denser. The semi-diameter of that element of the condenser is approximately equal to this distance times tan u. Since the ray continues to climb at least through the first two elements of a three-element condenser, the diameters can become very large by virtue of a high numerical aperture.

It follows from third order theory that spherical aberration is approximately a minimum when the deviations at the various surfaces of a lens are equal. Usually this makes a good starting point for a design. If u' and m are known, u can be found. Assuming a particular number of elements to be used, the deviation per surface is known and the work proceeds. If the total deviation is very large it may be profitable to use one or more aplanatic surfaces. Such a surface deviates a ray according to $\sin u' = (\sin u)/n$ without introduction of spherical aberration or coma. In extreme cases it may be desirable to use an aspheric surface, although centering of an aspheric lens element is extremely critical.

The procedure at this laboratory is to set up an initial case based on equal deviations or on a combination of the principles of equal deviations and aplanatism. The design parameters, i.e. distribution of power among the lenses, lens bendings, and in some cases surface deformations, are then varied in search of an optimum design. Tracing the rays backward toward the source, the first evaluation criterion is to ensure that all the desired rays originate within the luminous area. Once that condition is satisfied, effort is made to satisfy the more severe uniformity criterion described above.

Letter to the Editor: Sensitivity of Image-Orthicon Tubes

Dear Sir:

I would like to comment on some aspects of paper C-12 by Bernhard A. Bang, "High-Sensitivity Television as an Aid to Low-Light-Level Photographic Recording," pp. 141–146; and also *Jour. SMPTE, 70:* 719–724, Sept. 1961.

Mr. Bang does a very nice job of describing the capabilities of the new image-orthicon tubes now available, and his curves on performance should be very helpful to anyone considering the use of low-light-level television. It should be pointed out, however, that the claims on sensitivity are somewhat misleading when compared to photography.

About a year ago, the writer made some comparative sensitivity measurements (not published) on similar television systems and Royal X Pan Film, but using stars as the object. The surprising result was that within the accuracy of the experiment, roughly a factor of two, there was no difference in sensitivity! This apparent paradox is easily explained when resolution is taken into account.

When the limiting sensitivity is expressed in terms of lumens on a resolution element, film and the image orthicon are comparable. For extended objects, sensitivity is usually expressed in terms of lumens per square centimeter on the image surface, as done by Mr. Bang. In this case, the image orthicon, because of its lower resolution, is able to collect more lumens per resolution element, and therefore appears more sensitive. This is very similar to the increase in speed observed in coarser grain photographic film. In other words, the image orthicon can be considered a device which goes beyond available photographic films in the direction of less resolution but more sensitivity.

Another way to solve this dilemma would be on the basis of informational capacity, in which case it would be easy to show that information capacity per unit of flux, (or per photon) has not been increased. This latter way of defining sensitivity would be more meaningful when comparing such different media.

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