Possible Application of Pulsed Multiplier Image-Converters for Recording Tracks of Ionizing Particles in Luminescent Media *

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ADVANCES in the use of scintillation counters in experimental nuclear physics indicate the feasibility of developing an electron-optical device for recording elementary interaction-events. For an appraisal of the possibilities and requirements of such a scheme, we shall consider one of the most promising methods by which a detector of this type may be realized.

The basic part of the detector is a magnetically focused, pulsed, image converter of special construction, designed for the intensification of the luminous image of the tracks of particles in a luminescent phosphor, which has a semitransparent photocathode, a series (~ 10) of close-lying dynodes consisting of fine-mesh grids, a supplementary grid for control of the tube, an accelerating anode, and a fluorescent screen located behind the anode. The tube is controlled by a modulator -- a device employing well-known electronic techniques -- which increases the voltage on the control grid to allow the passage of the avalanche associated with the electron image. The modulator is operated by a pulse from a counter which detects the passage of particles through the luminescent phosphor (automatic operation) or is arranged to trigger the tube in synchronism with the bursts of a pulsed beam of particles (semiautomatic operation).

The fluorescent track of an ionizing particle in a luminescent phosphor having a short decay-time (a large luminescent crystal or a layer of luminescent liquid or plastic) is projected on the photocathode of the image converter by an optical system, thus producing an electronic image of the projection of the track because of the photoeffect across the "gap". As this image travels along the length of the tube, it is multiplied in passing through the system of apertured dynodes (grids or perforated foils) having small dimensions ($\leq 10^{-2}$ cm) and passes into the accelerating region due to the action of the control grid, the potential of which has been raised by the operation of the modulator. The electron avalanche then passes through the accelerating anode (made up in the form of a grid or perforated metal layer) and having been accelerated by a voltage of some tens of kilovolts, strikes the fluorescent screen, producing an intense luminous image which is a reproduction of the projection of the track and which can be recorded photographically or observed visually.

The possibility of photo-recording can be seen from the following calculation: the projected charge density of the electronic image of the track after multiplication is $q = \nu \alpha_1 \alpha_2 K (1/\Delta)$ where ν is the number of fluorescent photons per unit length of track excited by a singly-charged relativistic particle in the luminescent phosphor ($\nu = 3 \times 10^4$ in good luminescent phosphors); α_1 is the efficiency of the optical system used to project the fluorescent light on the photocathode (for simplicity we take $\alpha \approx 1\%$, thus obtaining an image scale equal to unity); α_2 is the quantum yield of the semitransparent photocathode (we assume $\alpha_2 \sim 10\%$); K is the multiplication factor associated with the electron avalanche. We may take $K \sim 10^6$, assuming that the magnetic focusing field does not reduce the multiplication efficiency of the mesh dynodes. For focusing fields of the order of hundreds of gauss, this assumption is justified provided that the grids have small dimensions, for example, $\sim 10^{-2}$ cm. (In ordinary mesh multipliers, grids having 40 thousand mesh per cm^2 are used.) The quantity Δ is the width of the trace of the electron image after multiplication. In the case of cascade magnetic focusing, $\Delta = 2\,lN(u/U)$, where l and U are the spacing and potential differences between adjacent dynodes, N is the number of dynodes and u is the potential which corresponds to that part of the secondary-emission energy distribution curve which applies to the electrons being considered. For $lN = 3$ cm, $U \approx 150$ v and $u \approx 5$ v, $\Delta \approx 0.2$ cm.

For the assumed values, we get $q \approx 1.5 \times 10^8$ electrons/cm^2 or 24 $\mu\mu$ coulombs/cm^2. This charge density is entirely adequate for contact photography if the accelerating voltage of the electrons striking the screen is of the order of 15 kv (for example, using an Agfa-Isochrome plate and a ZnS-Ag fluorescent screen, the blackening of the plate $S \approx 0.2$ for the values of charge density and accelerating which we have indicated)[1]. There is some possibility of increasing the conversion coefficients so as to allow non-contact photography.

The possibility of automatic control of the tube is determined by the relation between the delay time in the modulator and the emission time, and the time of flight of the electrons from the photocathode to the region in which the control grid is effective. With a favorable arrangement of the tube electrodes, a minimum transit time $\sim 10^{-8}$

sec is possible; the time required for the operation of the modulator is $\sim 3 \times 10^{-8}$ sec.

These figures clearly indicate the advantage of using image converters with localized mesh-dynodes which make possible the combination of fast image-electron accumulation at the anode, easily controlled resolving power at the output, and practically complete freedom from spurious scintillations on the output fluorescent screen for large values of the multiplication factor (down to $K \sim 10^9$). These features permit ultrafast photographic recording (during the accelerating pulse which may last for a time of several milliseconds) of developments in unusual processes under conditions of high noise and radiation backgrounds and they justify certain technical difficulties in the fabrication of fine-mesh dynodes of large dimensions (areas of 300 cm^2). Mesh tubes have the advantages of speed of operation, ease of control and reduction of noise as compared with multiple conversion tubes (for example, the tandem cascade tube due to Holst[2]) in which the intensification of the electronic image is accomplished at the expense of a long overall delay due to the delays (for luminescent phosphors suitable for use in vacuum devices) connected with the emission in the intermediate fluorescent screens.

Some general shortcomings of electron-optical detectors should be noted; the existence of distortions connected with the electron-optical conversions, the variations in the localized conversion parameters, the need for continual localized calibration of the apparatus if it is used for comparative measurements, the difficulty in obtaining stereoptic pictures of the tracks -- all these are substantial obstacles to the reproduction of an accurate picture of the interaction process. However, the inherent positive features of luminescent-electronic detection of elementary events -- the high detection efficiency, the high resolving power, the inertialess operation, the small dead time in detection, the comparative simplicity of transmitting the electronic image of the track and the ease of synchronous operation with a pulsed source of ionizing radiation indicate that this instrument may become a powerful experimental tool in cases where the reconstruction of a qualitative picture of an elementary process is needed in the search for new types of reactions.

Note *added in proof:* in a paper which appeared recently[3] there was reported the sucessful application of the idea of using an image converter for recording tracks of ionizing particles; however, no information was given concerning the image-converter which was used.

* This note is based on a thesis submitted to the physics faculty of Moscow State University by the writer in 1951.

[1] I. S. Stekol'nikov, *The Electron Oscillograph*, State Electronics Press, 1949, p. 112 and 115

[2] Brüche and Recknagel, *Electronic Apparatus*, (translated from German), State Electronics Press, 1949, p. 447 and 458

[3] E. K. Zavoiskii et al, Dokl. Akad. Nauk SSSR **100**, 241 (1955)

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High Threshold Scintillation Neutron Detector

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At the present time, most existing methods for detecting high energy neutrons (threshold detectors, the observation of the proton recoils) are characterized by a low efficiency-approximately 10^{-4} to 10^{-3}. Only in the last few years have scintillation liquids of large volume been used, permitting the detection of neutrons by proton recoils with an efficiency as high as 10%. However, these counters have a rather high sensitivity for undesirable background (for example, a γ-ray background). The methods using them and in particular the analysis of the results are rather complicated. In connection with these there is presented an interesting possibility of developing a simple and sufficiently efficient detector of high energy neutrons. In principle, the operation of this detector can be expressed by the reaction $C^{12}(n, 2n)C^{11}$, with a threshold at 20.2 Mev. A positron-emitting isotope, C^{11}, is formed, with a half-life of 20.2 min, and with the maximum energy of the β^+- spectrum being about 1 Mev. If ordinary graphite detectors whose activity is detected by means of a Geiger counter are used for observing this reaction, then the sensitive operating thickness of the detector is limited by the range in graphite of the positrons from the decay of C^{11}. This range is approximately equal to 300 microns. If the carbon which is activated by the high energy neutrons is a chemical constituent of an organic phosphor, and if the decay is detected by the subsequent light flashes in the phosphor, then it is possible to increase the sensitive operating thickness of the detector by factors of