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A Zoom Lens Set for Mega Pixcel CCTV with an Aspheric Lens

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Abstract

It was difficult to verify the car number or face of inspector in the closed circuit television because of low CCD pixels and low brightness of lens. So CCTV lens should have higher pixels and brightness. In this paper, the design of zoom lens for mega pixel Closed-Circuit Television (CCTV) was introduced. We applied aspheric lens in order to reduce the spherical aberration and distortional aberration. And we applied focal length of 5-50mm, F number of 1.4, 3 million pixel resolution and magnifying power of 10 times. Also we applied infrared correction in order to use the CCTV camera in day and night effectively. These norms are the most powerful in CCTV zoom lens of focal length of 5-50mm. And if we apply this lens to the box style CCTV camera, we can verify the car number or face within 50m.

Keywords: CCTV, Lens, Mega Pixel, Zoom

1. Introduction

In general, variable focal lenses are using in CCTV camera in order to verify the viewing angle. The CCTV camera seems to be important because it contained important evidence in order to arrest a suspect of victim. But the system always has a dark place because the angle of view is not enough. Wide angle lens has a wide angle of view and it can have an angle of wide up to 180 degree. The lens sets which can vary the angle of view are variable focal lens and zoom lens. If the angle of view is big, we can see widely but the object is too small to figure out. Also if the angle of view is small, we can see narrow view but the object is big enough to figure out. So variable focal or zoom lens can control the angle of view and the object size in order to figure it out[1].

2. The Design of Zoom Lens

We can choose the size and structure of zoom lens in order to fit to the purpose. The quality of lens set can be obtained by minimizing the aberrations and maximizing the transference. There are six kinds of aberrations such as spherical aberration, coma, astigmatism, curvature of field, distortion and chromatic aberration[2]. Spherical aberration and distortion can be adjusted by aspheric lens. Also chromatic aberration can be adjusted by combined lens set. The 50mm standard lens of full frame camera has an aspheric lens, five convex lenses and 2 concave lenses.

In order to receive enough light, the diameter of lens should be larger and lens pipe should be shorter.

The f-number N is given by focal length over effective aperture. Focal length of fitted object is defined by

$$f = v \times \frac{D}{V}, f = h \times \frac{D}{H} \tag{1}$$

where f: focus length, V: vertical size of object, H: horizontal size of object, D: distance between lens and object, v: vertical size of image, h: horizontal size of image.

Image sizes of CCTV camera are classified by 1”, 2/3”, 1/2”, 1/3”. 1/4” and lenses are classified by image sizes.

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Table 1. Typical one-half-stop f-number scale

AV	-1	-.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10
f/No	0.70	0.84	1.0	1.2	1.4	1.7	2	2.4	2.8	3.3	4	4.8	5.6	6.7	8	9.5	11	13	16	19	22	27	32

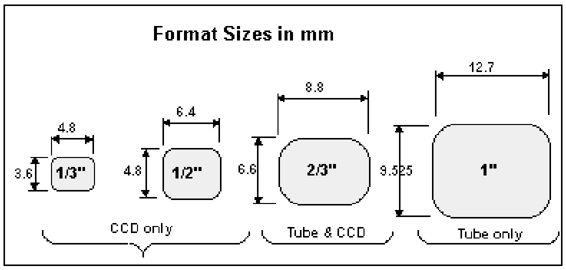

Figure 1. Image size of CCTV.

Figure 2 shows the structure of lens which explains the back focal length and flange back length.

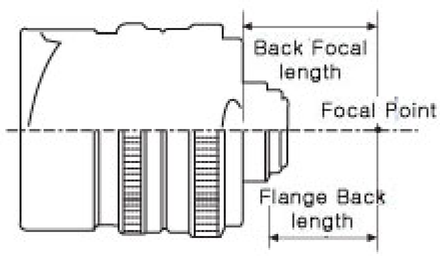

Figure 2. The structure of lens set.

Lens set has a tale of C-mount or CS-mount. The shape is similar but distance from flange is different. Figure 3 shows the C-mount and the CS- mount. In order to make a fine lens set, we should minimize the aberration. We can minimize these aberrations by using the aspheric lens in the lens set.

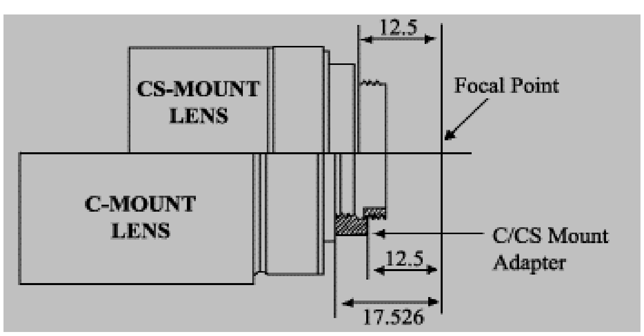

Figure 3. C-mount and CS- mount.

3. Computer Simulation for Optimizing

CCTV camera is more useful in the night than day time because several accidents occur in the night time. So we applied infrared ray correction to the lens set design by optical path length optimization of lenses array. Also we used aspheric lens in order to minimize spherical aberration and distortion[2]. Optimizing process can be performed by computer simulation[3].

3.1 Trajectory Analysis of 4 Group Lenses

We can obtain the desired solution of the four group lenses throughout the trajectory analysis of the 4 group zoom lenses. In the case of 4 group zoom lens, 16 solutions can be obtained by 4th differential equation, so we can choose 4 answers of 16 solutions.

If the infinitive object points G1, G2 are fixed, we can obtain the trajectory of 4 group lens by varying the k and bf.

$$[k_1, - z_1, k_2, - z_2, k_3, - z_3, k_4] = K \quad (2)$$

$$[k_1, - z_1, k_2, - z_2, k_3, - z_3] = Kbf \quad (3)$$

$$z_1 + z_2 + z_3 + bf = T \quad (4)$$

$$[k_1, - z_1, k_2, - z_2, k_3, - z_3]\, k_4 + [k_1, - z_1, k_2, - z_2, k_3] = K \quad (5)$$

$$[k_1, - z_1, k_2, - z_2, k_3, - z_3] = (1 - k1z1 - k1z2 - k2z2 - k1z2z1z2)^{*}\, k3 + k1 + k2 - (k1^{*}k2^{*}z1) \quad (6)$$

$$x_2 = T_1 - z_1 \quad (7)$$

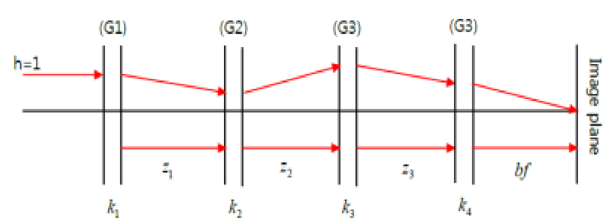

Figure 4. 4 group lens system.

```
4Group Zoom Initial Data at Infinite
m_d1w= 6.340 ;m_d2w= 40.767;m_d3w= 11.822;m_d4w= 13.878;
m_d1t= 40.370;m_d2t= 6.737;m_d3t= 10.132;m_d4t= 15.568;
m_EF0= 5.000;m_EF1= 50.000;

4Group Zoom Power Data at Infinite
k1= 2.05231977e-002,k2=-4.51919235e-003,k3=-1.21466909e+000,k4= 1.50748263e-001
F1= 48.72535051    ,F2=-221.27847712  ,F3=-0.82326949    ,F4= 6.63357561

k1= 1.75816248e-002,k2=-8.86791297e-002,k3= 3.32965371e-002,k4= 5.35154716e-002
F1= 56.87756444    ,F2=-11.27661044   ,F3= 30.03315320    ,F4= 18.68618494

k1= 3.40888211e-002,k2= 1.01205019e-001,k3= 1.75267027e-001,k4= 2.73669634e-001
F1= 29.33513007    ,F2= 9.88093289    ,F3= 5.70557974     ,F4= 3.65404076

k1=-2.51073138e+000,k2= 1.72934009e-001,k3=-7.64200794e+002,k4= 1.56618640e-001
F1=-0.39829032     ,F2= 5.78255259    ,F3=-0.00130856     ,F4= 6.38493606

4Group Zoom Locus Data at Infinite
```

1	6.34000	40.76700	11.82200	13.87800	72.80700	5.00000	1.00000
2	7.34000	39.76700	11.72870	13.97130	72.80700	5.22037	1.04407
3	8.34000	38.76700	11.63282	14.06718	72.80700	5.45567	1.09113
4	9.34000	37.76700	11.53429	14.16571	72.80700	5.70726	1.14145
5	10.34000	36.76700	11.43302	14.26698	72.80700	5.97667	1.19533
6	11.34000	35.76700	11.32894	14.37106	72.80700	6.26559	1.25312
7	12.34000	34.76700	11.22198	14.47802	72.80700	6.57591	1.31518
8	13.34000	33.76700	11.11208	14.58792	72.80700	6.90979	1.38196
9	14.34000	32.76700	10.99918	14.70082	72.80700	7.26960	1.45392
10	15.34000	31.76700	10.88325	14.81675	72.80700	7.65804	1.53161
11	16.34000	30.76700	10.76427	14.93573	72.80700	8.07815	1.61563
12	17.34000	29.76700	10.64225	15.05775	72.80700	8.53337	1.70667
13	18.34000	28.76700	10.51724	15.18276	72.80700	9.02759	1.80552
14	19.34000	27.76700	10.38933	15.31067	72.80700	9.56523	1.91305
15	20.34000	26.76700	10.25867	15.44133	72.80700	10.15129	2.03026
16	21.34000	25.76700	10.12548	15.57452	72.80700	10.79150	2.15830
17	22.34000	24.76700	9.99009	15.70991	72.80700	11.49236	2.29847
18	23.34000	23.76700	9.85296	15.84704	72.80700	12.26129	2.45226
19	24.34000	22.76700	9.71471	15.98529	72.80700	13.10676	2.62135
20	25.34000	21.76700	9.57617	16.12383	72.80700	14.03845	2.80769
21	26.34000	20.76700	9.43844	16.26156	72.80700	15.06737	3.01347
22	27.34000	19.76700	9.30300	16.39700	72.80700	16.20606	3.24121
23	28.34000	18.76700	9.17174	16.52826	72.80700	17.46876	3.49375
24	29.34000	17.76700	9.04715	16.65285	72.80700	18.87154	3.77431
25	30.34000	16.76700	8.93245	16.76755	72.80700	20.43240	4.08648
26	31.34000	15.76700	8.83182	16.86818	72.80700	22.17137	4.43427
27	32.34000	14.76700	8.75058	16.94942	72.80700	24.11040	4.82208
28	33.34000	13.76700	8.69556	17.00444	72.80700	26.27319	5.25464
29	34.34000	12.76700	8.67542	17.02458	72.80700	28.68474	5.73695
30	35.34000	11.76700	8.70103	16.99897	72.80700	31.37085	6.27417
31	36.34000	10.76700	8.78595	16.91405	72.80700	34.35746	6.87149
32	37.34000	9.76700	8.94691	16.75309	72.80700	37.67029	7.53406
33	38.34000	8.76700	9.20432	16.49568	72.80700	41.33569	8.26714
34	39.34000	7.76700	9.58300	16.11700	72.80700	45.38397	9.07679
35	40.34000	6.76700	10.11337	15.58663	72.80700	49.85851	9.97170

Figure 5. Solutions of 4^{th} differential equation in 4 group lens.

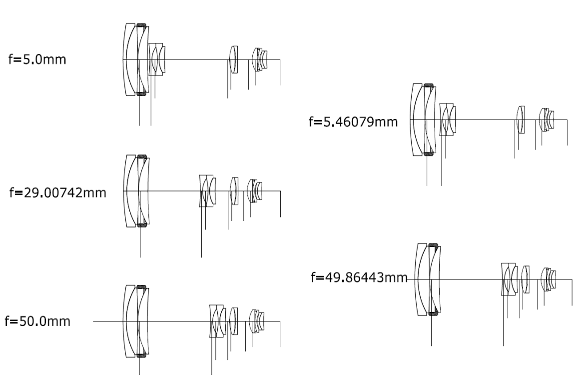

Figure 6. First design by zoom trajectory.

After first design we applied these data to Code-V program and optimized data. Figure 7 and Figure 8 shows 2 and 3 dimensional zoom lens design.

3.2 Infrared Correction

The relative contrast is given by the absolute value of the optical transfer function, a function commonly referred to as the Modulation Transfer Function (MTF). We varied F-no. and improved MTF in the region of visible and infrared.

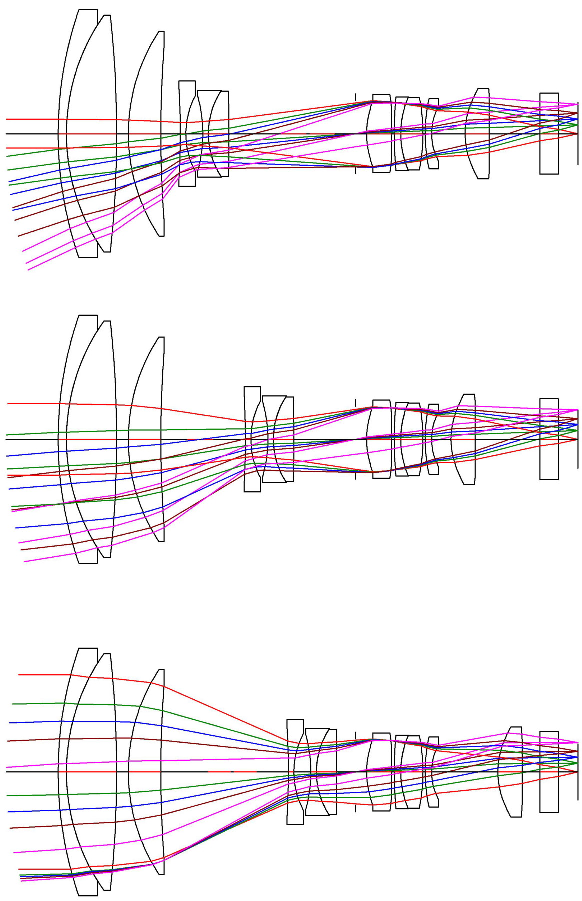

Figure 7. Design of zoom lens.

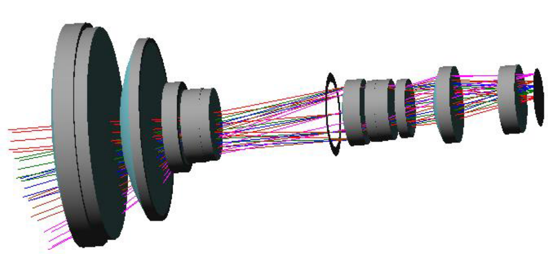

Figure 8. 3D modeling of zoom lens.

Designed lens set parameters are as follow. Focal length of lens: 5~50mm, iris: F1.4-Infinitive, lens mount: CS, CMOS size: 1/3″, horizontal angle of view: 1/3”: 42°~4.5°, 1/4”: 32°~3.4°, minimum of working distance: 0.5m . Also out look of designed lens set is shown in Figure 11 and Figure 12. First of all, the special parameter of this lens set is pupil. We applied 1.4 in nearest focus of CCTV camera lens.

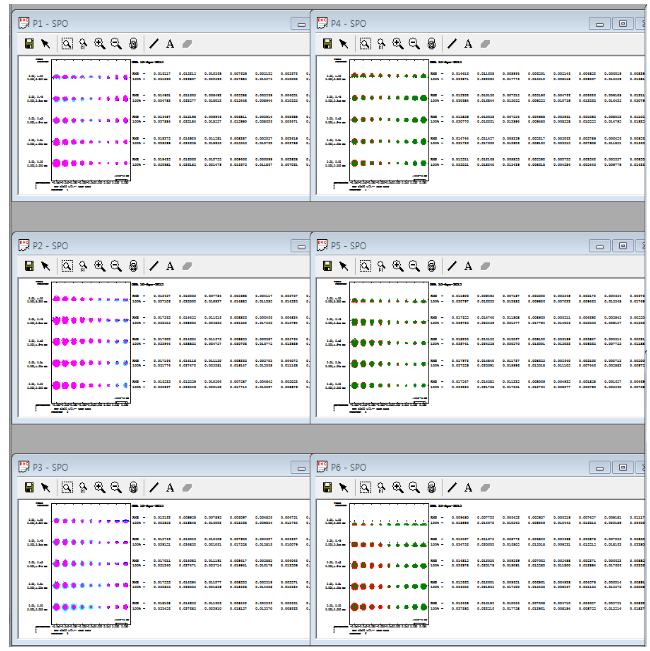

Figure 9. IR Correction in the Visible and Near Infra Red.

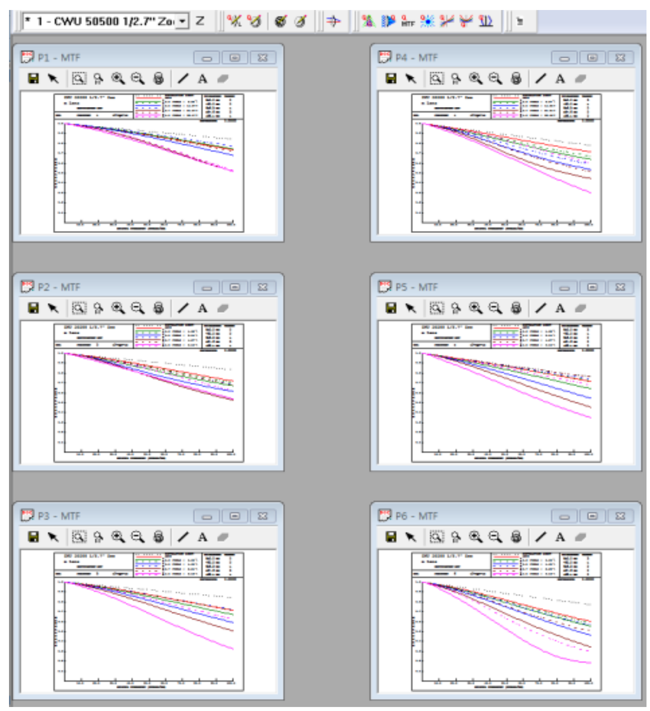

Figure 10. MTF of visible and near infrared (after IR correction).

4. Sample Test

We made test lenses for quality testing. Actually the important item of lens quality is a Modulation Transfer Function (MTF). When optical designers attempt to

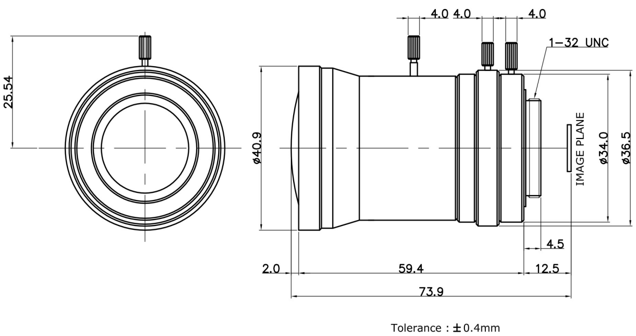

Figure 11. Design of external case of zoom lens.

Figure 12. Sample of external case of zoom lens.

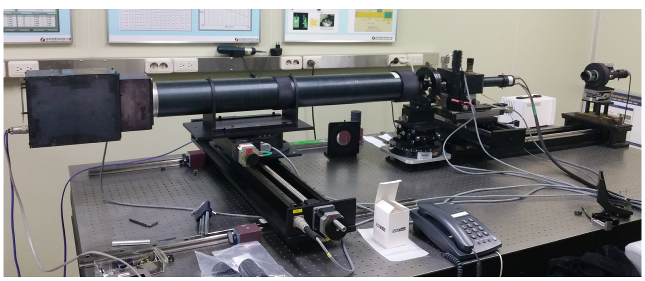

Figure 13. Lens testing equipment in KRISS.

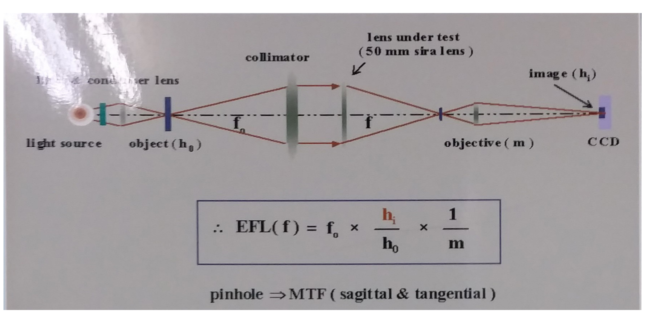

Figure 14. Schematic diagram of lens testing equipment in KRISS.

compare the performance of optical systems, a commonly used measure is the modulation transfer function. Figure 13 and 14 are a picture and a schematic diagram of lens testing equipment in KRISS. We got a meaningful MTF values with this test. Table 2 shows the MTF values of sample lens.

Table 2. MTF of sample lens

Frequency (mm^{-1})	Axial	0.5 Field	
		Tangential	Radial
20	0.931	0.878	0.881
40	0.846	0.693	0.746
60	0.744	0.515	0.607
80	0.639	0.384	0.486
100	0.539	0.295	0.385
120	0.450	0.230	0.302
140	0.369	0.181	0.224
160	0.299	0.145	0.160
180	0.235	0.118	0.113
200	0.182	0.100	0.076

5. Conclusion

We designed zoom lens set which have a focus range of 5-50mm and an F number 1.4 for 3 mega pixel CCTV camera. And we applied infrared ray correction in order to minimize the difference in the focal points of visible and infrared ray. Aspheric lens was used in the lens set in order to minimize the spherical aberration and distortion. Also CS-mount was applied to fit in the old camera system. These norms are the most powerful in CCTV zoom lens of focal length of 5-50mm. And if we apply this lens to the box style CCTV camera, we can verify the car number or face within 50m. Also we constructed the sample lens and got a meaningful MTF values.

6. References

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