , 1
 가 NAH1 , 1 가
 + 1 가 NAL1 ,

:

NAH1 < NA1
 0 NAL1 NA2

176 173 가
 t1 1 가 (1) 1 / 가 (2)(2 > 1)
 2 NA1 , 가 t2(t2 < t1) 2 가 NA2(NA2 < NA
 1) / 가 - 1 , 1
 가

가 NAH1 , 1 가 가
 -1 : 가 NAL1 ,
 :
 NAH1 < NA2
 0 NAL1 NA1
 , 177 가 (1) 1 173 , 가
 t1 , 1 NA1 , 가 t2(t2<t1) 2 가 (2)(2> 1)
 2 / 가 NA2(NA2>NA
 1) , 가 -1 , 1
 가 NAH1 , 1 가
 -1 : 가 NAL1 ,
 :
 NAH1 < NA2
 0 NAL1 NA1

178 168-177 ,
 5μm ,
 179 가 2μm ,
 180 가 2μm , 가 179 , 가
 가 2μm ,
 181 168-180 ,
 182 168-180 ,
 183 168, 169, 171, 172 174
 (image) 650nm 0.6 0.6mm 가 , 780nm 0.45 1.2mm 가
 ,
 184 183
 15 ,
 185 168 184
 ,
 186 가 ,
 187 186

가 188 168 187

189 188

185 188

$$\frac{1}{2} \left(\frac{1}{t_2} - \frac{1}{t_1} \right) \quad (t_2 > t_1)$$

(back focus) fB_1 , fB_2 ($f_2 > f_1$)

fB

$$fB = fB_2 - fB_1$$

가 $fB > 0$

$$f_2^2 - f_1^2 > 0$$

(1) $f_1 < f_2$

(2) $t_1 < t_2$

(3) $nd_1 < nd_2$

가 (over)가 $nd_2 < nd_1$ (3) 가

(1)-(3) (3) (2) (1)

가 DVD (1) 650nm (2) 780nm, DVD($t_1=0.6nm$) CD($t_2=1.2mm$)

$$\frac{1}{2} \left(\frac{1}{t_2} - \frac{1}{t_1} \right) \left(\frac{1}{f_2} - \frac{1}{f_1} \right) \quad (113a)$$

1 t_1 1 t_2 (2) -1

$$\frac{1}{2} \left(\frac{1}{t_2} - \frac{1}{t_1} \right) \left(\frac{1}{f_2} - \frac{1}{f_1} \right) \left(\frac{1}{n_2} - \frac{1}{n_1} \right)$$

1} , 가 2μm , .
 2); 191 : 1 1 ; 2 2 (1
 ; 1 2
 m (, m 0), 가 t1 1
 n (, n=m), 가 t2 (t2 t1) 2
 : , 가 T() , n , -0.0002/ <
 n/ T < -0.00005/ , 1 : 가 T() , 1 (
 nm) , 0.005nm/ < 1/ T < 0.5nm/ .

191 , 가
 , 192 1 1 , 2(1 2) 2 ,
 , 1 2 1 m(
 , m 0) 가 t1 1
 n(, n = m) , 2 가 t2(t2 t1) 2
 가 , 1 , 1, 2, t1 t2 2 > 1, t2 > t1
 가 NA1 , 1(mm) 가 f1(mm) , 가 T()
 1 rms) , 3 WSA3(
 $0.2 \times 10^{-6} / < WSA3 \cdot 1 / \{f \cdot (NA1)^4 \cdot T\} < 2.2 \times 10^{-6} /$

192 , 가 , ,
 , 193 가 , 191 192 , 1 , 2
 , 194 191, 192, 193 , t1 0.55mm-0.65mm, t2
 1.1mm-1.3mm, 1 630nm-670nm, 2 760nm-820nm .

192 1 1 , 2(1 2) 2 ,
 , 1 2 1 m(
 , m 0) 가 t1 1
 n(, n = m) , 2 가 t2(t2 t1) 2
 , 1 2
 195 , ,

3
 , 196 , 195 1 2
 197 1 / 2
 1 / 2
 , 192 1 1 , 2(1 2) 2 ,
 , 1 2 1 m(
 , m 0) 가 t1 1
 n(, n = m) , 2 가 t2(t2 t1) 2
 () , 1 2 0.07 rms 2

198 , 1 2 /
 가
 , 2 199 , 1 122-156, 198 1
 2
 ht) 1)가 , , 가 , (dominant wavelength lig
 (over)() , , 가 (under)()
 , 2
 , , B , b mm

$$\Phi_B = \sum_{i=1}^{\infty} B_{2i} h_{2i}$$

$$\Phi_b = \sum_{i=1}^{\infty} b_{2i} h_{2i}$$

(mm) , b /2 B /2 , B b ,
 , 1 , 가 (notch) ,
 2
 , 가
 0.5μm = 0.0005mm , 2 (2) -0.05(2 , -
 628.3) , 0 , 1 h=0.1mm , 2 h=0.141mm

mm, 2, b2=-0.05, f=-1/(2 · b2)=10

가 0

2, 6, 8, 10, 2, 0가

()

가

t1 (

t2

가

700nm, 600nm

80nm, 100nm, 200nm, 400nm

2

가

± / (2NA²) (image side numerical aperture), NA

가 80nm, (Abbe) 가 d

< 1 >

d > 50

1 2 2

가 x

y(x < y)

fR · R + fD · D = 0, fR, fD, R, D

R = (n0 - 1)/(nx - ny)

D = 0 / (x - y)

n0, 0

z f

f=f(R- D)/(R- D)

R, D (partial variance ratio)

(1) $R = (n_x - n_z)/(n_x - n_y)$

(2) $D = (x - z)/(x - y)$

, nz z .

, 0 = x = 635nm, y = 780nm, z = 650nm 가 (Hoya Co.)
) BSC7 (d=64.2), R = 134.5, D = -4.38, R = 0.128, D = 0.103 , f = 0.18 × 10⁻³ f가

, 가 E-FD1 (d = 29.5), R = 70.5, R = 0.136
 , f = 0.44 × 10⁻³ f가 .

, f , (R - D) , D 가 R ,
 , R D , (R - D) 가 (R - D)

R 가 가 , 2 f ,
 2 R 가 (1)

, 2가 R = a + b · R + R (a, b 가 (achromatic processing)
 , 2 f 2 R (1)

(1) 가 , 가 ,
 2 가

48 가 가 가
 D), 2 가 (20) , 가 t1 1 (, DV
 3 (CD)가 , (20) 가 t1 t2

(12) (1 1 (11) (1 = 610nm - 670nm), 2
 nm), 2 = 400nm - 440nm), 3 2 (13) (3 = 740nm - 870
 (1) 가 1 , 2 , 3 가

1 (11), (12) 2 (13) , (19)
 (3) (20) (21) , (1) (22)

(22) , (18)
 (30) , (toric lens, 29) 가 , (2)

, 가 , (3) (NA 0.65) 가 , (3) (NA
 0.45) , 3 가 / , (3) (NA

(1) 가 가 , , (definite conjugation type optical system) 가 , (11, 12, 13) (1)가 , 3 가 49 , 가 49 / (40) 48 (11), (12), 1 (31), 2 (32) (23) / (40) 1 가 (11) (23) (3) (stop down) , (1) (20) (21) (22) (22) (1) (3) (23) , 1 (11) (20) 1 (31) , 1 (31) 가 , 1 (20) 2 가 , (12) (23) , 1 (11) (3), (1) 2 (23) 0) (21) (22) , (3), (1) 2 (22) (1) (3) (23) (12) (20) 2 (32) , 2 (32) 가 , 3 가 , 2 (13), 3 (33) (24)가 (24) / (41)가 , 2 (13) (20) (24) (21) , (1) (22) (19) , (1) (22) (3) (19) , 3 (24) (33) , 3 (33) 가 , 3 (20) 2 3 가 , (4) (1) 가 a 가 a b , a 가 a b , (21) (22) , 가 , 가 , (21) (22) , 2 3 (1) , 가 1 (11), (12) 2 (20) (13) (21) 가, 1 (11), 4 (3) (CD) , NA 0.45 , NA 0.45 (20) , (22) (0.07 rms) 2 3 , CD, CD-R, CD-RW, CD-Video, CD-ROM, DVD, DVD-RO M, DVD-RAM, DVD-R, DVD-RW, MD ()

AV / , /
 4 가

67 (10) 67 , 2 3 (30)
 / (20) , 가 t1 1 (DVD), 2 (
), 가 t2 3 (CD)
 , t1 = 0.6mm , t2 = 1.2mm

(10) , 1 1 (11) (1 = 610nm - 670nm), 2
 (12) (2 = 400nm - 440nm), 3 2 (13)(3 = 740nm - 870nm),
 (1) 가 1 , 2 , 3 가

(20) (5) , 1 (11), (12) 2 (13) , , (2)
 (21) (22) , (2)
 (5) (1) .

(5)가 (1) , (4) , a 가 , , a
 , b , , a 가
 , 가 a , b , , 가
 , , (21) (22) .

가 DVD-RAM , 1 (11), (12) 2 (13)
 가 , 1 가 , 1 , (1) ,
 , 3 가

(12) 2 가 (13) , (1) (20) 1 (11), (21)
 , 4 , NA 0.45 , NA 0.45 가 , 3 (CD)
 , NA 0.45 , NA 0.45 , NA 0.45
 , (20) , (0.07 rms)

(3) (NA 0.65) 가 , ,
 (NA 0.45) , 3 가 / (67)
 3 (11, 12, 13) ()가 , 가

5 가 , 가 2
 , 4 ,

가 (0.07 rms) 가 (20) (22)

6 가

(CD) (DVD) 2 (3)

1.2mm (21) 0.6mm (21)

NA NA 0.5 NA 0.45 3 /

07 1, 2, 3 (1 < 2 < 3) NA1, NA2, NA3 RMS NA1 / 0. NA2 0.07 2 NA3 0.07 3 0.

3 NA NA 4 (flare)

4 6 3 , CD, CD-R, CD-RW, C D-Video, CD-ROM, DVD, DVD-ROM, DVD-RAM, DVD-R, DVD-RW, MD 2 , AV 가

[1 8]

1 8 가 1

$$z = \frac{h_2 / R_o}{1 + \sqrt{1 - (1+k)(h/R_o)_2}} + \sum_{i=2}^{\infty} A_{2i} h_{2i}$$

), Z, h, k (conical) (A, B, 1, 2i) (positive)

1-3, 6-8 mm

1 2

k=-0.10721 k=-11.653

A4=-0.0032315 A4=0.0038456

A6=-0.00058160 A6=-0.020800

A8=-4.6316×10⁻⁵ A8=0.0078684

A10=-3.79858×10⁻⁵ A10=-0.0019431

A12=-6.0308×10⁻⁶ A12=0.00024343

B2=-96.766

B4=-2.9950

B6=2.1306

B8=-0.12614

B10=-0.095285

2, 3

m, 2 3 =405nm =635nm 2
 7 8 9 10 11 12 =405nm 635nm
 0.60
 =405nm 635nm

=405nm =635nm 3 13 14
 15 16 3 =405nm 635nm 0.60
 17 18 3 =405nm 635nm

2 3 , =405nm =635nm 0.6mm , NA=0.6 ,
 , 0.03mm 가 .

2 3 .

2

₁ =405nm, f1=3.23, NA1=0.60 , .
₂ =635nm, f2=3.34, NA2=0.60 , .

, +1 , 1 , +1 . , 2

	R	d ₁	d ₂	n ₁	n ₂	d	nd
1(1 ·)	2.128	2.2	2.2	1.55682	1.53829	56	1.5405
2(2)	-7.359	1.0	1.0				
3		0.6	0.6	1.62230	1.58139	30	1.585
4							

(1 λ₁=405nm , 2 λ₂=635nm , d nd d .)

1 2

k=-0.15079 k=-3.8288

A4=-0.0021230 A4=0.0036962

A6=-0.00076528 A6=-0.020858

A8=-8.84957×10⁻⁵ A8=0.0079732

A10=-3.49803×10⁻⁵ A10=-0.0018713

A12=-2.38916×10⁻⁶ A12=0.00022504

B2=0.0

B4=-6.7169

B6=2.0791

B8=-0.31970

B10=0.00016708

3

λ₁=405nm, f1=3.31, NA1=0.60 , .

λ₂=635nm, f2=3.34, NA2=0.60 , .

, +1 , 1 , +1 . , 2

[3]

	R	d ₁	d ₂	n ₁	n ₂	d	nd
1(1 ·)	2.300	2.2	2.2	1.55682	1.53829	56	1.5404
2(2)	-7.359	1.0	1.0				
3		0.6	0.6	1.62230	1.58139	30	1.585

4							
---	--	--	--	--	--	--	--

(1 $\lambda_1=405\text{nm}$, 2 $\lambda_2=635\text{nm}$, d nd d .)

1 2

k=-0.19029 k=6.4430

A4=0.00030538 A4=0.037045

A6=-0.0010619 A6=-0.021474

A8=-7.5747×10⁻⁵ A8=0.0078175

A10=-6.7599×10⁻⁵ A10=-0.0016064

A12=-3.3788×10⁻⁶ A12=0.00014332

B2=-96.766

B4=-2.9950

B6=-0.25560

B8=-0.08789

B10=0.014562

4, 5

20 4 5 4 =635nm, 650nm, 780nm 19 0.50
 22 5 21 5 =635nm, 650nm, 780nm 0.50

20 22 (slippage) 4 5 =650nm , =635nm 가 =780nm

4 5

4

$\lambda_1=635\text{nm}$, f1=3.40, NA1=0.50 , .

$\lambda_2=780\text{nm}$, f2=3.41, NA2=0.50 , .

, +1 , 1 , +1 . , 2

[4]

	R	d ₁	d ₂	n ₁	n ₂	d	nd
1(1 .)	2.442	1.90	1.90	1.5417	1.5373	56	1.5438
2(2)	-5.990	1.68	1.68				
3		1.20	1.20	1.5790	1.5708	30	1.5830
4							

(1 λ₁=635nm , 2 λ₂=780nm , d nd d .)

1 2

k=-0.53245 k=7.3988

A4=0.24033×10⁻² A4=0.90408×10⁻²

A6=-0.91472×10⁻³ A6=-0.18704×10⁻²

A8=0.15590×10⁻⁴ A8=-0.47368×10⁻³

A10=-0.11131×10⁻³ A10=0.16891×10⁻³

b2=-0.36764×10⁻²

b4=-0.91727×10⁻⁴

b6=-0.34903×10⁻⁴

b8=0.77485×10⁻⁵

b10=-0.15750×10⁻⁵

5

λ₁=635nm, f1=3.40, NA1=0.50 , .

λ₂=780nm, f2=3.40, NA2=0.50 , .

, +1 , 1 , +1 . , 2

[5]

	R	d ₁	d ₂	n ₁	n ₂	d	nd
1(1 .)	2.160	1.80	1.80	1.5417	1.5373	56	1.5438
2(2)	-11.681	1.64	1.64				

3		1.20	1.20	1.5790	1.5708	30	1.5830
4							

($\lambda_1 = 635\text{nm}$, $\lambda_2 = 780\text{nm}$, d n_d d .)

1 2

$k = -0.17006$ $k = -40.782$

$A_4 = -0.30563 \times 10^{-2}$ $A_4 = 0.73447 \times 10^{-2}$

$A_6 = -0.45119 \times 10^{-3}$ $A_6 = 0.85177 \times 10^{-3}$

$A_8 = 0.58811 \times 10^{-5}$ $A_8 = -0.82795 \times 10^{-3}$

$A_{10} = -0.13002 \times 10^{-1}$ $A_{10} = 0.23029 \times 10^{-3}$

$b_2 = -0.74461 \times 10^{-2}$

$b_4 = 0.11193 \times 10^{-2}$

$b_6 = -0.85257 \times 10^{-3}$

$b_8 = 0.50517 \times 10^{-3}$

$b_{10} = -0.11242 \times 10^{-3}$

6 8

23, 30, 37, 6, 8, 24, 31, 38, 6, 8, =650nm, =780nm(NA=0.5), 6, 8

=650 ± 10nm, 가 0.60, 26, 33, 40, 6, 8, =780 ± 10nm, 가 0.50, =780nm, 가 0.60, 27, 34, 41, 6, 8

, 28, 35, 42, =650nm, 6, 8, rms, 29, 36, 43, =780nm, 6, 8, rms, 44, 45, 46, 6, 8, 2

6, 8, =650nm, NA 0.60, NA 0.50-0.60, 가, 가, =780nm, 6, 8, STO, IMA

6

$\lambda = 650\text{nm}$, $f = 3.33$, $NA = 0.60$, .
 $\lambda = 780\text{nm}$, $f = 3.37$, $NA = 0.50(NA = 0.60)$, . 780nm
 13.5% w , $w = 1.20\mu\text{m}$.
 , 44 , 1 2 가 1/2
 , -1 , +1 가
 1/2 , -1 + 1
 가 .
 , 27 , 2 $NA1 = 0.6$ +29 μm
 , $NA2 = 0.5$ +1 μm . $NA = 0.4$ 14 μm .

[6]

	R	d	n($\lambda = 650\text{nm}$)	n($\lambda = 780\text{nm}$)
OBJ				
		0.0		
2(1)	2.057515	2.2	1.54113	1.53728
3(2)	-7.8997731	1.0287		
4		d4	1.57789	1.57079
5		d5		
IMA				
		d4		d5
$\lambda = 650\text{nm}$		0.6		0.7500
$\lambda = 780\text{nm}$		1.2		0.35

1 2

$k = -1.7952$ $k = -3.452929$

$A4 = 0.51919725 \times 10^{-2}$ $A4 = 0.15591292 \times 10^{-1}$

$A6 = 0.10988861 \times 10^{-2}$ $A6 = -0.44528738 \times 10^{-2}$

$A8 = -0.44386519 \times 10^{-3}$ $A8 = 0.65423404 \times 10^{-3}$

$A10 = 5.4053137 \times 10^{-5}$ $A10 = -4.7679992 \times 10^{-5}$

$B2 = 29.443104$

$B4 = -14.403683$

$B6 = 3.9425951$

B8= -2.1471955

B10=0.31859248

7

=650nm, f=3.33, NA=0.60 , .
 * =780nm, f=3.37, NA=0.50(NA=0.60) , .
 , 45 , , +1 1 2 +1
 , 가 .

[7]

	R	d	n(=650nm)	n(=780nm)
OBJ		d0		
		0.0		
2(1)	2.145844	2.2	1.54113	1.53728
3(2)	-7.706496	1.0326		
4		d4	1.57789	1.57079
5		d5		
IMA				
		d	d4	d5
=650nm			0.60	0.70
=780nm		64.5	1.20	0.35

1 2

k= -1.801329 k= -8.871647

A4=0.1615422×10⁻¹ A4=0.1492511×10⁻¹

A6= -0.4937969×10⁻³ A6= -0.4447445×10⁻²

A8=0.11038322×10⁻³ A8=0.60067143×10⁻³

A10= -2.1823306×10⁻⁵ A10= -3.4684206×10⁻⁵

B2= -17.150237

B4= -4.1227045

B6=1.1902249

B8= -0.26202222

B10=0.018845315

8

=650nm, f=3.33, NA=0.60 , .
 * =780nm, f=3.35, NA=0.50(NA=0.60) , . w(780nm
 13.5%)=1.27μm
 , 46 , 1 2 -1
 , +1
 , 가 , -1 +1
 , 41 , 2 NA1=0.6 +68μm
 , NA2=0.5 +9μm
 , NA=0.4 +61μm .

[8]

	R	d	n(=650nm)	n(=780nm)
OBJ		d0		
		0.0		
2(1)	2.10598	2.2	1.54113	1.53728
3(2)	-7.90392	1.0281		
4		d4	1.57789	1.57079
5		d5		
IMA				
		d4		d5
=650nm		0.6		0.70
=780nm		1.2		0.34

1 2

k=-1.2532 k=-9.151362

A4=0.1007×10⁻¹ A4=0.133327×10⁻¹

A6=-0.85849×10⁻³ A6=-0.378682×10⁻²

A8=-0.15773×10⁻⁵ A8=0.3001×10⁻³

A10=3.2855×10⁻⁵ A10=4.02221×10⁻⁶

B2=3.4251×10⁻²¹

B4=0.0763977

B6= - 5.5386

B8=0.05938

B10=0.2224

(fluctuation) 6 8

± 2- ± 3nm , ± 2nm , (mode hop)

2nm

2 가 , 2

() 가 , 6

10nm , 640nm , 660nm , 6 , 650nm

가 0.001 rms , 6 , 0.035 rms , 7

가 , 가 , 10nm ()

가 가 , ()

가 30 , 가 30 , 6nm , 가 , ,

가 , 6 2 , 가 30 , 0.003-0.004 , ,

가 , 가 , 가 , 6 , 7 가 ,

30 가 0.035 rms , 가 , 가 , 6

가 , 가 , 가 , 가 , 2 가 2

가 , / , rms 가 0.07 가 ,

가 , 가 , 가 , 가 , 가 ,

가 , 가 , 가 , 가 , 가 ,

005/ , , 25 , -0.0001/ , -0.0002/ 가 -0.00

0.05nm/ 0.5nm/ , , 25

rms 0.07 , 가 , 가 , 가 , 가 ,

가 -0.0002/ , < n/ T < 0.5nm/ (n T())

가 0.05nm/ < 1/ T < 0.5nm/ (1 T)

가 , 가 , 가 , 가 , 가 ,

T() f(mm) 3 WSA3(rms) ,
 NA 4 (mm) .

(a1) $WSA3 = k \cdot (NA)^4 \cdot f \cdot T$

0.6 , k 3.36mm MOC/GRIN'97 Techni cal Digest C5 p40-p43, 'The Temperature characteristics of a new optical system with quasi-finite conjugate plastic objective for high density optical disk use' 650nm

DVD 30 WSA3 0.045 rms 가 , k=2.2x10⁻⁶ , (a1) 가 ,

DVD / 2가 , k / , k , k , 가 , 6 , 2 , k , k , 가

가 k=2.2x10⁻⁶ / k=0.4x10⁻⁶ / 가

k 0.3<k<2.2 가 (a1)

(a2) $k = WSA3 \cdot \{f \cdot (NA1)^4 \cdot T(NA)\}$

(a3) $0.3 \times 10^{-6} / < WSA3 \cdot \{f \cdot (NA1)^4 \cdot T\} < 2.2 \times 10^{-6} /$

(a3) , k 가 , ,

8 , 780 nm 6 , 660 nm , 650 nm 8 ± 10 nm , 0.020 rms , 0.07 rms가 , 2가 . 640 nm

(diffraction power) 가 47 , 가 47a 47b

가 , 47c , 6 , 가

8 , 2 가 , 4

7d 가 가

47c , 가 가 47d , 가

9 (a3) , 9 2 ,
 10 2 3 . 9 10 ,
 (a1) B .

50 51 =650 nm =780 nm 9 . 52 =650 nm
 0.60 . 53 54 =780 nm
 0.45 0.60 . 55 56
 =650 nm =780 nm 10 . 61 =650 nm =400
 nm 10 0.65 . 62 63 =7
 80 nm 10 0.45 0.65 . 64-
 66 =650 nm, =400 nm, =780 nm 10 .

9 10 , , NA 0.45 780 nm /

9 10 .

9 10 , r , d , n
 , v , d (=587.6 nm) vd () .

2 .

9

f = 3.33 NA 0.60 -0.194 (=650 nm)

f = 3.25 NA 0.45 (NA 0.60) -0.195 (=780 nm)

[9a]

	r	d	n	n	nd vd ()
	.	20.0			
	.	0.0			
2 (1 .		2.2	1.53771	1.5388	1.5404 56.0
2 (2)		1.7467	1.58030	1.57346	1.585 29.9
4	.	d4			
5	.	d5			
	.				

[9b]

	d4	d5
= 650 nm	0.6	0.7500
= 780 nm	1.2	0.3964

1 k = -0.1295292

$$A4 = -0.45445253$$

$$A8 = -0.00011777995$$

$$A10 = -5.3843777 \times 10^{-5}$$

$$A12 = -9.0807729 \times 10^{-6}$$

$$1 \ B2 = 0$$

$$B4 = -7.6489594$$

$$B6 = 0.9933123$$

$$B8 = -0.28305522$$

$$B10 = 0.011289605$$

$$2$$

$$A4 = 0.019003845$$

$$A6 = -0.010002187$$

$$A8 = 0.004087239$$

$$A10 = -0.00085994626$$

$$A12 = 7.5491556 \times 10^{-5}$$

$$10$$

$$f = 3.31$$

$$NA = 0.65 \quad -0.203 \quad (\quad = 650 \text{ nm}$$

)

$$f = 3.14$$

$$NA \ 0.65 \quad -0.190 \quad (\quad = 400 \text{ nm}$$

)

$$f = 3.34$$

$$NA \ 0.65 \quad -0.205 \quad (\quad = 780 \text{ nm}$$

)

[10a]

	r	d	n	n	n (=780 nm)
		20.0			

		0.0			
2 (1 · 1	2.45035 9	2.2	1.87707	1.92261	1.86890
3 (2 2)	9.10834 8	1.4503	1.58030	1.62441	1.57346
4		d4			
5		d5			

[10b]

	= 400 nm	= 650 nm	= 780 nm
d4	0.6	0.6	1.2
d4	0.5540	0.7500	0.4097

$$1 k = -0.08796008$$

$$A4 = -0.010351744$$

$$A6 = 0.0015514472$$

$$A8 = -0.00043894535$$

$$A10 = 5.481801 \times 10^{-5}$$

$$A12 = -4.2588508 \times 10^{-6}$$

$$1 B2 = 0$$

$$B4 = -61.351934$$

$$B6 = 5.9668445$$

$$B8 = -1.2923244$$

$$B10 = 0.041773541$$

$$2 k = -302.6352$$

$$A4 = 0.002$$

$$A6 = -0.0014$$

$$A8 = 0.0042$$

$$A10 = -0.0022$$

$$A12 = 0.0004$$

$2 B_2 = 0$

$B_4 = 341.19136$

$B_6 = -124.16233$

$B_8 = 49.877242$

$B_{10} = -5.9599182$

, 10 가 3 .

11-14

11-14 (a3) 14 (a2) 11-13 , b

B mm .

11-14 , 1 (DVD) 650 nm , 2

() 400 nm , 1 2

(t1) 0.6 mm . t1 1.2 mm (t2) 3

(CD) 780 nm . 400 nm, 650 nm, 780 nm

NA 0.65, 0.65, 0.5 가 .

11

11 4 , 가 .

68-70 =650 nm 11 . 71 72 =

650 nm =400 nm 0.65 11 . 73 74 =

=780 nm 0.45 0.65 11 . 75

-77 =650 nm, =400 nm, =780 nm 11 .

11 가 . 11 , r , d .

, n .

11

f = 3.33 NA 0.65 (=650 nm)

f = 3.15 NA 0.65 (=400 nm)

F = 3.37 NA 0.45 (=780 nm)

(NA 0.65)

[11a]

	r	d	n (=650 nm)	n (=400 nm)	n (=780 nm)
		0.0			
2 (1 1	2.17730 3	2.2	1.80256	1.84480	1.79498
		0.6985			

3 (2 2)	6.45731 5				
4		d4	1.58030	1.62441	1.57346
5		d5			

[11b]

	=650 nm	= 400 nm	= 780 nm
d4	0.6	0.6	1.2
d4	0.7500	0.6288	0.3995

$$1 k = -0.1847301$$

$$A4 = -0.0090859227$$

$$A6 = 0.0016821871$$

$$A8 = -0.0071180761$$

$$A10 = 0.00012406905$$

$$A12 = -1.4004589 \times 10^{-5}$$

$$1 B2 = 0$$

$$B4 = -69.824562$$

$$B6 = 0.35641549$$

$$B8 = 0.6877372$$

$$B10 = -0.18333885$$

$$2 k = -186.4056$$

$$A4 = 0.002$$

$$A6 = -0.0014$$

$$A8 = 0.0042$$

$$A10 = -0.0022$$

$$A12 = 0.0004$$

$$2 B2 = 0$$

$$B4 = 745.72117$$

B6 = -334.75078

B8 = 81.232224

B10 = -5.3410176

11 (12) 3 ,
 , 가 . 74 ,
 NA 0.45 3 .

12

12

78-80 =650 nm, =400 nm, =780 nm 12
 81 82 =650 nm =400 nm 0.65 12
 . 83 84 =780 nm 0.45 0.65 12
 . 85-87 =650 nm, =400 nm, =780 nm 12

12 가 .

12

f = 3.31

NA = 0.65 -0.203 (= 650 nm)

f = 3.14

NA 0.65 -0.190 (= 400 nm)

f = 3.34

NA 0.65 -0.205 (= 780 nm)
 (NA 0.65))

[12a]

	r	d	n (=650 nm)	n (=400 nm)	n (=780 nm)
		20.0			
		0.0			
2 (1 . 1	2.45035 9	2.2	1.87707	1.92261	1.86890
3 (2 2)	9.10834 8	1.4503			

4		d4	1.58030	1.62441	1.57346
5		d5			

[12b]

	=650 nm	= 400 nm	= 780 nm
d4	0.6	0.6	1.2
d4	0.7500	0.5540	0.4097

$$1 \text{ k} = -0.08796008$$

$$A4 = -0.010351744$$

$$A6 = 0.0015514472$$

$$A8 = -0.00043894535$$

$$A10 = 5.481801 \times 10^{-5}$$

$$A12 = -4.2588508 \times 10^{-6}$$

$$1 \text{ B2} = 0$$

$$B4 = -61.351934$$

$$B6 = 5.9668445$$

$$B8 = -1.2923244$$

$$B10 = 0.041773541$$

$$2 \text{ k} = -302.6352$$

$$A4 = 0.002$$

$$A6 = -0.0014$$

$$A8 = 0.0042$$

$$A10 = -0.0022$$

$$A12 = 0.0004$$

$$2 \text{ B2} = 0$$

$$B4 = 341.19136$$

$$B6 = -124.16233$$

B8 = 49.877242

B10 = -5.9599182

12 3 , 가 .
 84 , NA 0.45 3 .
 13
 13 4 , ,
 88 90 =650nm, =400nm, =780nm 13 91
 92 =650nm, =400nm 0.60 13 93
 94 =780nm 0.45 0.60 13
 95 97 =650nm, =400nm, =780nm 13
 13 가 .
 13
 f=3.31 NA 0.60 (=650nm)
 f=3.14 NA 0.60 (=400nm)
 f=3.34 NA 0.45 (=780nm)

(NA 0.60)

[13a]

	r	d	n (=650nm)	n (=400nm)	n (=780nm)
	∞	0.0			
2(1 1)	2.016831	2.2	1.53771	1.55765	1.53388
3(2 2)	-12.04304	0.7555			
4	∞	d4	1.58030	1.62441	1.57346
5	∞	d5			
	∞				

[13b]

	=650nm	=400nm	=780nm
d4	0.6	0.6	1.2
d4	0.7500	0.7500	0.3409

$$1 = -0.3363369$$

$$A_4 = -0.0025421455$$

$$A_6 = -0.0010660122$$

$$A_8 = 4.7189743 \times 10^{-5}$$

$$A_{10} = 1.5406396 \times 10^{-6}$$

$$A_{12} = -7.0004876 \times 10^{-6}$$

$$1 B_2 = -177.66083$$

$$B_4 = -46.296284$$

$$B_6 = -6.8014831$$

$$B_8 = 1.6606499$$

$$B_{10} = -0.39075825$$

$$2 = 43.44262$$

$$A_4 = 0.002$$

$$A_6 = -0.0014$$

$$A_8 = 0.0042$$

$$A_{10} = -0.0022$$

$$A_{12} = 0.0004$$

$$2 B_2 = 241.52445$$

$$B_4 = 402.41974$$

$$B_6 = -191.87213$$

$$B_8 = 64.779696$$

$$B_{10} = -8.6741764$$

가 . 94
가 .

NA 0.45

3

14

14 6
780nm

400nm, 650nm

98 =400nm 14 =650nm ± 10nm, =780nm ± 10nm 0.65 14 99 101 =400nm ± 10nm,

14 가

14

f= NA 0.65 (=650nm)

f= NA 0.65 (=400nm)

f= NA 0.45 (=780nm)

(NA 0.65)

[14a]

	r	d	n (=650nm)	n (=400nm)	n (=780nm)
	∞	d0			
	∞	0			
2(1)	2.15759	2.400	1.561	1.541	1.537
3(2)		0.976			
4	∞	d4	1.622	1.578	1.571
5	∞	d5			
	∞				

[14b]

	=400nm	=650nm	=780nm
d0	∞	∞	75.17
d4	0.6	0.6	1.2
d5	0.649	0.733	0.532
	3.33	3.44	3.46

1 = -2.0080

A₄ = 0.18168 × 10⁻¹

A₆ = -0.91791 × 10⁻³

A₈ = 0.16455 × 10⁻³

A₁₀ = -0.11115 × 10⁻⁴

b₂ = -0.51589 × 10⁻³

가 1 가 DVD(650nm) , 2 가 CD(780nm) 1
 가 (400nm) , 2 가 DVD(650nm) 가
 , , (aperture regulating means)
 , ,
 가 15, 16, 17 18 7
 가 0.07 rms
 .
 15
 118 15 () 119
 15 ()=640, 650, 660nm 0.06
 120 15 , 가 118
 . 121 120 =770, 780, 790nm 0.60
 .
 15 , NA 0.60 119 =650nm
 가 =780nm 120 121 , =780nm NA 0.60
 0.45 .
 , 15 1, 6, 8 780nm
 , 650nm (NA 0.60)
 .
 15
 =650nm ,
 f=3.33, NA=0.60, ()
 =780nm ,
 f=3.38, NA=0.60,

[15a]

	R	d	n(=650nm)	n(=780nm)
OBJ				
		0.0		
2(1)	2.06085	2.2	1.54113	1.53728
3(2)	-6.98986	1.059		
4		d4	1.57787	1.57084
5		d5		

[15b]

	d4	d5
=650nm	0.6	0.700
=780nm	1.2	0.364

1

= -1.0358

$A_4 = 4.8632 \times 10^{-3}$

$A_6 = 5.3832 \times 10^{-4}$

$A_6 = -1.5773 \times 10^{-4}$

$A_{10} = 3.8683 \times 10^{-7}$

2

= -9.256352

$A_4 = 1.5887 \times 10^{-2}$

$A_6 = -5.97422 \times 10^{-3}$

$A_6 = 1.11613 \times 10^{-3}$

$A_{10} = -9.39682 \times 10^{-5}$

(650nm)

$b_2 = 6.000 \times 10^{-3}$

$b_4 = -1.317 \times 10^{-3}$

$b_6 = 1.5274 \times 10^{-4}$

$b_8 = -6.5757 \times 10^{-5}$

$b_{10} = 6.2211 \times 10^{-6}$

16

122 16 ()=640, 650, 660nm () 123
 16 ()=640, 650, 660nm 0.60 12
 4 16 , =770, 780, 790nm 122 0.60
 125 124

16 , NA 0.60 123 =650nm
 가 =780nm 124 125 , , =780nm , NA 0.60 0.45

16, 650nm, 1,68 (NA 0.60), 780nm, NA 0.6, 가, (pa)
 axial power of diffraction)

16

=650nm

f=3.33,

NA=0.60,

=780nm

f=3.36,

NA=0.60,

[16a]

	R	d	n(=650nm)	n(=780nm)
OBJ				
		0.0		
2(1)	2.09216	2.200	1.54113	1.53728
3(2)	-7.49521	1.024		
4		d4	1.57787	1.57084
5		d5		

[16b]

	d4	d5
=650nm	0.6	0.699
=780nm	1.2	0.345

1

= -1.1331

$A_4 = 4.5375 \times 10^{-3}$

$A_6 = 1.2964 \times 10^{-3}$

$A_6 = -3.6164 \times 10^{-4}$

$A_{10} = 2.0765 \times 10^{-5}$

2

$K = -4.356298$

$A_4 = 1.57427 \times 10^{-2}$

$A_6 = -4.91198 \times 10^{-3}$

$A_8 = 7.72605 \times 10^{-4}$

$A_{10} = -5.75456 \times 10^{-5}$

(Diffraction surface coefficient)(650nm)

$b_2 = 2.1665 \times 10^{-3}$

$*b_4 = -2.0272 \times 10^{-3}$

$b_6 = 5.5178 \times 10^{-4}$

$B_8 = -1.8391 \times 10^{-4}$

$b_{10} = 1.8148 \times 10^{-5}$

17

126 17 () = 640, 650, 660nm (numerical aperture) 0.
 127 17 (spherical aberration diagram) 128 17
 60 , = 770, 780 790nm 126 0.60 129 128
 17 , NA 0.60 127 = 650nm
 가 128 129 , NA 0.60
 = 780nm 가 , = 780nm 0.45 15 - 17
 (axial chromatic aberration) (ring-zonal pitch)

17 , 650nm 1, 6, 8 (NA 0.60)

17

= 650nm ,

f = 3.33, NA = 0.60

= 780nm ,

f = 3.34, NA = 0.60 (Infinite specification)

[17]

	R	d	n(=650nm)	n(=780nm)
OBJ				
	2.14757	2.200	1.54113	1.53728

2(1)				
3(2)	-7.74682	1.0333		
4		d4	1.57787	1.57084
5		d5		

	d4	d5
=650nm	0.6	0.700
=780nm	1.2	0.327

1

$$K = -1.0751$$

$$A_4 = 5.0732 \times 10^{-3}$$

$$A_6 = 4.3722 \times 10^{-4}$$

$$A_8 = -1.4744 \times 10^{-4}$$

$$A_{10} = 9.6694 \times 10^{-7}$$

2

$$K = -10.41411$$

$$A_4 = 1.59463 \times 10^{-2}$$

$$A_6 = -6.02963 \times 10^{-3}$$

$$A_8 = 1.11268 \times 10^{-3}$$

$$A_{10} = -9.3151 \times 10^{-5}$$

(650nm)

$$B_2 = -2.000 \times 10^{-3}$$

$$B_4 = -1.4462 \times 10^{-3}$$

$$B_6 = 1.1331 \times 10^{-4}$$

$$B_8 = -6.6211 \times 10^{-5}$$

$$B_{10} = 6.8220 \times 10^{-6}$$

18

130 18 ()
 . 131 18 () = 390, 400, 410nm (numerical apertur
 e) 0.70 (spherical aberration diagram) . 132 18
 = 640, 650 660nm 130 0.70 . 133 132

* 18 , NA 0.70 131 = 400nm
 가 = 650nm . 132 가 , NA 0.70
 , 17 400nm 1, 6, 8 650
 (NA 0.70)

18
 = 400nm ,
 f = 3.33, NA = 0.70 (Infinite specification)
 = 650nm ,
 f = 3.43, NA = 0.70 (Infinite specification)

[18]

	R	d	n(=650nm)	n(=780nm)
OBJ				
2(1)	2.65858	2.40	1.71657	1.68987
3(2)	-15.86969	1.297		
4		d4	1.62518	1.57787
5		d5		
	d4	d5		
=650nm	0.1	0.704		
=780nm	0.6	0.469		

1

K = 0.0

A₄ = -7.9616 × 10⁻⁴

A₆ = -5.7265 × 10⁻⁴

A₈ = 8.3209 × 10⁻⁵

$$A_{10} = -4.1599 \times 10^{-5}$$

2

$$K = 0.0$$

$$A_4 = 3.11131 \times 10^{-2}$$

$$A_6 = -1.18548 \times 10^{-2}$$

$$A_8 = 1.63937 \times 10^{-3}$$

$$A_{10} = -6.60514 \times 10^{-5}$$

(Diffraction surface coefficient)(400nm)

$$b_2 = -1.4046 \times 10^{-3}$$

$$b_4 = -8.6959 \times 10^{-4}$$

$$b_6 = 2.3488 \times 10^{-4}$$

$$*b_8 = -5.2455 \times 10^{-5}$$

$$b_{10} = 3.6385 \times 10^{-6}$$

, 1 3 14 18

(annular bands)

PF(mm) ((Ph/Pf) - 2) 19

[19]

	Pf	Ph	Ph/Pf - 2
1	0.009	0.110	10.2
2	0.067	0.255	1.8
3	0.012	0.032	0.67
14	0.039	0.221	3.7
15	0.027	0.091	1.4
16	0.014	0.353	23.2
17	0.010	0.065	4.5
18	0.011	0.060	3.5

0.4 (Ph/Pf) - 2 25 (b1)

(lower limit) 가 , (b1) , (Ph/Pf) - 2 ,
 (upper limit) 2 , 가 가 ,

, (b2) , (b3)

0.8 (Ph/Pf) - 2 6.0 (b2)

1.2 (Ph/Pf) - 2 2.0 (b3)

, 8 .
 650nm NA1 0.6 , DVD 780nm NA2 0.45 (CD 0.5). ,
 NA1 .
 , 가 .
 , (releasing property) , CD , 가 (light-converging sp
 ot) 가 . 가 가
 , 가 , 1 (circumference of a circle) +1 가
 NAH1 , 1 NA1 가
 , +1 가 .

NAH1 < NA1

0 NAL1 NA2

1 가 DVD , 1 1 650nm , 2 CD , 2
 2 700nm , NAH1 0.43 0.55 , NAL1 0.10 0.40 .
 * , 1 +1
 , 1 .
 . 가 . , 2k
 , k가 k 가 , k 1 - 10
 2 가 , +
 1 가 NAH2 , 가 NAL2 , 가 .
 가 가 , 2 가 NA
 H2 .
 , 1 가 NA1 , 1
 0.07 rms 가 , 2
 가 NAH2 0.07 rms 가
 , , 1 가 NA1
 1 0.05 rms 가

1, 2 가 , ,
 1 2 .
 , 1 2 .
 , 1 2 .
 1 2 , 가 , 가 , 가
 , 2 가 , 1
 , .
 114 NAH2가 NAL2 , 2 (CD)
 (fB = 0), 2 .
 NAH2 2 fB가 0 A S , NAH2
 B , .
 , NAH2 NA1 , NAH2 (gap) 2 fB
 , NAH2 NA1 , NAH2 (oscillate
 , 1 2 , 1 2 ,
 d wavelength) , 가 .
 NAH2 NA1 , NAH2 2 가 1 2
 , 2 , 2 , 2 +1 1 2
 2 , 115 .
 , 115(a) 1 , ,
 , NAH1 , NAH1 +1 ,
 , 115(b) , 2 NAH2
 , 가 , NAH2 ,
 , .
 2 1 2 2 , 2
 -1 2 , 113 , NAH2 NA1
 , 2 , NA 가 NA
 H2 2 , NAH2 , 116(b) , NAH
 , NAH2 , 가
 , .
 가 , 1 , 2

1 , 가 , , 1 , 2 (ring-zonal filter)가, 1 2 가 , , 가 1 2 가 8 1 7 102 1 1 (112) 1 (111) 2 , 1 , 1 (111) , (111) (112) , 1 (190), (120), (130) 1/4 (170) (stopped down), (160) 1 (200) (210) (2) 20) . (220) (160), (170), 1/4 (140) (130) (astigmatism)가 (120) , (300) , (cylindrical lens; (200) 18) 1 (200) . (300) (220) , 1 (111) 1 (200) (220) 2 (150)가 (160) , (111) (160) 2 (112) , 가 (120), (130), 1/4 (190) , 1 (111) (160) , 2 (200) (210) , (220) (140), (170) . (220) (160) , (170), 1/4 (1 40), (130), 2 (120) (180) (300) , (150) 1 가 , (300) , 2 (160) (160) . , 2 (150) 103 2 가 , , 102 가 , 1 (111) , (121) (190) (131) 1/4 (141) , (160) 1 (200) (21) 0) (220) .

(190), 1/4 가 (141) , (220) (131) (301) (121) (160) (170) 1 (200)

(301) 2 (200) , 2 (150)가 (160) (160) 1 (111) (11)

1) 2 (210) (132) 1/4 (190) (220) (142) (112) (170) (160) 2 (122) (200)

(190) 2 (200) , 1/4 가 (220) (142) (132) (302) (160) (170) (122)

(302) 200 (220) , 2 (150) 2 (112) (112) 1 () (160) (160)

104 3 가 , 1 (111) (190) (120) (131) 1/4 1 (60), (141) (200) (210) (220) (170) , (1) 60) 1 (200)

(140) 가 1 (130) (220) (50) (120) (301) (160) (170) 1/4 (180) (200)

(301) (200) (220) , 2 (150) 1 (111) (111) 1 (160)

2 (230) (unit)' (112) , / (unitization)' (400), (302) 1

2 0) (170), (112) (120), (230) (130) 1/4 (140) , (19) (160) 2 (200) (210) (220)

(140), (130) (302) (220) (120) (160) (170) 1/4 (230) (190) 2 (200)

(302) (160) 2 (150)

105 4 1 , 1 (111) /
 (410) (301) (231) , 1 (111) (
 231) , (170) (190) 1 (130) (200) (210) ,
 (220) .
 (130) (190) (220) (160) (170)
 1 (200) (231) (301) ,
 (302)
 , (160)가 2 (150) .
 2 , 2 (112) / (42) (302)
 (232) , 2 (112) (232) , (190)
 (200) (210) (130) (220) (160) 2
 (130) , (220) (160) (170)
 (190) 2 (200) (232) (302)
 (302)
 , (160)가 2 (150) .
 106 , 1 (111), 2 (112), (30) (230)
 / (430) .
 1 , 1 (111) (230) (130)
 (210) , (170) (160) 1 (200)
 (220) .
 (130) (220) (160) (170)
 2 (200) (230) , (203) .
 (300)
 , (160)가 2 (150) .
 2 , 2 (112) (230) (130)
 (210) , (160) (220) , 2 (200)
 (130) (220) (160) (170)
 2 (200) (230) , (300) .
 (300)
 , (160)가 2 (150) .
 107 , 1 (111), 2 (112), 1 (301), 2 (
 302) (230) / (430) .
 1 , 1 (111) (230)
 (130) (200) (210) , (170) (160)
 1 (220) .

(130) (220) (160) (170)
(301) , (230) , 1
(200)

(301) (160)가 2 (150)

2 , 2 (112) (230)
230) (130) 가 (170), (160) 2 (200)
(210) (220)

(130) (220) (160) (170)
(302) , (230) , 2
(200)

(302) (160)가 2 (150)

108 7 ,

1 , 1 (111) , (120)
(131) 1/4 (60), (190) (170) , (1
60) 1 (141) (200) (210) (220)

(140) (130) (220) (160) (170) 1/4
1 가 (200) , (50) (120) (180) 가
(301)

(200) , 2 (150) 1 (111) 1
(220) (160) , (111)

2 2 (112) , (302) (230) /
(400)

2 (112) (230) (19
0) , (120), (130) 1/4 (140) ,
(170) (160) 2 (200) (210) (220)

(140), (130) (220) (160) (170) 1/4
, (302) (120) , (190) 2 (200) (230)

(302) (160)가 2 (150)

1 1 NA , 1 3 RENS t1

3 RENS (near field optics) 가 109 .

RENS 3 , 1 (111)
 (60), (190) (120) (130)
 1/4 (140) (170) , 1 ()
 200) 1 (240) (120) (250) (160) .
 (250) , 가 2 (260) (270)
 (220) , (220) (305)
 , 3 (200) (90) ,
 (250) (160) (170) 1/4 (140)
 (130) , (120) (180)
 가 (50) (301) , (301) , 2
 (150) 1 (111) 1 (250) (160)
 (160) , (111) (160)

1 DVD , 2
 가 CD ,

(1) ,
 (2) ,
 (3) 가 (2)

(2) , CD NA2 t2 - t
 1 (NA2) 4 . 110 CD 2 = 780nm
 가 0.45 , 1 = 650nm
 DVD 가 DVD M2
 M2가 0 , DVD
 M2=0 , Marechal 0.07 rms 0.13 rms 가
 (wave-front aberration)가 Marechal DVD CD
 가 (-) , 가 , M -0.06
 Marechal , M -0.06 , CD-
 R 가 , NA가 0.5 .
 / , 가
 0

di' ni' 2

(t2=1.2mm).

[21]

2	(1)	$0 \quad H \quad 1.16984$ $k = -3.6612 \times 10^{-2}$ $A_1 = -3.2000 \times 10^{-3} \quad P1=4.0$ $A_1 = -9.5500 \times 10^{-4} \quad P2=6.0$ $A_1 = 9.4024 \times 10^{-5} \quad P1=8.0$ $A_1 = -2.8750 \times 10^{-6} \quad P1=10.0$
	(2)	$1.6984 \quad H$ $k = -9.8006 \times 10^{-1}$ $A_1 = 6.0790 \times 10^{-3} \quad P1=4.0$ $A_2 = 2.8149 \times 10^{-4} \quad P2=6.0$ $A_3 = 6.6735 \times 10^{-6} \quad P3=8.0$ $A_4 = -2.8790 \times 10^{-6} \quad P4=10.0$
3		$k = -2.4934 \times 10$ $A_1 = 9.6641 \times 10^{-3} \quad P1=4.0$ $A_2 = -3.7568 \times 10^{-3} \quad P2=6.0$ $A_3 = 7.9367 \times 10^{-4} \quad P3=8.0$ $A_4 = -7.3523 \times 10^{-5} \quad P4=10.0$

112(a) 635 nm S2
 112(b) 780 nm S2r
 (t2=1.2 mm)

가 111 S2d , 가 112 S2r . 111
 1 S2d (t1=0.6 mm) 가

NAH2 = 0.5 NAL2 = 0
 21 μm , 13 가

NAH2 = 0.45 NAL2 = 0
 NAH2 4 , 9 , 13 μm .

NAL2 = 0 , 가 .

가 2μm , 가 가

가 , 가 , 가 가

(1) CD DVD , . m
 CD(CD) - mDVD(DVD)가 -1/15 - 0

(2) 가 가

, DVD 0 , CD -0.03 , 1/2
 , NAH2가 CD-R 0.5가 , 7 , 11μm .

, S2 S2d S2r 가

DVD CD 0 , NAL2가 0.36 , 가 NAL2
 WSA(NAL2) 0.053 rms , DVD
 0 , NAH2 , RMS .

가 NAH2 WSA(NAH2)

$$WSA(NAH@) = (NAL2/NAH2)^2 * WSA(NAL2)$$

, NAH2=0.45 0.034 rms , NAH2=0.5 0.027 rms , Marechal

, NAL2 가 , NAL2 NAH2 0
 , NAL2 가 , N

AL2 6 , NAH2=0.45 , NAH2 = 0.5 4가 . , N

CD DVD 가 , , DV
 D CD 가 가

, 가 0.1 mm 가 ,
 가 , 2- 가 , 0.85가 NA1 , CD-RW ,
 가 1.2 mm 780 NA2가 0.55가 , DVD
 CD-R(NAH2=0.5) NA2가 t1-t2 2.7 ,
 35가 .

가 가 , NA1

가 .

NAL2 NAH2

, t1 t2 , 가 -1 .

, DVD CD , CD DVD , 가
 , 가 -1 .

, DVD CD , 2
 , 1 , 1 2
 2(2 1) , t1 t2 , +1 , t1 t2 -1
 1 DVD(1) CD(2)

SHG

가 가 , 가
 , / NA NA 2 , 가 .

(1) t1 t2, NA1 NA2

(2) t1 t2, NA1 NA2

(3) t1 t2, NA1 NA2

(4) t1 t2, NA1 NA2

AL1, NAH2 , NAL2), (1) 가 1 가 , (NAH1, N
 , 2 NA , 가 0.07 rms NA , NA
 , (2), (3) (4)

(1) , 가 ,
 UV- 가 가 .
 , 2 , 1 가

1-19 , 1 , 가 .

10% 2 , 30 % ,
 50% , 70 %

2 가 , 가
 , 2 , 가

2 가 0.07 rms ()

2 , / 가 / , 가 2

2 가 72 - 88 , 가 ,

1 , 89-98 , , 가 3 ,
 / 가 ,
 가 .

99-112 , 3 ,
 , ,
 가 .

113-181 , 1
 , 가

가 , , ,
 , .

2 , , , /

(57)

1. / ,

2 / 1 1 ;
 1 / 2 2 ;
 3 / 3 -
 1 < 2 < 3 - ;

가 , 3 ,

1, 2 3
 1 2

1 2 ,

3 .

2.

1 ,

1 .

3.

1 2 ,

2 가 /

.

- 3 4. ,
1 , 2 가
- 1 5. 2 ,
가
- 1 6. 2 ,
가 1
- 1 7. 2 ,
1 / NA2;
2 / NA1;
3 / NA3 가
,
NA1, NA2 > NA3
- 7 8. ,
가 ,
가 NA2 1 NA1 2
- 7 9. ,
NA3 3 , 3
- 7 10. ,
NA1=NA2
- 7 11. ,
3 , 3 / , NA3
가 가
- 1 12. 2 ,

1 2

13.

1 2 ,

3

14.

/

,

1, 2 3

, 3

가

가 1, 2 ,

/

1 < 2 < 3

,

1 2 ,

2 1 ,

3 3

15.

14 ,

1

16.

14 15 ,

2

가

/

17.

16 ,

1

,

2

가

18.

14 15 ,

19.

14 15 ,

가 1

20.

14 15 ,

1

/

NA2;

2

/

NA1;

3

/

NA3 가

NA1, NA2 > NA3

21.

20

가 ,

가 NA2

1

NA1

22.

20

NA3

3

3

23.

20

NA1=NA2

24.

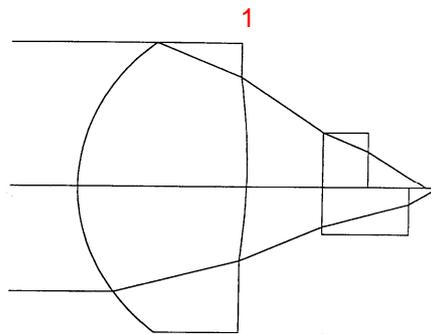
20

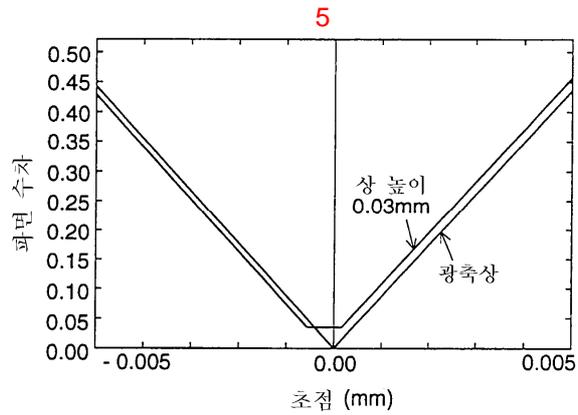
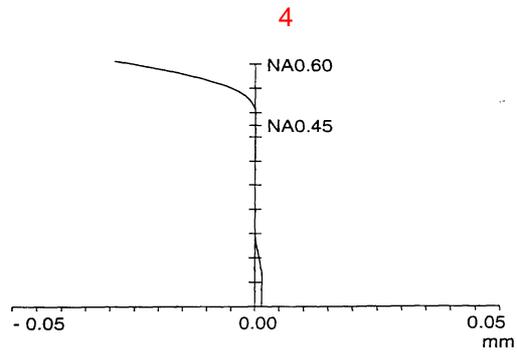
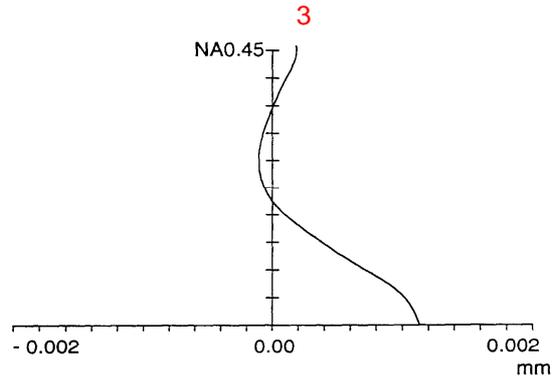
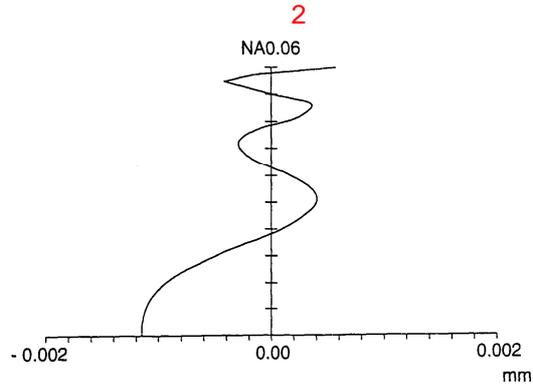
3

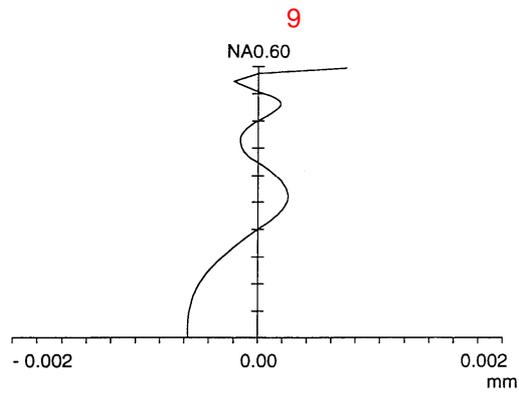
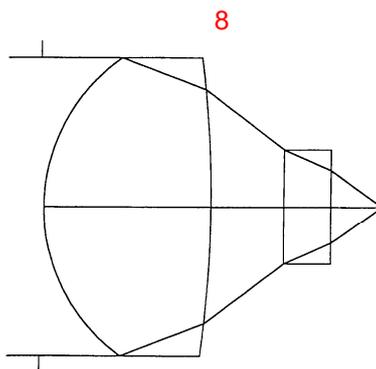
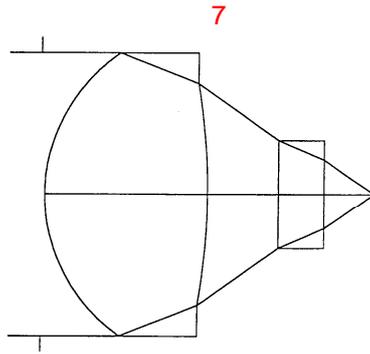
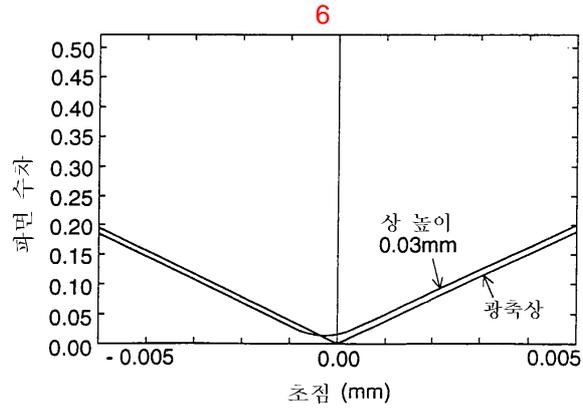
3

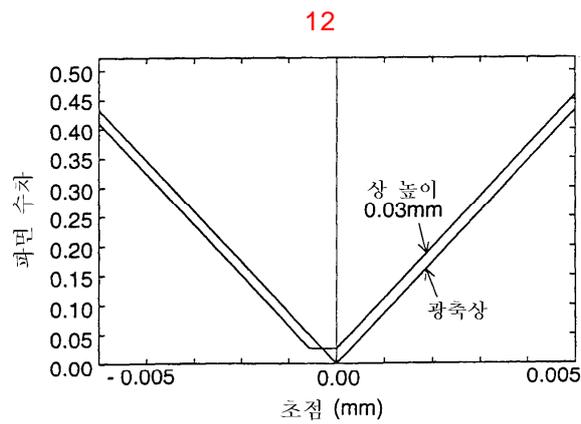
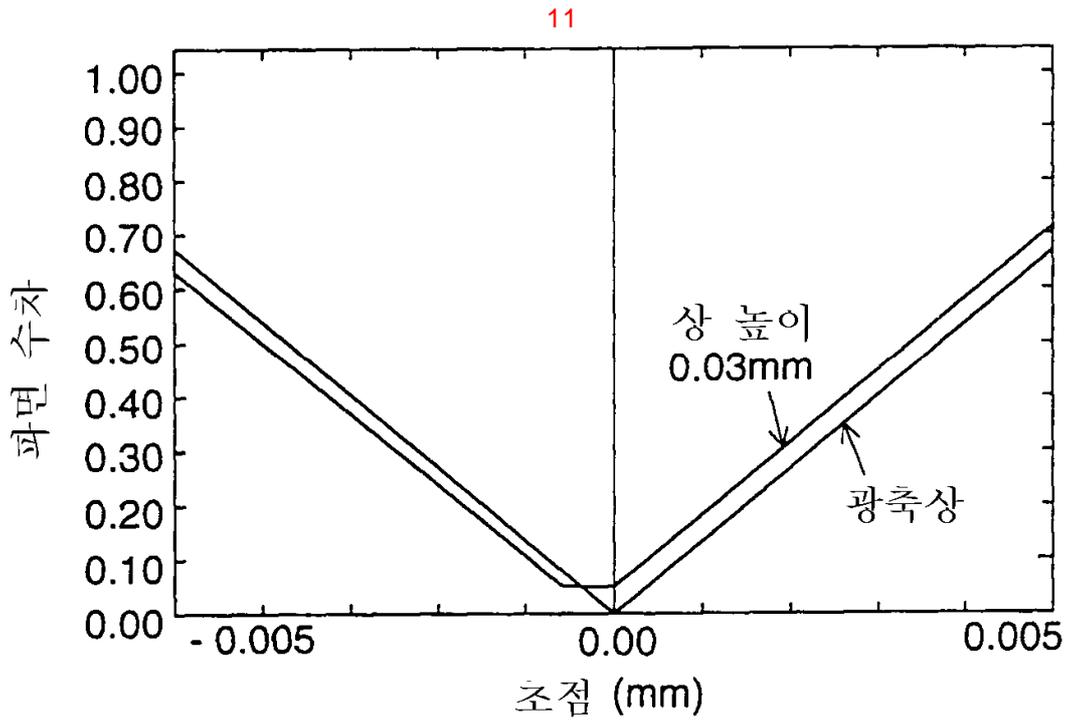
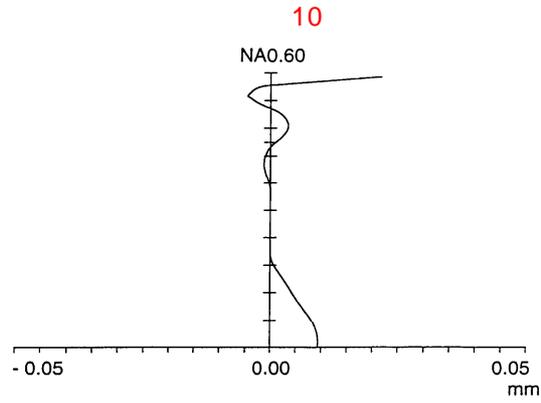
/

NA3
가 가

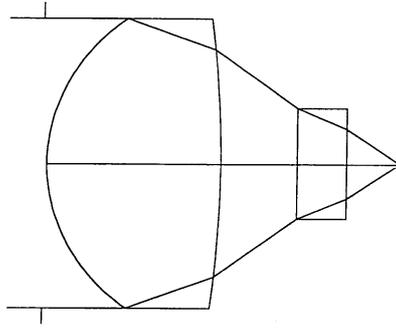




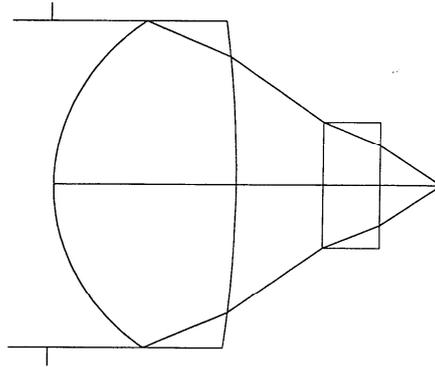




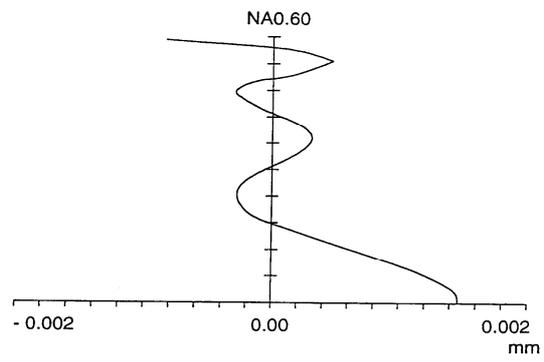
13



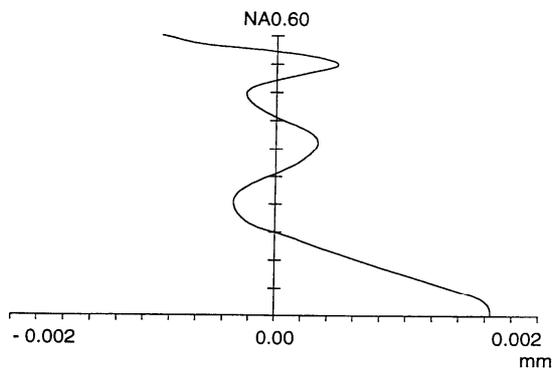
14



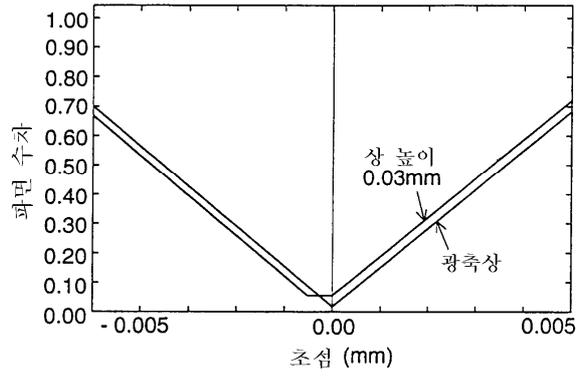
15



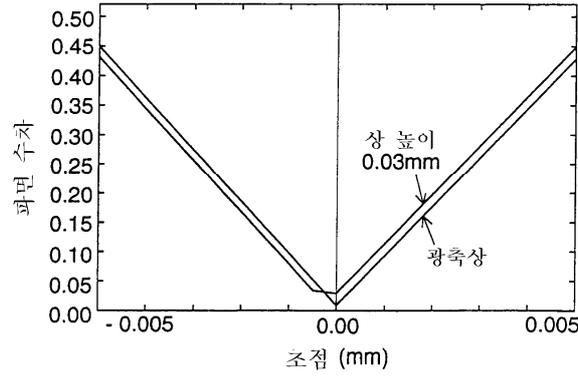
16



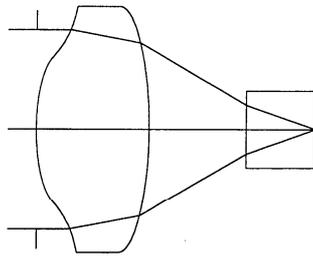
17



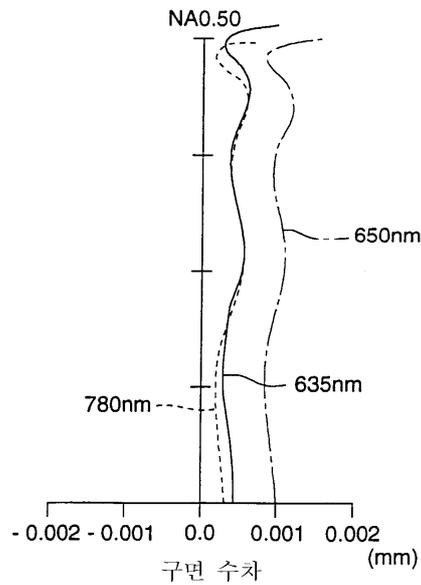
18

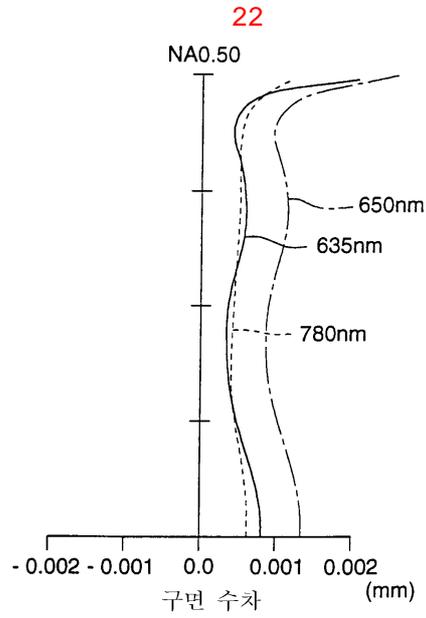
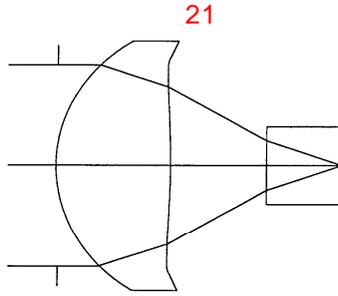


19



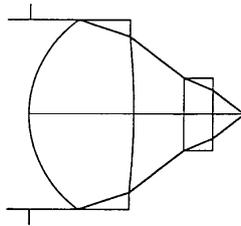
20





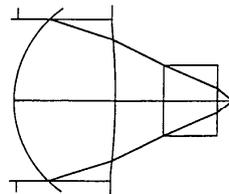
23

예6의 단면도 및 파장 $\lambda=650\text{nm}$ 에 대한 광경로도



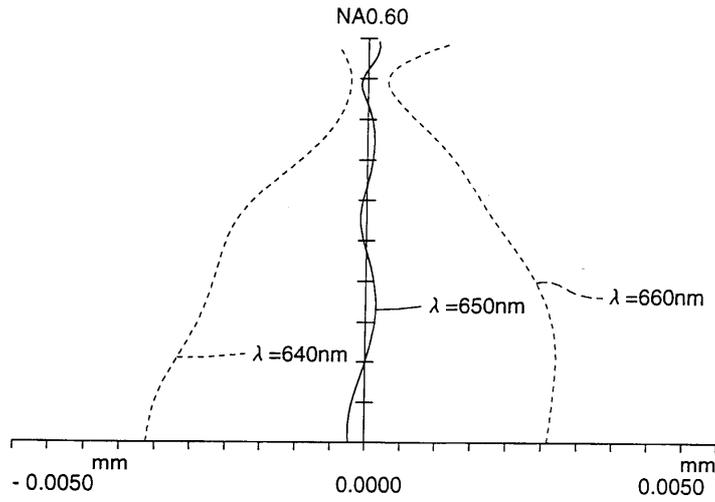
24

예6의 단면도 및 파장 $\lambda=780\text{nm}$ 에 대한 광경로도 (NA0.5)



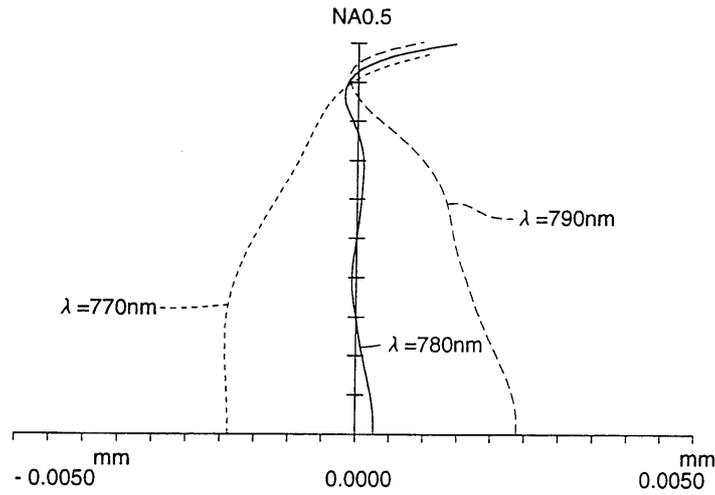
25

예6에서 파장 $\lambda=650\pm 10\text{nm}$ 에 대한
구면 수차도



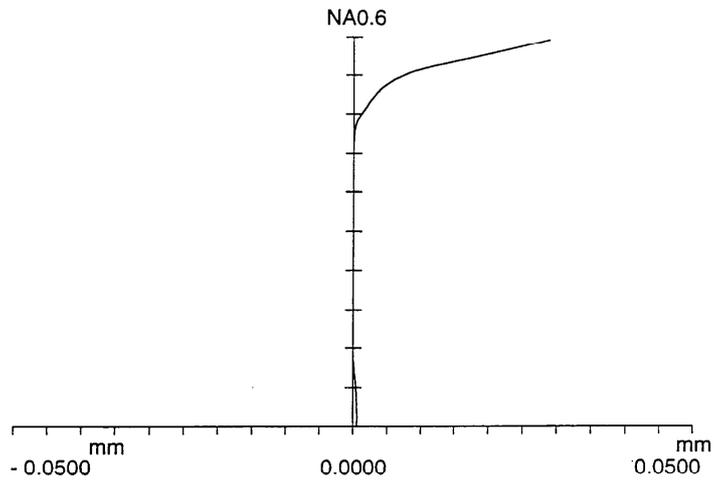
26

예6에서 파장 $\lambda=780\pm 10\text{nm}$ 에 대한
구면 수차도 (NA0.5)



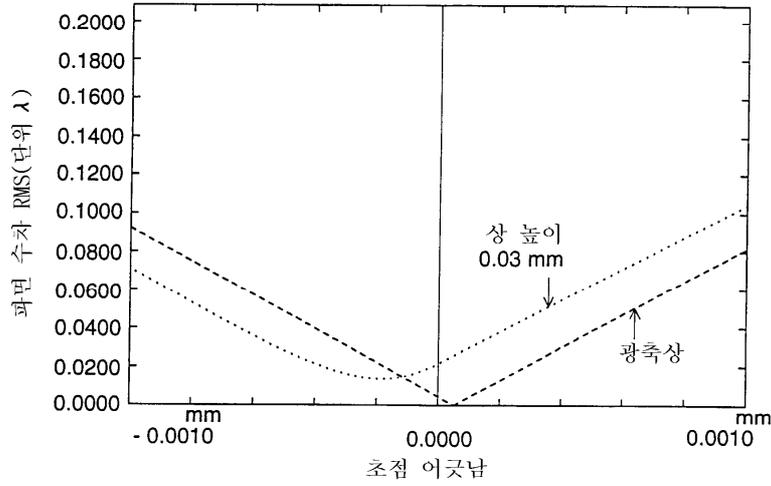
27

예6에서 파장 $\lambda=780\text{nm}$ 에 대한
구면 수차도



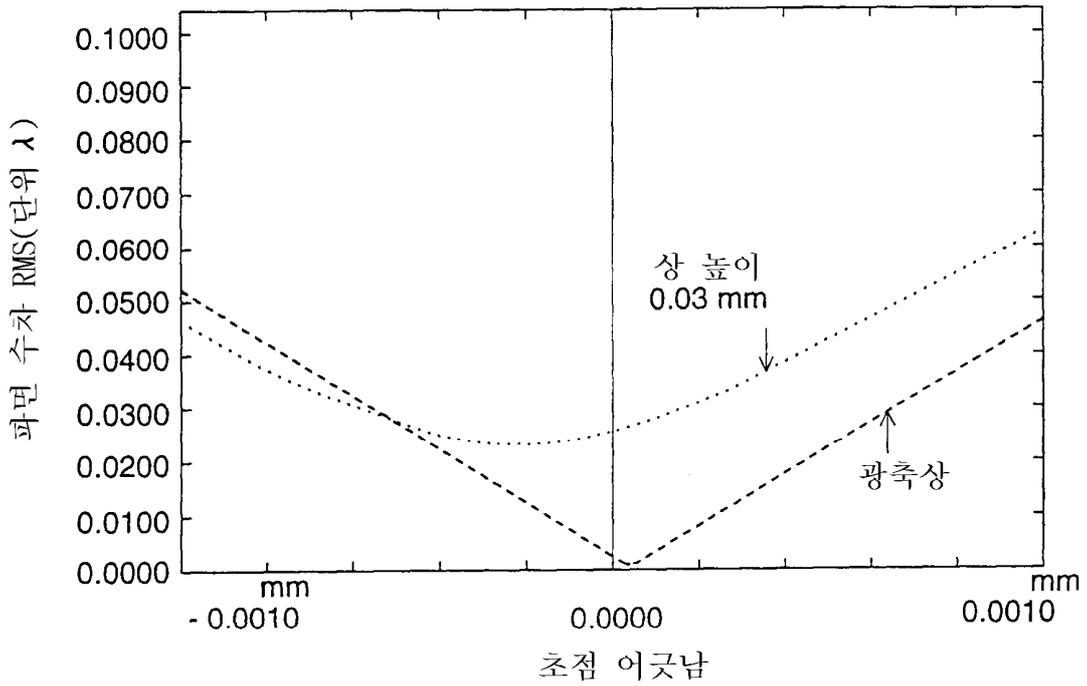
28

예6에서 파장 $\lambda=650\text{nm}$ 에 대한
 화면 수차 RMS를 도시하는 도면



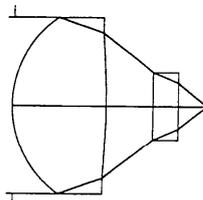
29

예6에서 파장 $\lambda=780\text{nm}$ (NA0.5)에 대한
 화면 수차 RMS를 도시하는 도면



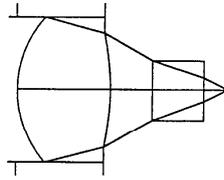
30

예7의 단면도 및 파장 $\lambda=650\text{nm}$ 에 대한
 광경로도



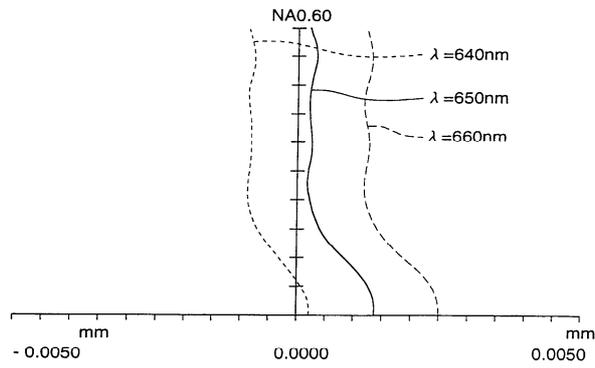
31

예7의 단면도 및 확장 $\lambda = 780\text{nm}$ 에 대한 광경로도 (NA0.5)



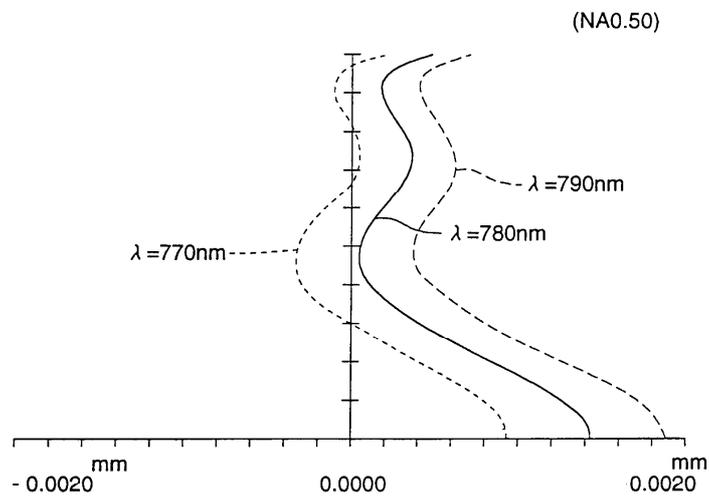
32

예7에서 확장 $\lambda = 650 \pm 10\text{nm}$ 에 대한 구면 수차도



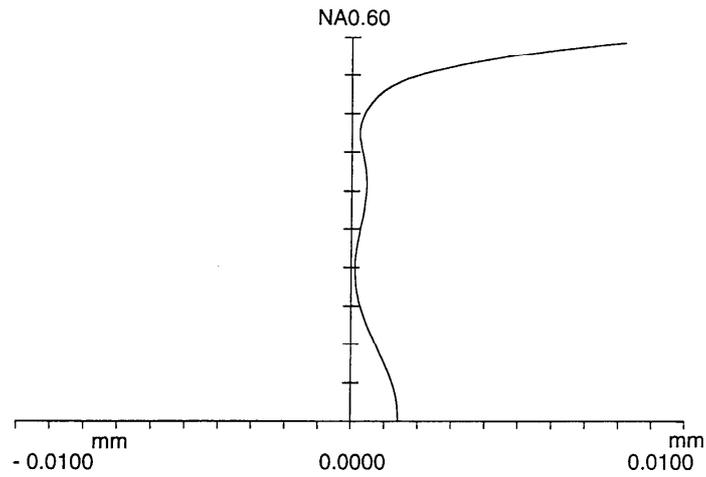
33

예7에서 확장 $\lambda = 780 \pm 10\text{nm}$ 에 대한 구면 수차도 (NA0.50)



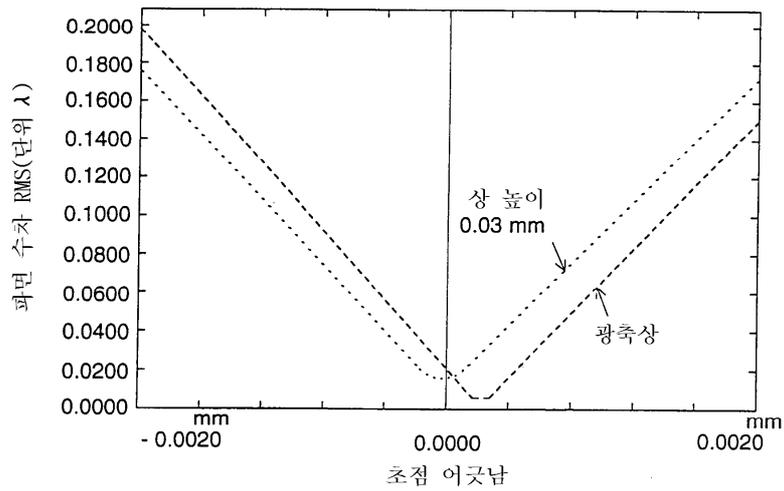
34

예7에서 파장 $\lambda=780\text{nm}$ 에 대한
구면 수차도 (NA0.60)



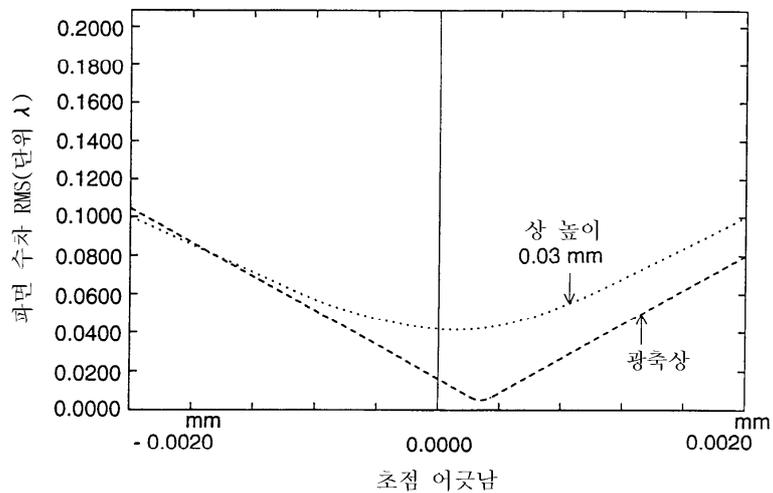
35

예7에서 파장 $\lambda=650\text{nm}$ 에 대한
파면 수차 RMS를 도시하는 도면



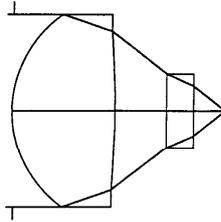
36

예7에서 파장 $\lambda=780\text{nm}$ 에 대한
파면 수차 RMS를 도시하는 도면



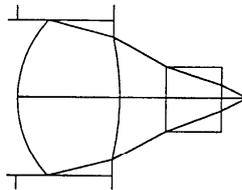
37

예8의 단면도 및 확장 $\lambda = 650\text{nm}$ 에 대한
광경로도



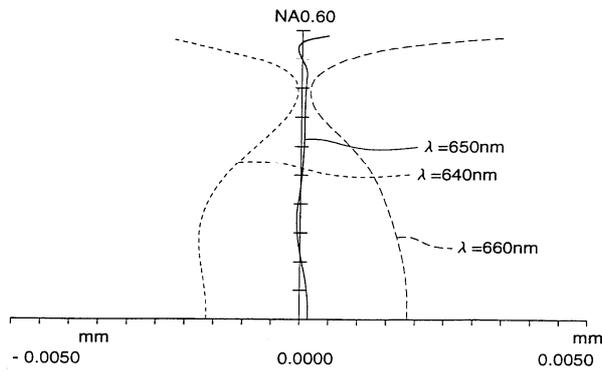
38

예8의 단면도 및 확장 $\lambda = 780\text{nm}$ 에 대한
광경로도



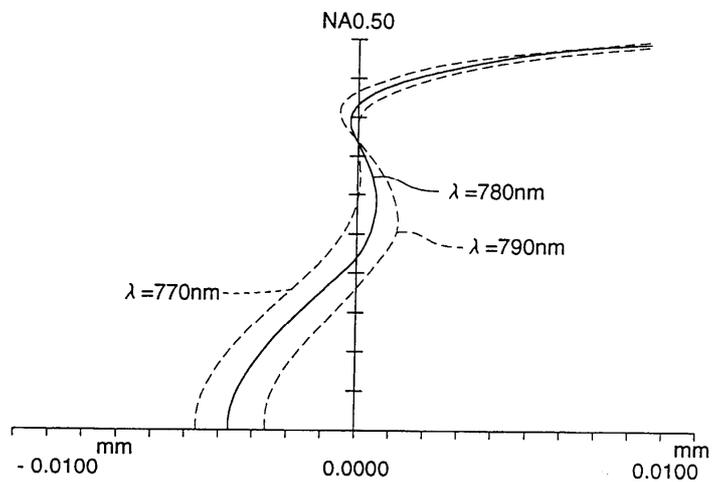
39

예8에서 확장 $\lambda = 650 \pm 10\text{nm}$ 에 대한
구면 수차도



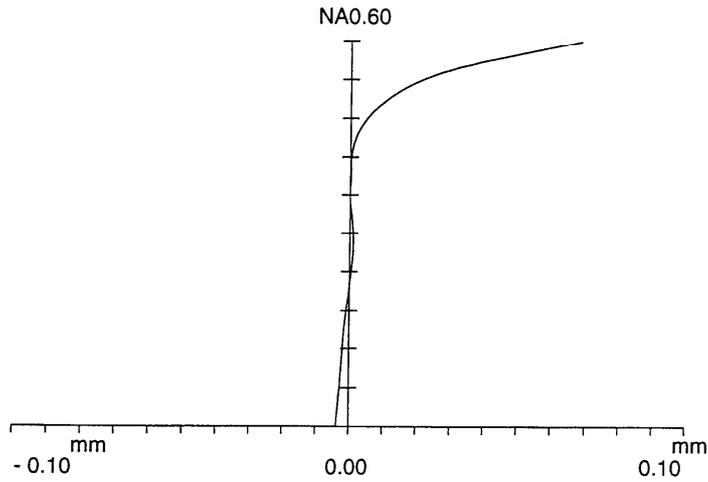
40

예8에서 확장 $\lambda = 780 \pm 10\text{nm}$ 에 대한
구면 수차도



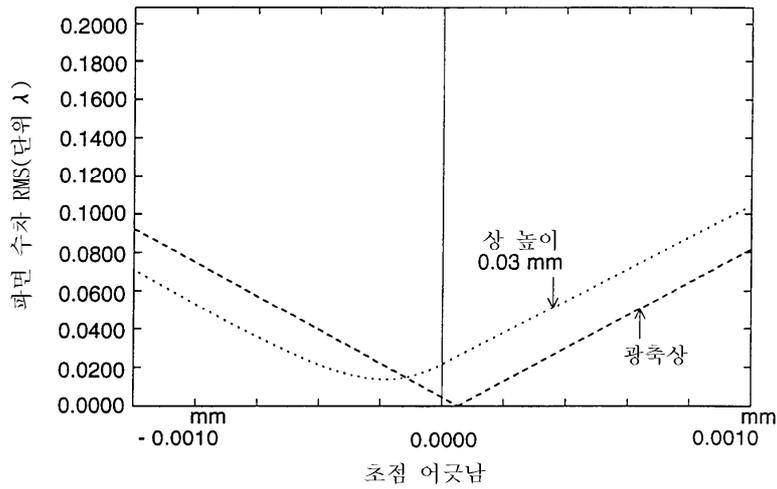
41

예8에서 파장 $\lambda=780\text{nm}$ 에 대한
구면 수차도 (NA0.60)



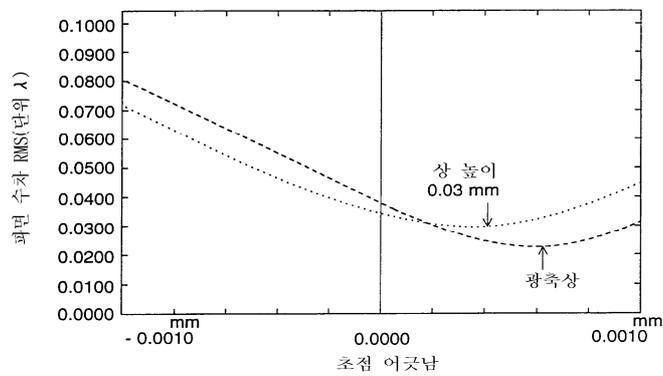
42

예8에서 파장 $\lambda=650\text{nm}$ 에 대한
화면 수차 RMS를 도시한 도면



43

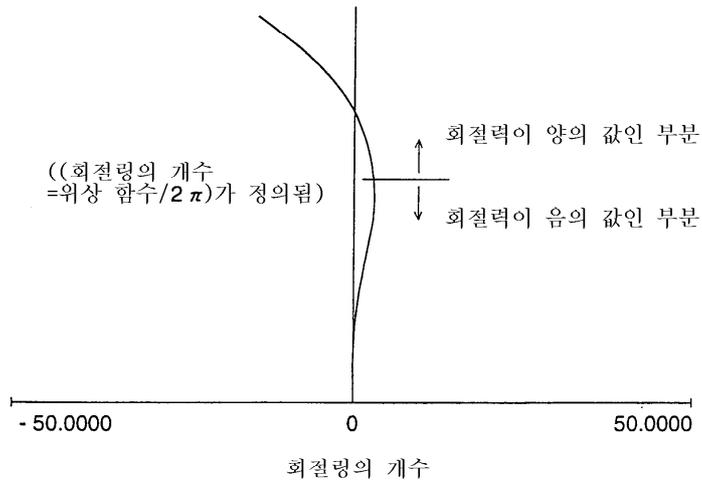
예8에서 파장 $\lambda=780\text{nm}$ 에 대한
화면 수차 RMS를 도시한 도면



44

예6에서 회절령의 개수와 광축으로부터의 높이와의 관계

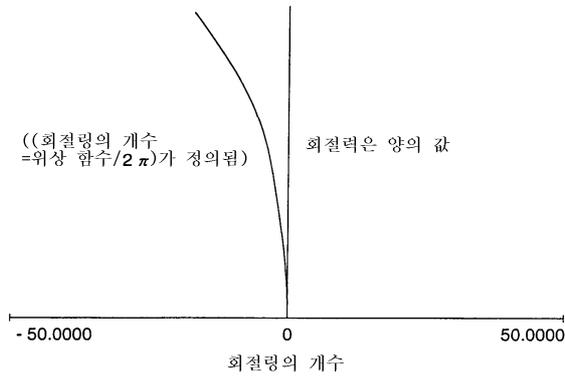
HMAX 2.0084 (광축으로부터의 높이)



45

예7에서 회절령의 개수와 광축으로부터의 높이와의 관계

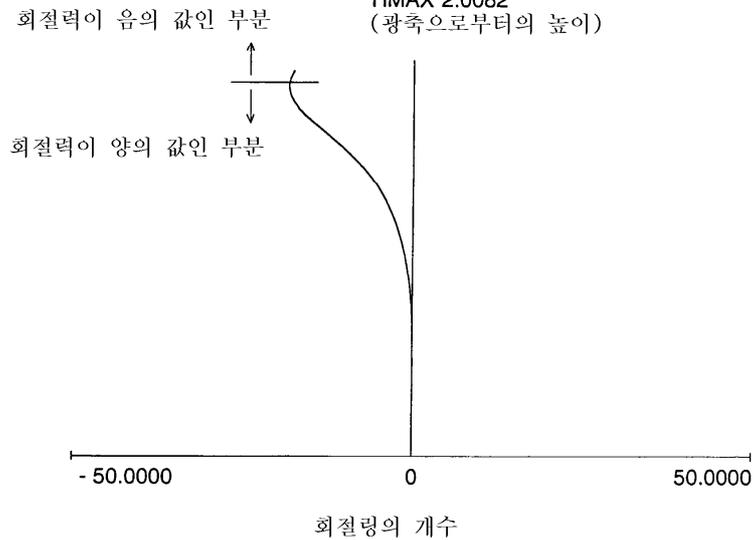
HMAX 2.0082 (광축으로부터의 높이)



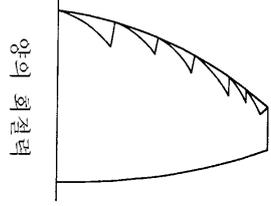
46

예8에서 회절령의 개수와 광축으로부터의 높이와의 관계

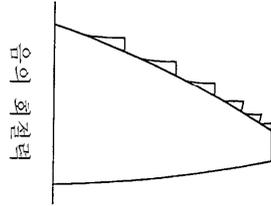
HMAX 2.0082 (광축으로부터의 높이)



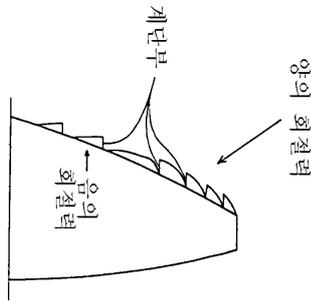
47



(a)

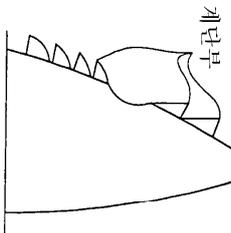


(b)



(c)

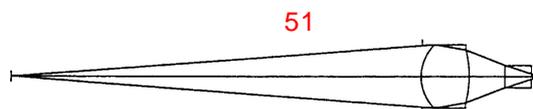
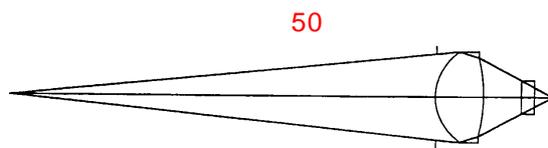
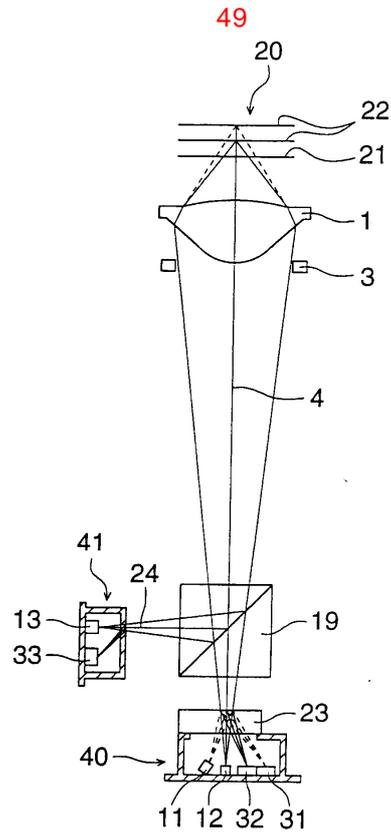
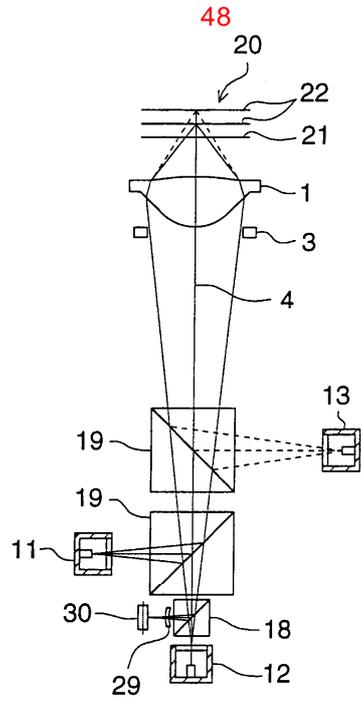
광축 부근에서
회절력이 양의 값이고
중간 부분부터는 렌즈
값으로 바뀌는

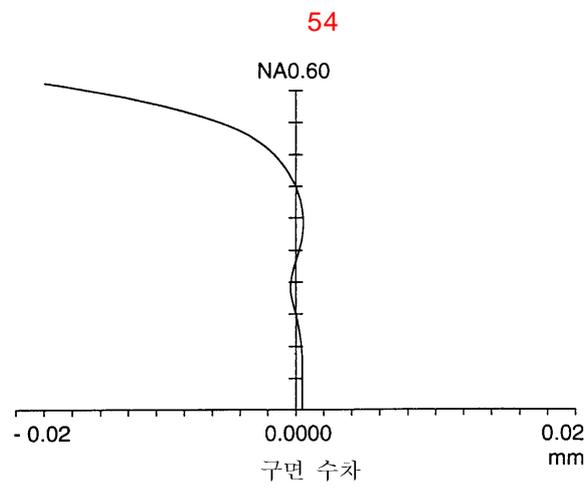
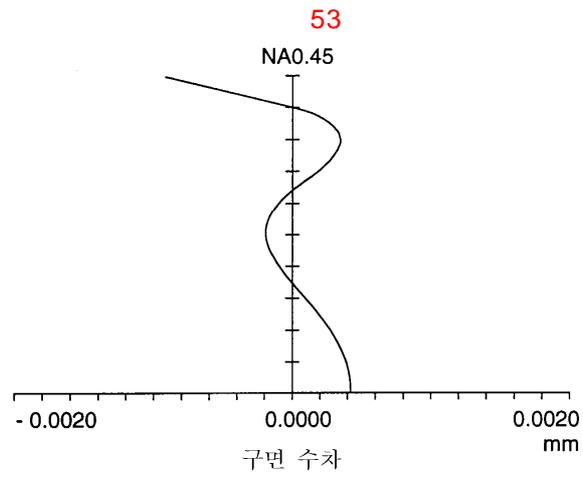
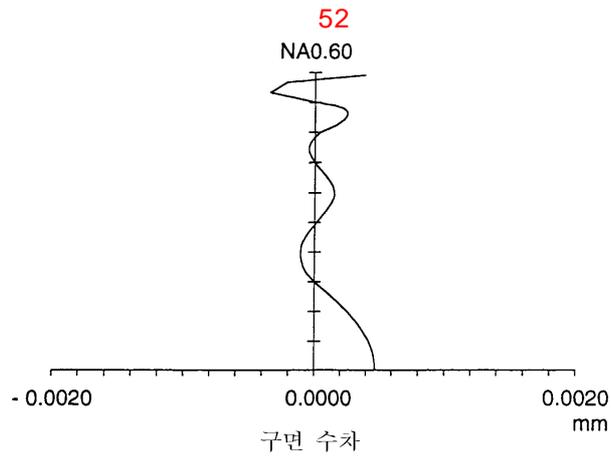


(d)

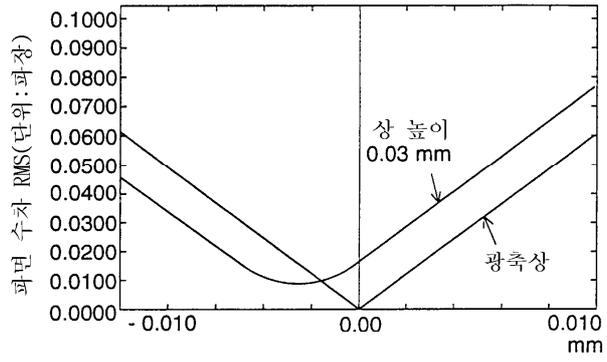
광축 부근에서
회절력이 양의 값이고
중간 부분으로부터는 렌즈
값으로 바뀌는

회절력과 렌즈 영상

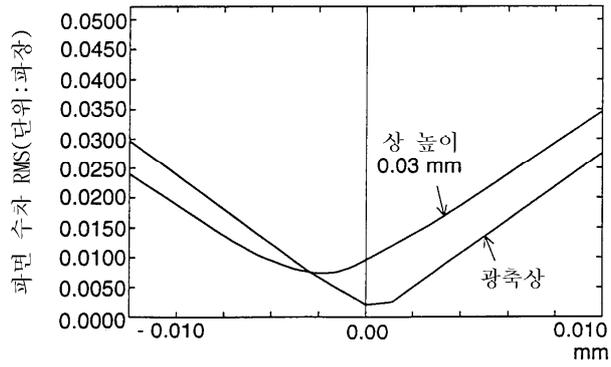




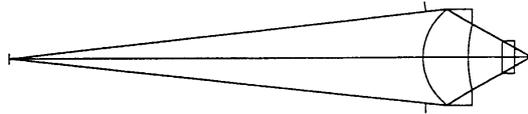
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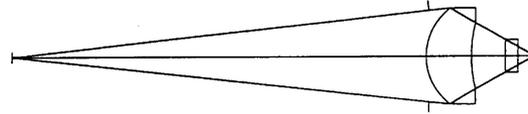
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57



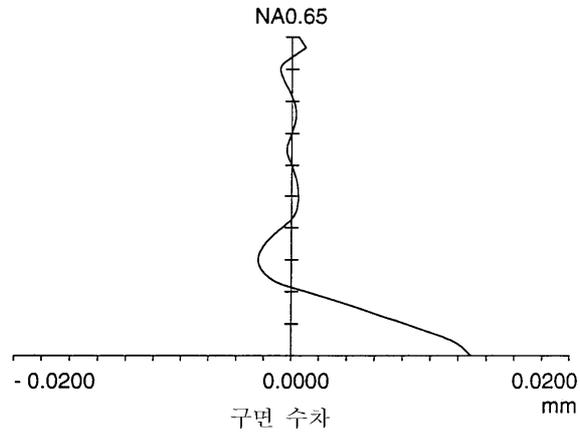
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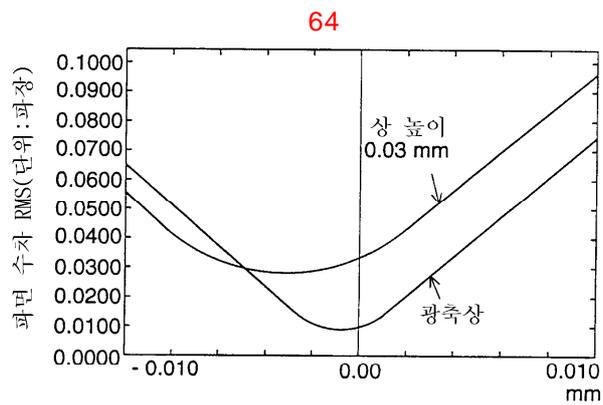
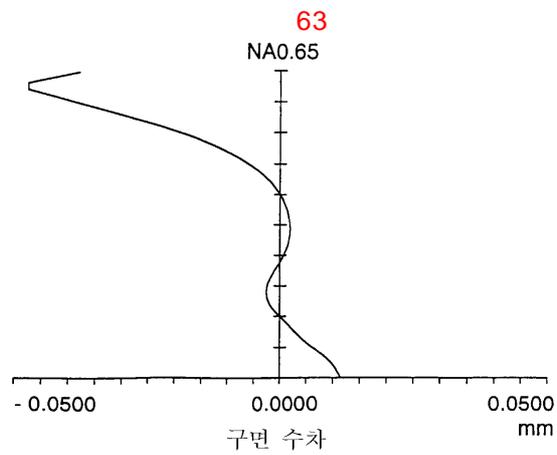
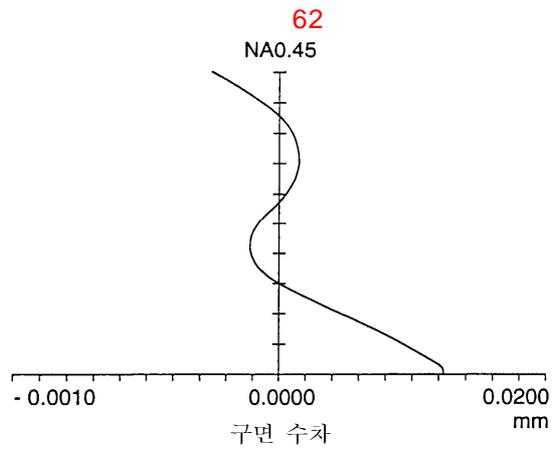
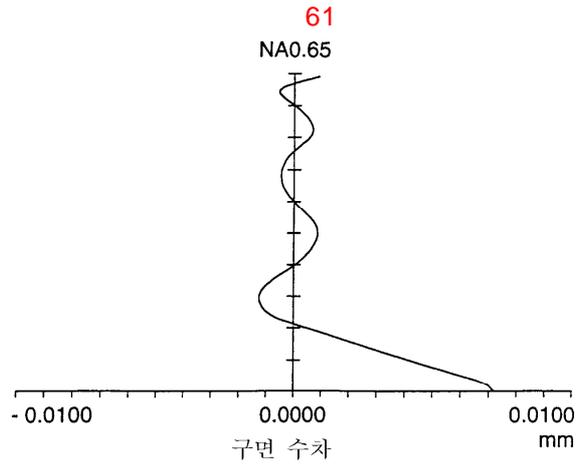


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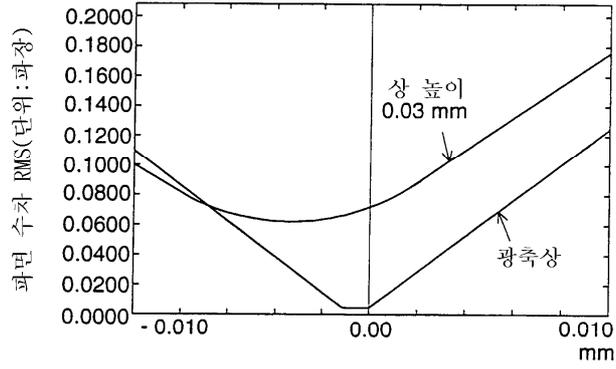


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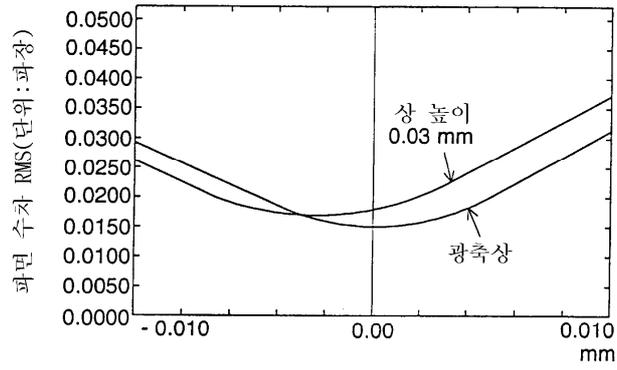




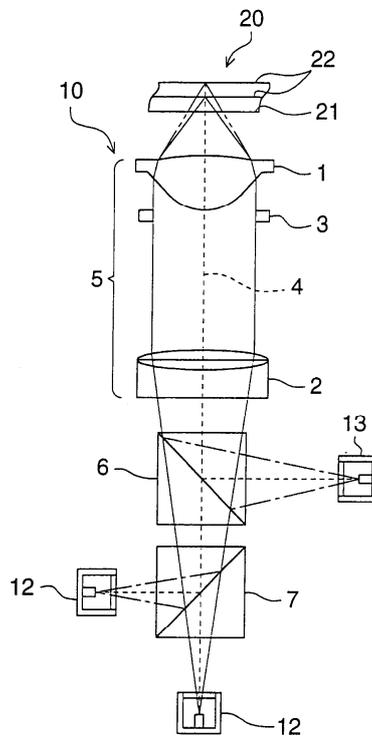
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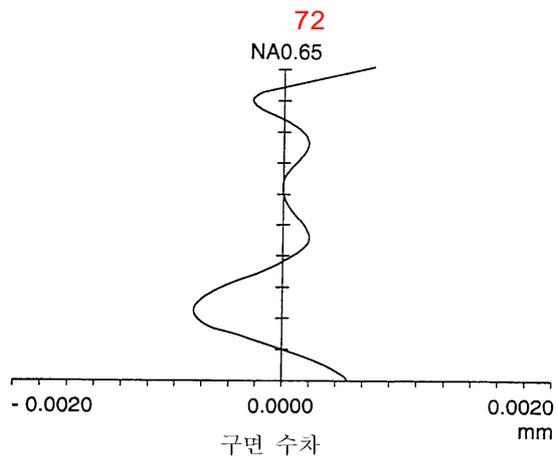
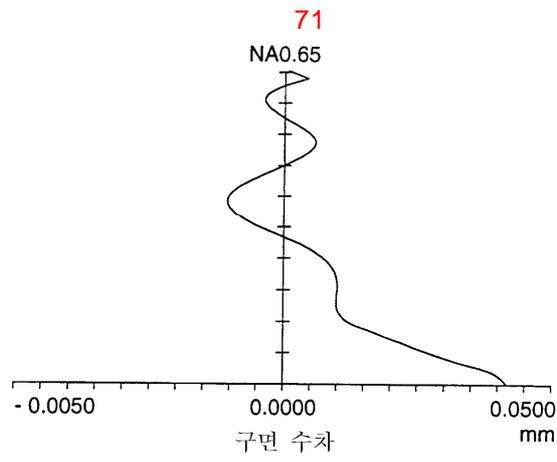
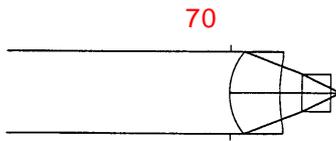
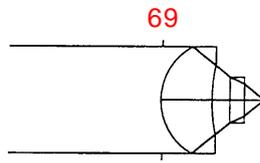
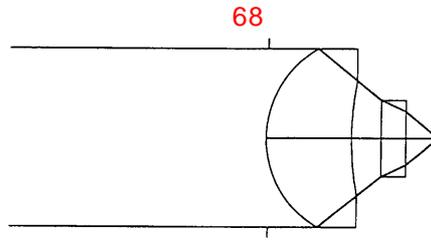


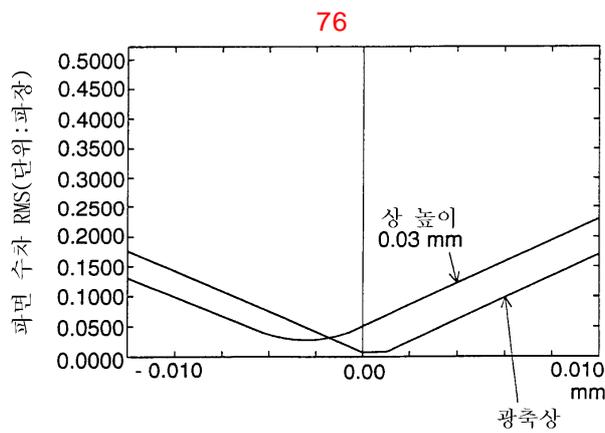
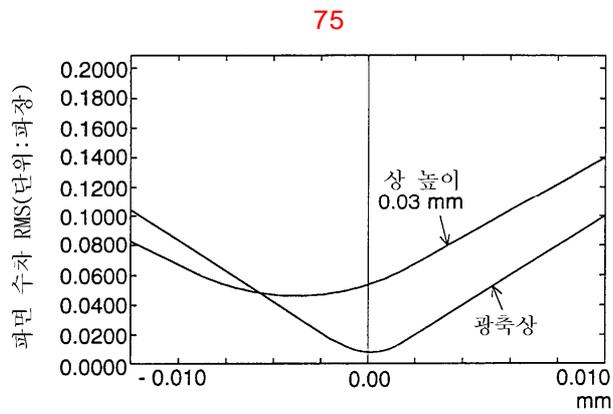
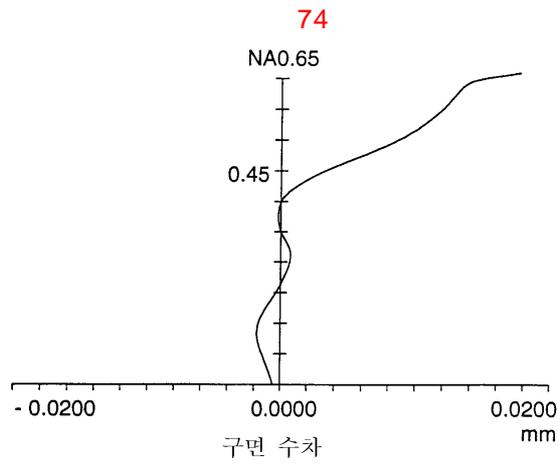
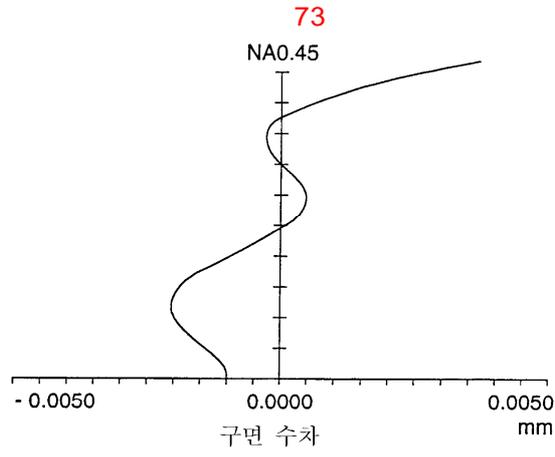
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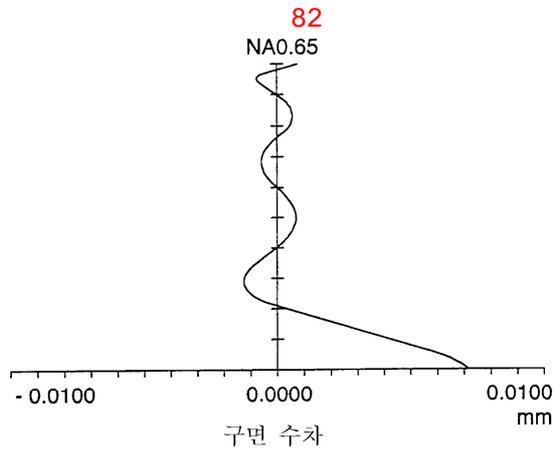
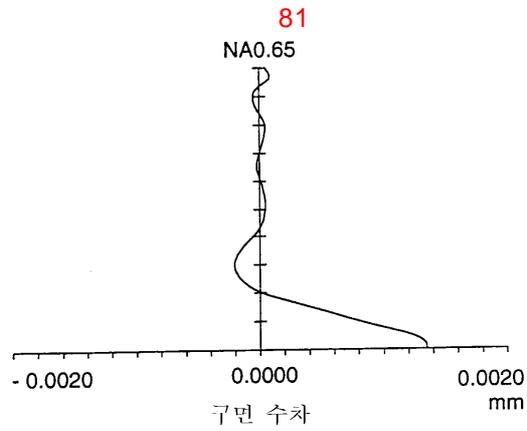
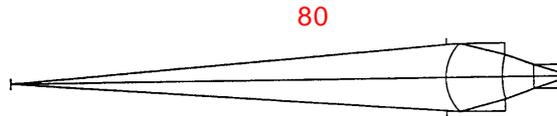
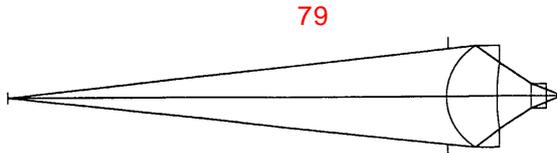
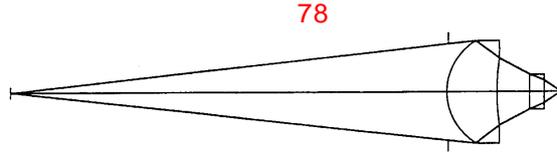
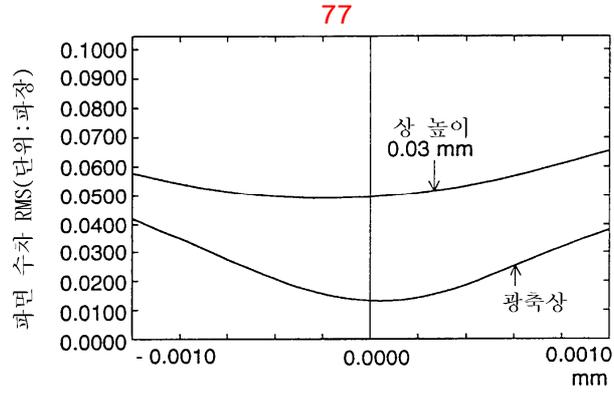


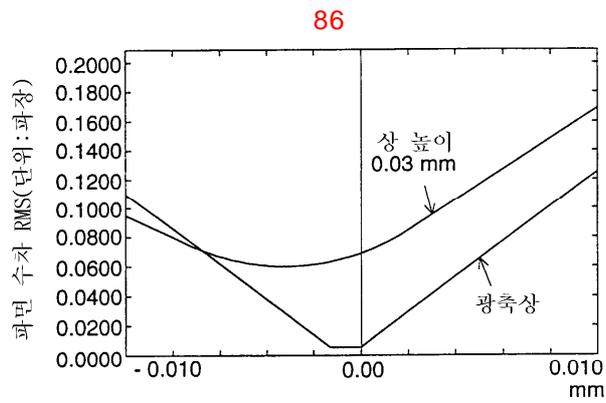
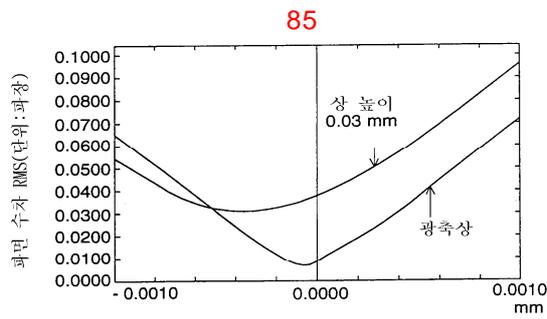
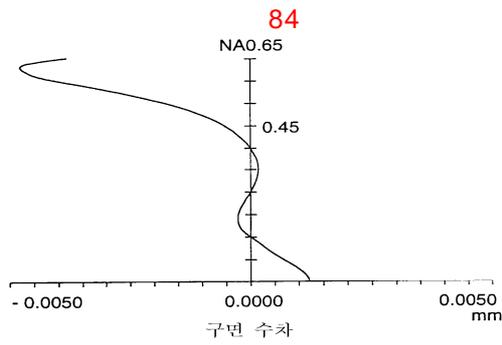
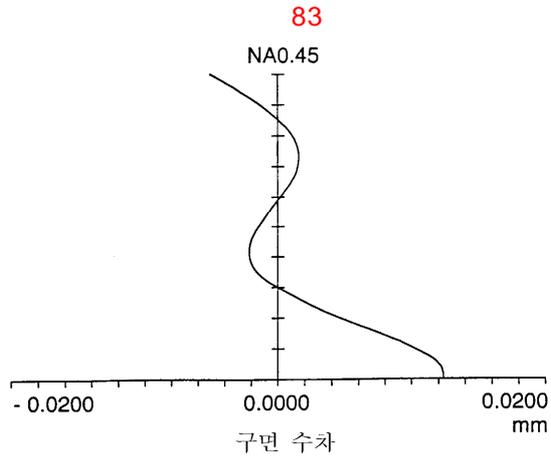
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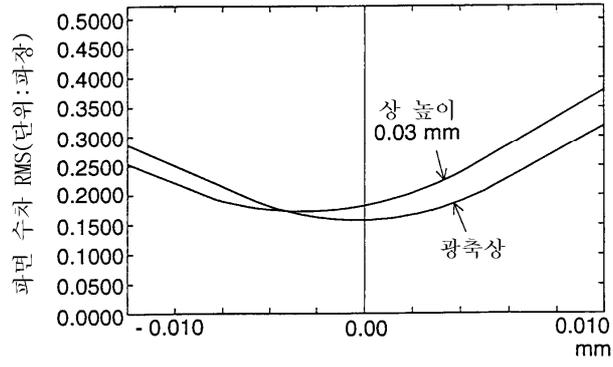




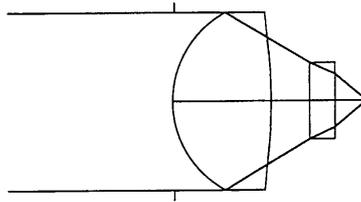




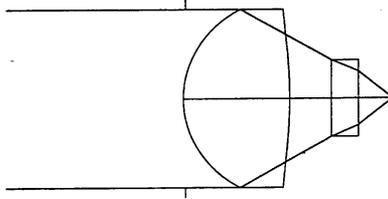
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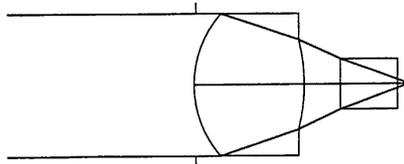
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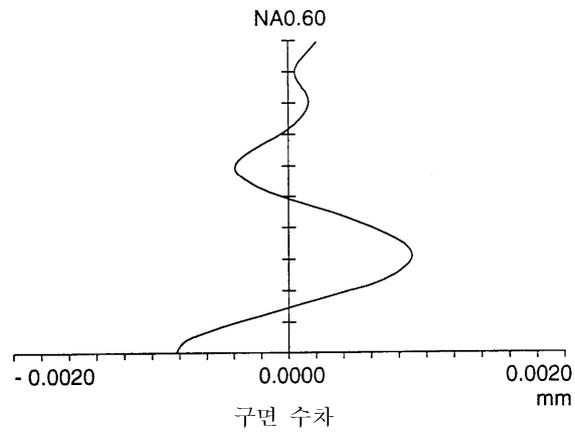
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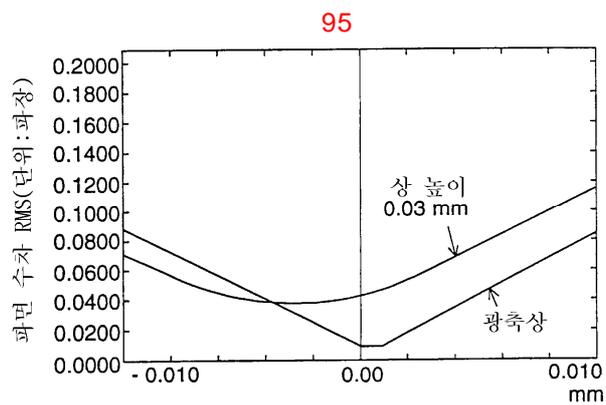
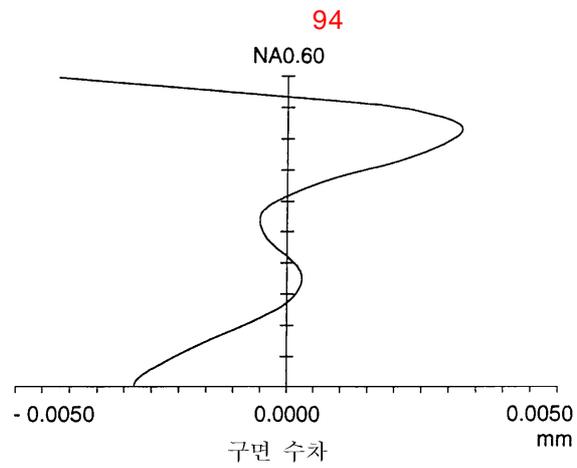
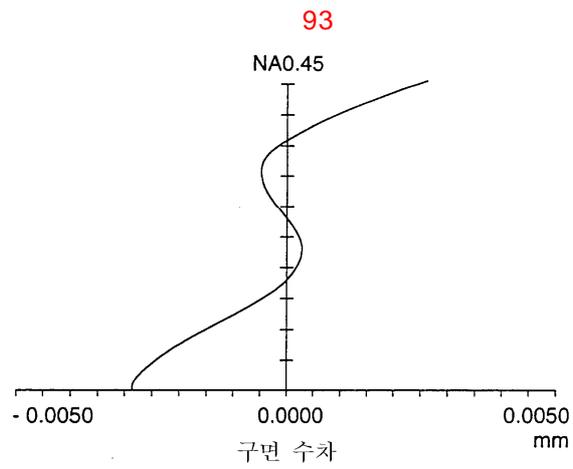
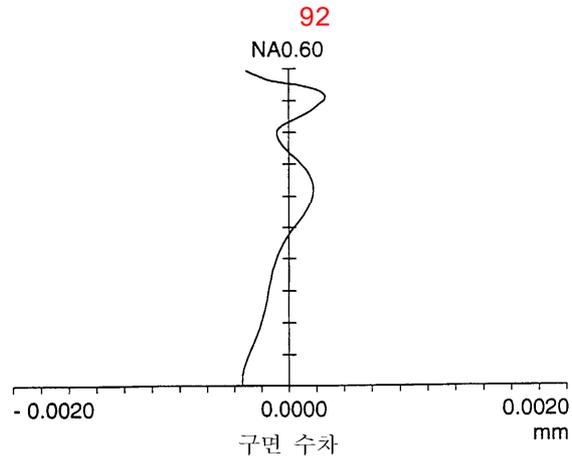


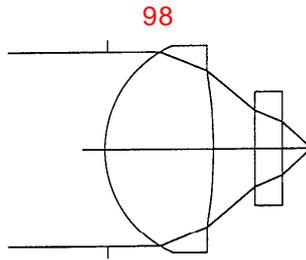
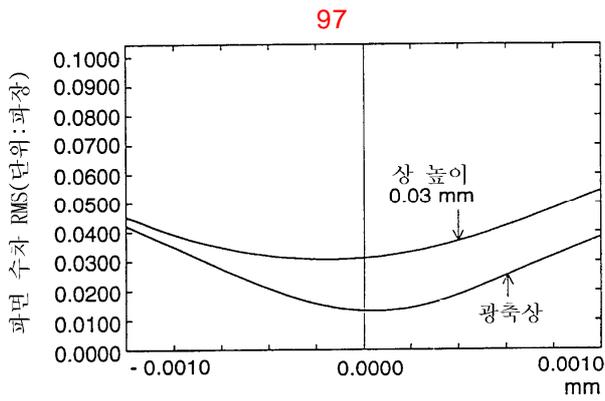
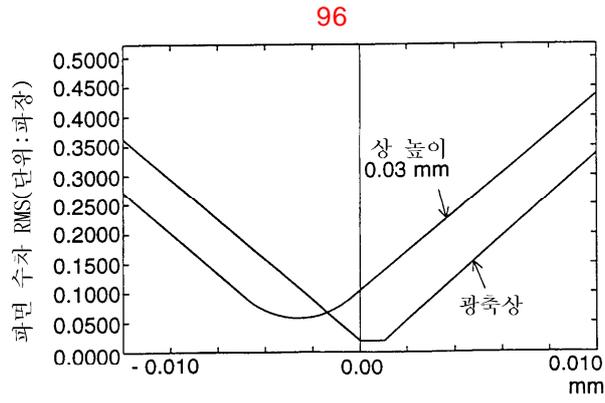
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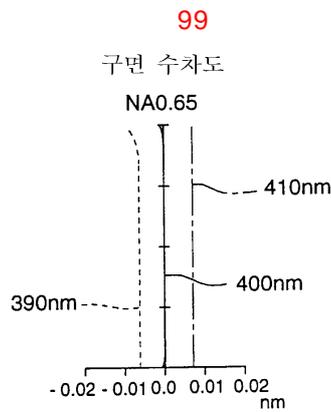
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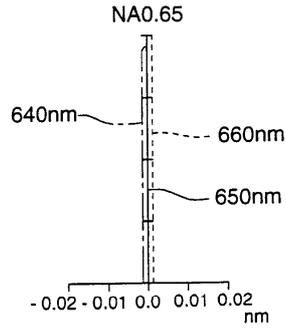




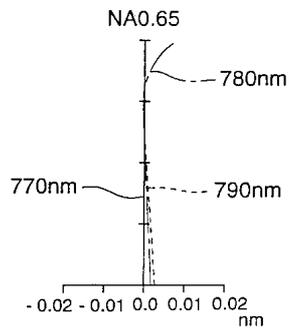
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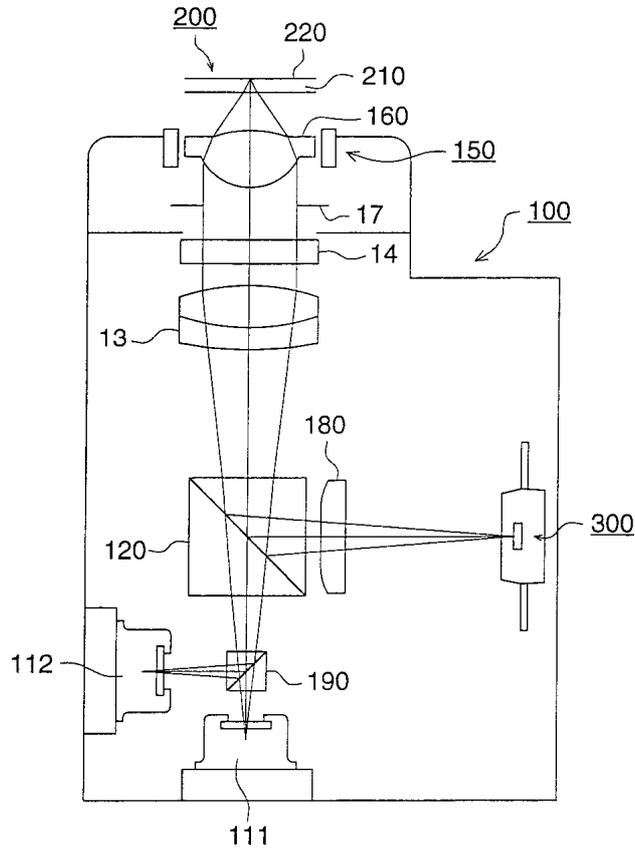
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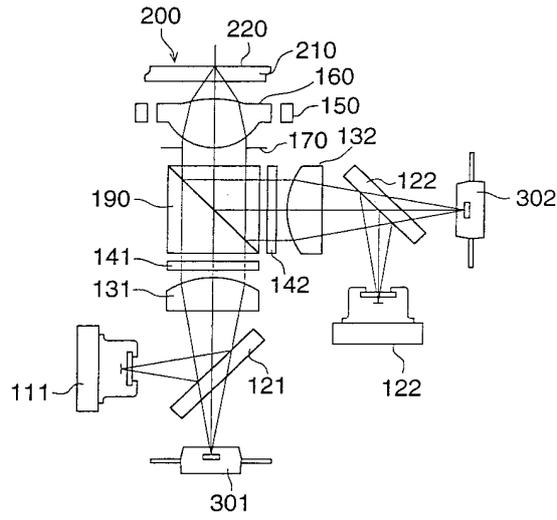
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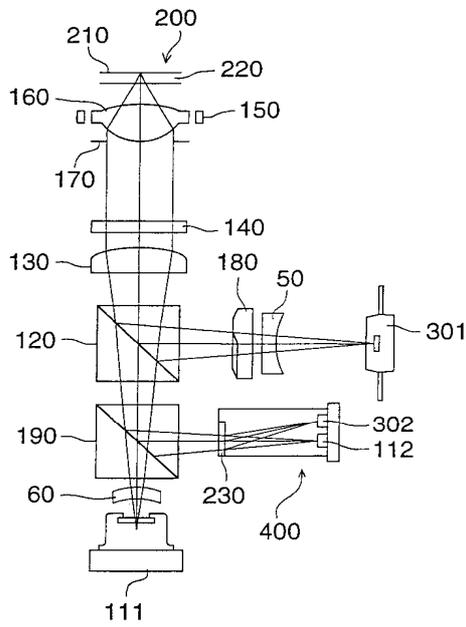
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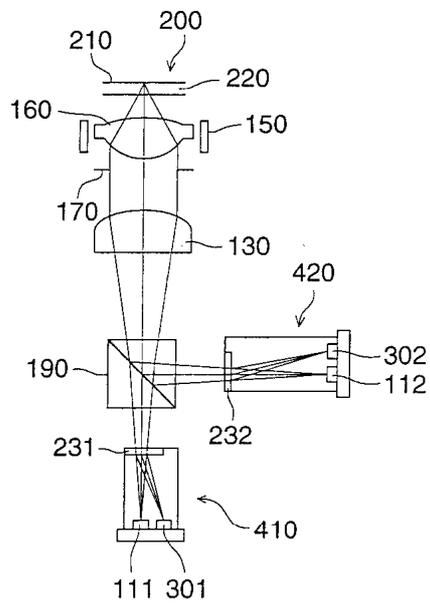
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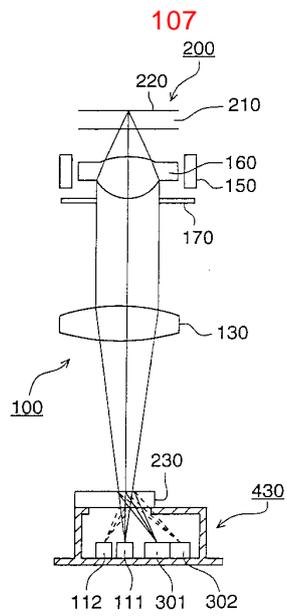
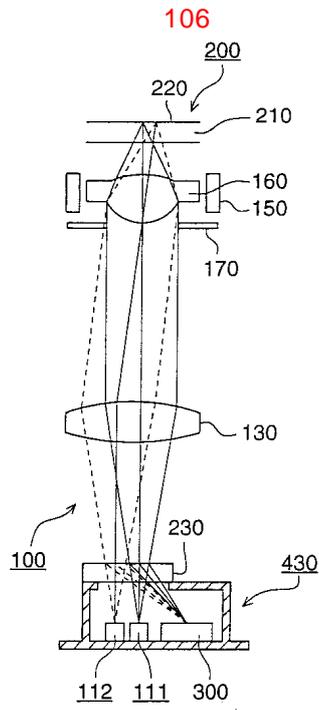


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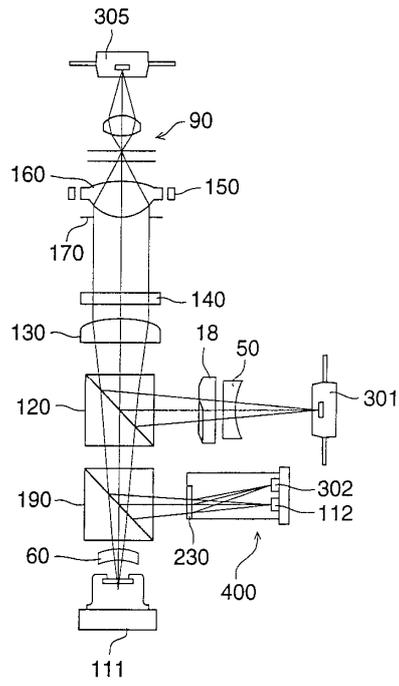


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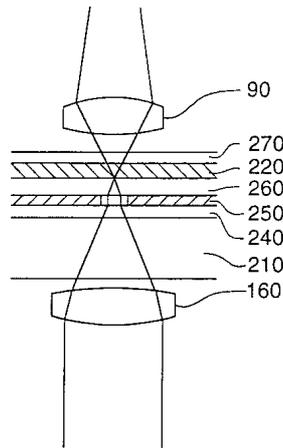




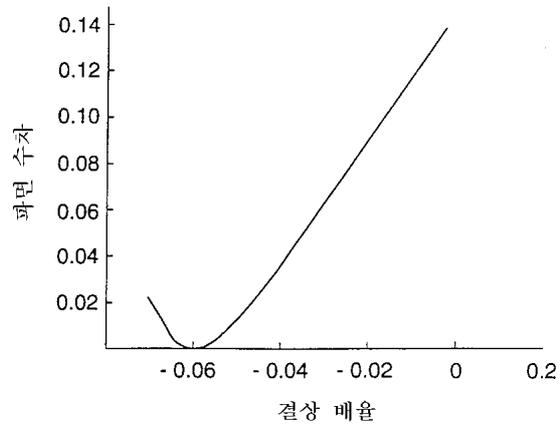
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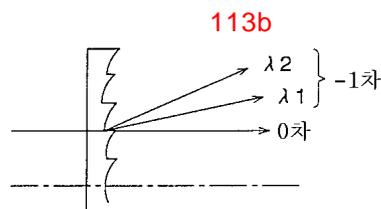
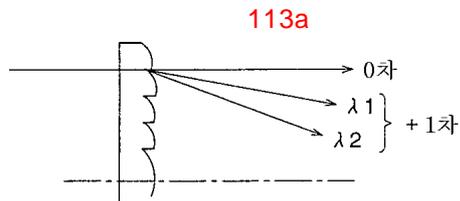
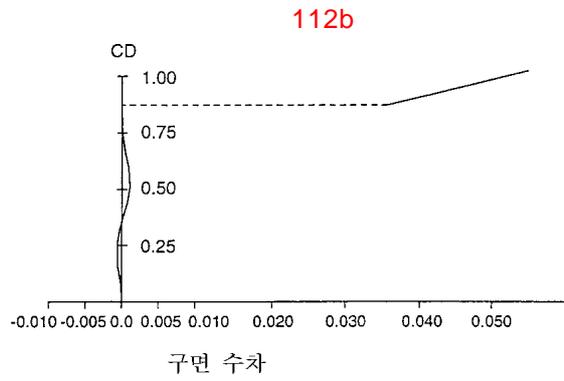
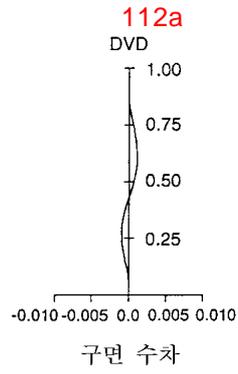
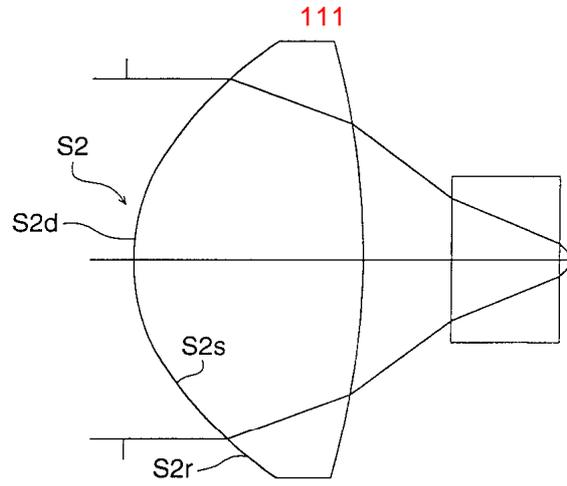


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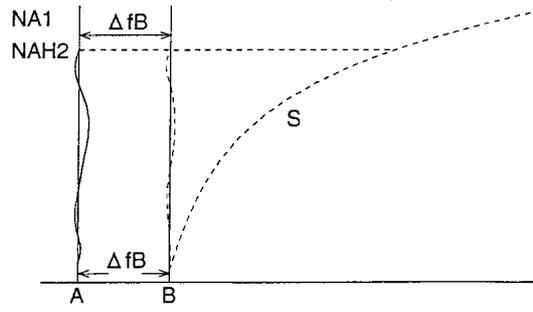


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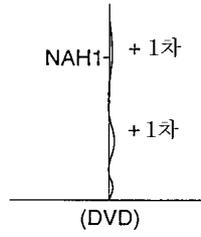




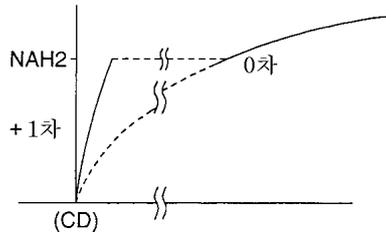
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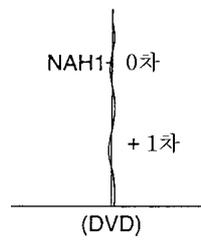
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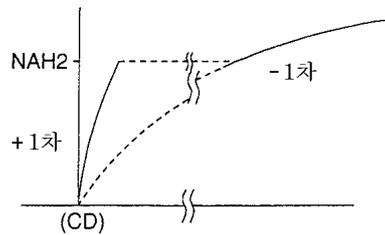
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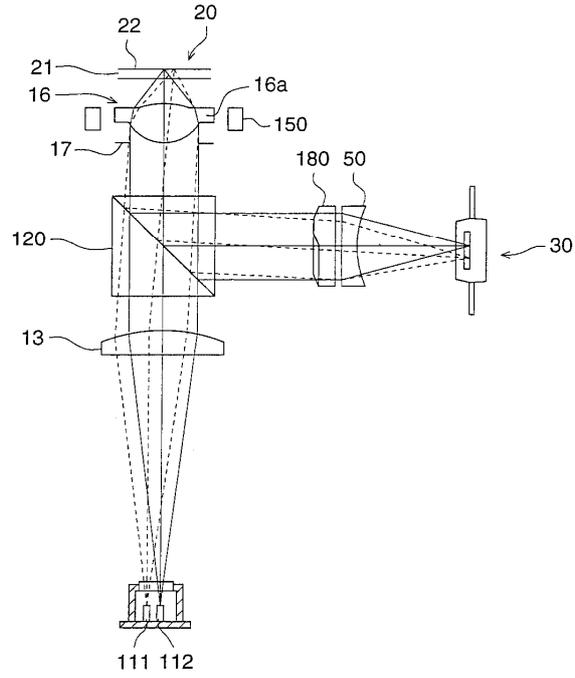
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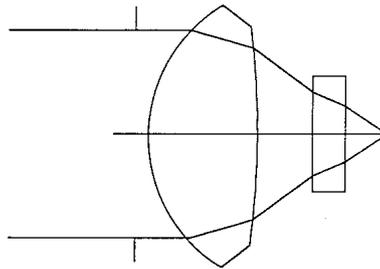
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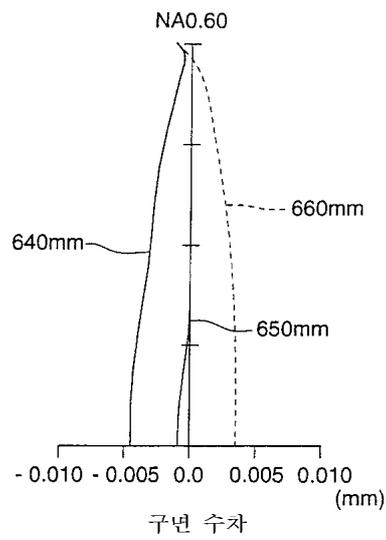
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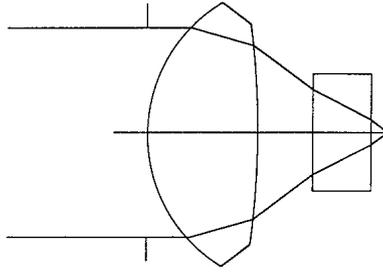
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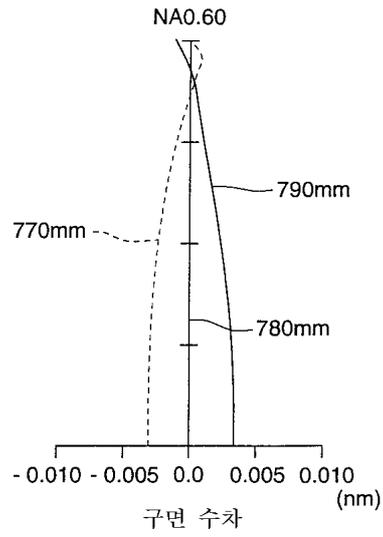
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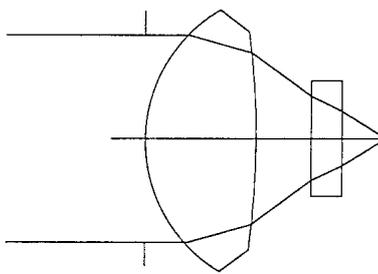
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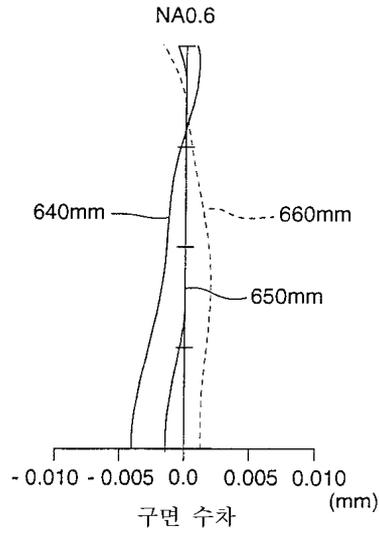
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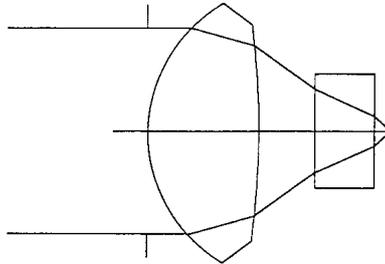
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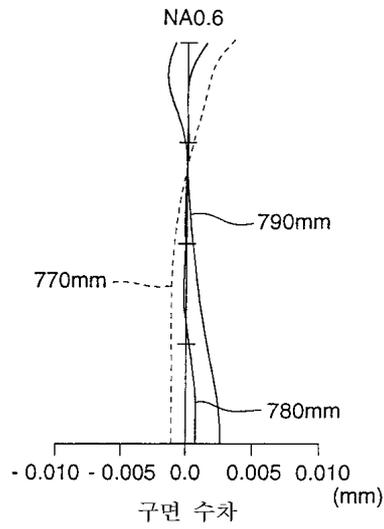
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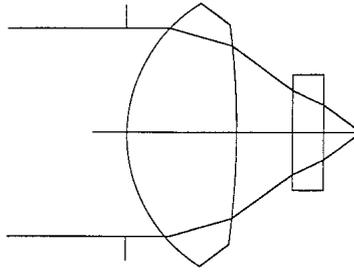
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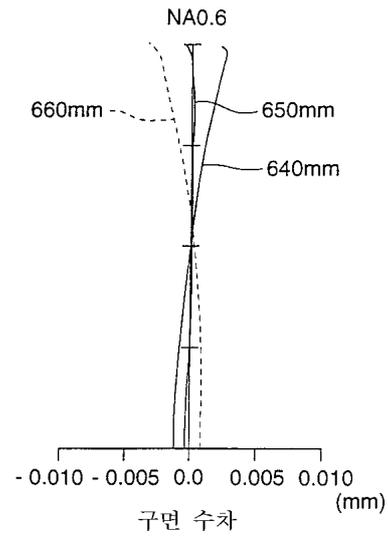
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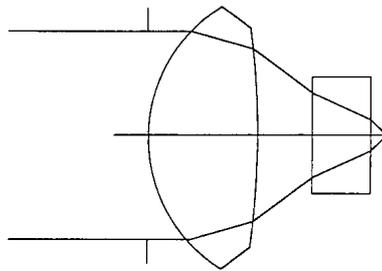
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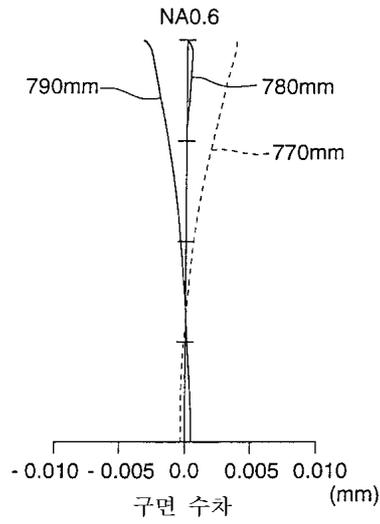
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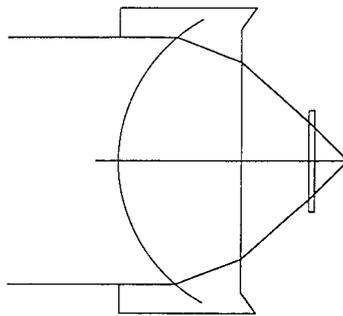
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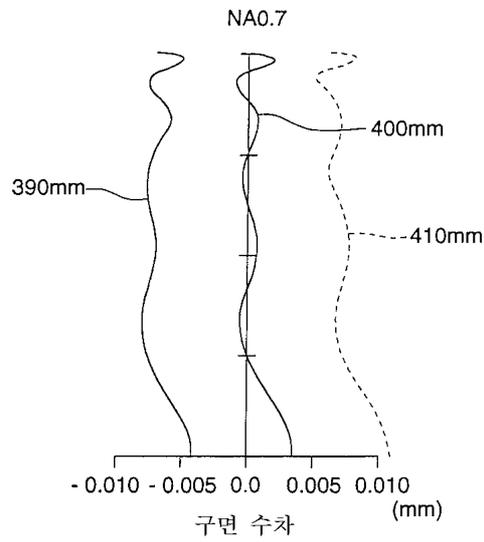
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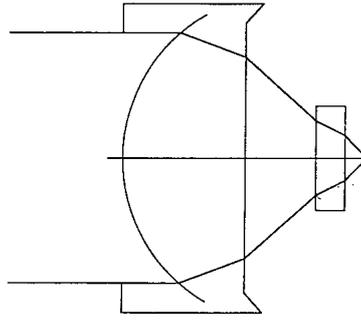
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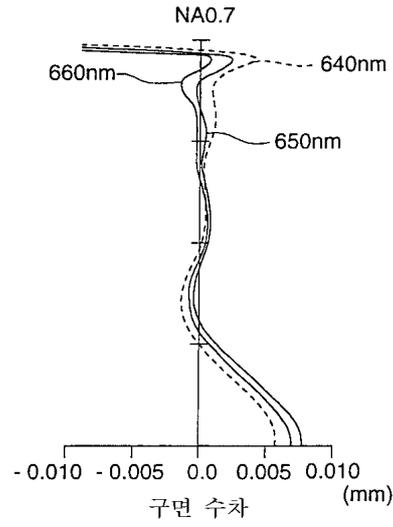
131



132



133



134

