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SOME ADVANCES IN THE USE OF THE LIGHT PRODUCED
BY ELECTRON AVALANCHES IN GASEOUS DETECTORS

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ABSTRACT

We describe a detecting structure where electron avalanches in a wire chamber produce light pulses of 2 ns width which can be transmitted over large distances with a high efficiency by a plastic wavelength-shifter, with a decay time, for the converted light, of about the same value. This structure can bring about improvements in counting rates, multitrack resolving power, and accuracy.

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The use of the light pulses produced in a gas by electron avalanches has a long history [1]. Several groups have shown that, in some gases, a good sensitivity can be reached with photomultipliers directly detecting the visible light emitted by the atoms excited in the avalanches near a wire but with no real advantage over the detection of the pulses induced on the wire by the moving charges. The only breakthrough came from the pioneering work of the Coimbra Group [2], which showed that by detecting the VUV light it is possible to work without electron multiplication, using only the VUV quanta emitted by noble gas molecules excited by electrons drifting in electric fields [3].

A step forward in the use of the visible light from electron avalanches came in 1975 with the introduction of the scintillation drift chambers [4-6], where the arrival of the drifting electrons is detected by the light pulses produced at the sense wires. The visible light is produced by converting the energy of argon excited states into nitrogen states radiating visible photons. Figure 1 shows the emission spectrum of a nitrogen + argon mixture [7]. The main result of these investigations was to show that even at moderate amplifications, such as 10^3 , the reduction of the space-charge effects limiting the rates in wire chambers leads to a great improvement in rate capacity. Fluxes of $10^6/\text{mm}^2 \cdot \text{s}$ were handled without any alteration of the counting plateaux.

We are at present investigating the detection of low-energy X radiation, of the order of 3 keV, where the energy is obtained from the counting of the number of electrons in the ionization produced in a gas by the absorption of an X quantum. Siegmund et al. [8, 9] have demonstrated that visible pulses of the order of 2 ns width are produced in a narrow parallel-plate counter using argon + nitrogen mixtures, quenched with carbon dioxide and/or methane. We observed that it was equally easy to detect single electrons, with the same gas, from the light produced by the avalanche in a wire chamber.

The electrons were obtained by drifting the ionization electrons produced by the absorption in the gas of 1.5 keV photons in a low-field drift space

(Fig. 2a), as in the so-called time expansion chambers [10], followed by a multi-wire chamber. We then clearly observed the separation of the light flashes emitted by the avalanches produced by single electrons near the sense wires.

While this is promising for electron counting in ionization clusters, it is clear that the use of the light pulses for most particle detectors is limited by the necessity of having the photomultiplier close to the wire, detecting photons from a small area only. This led us to search for a plastic wavelength-shifter that would convert the light from the avalanches into a light suitable for ordinary photomultipliers, would keep the sharp timing property, and have a small attenuation for the converted light. Such a converter, with quite favourable properties, has been produced at Saclay by M. Bourdinaud [11] and his group.

Figure 3 shows the spectral properties of the converter, at absorption and emission [11], which match well the N_2 lines and PM's sensitivity. Table 1 summarizes its main properties. The absorption length is 2.5 mm for the absorbed light at the peak sensitivity, and 2.5 m for the emitted light, thus permitting the use of long, narrow strips of converters followed, if necessary, by convenient light-guides. The 2.5 mm absorption length will allow two-dimensional detection by superimposing millimetre-thick strips at varied angles.

Figure 4 shows the results obtained from single electrons, in the geometry of Fig. 2b where the photomultiplier looks at the photons emitted at the edge of a 3 mm thick piece of the light converter. The gas mixture was Ar (85%), N_2 (10%), and CH_4 (5%). We observed that here the light pulses are as sharply separated as they are by direct detection. The drift section of the counter was later removed and a gas mixture of Ar (78%), N_2 (10%), and CO_2 (12%) was used to reduce the electron diffusion. The pulse width was less than 5 ns for most 1.5 keV X-rays, and about 12 ns for 5.9 keV X-rays. Figure 5 shows the pulses from a beta particle traversing the counter. Since the drift velocity in this gas is measured to be about 200 ns/cm, events as little as 0.2 mm apart should be easily separated.

We can thus foresee the construction of gaseous detectors with amplification around wires or between parallel grids, and with the addition of thin, narrow

light converters bringing the light from relatively large detector surfaces to batteries of photomultipliers. This has the considerable advantage of producing pulses of 2 ns width, free of many limitations connected with the detection of induced charges on the electrodes.

The following obvious applications could be envisaged:

- Detectors with a high separation power for multitracks. The resolving power should be limited only by the diffusion along the drift path.
- The use of parallel grid amplification for drift chambers, which offers many advantages in connection with the uniformity of the electric field.
- A gain by several orders of magnitude in the counting rate, since moderate amplification is required for the light detection.
- High-accuracy hodoscopes: despite the costly use of photomultipliers, the advantage over conventional plastic scintillators is that it is easy to have geometries with wide strips of converters sharing the light from an avalanche and giving the centroid with an accuracy much better than the strip width.
- Energy loss measurements based on cluster counting. This approach would obviously lead to better separation than with the induced pulse detection.

This short enumeration justifies a detailed investigation of this type of structure, at various gas pressures and with different gas compositions.

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Table 1

Properties of Altustipe WLS 390 A *) converter

Peak absorption at 400 nm, absorption length 2.5 mm,
efficiency 80-90%

Peak emission at 433 nm, attenuation length 2.5 m

Fluorescent light rise-time: ≤ 1 ns

decay-time: ≤ 2 ns

Refractive index: 1.520

Basis: Polymethyl methacrylate

*) Commercialized by Altulor, Tour Gan, Cedex 13,
F-92082, Clichy.

Figure captions

- Fig. 1 : The emission of an Ar (99.9%) + N₂ (0.1%) mixture (Ref. 7).
- Fig. 2 : Detector geometries: a) Direct collection of light from avalanches around wires. b) Light collection at edge of 3 mm thick wavelength shifter, photomultiplier PM XP 2020, Altustipe WLS 390 converter. The anode consists of 10 μ m wires at 4 mm spacing.
- Fig. 3 : The absorption and emission spectra of Altustipe WLS 390 converter.
- Fig. 4 : Signals from single electrons. The electrons are produced by absorbing 1.5 keV X-rays and then separating them by diffusion. The scale is 2 ns/major div. and the gas mixture used is Ar + N₂ + CH₄ (85,10,5).
- Fig. 5 : Pulses from a beta particle traversing the detector with the drift section (A) removed. The scale is 40 ns/major div. and the gas mixture is Ar + N₂ + CO₂ (78,10,12).

Fig. 1

Fig. 2

Fig. 3

2 nsec / div.

Fig. 4

40 nsec / div.

Fig. 5

 