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MCP-PMT Anode Development for Picosecond-Resolution Time-of-flight Detectors

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Our goal is to build a system using microchannel plate photomultiplier tubes (MCP-PMTs) to make very fast (∼ 1 picosecond) time of flight measurements over a large area. In our design, Cherenkov light produced in the window of a MCP-PMT travels directly to the photocathode, so that variations in the optical path of the light are small, as there are no bounces. The two basic factors which dominate the time resolution of such a system are the transit-time spread (TTS) of the microchannel plate and the intrinsic difficulty of collecting a fast signal from an area which is large compared to the distance corresponding to one picosecond (1 ps $\simeq$ 300 μm).

While existing large area microchannel plates have $\sigma_{TTS} \approx 30$ ps for single photoelectrons, this timing uncertainty is significantly reduced by the large (∼100) number of photoelectrons per incident particle. However the difficulty of collecting a fast signal from a large area is independent of the number of photoelectrons. There are two main obstacles to high speeds: electrons arriving on the anode are spread out over a large area, and the traditional return path through a high voltage power supply to the last stage of the MCP forms a loop with large inductance. This return path is shown in Figure 1.

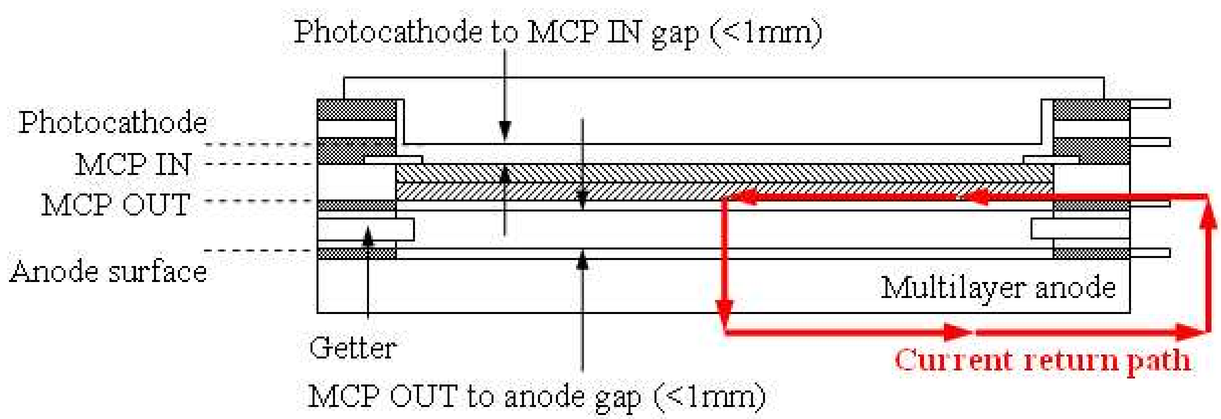

Figure 1: A sketch of a side view of an MCP-PMT, showing the long (several hundred psec) return path of the current on the surfaces of the anode and MCP.

We have designed and simulated a 5-cm by 5-cm printed circuit board multianode with 64 pads summed to four output channels (one per quadrant). In our design, the return path and signal form a differential pair; the return path couples capacitively to the last stage of the MCP (MCP OUT) through a grid on the anode surface. Equal-time transmission lines are constructed with traces on two adjacent layers and bring the differential signal from each pad to one of four central collection points. The grid itself is held at some fraction of the MCP OUT voltage and is AC-coupled to the TDC electronics. The surface of the anode is shown in Figure 2.

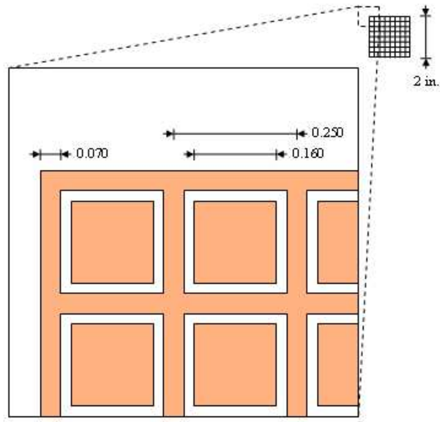

Figure 2: A 'head-on' view of the anode, showing the pads embedded in the grid structure. The grid has a large capacitance to MCP OUT; it is this capacitance that shunts the inductive path and provides a fast AC return path.

To test the idea of capacitatively coupling the return back to MCP OUT we have made a simple equivalent circuit which can be simulated in SPICE. Input pulses are made with the detector simulation that starts with a relativistic particle traversing the window of the MCP-PMT. The detector simulation takes into account the Cherenkov radiation spectrum, absorption in the window, path length of the photons to the photocathode, the photocathode quantum efficiency, the transit-time spread of the MCP[1], and the footprint and arrival times of the charge on the anode pads. Our simulations indicate that even a small capacitive return path dramatically increases the size of very fast signals. Figure 3 shows the resulting pulses for ten incident particles with a grid to MCP OUT capacitance of 2 pF.

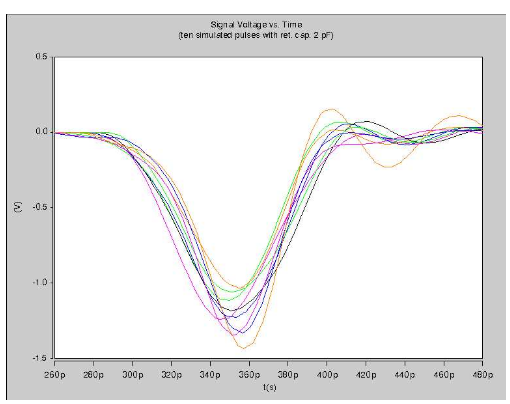

Figure 3: Simulated pulses arriving at TDC electronics for 10 particles incident on the MCP-PMT window for a fixed grid to MCP OUT capacitance of 2 pF.

We will present a detailed description of the physical and electrical characteristics of the anode design for a 5-cm by 5-cm tube.

[1]The TTS is simulated as a Gaussian, which is a good approximation of the leading edge but neglects a long tail. We would like to be able to fully simulate the MCP response in the future.