

SECTION C—Discussion: Electronic Shutters

Note: A participant's full name and address are given with his 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.

Paper C-1: The Astracon Tube and Its Application to High-Speed Photography, A. E. Anderson, G. W. Goetze and H. Kanter, Westinghouse Research Laboratories, Beulah Rd., Pittsburgh, Pennsylvania.

Dr. Werner G. Braun (U. S. A. F. Research Division, Wright Field, Ohio): If the system is to be used as a shutter system, do electrons produced at the cathode before pulsing the shutter contribute also to the image produced on the screen?

A. E. Anderson: The nuclear track camera used in these experiments was gated on by every ionizing event so that there was no opportunity for space charge accumulation near the cathode which could later act to fog the film. In any case, it is not necessary to reduce the cathode field to zero in order to cut the tube off. It is therefore possible to sweep the space between the cathode and the first dynode clear of electrons between gate pulses.

John H. Jacobs (Bell & Howell Research Center, Pasadena, California): I would like to comment on Dr. Braun's question. I should think that electrons which are floating in the neighborhood of the photocathode, having been ejected from the cathode by a prior image, would tend to distribute themselves evenly in a plane close to the cathode due to space charge effects. Hence, we would expect them to produce a spatially uniform signal at the final anode; that is, they would contribute to background fog, but not form a spurious image. It might be difficult to distinguish this effect from dark current.

A. E. Anderson: There is a possible background not related to the focused image. However, in the apparatus that we're talking about, any excess electrons, due to thermionic emission or other causes, will register as individual black spots on the film because the gain of the system is high enough to do this.

With the photocathode operated at ground potential, the dark current is as low as 50 electrons/sec over the total area. As stated before, in these experiments there is no continuous illumination of the cathode. For these reasons the probability of a spurious event occurring during the time of any short-duration gate is extremely small.

Paper C-2: Very-High-Gain Image Intensifier Systems and the Photography of Single Photons With Microsecond Time Resolution, Martin L. Perl and Lawrence W. Jones, The Harrison M. Randall Laboratory of Physics, The University of Michigan, Ann Arbor, Michigan.

Dr. A. Folkierski (Department of Physics, Imperial College of Science and Technology, London, England): Why was one image intensifier pulsed positively on the dynode and the other negatively on the cathode? Is there a limit to the shortness of pulse due to capacitive currents?

Dr. M. L. Perl: One way to gate on the three-stage RCA tube for a short time is to bias the tube off by a steady voltage on the first photocathode, positive with respect to the first focusing electrode. The tube is then turned on by dropping this positive voltage to zero for the required on time of the tube, and then reimposing this voltage. However, in most of these tubes, the high cathode resistivity causes the image to smear or streak if the tube on time is about one millisecond or less. To avoid this, we bias the tube off by putting a steady voltage on the first focusing electrode, negative with respect to the first photocathode.

The tube is turned on by putting a positive square-wave pulse onto the first focusing electrode, which brings it to the proper potential with respect to the first photocathode. This gives images equal in quality to those obtained in steady-state operation of the tube. We have had on times as short as one microsecond with this technique. No difficulty with the tube capacitance occurred.

Paper C-4: Development of a Photo-Electronic Shutter Tube, Leonard Mandel, Imperial College of Science and Technology, University of London, South Kensington, London S.W.7, England.

Thomas P. Dixon (ITT Laboratories, Bledsoe St., San Fernando, California): What type and amount of geometric distortion is present in the output image of the intensifier shutter tube?

L. Mandel: As in most magnetically focused image tubes, the principal distortion is S-type distortion. We have not made careful measurements, but it does not amount to more than the resolution limit, at least near the central part of the field.

Paper C-5: Image-Converter Systems With Fast Image Group Repetition Rates, Robert W. King, Jr., and John H. Hett, Hett Associates, Incorporated, 24 Burton Place, Cresskill, New Jersey.

Kenneth R. Coleman (Atomic Energy Authority, Aldermaston, Berkshire, England): Could you comment on the pictures that have been taken with your image-converter cameras?

Dr. J. Hett: Pictures have been taken with all these systems — the 1st system, the 2nd and the 3rd. The resolution of the tube, statically, runs as high as 40 lines/mm. When you operate dynamically you do not exceed that, of course. The resolution then depends upon the mode of operation. Usually one is fairly happy to get sequential pictures with a resolution of 15 to 20 lines/mm.

Paper C-9: A Kerr Cell Camera with Synchronized Light Source for Millimicrosecond Reflected Light Photography, George A. Theophanis, Avco Research and Advanced Development Division, Wilmington, Massachusetts.

Dr. R. F. Saxe (Queen Mary College, Mile End Road, London E.1, England): In your contribution you spoke of a small amplification of the pulse from the coaxial cable. I do not see how this comes about. I feel that you should get only a gain of unity; or else of two, if you use the Blumlein connection.

G. A. Theophanis: The value of the load resistor is chosen so that you have a condition somewhere between a match and an open end. This will result in a voltage change across the resistor, of between E and $2E$, assuming the cable was charged to a voltage E . Of course, there will be some ringing in the cable, but if the amplitude of the ringing is no greater than one third of the operating voltage of the cell, then the cell will not open significantly.

Paul R. Yoder, Jr. (U.S. Army Ordnance, Frankford Arsenal, Philadelphia, Pennsylvania): I'd like to ask the speaker two questions. What type of linear polarizer is used in the Kerr cell? What is the light transmission of the open Kerr cell?

G. A. Theophanis: We used type HN22 sheet polarizers manufactured by Polaroid Corporation. The insertion loss of the open cell was equivalent to a neutral density of about 1.4.

Paper C-10: Kerr Cell Framing Camera, Willis C. Goss, University of California, Lawrence Radiation Laboratory, Livermore, California.

Dr. Hubert Schardin (Institut Franco-Allemand de Recherches, St.-Louis, France; and Ernst-Mach-Institut, Freiburg i.Br., Germany): A somewhat similar arrangement was studied about 1951 at the Institut Franco-Allemand de Recherches, St.-Louis, France, by Schardin and Struth. Schardin gave a brief description of this in 1952 at the First Congress on High-Speed Photography in Washington, "The Development of High-Speed Photography in Europe," published in the *Journal* of the SMPTE in 1953. The difference between our arrangement and that described by the author is that at that time we used a brief spark instead of a Kerr cell. The light from this spark was delayed by several reflections from two mirrors. In our setup, the phenomenon had to be studied in transparency. By using the Kerr cell, as Goss does, self-luminous objects can also be studied.

W. C. Goss: I've discovered since I wrote this paper that E. O. Lawrence (of the Lawrence Radiation Laboratory) did a somewhat similar thing back in 1932 — so it's not very new. Of course, at that time they didn't have components as highly developed as those available now.

Paper C-12: High-Sensitivity Television as an Aid to Low Light Level Photographic Recording, Bernhard A. Bang, The Bendix Corporation, Friez Instrument Division, Baltimore, Maryland.

Wallace H. Allan (Naval Ordnance Test Station, China Lake, California): I would like to refer to the film that has just been shown. This film of a missile was taken by an operator tracking by eye. This leads to the inference that the eye is more sensitive than the system. Is this true?

B. A. Bang: When you wish to compare the relative sensitivity of the eye and television, you must stipulate certain parameters. In our work, we put it on a resolution basis. For example, we could compare the dark-adapted human eye, aided with using 7×50

binoculars, with a television camera tube fitted with, say, an $f/2$ lens of such a focal length that the system had the same field of view as the eye with binoculars. Under these conditions, the magnesium oxide tube (without any intensifier stage) and the eye are just about the same. If you use integration technique with the same tube, the tube will beat the eye. Of course, we realize that the answer depends on the basis of comparison, and we have tried to develop one which we thought fair.

W. H. Allan: How long a time interval do you have to integrate before the system is more sensitive than the eye?

B. A. Bang: One-quarter of a second, one-half a second or a second. The original comparison was on a 30 frame/sec basis. You would be much better off, of course, with an intensifier tube. Two or three such tubes have been made by RCA.