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Effect of aperture stop on kinematic aberration in ultra-high speed cinematography with image commutation

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In the paper [1] it has been shown that in the cameras with image commutation of Miller type (fig. 1) in which the reflecting plane of the rotating mirror (RM) does not contain the axis of rotation (which is typical for technological reasons), there appears some blurring of the optical image which has been called the kinematic aberration. A distance, by which the image point is shifted on the film surface during the period

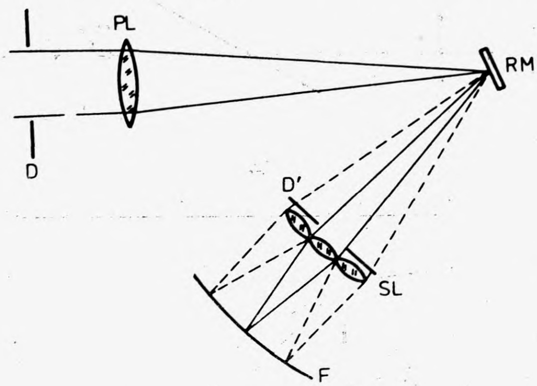

Fig. 1

of time within which the chief ray of the commuting beam is displaced transversaly accros the secondary lens (SL) (fig. 2), is assumed as a measure of this aberration. The value of the kinematic aberration may be estimated from the formula [1]:

$$A_k = |2g'| + |\sigma| = z\left(|\varrho \cos d\alpha - \cos\alpha| + \frac{\beta h}{2b}\cos\gamma \sin|\alpha|\right),$$

where:

$$z = \frac{4\beta r \sin d\alpha}{\cos\gamma}, \quad \varrho = \frac{r'}{r}, \quad \beta = \frac{y}{x} = \frac{b}{a},$$

and $2\,d\alpha$ – rotation angle of the rotating mirror (RM) when the chief ray of the commuting beam is shifted transversely accros one of the secondary lenses,

r' – distance of the first intermediate image produced by the primary lens (PL) from the rotation axis,

r – distance of the reflecting plane of the rotating mirror (RM) from the axis of rotation.

The meaning of the other parameters is clear from the figs. 2 and 3, in which A, B, and C denote the successive positions of the intermediate image produced by the primary lens (PL) the shift being caused by the rotation of the mirror (RM) while the chief ray of the commuting ray falls upon the left edge – L, middle point – O, and right edge R of the secondary lens, respectively; $LR = h$.

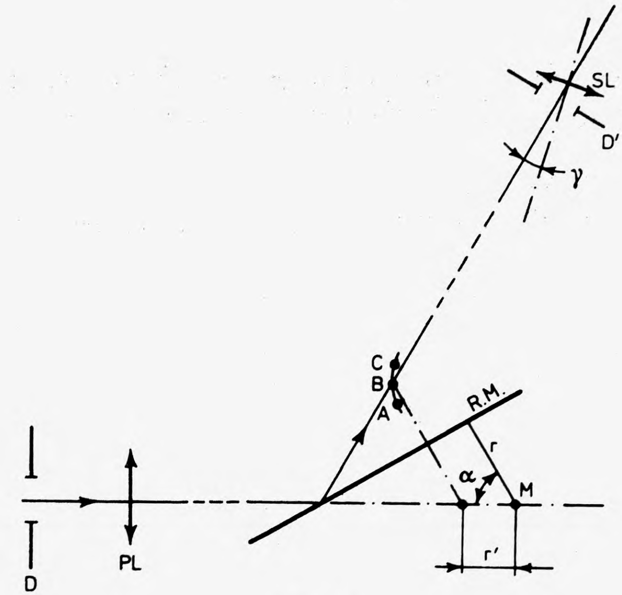

Fig. 2

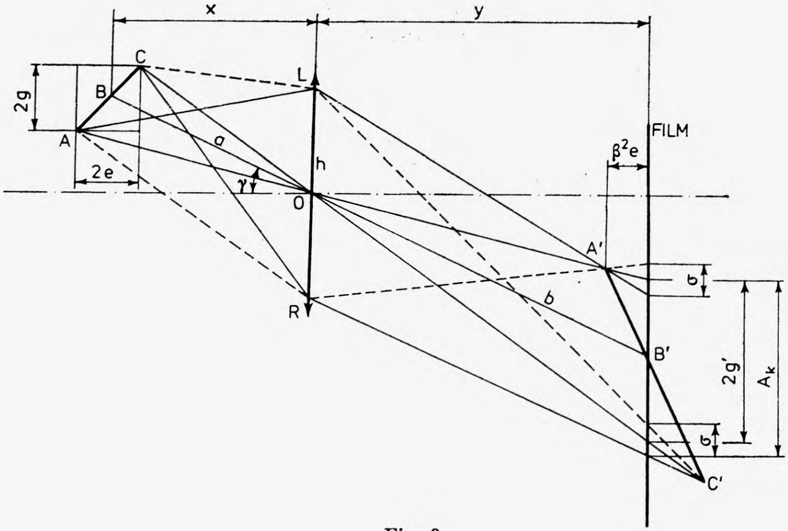

Fig. 3

In the paper [2] a discussion of the formula (1) has been carried out to minimize the aberration.

The beam aperture is defined by the diaphragm (*D*) (fig. 1), which is placed in front of the primary lens (*PL*), at such distance that its real image appears at the place where the secondary lens is located. Depending on the width of the diaphragm (*D*) the commuting beam falls into one or more secondary lenses, whereby it is sharply restricted at this place.

During derivation of the formula (1) it has been assumed in [1], that the aperture of the commuting beam is sufficiently great and covers at least two neighbouring secondary lenses. However, it happens often that the diaphragm width is chosen so that it covers only one secondary lens [3]. In this case, when considring the ray trace of the commuting beam (fig. 3) it may be noticed, that when the intermediate image is positioned at A the right hand part (OR) of the secondary lens does not work yet (no ray ARA' marked by the broken line). Similarly, when the intermediate image is at C the left hand part of the secondary lens LO does not work any longer (no ray CLC'). Hence it is visible, that the kinematic aberration is not expressed by $|2g'|+|\sigma|$, but by

$$A_k = |2g'|+\frac{|\sigma|}{2} \approx z\left(|\varrho\cos d\alpha-\cos\alpha|+\frac{\beta h}{4b}\cos\gamma\sin|\alpha|\right).$$

The components $2g'$ and σ are the functions of the angle α defining the momentary position of the rotating mirror. Each camera possesses some working sector defined by the maximal and minimal values of the angle α, at which the commuting beam falls onto the first and last secondary objective, respectively [2]. The numerical analysis shows that except for small region in the surrounding of α_m, for which $2g' = 0$, the component $|\sigma|$ is much less than $|2g'|$.

References

[1] Wnuczak E., Opt. Appl. **III** (1973), 57–59.
[2] Wnuczak E., Opt. Appl. **IV** (1974), 49–51.
[3] Wnuczak E., Krzeczkowski S., Opt. Appl. **III** (1973), 29–31.

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