

# SECTION H—Discussion: Multiple Frame Cameras

*Note: A participant's full name and address are given with the first contribution to the Discussion. Authors' full names and addresses are given with the title of each paper. For subsequent entries the addresses are omitted.*

*Papers H-2 and H-3: Focal Plane Shutters and the Design of High-Frame-Rate Cameras, Sigmund J. Jacobs, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland; A Rotating-Mirror Framing Camera with Multiple Focal Plane Shutters, Sigmund J. Jacobs, J. D. McLanahan and P. F. Donovan, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.*

*Dr. J. S. Courtney-Pratt (Bell Telephone Laboratories, Incorporated, Murray Hill, New Jersey):* There is a U.S. Patent No. 2,816,476 by B. T. Rodgers and W. C. Davis which describes a single-frame camera that has, in effect, a focal-plane shutter, using reflections successively from two faces of a rotating mirror. Just as for Dr. Jacob's designs, the exposure time for each part of the field can be very much shorter than the interframe time.

I have recently considered the image converter tube analogue of some similar focal-plane shutter cameras. One could use two image converter tubes — one to sweep the image past a slit, and the other to reconstitute the image. Alternatively, one may use a single image converter tube twice over, so that one half of the image converter tube sweeps the image past a sampling slit, and the other half of the same tube reconstitutes the short exposure image. See Part VII of my paper "Some Unconventional Methods of High-Speed Photography," published in these *Proceedings*.

*A. Skinner (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England):* Can the author show any pictures taken with this type of camera?

*Dr. S. J. Jacobs:* At the time of presentation, the only picture was a still, taken while the Dove prism-type camera was running without prisms but with 1.6-mil slits in place.

*A. Skinner:* What exposure/frame ratio is used? It would seem that this principle would offer a real advance if the *eff* ratio was 1/100 or 1/50 or thereabouts. In the Beckman & Whitley Model 189 camera, and in similar cameras developed in England, the *eff* ratios in general use are about 1/3 or 1/6. In practice the light levels of the normal run of events do not permit of greater ratios when the framing rates are as high as  $10^6$  to  $10^7$ /sec.

*Dr. S. J. Jacobs:* Exposure/frame ratio can vary from 0.5 to about 0.01 when optical compensation is used. At frame rates of  $10^6$ /sec, many subjects will permit an *eff* ratio of 1/50. For lower frame rates, 1/100 may often be of advantage.

*D. P. C. Thackeray (Vickers Research Ltd., Sunninghill, Berkshire, England):* Have you examined, even if only on paper, the rotating-drum (as opposed to the rotating-mirror) forms of this focal-plane system?

*Dr. S. J. Jacobs:* Yes. Figure 1 of the first paper is an example. Other ideas have been considered for more efficient designs with frame splitting, for which narrow focal-plane slits would offer distinct advantages over in-the-lens shutters. These have not been pursued at present because the author's interests lie in the higher frame rates possible with rotating mirrors. Many existing cameras can be modified to use focal-plane shutters.

*Paper H-6: Tripod-Mounted High-Speed Framing Camera, Richard J. Krumhansl, Lawrence Radiation Laboratory, University of California, Livermore, California.*

*Dr. F. L. Curzon (Department of Physics, University of British Columbia, B.C., Canada):* Under what conditions was the resolution tested?

*R. J. Krumhansl:* Dynamic; chart 5 ft away from camera.

*Dr. F. L. Curzon:* Have you compared dynamic and static resolving power in order to determine the effects of mirror distortion on the picture quality?

*R. J. Krumhansl:* No.

*Dr. F. L. Curzon:* Does the image quality vary over the series of framing lenses?

*R. J. Krumhansl:* The resolution is constant over the framing arc; but at the extremes, part of the image is lost because of vignetting at the rotating mirror.

*Paper H-7: The CORE Camera: Continuous Receptivity — One Rotating Element, J. N. Whyte, Armament Research and Development Establishment, Sevenoaks, Kent, England.*

*D. P. C. Thackeray:* Is the author optimistic about the adhesion of the various parts of his prismor at these high speeds? Are the adhesives that would hold them together sufficiently kind to the optical glass?

*J. N. Whyte:* Yes. The best adhesives for sticking purposes, anyway, are those that do not distort the optics. We are proceeding as far as possible with an ordinary solid cement.

*Dr. David C. Oakley (University of California, Lawrence Radiation Laboratory, Livermore, California):* It appears that your prismor will give a large color dispersion, especially when the mirror surface is parallel to the optical axis.

*J. N. Whyte:* In the second camera arrangement this, of course, doesn't apply at all. In the first camera system — that is with the compensated prismor — we have a plain glass block and a prismor on top of it; and the system is working in a converging beam. The axial chromatic aberration can be eliminated by adjustment of the design of the previous optical train. The cyclicly varying aberration cannot be so easily compensated. There is a proposal, which we are investigating, of substituting a back-silvered wedge for the stationary mirror. This, we find, does compensate to a considerable extent for one of the prism chromatic-aberration effects.

*Paper H-9: High-Speed Intermittent Camera Using Multiple Shuttering of Each Frame, Robert L. Rodgers, D. B. Milliken Company, 131 North Fifth Avenue, Arcadia, California.*

*Martin R. Dachs (Farrand Optical Company, 4401 Bronx Blvd., New York 70, New York):* How short is the exposure time achieved at 9600 pictures/sec?

*R. L. Rodgers:* The exposure time  $T_e$  (in seconds) is given by the formula:

$$T_e = \frac{\text{angle of shutter opening (in degrees)}}{360 \times \text{rate of rotation (in rps)}}$$

Using the example of a shutter  $3^\circ$  open,  $12^\circ$  closed, rotating at 400 rps, the sampling rate is 9600/sec. The exposure time  $T_e = \frac{3}{360 \times 400} = \frac{1}{48,000}$  sec. Exposure time can be varied to suit the need by decreasing or increasing the angular size of the open sector. Frequency can also be varied to suit the application.