OPTOELECTRONIC DELAY FOR THE READ–OUT OF PARTICLE TRACKS FROM SCINTILLATING FIBRES(*)

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ABSTRACT

Due to the high event rate envisaged in future hadron colliders, the optoelectronic read–out of a scintillating fibre tracker will need a device, able to pipeline optical images during the first level trigger decision time. We describe in this paper the principle of a gatable optoelectronic delay line. A first prototype is also presented, and preliminary results confirm the expected space resolution.

1. INTRODUCTION

Within the framework of the LAA Project [1], we are developing a compact scintillating fibre tracking detector for future hadron colliders. It will be operated in a uniform magnetic induction. The tracker is made up of bundles of narrow–diameter (30 µm) scintillating fibres, which are arranged in three concentric, cylindrical shells(**). Since most of the track images are uninteresting for physics, only a small fraction (≈ 0.1%) of them should be transmitted for further processing. This fraction is selected by trigger signals which arrive with a delay of ≈ 1 µs. Therefore, all track images must be delayed accordingly, the vast majority must be rejected, and only the small triggered fraction should be transmitted. This contribution describes a delay tube, which we have designed for this purpose.

2. ROLE OF THE DELAY TUBE IN THE TRIGGER SEQUENCE

A 10^{33} $cm^{-2}s^{-1}$ design luminosity with an event cross section of 100 mb produces a mean event rate of 100 MHz. The expected time needed to process and transmit the first

(*) The work reported here is part of the LAA Project.
(**) See contribution of H. Leutz, these proceedings.

level trigger signals to the gates of the optoelectronic chains is much longer than the time between two successive bunch crossings (≈ 15 ns). Consequently, optical images produced by our tracker must be pipelined. For that purpose, we designed an optoelectronic device able to delay in a controlled way those images, and to select and amplify a small fraction of them [2]. Assuming a rejection capability of 10^3 for the first level trigger, the rest of the optoelectronic chain is fed at an image rate of 10^5 Hz. We can then envisage a UA2–like design [3] for subsequent read–out.

3. MAIN FEATURES OF THE DELAY TUBE

The image delay should have the following characteristics:

- a delay capability to wait for the 1st level trigger decision,
- gating facilities to select triggered events (data reduction ≈ 10^{-3}),
- a good detection efficiency and a high gain,
- a space resolution which is better than the optical resolution of the fibres, i.e. ≤ 30 µm,
- an <u>intrinsic</u> time resolution (≈ 10 ns) which minimizes the mixing of successive images.

4. BASIC SCHEME OF THE DELAY TUBE

The delay tube is a 600 mm long, electromagnetically focused image intensifier. The tube is divided in 6 sections separated by 5 grids labelled G1 to G5 (fig. 1).

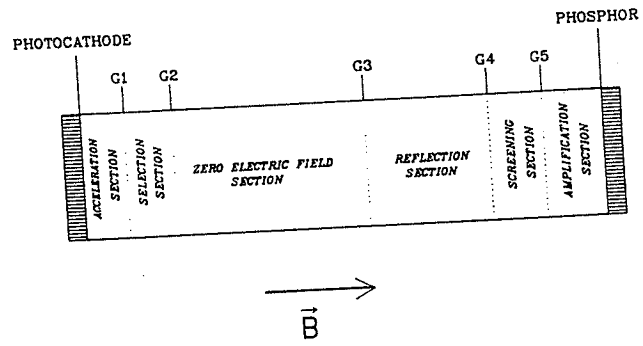

Fig. 1 – Basic scheme of the delay tube.

The requirements stated in the previous paragraph are fulfilled in the following way:

- the delay is ensured by to and fro drifts of eV photoelectrons in the first four sections of the tube,

- the gating is realized by blocking the photocathode before applying an ultra short negative pulse on grid G1 (see below),
- the blue light coming from the scintillating fibres is detected by a bialkali–like photocathode (Q.E. ≈ 15%, including the input fibre optic window transparency), and amplified by a P47 (or similar) phosphor screen supplied at 15 kV (yielding an expected photon per photon gain of 10),
- the focusing of the images is ensured by the detector magnetic field, parallel to the photoelectrons trajectories,
- the time resolution is guaranteed by a compensation of the photoelectron velocity spread at the emission from the cathode by transit time effects during the electron drifts in the tube (sect. 5.).

5. THE BUNCHING PRINCIPLE

Electrons are emitted from a photocathode with complex angular and energetic distributions. In case of blue incident light and with bialkali photocathodes, the maximum photoelectron energy can be as high as 1.8 eV. Without additional bunching of the electronic images, fast photoelectrons of the actual image will catch up slow ones of the previous images.

In the delay tube, the bunching is ensured by the reflex klystron principle [4]. After emission, electrons are accelerated by G1 and drift at constant velocity between G1 and G3 (G1, G2 and G3 being at the same potential of a few volts above the cathode potential). A reflector grid G4, operated below cathode potential, makes the electrons return to G1. Since the faster electrons penetrate farther into the reflection region and therefore take longer to return, all the electrons finally form in bunches. The condition for two electrons of emission energy V_{01} and V_{02} (with $V_{01} < V_{02}$) to bunch within the selection section can be found with a mechanical analogy [4]:

$$\frac{D}{d} = 2 * \left(\frac{V_{01} + V_G}{V_{02} + V_G}\right)^{1/2}$$

where D (in m) is the length of the selection and zero electric field sections, d (in m) is the distance travelled by the fastest electron in the reflection section, and V_G (in V) is the voltage applied at grids G1, G2 and G3. V_{01} and V_{02} are expressed in eV.

In this approach, the influence of the transit time in the acceleration section has been neglected. Starting from the above condition, we designed, assisted by computer simulations, a tube with a time resolution of 10 ns.

6. THE IMAGE ELIMINATION MODE

The delay tube works in "image elimination mode" when the first level trigger is not active: in this case, every image arriving on the cathode must be finally discarded. After their to and fro drift, the electrons are slowed down between G1 and the cathode and finally absorbed by the cathode (fig. 2).

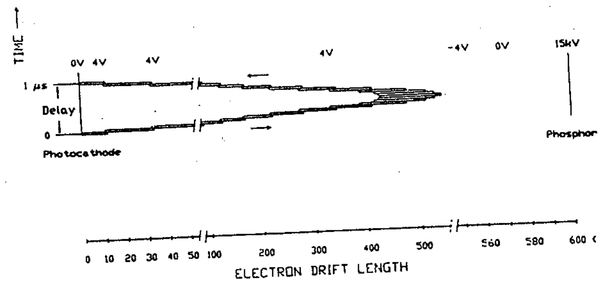

Fig. 2 – Image elimination mode(*).

7. THE IMAGE SELECTION MODE

The selection process of one image, actuated by the first level trigger, can be decomposed in three phases (fig. 3):

- Just before the reflected image to be selected enters from G2 the selection zone (fig. 3(a)), the cathode voltage is increased (from 0 to 10 V) in order to prohibit any subsequent photoelectron from being emitted. The selection zone is thus gradually cleared from forward–drifting electrons.
- As soon as the triggered image is completely confined between G1 and G2, a 4 ns negative (– 300 V) pulse is applied on grid G1 (fig. 3(b)). Most of the electrons inside the selection zone acquire a large velocity (20 eV) and are sent back to G3. At the same time, the photocathode is grounded, to provide again new track pictures.
- The delay tube runs again in image elimination mode while the selected electrons cross the reflection and the screening zones, are accelerated by the high voltage (15 kV) applied on the phosphor screen and produce a light signal into it (fig. 3(c)).

The duration of the positive voltage applied on the photocathode determines the dead time of the tube. It is of the order of 40 ns.

(*) The potential values given here are only typical.

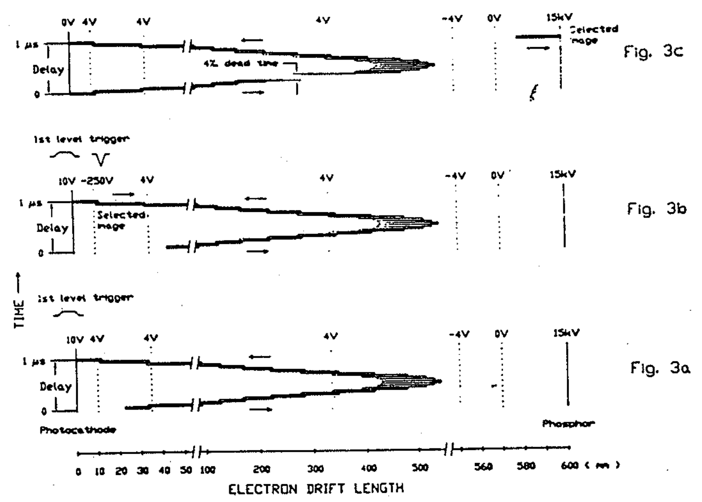

Fig. 3 – Image selection mode

8. THE FIRST DELAY TUBE PROTOTYPE AND ITS SPACE RESOLUTION

A first, 400 mm long, simplified prototype of the delay tube has been built by EEV Ltd (England). It is made up of an acceleration section, a constant velocity drift space and an amplification section. The different zones are separated by two grids G1 and G2. G1, the drift space cylindrical wall (made in stainless steel) and G2 are electrically connected.

We have measured the Contrast Transfer Function (CTF) [5] of the tube in a 0.7 T magnetic induction. The potentials of the grids and the phosphor screen (with respect to the cathode) were 100 V and 6 kV respectively. The results of the measurements are reproduced in fig. 4. A fit with a gaussian transfer function gives a limiting resolution of about 40 lp/mm (or equivalently a 25 μm FWHM point spread function). The discrepancy between the experimental points and the fit above 30 lp/mm is due to the fact that the resolution has been measured by a CCD camera about $20 \times 20\ \mu m^2$ in pixel size.

9. CONCLUSIONS

For the read–out of a scintillating fibre tracker, a novel optoelectronic delay line has been designed, providing image delay, selection and amplification. It consists of an electromagnetically focused image intensifier working with low energy photoelectrons. The space resolution of a first prototype has been measured, and is of the order of 25 μm for a 400 mm long tube in a 0.7 T magnetic induction.

We are currently studying electron transit times in the same prototype. We have also designed and ordered a test cell intended to measure photoelectrons absorption efficiency by a photocathode. Finally, we will study the whole principle of the delay tube, including image

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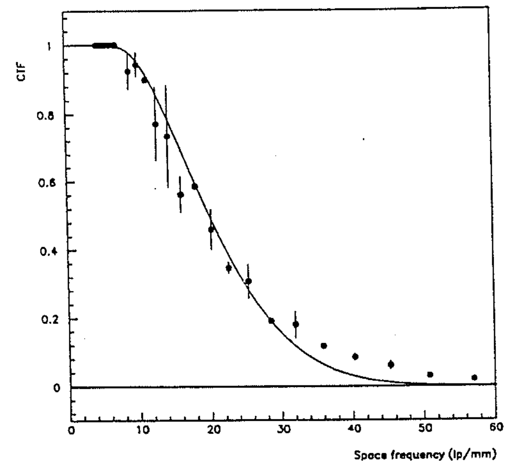

Fig. 4 – Contrast Transfer Function obtained with electrons drifting 40 cm in a delay tube. The least squares fit of the measured values is indicated by the solid curve. The limiting resolution (at 0.03 contrast) is 40 line pairs/mm or 25 μm.

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