A Comparison of Kerr Cells and Image Tubes as High-Speed Shutters

PAPER C—8

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Introduction

The Kerr cell and the image tube have been the two most successful shutters where exposures in the submicrosecond range are required. Cameras have been developed in the Atomic Weapons Research Establishment, Aldermaston, which use one or other of these shutters.

The relative performance of the two types of camera have been compared under controlled conditions to supplement the experience gained in the operation of the cameras over a period.

Method of Comparison

The cameras chosen were standard ones of their type developed in the Establishment. Kerr cells and their polarizers are made in AWRE and are found to be superior to any obtainable elsewhere. The image tube was a standard Mullard ME1201 operated as a triode with 6 kv on the anode and an interelectrode difference of 3 kv. To simplify the comparison, identical objective systems were fitted to the cameras and the optics of the image-tube camera were altered so as to give final images of the same size in both cameras. A spark discharge in argon was photographed by both systems simultaneously from similar viewpoints. Pulses of 0.2-μsec duration were applied to Kerr cell and image tube by similar sets of electronic equipment, the only difference being that a pulse of 16 kv was applied to the Kerr cell whereas the image tube required a pulse of 6 kv. The synchronizing variations were not greater than 0.1 μsec. Ilford HPS quarter plates were used and were developed simultaneously in pairs, one plate from each camera, in Microphen at 21 C for 5 min. In order to obtain curves of image density against relative logarithmic exposures (γ-curves), photographs were taken through a series of neutral density filters, placed over the event so that both cameras used the same filter.

Comparison of Performance

γ-Curves: Figure 1 was compiled from a number of records. The curve for the Kerr-cell camera is similar to the curve obtained in the usual way for the photographic emulsion alone. The image-tube curve has a similar slope except at greater exposures. The level position CD coincides with image distortion resulting from overexposure. The cause is clearly high photo-current but the mechanism is not so obvious: it may be a space charge effect or a build-up of charge patterns on the photocathode surface due to its transverse resistance. However, the portion BC is usable and gives a logarithmic exposure range of nearly 2.

The curves show a log-exposure gain in favor of the image tube, over this range, of about 0.9, — a linear exposure gain of about 8 times. In the Kerr-cell camera a factor of 10 in the light value is lost in the Kerr cell and its polarizers; also it is less sensitive to blue light than the image tube. But taking all factors into account, the single-stage image-tube camera is not an effective light amplifier because even with the best available recording optics only $\frac{1}{20}$ of the light output of the screen of the tube is actually used. [The use of a fiber optics window on an image tube can allow it to operate as a light amplifier. *Ed.*]

Image Resolution: The quality of the image from the Kerr-cell camera is superior to that of the image tube, 30 line pairs/mm, representing 1000 line pairs/frame can be obtained with the Kerr-cell camera; the image tube resolves about half as well.

Image Distortion: In normal conditions, distortion is negligible in both systems: it becomes apparent in the image tube only during overexposure.

Comparison of the Conditions in Which the Two Systems Can Be Used

Ease of Operation: In its present form the image-tube camera requires greater care and more critical adjustment in its operation than the Kerr-cell camera.

Shutter Capabilities: The Kerr cell never completely excludes light: the open-to-shut ratio is 10,000:1 at best and often only 1000:1. An auxiliary shutter must be used, therefore, if the duration of the light source is long compared with the exposure, as it is, for example, in the photography of nuclear explosions. There is no significant break-through of light during photography of high-voltage discharges. The only break-through of light ever detected at AWRE in Mullard image tubes was through pinholes in the phosphor and its aluminum

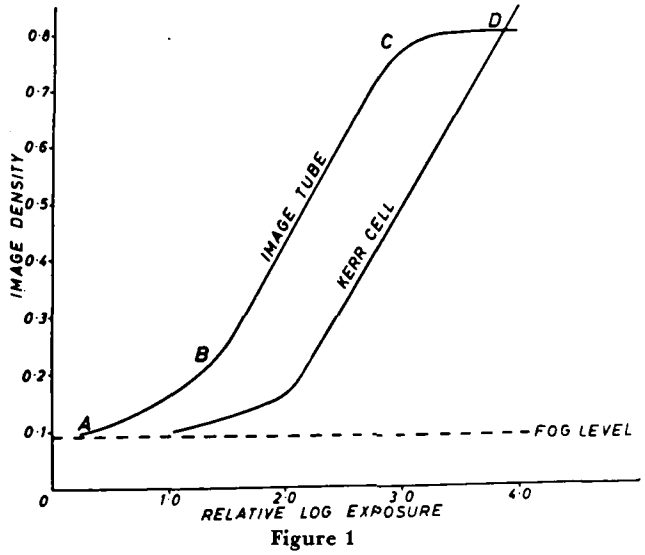

Figure 1

Submitted to the Fourth International Congress on High-Speed Photography in Cologne, Germany, by George H. Lunn and E. D. Menzies, Atomic Weapons Research Establishment, Aldermaston, Berks, England. Submitted in its present form on March 21, 1961, for publication here.

backing. This would be significant only when recording events of long duration using objectives of long focal length.

Repetitive Shuttering: Both systems are equally applicable to single-shot photography, but the Kerr cell only can be used as a rapidly repetitive shutter: the afterglow of the image tube precludes repetitive use above about 10^5 frames/sec. The image tube can, however, be readily used in a streak camera and will give writing speeds of up to 200 mm/μsec.

Effect of Magnetic Fields: Magnetic fields have no effect on the Kerr cell but may alter the focusing of an image tube. It is essential, therefore, not to use unnecessary magnetic materials in the construction of an image-tube camera and to keep power transformers at least 1 m away from the tube.

Reliability: Both Kerr cells and image tubes are reasonably reliable and a good working life can be obtained by proper use. High temperatures and bright lights for long periods cause the photocathode of the image tube to deteriorate. It may be noted also that the nitro-benzene in a Kerr cell freezes at about 5 C, and the shutter will not work below this temperature.

Conclusion

The two systems are to some extent complementary. Given adequate light, the Kerr-cell camera is superior but at low levels of light there will be times when only the image-tube camera can be used. Its advantages in conditions of poor illumination may become even more marked with further development of the image tube. The Kerr-cell camera, on the other hand, is unlikely to be improved greatly in sensitivity.