Advances in Time Response Characteristics of Micro-channel Plate PMT Detectors

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Abstract

The output rise time and jitter in the time response of photomultiplier tubes (PMT) is severely reduced in microchannel plate (MCP) models compared to more standard dynode chain PMTs due to a vastly reduced variation in the path length of the electrons through the amplifying system. Typically the jitter in photon detection can be < 50 ps and rise times in the region of 100 ps compared to the nanosecond domain occupied by the best conventional PMTs. We illustrate advances in pulse rise time and width through the direct comparison of MCP-PMTs manufactured with 3.2 μm and 6 μm pore diameter MCPs.

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Fast photon detectors are important components in time correlated single photon counting (TCSPC) where the time resolution of the system is dominated by the pulse response of the detector [1]. TCSPC is used in fluorescence lifetime measurements in chemical [2] or biological [3] applications in the picosecond or nanosecond time domain. High time resolution detectors are also used in laser ranging systems [4] and high-speed communications [5].

The construction of an MCP based PMT follows closely the construction of a standard image intensifier, but has an anode where the intensifier would have a phosphor screen. Input light activates a transmitting photocathode that ejects electrons into the MCP stack. The cathode and front MCP are positioned in close proximity to ensure a high electric field. The electrons are amplified on each collision as they bounce off the internal walls of the MCP pores. On exiting the final MCP the electrons are drawn towards the anode by a further electric field.

MCP-PMTs have considerable advantages in time response over their traditional dynode-chain counterparts due to the narrow amplification channels of the MCP pores. The tight restriction on the possible electron path through the gain medium dramatically reduces the spread of arrival times at the collection anode and hence gives a very fast rise time. Previous work [6] has studied various MCP-PMT parameters including a comparison of 6 μm and 10 μm pore MCPs. In this paper we focus on the improvements in rise time and pulse FWHM by using 3.2 μm pore MCPs in 1 and 2 plate detectors.

The four detectors used in this study were two PMT110s (1 MCP, 10 mm diameter anode), and two PMT210s (2 MCPs, 10 mm diameter anode). One of each type used 3.2 μm pore diameter (d) MCPs with a bias angle of 5° and a thickness (l) of 0.18 mm (giving an l/d ratio of 56:1) and the other used 6 μm pore diameter MCPs with a bias angle of 5° and a thickness of 0.33 mm (giving an l/d ratio of 55:1). All of the detectors were constructed in 25mm diameter bodies with an identical tapered 50 Ω anode design and accelerating mesh. The 3.2 μm pore MCPs have a working area diameter of 18 mm and the 6 μm pore MCPs have a working area diameter of 25 mm.

The conventional definition of rise time is the time for the pulse to go from 10% to 90% of the pulse amplitude. Due to the nature of electron avalanche detectors the leading edge of the response pulse will go negative and some may consider this to be a fall time, but the convention in such detectors is always to consider the leading edge as being the rise time and is treated as such in this analysis.

The rise time of the PMT detectors were measured by an Agilent 86100C sampling oscilloscope operating at a sampling rate of 18 GHz. To remove random noise all traces were averaged over 16 cycles of the oscilloscope. The PMTs were stimulated by the same laser operating at a wavelength of 650 nm with a pulse width believed to be less that 50 ps FWHM, running at a repetition rate of 10 kHz. The laser pulse was attenuated by an appropriate strength of ND filter, depending on the gain of the PMT. The gain of the 2 plate PMTs was sufficient to detect single photon events. To ensure that the minimum rise time and pulse widths were recorded for each trace, the field between the MCP and anode was increased to the point were no further improvement was observed. The results for the two sets of detectors are shown on Figure 1and Figure 2.

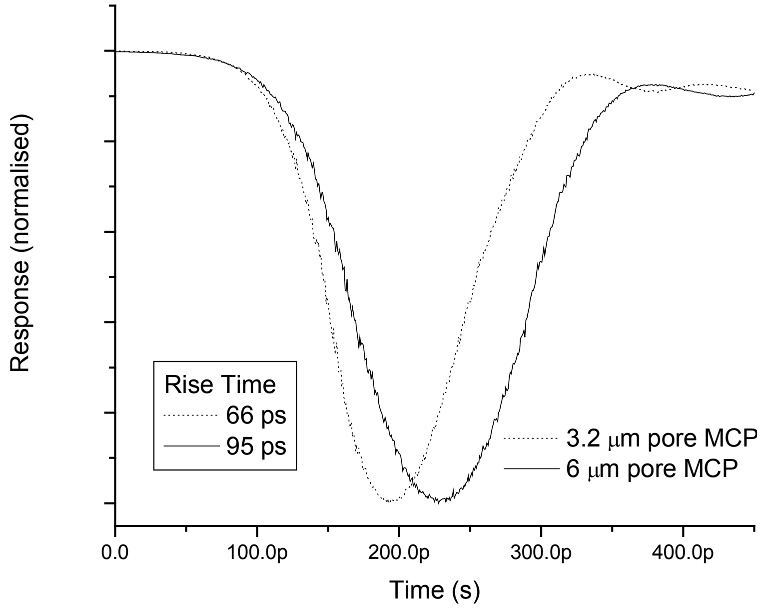

Figure 1. Time response curves for two models of PMT110 with different MCP pore diameters. The 3.2 μm pore MCP model has a FWHM of 110 ps and the 6 μm pore MCP model has a FWHM of 133 ps.

The model of Fraser *et al.* [7] suggests that the transit time spread through a single MCP with a fixed *l*/*d* ratio would vary linearly with pore diameter. Figure 1 combined with the fact that Photek photodiodes that have no MCP normally have rise times of between 60 ps and 70 ps would indicate that we might have reached the bandwidth limit of the measurement system for the very fast rise times. Figure 2 would further indicate that even though the transit time spread across the anode was minimised by applying a large electric field, there is still a contributing factor preventing the expected factor of 2 improvement in comparing 6 μm pore and 3.2 μm pore diameter MCPs.

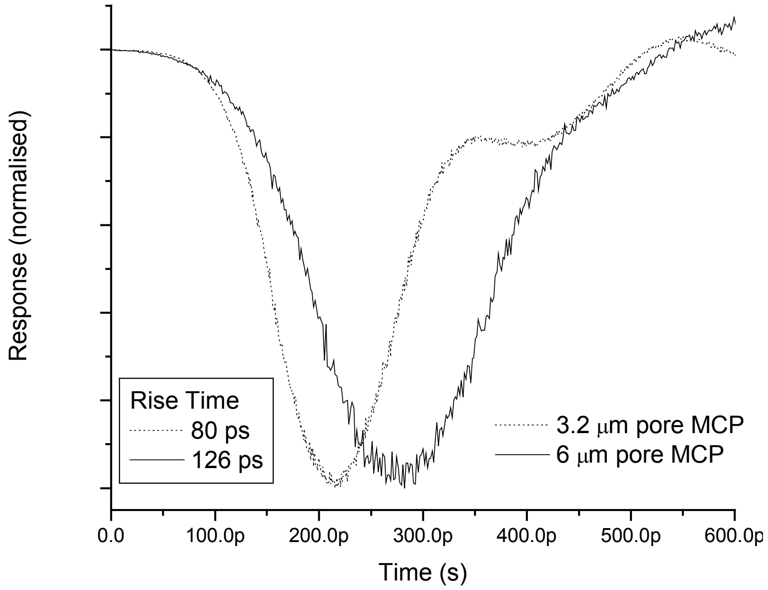

Figure 2. Time response curves for two models of PMT210 with different MCP pore diameters. The 3.2 μm pore MCP model has a FWHM of 140 ps and the 6 μm pore MCP model has a FWHM of 190 ps.

We believe that the results presented here offer conclusive proof that tightening the allowed electron path lengths through the gain medium by using smaller pore and thinner MCPs gives a significant reduction in the spread of arrival time at the collecting anode and therefore produces a considerable improvement in the rise time and pulse FHWM. Photek Ltd gratefully acknowledges the co-operation of Photonis for the supply of the developmental 3.2 μm pore MCPs.

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