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Modeling of Color TV-tube Shadow Mask Surface

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Quality of color gamut reproduced by color TV-tubes with planar electronic-optical system (EOS) strongly depends on geometrical parameters of shadow mask surface slit, which are typically found during empirical experiments. Such method requires lots of expenses and lasts for a long time.

Technique offered in this work is based on electron trajectory modeling in measured or modeled electric and magnetic fields, created by developed TV-tube [1,2].

Initial modeling data:

- analytical or tabular description of electric and magnetic fields;
- curvature function of TV-tube screen inner surface ($z_e = z_e(x, y)$);
- x-spacing function of monochrome luminophor elements $\Delta x = \Delta x(x, y)$;
- EOS, TV-tube and magnetic field geometric and electromagnetic parameters.
- it is considered, that the mask is symmetric along X and Y axes, thus mask surface is formed in one mask quadrant.

Two mask surface function creation methods were analyzed:

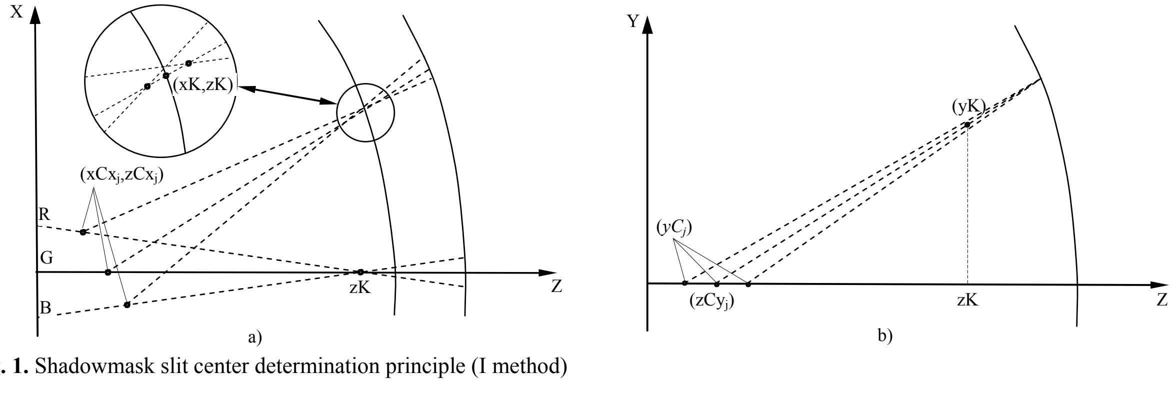
1. Rectangular base-point mesh is formed in the screen surface quadrant. Each base-point of the screen matches the point of the screen, coordinates *xK* and *zK* of which are average values of corresponding coordinates of intersection points of „red“ (R) and „green“ (G) and also „blue“ (B) and G electron trajectory projections in X0Z plane (Fig. 1,a). The third mask point coordinate (y) is the coordinate of G electron trajectory, when *z=zK* (Fig. 1,b)

In the second technique we assume, that mask point coordinates *xK* and *zK* are defined by coordinates of intersection point of R and B electron trajectory projections in X0Z plane (Fig. 2,a), and the third coordinate *yK* is the average value of *y* coordinates of the same electron trajectories when *z=zK* (Fig. 2,b).

Mask surfaces, calculated using first or second methods, will differ. So question is: which method is better? Main criterion could be least mean of maximal difference between ideal and real electron traces on luminophor elements according X axis.

Initially, modeling electron trajectories using approach method, R, G and B electrons are very precisely deflected to central screen point luminophor elements and with ~ 0,1 mm precision to other screen base luminophor elements.

At first during modeling of electron trajectories by successive approach technique, R, G and B electrons are deflected with great precision to the luminophor elements of the central screen point and with precision of ~0,1 mm – to other base centers of the screen luminophors. After crossing projections of „monochromatic“ electrons of zero deflection and defined deflection trajectory lines in X0Z and Y0Z planes, deflection center coordinates of these electrons are found – xCx_j, zCx_j and zCy_j (Fig. 1) (it is assumed that yC_j=0).



a) b)

Fig. 1. Shadowmask slit center determination principle (I method)

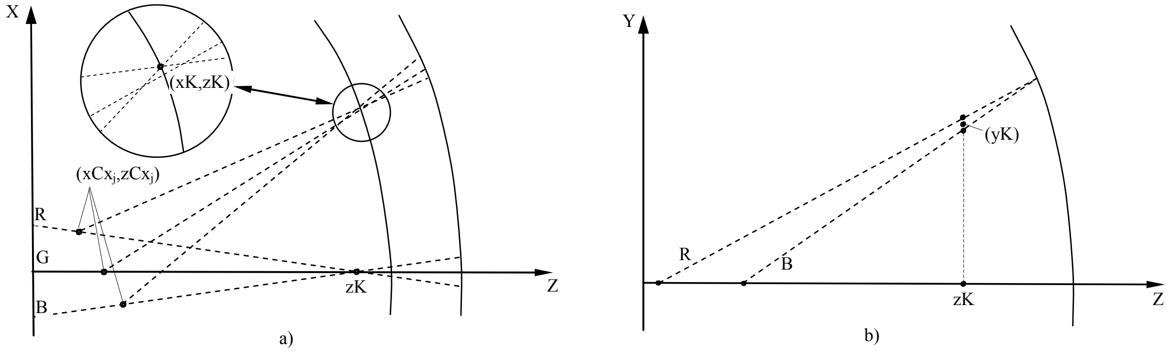


Fig. 2. Shadowmask slit center determination principle (II method)

It was ascertained during investigation, that when deflecting electrons to various points of the screen the coordinates of deflection centers does not change much, furthermore, the variation laws of all three electron deflection centers are similar.

When modeling the surface of the shadowmask by the first method, only G electron will always hit the center of its own luminophor, thus high precision is not needed when deflecting G electron to the defined point of the screen. Assume, that xe, ye are the coordinates of G electron on the screen. Ideally coordinates of R and B electrons on the screen should be:

$$xe_{R,B} = xe_G \mp \frac{\Delta x(xe,ye)}{3}; \qquad (1)$$

$$ye_{R,B} = ye.$$

It is attempted to deflect R and B electrons to these points as precisely as possible. Suppose that there is no deflection error. Then, knowing direction coefficients of all electron trajectory lines at the points of the screen, it is possible to find the coordinates of deflection centers and shadowmask point coordinates. Since coordinates of the deflection centers vary very little in the limits of one luminophor triad, then after drawing lines through the deflection centers and the point of the shadowmask the real coordinates of R, G and B electron traces – $xe^*_{R,G,B}$, $ye^*_{R,G,B}$ – are found on the screen (the real trace of G electron coincides with the ideal).

The projections of distances between multicolor traces on the screen:

$$\Delta xe^*_{R,G} = xe^*_R - xe^*_G; \qquad (2)$$

$$\Delta xe^*_{B,G} = xe^*_B - xe^*_G; \qquad (3)$$

$$\Delta xe^*_{R,B} = xe^*_R - xe^*_B + \frac{\Delta x(xe,ye)}{3}; \qquad (4)$$

$$\Delta ye^*_{R,G} = ye^*_R - ye^*_G; \qquad (5)$$

$$\Delta ye^*_{B,G} = ye^*_B - ye^*_G; \qquad (6)$$

$$\Delta ye^*_{R,B} = ye^*_R - ye^*_B. \qquad (7)$$

Ideally the projections of these distances should be $\Delta xe_{i,j} = \frac{\Delta x(xe,ye)}{3}$, and $\Delta ye_{i,j} = 0$.

Distance deviations from the ideal determine systematic error of the method along X and Y directions:

$$PX_{i,j} = \left|\Delta xe^*_{i,j}\right| - \frac{\Delta x(xe,ye)}{3};\ PY_{i,j} = \Delta ye^*_{i,j} \qquad (8)$$

Analogously systematic error is found for the second method also; in this case we can deflect R electron to the defined point of the screen with low precision.

Let's say, that coordinates of R electron trajectory modeling trace on the screen are xe_R, ye_R. Then coordinates of ideal trace of B electron will be

$$xe_B = xe_R + \frac{2}{3}\Delta x(xe_R, ye_R),\ ye_B = ye_R. \qquad (9)$$

B electron should be deflected to this point as precisely as possible. If there is no deflection error, then the real traces of R and B electrons will coincide with the ideal. We deflect G electron to the point of the screen also

$$xe_G = xe_R + \frac{\Delta x(xe_R, ye_R)}{3},\ ye_G = ye_R \qquad (10)$$

using low precision. Knowing direction coefficients of R, G and B electron trajectories at the points of the screen, the coordinates of the deflection centers and shadowmask point coordinates are found. After drawing lines through deflection centers and the point of shadowmask the real coordinates of R, G and B electrons on the screen xe^*_i, ye^*_i (i=R,G,B) are found.

The systematic error of the method is found similarly like for the first method (expressions (2)-(7)).

Method systematic errors should be calculated at the various points of the screen and only then decisions should be taken regarding suitability of one or another technique.

The question is what precision is needed when deflecting R and B electrons (I method) and B electron (II method) to the needed points of the screen. If R and B electrons (in the first method) and B electron (in the second method) will be deflected to the defined points of the screen with errors δx and δy, then the points of the modeled shadowmask surface will be at another place, and real electron traces on the screen will no longer coincide with traces received during error-free shadow mask formation. The new shadowmask point will form a new triad of traces on the screen, in which distances between multicolor traces will also be different. The purpose functions are found after estimating differences of the new distances and ideal distances, analysis of which gives opportunity to determine allowable errors of electron deflection to the screen. Since electron deflection errors are small, linear perturbation method can be applied to solve this problem. Due to equation complexity these expressions are not presented here.

Mask surface described by 8th order two-dimensional exponential series using least squares technique is shown in Fig. 3, and difference of mask surfaces received during modeling of mask by first and second methods is shown in Fig. 4.

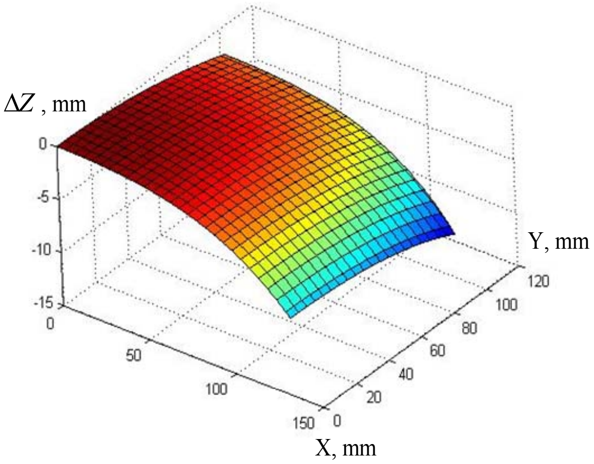


Fig. 3. Mask surface (Quadrant I)

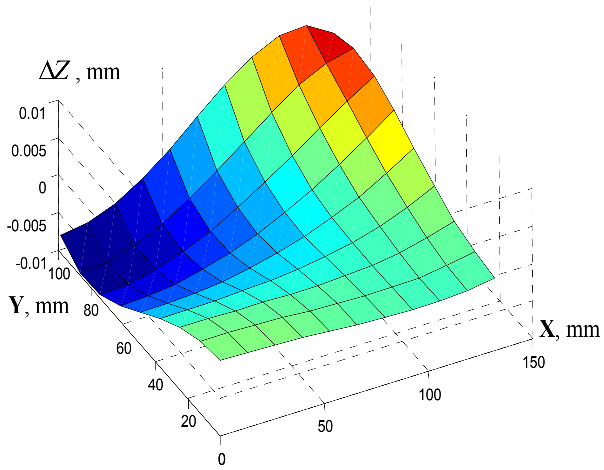


Fig. 4. Difference of mask surfaces (Δz) received during modeling of mask by first and second methods

Systematic deviations of the first and the second method at various points of the screen are presented in Table 1. In this table: *x, y* – screen point coordinates, mm; PxMN – systematic method deviation (error) along X direction between traces M and N; PyMN – systematic method deviation along Y direction between traces M and N.

Table 1. Systematic deviations

		first method		second method	
x y		49	142,5	49	142,5
47,5	PxRG	-0,00234	-0,00742	-0,00237	-0,00758
	PxBG	0,00229	0,00704	0,00226	0,00687
	PxRB	0,00005	0,000383	0,000101	0,000710
	PyRG	-0,00886	-0,0224	-0,00886	-0,0223
	PyBG	0,00278	0,0127	0,00278	0,0127
	PyRB	-0,01164	-0,0350	-0,0116	-0,0350
107	PxRG	-0,00197	-0,00844	-0,00200	-0,00854
	PxBG	0,00141	0,00318	0,00138	0,00307
	PxRB	0,00057	0,00526	0,000617	0,00546
	PyRG	-0,02122	-0,0655	-0,0212	-0,0655
	PyBG	0,00831	0,0400	0,00831	0,0400
	PyRB	-0,02952	-0,1055	-0,0295	-0,1055

Electron trace separation influence coefficients for imprecise R and B electron deflection to the screen, when shadowmask is modeled by the first method, are presented in Table 2, and influence coefficients for imprecise B electron deflection to the screen, when shadowmask is modeled by the II method are presented in Table 3. In these tables IKxMN – M and N trace separation influence coefficient along X direction of imprecise R or B electron deflection to the defined point of the screen; IKyMN – M and N trace separation influence coefficient along Y direction of imprecise R or B electron deflection to the defined point of the screen.

Table 2. Influence coefficients (first method)

		R influence		B influence	
x y		49	142,5	49	142,5
47,5	IKxRG	-0,4993	-0,4975	0,4899	0,4772
	IKxBG	-0,510	-0,5226	0,5005	0,5013
	IKxRB	1,0094	1,0201	-0,9904	-0,9785
	IKyRG	-0,00395	-0,00981	0,00464	0,00996
	IKyBG	-0,00404	-0,0103	0,00474	0,01047
	IKyRB	0,00799	0,0201	-0,00938	-0,02043
107	IKxRG	-0,4988	-0,4937	0,4915	0,4799
	IKxBG	-0,5072	-0,5122	0,4999	0,7979
	IKxRB	1,00599	1,0059	-0,9914	-0,9778
	IKyRG	-0,00936	-0,0247	0,01132	0,0257
	IKyBG	-0,00952	-0,0257	0,01152	0,0266
	IKyRB	0,0189	0,0504	-0,0228	-0,0523

Table 3. Influence coefficients (second method)

		B įtaka	
x y		49	142,5
47,5	IKxRG	0,4946	0,4871
	IKxBG	0,5052	0,5118
	IKxRB	-0,9998	-0,9989
	IKyRG	0,00430	0,00987
	IKyBG	0,00439	0,01037
	IKyRB	-0,00869	-0,02024
107	IKxRG	0,4951	0,4867
	IKxBG	0,5035	0,5049
	IKxRB	-0,9986	-0,9916
	IKyRG	0,01035	0,02518
	IKyBG	0,01052	0,02613
	IKyRB	-0,02087	-0,05130

Maximum total influence coefficients for trace separation along X direction (MNx) due to imprecise deflection of R and B (I method) or B (II method) electrons to the defined point of the screen along X and Y directions are presented in Table 4.

Table 4. Total influence coefficients

		first method		second method	
x y		49	142,5	49	142,5
47,5	RGx	0,9978	0,9945	0,4989	0,4970
	BGx	1,0193	1,0446	0,5096	0,5221
	RBx	2,0171	2,0392	1,0085	1,0191
107	RGx	1,0110	1,0240	0,5054	0,5119
	BGx	1,0282	1,0623	0,5140	0,5310
	RBx	2,0391	2,0864	1,0194	1,0429

Modeling was performed for TV-tube A36 with Coty EOS and A36 KS1500 deflection system.

Conclusions

1. Two shadowmask modeling methods are presented in this work; their selection is determined by the features of particular system (TV-tube – deflection system).

2. After comparing systematic errors of both methods a conclusion can be made, that they differ very little and they are determined by the features of considered system.

3. Systematic error of the method increases with increase of distance from the center of the screen; at the same time electron trace separation influence coefficients of imprecise electron deflection to the screen practically do not depend on coordinates of considered screen (shadowmask) point.

4. After analyzing electron trace shift on the screen influence coefficients of imprecise electron deflection to the defined point of the screen, a conclusion can be made, that the second modeling method is better: total influence coefficients of the mentioned relation are approximately two times smaller, i.e. the error (deviation) of electron deflection to the screen can be two times bigger.

References

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2. **Čepulis V., Markevičius V., Navikas D., Tarvydas P.** Modeling of TV tube electronic optical system // ITI 2004: Proceedings of the 26th International Conference on Information Technology Interfaces, June 7-10, 2004, Cavtat, Croatia. – ISBN 953-96769-9-1. – Zagreb, 2004. – P. 513–518.

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There are presented two color TV-tube shadow mask surface modeling methods. Technique offered in this work is based on electron trajectory modeling in measured or modeled electric and magnetic fields, created by developed TV-tube. In order to reduce calculation duration electron trajectories deflection centers coordinates are approximated using power polynomial. Analysis of both methods systematic errors is presented. There are calculated electron trace shift on the screen influence coefficients of imprecise electron deflection to the defined point of the screen. Both methods can be used in TV-tube design stage. Ill.4, bibl.2 (in English; summaries in English, Russian and Lithuanian).

В. Чяпулис, Д. Навикас. Моделирование поверхности теневой маски цветного кинескопа // Электроника и электротехника. – Каунас: Технология, 2006.–№ 5(69). – С. 87–90.

Представлены два метода моделирования теневой маски цветного кинескопа. Эти методы основаны на моделировании траекторий электронов в измеренных или смоделированных электрических и магнитных полях, которые создаются в проектируемом кинескопе. Чтобы ускорить расчеты, используется описание центров отклонения траекторий электронов полиномом. Проведен анализ системных погрешностей обеих методов, а также установлены коэффициенты влияния неточной наводки электронов в заданную точку экрана на сдвиг следов электронов. Оба метода могут быть использованы на этапе проектирования цветного кинескопа. Ил. 4, библ. 2 (на английском языке; рефераты на английском, русском и литовском яз.).

V. Čepulis, D. Navikas. Spalvotojo kineskopo šešėlinės kaukės paviršiaus modeliavimas // Elektronika ir elektrotechnika.- Kaunas: Technologija, 2006. – Nr. 5(69). – P. 87–90.

Pateikti du spalvotojo kineskopo šešėlinės kaukės paviršiaus modeliavimo metodai, pagrįsti elektronų trajektorijų modeliavimu išmatuotuose ar sumodeliuotuose elektriniuose ir magnetiniuose laukuose, sukuriamuose projektuojamame kineskope. Skaičiavimams paspartinti panaudotas elektronų trajektorijų kreipimo centrų koordinačių aprašymas laipsnine eilute. Atlikta abiejų metodų sisteminių paklaidų analizė bei nustatyti netikslaus elektronų nukreipimo į nurodytą ekrano tašką įtakos elektronų pėdsakų poslinkiams ekrane koeficientai. Abu metodai gali būti panaudoti spalvotojo kineskopo projektavimo etape. Il. 4, bibl. 2 (anglų kalba; santraukos anglų, rusų ir lietuvių k.).