New analysis method of electrostatic lens for CRT

J. M. Seok, Y. S. Nam, J. I. Lee
Components R & D Team, ORION ELECTRIC CO., LTD., 257 Gongdan-dong Gumi Kyung-Buk Korea

Abstract

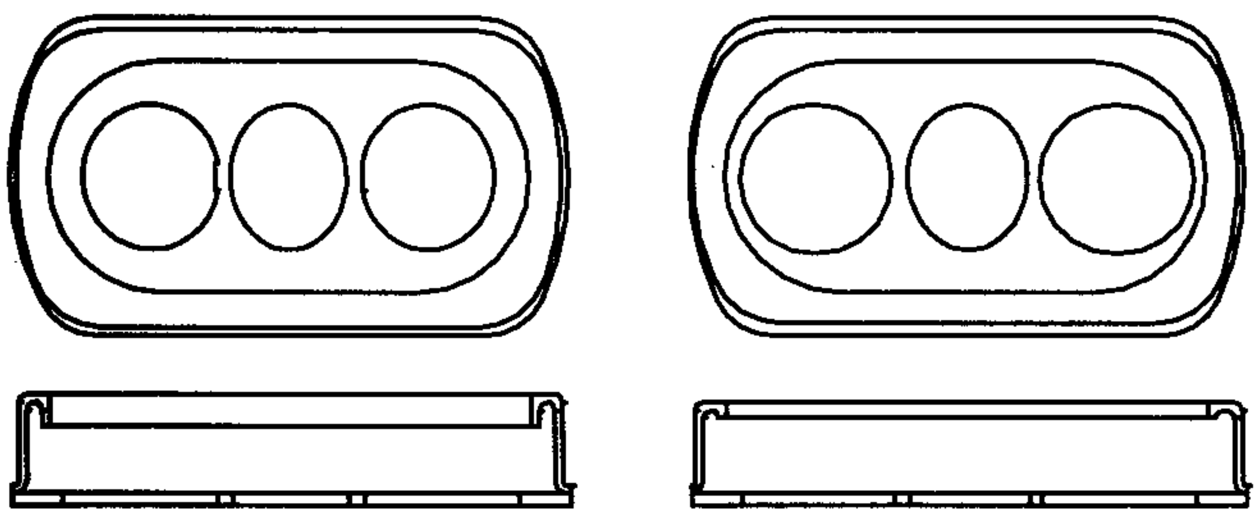
The spherical aberration and optical integer (f) of the electron gun's main lens in color CRT is obtained, using electron beam trajectory. A spherical aberration is obtained from the relation between the object plane and the image of a beam trajectory. To analyze beam profile, 3rd and 1st order coefficient were obtained and used. It is shown that, in practice, they are applied to electron gun design.

1. Introduction

As the CRT has moved to higher resolution, to higher brightness, the design of electron gun has become more complicated. Especially, the Design of Main lens is one of the most important parts in the electron gun design. The major function of a main lens is focusing electron rays on the screen and bending side beam to converge all three beams on the screen. At present, the main lens being used most is the extended lens.

For example, dynamic focusing electron gun system,

Figure 1.shows the configuration of the extended lens. It consists of dynamic focusing (G5) and accelerating (G6) electrode, and each electrode have rim parts and plate parts, which adjust astigmatism.



< G5 electrode > < G6 electrode >

Figure 1. Structures of main lens, shows front and cross-sectional views

Consideration for spherical aberration and optical integer are very important for the main lens design. In this paper, a new method to get spherical aberration and optical integer (f) will be introduced. And then practically calculate them and analyze the result about a few types of main lens and will show an application.

2. Theory

2.1 Spherical aberration

In the electron gun, the spot size (D_s) of electron rays entering the main lens can be written

$$D_s \propto MC_{sa}\alpha^3 \text{ ------------------------- (1)}$$

Where M is the magnification, C_{sa} is the spherical aberration and α is the slope angle of the ray.

Equation (1) indicates that if the electron rays entering the main lens are same, the smaller M and C_{sa}, the smaller spot size.

First, considering spherical aberration in CRTs, it is a large contributor to the size of the electron spot.

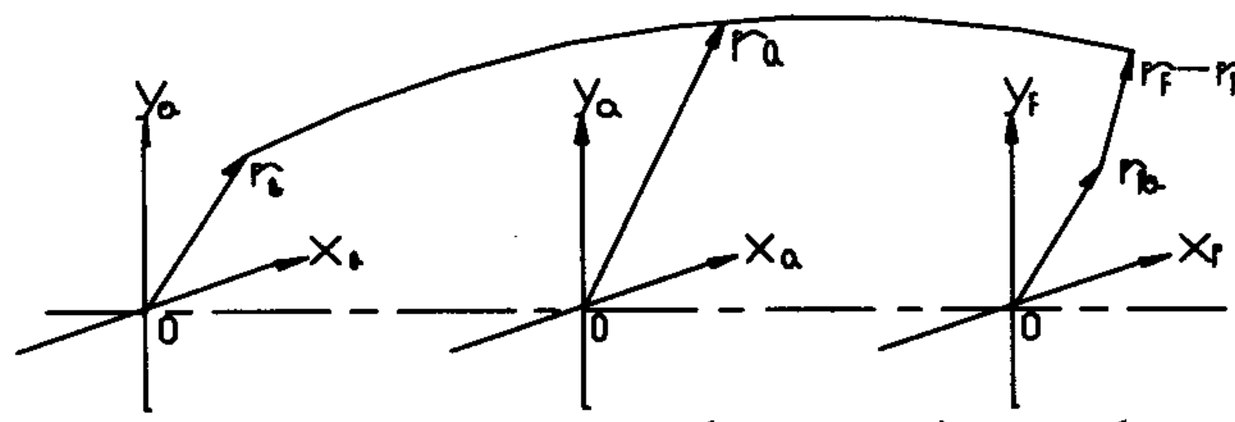
Any electrostatic lens has always spherical aberration.

In cylindrical lens, the radial field(E_r) for the potential (Φ) can be expressed as

$$E_r(r,z) = -\frac{1}{2}r\frac{\partial^2\Phi(r,z)}{\partial^2 z} \text{ ------------------- (2)}$$

Then since E_r has r dependence, there is spherical aberration for the lens.

The deflecting power of axially symmetric electric lenses is greater for rays passing further from the center of the lens than it is for paraxial rays, as expressed in Equation (2). Hence, parallel rays entering the lens cannot be focused to a point as would be expected of an ideal lens. Rather, they form a spot of radius Δr .



<object plane> <aperture plane> <image plane>

Figure 2 Object, aperture, image plane

The spherical aberration is the only type of aberration that exits for a point object on the axis because it does not depend on r_o, but only r_a.

Assuming the electrostatic field to be continuous throughout the lens space, the coordinates of each point at the image plane can be expressed by a power series of the coordinates of the rays at the object plane and aperture plane.

Taking into account the fact that the electrostatic lens field is axially symmetric, the higher order terms for the radial coordinates r_i of an electron ray in the image plane can only be odd terms. If neglecting fifth- and higher-order terms in Δr, it can be expressed as

$$\Delta r = c r_a^3 \text{ ------------------------------------ } (3)$$

As Equation 3 says, spherical aberration is obtained from the relation between image and aperture plane and in this paper, from the image and object plane relation, spherical aberration has been calculated.

By this approach, spherical aberration is simply obtained.

At first, to calculate spherical aberration, we use parallel electron rays.

The diameter of parallel electron rays is 3mm. In the simulation, the length of each electrode is also taken as twice more aperture size of its plate. Electron rays go throughout from G6 to G5 electrode.

The spherical aberration can be obtained as relation between the coordinates r_i of parallel electron rays in the object plane and r_0 in the image plane

The spherical aberration coefficients of x and y component for beams can therefore be written

$$\begin{aligned} \Delta x &= cx^3 + dx + e \\ \Delta y &= cy^3 + dy + e \end{aligned} \text{ --------------------------- } (4)$$

where c, is third-order coefficient, d is first order coefficient. Constant term e is obtained only in the side beam, d, first order coefficient, is obtained, as aperture size is small. If the size of the lens is larger, it is not appear, but 3-rd order superior.

In the Equation (4) as matter of fact, spherical aberration is only c, but to consider both c and d is very helpful for main lens analysis.

The side beam in the electron gun goes through the asymmetric main lens. Thus the coefficient of the side beam is obtained to divide x into x<0, x>0. The path of this beam has slope, so appears constant term. It is negligible.

Thus, the coefficients of rays summarized as table 1.

Table 1. Spherical aberration's coefficients of rays

Center beam		Side beam		
x	y	x<0	x>0	y
c, d	c, d	d	c, d	c, d

2.2 Optical integer (f)

The focal length of main lens is calculated by following equation, using paraxial rays.

$$\lim_{r_0 \to o} \frac{r_o'}{r_i'} \text{ ---------------------------------- } (5)$$

where prime means the derivative with respect to z.

It is obtained for center beam and side beam divide into x and y-axis. In case of the side beam, as consider convergence, it has path's slope, thus calculated correct that

In the same as tube, the length from the main lens to the screen is same. As f is larger, spot size is smaller.

3. Application

3.1 Compare of main lens

Figure 3 shows three types main lenses using in the electron gun of 17"FLAT CDT. Compared these with spherical aberration and f.

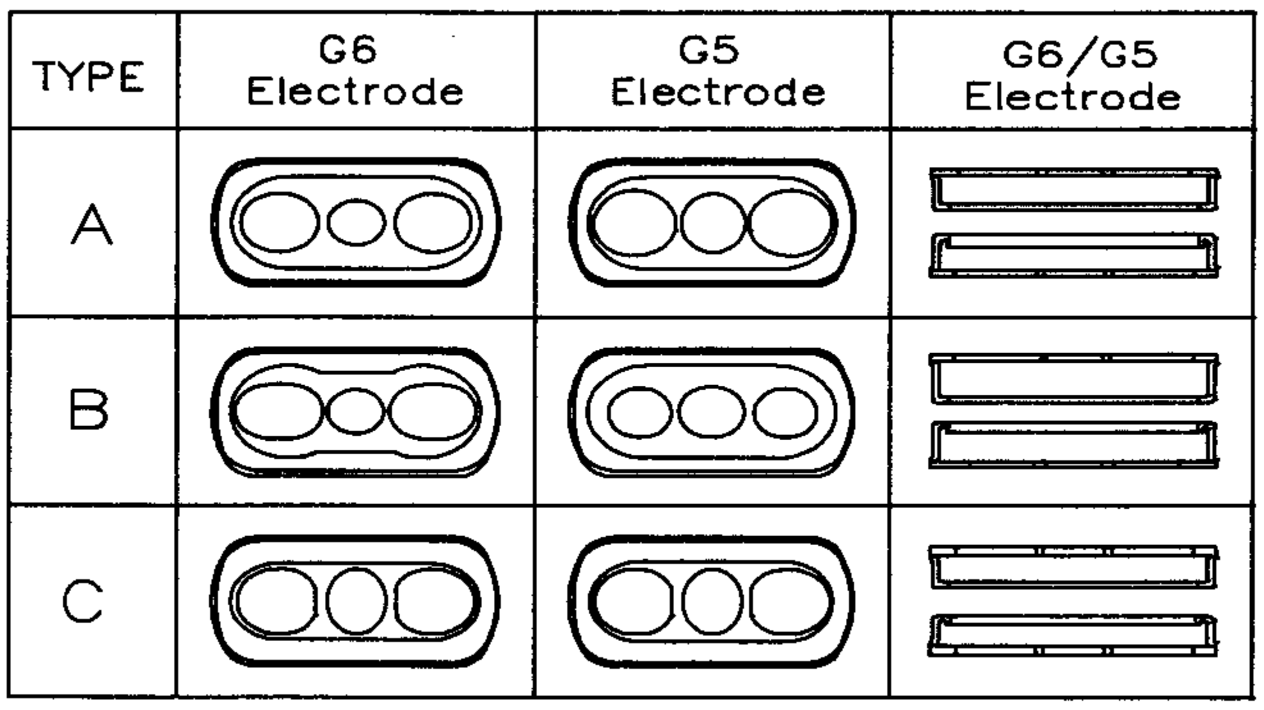


Figure 3. Main lenses of A, B and C type,shows front and cross-sectional view

A type: G5 and G6 electrode length are same. Astigmatism plate has circle and elliptical apertures.

B type: G6 electrode length is larger than the G5. G6 rim parts has dogbone type, astigmatism plate has circle and race track aperture.

C type: Rim parts size is smaller than others, plate thickness is large, astigmatism plate of G5 and G6 electrodes are same.

Spherical aberration and f are simulated around focus voltage by constant interval for each electron gun.

Figure 4, 5, 6, 7 and 8 show changes of spherical aberration to f for main lenses. 3rd(c) and 1st-order(d) coefficients to f say characteristics among main lenses.

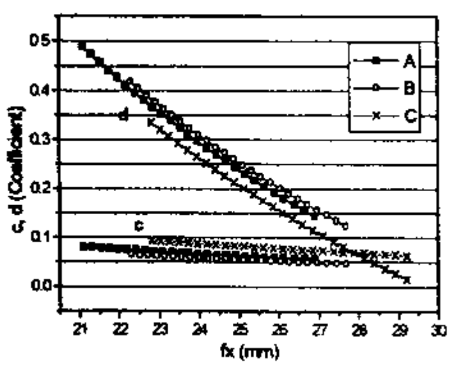


Figure 4. Center beam, x .

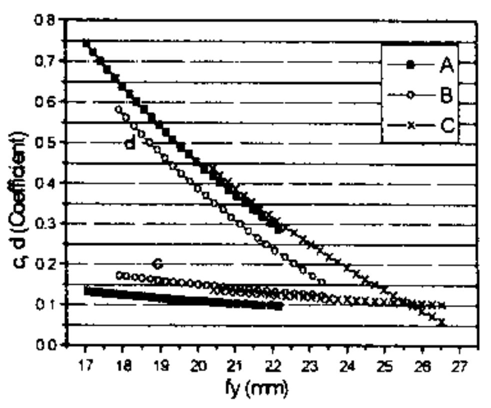


Figure 5. Center beam, y.

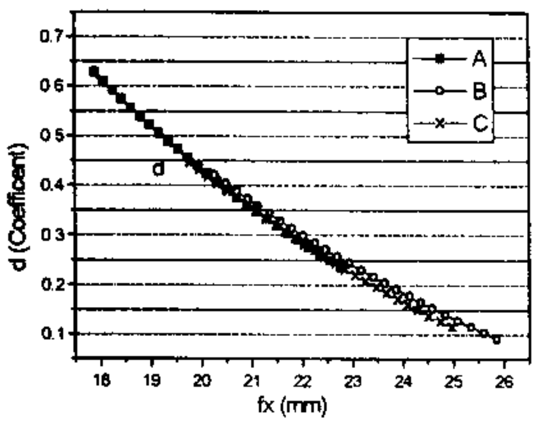


Figure 6. Side beam, x<0.

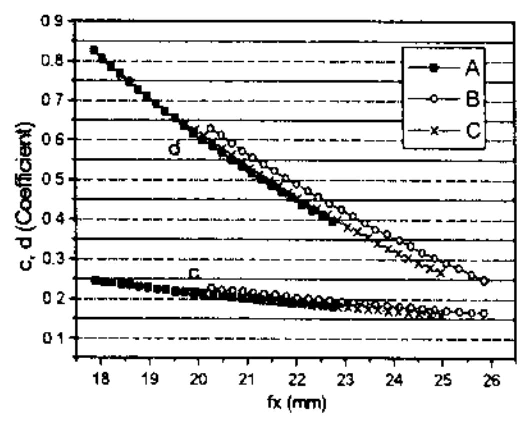


Figure 7. Side beam, x>0.

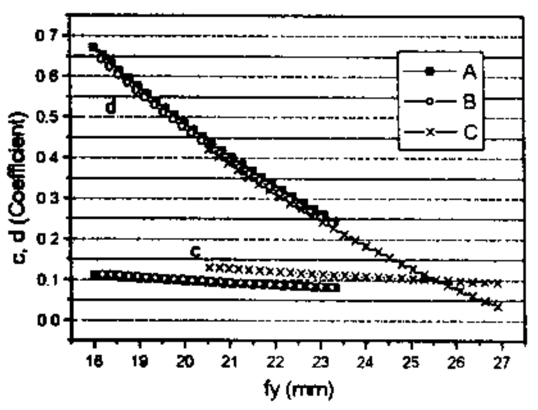


Figure 8. Side beam, y.

In practice, these figures show the difference of spherical aberration is small, but big to focus voltage.

The higher focus voltage, the more advantage. C type's main lens is higher focus voltage to others. so it has the smaller spherical aberration.

And the shape of spot profile is mostly known 3rd(c) and 1st-order(d) aberration coefficients. In case that 1st-order coefficient is getting large, it has halo components in display. In reverse if 3rd-order is getting large, it has moiré. B type's main lens has large d and small c for others. So appears halo. Thus 1st and 3rd are adjusted properly is important.

3.2 Apply to Gun design

There are two electron guns, A and B type, dynamic focusing, which is same from cathode to main lens before. Main lens is different. Specially, as figure 8. is shown, only G6 plate electrode is different in the main lens

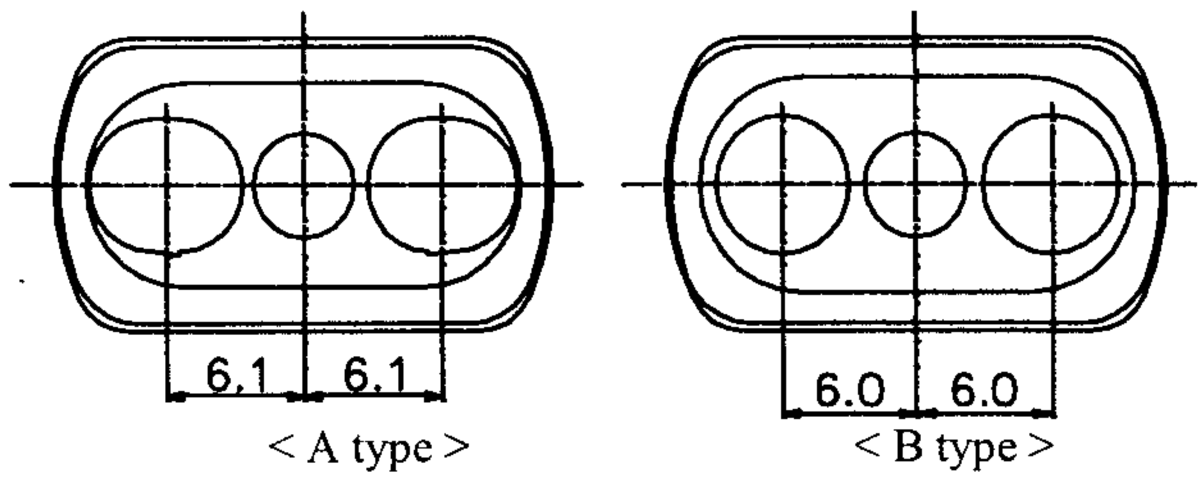


Figure 9. A and B type's G6 electrode

A type's G6 plate electrode has side aperture of race track type.

B type's G6 electrode has the plate which center and side aperture all are circle, center circle is smaller than the A type.

The distance of between of aperture is also different, as showed in Figure 9.

Table 2 shows spherical aberration, optical integer and spot size.

Table 2. Spherical aberration & f of type A and B

▶. Center beam

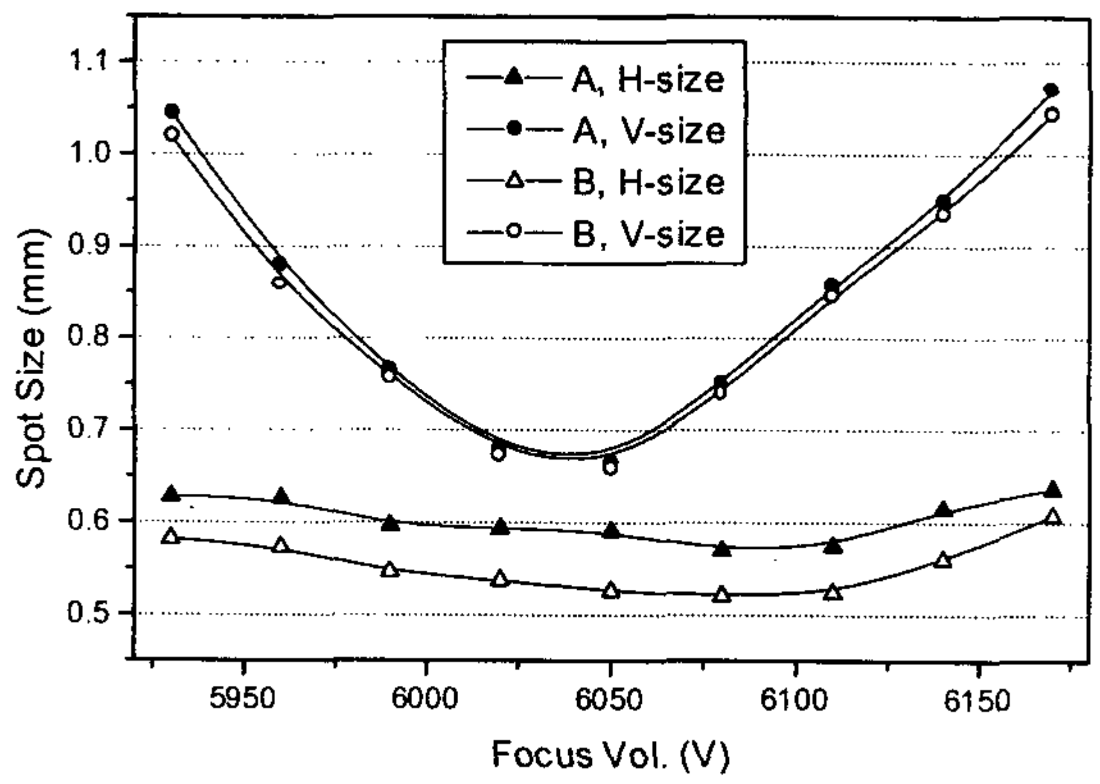
Type	Focus vol. (V)	fx (mm)	x		fy (mm)	y	
			c	d		c	d
A	6050	21.948	0.077	0.408	18.128	0.127	0.586
B	6050	22.408	0.075	0.396	18.202	0.124	0.620

▶. Side beam

Type	Focus vol. (V)	fx (mm)	x			fy (mm)	y	
			x<0	x>0				
			d	c	d		c	d
A	6050	18.353	0.526	0.257	0.762	19.170	0.105	0.535
B	6050	18.981	0.522	0.229	0.709	19.199	0.104	0.557

In both spherical aberration and optical integer, B type is better. x component in the center and side beam is more improved than y component. x components of aberration is improved by 2~11%, y component by 1.4~2.1%.

Spot size is calculated in computer about two type's gun. The result is shown in Figure 10, In the center and side beam, x and y component is each about 6% and 1.6% improved.



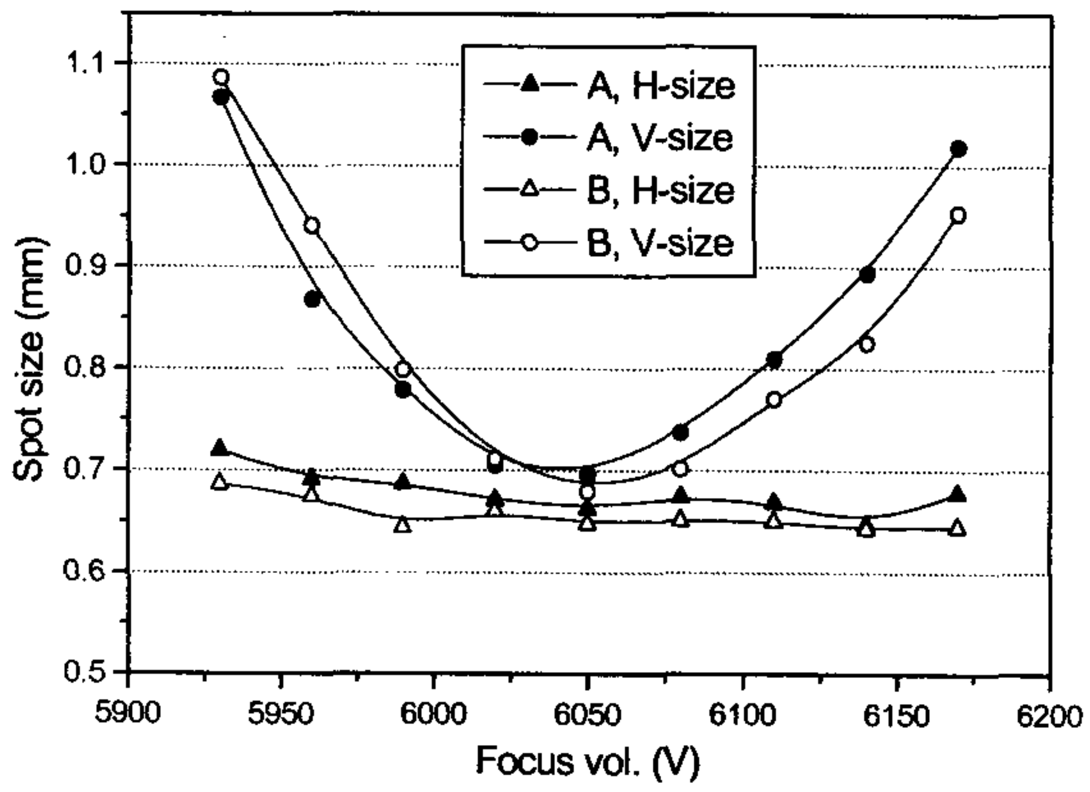


Figure 10. Spot sizes of A and B type guns, upper graph is about center beams and lower is about side beams

4. Conclusion

A new method to calculate spherical aberration and optical integer has been introduced. The advantage of the new method is obtaining the aberrations of main lens from the beam trajectory and the basic optical integers as well. 3rd-and 1st-order coefficients obtained from the trajectory can express beam profile. In addition, it is possible to analyze main lens numerically. By this method, we compared various types of main lens. In the same size CRT, if optical integer becomes larger, magnification is decrease and spherical aberration of main lens becomes smaller, As a result, spot size becomes smaller. The improved main lens in spherical aberration and optical integer has good spot size, therefore this method is helpful for main lens design.

5. References

[1] Hiroshi suzuki. Electron gun system for color cathode ray tubes. Advances in imaging and electron physics. vol.105. 295p

[2] Geissler and J. Zadunaisky. Am.J.Phys. vol. 42, 1974, 1002p

[3] AMERICAN JOURNAL OF PHYSICS, vol.43, No.8, AUGUST 1975, 1002p

[4] M.H.L.M. van den Broek. J. Appl. Phys., vol. 60, No.11, 1 December 1986.