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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

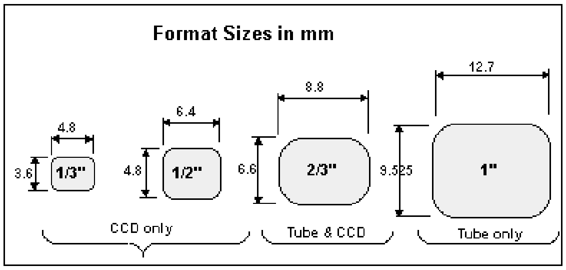

Figure 1. Image size of CCTV.

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

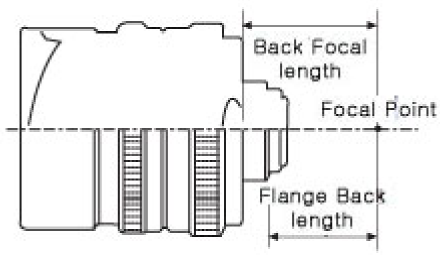

Figure 2. The structure of lens set.

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.

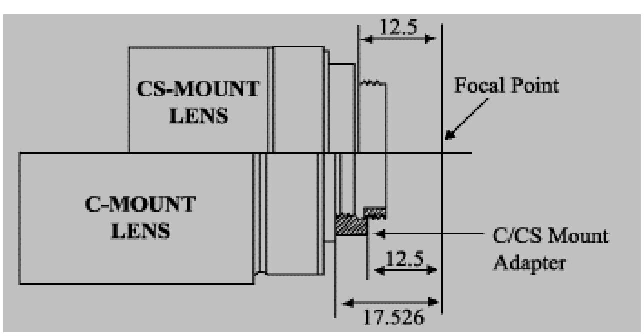

Figure 3. C-mount and CS- mount.

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.

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

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

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

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

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

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

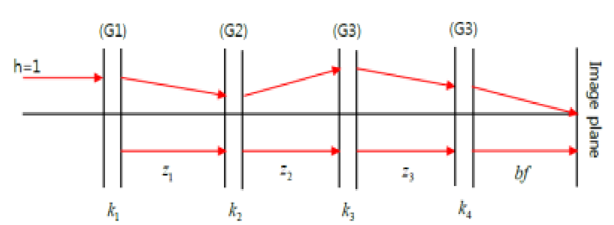

Figure 4. 4 group lens system.

```
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
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Figure 5. Solutions of 4th differential equation in 4 group lens.

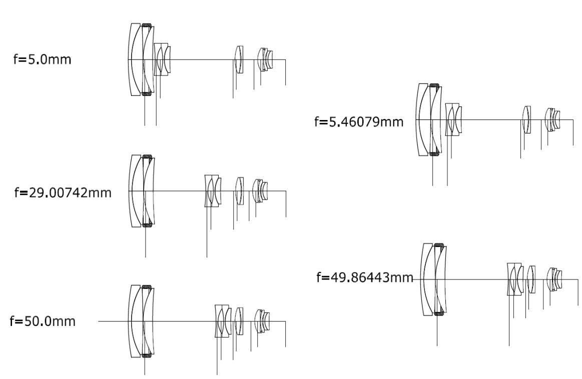

Figure 6. First design by zoom trajectory.

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.

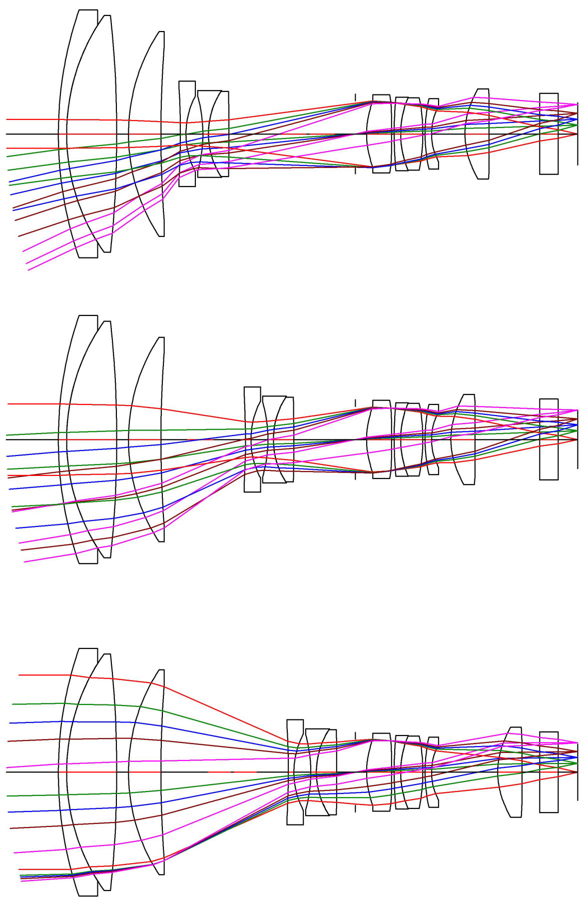

Figure 7. Design of zoom lens.

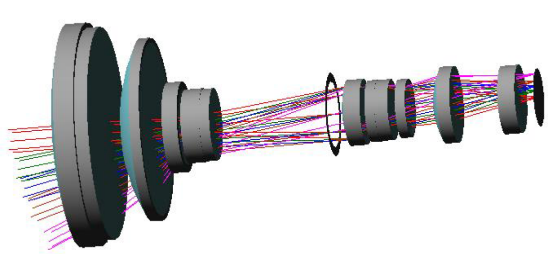

Figure 8. 3D modeling of zoom lens.

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.

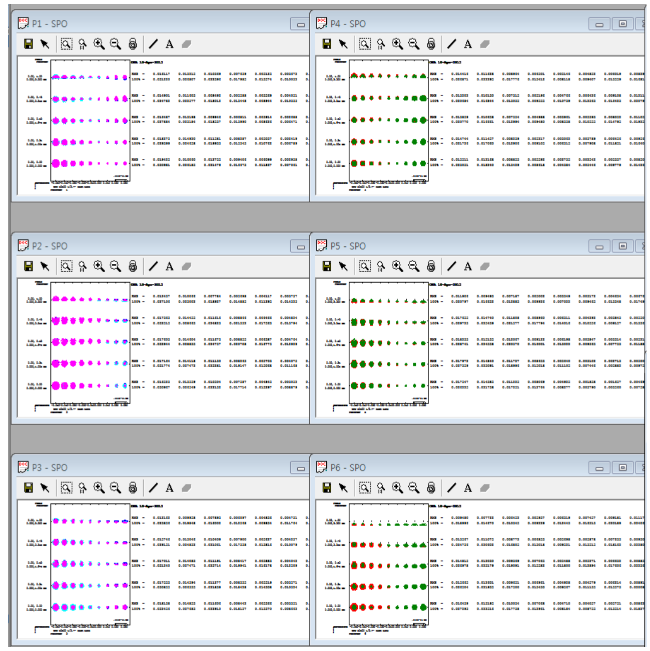

Figure 9. IR Correction in the Visible and Near Infra Red.

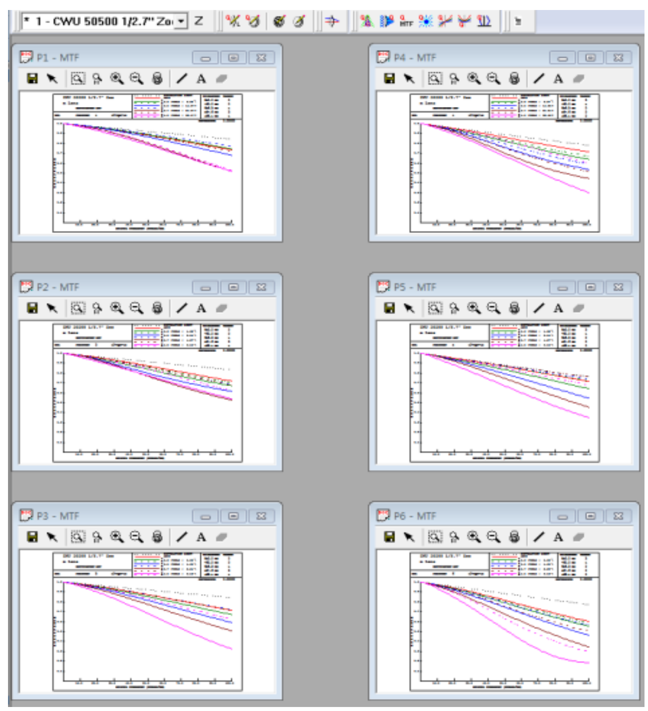

Figure 10. MTF of visible and near infrared (after IR correction).

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

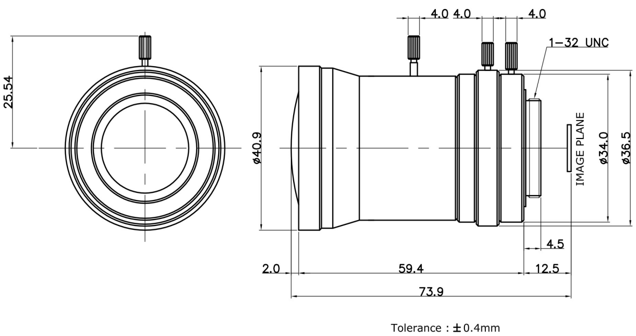

Figure 11. Design of external case of zoom lens.

Figure 12. Sample of external case of zoom lens.

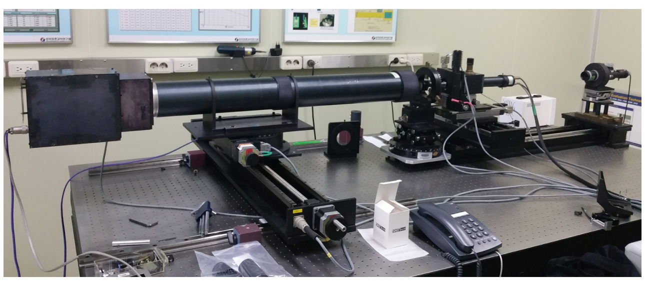

Figure 13. Lens testing equipment in KRISS.

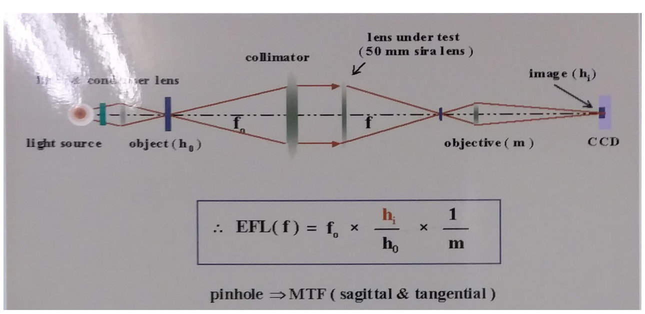

Figure 14. Schematic diagram of lens testing equipment in KRISS.

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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